



MALDIVES

Post-Tsunami Environmental Assessment

United Nations Environment Programme



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Indian Ocean tsunami reaching Male'



at approximately 9:20 a.m. on 26 December 2004, approximately three hours after tremors were felt. Credit: L. Hiller

FOREWORD

by Klaus Töpfer
United Nations Under-Secretary General
Executive Director of the United Nations Environment Programme



Credit: UNEP

In the immediate aftermath of the enormous devastation and suffering caused by the 26 December 2004 Indian Ocean Tsunami, UNEP established the Asian Tsunami Disaster Task Force. At the request of the governments of affected countries, the Task Force has assessed tsunami-related environmental damage, worked to ensure that environment is a part of national recovery agendas, and mobilised environmental recovery assistance.

In February 2005, UNEP issued a rapid environmental assessment of seven of the tsunami-impacted countries (see http://www.unep.org/tsunami/tsunami_rpt.asp). This report, which was developed in close cooperation with the Ministry of Environment & Construction and with the generous support of the UK's Department for International Development and the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), elaborates the findings of the rapid

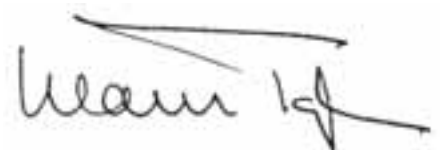
assessment in the Republic of Maldives, based on a detailed expert investigation of the tsunami's environmental impacts.

Maldives, a country of 1,192 islands and 290,000 citizens, is highly dependent on its natural resources. Along with tourism, which provides more than 30 percent of the country's income, fisheries and agriculture are essential to livelihoods on the country's 199 inhabited islands. Although it has not been widely reported in the media, on a per capita basis Maldives was one of the worst affected countries. According to the Asian Development Bank, the tsunami affected services that account for two-thirds of Maldives gross domestic product.

The impact on the country's environment was also profound. Coastal zones were eroded, and the tsunami's waves spread solid waste around the islands. Demolition waste was discovered to contain hazardous materials, including asbestos used in roofing material. Groundwater supplies were badly contaminated with salinity from sea water and faecal coliforms, further compromising an already fragile drinking water supply system. Soils, too, were inundated with seawater, damaging or destroying vegetation and home gardens crucial to island life.

The post-tsunami assessment also brought to light the many urgent environmental problems that existed prior to the tsunami in such areas as waste management, sanitation, protection and recovery of groundwater resources, and coastal zone protection. These chronic challenges were greatly exacerbated by the tsunami. Equally important, the tsunami made evident the urgent need for effective early warning systems, disaster risk management plans and sustainably designed infrastructure.

During the months since the tsunami, the global outpouring of assistance to impacted countries has been truly remarkable. Relief efforts throughout the region have evolved into longer-term reconstruction efforts. In Maldives, the environment is widely recognised as a crucially important reconstruction priority. The country's small but dedicated environmental protection staff has worked hard to address the country's significant needs. UNEP is committed to supporting Maldives during the months and years ahead, as it restores its environmental services and works for a sustainable future for its citizens.

A handwritten signature in black ink, appearing to read 'Hamid', with a long horizontal line above it.

INTRODUCTION

Tsunami waves ranging between one and five metres high were reported in all parts of Maldives. The force of the waves caused widespread infrastructure devastation in the islands, 80 percent of which are less than one metre above sea level. One in three of the Maldives' 290,000 residents were affected by the tsunami. Homes were destroyed, livelihoods lost and infrastructure damaged on 69 of 199 inhabited islands, including Fonadhoo, pictured here. According to the Government, 29,577 residents were displaced by the tsunami. Approximately 12,000 remain homeless, living in temporary shelter or with friends and relatives on their own or other islands. Credit: L. Hiller





The Indian Ocean tsunami reached the Republic of Maldives at 9:20 a.m. local time, approximately three hours after tremors were felt. Tidal waves ranging between one and five metres high were reported in all parts of the country. The force of the waves caused widespread infrastructure devastation in the atolls, 80 percent of which are less than one metre above sea level.

On a per capita basis, Maldives was one of the worst affected countries. The tsunami's impact was national in scope. Sixty-nine of the country's 199 low-lying inhabited islands were damaged, 53 of them severely. Twenty were largely devastated, and 14 had to be evacuated. According to the Government, 29,577 residents were displaced by the tsunami. Approximately 12,000 remain homeless, living in temporary shelter or with friends and relatives on their own or other islands. In all, nearly a third of the country's 290,000 residents suffered from loss or damage of homes, livelihoods and local infrastructure.

The tsunami had an enormous impact on the national economy, which depends largely on nature tourism, fishing and agriculture. According to the World Bank-Asian Development Bank-UN System, total asset losses were estimated to be \$472 million, equalling 62% of the country's GDP.¹

Flooding wiped out electricity supplies on many islands, destroying communication links with most atolls. Communications were lost for ten hours or more on 182 islands. Four islands remain without direct communication. Twenty-five percent of the islands experienced major damage to essential infrastructure such as jetties and harbours, which provide crucial links between the islands and the outside world. Water supplies were disrupted in approximately 15% of the islands.

Overview of the government's disaster response

Within hours after the tsunami struck, the Ministry of Environment and Construction (MEC) joined a Ministerial Committee and Task Force organised by the President of Maldives, H.E Maumoon Abdul Gayoom. On impacted islands, communities organised emergency committees and quickly mobilized support for their neighbors. Early on 27 December relief supplies were dispatched, and within 24 hours communications were restored to 11 atolls.

The Government of Maldives (GOM) created a National Disaster Management Centre (NDMC), which continues in operation. The Ministry of Defense and National Security (MDNS) has coordinated the overall relief effort. The Ministry of Finance and Treasury (MoFT) is coordinating donor assistance, and the Ministry of Planning and National Development (MPND) is coordinating long-term response and planning. In the interest of creating transparency the GOM created the Tsunami Relief and Reconstruction Fund, which will expend recovery and reconstruction funds under the supervision of a Monitoring Board and auditors.

The environmental response

Immediately following the tsunami, the MEC conducted a survey of affected islands to assess the extent of damage to water, sanitation, waste, coastal and other environmental infrastructure. On behalf of the GOM, the MEC requested the Joint UNEP/OCHA Environment Unit to assist the Ministry with the environmental emergency caused by the tsunami. On 28 December 2004, an environmental expert arrived in Maldives and undertook a rapid assessment of the tsunami's environmental impacts as a member of the United Nations Disaster Assessment and Coordination team. On 3 January 2005, based on the findings of the UNEP/OCHA rapid environmental assessment,

¹ By comparison, Sri Lanka suffered approximately \$1 billion in economic losses, representing 4.5% of the country's GDP, and Indonesia experienced \$4.5 billion in losses, equalling 2.6% of GDP.

the MEC requested UNEP's further assistance with the country's environmental recovery and reconstruction work, in particular in addressing waste management issues.

A total of \$950,000 was included in the UN Flash Appeal to cover environmental assessment and waste management activities. On 10 January, UNEP deployed a waste management expert to Maldives to provide immediate technical assistance. At the same time, UNEP began providing environmental inputs to external assessments of the country, including the Joint Needs Assessment. UNEP also developed project proposals with MEC on waste management, clean-up and comprehensive environmental assessment. Throughout all stages of the response, UNEP has worked in close cooperation and partnership with the MEC and national authorities.

UNEP's assessment work

This report follows a rapid environmental assessment completed by UNEP in cooperation with the MEC and national environmental counterparts. (See www.unep.org/tsunami) The rapid environmental assessment identified a number of significant environmental impacts of the tsunami, including:

- spreading of solid waste, including hazardous materials;
- contamination of groundwater supplies with salinity and faecal coliforms;
- disruption of water supplies and sanitation systems;
- contamination of soils with salinity; and
- damage to livelihoods dependent on the environment including tourism, agriculture and fisheries.

For purposes of UNEP's assessments and the work to follow, the MEC convened an inter-ministerial environmental task force comprising representatives from the NDMC, Ministry of Tourism (MoT), Ministry of Fisheries, Agriculture and Marine Resources (MoFAMR), Ministry of Communication, Science and Technology (MCST), Maldives Water and Sanitation Authority (MWSA), Department of Meteorology, Environment Research Centre and the Marine Research Centre. The task force has informed and supported UNEP's assessment work.

On 21-27 February a team of UNEP and national experts conducted a field mission to 16 islands on 8 atolls.² The mission team was multi-disciplinary, involving experts knowledgeable in priority areas pre-identified by the GOM in consultation with UNEP.

Experts from the World Health Organization (WHO) and the U.S. Geological Survey (USGS) joined the UNEP mission. The areas investigated included: coastal geology, groundwater, soils, waste (solid, hazardous, health care, asbestos), wastewater and sanitation, terrestrial biodiversity, industry, livelihoods, and institutional capacity to protect the environment. Each international expert worked side by side with national counterparts. On 1 March, at the request of the Government, UNEP briefed government officials from various ministries and agencies on the mission's preliminary findings.

² UNEP waste management experts conducted site visits at eight additional islands: Banyan Tree Resort, Dhiggaru, Dhoonidhoo, Ganu, Funadhoo, Kolhuvaariyaafushi, Madhifushi, Mulah, Muli, Naalafushi, Rakeedhoo and Thilafushi.



Throughout the process, UNEP has aimed to gather the best environmental information and data available at the time of publication and to make targeted recommendations in the hope that this assessment can be of assistance to Maldives in the development and implementation of its recovery and reconstruction plans. UNEP and national experts consulted relevant pre-tsunami baseline documentation and gathered available information about the tsunami's impact on each of several environmental and cross-cutting issues.

A number of limitations in data gathering were identified, including inadequate pre- or post-tsunami data on the Maldives environment; a lack of geographic information system (GIS), satellite imagery or other visual information; the absence of an official tsunami impact assessment; the general lack of environmental monitoring and reporting at the atoll or island level; and logistical obstacles to inspecting impacted areas.

International environmental relief and recovery efforts

A number of international organisations have conducted important assessments and activities in the environmental sector. An interdisciplinary team sponsored by the Australian government (AusAID) studied the tsunami's impacts on coral reefs. USGS (in cooperation with the U.S. Agency for International Development, the Japanese Society of Civil Engineers/Japan International Cooperation Agency (JICA), a coalition of Australian universities and the International Oceans Commission have conducted geological, geomorphologic and vulnerability assessments. UNICEF, Oxfam, the International Federation of Red Cross and Red Crescent Societies (IFRC), the U.S. Army and the Governments of U.K., Norway and Germany ran emergency water and/or sanitation relief programmes. IFRC and UNICEF have continued these activities into the recovery phase, and IFRC is planning to implement a UNEP-initiated tsunami waste clean-up project. The Asian Development Bank and JICA are also preparing to assist Maldives in the area of solid waste management. WHO has focused on health care waste management and environment and health issues. The United Nations Development Programme (UNDP), with the assistance of UN Volunteers, is promoting sustainable approaches to disaster risk reduction, shelter, livelihoods and coordination activities and is providing ongoing technical and project-related assistance to the MEC. The Food and Agriculture Organization of the United Nations (FAO) has investigated soil and groundwater conditions whilst providing assistance to the agricultural and fisheries sectors. UNEP is grateful for the extremely good cooperation achieved with the UN Country Team in Maldives and with international organisations, such as AusAID, USGS, WHO, FAO, that have made direct contributions to this report.

The road ahead

In March 2005, the GOM issued its National Recovery and Reconstruction Plan (NRRP). The NRRP identifies environmental protection as one of five key objectives and priorities for recovery and reconstruction. It is hoped that the information provided in this assessment will assist the GOM during the crucial period of recovery and reconstruction.

Many of the environmental issues identified below pre-existed the tsunami but posed heightened risks after its impact, illustrating the linkage between environmental protection and disaster risk reduction that was highlighted during the UN World Conference on Disaster Reduction in Kobe, Japan in January 2005. With the continued support of the international community, Maldives can address its key environmental challenges, reduce potential disaster risks and move toward the creation of a 'green state' that would safeguard the country's extraordinary natural heritage and provide a global model.

FINDINGS & CONCLUSIONS

A major impact of the tsunami was the creation of approximately 290,000 cubic metres of demolition waste. This amount combined with an estimated 50,000 cubic metres of pre-existing household and other waste that had not been properly managed. The tsunami waste includes hazardous waste, vegetation, soil, sediment, municipal waste from dump sites, healthcare waste, demolition waste from destroyed buildings, oil spilled from generators, leakage from septic tanks and wastes generated by relief operations. Waste deposited on the soil and beaches threatens to contaminate groundwater supplies and the marine environment. Waste dump sites, such as the one in Guraidhoo pictured here, are typically uncontrolled. Credit: L. Hiller





GEOLOGIC SETTING AND TSUNAMI CHARACTERISTICS

Geologic setting

The Maldivian islands consist of 1,192 islands on 26 natural atolls that encompass an area of ~107,500 km² of which less than 0.3 percent is land area. The country's total land area is estimated to total roughly 300 km², with islands varying in size from .5 km² to 5.0 km².

The islands occupy the central portion of the 3,000 km-long Laccadive-Chagos submarine ridge, which is a major feature of the Indian Ocean seafloor. They form a double chain of north-south oriented parallel atolls separated by an inner sea. The atolls rest on a submarine plateau that is 275-700 m deep, 700 km long and up to 130 km wide. Several east-west trending deep channels (~1000 m) separate the atoll groups.

The islands are low-lying and began forming between 3,000 and 5,500 years ago. They represent the most recent deposition along a submarine plateau that is underlain by approximately 2,100 metres of mostly shallow-water carbonates resting on a slowly-subsiding volcanic foundation. The islands are composed primarily of reef-derived carbonate sediment that has been deposited by waves and currents. In simple terms, the islands tend to have taken one of three forms:

- seaward-edge islands on the peripheral atoll rim, formed of sand and gravel with steep, coarse beaches along their seaward margins and sand beaches along their lagoon shores;
- lagoon-edge islands composed mostly of sand with minor amounts of gravel; and
- sand-cay type islands that form on peripheral rims and within lagoon, reef-top settings.

The reef foundations have been in existence for millions of years. The islands, however, are some of the youngest land surfaces on earth. Because of their unconsolidated nature, the islands should be considered ephemeral from the perspective of geologic timescales.

Island shorelines consist of sand, gravel, and a variety of engineering structures. The country's beach systems are highly dynamic and subject to seasonal conditions, especially from monsoons. Although Maldives is located away from the main pathways of tropical cyclones, the presence of gravel beach ridges and cemented conglomerates attest to the fact that storm waves are an important element in the development of the islands.

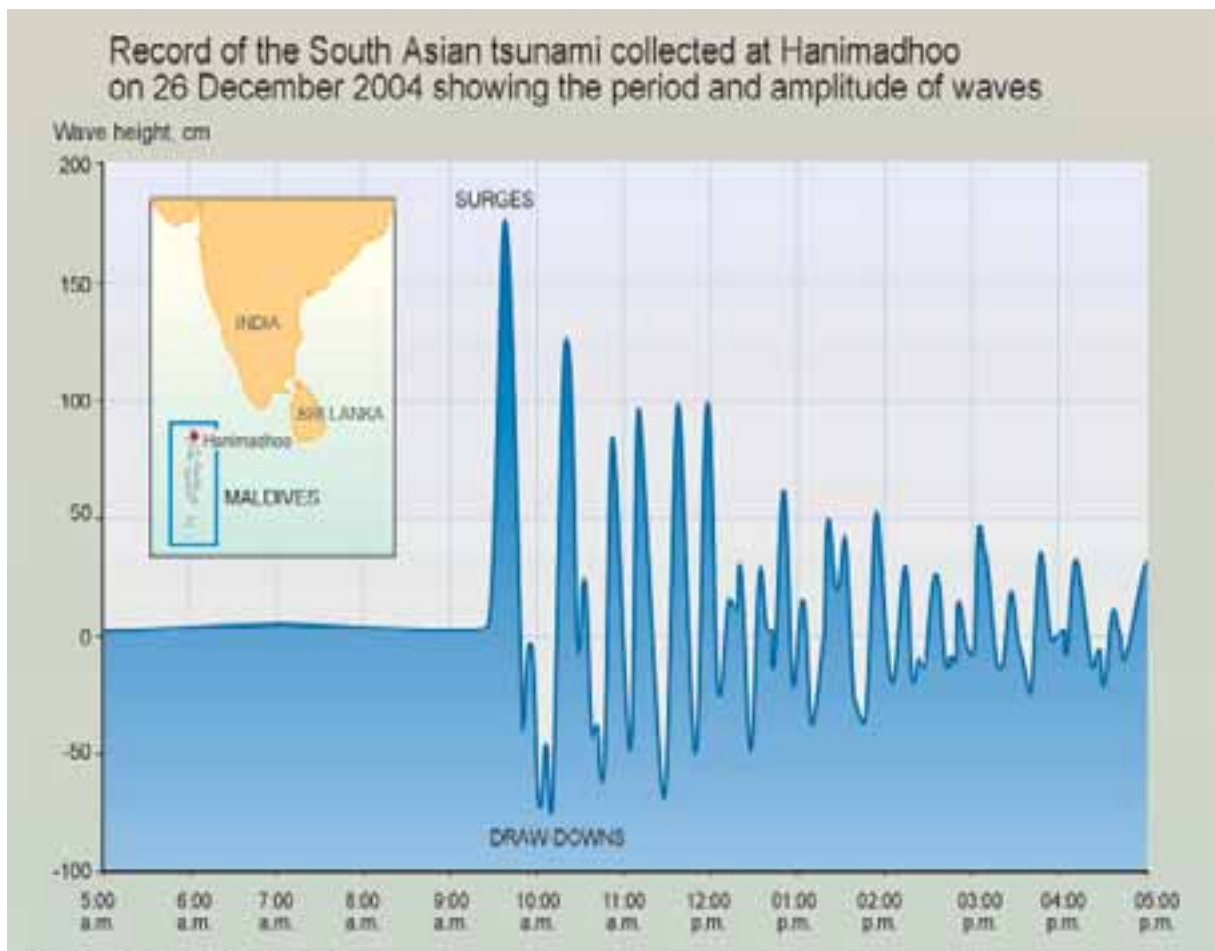
Erosion and accretion are, in fact, ongoing processes to which local communities have adapted in the past. Increases in population and the development of permanent infrastructure in close proximity to shorelines, however, have made erosion a prominent hazard to the country's social and economic well-being.

It is estimated that 80% of the islands are one metre or less above sea level. Their low elevation makes them particularly vulnerable to storms and changes in sea level. The prospect of global sea level rise and its potentially catastrophic impact on low-lying islands makes erosion management all the more urgent.

Tsunami characteristics

Three hours and 18 minutes after the Sumatran earthquake, the tsunami reached the shores of Maldives islands. Government officials received several reports that, immediately prior to the tsunami's impact, freshwater flowed out of wells and up from the ground.

Sea-level station records reported by the University of Hawaii Sea Level Centre (<http://ilikai.soest.hawaii.edu>) show a southward decrease in the amplitude of the tsunami tidal-record signal from ~1.8m above mean sea level (msl) at Hanimaadhoo in the north, ~1.5m for Hulhule, Male' in the central region, and ~0.8m for Gan in the south. The sea-level station data are filtered and do not show absolute heights of the tsunami.

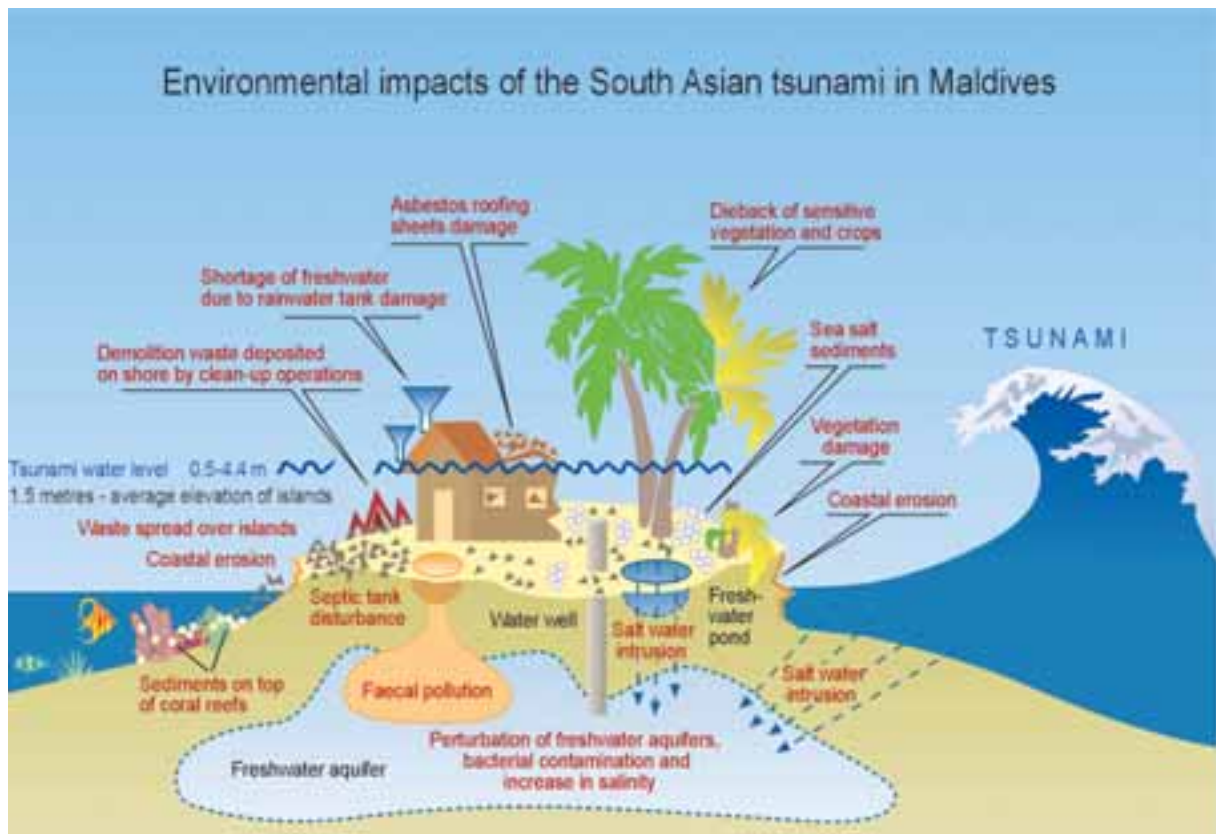


Source: University of Hawaii Sea Level Centre 2005

The Research Group on The December 26, 2004 Earthquake Tsunami Disaster of Indian Ocean (<http://www.drs.dpri.kyoto-u.ac.jp/sumatra/maldives/Maldives.htm>) reported corrected tsunami heights for 59 locations throughout the Maldives. According to the Group, tsunami inundation heights ranged from 0.65m in South Male' to 3.22m in L. Fanadhoo. A maximum run-up height of 4.43m above msl was measured at L. Fanadhoo. Uncorrected tsunami water levels measured by UNEP showed a range from barely measurable to 3.25m, with most measurements in the 2.0 - 2.6m range.



The tsunami's height typically decreased from east to west as it traveled across islands. Many islands reported the tsunami approaching from the west, quite probably because it refracted around the ends of the islands. Eyewitness accounts often referred to several (usually three) waves approaching in rapid succession (30 seconds to minutes) with minimal draining of water between waves. Wave effects were most pronounced on eastern shores, but flooding and damage to coastal infrastructure was widespread among the islands.



The tsunami arrived in Maldives during daylight hours near low tide. These two factors probably contributed to a relatively low death toll.

IMPACTS ON THE NATURAL ENVIRONMENT

Coastal land forms

The coast is an important element of life for all Maldives citizens. The coastal zone provides the country with a range of recreational, economic, conservation and heritage values. According to the 2004 State of the Environment report, however, coastal erosion was reported in 109 islands and is visible in most islands. The coastal infrastructure of most islands is vulnerable because of the vegetation line's close proximity to the sea.

Quantification of island change, either by the tsunami or other mechanisms, requires accurate baseline data. Very little baseline data exists in the Maldives; and topographic, bathymetric, or geologic



Source: Government of Maldives 2005, UNEP Maldives Assessment Team 2005, AusAID and Australian Assessment Team 2005, Japan Assessment Team 2005

maps are not readily available. These factors hindered UNEP's ability to make precise determinations about the extent of the tsunami's impact on coastal zones.

Impacts varied from complete island overwash to inundation around island margins. UNEP's field mission found that natural shorelines and land surfaces, either on uninhabited islands or natural areas of inhabited islands, exhibited much less damage than developed areas. Among the islands inspected by UNEP, changes to coastal morphology tended to be greatest among those islands located close to the eastern reef rim facing the direction of the tsunami's approach. Beach erosion on these islands appeared to be widespread and characterized by the formation of erosional scarps typically 0.3 to 0.5 m high.

Material was generally deposited landward of the eastern beach ridge (especially in mangroves) and within western lagoon areas. Because island coastlines buffer island inhabitants and infrastructure and are of crucial importance to the country's tourism, coastal erosion is a serious concern.

Where the eastern beaches consisted of mostly gravel-sized reef debris, material was deposited as sheets, 10-20 m wide and 10-20 cm deep, landward of the bund. In areas where the island was overwashed, prominent scarps developed along western sandy shorelines resulting in deposition of sediment westward into adjacent reef flat/lagoon areas. Changes to island interiors was generally limited to local scour around obstacles, such as buildings, and development of thin, patchy sediment deposits.

Based on observations made by UNEP during its field mission, the dredging of sand and gravel from reef areas appeared to be widespread in Maldives. The tsunami worsened chronic shoreline erosion problems caused by sand mining and poorly designed coastal engineering structures. Tsunami-related scour around foundations and walls was prominent along eastern areas, resulting in the collapse of many structures. Inadequate foundations, either too shallow or improperly reinforced, appeared to have been a major cause. The north end of K. Guraidhoo, for example, appears to have undergone long-term erosion as a result of reef flat dredging operations from a nearby resort. The tsunami accelerated this erosion, undermining several coastal structures.

Several parameters appear to have been controlling factors in the local variability of impacts. One was the width of the reef flat. Wider reef flats dissipate more wave energy and therefore offer more protection to the coast. Damage on land also correlated with coral reef location. UNEP findings during a recent assessment of post-tsunami impacts in Seychelles echoed findings similar to UNEP's findings in Maldives:

Fringing reef crests serve a protective role against normal waves. However, in the case of the tsunami, major terrestrial and coastline damage was located in areas sheltered by fringing reefs. At these locations, damage was focused near deeper channels that allowed the waves to break closer onshore. Thus, two of the primary assets of the fringing reefs — the combined shelter and ocean access that have allowed coastal development just above the high tide line — were also the reason for vulnerability to the tsunami, and thereby to other wave- and storm-related threats. Deterioration of reefs will certainly make matters worse in coping with those hazards in the future.

Another factor was the height of the beach bund. Higher bunds provide physical barriers against overtopping. Bunds in the Maldives usually range between 1-2m. Another factor appears to have been the orientation of the tsunami's approach. Islands that were parallel to the waves' approach suffered more damage. Offshore bathymetry appears to have influenced tsunami characteristics as it approached land. With little information from the Maldives, however, it is difficult to quantify the effects.

Coastal vegetation and forests

Coastal vegetation in Maldives consists of a limited range of species, most of which are of pantropical distribution, widespread and locally abundant. There is a clear zonation of species from pioneers that colonize beach sand to much larger, longer-lived tree species in the island interiors. On larger islands, where a mature soil has developed, patches of high forest occur. Small islands with sandy saline soil support only species-poor scrub vegetation. There are very few endemic species; a large proportion of the flora, particularly on resort islands, is introduced. Coconut trees (*Cocos nucifera* L.) are cultivated extensively on almost all islands. Natural forests are composed of species that are stress tolerant and disturbance adapted, making them very resilient to extreme natural events. Overall, approximately 3% of the country's land mass is thought to have forest cover.

On inhabited islands, areas of natural *jungali* are being rapidly cleared for agriculture and housing development. The coastal zone has been extensively re-modeled on most inhabited islands. Jetties, sea walls and landfill have replaced natural vegetation. Although there is some legal protection provided for natural vegetation on uninhabited islands, there is little capacity for monitoring or enforcement.

The Maldives signed up to the Agenda 21 Action Plan at the United Nations Conference on the Environment and Development in 1992, thus making a commitment to develop Integrated Coastal Zone Management (ICZM). The purpose of ICZM is to minimize conflicts between competing demands on the coastal zone, whilst enabling sustainable use. Thus far, Maldives has not made much progress in the development of ICZM. The management of coastal vegetation is a key area of ICZM, both for conservation and to ensure that where modifications occur they do not increase vulnerability to erosion or storm surges.

The most important tsunami-related impact on coastal forest has come from clean-up operations. Clean-up crews caused significant damage to coastal forest on a number of inhabited islands by bulldozing demolition debris and garbage into and over thickets of vegetation along the coast. Otherwise, damage to intact natural coastal forest was minor.

Much of the tsunami's force was dissipated in areas where the coast was fronted by a dense littoral hedge of native shrubs such as *magoo* (*Scaevola sericea* Vahl) and *kuredhi* (*Pemphis acidula* J.R.

Forst & G. Forst.). Apart from accumulations of debris, there was little evidence of damage. Because native species are all salt-tolerant, there has been no widespread mortality in natural coastal forests as a consequence of salination.



The force of the tsunami divided the island of K. Madhifushi. Credit: I. Naeem

Coastal forests were most resilient to the tsunami impacts when left as an undisturbed, mixed-species community. Where relic individual trees were left or cultivated in areas otherwise cleared of vegetation, they were often undermined or pushed over. One spectacular example was a very large *kinbi* (*Barringtonia asiatica* L.) tree (>1.0m dbh), growing alone, adjacent to a small mosque on the island of M. Kolhufushi. The tree was

washed over 200 m from the coast. The photo (next page) shows how the roots of cultivated native trees planted along a modified coast on the island of K. Huraa have been exposed by erosion.

The contrast between the low levels of direct damage inflicted on natural coastal forest and the severe damage and subsequent high mortality of cultivated and ornamental plants was striking. Plainly, natural vegetation provided resilient coastal protection.

In general, natural shorelines and land surfaces fared better during the tsunami than did developed features. Tsunami impacts were greatest where villages or cultivated fields directly abutted the sea with little or no coastal protection. Wherever a fringe of natural coastal forest or mangroves had been left untouched there was a marked reduction in erosion and destruction of buildings. Natural vegetation withstood the impact, reduced flow velocities and filtered large quantities of debris from the waves. Scrub vegetation appears to have been more effective as a natural defence than mature trees. Groves of coconut trees and banana plantations with little undergrowth appeared to have provided little protection and in some cases may have increased turbulence and scour.



Erosional scarping along the sandy western beach of southern Th. Kalhufahalafushi. The notebook is approximately 70 cm. tall.
Credit: B. Richmond

The dense network of stems and extensive fibrous root networks of *magoo* and *kuredhi* were particularly effective at reinforcing beach sand against tsunami erosion. On many of the islands inspected during UNEP's mission the beach had been severely cut back as far as the littoral hedge. No instances were seen where this littoral hedge had been washed away. Mangroves were equally resilient to the tsunami impact. In Maldives, however, mangroves rarely occur as fringing forests. Their role in providing protection for people and infrastructure was therefore limited.

The government has reported that on some islands, large areas of coastal vegetation, which includes a local variety called *heylyhi*, as well as sea lettuce, ironwood and screw pine, were either damaged or completely destroyed. Although UNEP did not witness destruction of this vegetation type, it is possible that catastrophic erosion could have caused such damage.

Mangroves

There is very little documented information available on the mangroves of the Maldives. A 1991 study by Untawale and Jagtap, however, identified 13 species of mangroves as well as six species of plants and 37 species of fungi associated with mangrove habitats. Fringing mangroves act as important nurseries for many species of fish and crustacea and protect coastlines from erosion. They are, therefore, of value for conservation and protection and are important in sustainable natural resource use.

Mangrove habitats are not evenly distributed across the country. Southern atolls have more abundant and diverse mangrove areas than those in the north, with the northern atolls of Shaviyani and Haa Dhaalu providing the exception. On many islands, the mangroves are 'closed' and are found in

island depressions that typically contain large quantities of humus. Other islands have mangroves fringing brackish water regions.

The conservation value of mangroves has only been recently recognized. Many valuable areas have been degraded or lost due to uncontrolled timber harvesting, waste disposal and infilling for development. Although the MEC is in the process of designating a number of mangrove forests as terrestrial protected areas (such as that on the island of K. Huraa), these designations have yet to come into force.

The MEC has conducted biodiversity inventories of a number of mangroves and carried out a clean-up programme in the K. Huraa mangrove. Community support for this process, however, has so far been limited. An impressive community initiative, the ‘Magulas Club’ on the island of HD. Kulhudufushi, is working to replant areas from which mangroves have been lost and to create a nature reserve for education and ecotourism.



Housing recently constructed on the site of a former mangrove forest on the island of L. Fonadhoo. Credit: N. Brown

Undisturbed mangrove forests proved remarkably resilient to direct tsunami impacts. Most mangrove trees have widespread root networks and strong, flexible stems ideally suited to withstanding a strong surge. In all four of the mangrove forests visited during UNEP’s field mission large volumes of sand and coral rubble had been swept into these low-lying areas. It appeared that aerial stilt roots had sieved debris from the tsunami wave, increasing the quantity of deposition.

Coastal planning and natural barriers

Although records are inexact, it would appear that earthquake-generated tsunamis of greater than 1.0 m in height have occurred on three occasions in the Indian Ocean since 1883. A tsunami of the magnitude experienced on 26th December 2004, which was approximately 4.0 m in height, is an extremely rare event. In the future, however, it is likely that flooding such as that experienced in Maldives in 2004 will be caused by much smaller natural events. The sea level is predicted to rise by 12-18 cm by 2030. This means that the magnitude of extreme events needed to induce serious flooding will decrease as their frequency increases.

Pre-tsunami initiatives to reduce the vulnerability of the Maldivian population to flooding have focused on engineering coastal defenses that would protect against storm waves. The capital island, Male’, is ringed by a huge seawall built from concrete tetrapods donated by Japan at a cost of \$60 million dollars. According to a study performed by Japan Society of Civil Engineers after the tsunami, the seawall reduced the tsunami’s impact in Male’. Building sea defenses of this caliber around all inhabited islands, however, would not be economically feasible. Alternative strategies will be needed to reduce flooding impacts on people and their property.

The GOM is proposing to accelerate its Population Development and Consolidation ‘Safe Island’ Program, which was first developed prior to the tsunami. Under the ‘Safe Island’ Program communities living on smaller, less inhabited and potentially more vulnerable islands, would be settled on larger islands, presumably with better natural protection and enhanced coastal defences. According to the NRRP, the Government proposes to develop five ‘host islands’: R. Dhuvafaru, A. Sh. Maamigili, Dh. Kudahuvadhoo, Th. Vilifushi and L. Gan. The stated objective of the \$15 million

project is to address the shelter needs of tsunami-impacted populations from R. Kandholhudhoo, M. Madifushi, Th. Vilifushi, Th. Gaadhiffushi, L. Kalhaidhoo and L. Mundoo as well as “families from other affected islands who are willing to move to host islands”. The GOM has stated that it will achieve economies of scale by concentrating populations and developing them as growth centres with community access to public facilities and services. Relocation, according to the GOM, would be “totally demand driven and voluntary”.

To date, criteria for identifying ‘Safe Islands’, i.e., geophysical characteristics beyond size that would allow them to be considered ‘safe’ have not been fully elaborated. Mitigation of environmental impacts and reduction of disaster risks must be a priority during any plan to dramatically increase the land mass, population and infrastructure on islands as physically vulnerable and ecologically sensitive as those in Maldives. The GOM has developed conceptual designs for enhanced mitigation features on the proposed host islands. See Figures 1a and 1b below.

Figure 1a. Conceptual design for enhanced mitigation. According to the NRRP, elevated areas are to be distributed within islands to enable emergency evacuation. Public and schools and public buildings will be constructed up to two stories.

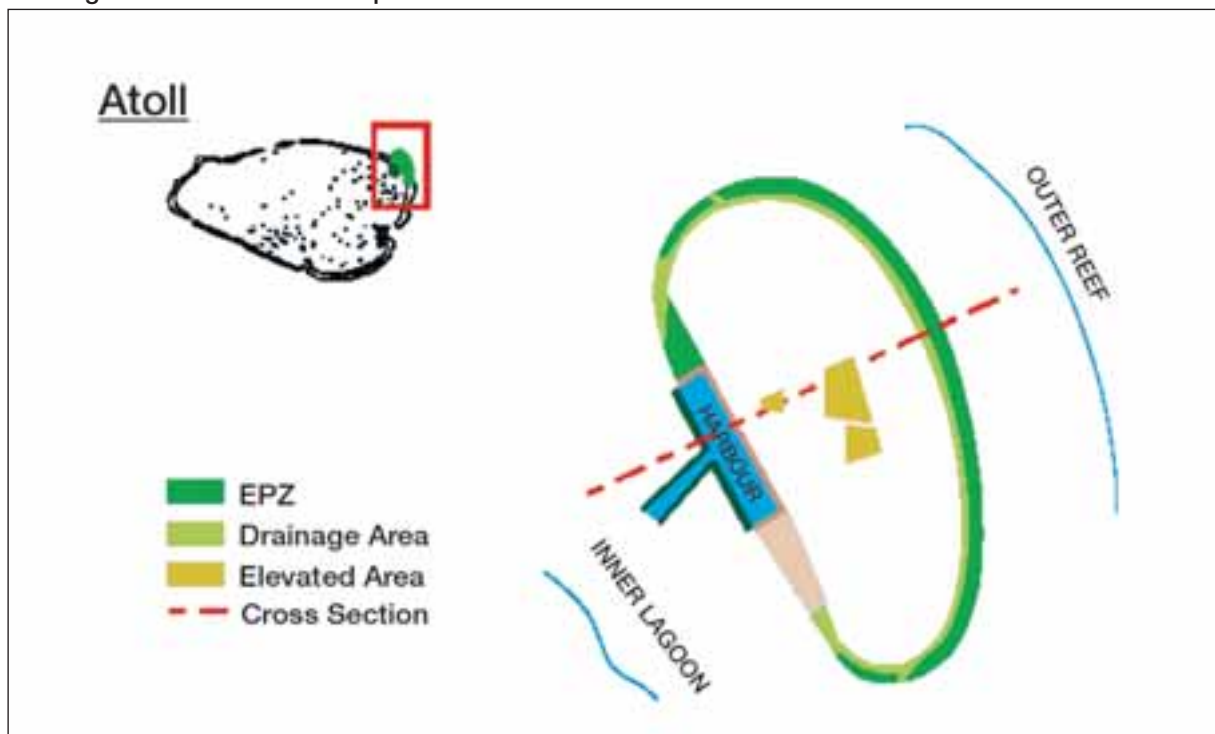
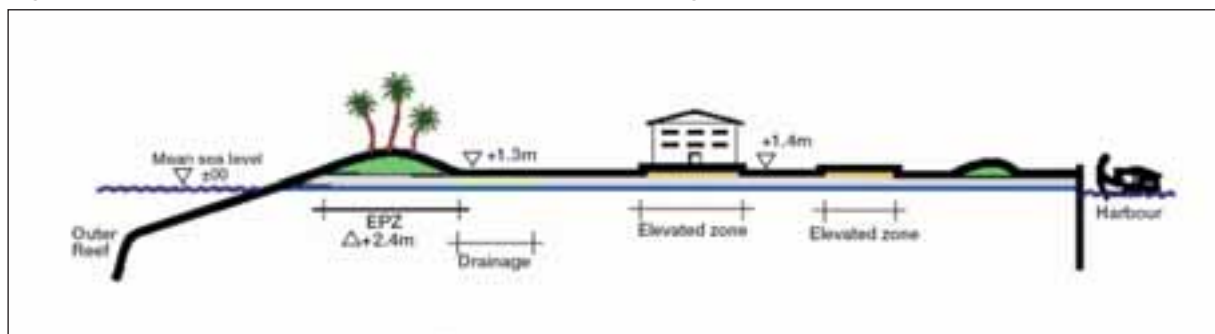


Figure 1b. Cross section of an island with enhanced mitigation features



Wetlands

Wetland forests are of very limited extent in the Maldives but contribute disproportionately to the terrestrial biodiversity of many islands.³ Forty-one islands have wetlands with a total area of just over 175 hectares. Brackish and freshwater wetlands support a great variety of trees and a large number of invertebrates, birds and fish. Wetlands are particularly important habitat for a small number of rare endemic bird subspecies including the Maldivian Little Heron (*Butorides striatus albidulusi*) and the Maldivian Pond Heron (*Ardeola grayii phillipsi*).

Two out of the four wetlands UNEP visited were not connected directly to the sea prior to the tsunami. Floodwaters had breached the sand/rubble bund between the sea and the wetland. These changes will inevitably alter both the salinity and the hydrodynamics of the wetlands. In the long term, these areas may experience successional changes in vegetation as a result.

Soft engineering

Over the last decade there has been a major shift in approaches to coastal defence, particularly in North America and North Western Europe. Engineers have come to appreciate that it is often safer, more cost-effective and more sustainable to defend a coastline by mimicking natural coastal processes rather than by disrupting them with rigid constructed reinforcements. Rigid structures that stop erosion artificially also stop the input of sediment to a beach or reef, increase instability and may ultimately accelerate their own demise. In addition, artificial anti-erosion measures prevent the circulation of sediment to beaches elsewhere that may be experiencing erosion.

‘Soft-engineering solutions’ start from the premise that sustainable coastal protection needs space. Wide beaches, mudflats and reefs, which are typically covered with natural vegetation, dissipate the energy from flood waves. Although they do not necessarily prevent flooding, they do significantly reduce the damage caused by the impact of high-energy waves breaking against artificial structures. The approach is to absorb a flood rather than deflect it.

An important development in these techniques was the recognition of the fundamental role played by natural vegetation in regulating coastal processes. Plants may be very effective at dissipating wave energy, reducing flow velocity and encouraging the accretion of soft sediments. Their roots systems have enormous tensile strength and can reinforce unconsolidated sediments. Experiments have shown that small amounts of live root can provide a substantial increase in the shear strength of sediments. Anchored and embedded stems can act as buttress piles or arch abutments to counteract shear forces. Plant litter decomposes to create soil organic matter that promotes the flocculation of soil particles and enhances microbial growth ‘gluing’ a soil together.

In Maldives, a number of inhabited islands had retained some coastal scrub on the ocean side of the island but had been developed right up to the coast on the lagoon side. The tsunami is reported to have hit the eastern side of islands first, but then wrapped around the north and south and hit from the west shortly afterwards. Many eye witness accounts report floodwaters sweeping one way across the island and then sweeping back in the opposite direction. This would imply that all coasts are vulnerable and need adequate protection. Observations on tsunami-impacted islands suggest that a strip of coastal vegetation >5 m wide provides the most effective coastal protection. This type of buffer strip would also have additional biodiversity conservation values.

During UNEP's mission, there appeared to be a relatively low level of awareness of the conservation value of wetland areas among many of the local residents. On two of the islands visited, wetland areas had been used for disposal of demolition debris and garbage during clean-up operations. It is crucially important that the small remaining areas of wetland are not further degraded in this way or viewed as potential sites for land reclamation during the process of resettlement and restoration. There is a real danger that a key habitat may be irretrievably damaged by well intentioned but poorly informed recovery actions in the coming months.

Soil

Most of the islands have shallow, humus topsoil layers (A-horizon) only where there is vegetation. Residential areas are almost free of topsoil layers. In agriculture zones, thin topsoil layers are concentrated only around plants, i.e., in the fertilizing zone. Increased imports of organic fertilizer (e.g., cow dung) indicate the fundamental lack of organic matter in topsoils.

The soils' structure has low water- and nutrient capture capacity. Due to the low density and high porosity of primary aggregates (mostly of limestone and/or dolomite origin), high degrees of evaporation and erosion can be expected. Nutrients are quickly either evaporating into the atmosphere (e.g., ammonia) or leaching into the groundwater layer (e.g., nitrates).

An FAO expert field mission conducted from mid-February to mid-March studied soils composition and tsunami impacts in detail. FAO reported that Maldives soils are:

residual soils derived by the weathering of the calcareous coral formations which form the bed-rock foundation of these islands. In the weathering process, limited amounts of shell debris may also have become intermixed. The weathered layer is usually not more than 50-70 cm deep and consists almost entirely of medium-sized CaCO_3 sand grains. The topsoil of some 15-20 cm thickness is always darker coloured by the organic matter remaining from the cleared natural vegetation and contrasts with the underlying yellowish-white pure sand which forms the column of the profile. At the bottom of the soil profile, the sand material becomes increasingly mixed with different sized coral rubble before reaching the underlying non-weathered coral rock. The depth of this half-weathered rubble layer could not fully be assessed but is probably in the order of 0.5 m with the rubble layer occurring at 30-40 cm depth.

As the soils do not have the silt and clay material which provides soils with adsorption capacities for water and nutrients, all holding capacity of these soils is vested in the organic matter in the topsoil and in the little capillary holding capacity of the medium sized sand. Part of the organic matter formed under the natural vegetation is burnt by the sun exposure when the land is cleared and used for cropping. The natural fertility of these soils must be very low whilst the total available water holding capacity (at the field capacity state) is probably not more than some 30-40 mm.

The soils must have a very high permeability for water. Much of the rainfall occurs as intense storms but no signs of erosion were observed, confirming the presumed high infiltration capacity. The hydraulic conductivity (K-value) of medium sized sand should be at least several metres per day. Also the underlying coral bedrock has a high permeability (K-values of at least 5-10 m/ day, estimated on the basis of a rough well test).

¹ Although Green turtles are protected in Maldives, their eggs are not.

The government has reported that pressure from the tsunami buckled house floors upward, a phenomenon observed by UNEP. This would seem to confirm the high permeability of the subsurface and a direct connection between groundwater and the surrounding seawater.

On some of the islands UNEP visited (e.g. HA. Filadhoo), the tsunami waves washed off topsoil. On others (e.g., M. Kohulfushi), flooding partly covered the topsoil with sediments and sand. Overall, however, the tsunami had only a slight impact on topsoil.

By far the worst effect on soils was the extent to which the tsunami deposited salt from seawater. The change in soil composition impacted local vegetation and agricultural productivity and home food gardening. FAO has reported, however, that by March 2005 there had already been enough rain to leach most of the imported soils from root zones. The remaining salts can be expected to leach out after additional rains during the monsoon season. At the time of FAO's mission, farmers in southern atolls were already successfully planting crops, whilst soils in northern atolls were still too saline for planting. The FAO soil assessment stated:



UNEP expert taking soil sample on agricultural island of HD. Theefaridhoo. Credit: J. Bennett

Although most of the saline flood water eventually drained back to the sea and the period of flooding in some cases was quite short, enough seawater infiltrated or remained on the land to leave a considerable salt load in the soil. Assuming an average pre-tsunami water table depth of 70 cm, a soil storage capacity of 40%, an average 5 cm depth of remaining water (non-uniformly distributed over the uneven land surface) and a sea water salinity of 35,000 ppm, this salt load may be estimated to amount to some 120 tons per ha (12 kg per m²). After the retreat of the saline flood water, much of this salt remained in the root zone, raising the soil salinity in this zone to an estimated level as high as E_{ce} ~ 50–60 dS/m.

These high soil salinity values prevailed for some time after the flooding, until the arrival of the first rain....Since the flooding, many of the affected areas in the South have had up to 100-150 mm of rainfall which rain (given the high infiltration rate and low water holding capacity of these sandy soils) has washed down most of the salts and reduced the soil salinity in the root zone to safe levels. [A] meteorological station in the South (at L. Kadhoo Airport)...has recorded some 176 mm of rain since the tsunami. Due to the non-uniformity of the rainfall, there may, however, be some areas where the soil salinity is still a bit at the high side for sensitive plants/trees.

UNEP took soil samples at power stations and oil storage facilities to determine the nature and extent of impacts on soils and groundwater from leaked or spilled oil components. Although laboratory testing identified relatively recent soil stains, it could not be established definitively whether the staining pre-dated or was caused by the tsunami. The samples, which were analysed for levels of total organic carbon (TOC), C6-C10, >C10-C25, >C25-C35 and polyaromatic hydrocarbons (PAH), confirmed high levels of oil contamination – in the range of 1-29 g/kg of TOC. Testing indicated the components were from diesel fuel.

Groundwater

Groundwater aquifers in the Maldives islands normally lie between 1 and 1.5 metres below the soil surface. The proximity of the aquifers to the island surfaces makes them vulnerable to pollution and contamination from human activities as well as saltwater intrusion. In addition, population and development pressures have led to increased groundwater extraction, resulting in depletion of the country's freshwater lenses during the past several years. For all of these reasons, the availability of groundwater as a freshwater resource has been limited. According to the 2004 State of the Environment Report, only 39 inhabited islands had groundwater that was suitable for drinking before the tsunami.

Aquifer thickness is dictated by several factors including net rainfall recharge, size of the island and permeability of the soil column. Because these parameters vary from island to island, the quality of the aquifers vary. Previous studies have shown the existence of long-term impacts on freshwater aquifers from increased salinity and bacterial contamination.

During its field mission, UNEP confirmed that a number of pre-tsunami conditions, including salinity, washout from sanitary facilities and point source contamination had apparently harmed groundwater supplies over time. Elevated levels of abstraction, for example, had caused seawater to intrude into the freshwater aquifer, increasing salinity levels. Septic tanks consist solely of soak-pits from which sewage can freely migrate through the highly porous island soil and contaminate groundwater sources. Oil products, fertilizers and pesticides are also contaminating groundwater.

The unavailability of historical baseline monitoring data for most islands visited by UNEP made it difficult to distinguish definitively tsunami-related impacts on groundwater quality from historical pollution. It is clear, however, that freshwater lenses were significantly affected by the tsunami throughout the impacted islands. The tsunami's high waves and flooding caused sea water to intrude and infiltrate groundwater resources horizontally, due to increased sea level, and vertically into the ground in flooded area. Fresh water was forced up and out of some wells, whilst others were inundated by floodwater. Groundwater supplies experienced high levels of salinity and faecal coliform contamination.

Field samples taken by UNEP and MWSA were analysed for a variety of parameters including physical,



The communal dumpsite on L. Gan illustrates the risks of groundwater contamination from surface waste. Credit: E. Spitaler



Leaking oil drums with spillage on agricultural island of HD. Theefaridhoo. Credit: E. Spitaler

inorganic elements, heavy metals, biological and organic components. UNEP-MWSA's in-situ measurements found very high concentrations of conductivity, in the range of >1000 to 36000 $\mu\text{S}/\text{cm}$ and salinity in the range of 500 to > 24,000 parts per thousand. (A full list of samples and results can be found in Annex 2.)

Sewerage systems are generally located close (within 5 - 10 metres) to private wells that supply water for bathing, and for washing food and dishes. UNEP found minimal evidence of damage to septic tanks, suggesting that microbial contamination of groundwater supplies, though undoubtedly worsened by the tsunami, was a serious chronic problem that pre-existed the tsunami. On severely damaged islands, the demolition of damaged buildings was already well advanced and the status of the sewerage systems in these areas could not be monitored. Nevertheless, it is clear that the tsunami washed out waste and sanitary installations, very probably worsening groundwater quality significantly.

Indeed, in-situ measurements for biological contaminants and inorganic elements showed a high degree of contamination. UNEP-MWSA field samples found

total coliforms and E-coli values uniformly >100/100 ml, substantially in excess of acceptable levels. These findings were consistent with post-tsunami samples taken by a joint UNICEF-MWSA mission and by the FAO, which also found high levels of salinity and microbial contamination. UNEP-MWSA samples also found high levels of nitrates (NO_3) in the majority of the samples, clearly indicating a strong impact to the groundwater from the sewerage system. Nitrates in drinking water pose a severe risk to infants and young children. According to the WHO, drinking water containing greater than 30 mg/l of nitrates poses risks to the health of infants and children. A number of UNEP-MWSA samples were substantially in excess of this threshold.

Most of the groundwater wells UNEP inspected had not been destroyed. Some wells in the southern part of the country (L. Fonadhoo, L. Gan), however, had been constructed using concrete made with coral sand and were destroyed. In highly affected areas, especially areas with damaged and abandoned buildings, demolition waste and household waste was found in the wells. It is unclear whether most wells have been cleaned and properly closed in demolished areas. Although some wells had been covered, many UNEP inspected were not and remained vulnerable to further impacts during clean up and reconstruction activities. The waste left in wells poses a potential risk to public health and could very well further spread contaminants (e.g., nitrates, ammonium, biological contaminants) to the aquifer. The contaminated wells may also provide breeding grounds for disease vectors such as mosquitoes.

Remediation of groundwater supplies that have been rendered unusable will likely take several years. In the meantime, residents of affected islands would face risks from kidney damage and various diseases (cholera, typhus, diphtheria and enteric fever) if they were to consume groundwater with high levels of salinity and faecal coliforms.

UNEP observed small fresh oil spills at the majority of the power stations inspected. Although it was not possible to distinguish between tsunami-related oil spills and more long-term impacts, the spills

seemed to have been caused by the handling and drawing of oil, especially around oil barrels, and leaks in pipe joints and/or valves and filters. Except for one sample taken at a power station in HA. Filadhoo, groundwater samples showed no indication of oil contamination. The HA. Filadhoo sample showed a very low concentration of an unidentified hydrocarbon.

Surface water

Freshwater can be found in ponds on some islands. These ponds provide important habitats for island ecology, serving as water reserves for animals and plants. Floodwaters from the tsunami have increased salinity in ponds on the impacted islands. Because the bottoms of these ponds are impermeable, recovery from the tsunami's impact will likely take many years.

Protected areas

The Maldives has 25 officially designated marine protected areas (MPAs) and one area that encompasses both marine and terrestrial ecosystems (Hithadhoo Protected Area). These areas have significant biological, physical, aesthetic and recreational value. Although they have not been declared protected areas, two islands, S. Hithadhoo and A.Dh. Hurasdhoo, have been identified as ecologically significant. Hithadhoo has the largest frigate bird nesting site in the country, and A.Dh. Hurasdhoo is a uniquely formed island with endemic vegetation.

UNEP's investigation of A.Dh. Hurasdhoo found that, although the island is small and low-lying, the tsunami impacts on it were only slight. Debris, caught at heights of 1-2 m above the forest floor, testified to the inundation of the island. There was, however, little or no tree mortality and no evidence of scour from the forest floor. The forest retained a thick litter layer and shallow peaty soil with dense natural regeneration.

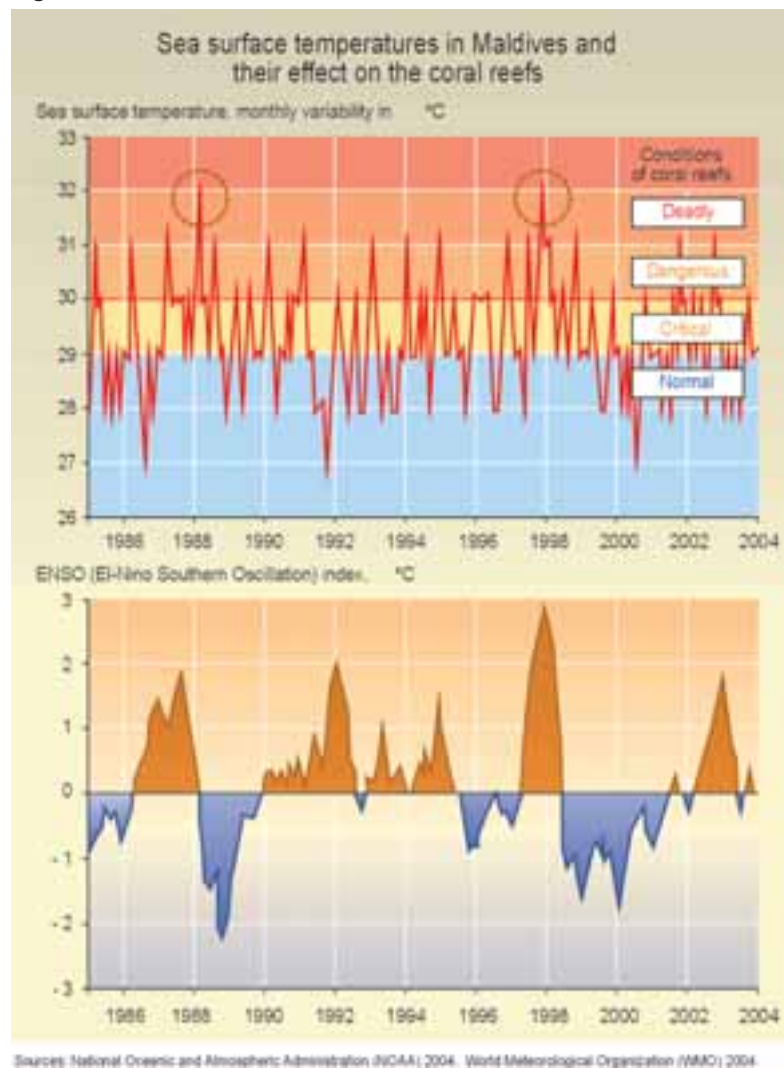
Very limited assessments have been undertaken to identify the environmental impacts of the tsunami on protected areas. An expert team sponsored by the Australian government visited two MPAs. The team reported that there was no significant physical damage to the MPAs visited. They did, however, find evidence of sedimentation at these sites. No physical damage was identified on the recently designated Hithadhoo Protected Area. It is possible, however, that salt water may have impacted the Eidhigali Kilhi area, which has the highest conservation value within that Protected Area. Although no field assessments have been carried out at S. Hithadhoo, the S. Hithadhoo Atoll Office reports that some of the vegetation that supports the frigate birds roosting on Hithadhoo has been damaged.

Coral reefs

The Maldives is home to a vast system of world famous coral reefs that attracts tourists from around the world. The country's lagoons and reefs combined make up approximately 21,300 square kilometres. The reefs comprise approximately 200 coral species and provide habitat for an extraordinary array of fishes and marine life. In 1998, the country's reefs suffered from extensive bleaching that killed an estimated 90 percent of the country's coral. Against that backdrop, any further damage to the coral reefs must be taken seriously.

In February 2005, an interdisciplinary team from Australia's leading marine science agencies (CSIRO, Australian Institute of Marine Science, Great Barrier Reef Marine Park Authority and James Cook University) completed a survey of 124 coral reef sites (spanning 177 kilometres of reefs) at seven of the country's 26 atolls. The mission included expertise in coral and coral reef fish ecology, reef health and management, reef and island geomorphology and baitfish. Additional information came from 65 tourist dive sites. The work was prepared in cooperation with the Maldives Marine Research

Figure 2.



Centre and as the result of a request from President Gayoom of Maldives to Australian Prime Minister Howard. The Government of Australia (AusAID) sponsored and coordinated the mission.

The Australian team focused on coral reef health, including the nature and extent of any tsunami-related damage; the nature and extent of structural damage or changes to island geomorphology and associated reef systems resulting from the tsunami; and the impacts of the tsunami on baitfish populations in atolls and coral reef lagoons. The assessment's findings included detailed recommendations for further action, which may be found in the Recommendations chapter below.

The following key findings regarding corals and coral reef health were reported by the AusAID team:

Although there was damage to coral and movement of sediments in all regions these perturbations varied in extent and intensity. Even so, surveys generally indicated that direct damage to reefs from the tsunami was minor. However, the reefs of the Maldives are in the early stages of recovery from the massive bleaching in 1998 and the most

significant consequence of the tsunami may be to hamper this process. Many survey sites had a light coating of sand. Small coral recruits are most vulnerable to smothering by sand and rubble and even a light coating of sand may make reef surfaces unsuitable for future settlement. In general little is known of the biodiversity or prior ecosystem status and past changes on coral reefs of the Maldives. This complicated the assessment of the effects of the tsunami and, given the economic importance of coral reefs to the nation, this is a gap.

Sea grass beds

Sea grass beds are known to play an important role in the shallow tropical marine environment. They are a nursery habitat for many species of reef fish, a major source of organic biomass for coastal food webs, and they stabilize unconsolidated coastal sediments. There are unconfirmed reports that sea grass meadows have been expanding in the Maldives in recent years. This expansion has been attributed to increased coastal development. Moderate nutrient enrichment is known to increase sea grass productivity, and this may be particularly important in oligotrophic tropical marine environments. On many islands sea grass litter is collected from beaches and used as a green manure on field and home gardens. Sea grass meadows are unpopular with resort islands as they are perceived to be unsightly, and decomposing litter has an unpleasant smell. Two resorts visited during UNEP's field mission had attempted to control the spread of sea grass by covering it and digging out rhizomes.



Seagrass meadows smothered in sand on the eastern reef flat of HD. Kulhudufushi. Credit: N. Brown

Areas of seagrass (*Thalassia hemprichii*) on M. Kolhufushi, Th. Vilafushi and HD. Hanimaadhoo islands appeared to be in poor condition. There was little evidence of direct mechanical damage resulting from the impact of the tsunami. Most damage seems to have resulted from sediment smothering and increased turbidity over the reef flat, the results of soil, sand and debris having washed from the islands and post-tsunami clean-up operations. These impacts are likely to be short-term and reversible, except where clean-up operations have pushed large volumes of demolition and household waste onto the reef flat or where the shore profile has been significantly altered. In such instances, long-term changes to coastal sediment dynamics may result in lasting impacts on sea grass.

The most extensive sea grass meadows are associated with densely inhabited islands where nutrient discharges to coastal waters are highest. These tend also to be areas that have been more severely impacted by the tsunami, and there is a risk that they may be vulnerable to sediment smothering during intensive clean-up activities.

Seagrass beds are an important food resource for the Green turtle (*Chelonia mydas*). Maldives is a globally important nesting site for this species. The Green turtle is included on the IUCN Red List of endangered species, and habitat degradation in its feeding areas is recognized to contribute to the species current rapid population decline. Population trends in the Maldives are unknown. As seagrass meadows appear to be thriving, it is unlikely that loss of feeding areas is a major factor in population change.



Central dumpsite on Thilafushi island, near Male'. Credit: E. Spitaler

IMPACTS ON THE HUMAN ENVIRONMENT

Solid waste

Waste is one of the most environmentally challenging issues in the Maldives. The inhabited islands UNEP visited once presented postcard images of pristine nature, but are now dotted with garbage. Although streets and homes are well cleaned, less developed, 'jungle' areas are littered with household waste that is simply dumped or burnt. According to UN studies, environment issues have risen dramatically as a source of public concern in Maldives between 1998 and 2004. The visible increase of waste on the islands is very likely a strong contributing factor to this increase in concern.

Waste disposal practices in Maldives vary among islands depending on access to disposal facilities, local custom and government/municipal intervention. UNEP's field mission found no evidence of regular, controlled waste collection. Householders typically carry their waste either to designated

disposal sites or to the periphery of the inhabited areas. Local women's committees also transport waste to the dumps. According to the 2004 State of the Environment Report, less than 2% of the islands have established fee-for-service waste management systems, and UNEP's field mission found no evidence of regular, controlled waste collection.



Debris and building materials being used to reclaim land and cover erosional scarps from tsunami on the western shore of M. Kolhufushi. Credit: B. Richmond

Disposal practices on all islands visited by UNEP were inadequate. Disposal sites are uncontrolled, unmanaged and often located along vegetation lines or shorelines. Waste is simply dumped and/or burnt. Uncontrolled burning produces dioxins, furans, and formaldehydes, SO₂, PM₁₀ and NO_x, all of which are hazardous to human health. Impacts on groundwater supplies, the coastal zone and



reefs are also likely. UNEP found evidence of leaching that is undoubtedly intruding into the groundwater layer and creating threats of waterborne disease from concentrations of chlorides, sulphates, nitrates, ammonium and organic contamination.

There are three regional landfill sites – in the north, central and south of the country. These facilities have limited disposal capacity and have not been effectively implemented. The regional landfill on HD. Kulhudufushi, however, has primary infrastructure, such as hazardous waste storage, a recycling area, a greenhouse, drying beds for sewage sludge, an access road and a tipping area of adequate size.

There is little segregation of waste, except at K. Thilafushi Island, which collects waste from Male' and the neighboring islands of K. Villingili and Hulhule. Some communities that depend on firewood may segregate wood, coconuts and other combustible waste. UNEP observed some privately organised waste segregation on HD. Kulhudufushi, where sewage sludge is being dried and used as fertilizer for vegetable production. Other goods (e.g., metal, polyethylene) are being segregated, but due to the lack of broader recycling activities, not recycled.

UNEP's field mission visited two uninhabited islands, Th. Kalhufahalafushi, and A.Dh. Hurasdhoo. Evidence of tourism-related waste was found on A.Dh. Hurasdhoo, which may be designated a protected area.

Waste practices on resort islands are decidedly better than those on inhabited islands. The resort islands, as a result, appear clean. The two resort islands inspected by UNEP, Fun Island and Angaga, collect and segregate waste at central locations. Combustible waste is incinerated at 800°C. At Fun Island, however, the incinerator was not working, and waste was being shipped to Thilafushi. Kitchen waste, however, is dumped offshore into the open sea in accordance with the regulations of Ministry of Tourism on deep-sea disposal of waste. Waste that cannot be reused or incinerated is transported by boat to the country's central dumpsite at Thilafushi.

UNEP estimates that resort islands (tourists and staff) produce 2.5kg per person/day of household waste. This compares with an estimated 0.3-0.5kg/person/day on inhabited islands and 0.8-1.0/person/day in Male'.

Thilafushi landfill serves the approximately 80,000 inhabitants of Male' and neighboring islands. It also receives waste from a number of resort islands. An estimated 180,000 tons of waste are disposed

on the island annually. In order to reduce waste, combustible wastes are burnt. Due to the high permeability of limestone and the absence of underground protection measures, leakage into the groundwater and into the sea is obvious. Land reclamation activities using untreated and unsorted demolition waste are contaminating zones along the sea's edge. Oil is spilling from uncontrolled and leaking oil drums, also polluting the water. Poly-aromatic hydrocarbons (PAH), Mono-aromatic hydrocarbons (BTEX), PCBs and polychlorinated pesticides, high chemical oxygen demand (COD) and concentrations of anionic and cationic elements can all be expected to be found in the surrounding and underground waters.

Table 1. Estimated air pollutants emitted by Thilafushi (UNEP calculation)

Parameter	WHO Limits ⁴	Estimated Range ⁵	
TSM (total suspended matter)	120	700	1200
PM 10 (particles with diameter less than 10 micrometres)	70	300	1000
SO ₂ (sulphur dioxide)	100	250	700
NO ₂ (nitrogen dioxide)	100	350	650
HCHO (formaldehyde)	0.8	10	20
Pb (lead)	1	1	2
As (arsenic)	0.03	0.06	0,1
Hg (mercury)	0.01	0.1	0.3
Dioxins ⁵	13	300	1000

It is generally assumed that burning mixed waste in landfills emits dioxins and furans in the range of approximately 1,000 micrograms TEQ⁶/ton of material burnt. According to the World Health Organization, the inhalation of dioxins is known to cause serious public health risks. Uncontrolled domestic waste emits in the range of 300-1,000 micrograms TEQ/ton of material burnt. At Thilafushi, therefore, emissions of 300 - 1000 micrograms TEQ/ton of material burnt can be assumed. If an average of 17,000-25 000 tons of waste were burnt per year at Thilafushi (7-15% of the total amount collected), the quantity of dioxins and furans emitted to the ambient air may reach as high as 5 - 25 grams TEQ/year. By contrast, if this waste were burnt using a controlled incinerator, total emissions would likely equal 13 - 16 micrograms TEQ/ton of material burnt with obvious benefits to human health and the environment.

UNEP estimates that the tsunami created approximately 290,000 cubic metres of demolition waste. This amount combined with estimated 50,000 cubic metres of pre-existing household and other waste. The tsunami waste is diverse in nature, comprising hazardous waste (oil, asbestos, batteries, etc.), vegetation, soil, sediment, municipal waste from dump sites, healthcare waste, demolition

⁴ all limits in µg/m³

⁵ values in µg/ton

⁶ TEQ = toxic equivalence

waste (concrete, brick, timber, etc.) from destroyed buildings, oil spilled from generators, leakage from septic tanks and wastes generated by relief operations.

Much of this debris was dispersed over the affected islands. Dumpsites on several islands visited by UNEP (HA. Filadhoo, M. Muli, M. Kolhufushi, Th. Vilufushi, Th. Guraidhoo and K. Huraa) were completely washed into the sea. Waste on other islands (L. Fonadhoo, K. Huraa, K. Guraidhoo) was spilled onto the shore by the tsunami or storm waves. It can be safely assumed that similar problems occurred on all of the impacted islands.

Redistributed waste lying on the soil and beaches threatens to contaminate groundwater supplies and the marine environment. Clean-up efforts have either not improved conditions or, in some cases, have worsened them. These conditions are impeding island services and access routes and may adversely impact recovery and reconstruction efforts.

Improperly managed waste also poses risks to human health from illness, infection, injury or inhalation of smoke. A health official in HD. Kulhudufushi reported to UNEP that there have been recent cases of scrub typhus reported in the Haa Dhaal region. In 2003, 106 cases of scrub typhus were diagnosed nationally. Vermin associated with waste, especially rats, are known scrub typhus vectors.

The rate of damage to buildings from the tsunami strongly depended on the location of the island; the angle of the tsunami wave, building location (i.e., altitude, windward/leeward side, relation to the shoreline, proximity to natural vegetation); and the construction standards used (i.e., concrete made with coral vs. river sand; use of ring beams), which seems to be a function of income level and awareness. As shown in Table 2 (next page), the highest rates of destruction and demolition waste were found on Th. Mahdifushi, M. Kolhufushi, Th. Vilufushi, L. Fonadhoo and K. Guraidhoo.



The mosque on K. Guraidhoo survived intact while structures around it were destroyed. Credit: M. Mohammed

Table 2. Rate of building destruction, by island

Island	RADEEKHOO	MULI	MADHIFUSHI	KOLHUFUSHI	NALAFUSHI	FILLADHOO	KULHUDUFFUSHI	FILUFUSHI	FONADHOO	GAN	KALHAIDHOO	GURADHOO	HURAA	Sum
PE ⁷	376	376	190	1215	475	475	7670	7670	1760	832	456	1475	720	23.690
buildings	74	134	38	179	78	140	1200	206	293	358	96	96	172	3.064
damaged buildings	21	73	2	41	50	78	200	26	26	30	20	18	17	602
destroyed buildings	2	21	33	41	6	15	0	160	47	5	24	39	2	395
damaged& destroyed buildings	23	94	35	82	56	93	200	186	73	35	44	57	19	997
impact rate [%]	31%	70%	92%	46%	72%	66%	17%	90%	25%	10%	46%	59%	11%	33%

Table 3. Estimation of tsunami-related waste by general category

Island	RADEEKHOO	MULI	MADHIFUSHI	KOLHUFUSHI	NALAFUSHI	FILLADHOO	KULHUDUFFUSHI	FILUFUSHI	FONADHOO	GAN	KALHAIDHOO	GURADHOO	HURAA	Average
Inert material waste [%]	60	85	80	80	90	94	85	87	89	89	89	90	80	79%
Reusable const. waste [%]	80	80	80	80	75	15	15	15	30	30	15	20	20	40%
Vegetation and organic [%]	30	9	4	4	2	2	10	5	5	5	3	4	10	7%
Metal [%]	5	2	5	3	3	2	2	5	3	3	3	3	5	4%
Household related	5	3	10	8	4	2	2	2	2	2	4	2	4	4%

⁷ PE = population equivalent

Most of the tsunami-related waste produced was demolition waste and vegetation. Table 3 provides an estimation of tsunami-related waste by general category.

Demolition waste ranged from 60-94% inert material, averaging 79%, whilst organic waste comprised 4-30%, metals 2-5%, household-related waste 2-10% and hazardous materials, 1%. Inert materials included concrete-based material, ceramic, coral stone from walls, bricks, sand and sediments and topsoil. Organic fragments and vegetation, such as palm leaves, trees, trunks, branches and a small amount of soft organic matters comprised an average of 7% of the demolition waste.

UNEP estimates that an average of 40% of the demolition waste inspected could potentially be reused, with rates ranging from 15-80%, strongly depending on the age of the construction material and island income levels. See Table 4, below. The extent to which demolition waste, such as undamaged bricks, can be reused depends on the waste's composition and condition. Recyclable inert material consists of broken bricks, concrete fragments, ceramic and coral stones.

Table 4. Estimated percentage of reusable construction waste, by island.

Island	RADEEKHOO	MULI	MADHIFUSHI	KOLHUFUSHI	NALAFUSHI	FILLADHOO	KULHUDUFFUSHI	VILUFUSHI	FONADHOO	GAN	KALHAIDHOO	GURADHOO	HURAA	Average
Reusable const. waste [%]	80	80	80	80	75	15	15	15	30	30	15	20	20	40%

Between approximately half to two-thirds of all homes UNEP inspected are covered with metal sheets. Most of the metal mixed within the demolition waste, therefore, consists of roof sheets from damaged buildings.

Household-related waste includes treated wood from furniture, plastic pipes and tubes, tools, plastic furniture, and typical household. The island of Th. Mahdifushi seemed to have the highest percentage of household waste due, most likely, to the fact that its inhabitants have been evacuated to AD. Mamagilli and no clean up activities have taken place thus far. UNEP also observed a high rate of household waste on M. Kolhufushi, where waste is generally not well controlled. Inhabitants are living at the moment in temporary shelters and have not actively taken part in the clean up and reuse of household-related goods.

UNEP investigated temporary housing sites on M. Kolhufushi and K. Guraidhoo. Household waste from these sites was being disposed on the shorelines, where it is eventually swept out to sea. Similarly, waste produced at two camps for internally displaced people in Gan was being burnt once or twice weekly.

Without exception, improperly managed clean up work has worsened environmental conditions on the impacted islands. Approximately one-third of tsunami-related demolition waste has been dumped directly into the sea, and the process is ongoing. The Ministry of Atoll Development and the MEC's



Cement bags and construction waste on K. Guraidhoo. Credit: E. Spitaler

Public Works Section provided a number of islands with heavy equipment to clean up affected areas. Crews frequently moved mixed demolition waste onto shorelines in an effort to either marginalize its impact or begin land reclamation. As a result, mixed organic waste has been contaminating groundwater supplies and entering the marine environment.

In general, islands with high unemployment and lower income levels seemed to be segregating and stockpiling reusable materials, like bricks, roof sheets, wood for heating and coral stone. Some islands, e.g., M. Naalaafushi, are using unsegregated rubble to develop a breakwater along the shoreline. (The breakwater is not engineered, however, and is unlikely to provide protection against storm and/or tsunami waves.) Th. Vilufushi has started partly segregating and reusing material (mostly coral stone) for land reclamation. Only one island visited by UNEP, HA. Filadhoo, had stockpiled segregated inert material at a defined location. The rest were simply pushing waste onto the coast and into the sea.

Reconstruction work can be expected to produce an enormous volume of construction and imported packaging waste. Unless properly managed, these additional volumes will add to the already great waste management burden facing the islands.

Based on UNEP's initial assessment of damaged areas, the MEC has introduced 'Guidelines for the Management of Tsunami-related Waste', which provides guidance for the safe management and disposal of wastes, including asbestos. This guidance has been issued to all atoll offices and committees on tsunami-damaged islands.

Hazardous waste

In general, there appear to be chronic gaps in Maldives approach to collecting, treating and disposing of hazardous waste, which is currently not consistent with environmental and public health requirements. It is unclear to what extent hazardous waste is identified as such in Maldives. At present, efforts to handle and dispose of hazardous waste properly are minimal, and the country lacks a secure hazardous waste storage, treatment or disposal facility.⁸

The main sources of hazardous waste on the islands are power stations, oil/fuel supply storage areas, fertilizer and pesticide storage areas, farming activities. See Table 5 below for an estimation of hazardous waste source on the islands UNEP visited.

On the inhabited islands inspected by UNEP, hazardous waste, except for oil, was handled and disposed no differently than other forms of solid waste. The resort islands transport hazardous components to the landfill facility at Thilafushi, which stores oil, batteries, accumulators and other hazardous waste.

Table 5. Estimation of hazardous waste source on the islands visited by UNEP.

Island	RADEEKHOO	MULI	MADHIFUSHI	KOLHUFUSHI	NALAFUSHI	FILLADHOO	KULHUDUFFUSHI	VILUFUSHI	FONADHOO	GAN	KALHAIDHOO	GURADHOO	HURAA	Sum
Oil drums [barrels]	2	23	8	15	3	20	10	10	10	10	13	8	5	137
Fuel stored [litre]	6000	2500	940	1.150	150	2500	400000	2500	40000	2500	2000	30.000	1200	491.440
Oil and fuel store public	x	x	x	x	x		x	x		x	x	x	x	
Oil and fuel store private						x	x		x					
Waste oil storage	PH	PH	unpr.	unpr.	unpr.	PH	PH	PH	PH	PH	unpro	PH	PH	
Fuel store	Barrels	Tank	Tank	Barrels	Barrels	Barrels	Tank	Barrels	Tank	Tank	Barrels	Tank!	Tank	
Pipeline							x		x			x		
Fuel truck							x					x		
Fertilizer store														

¹ N.B. A hazardous waste storage facility on HD. Kulhudufushi is not currently in use.

UNEP found diesel fuel and oil in use on all the inhabited islands visited during its field mission. Power stations store oil drums, and a central oil storage facility is often located close to the harbour. In general, the power stations appeared to be well managed and maintained. Except in K. Guraidhoo, however, the storage facilities inspected were handling and/or storing supplies directly on the ground and had not installed protective measures or separators to clean oil-contaminated surface water. These conditions create a high risk that oil will affect soil and groundwater in case of spills or leakage.

A power station that generates 400 kW will produce approximately 35- 40 litres waste oil per month. Waste oil from state-operated power stations tends to be sent to the dumpsite at Thilafushi. Most of the power stations, however, store waste oil on site. It is also commonly sold or provided for painting activities. At a number of sites waste oil was simply being burnt openly or discharged into the sea or groundwater layer. Oil and fuel filters were also open burnt or dumped. On the island L. Fonadhoo it is common to reuse oil and fuel filters after cleaning them with fuel in open space, near the groundwater well. All of these practices create air, soil and groundwater pollution.

The extent to which the islands' central oil storage facilities have taken protective measures seems to have varied widely. At very few facilities UNEP inspected had the oil tank and barrels been placed on concrete with a retaining wall to protect the environment in case of a spill or major leak. As was true of the power stations, small-scale spillage was found where the oil was being handled. Three islands visited (HD. Kulhudufushi, L. Fonadhoo and K. Guraidhoo) were pumping fuel from vessels to central tanks without the use of a suction devices that could prevent leaks and pollution.

On Thilafushi landfill, drums of waste oil, have been widely dispersed, and large-scale oil spills have occurred. The site's management has recently begun to organise central storage and separation of oils. At present, approximately 200 drums of waste oil are being stored.

According to interviews with local residents, the tsunami washed off an unidentifiable quantity of fuel, oil, pesticides and fertilizers. Exact data is unavailable, however, due to the absence of accurate records regarding any of these substances. The tsunami damaged some of the power stations, causing oil and fuel to spill and drums to be washed away. HA. Filadhoo, for example, reported that 22 fuel drums were swept out to sea by the tsunami. L. Fonadhoo also experienced losses of unknown kinds and quantities of fertilizer and pesticides from two of their three storage facilities.

Large central oil and fuel storage facilities, however, showed almost no physical impacts, suggesting risk reduction advantages. Most of the worst-impacted power stations were under the management of the islands. Those operated by the government electricity company, STELCO (State Electricity Company), reported to UNEP almost no damage.

On resort islands, air conditioning units using refrigerants R22 and R12 were damaged by the tsunami. At present, Maldives has no sufficient disposal practice for refrigerants.

Asbestos

Asbestos is known to cause fatal respiratory diseases, and is a proven carcinogen. The risk from asbestos is caused by the inhalation of airborne asbestos fiber and is believed to be dose related, though there is no known safe threshold limit for asbestos exposures.

Epidemiological studies have proved that smoking and exposure to asbestos have a synergistic effect, increasing by as much as 50 times the risk of suffering from asbestos-related disease.

Asbestos products in a good and sealed condition are not hazardous. The risk from in-situ asbestos cement products is low, provided the materials have not been damaged or abraded. Health risks

arises when asbestos fibres become airborne, which usually occurs by damaging asbestos, such as breaking, sawing, drilling, sanding or crushing.

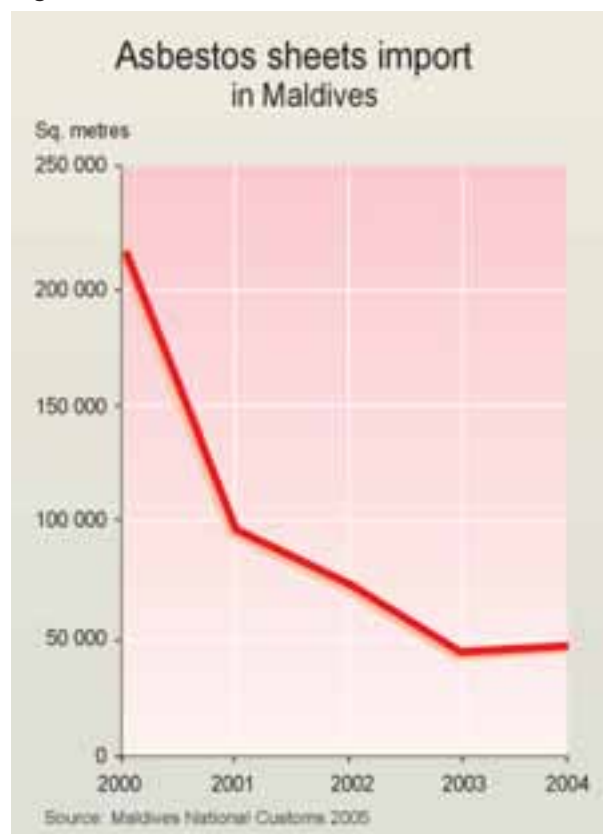
The Maldives Customs Services does not restrict the importation of asbestos materials or recognize asbestos material as a hazardous substance. The MEC imposes no rules on the receipt of asbestos materials, though there are some regulations in place for the receipt of other hazardous materials (e.g., freon gas).

Asbestos usage in the Maldives appears to consist predominantly of relatively 'low risk' asbestos cement products – primarily in the form of corrugated roofing sheets and ceiling panels. Resort companies import asbestos products directly for use in construction, as do airports, shipping and fisheries organisations. In general, however, imports of asbestos products have steadily declined during the past five years, as has their use within the construction sector. See Figure 3 below.

The construction section of the MEC is responsible for all Government construction projects. Asbestos was specified as a building material until the mid-1980s. Since then, asbestos-containing materials have not been included in Government specifications, though there is no ban on their use.

The current use of asbestos materials in Maldives, i.e., mainly for weatherproofing presents little risk to occupants of buildings. Asbestos-containing roofing materials appears to be in generally good condition. Rainwater collected from asbestos-containing roofs, therefore, is likely to contain very low levels of fiber and is unlikely to pose health hazards.

Figure 3.





Destroyed, debris-strewn landscape on K. Madhifushi. Credit: E. Spitaler

Construction using asbestos materials poses an increased risk to construction workers. Intact asbestos sheets, however, have historically been reclaimed and reused as building materials. If intact roofing sheets can be used again, the risk of such use would be minimal relative to the benefits that could be provided to tsunami-affected villages. Awareness of the need to minimise dust release during handling, however, would be of direct benefit to persons involved in the reuse of this material.

At present, there are no regulations or guidelines in place in Maldives for the safe disposal of asbestos-containing materials. One reason may be that responsibility for asbestos appears to be spread over various ministries, none of which have clear responsibility. In addition, there is not yet adequate public awareness of asbestos and its risks, whether in government, trade groups or among the general public.

In Maldives, asbestos waste has traditionally been considered construction and demolition waste and has been mixed in with general waste on Thilafusi and inhabited islands. Following a UNEP site visit, waste authorities announced a decision to separate asbestos materials, though there remained uncertainty about how asbestos materials would be properly identified and sorted. The currently accepted best disposal practice for asbestos is to bury it in secure landfill sites. Normally, the waste is wrapped and sealed in heavy-duty polythene or visqueen before it is buried.

UNEP identified tsunami-damaged asbestos cement roofing sheets and ceiling boards throughout the islands visited. UNEP observed that clean-up teams moving around the islands were not removing or separating damaged pieces of asbestos cement from building rubble. On most islands inspected by UNEP, some roof sheets had been salvaged and stacked for re-use whilst others had been crushed and broken into small fragments. In some cases, attempts had been made to burn it. These activities increase risks by releasing fibres into the atmosphere. Because the waste has been stacked in open areas where fiber levels can be quickly dispersed, the overall risk from asbestos-related diseases appears to be very low. Nevertheless, the presence of asbestos in uncontrolled landfills does pose a continued, if small, risk of exposure during future excavation work.

Health care waste

A World Health Organization (WHO) health care waste expert, as well as an expert from the Ministry of Health, participated in UNEP's expert field mission and visited a number of island health care



facilities⁹ in addition to sites visited during a broader investigation of health care waste.¹⁰ The WHO expert observed that the quality of health care facilities infrastructure and service appeared to be high. Sound management of health care waste, however, had not yet been established. As is true of waste management generally, there is an absence of law, policy, regulations, guidelines and monitoring.⁴ Authorities and the public are not yet well enough aware of the hazards associated with health care waste and the options available to manage it properly.

In general, health care waste (HCW) was better managed inside facilities, where high standards of property, hygiene and management skills appear to have been applied. In Male' and in regional or atoll facilities, waste was separated inside facilities. In health centres, health posts and family health centres, separation was found to be sporadic, if existent. Liquid wastes and chemicals from laboratories and wards are typically discarded in sinks, sometimes after disinfection or dilution. Attendants handle and transport wastes. Medical staff does not generally feel responsible for the fate of wastes disposed in their receptacles.

Waste is frequently manipulated a number of times (e.g., from a bucket to a plastic bag, then to a bigger bag, etc.) Waste segregated by the medical staff is frequently all collected together subsequently. Attendants wear no protective clothing whilst collecting waste, except possibly latex gloves. Nor is there systematic reporting of injuries or follow-up in most facilities.

Waste management outside of health care facilities was observed to be haphazard and risk producing more than risk reducing. ADK Hospital in Male' incinerates HC waste. Little attention, however, is paid to burning procedures, waste quantities or emissions. Ashes and slags are bagged and sent together with the general waste for disposal to Thilafushi.

Indira Gandhi Memorial Hospital had an incinerator until 2002 when it was dismantled and removed. Since then, all waste is collected on a daily basis by a private transport contractor and hauled to Thilafushi landfill. When marked hazardous HCW bags leave the hospital compound, the

⁹ HA Filadood health post; HD Kulhudufushi Regional Hospital; M Kolhufushi health centre; Th Villufushi; Th Veymandoo Atoll Hospital; L Gan Regional Hospital; L Gan Family Health Section under the Regional Hospital; L Fonadhoo Health Centre.

¹⁰ In Male': ADK Hospital (private), Indira Gandhi Memorial Hospital, Lion Clinic (private), Public Health Laboratory; K Guraidhoo Health Centre; K Hulemale' Hospital; Male' waste site; regional waste facility, HD. Kulhudufushi.

HCW is combined with the general waste stream and receives no further specific attention or treatment.

Regional and atoll hospitals tend to be equipped with simple, locally produced burning furnaces that are called ‘incinerators’. All waste categories previously segregated are burnt together. A common risky practice used by operators is to open all waste bags prior to feeding them into the furnace in order to remove unburnable elements such as fresh coconut shells, glass bottles and plaster rolls. Coconut shells are dried and used as fuel for cooking. Bottles are usually buried together with the ashes and combustion residues. No protective clothing is used, apart from the occasional use of cotton facial masks and latex gloves. Ashes, partially or unburnt waste and articles segregated from the waste are disposed near the furnace. Sometimes they are buried or covered with sand. The disposal place is often not fenced, and unburnt waste is commonly found scattered around the burning and disposal sites.

At health posts and health centres on smaller islands, all categories of HCW is burnt in oil drums or openly burnt in pits or on land. Burning occurs inside or outside the health care compounds. Incompletely burnt syringes and plastics are often visible at sites, which are not fenced. Dustbins are often too full, and HCW is commonly found scattered around. At family health centres, HCW is treated just like general waste. Quantities are small, however, so the risk of infection is minimal.

Although 45 health posts on the islands were damaged by the tsunami, the health care facilities inspected by UNEP-WHO had withstood the tsunami better than most other buildings. Except for the Vilifushi Health Centre, which had lost its inventory and is in the midst of a mostly evacuated village, health care facilities were generally repaired, repainted and operating normally. The tsunami spread HCW ashes and burnt residues. Given the negligible quantities involved, however, these impacts cannot be regarded as significant.



Exposed small-bore sea outfall on K. Vilifushi.
Credit: E. Spitaler

Wastewater and sanitation

Wastewater and sanitation is an urgent problem in Maldives. On most islands, sanitation depends on pour-flush latrines and cistern-flush toilets connected to septic tanks and, to a lesser extent, holes in backyards. The septic tanks are typically a combination of small-scale pre-sedimentation tanks and soak pits from which sewage migrates freely through the highly porous island soil and contaminates groundwater supplies. These units are often poorly constructed and maintained due to the unavailability of material and skilled labour. Most have also been located too close (less than one metre) from groundwater wells, thus providing additional sources of water supply contamination.

The remaining septic systems are connected to small-bore sea outfalls. These systems are generally not well designed and maintenance is often deferred. As a result, they often

Table 6. Sanitation and wastewater treatment and discharging systems

Island	KOLHUFUSHI	NALAFUSHI	FILLADHOO	KULHUDUFFUSHI	VILUFUSHI	FONADHOO	GAN	KALHAIDHOO	GURADHOO	HURAA
Septic tanks				x	x					
Sedimentation tank & soak pit	x	x	x	x	x	x	x	x	x	x
Sea outfall	x								x	
Wastewater treatment plant				x						

malfunction and convey raw sewage directly into the marine environment. Male' is not served by a sewage treatment system, and sewage treatment systems are generally scarce in the islands.

UNEP estimates that the small-scale sedimentation tanks, which can hold 1 m³, provide an average family with suitable capacity for approximately 200 days¹¹, after which they require maintenance and sludge disposal. Most tanks are sealed with concrete and are located under topsoil, making regular maintenance nearly impossible. In addition, the surfaces of the tanks are too small to provide adequate retention time and settling. As a result, most of the untreated sludge discharges directly into soak pits and, from there, into groundwater resources. As discussed in the groundwater section above, UNEP and other organisations that have surveyed groundwater supplies have consistently found excessively high levels of pathogenic contamination.

Most island residents who desludge are disposing of the sludge in the open sea and/or burying it. Due to the high groundwater levels (max. -1,5 m) faecal coliform, ammonium, nitrate and nitrite contamination from the unconcentrated, unstabilized sludge can be expected.

¹¹ The pre-sedimentation tanks are: LxBxH 1= 150 x 100 x 70 The sludge volume of the sludge settling chamber is therefore: $V = 1.05 \text{ m}^3$. At a daily median water consumption of 80 litre/person and an average of 6 family members, the daily hydraulic load would equal 480 liter. The sludge load of 70 gr/person/day results in a amount of 420 gr DS₂/day. In the sludge settling chamber a sludge density of 8-11% of DS can be reached, which results in a daily sludge production rate of 5.25 kg (8%DS) per day.



Typical small-scale sedimentation tank on L. Gan.
Credit: E. Spitaler

A pilot wastewater treatment plant in HD. Kulhudufushi serves 60 households (5% of the population). Pre-sedimented water is collected in a small underground basin and filtered. The overflow is pumped into a modified trickling filter system. Because the pre-sedimentation is not efficient enough, however, the sludge content of incoming water is too high and the system becomes blocked. UNEP groundwater samples taken near the plant contained very high levels of ammonium and nitrate.

HD. Kulhudufushi offers regular sludge maintenance service to residents. Sludge is transferred to provisional drying beds in the central landfill and used for fertilizer production. The fertilizer is applied in an on-site greenhouse, where a private company grows vegetables.



Sludge-drying bed on HD. Kulhudufushi. Credit: E. Spitaler

Fun Island and Angaga resorts, both inspected by UNEP, have similar sanitation and wastewater systems. Both use septic tanks and offshore outfalls for overflows. Regular septic maintenance service is arranged, and sludge is buried on the islands. In the residential area of the agriculture island, HD. Theefaridhoo, and on the industrial islands of L. Maandhoo and Thilafushi central sanitation networks lead to sea outfalls. L. Maandhoo is also discharging process and cleaning water (mostly brackish) through a sea outfall.

Emergency water and sanitation requirements for the Maldives were initially identified to support approximately 2,200 affected households (equivalent to an estimated population of 15,000) in 69 islands. In extensively affected areas, where entire islands were subjected to flooding for an extended period of time, septic tanks need to be replaced or, if undamaged, desludged. According to the Government, up to 90 percent of toilets may have been lost on very highly impacted islands, up to 75 percent on highly impacted islands. Otherwise, the tsunami appears to have caused little

Table 7. Sludge disposal and treatment systems

Island	KOLHUFUSHI	FILLADHOO	KULHUDUFUSHI	VILUFUSHI	FONADHOO	GAN	KALHAIDHOO	GURADHOO	HURAA
Sludge treatment									
Disposal into open sea	x			x	x	x	x		x
Burying		x		x	x	x	x	x	x
Drying and fertilizer production			x						

Table 8. Destroyed sanitation infrastructure, by island

Island	KOLHUFUSHI	FILLADHOO	KULHUDUFFUSHI	VILUFUSHI	FONADHOO	GAN	KALHAIDHOO	GURADHOO	HURAA
Evidence of destroyed sea outfalls								x ¹²	
Evidence of destroyed sedimentation tanks									x
Evidence of destroyed sanitation facilities	x	x	x	x	x	x	x	x	x

physical damage to sewage infrastructure on the impacted islands. Only on one island investigated by UNEP, K. Huraa, was there evidence of that a pre-sedimentation tank had been destroyed. See Table 7 below for a breakdown of sludge disposal and treatment systems, by island.

Pollution from the islands' already severe chronic wastewater problems, however, was made worse. Most sanitation facilities (toilet and washing chambers) were destroyed. Sludge from the septic tanks over-topped into the groundwater, causing extensive contamination of the groundwater body (i.e., E-coli, ammonium, nitrates, increase solid matter, turbidity).

The addition of displaced families from severely impacted islands has, in some cases, doubled host island populations, putting additional strain on local sanitation systems. UNEP observed that camps created for internally displaced persons (IDPs) and other temporary housing arrangements on islands such as M. Kolhufushi and K. Guraidhoo are discharging wastewater directly into the open sea via outfalls. In M. Kolhufushi, the outfall is no more than 3-10m from the shore. Septic water is accumulating near the shoreline and is very probably intruding into the groundwater lens. IDP camps in L. Gan are using septic tanks that are not sufficiently managed and are causing additional groundwater contamination. In all cases, discharges combine household and sanitation water.

The Fun Island resort and the industrial island of L. Maandhoo each suffered slight damage to their sea outfalls, but both continue to function. On Fun Island it can be assumed that flooding from the tsunami would have caused sludge from the septic tank to pour into the sea via the outfall.

Water supply

Water remains one of Maldives most scarce and precious resources, and access to safe drinking water is a challenge. Historically, groundwater was regularly used for drinking, especially during the dry season. A number of major water-borne disease outbreaks linked to polluted groundwater in the 1970s and 1980s, however, led to the introduction of rainwater tanks as the primary source of drinking water. Today, most Maldivians – an estimated 75% of the population – collect water from communal rainwater storage tanks or individual household tanks. If Malé, where drinking water is desalinated, is not considered, the proportion of the remaining population deriving drinking water from rainwater tanks increases to 87% (GoM-UNICEF, 2000). Except during two or three dry season months when rainwater supplies have become too depleted, groundwater is used mainly for non-

¹² Destruction through clean up activities

potable purposes. In most cases, the combined use of rainwater and groundwater has been sufficient to meet normal water demands.

Water is also supplied to some islands by reverse osmosis desalination plants and bottled water. To date, four islands comprising 28 percent of the population (including Male') have desalinated water available. Desalinisation ensures consistently high water quality. It is, however, an expensive option and has much higher operation and maintenance requirements than rainwater harvesting and groundwater extraction. In addition, the overuse of reverse osmosis as a solution to meeting water supply demands can have the long-term effect of encouraging continued mismanagement of groundwater resources.

In general, groundwater supplies have been under significant pressure for a number of years. The tsunami, however, clearly increased stress on Maldives water resources. According to initial reports by the MWSA, a high percentage of rainwater storage tanks and/or catchment areas were damaged on the worst impacted islands. There were no reports of significant impacts to water distribution in Male' or Villingili. The loss of freshwater came during the dry season in the Maldives, when there was little rain to help recharge freshwater supplies, making the complete impacts of this loss difficult to identify at present. UNICEF and IFRC have taken significant steps toward addressing the lack of rainwater harvesting equipment on impacted islands, and newly constructed shelter is expected to include rainwater harvesting tanks and collection equipment.

Table 9. Preliminary damage assessment (Source: Joint Needs Assessment)

Damage indicator	Estimated damage
Community rainwater tank	Up to 1,000
Household rainwater tanks	Up to 6,000
Rainwater supplies	20,000 m ³
Roof harvesting piping and gutter systems	5,000 households

ECONOMY & LIVELIHOODS

The economy of Maldives has experienced rapid development in the past 25 years, averaging 9% growth since 1978. Since 1980, per capita incomes have tripled, reaching an estimated \$2,261 in 2004. See, e.g., NRRP, Joint Needs Assessment. As the result of sustained economic growth and progress in a number of key socio-economic indicators (school enrollment, literacy, health status), the United Nations determined in December 2004 that Maldives should be graduated from 'least developed country' status during the next three years.¹³

The Maldivian economy reflects the country's geographical characteristics: its tropical climate and beautiful coral islands have become attractive destinations for tourism, and its mid-oceanic location

¹³ United Nations General Assembly Resolution A/59/L.48 recommended graduation of Maldives from Least Developed Country (LDC) status, providing that the country would be entitled to LDC status until 20 December 2007.



Source: UNEP Maldives Assessment Team 2005, World Food Programme Rapid Assessment 2005. Bathymetry is derived from coral reef database www.reefbase.org

has encouraged a vibrant fishing industry. Agriculture plays a smaller but highly significant role in the lives of the island communities.

Key development challenges include the fact that the population is dispersed across the archipelago. More than half of the islands are inhabited by 1,000 or less, and only 2% of the islands have a population of greater than 5,000. As a result, per unit costs for the transportation and provision of goods and services is high. In addition, the country's low-lying islands make Maldives among the countries in the world that are most vulnerable to sea level rise from climate change.

The Joint Needs Assessment estimated that the tsunami could slow GDP growth in 2005 to 1% (as compared to a pre-tsunami forecast of 7.5%), double the country's current account deficit to 25% of GDP and widen the fiscal deficit to 11% of GDP. Banks will need to reschedule loans and to ensure adequate finance for reconstruction. Financing, transport and labour all represent potential bottlenecks. Overall, however, economic growth has been projected by the International Monetary Fund to rebound strongly between 2006-2010 (6-9% per year) based on recovery of the tourism sector. See map below for indication of tsunami impacts on livelihoods across the country.

Tourism

Tourism is the most important sector of the Maldives economy and has been the driving force behind the country's recent economic expansion. Since 1978, the number of resorts has more than quintupled, from 17 to 87¹⁴. During that same period, tourist arrivals rocketed from 30,000 to over 615,000 in 2004. As a result, the sector last year accounted for \$415 million, or 33% of the country's gross domestic product (GDP).

Tourism is also a key source of employment, with approximately 17,000 of the country's economically active population of 88,000 working in the industry – nearly one in five jobs nationwide. Local islanders hold approximately 56.5% of these jobs, with the remainder being held by immigrants. Tourism also

Figure 4.

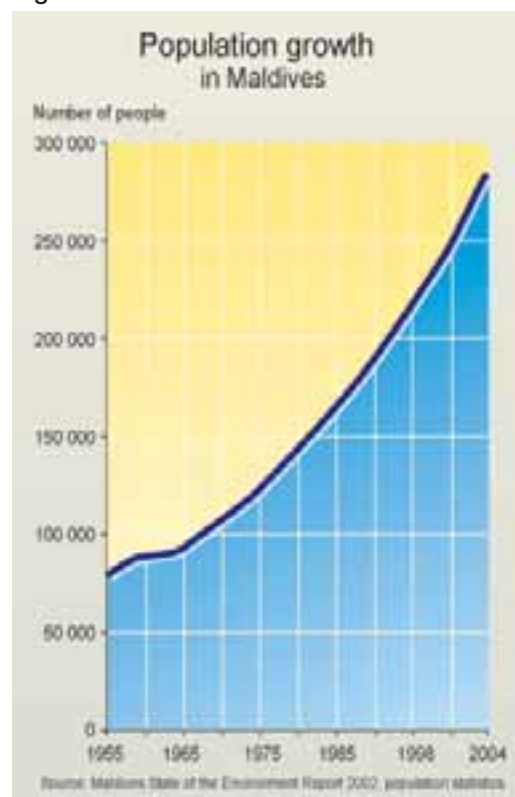
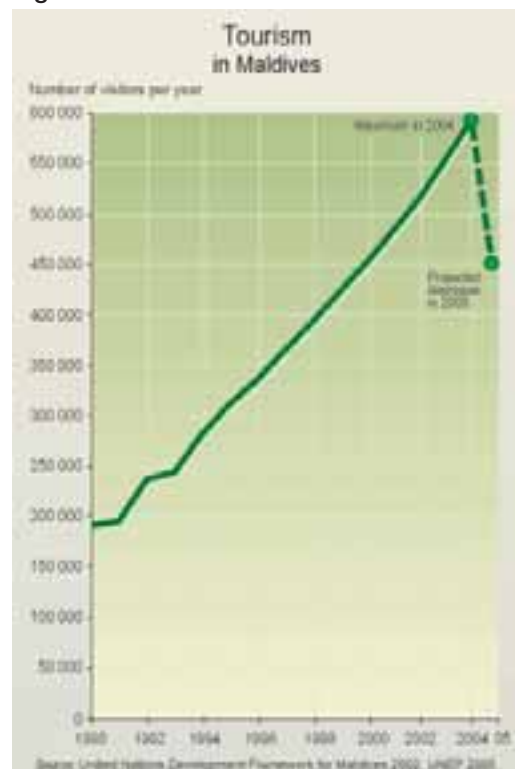


Figure 5.



¹⁴ The MoT has announced that an additional 11 islands have been designated for resort development. See SoE, 2004 p.32.

Environmental models

Monitoring: The Villa Group of resorts – Fun Island, Sun Island, Holiday Island, Royal Island and Paradise Island – follow Resort Environmental Safety Management Plans. In accordance with guidelines established by the International Financing Corporation, a branch of the World Bank, the resorts monitor and maintain records on water, waste and sanitation, among others.

Research: In 2004, Banyan Tree Resort created a Marine Laboratory on its Vabbinfaru Island. Under the guidance of a Marine Environmental Advisor, the Laboratory performs research into coral spawning as well as Green Sea Turtle and Black Tip Reef Shark conservation, often working in collaboration with visiting scientists. In addition to conducting primary research, the Laboratory offers environmental education opportunities for guests and students.

provides knock-on economic benefits to the agriculture, fishing, transport, import, handicrafts and skilled labour sectors. Counting indirect employment in these sectors, the Ministry of Tourism (MoT) estimates that a total of 25,000 jobs can be attributed to tourism.

Environmental impact assessments (EIAs) are required for resorts buildings, jetties, sea walls and breakwaters. Resorts are required to install incinerators, compactors and bottle crushers, and new resorts must have sewage treatment plants and outfalls. (See <http://www.sommets-tourisme.org/e/sommetsG/premier-sommet/actes/saeed.html>)

A small but dedicated MoT environmental unit regulates the environmental aspects of the resorts, reviews EIAs and conducts periodic inspections. A review of MoT circulars indicates the existence of environmental problems such as the dumping of resort waste, such as plastics and bottles, in the sea (see circulars CIR-ES/2002/12, CIR-ES/97/102, and CIR-ES/97/94) over-fishing of sharks from reefs, inner lagoons and within atolls (see circular 88-ES/CIR/98/49) and construction without an EIA or permission (see circular CIR-ES/98/07).

The tsunami had a profound impact on the tourism sector. Three foreign tourists died, and 19 resorts were initially closed. Approximately, 1,200 hotel beds sustained serious damage and will remain closed for 2005. In the two months following the tsunami, tourist arrivals declined markedly. Scheduled and charter flights were reduced and a number of resorts cut their staff sizes. Occupancy rates fell to 40%. Seventy-four resorts are currently operational. The remaining resorts are being repaired or reconstructed, some using the closure as an opportunity to upgrade their facilities.

The GOM has estimated that rebuilding the resorts will cost \$100 million and that business losses for the sector may total \$250 million. The Joint Needs Assessment anticipated that the resorts would experience 25% fewer bed nights in 2005 than in 2004. Arrivals during the first quarter of 2005, normally the peak season, were 44% lower than during the same period in 2004. By March, the occupancy rate returned to 70% (of available rooms) and improvement continued through April. By early May, however, occupancy levels were again substantially down, perhaps a result of the 28 March 2005 Sumatran earthquake, which measured 8.7 on the Richter scale. According to Visa Asia-Pacific, the regional division of the international credit card company, Visa Card spending by visitors to Maldives in early April was nearly equal to the comparable period in 2004. During the four weeks that ended on 8 May 2005, however, spending plunged to a 35% decline compared to the

same period in 2004. See ‘Tourism Slumps in Tsunami Area’, Mapes, T., *Wall Street Journal*, 21 June 2005.

In the interest of regaining previous tourist arrival rates and restoring damaged resort capacities, the MoT has been providing situation updates to travel and trade partners and diplomatic missions. The Ministry has also formulated a post-tsunami marketing campaign, relaxed resort leases rents for a 3-month period and provided technical assistance to the tourism industry regarding insurance claims. The strategy appears to have yielded benefits, as tourism is now on the path to recovery.

Fishing

Fishing is a crucially important livelihood in Maldives and represents a major source of protein for Maldivians. In 2004, the sector contributed 9.3% of the country’s GDP and employed over 14,000 (not including fish traders, processors, boat-builders, chandlers, etc). In 2003, fish exports produced \$75.6 million in revenues, equal to \$250 per capita.

Approximately one-third of the annual catch is consumed domestically. See Annex 9, Joint Needs Assessment. The principal catch is tuna, although significant reef fish fisheries also exist. The sector is a key component of rural livelihoods and income, and is commercially very significant.



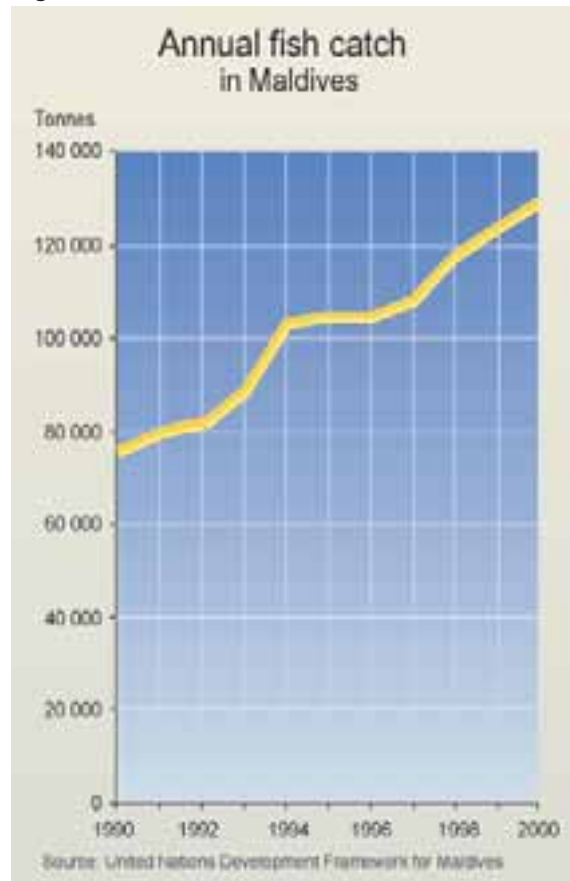
Fish seller in Male' Credit: L. Hiller

Fishing in Maldives consists of subsistence pole and line fisheries as well as commercial fisheries and small processing units. Traditional tuna fishing involves catching baitfish before dawn from the lagoon shallows using lights and nets. The baitfish are held in a flooded compartment on the fishing boats until tuna are found. When tuna are located, the live bait is thrown overboard to attract tuna, which are then hooked by the fishermen. The tuna are either sold directly to merchant traders or smoked and dried for subsequent sale.

The fishing industry is in the process of modernizing. Larger commercial vessels are replacing traditional dhoni boats. Drying and curing the catch is giving way to modern freezing and canning. Fishes are now often sold to Japanese, Thai or Taiwanese freezer vessels, which export the tuna for canning in Thailand.

According to SoE, 2004, the total recorded catch increased more than 50% between 1995-2003 (from 100,000 tonnes to 155,400 tonnes). (It is unclear if these figures include fish sold directly from fishing boats for home consumption.) Because the sustainable yield of fish stocks in Maldives waters has not been determined, it is not known how the rapid modernisation of the fleet, privatisation of the industry and expansion of fish processing capacity will impact fish stocks.

Figure 6.



The government faces a number of challenges including a lack of reliable catch data, the use of household chemicals for bait fishing, and over-exploitation of sea cucumbers, aquarium tropical fish, grouper fish and sharks. In 1995 and 1999 the government introduced regulations banning shark fishing inside and within 12 miles of the main tourism atolls.

Pole and line tuna fishing and small processing units lost equipment during the tsunami. The GOM reported that damages included the loss or destruction of 120 fishing vessels, partial damage to 50 vessels and several boat sheds as well as losses of reef fishing boat equipment and ocean cages. In addition, the GOM reported that 374 small fish processors lost equipment and two fishery institutes were damaged.

To assist the fishing sector after the tsunami, MoFAMR and the state-owned Maldives Industrial Fishers Company (MIFCO) agreed to raise the purchase price of skipjack tuna at the expense of MIFCO and three private tuna businesses. See Annex 9, Joint Needs Assessment.

Fishing activity appears to have improved steadily since the tsunami. In February 2005, AusAID conducted a survey of fishermen. The AusAID team reported that fisheries were returning and that declines in fishing were principally related either to seasonal fluctuations or resort closures in the aftermath of the tsunami. By the end of the first quarter of 2005, however, catches had exceeded levels recorded during the first quarter of 2004, due mainly to high volumes landed in the southern part of the country.

Agriculture

In recent years, agriculture has become more commercially significant in Maldives, with increases in private and public sector investments. In 2003, agricultural production was estimated at 35,821 tons, contributing 2.6 percent to the country's GDP. The demand for fresh agricultural products has paralleled increases in the country's tourism base. Coconut is the most widely harvested product, but production of cucumbers and melons has also increased significantly in recent years.

For commercial farming purposes 32 uninhabited islands are rented for 21-year periods. Another 941 uninhabited islands are leased out through a nationwide leasing system for development activities that include agriculture. In addition, 75 percent of inhabited islands have some degree of agricultural activity.

Most islands in Maldives have a poor sandy soil and few have enough land for agriculture. Although agriculture contributes only a small percentage to the country's economy, this disguises the fundamental importance that growing fruit and vegetables play in most people's livelihoods. The majority of rural families grow crops in home gardens. Mostly, these are fruit trees or shrubs with some small-scale production of green leaf vegetables. Very few families are dependent on their own production for food, preferring to sell their produce as an important source of cash income. Demand for fresh fruit and vegetables far outstrip supplies in the Maldives. As a consequence prices are high. Most staple foods, including rice, flour and sugar, are imported from other countries, and all families require some cash income in order to purchase these products.



Fertilizer production in greenhouse on HD. Kulhudufushi.
Credit: E. Spitaler

On larger islands a number of small holdings produce crops for sale in Malé and in other towns and resorts. Their productivity, however, is constrained by poor and unpredictable transport links. A ready market for fresh fruit and vegetables is encouraging the development of a local market garden sector.

Some island communities have been involved in recent collaborative experiments in permaculture with the MoFAMR. As they seek to compete with the price and quality of imported products, however, market gardens are relying more and more heavily on imported chemical fertilizers and pesticides. Although annual statistics regarding the kind and amount of fertilizers and pesticides used are not readily available, records indicate that fertilizer imports have increased from 1,300 to 6,400 tons per annum since 1998. The main imports are nitrogen-based fertilizers. Except in L. Fonadhoo, UNEP found no evidence of proper storage facilities.

The soils on most islands have little organic matter and, therefore, have a low capacity to retain nutrients and water. Runoff of pesticides and fertilizers is a particular problem on such soils. Increases



Fruit markets in Male' provide important outlets for growers.
Credit: L. Hiller

in nutrient concentrations in coastal water may result in expansion of seagrass beds and eutrophication of coral reefs, with negative impacts on both tourism and fisheries. Agricultural pesticides have been implicated in reduced fish spawning in coastal waters in the region. Bioaccumulation of pesticide residues in reef fish that form a staple part of the diet is a significant concern. For example, the systemic insecticide *Imidacloprid* (Bayer), was in use on two of the farms visited by UNEP on the island of Gan. This pesticide is soluble, highly mobile and persistent in the environment and is therefore a potential water contaminant. It is toxic to crustaceans, including shrimps, at concentrations of 60ppb.

Pesticides are a relatively cheap and effective way to limit economic losses to disease and pest attacks in agriculture and forestry. Most resorts and some island authorities spray insecticides to reduce the nuisance of mosquitoes. Much of the harm that is done by pesticides comes from their misuse rather than their use. Misuse includes unsafe storage, over-application and unsafe application methods. During UNEP visits to a limited number of farms it was clear that there is widespread mis-

use of pesticides and a low level of understanding of their potential health and environmental risks. A number of farmers used pesticides liberally but were unsure of their purpose, application rate or safe application methods. Pesticide containers were commonly stored on the ground or in wheelbarrows.

The agriculture sector was one of the worst hit by the tsunami. Salinity from seawater severely damaged crops, trees and plants on all of the impacted islands. Sodium and chloride are both soluble and highly mobile and can damage plants by direct absorption into the roots, and by destroying soil structure, thereby impeding soil drainage and root growth. Fortunately, the salinity will be washed out by monsoons, a process which has begun already.

Foremost amongst plants killed were fruit trees and agricultural crops. Not all plants were equally sensitive; some, although defoliated, have recovered. Food-plants that proved to be salt-tolerant

are typically used only for local consumption and have little commercial value. Recovery has been greatest for large trees growing in areas where groundwater has not been excessively contaminated. The GOM estimates, however, that six to nine months will be required to correct vegetable production and over five years to restore agriculture to pre-tsunami levels.

FAO made a similar finding:

In almost all cases, [these] rains came too late or were too little for the field crops to survive and also too late/little for many fruit trees. Field crops died because they could not cope with the high osmotic stresses imposed by such high soil salinities, although the high toxicity of the floodwater (especially due to high Na and Cl concentrations) was probably also contributing factor. Fruit trees which take up their water both from the soil and the groundwater, must have suffered the same high osmotic stresses and toxicities but had a chance to survive on the groundwater uptake, if not too salinated.

Table 10. Salt sensitivity of food plants grown in the Maldives

Highly sensitive plants (all individuals killed)	banana, papaya, guava, mango, watermelon, chili, aubergine (brinjal), green peppers, and green leaf vegetables
Sensitive plants (most individuals killed or defoliated/some recovery)	breadfruit, Malay apple (janbu) (<i>Syzygium malaccense</i> Merr. & Perry), lime (<i>Citrus aurantifolia</i> Swingle)
Salt tolerant plants (most individuals survived or showed only mechanical damage)	coconut, ahi (<i>Morinda citrifolia</i>), jam (<i>Muntingia calabura</i> L.), tamarind (<i>Tamarindus indica</i>), Natal plum (<i>Carissa macrocarpa</i>), tropical almond (<i>Terminalia catappa</i>)

There is considerable scope to increase the salt-tolerance of many plants in Maldives through conventional plant breeding. Much progress has already been made with agricultural crops.

Although the financial scale of losses resulting from loss of trees and crops may be comparatively small, for low-income families they may constitute a very high proportion of their total cash income. Many fruit trees may take many years to regrow to a size at which they will produce a valuable crop. A mango tree, for example requires a minimum of six years to grow to a fruiting size and will not reach full productivity for fifteen years.

On the island of M. Kolhufushi, for example, UNEP interviewed a local resident who had used the income from 40 chili bushes to build his house. He had lost both his house and home garden in the tsunami and now had no means to purchase new building materials.

Low-income families are often least able to cope with the consequences of an extreme event and to adapt their livelihood systems to cope with it. They have little or no access to information, technology, new skills or training. Nor do they have the time or resources to invest in new forms of production. One likely response to the sudden loss of income from agricultural production is greater dependence on exploitation of fisheries. The post-tsunami period may increase demands and stresses on the marine environment.

The tsunami has underscored the importance of correct storage and inventory of pesticide stocks. Unknown quantities of fertilizer and pesticides were lost into the sea. Farmers reported significant losses of pesticides, fertilizers and equipment. Losses of spray equipment and protective clothing

may increase risks to public health and the environment. Until farmers can afford to replace them they may be tempted to use unsafe application methods. One farmer was applying *Carbaryl*, a wide-spectrum insecticide, with a watering can. This technique would almost certainly lead to over-application and considerable soil loss. Domestic use of pesticides and fertilizers in home gardens was limited, so losses are likely to have been very small.

The symptoms of salt damage (small or misshapen, yellowing leaves, marginal leaf burn, shoot die-back, poor seed germination) are similar to those of some nutrient deficiencies. Some farmers, therefore, may be tempted to apply fertilizers to encourage salt-damaged plants to recover. The toxic effects of excessive salt can, in fact, be compounded by the addition of soluble chemical fertilizers. Salt can only be removed from the plant root zone by frequent and heavy watering.

UNEP observed that large agricultural fields suffered soil erosion. A crude estimate, based on the reduction in the soil surface level around surviving structures, suggests that approximately 4 centimetres (out of an average of 15-20 centimetres) of topsoil was lost or covered. Home gardens were less vulnerable to soil loss due to the cover of woody perennials. It would appear that intensive horticulture is an intrinsically vulnerable production system in a flood-prone island.

Construction

The construction industry is an important contributor to the Maldives economy, representing 3.6% of GDP in 2003. The sector has grown in recent years, largely as the result of a 19% increase in the number of households between 1999-2000, particularly in Male', and consequent demands for more housing. See SoE 2004, pp. 26, 28.

Traditional buildings still predominate in most islands: coral blocks are held with toddy mortar (a mixture of coconut sap, lime and coral sand), supported by timber beams and roofed with asbestos cement or steel sheets. Traditional building methods used coral sand, but stockpiled it for 2-3 years to allow rainwater to wash out the salt. This traditional method of preparing coral sand appears to no longer be in use.

Historically, corrugated roof sheets of either galvanized steel or asbestos-containing cement have been used on islands. In Male', where construction projects tend to be larger, projects are managed and regulated by consultants, Housing and Urban Development Board, fire department or the GOM, and asbestos-containing materials are not usually specified. On the other islands, construction is usually confined to private residences and small buildings. There is ordinarily no project planning (architect, consultant, etc.), and construction materials are purchased and used independently.

Modern building methods using steel reinforced concrete ring beams and columns are gradually being introduced. Government buildings (mosques, schools, clinics and island offices) have been constructed using modern methods and materials (including imported washed aggregate). The lack of an adequate building code, suitable building materials and construction methods, however, means construction methods vary between islands.

The tsunami destroyed or damaged approximately 6,000 homes. UNEP's field mission observed that catastrophic building collapse on tsunami-impacted islands appeared to have been more common when structures were constructed from traditional materials including boundary walls. In general, buildings constructed using washed aggregate and steel-reinforced ring beams survived better than traditionally constructed buildings.

Maldives is now commencing a broad-scale housing repair and reconstruction effort. According to the NRRP, 58 islands require homes to be rebuilt, and 75 islands have homes in need or repair.



Woman building wall on HD. Kulhudufushi. Credit: J. Bennett

Every homeowner whose property was damaged beyond repair is to receive a 3-bedroom house (at a unit cost of \$23,400 USD/home). Key Government partners in shelter reconstruction include UNDP and UN-Habitat, EU-ECHO, and IFRC. It will be essential that new properties are flood resistant and use sustainable construction designs and materials.

Coral extraction

UNEP's field mission found that artisanal extraction of coral sand from lagoons (manually using sacks) was evident at nearly all islands visited. UNEP witnessed active and uncontrolled coral sand exploitation, and visual evidence indicates that coral sand extraction has increased since the tsunami. The application of coral sand on roads/paths and the infilling of depressions appears to be widespread.

The GOM has recognised that coral reefs represent important defences against natural disaster and provide crucial marine habitat. In 1992, the Government banned mining of shallow coral house reefs around an island or on atoll rim reefs. Common bait fishing reefs was also banned. MoFAMR administers applications for coral, sand and coral aggregates from the beaches and reefs around uninhabited islands. The MEC plays an advisory role. Nevertheless, Maldives reefs have been extensively exploited for construction purposes. Although official statistics show dramatic reductions in the total volumes of sand and coral extracted this may be due to the under-reporting of a now-illegal activity rather than a substantial reduction in demand.

A review of sand mining regulations from other countries that are less vulnerable to sea level rise and storm surge than the Maldives, including France, UK, Japan, Malaysia, Netherlands and USA,

indicates that sand mining in those countries is restricted to depths greater than 10m and at a minimum distance from shore of 600 metres (See, e.g., <http://www.seafriends.org.nz/oceano/seasand.htm>). It is not known if the restrictions placed on beach sand mining in Maldives have been assessed to determine their ability to protect islands from increased vulnerability.

Maritime transport and infrastructure

Sea transport among the islands operates on a periodic and largely unscheduled basis. Residents of the islands visited by UNEP reported that the unscheduled and ad hoc provision of supplies and collection of produce (fish, fruit and vegetables) has serious implications for local planning. There is little incentive to invest in harbours, and trade-related equipment, all of which could stimulate island development. In addition, farmers (and small-scale supplemental income farming operations) reported a reluctance to invest in high-yield cash crops. Without a dependable transport and distribution system, products cannot be reliably brought to market.

In addition to the main port in Male', the country's 199 inhabited islands are serviced by 90 man-made harbours, quays, basins and breakwaters; several natural harbours and jetties; and approach channels to access inner atolls. The maritime transport sector also includes inter-island shipping routes marked by 19-kilometre light beacons and 3-kilometre reef markers and harbour entrance markers.

The GOM reported that the tsunami damaged or destroyed 36 jetties (totaling 1,600 metres in length); 4,200 metres of quay wall; 15,000 metres of harbour sea walls; 375,000 cubic metres of basin dredging; 145,000 cubic metres of entrance dredging; twenty-five 19-kilometre light beacons; sixty-five 2-mile reef markers; 120 (of 390) entrance markers and approximately 300 metres of causeway.

UNEP's field mission found relatively minimal damage to marine infrastructure. In general, maritime facilities located on the inner sides of the atolls experienced less damage from the tsunami than did other maritime infrastructure. Although UNEP did not observe widespread tsunami damage to harbour facilities, the government has reported harbour damage on 104 islands. The UNEP mission did observe the silting-up of harbours (both before and after the tsunami) as well as damage to coral block breakwaters.

Energy

The Maldives has no domestic nonrenewable energy resources (e.g., oil and gas) that it can utilize to meet its energy needs. The country instead relies on imported petroleum fuels to provide for power generation, transportation, lighting and food preparation. Diesel is the dominant fuel source, much of it used for fishing and sea-based transport. Resorts consume approximately 56% of the country's diesel oil for their own private electricity production, 29% is used by STELCO (State Electricity Company), and the remaining 15% is consumed on the inhabited islands and for industrial purposes. Household energy demand is commonly met by liquefied petroleum gas and kerosene. Total greenhouse gases produced by Maldives equals approximately 665,000 tons of CO₂.

STELCO provides approximately one-third of the electricity produced in Maldives, with an estimated 82% of that supply being used in Male', Vilingili and Hulhule Islands. Private or community-owned electricity producers serve the remaining inhabited islands.

Although Maldives equatorial exposure to sunlight would seem to make the country especially conducive to solar power, this clean, renewable and abundant source has scarcely been tapped to

date. Solar heating is used primarily in the resorts, where approximately half of all hot water is solar heated.

In 2004, a survey conducted for the Ministry of Communication, Science and Technology examined the potential of biomass resources¹⁵ to supply energy in Maldives. The study concluded that as much as 10-15% of Maldives energy requirement (excluding transport) could be met by exploitation of these renewable resources. At present, only a quarter of this potential is being realized.

Damage to the energy sector from the tsunami included failure of island power systems due to damaged diesel generators, electricity distribution networks and street lights. All of the islands visited by UNEP have electrical generator power stations. Some of the stations had been damaged by the tsunami. The MCST has not conducted a full assessment of the impact to the energy sector in the resort islands, industrial islands and airports.

It is unclear if electricity charges are based on a flat fee or by usage (metered). Based on consumption pattern observed (e.g., use of fans and air conditioning), there appears to be little awareness of the cost of electricity and the potential for demand side management.



Hulhule Island and Airport during the tsunami, 26 December 2004. Credit: T. Rempel

Airports

The airport sector consists of one international airport, in Male', three southern regional airports, one in the northern atolls and a number of private airstrips. The islands on which the airports are located were only minimally impacted by the tsunami.

ENVIRONMENTAL MANAGEMENT CAPACITY

Policy framework

Environmental protection and sustainable development have been key elements of Government policy in Maldives for a number of years. The country's aspiration for environmental protection and preservation is expressed in *Vision 2020 of the Maldives*:

Maldivians will be able to take sufficient protective measures against the threats posed to the country as a result of global ecological degradation. They will be pursuing environmentally friendly lifestyles with the aid of modern technology.

The 6th *National Development Plan* for the period 2001-2005, published in 2002, stresses the direct link between sustainable resources management and economic development and states that environment protection is a top Government priority. The Plan calls for the integration of

¹⁵ Biomass resources include solid biomass and agro/waste (fuel wood, saw dust, palm fibres, coconut shells and coconut tree parts) animal waste/organic household waste and household waste.

environmental and natural resource protection and sustainability into various components of the Country's development strategy.

Stronger incorporation of environment and resources management into national planning is also reflected in the second *National Environmental Action Plan (NEAP II)*, which is the principal guidance document for development of national environmental policies.

The first *NEAP*, formulated in 1989, represented the country's initial attempt at establishing and implementing a comprehensive environmental strategy. The NEAP's principle aim was to enable the GOM to maintain and improve the state of the environment and to manage the country's natural resource base in a sustainable manner. Accordingly, the NEAP identified priority environmental problems and established mechanisms for sound environmental protection and management in the future.

NEAP II established a comprehensive framework that has been used for the period 1999-2004 to ensure sustainable development and prioritize the country's environmental agenda. Key priorities include climate change and sea-level rise, coastal zone management, and conservation of biological diversity. NEAP II highlights the importance of science, research and human resources development and calls for strengthening environmental law and administration, education and public awareness, science and research, and human resource capacities.

A number of other national plans have integrated environmental resources management into their programmes. These include:

- *First National Communication of Maldives to the UN Framework Convention on Climate Change (UNFCCC)* (MEC)
- *State of the Environment Report 2002* (MEC)
- *State of the Environment Report 2004* (MEC)
- *National Biodiversity Strategy and Action Plan & First National Report to the Conference of the Parties to the Convention on Biological Diversity* (MEC)
- *National Environmental Health Action Plan* (Ministry of Health)
- *Sustainable Tourism Master Plan* (Ministry of Tourism)
- *Agenda for Integrated Reef Resources Use* (MoFAMR)
- *Integrated Atoll Development Plan* (Ministry of Atolls Development)

The *First National Communication of Maldives to the UNFCCC* (2001) was produced in the framework of a Global Environment Facility-funded project called "Maldives GHG Inventory and Vulnerability Assessment: A Climate Change Enabling Activity".

The country's third and most recent *State of the Environment Report* was published in 2004. The 2004 SoE addresses a number of priority issues including climate change and sea level rise, fresh water resources, waste management, air pollution and biodiversity conservation.

As a party to the Convention on Biological Diversity, the GOM has been implementing the National Biodiversity Strategy and Action Plan Country Report Project through which it produced a first

national report and, in 2002, the *National Biodiversity Strategy and Action Plan* (NBSAP). A key NBSAP goal is to build capacity through governance strengthening. The NBSAP urges integration of biodiversity conservation into the national development process, strengthening of legal and policy frameworks, improving in-situ conservation and establishing a long-term financing mechanism and other economic incentives.

The National Environmental Health Action Plan, 1998-2001 (NEHAP) outlines Maldives approach to operationalizing the health and environment aspects of Agenda 21. The NEHAP was a joint initiative of the Ministry of Health (MoH) and the former Ministry of Planning, Human Resources and Environment.

In 2004, UNDP initiated a *National Solid Waste Management Policy* (NSWMP) project. The project developed a framework for the NSWMP, which received broad approval during stakeholder consultations. Barriers preventing effective waste management were identified and measures for their removal were recommended.

Altogether, Maldives has produced an impressive and forward-thinking set of policy documents. The ultimate measure of success for these initiatives, however, should always be whether they have been implemented and produced concrete benefits to the country's environment. Although the GOM's environmental policy priorities correspond with the country's principal environmental problems, the status of policy implementation has not been measured or benchmarked.

According to the country's framework environmental law, the Environment Protection and Preservation Act of 1993 (EPPA) (Law no. 4/93), the MEC is responsible for formulating environmental policies, establishing a nationwide environmental policy, integrating sectoral priorities and coordinating the environmental protection activities of the various ministries that have environmental and natural resource competences. At present, however, most ministries have established their own policies and guidelines. To improve opportunities for efficient implementation of environmental protection activities, the country's disparate policies need to be better integrated into a cohesive framework.

Legal framework

In general, the country's environmental legislation is very underdeveloped. Sectoral legislation has not been enacted in such fundamentally important areas as solid waste, hazardous waste, wastewater, air, clean water, drinking water, protected areas, biodiversity protection, physical planning and coastal zone management. As a result, the MEC lacks inspection and enforcement authority in most key areas of environmental policy.

Environmental Protection and Preservation Act of 1993

In 1993, the People's Majlis (Parliament) adopted the EPPA. The EPPA established a framework within which regulations and policies could be developed to protect and preserve the country's environment and natural resources. The Act recognises such principles as pollution prevention, waste reduction, the precautionary principle and polluter pays and also acknowledges the crucial link between environmental protection and economic development. The EPPA emphasizes preservation of land and water resources, flora and fauna as well as beaches, reefs, lagoons and all natural habitats. Key provisions call for:

- the GOM to create guidelines on environmental protection, which are to be given due consideration by all parties;

- the Ministry of Home Affairs, Housing and Environment (the MEC's predecessor) to formulate environmental policies, rules and regulations in areas where a designated authority is not already performing such functions;
- identification and designation of protected areas and nature reserves;
- EIA guidelines;
- mandatory EIAs for new development projects the Ministry determines could potentially impact the environment adversely, with the Ministry authorized to terminate projects having any undesirable impact on the environment;
- regulation of the disposal of waste, oil and poisonous substances;
- regulation of trans-boundary movement of hazardous, toxic and nuclear wastes and prohibition of its disposal;
- fines for damaging the environment; and
- compensation for environmental damage.

Sectoral laws

The EPPA is supported by a number of laws pertaining to the sustainable management of natural resources:

The *Law on Fisheries (Law no. 5/87)* directs the MoFAMR to conserve and manage the sustainable use of marine and fisheries resources. The MoFAMR has prepared a new fisheries law. The new law would enable more comprehensive and integrated marine resources management. Authorities anticipate that the law will be adopted by Parliament in autumn 2005.

The *Act relating to Uninhabited Islands (Law no. 20/89)* and the *Act relating to Coconut Palms and Trees of Inhabited Islands (Law no. 21/89)* authorize the MoFAMR to conserve all terrestrial flora and living resources in the Maldives. Timber on uninhabited islands can be logged only with written permission from the MoFAMR, and logging can only occur in the presence of a representative of the atoll office and a representative of the land lessee. Every tree that is logged must be replaced by a tree under the direction of the MoFAMR, and every coconut palm that is logged must be replaced with two coconut palms.

The *Tourism Law of 1979* authorizes the MoT to formulate and enforce regulations relating to all tourism activities, including those designed to minimize the impact of tourism development on atoll ecosystems. The newer *Tourism Law (Law no. 2/99)*, which came into force in 1999, introduced more extensive environmental controls on resorts and coastal developments including mandatory EIAs. The MoT is the main implementing agency of these policies along with the Tourism Advisory Board, which serves as policy-coordinating body.

Other relevant laws include the *Maritime Zones Act (Law no. 6/96)* and the *Law relating to Vessels that Sink or Get Foundered (Law no. 7/69)*.

A glaring gap in the country's legal framework is the absence of a framework physical planning law that incorporates due consideration of environmental factors.



Man leaning against damaged wall on unidentified island. Credit: NDMC

Regulatory framework

Environmental Impact Assessment: EPPA provides that EIAs should be submitted to the MEC before development projects are implemented. In 1994, an EIA law was enacted. Although the EIA process is still relatively new, it has been instrumental in streamlining development activities in some sectors. Since 2000, 93 development projects have been subjected to an EIA process. Most of them were private sector projects in the tourism and fisheries sectors. In one instance, the MEC stopped a beach nourishment project because there was no EIA approval. Many public sector development projects, however, have been undertaken without EIAs. Since 2001, 74 coastal modification projects have been undertaken in the inhabited islands without any formal environmental review.

The MEC's guidelines for the development of EIA reports, issued in 1994, do not specify project categories requiring screening. As a consequence, all development proposals submitted to relevant authorities for approval are potentially subject to EIA, depending entirely on the discretion of the MEC. The MEC reviews environmental impact studies and provides technical summaries to the National Commission for the Protection of the Environment for final determination.

The MEC receives an average of five to six EIA reports per month. There is a lack of qualified EIA expertise in the country; only a few environmental consultancy firms regularly prepare EIA reports. On occasion, MEC staff act as consultants and prepare the EIA reports themselves, a clear conflict of interest. The MEC is expected to review EIA reports within one month. MEC staff often have difficulty following this timeframe due to a lack of technical expertise. Thus far, the public has not participated in decision-making regarding project approvals.

The GOM's Focus Island Concept and Population Consolidation Strategy aims to identify structurally sound islands where infrastructure can be built and to which populations from smaller, less inhabited islands can be relocated. Taken together with the extensive post-tsunami reconstruction

anticipated, a great deal of development is clearly on the horizon. Effective environmental planning and impact assessment work will be of paramount importance.

Other regulations: A number of environmental regulations and directives have been issued. One prohibits the logging of 20 designated plant species without the prior consent of the MoFAMR. Another, the regulation on Sand and Coral Mining (2000), prohibits coral and sand mining on designated atolls, areas in atolls and islands and requires prior permission for mining in other areas.

In 1995, a directive issued by the former Ministry of Planning, Human Resources and Environment established 15 protected areas for biodiversity conservation. A subsequent directive in 1999 designated 10 additional protected areas. Additional directives have protected 70 bird species.

Regulations under the Fisheries Law ban the use of dangerous weapons, toxic chemicals and non-target species gear for fishing in Maldivian water. Specified gear are prohibited for particular fisheries. Other directives ban fishing in certain areas, including bans on shark fishing in seven atolls. Several living marine species are protected from harvesting or exploitation.

Compliance & enforcement

A number of problems impede effective implementation of the country's environmental laws and regulations. Government officials lack sufficient awareness of the country's existing environmental laws, regulations and policies. As discussed above, the legal framework has a number of substantial gaps, making enforcement impossible in many cases. There is also virtually no monitoring of compliance, a problem compounded by geography and the lack of clearly delineated mandates and responsibilities within the GOM. The MEC has limited staff capacity, no field offices and no environmental inspectorate. Nor is any other government body conducting environment-related inspections.

The monitoring of EIA-approved projects, for example, is very weak. The MEC lacks resources to track activities and the implementation of mitigation measures. In some cases, projects have already begun construction activities prior to EIA approval.

Line ministries generally carry out licensing functions. Tourism development proposals are submitted to the MoT. Harbour construction and land reclamation proposals are submitted to the Ministry of Planning and Development. The MoFAMR issues licenses for sand and coral mining, tree cutting, and the use of marine resources. It seems that there are no licensing criteria in place for natural resource uses, however, so the MoFAMR makes decisions on a case-by-case basis. Only a fee for cutting trees is currently in place. The MEC is periodically consulted to review the environmental impacts of various proposals. In such instances, inter-ministerial committees are established to review issues of concern.

In principle, the EPPA authorizes penalties for non-compliance with its provisions. These vary from 5 to 100 million Rufiya (\$.40 to \$7.6 million). In the absence of monitoring, inspections or reporting for non-compliance, however, penalties and fines are only rarely imposed. The Coast Guard, which is under the Ministry of Defense, occasionally reports environmental violations and impose penalties and fines. All fines go into the general GOM treasury.

Institutional framework

Environment functions were first established within the Ministry of Home Affairs in 1984. The Environment Section was subsequently transferred to the Ministry of Planning and Development, which became the Ministry of Planning and Environment, elevating environment to ministerial status. In



Tents and temporary housing for displaced persons on M. Kolhufushi. Credit: J. Bennett

1993, the Ministry of Planning, Human Resources and Environment was formed. In 1998, environmental protection and management functions were transferred to the newly formed Ministry of Home Affairs, Housing and Environment. At the same time, the Environment Research Unit was elevated to the status of Environment Research Centre under the Ministry of Home Affairs, Housing and Environment. On 1 September 2004, the government was again reorganised, and the Environment Section combined with construction functions to form the Ministry of Environment and Construction.

The Environment Section of the MEC is struggling to carry out its mandate effectively, mostly due to financial and human resources constraints. In addition, the mandate of the MEC overlaps with the mandates of other ministries and government bodies. Environmental capacities at the atoll and island level are virtually non-existent, although recently two environmental units have been established at the Ministry of Atolls Development's Regional Development Project Management Offices in the north and the south of the country.

In 1989, the GOM formed the *National Commission for the Protection of the Environment (NCPE)*. The NCPE's mandate is to advise the GOM on environment assessment, planning and management and to ensure that environment protection is a vital component of all development projects. The NCPE does not formulate or approve policy. Created to be a high-level intergovernmental monitoring and coordination body for environment-related issues, the NCPE is currently composed of GOM officials from departments such as the MoT, MoFAMR, and the MPND, among others. The Deputy Minister of the MEC chairs the NCPE.

Organisational structure of MEC

At present, the Minister of MoFAMR is the Acting Minister for Environment and Construction. In theory, the MEC's combination of environmental and construction functions offers opportunities for planning synergies. In practice, the two functions are divided, and the Environment Section is in the peculiar position of having to regulate a branch of its own Ministry to ensure compliance with

EIA and other environmental policies. The absence of an arms-length relationship between these functions may very well inhibit the proper implementation of environmental policies. As noted, EIA requirements appear not to be applied uniformly to public projects.

On a day-to-day basis, a Deputy Minister supervises the MEC's environment portfolio, which is divided among three major departments: the Environment Section, the Environment Research Centre and the Department of Meteorology.

The *Environment Section* (ES) is responsible for policy formulation, implementation, monitoring, and enforcement. The Section employs 23 staff in four divisions: Assessment and Management, Law and Policy, Planning and Coordination, and, Administration and Information.

The *Environment Research Centre* (ERC) functions as the main technical policy support and research unit of the Ministry. It also aims to develop and strengthen national capacity to undertake environmental research and apply relevant data and information in environment management. The ERC has approximately 25 staff.

The *Department of Meteorology* (DoM) is principally focused on monitoring meteorological, seismic and oceanographic conditions and collecting relevant data. The Department has five meteorological stations on as many islands. It has indirect involvement in policy formulation through the provision of data for climate change monitoring. Air quality monitoring was recently added to its mandate. The DoM has approximately 90 staff.

Although the three environmental functions nominally operate under the supervision of the Deputy Minister of the Environment, in practice, they operate independently of one another. Each branch implements separate work plans and activities, and interaction with the others is confined to infrequent meetings and technical conferences. The disconnection among these environment functions, particularly between the ES and the ERC, has caused some duplication of effort and inefficiencies at a time when greater capacity is urgently needed. The lack of coordination can be attributed in part to the absence of a common operational framework that integrates, coordinates and rationalizes projects and activities based on a common agenda and set of goals.

A 2003 UNDP project¹⁶ assisted the MEC's efforts to create an efficient structure for national and local environmental governance. The project, which aimed to support institutional strengthening of the ES and the ERC, issued a report that included several recommendations for improving the ES and the ERC. Among other things, the report called for a fundamental restructuring of the tasks and responsibilities of the ES and ERC and their integration under a single management system. The Ministry is still in the process of implementing these recommendations.

Other ministries and agencies with environmental functions

A number of other Government agencies and ministries have environment-related mandates:

- The *Ministry of Fisheries, Agriculture and Marine Resources* is authorized to conserve all living and non-living marine resources in the ocean, reefs and associated territories of the Maldives. It is also empowered to conserve all flora and living resources on uninhabited islands in the Maldives.
- The *Marine Research Centre (MRC)*, which is part of the MoFAMR, is the main technical research unit responsible for gathering and analyzing data on marine resources, including

¹⁶ The project was called "Institutional Support for Coordination and Integration of Environmental Considerations in National and Atoll/Island Policies, Budgets and Administrations".

the sustainable management of fisheries and other marine resources. This mandate is perceived to overlap with the MEC's biodiversity conservation and protected areas management mandate.

- The *Ministry of Atolls Development* is responsible for the conservation of all terrestrial flora and living resources on inhabited islands in the Maldives.
- The *Ministry of Tourism* is responsible for the conservation of all terrestrial flora and living resources on resort islands. The MoT imposes rules and guidelines governing the operation of resorts and tourist-related projects, including environmental policies and standards regarding the preparation of EIAs, the use of dive sites, construction of marinas, jetties and piers, and solid waste management. Compliance with these policies is monitored by the MoT.
- The *Ministry of Defense*, through its police and coast guard, is responsible for law enforcement.
- The *Ministry of Planning and National Development* is responsible for urban planning (including harbour development), national development planning and atoll land use plans. The Housing and Urban Development Board is an advisory body to the Ministry.
- The *Ministry of Health* and the *Maldives Water and Sanitation Authority*, which is within the Ministry, regulate water quality and set standards.
- The *Ministry of Communications, Science and Technology* is mandated to conduct research and activities in the area of energy & renewable energy. Plans are underway to establish an energy agency.
- The *Municipality of Male'* is responsible for the municipality's planning and infrastructure development, for managing and overseeing the civil register and for maintaining streets and public parks and managing municipal waste.
- *Male' Water and Sewerage Company* supplies and maintains water and sewerage services in the municipality of Male'.

In general, these ministries and government bodies do not have adequate environmental capacity. Only the MoT and the MoFAMR have environmental units within their structures.

Atoll and island governance

Because of the country's broad geographic distribution, governance at the atoll and island levels is crucially important in Maldives. Islands and atolls are the basic units of planning and development for purposes of delivering physical, social and economic services and associated infrastructure.

The Ministry of Atolls Development administers atoll and island level governance. Atoll Chiefs are appointed by the President and are responsible for implementing GOM policy at the atoll level. The Atoll Chief chairs an Atoll Development Committee comprising appointed and/or elected representatives from the atoll's inhabited islands.

Each island has an Island Chief who is the island's senior government official and oversees all aspects of the island's operation and development. Island Chiefs chair Island Development Committees and facilitate the work of Women's Committees. Although these officers and organisations are responsible for local implementation of environmental policies, there is only minimal active environmental protection on the island level.



Extensive erosion and scour on western side of the causeway connecting L. Fonadhoo and L. Kaddhoo.
Credit: B. Richmond

Institutional capacity for environmental protection

More so than many countries, the economy of the Maldives depends strongly on protection of its highly prized natural resources. Meeting this challenge requires strong technical and scientific expertise and inputs into the preparation of policies and standards. At present, the MEC Environment Section and the Environment Research Centre lack the human resources for the broad and sometimes unclear mandates given them. Each has too few appropriately trained and educated technical staff.

Environmental capacities at the atoll and island level are virtually non-existent, which severely curtails the MEC's ability to monitor environmental conditions and implement policies. In the face of urgent needs to implement programmes and projects to address priority environmental concerns, the Ministry's two environmental units have been limited to coordinating, monitoring and performing desk-bound reviews of government activities and the broad range of issues within the MEC's mandate.

The MEC's capacity is further hindered by a limited budget. Although the overall budget allocation to the environment sector has experienced annual increases in recent years, these increases were not available for operational activities. As a result, the Ministry has had a very limited ability to create new positions or recruit staff.

At the same time, other government institutions have, in some areas, competing and overlapping mandates to protect the environment and regulate natural resources. Coordination among these institutions on policies, strategies and programmes is generally weak, and all suffer from insufficient

human resources, financial constraints and inadequate management systems. Harmonisation of the GOM's environmental strategies, policies and regulations is essential.

Public awareness & NGOs

The Maldivian public is not generally well informed about the risks of pollution, the relationship between the environment and public health, and the benefits of a clean environment to the economy and society as a whole. Nevertheless, environmental issues are apparently rising in public importance. A 1998 Vulnerability and Poverty Assessment conducted by the United Nations surveyed community opinion about various matter in an effort to identify local priorities. Environment was rated the lowest among several concerns. In a follow-up assessment conducted in 2004, environment had risen to the sixth highest local priority. Environmental concerns raised by the island communities UNEP visited included waste, coastal erosion, resource use, water and sanitation – issues that had yet been satisfactorily addressed on the local level.



Family leaving K. Guraidhoo during tsunami. Credit: NDMC

The MEC has no communications programmes or staff dedicated to a building public awareness systematically. Various ministries and institutions (e.g., MEC Environment Section, ERC, MoFAMR, MRC) and a number of NGOs, however, have been conducting public awareness and education programmes to promote environmental conservation. Activities include awareness campaigns, workshops, clean-up activities, and the publication of posters and brochures. In addition, resource materials have been developed for use within schools at various levels. Environmental subjects have been integrated into the primary school programme since 1984. At secondary school level, fisheries science is offered as an optional subject, and 'ECO Clubs' have been established at several schools.

The GOM has undertaken initiatives to raise environmental awareness through programmes such as the "President of Maldives Green Leaf Award", the "President of Maldives Green Resort Award", the "Two Million Trees Programme", "Independent Maldives, Clean Maldives", the establishment of ECO Clubs at schools, World Environment Day, and campaigns such as the Save the Turtles Programme. Government awareness-raising activities are broadly supported by environmental NGOs and have contributed to introducing principles of conservation and sustainability at the urban and island level.

The NGO community in Maldives is not strong. Many NGOs are chronically under-funded and operate under difficult conditions. Activities are mainly focused on education and awareness rather than on influencing environmental decision-making. The relative weakness of the NGO community is

compounded by the fact that its members rarely cooperate among themselves. Nor is there is an umbrella association that could spearhead a major environmental NGO movement.

Banyan Tree Resort provides environmental education opportunities for groups of students from Male'. The children visit the Resort's turtle and coral projects, where they are instructed by the Resort's marine laboratory staff and visiting scientists. Banyan Tree has also created the Hithadhoo Children's Park, in Hithadhoo, which offers environmental awareness classes on selected days.

International cooperation

Maldives is party to several multilateral environmental agreements (MEAs). Among these is the UNFCCC, which represented one of the country's first steps toward addressing climate change and related issues. Other MEAs to which Maldives is a party include:

- Convention on Biological Diversity
- UN Convention of the Law of the Sea
- United Nations Convention to Combat Desertification
- Cartagena Protocol on Biosafety
- Kyoto Protocol to the Framework Convention (the Protocol's first signatory state)
- Montreal Protocol on Substances that Deplete the Ozone Layer
- Vienna Convention for the Protection of the Ozone Layer

In preparation for the World Summit on Sustainable Development, Maldives produced a report on the country's implementation of Agenda 21. Civil society organisations contributed to preparation of the report and made valuable inputs through a participatory process.

UNDP has been a partner with GOM on environmental matters and has initiated several environmental projects including, among others: the Renewable Energy Technology Development and Application Project; support for the National Biodiversity Strategy and Action Plan; the Atoll Ecosystem-Based Conservation Programme in Baa Atoll; Atoll Development for Sustainable Livelihoods, and support to the GOM's efforts to adapt to climate change, promote waste management, develop coastal zone management and strengthen environmental governance.

Coastal zone management

Responsibility for coastal zone management is not properly defined and is spread over several ministries – the MEC, Ministry of Atolls Development, MoFAMR, MoT, Ministry of Planning and National Development, and the Ministry of Transport and Civil Aviation. The dispersion of responsibility has hindered the formulation of an integrated and sustainable coastal zone management plan. Attention has, instead, been focused on promoting measures to minimize beach erosion.

In 2004, the staff of the MEC undertook coastal zone management awareness training for local island inhabitants. The training aimed at establishing a community-based network and creating baseline environmental conditions against which to assess coastal vulnerability to future impacts. Operation of the network, however, has been delayed by the lack of a formal institutional agreement.

In February 2005, Maldives participated in a UNEP-organised meeting in Cairo, Egypt on coastal zone protection and management in regions affected by the tsunami. Representatives of a dozen nations as well as various UN agencies, international and regional organisations, international financial institutions, donor nations and NGOs attended the meeting. At the meetings conclusion, participants issued a set of twelve “Guiding Principles for Post-Tsunami Rehabilitation and Reconstruction”. Among others, the Guiding Principles aimed at reducing vulnerability of coastal communities to natural hazards, promoting early and sustainable resettlement, using natural systems to protect people and livelihoods and the adoption of best design practices and ecosystem-based management.

Early warning

The Department of Meteorology keeps watch for weather-related disasters and issues warnings in the event of tropical disturbances, torrential rains or strong winds. The Department also monitors seismological activities and physical oceanography. Since the Indian Ocean tsunami, the Department has been continuously monitoring seismic activity reports from seismic centres around the world and feeding relevant information to the GOM Disaster Management Centre. Since the Indian Ocean tsunami, the Department has been continuously monitoring seismic activity reports from seismic centres around the world and feeding relevant information to the GOM Disaster Management Centre. Although seismometers are vital to maintaining continuous records of earthquakes, the high cost of seismic monitoring systems has prevented Maldives from obtaining one.

A tsunami warning system is in place across the Pacific Ocean, but not in the Indian Ocean. Tsunamis are more rare in the Indian Ocean, where seismic activity is less frequent than in the Pacific. There have, however, been seven recorded tsunamis triggered by earthquakes near Indonesia, Pakistan and the Bay of Bengal. The implementation of a proposed Indian Ocean Tsunami Warning system would take an estimated two to three years. During that period, the Maldives will remain highly vulnerable to natural disturbances – a point reemphasized by the 28 March 2005 Indian Ocean earthquake.

Disaster risk management

The country’s mandate for disaster management was originally given to the Committee on Natural Disasters. The Committee was subsequently merged into the National Commission for Protection of the Environment in recognition of the linkage between disaster risks and environmental threats such as storm surges, high winds and sea level rise.

Immediately following the tsunami, a Ministerial Committee and Technical Task Force was established to facilitate response and coordination. On the atoll and island levels task forces were established to assess the damage and coordinate local recovery measures. This rapid and coordinated response enabled mitigation of the most severe effects of the tsunami.

The Ministerial Committee was transformed into the National Disaster Management Centre, which has facilitated the GOM’s ongoing response and coordination activities. Recently, the Government has decided to reorganise the work of the Centre into three core areas: the National Disaster Relief Coordination Unit, the National Economic Recovery and Reconstruction Programme, and the Transport and Logistics Unit.

The major disaster risks facing the Maldives are related to climate change factors, storm surge and tsunamis. Whilst tsunamis are extremely destructive, they are also unusual events. Nor has Maldives been significantly affected by cyclones, which often hit other areas of the Indian Ocean. As a consequence, the country has focused on what it has perceived to be its main risk – global warming

and rising sea levels. Due to the special geophysical characteristics of Maldives – i.e., small and low-lying islands – the country’s vulnerability to sea level rise is quite high.

Disaster risk management policies have not been well developed to date. No single ministry has overall responsibility for coordinating disaster risk management. Individual ministries and agencies address the issue independently, and uniform operating procedures have not been established. One result is that Maldivians are generally not well prepared to minimize risks to themselves and their families in the event of another natural disaster.

The GOM is currently in the process of identifying strategic locations where ‘safe islands’ could be developed and populations could be relocated. Also known as the Population Development and Consolidation Program, the President has stated that islands developed under the ‘Safe Islands’ Program would be economically viable and environmentally sustainable. In order to ensure the reduction of disaster risks, it will be of utmost importance to effectively integrate environmental planning and impact assessment into this and other aspects of the reconstruction process.

Health & safety regulations

There are no health and safety regulations in Maldives. The Ministry of Employment and Labour is responsible for health and safety regulations and occupational exposure standards. The Ministry is developing guidance focused on the safety of workers on construction sites, where most accidents and injuries occur. In 2004, the Ministry launched an effort to introduce occupational health and safety standards. To date, however, none have been established. The Ministry, which lacks capacity to enforce regulations, is eager to address resource, expertise and monitoring needs before creating standards. The MoT has basic health and safety regulations for resort facilities.



Unidentified girl with mother in aftermath of tsunami. Credit: NDMC

RECOMMENDATIONS

According to the Joint Needs Assessment, Maldives experienced total asset losses of \$472 million, equalling 62% of the country's GDP. Government, UN and donor reconstruction strategies all acknowledge environment as a key theme. National authorities, with the support of the international community, should ensure that reconstruction efforts reduce future disaster risks by addressing chronic environmental problems and employing sustainable design and construction approaches. Credit: L. Hiller





Maldives is famous worldwide for the beauty of its nature. The Indian Ocean tsunami worsened and brought to prominence a number of chronic environmental problems that Maldives had been facing before the tsunami. Whether the issue is waste, wastewater, groundwater, coastal zone or biodiversity protection, inadequate management practices are jeopardizing the country's greatest and most precious asset: its natural resources. Although the challenges may seem, and are, widespread, they exist in a landscape that is relatively free of long-term historical pollution. With attention, resources and the full support of all Government sectors, Maldives could solve its worst environmental problems without the difficulties other, more industrialized countries face.

Environment has already been acknowledged as a key reconstruction theme in the National Recovery and Reconstruction Plan. Environmental 'recovery plus' will mean not just the restoration of environmental services, but investments today that will lead to the creation of a more sustainable path for the country. The Government should immediately commit itself to transforming Maldives into a global environmental leader – a 'green state' and should enact laws, dedicate resources, adapt best environmental practices and implement programs designed to protect the country's unrivalled natural heritage for the benefit of future generations of Maldivians. The assistance of international partners will be crucially important during and beyond the tsunami recovery phase.

REHABILITATING NATURAL RESOURCES

Environmental planning

- *Environmental reviews of all planning:* As recovery and reconstruction efforts progress it is essential that detailed environmental review and planning be conducted in advance of development in order to properly site new infrastructure, prevent pollution, reduce environmental risks, establish appropriate environmental management systems and avoid future clean-up costs. The conceptual designs for envisioned shelter and 'host islands' should be subject to strategic environmental assessments, and detailed EIAs will be needed for

specific 'host island' plans. Building codes should be strengthened to ensure structural integrity of planned structures.



Man bringing fish catch ashore on L. Filadhoo. Credit: L. Hiller

This process should be spearheaded by the MEC, which will require additional support and training, working in close cooperation with the Ministry of Planning and National Development. Legal instruments for enforcing land use planning and building codes are needed. Local community members should be actively involved throughout all planning and review processes.

- *Coastal zone planning:* Coastal developments, especially on areas of reclaimed land, need to be very carefully considered in order to avoid increasing vulnerability to flooding. Development plans should always incorporate analysis of vulnerability and the need for coastal protection. Many of the developments that are already under way will require expensive and elaborate coastal defences if they are to survive the next half century. The effectiveness and multiple benefits of natural systems and 'soft engineering' should be given strong consideration. In responding swiftly to alleviate the problems created by the tsunami it is important to avoid creating safety and environmental problems for the future. An Integrated Coastal Zone Management plan should weigh the conflicting demands on coastal areas and include a strategy that minimizes environmental degradation and risk and ensures safety. Coastal zone management plans should be integrated with environmental and social goals and should be made with the early and active participation of community members. This is a basic requirement of the ICZM process.

Profiling/mapping

- *Geological profiling:* The subsurface geology of the islands is poorly documented. Detailed profiling should be performed in order to understand the structural integrity of the islands, groundwater resources and appropriate choices for construction materials. At minimum, the GOM should create a central repository and compile geologic information from existing dredge, excavation, and borehole operations. Baseline geological and elevation data should be made available to assist in defining 'safe islands'.
- *Mapping:* Accurate topographic and bathymetric maps of island and reef areas are essential to understanding and quantifying changes in island formation resulting from tsunami impacts and/or other natural disasters. Existing maps available in the Maldives are inadequate. The Government should take steps to improve its inventory of baseline maps. Airborne lidar for topographic and bathymetric mapping may provide a cost-effective method for developing accurate digital elevation maps of priority areas. These maps would be useful for a variety of applications including vulnerability assessments and coastal planning strategies.

Monitoring

- *Shoreline monitoring:* Shoreline engineering structures are widespread. It is important to understand the impacts of structures on adjacent shorelines through a consistent monitoring. A simple program of monitoring island shorelines at selected sites should be implemented, in order to better understand seasonal and long-term trends, as well as the effect of major events such as a tsunami.
- *Coral reef monitoring:* The Maldives coral reef monitoring program needs to be expanded to cover more reefs and allow detailed examination of the impacts of the tsunami on fragile coral populations and associated ecosystems currently rebuilding after the massive coral bleaching event of 1998.
- *Reef dredging:* Reef dredging operations are widespread and supply needed construction materials for the Maldives. Monitoring of operations and information on their potential impact to adjacent reefs, however, appears to be lacking. Because so much of the country's economy depends on having a healthy marine environment, it is important to develop a sand mining policy that is based on regular monitoring and quality data and that will minimize adverse impacts.

- *Sea grass monitoring:* There has been some damage to seagrass beds by sediment smothering but remedial action is not required – natural recovery should be adequate. The extent and condition of seagrass meadows, however, should be monitored on a regular basis.
- *Monitoring capacity:* Most of the above mapping and monitoring activities (reefs, shorelines, sea grass) can be accomplished through training of Maldivian nationals. Training activities can vary from individual studies at overseas universities to in-country workshops by outside experts.

Natural resources management

- *Wetland protection:* Rapid action is needed to put in force formal protection for the country's largest wetland areas. They are facing more serious threats from infilling and development now than in the period prior to the tsunami.
- *Protected areas management:* Management and recovery plans are required for short and long-term management of the country's protected areas. Conservation efforts are only likely to be successful with local support. Protected area management must include participation from local stakeholder groups. Communities need a strong motive to become involved in conserving their local environment. This is likely to be economic or livelihood-based, but political empowerment or cultural preservation could also provide sources of inspiration.
- *Marine protected areas:* In order to protect the biodiversity of coral reef ecosystems and the marine environment generally the country's network of marine protected areas should be expanded.
- *Marine science:* To facilitate increased monitoring and analysis of coral reef resources, fisheries and the marine environment generally, there is a critical need to increase national capacity in marine sciences.
- *Forest protection:* Direct damage by the tsunami to natural coastal forests was minor, and no remedial action is required. Clean-up operations are having a far greater impact than the tsunami itself and must be managed to ensure that there is no further damage or degradation of coastal forests. Base-line data should be collected on the extent and condition of coastal forests in order to permit accurate monitoring of future trends and to inform the planning process.

REHABILITATING THE HUMAN ENVIRONMENT

Waste management

- *Disaster waste management:* The continued presence of disaster waste, some of which contains hazardous materials, poses imminent risks to public health and safety and the environment. A comprehensive program to clean up disaster waste on the tsunami-impacted islands is urgently needed. Activities should include proper training and capacity building for clean-up crews, supervised clean up campaigns, hazardous and health care waste collection and storage, identification of appropriate sites, and reorganisation of waste handling and transportation. Community-based strategies should be developed and



Demolition waste accumulated in the aftermath of destruction on the island of K. Madhifushi. Credit: U. M. Badeau/ UNDP

implemented as soon as possible to reduce short-term risks and build toward long-term integrated waste management.

- *Waste management:* A number of basic waste management measures need to be implemented under the guidance of the MEC and in the framework of a longer-term effort to establish integrated solid waste management.
 - *Short-term management:* The MEC has produced valuable guidance for the handling and disposal of waste materials on tsunami-damaged islands. This guidance should be integrated into the work programmes of ministries and agencies participating in tsunami clean up and reconstruction activities. Uncontrolled dumping and open burning need to be phased out and replaced with waste reduction, monitoring, segregation of reusable and recyclable waste, and identification and preparation of recycling or intermediate storage sites. Local capacities will need to be strengthened and accompanied by intensive public awareness raising and participation. Market opportunities in, e.g., waste reduction or recycling should be promoted to the extent possible.
 - *Medium-to-long term management:* Regular professional waste collection systems (preferably fee based) will need to be developed and implemented along with transport systems that can link collection to island or atoll-based recycling and disposal facilities. Biodegradable components should be segregated for composting. Metal, glass and other materials should be reused/recycled. Non-recyclable waste should be treated and stored. Public participation and awareness initiatives will be vitally important.
- *Waste reduction:* A small-scale domestically produced waste to energy unit that is being pilot tested on Thilafushi by a private company with support from the Ministry of

Communication, Science and Technology offers the prospect of burning household waste and creating free organic fertilizer and methane gas fuel as by-products. If successfully implemented on inhabited islands the unit could cut waste volumes in half whilst reducing the country's dependence on greenhouse-gas producing LPG.

- *Dumpsite preparation:* The lack of adequate waste disposal facilities is one of several reasons that waste is improperly dumped. Sites with adequate capacity to handle tsunami-related and daily waste production need to be prepared (including transport, transfer, treatment and disposal zones), together with implementation of monitoring, leak prevention and green zones that will protect coastal zones and the marine environment. The MEC has developed technical minimum standards for dumpsites. Efforts to implement these standards at the country's three main landfills should be supported as an important first step toward long-term waste management.

Health care waste

- *Immediate Action Programme (IAP):* In the near-term an IAP should be developed and implemented either by all health care facilities in the country or, at minimum, facilities under the management of the Ministry of Health. Several immediate action priorities are recommended:
 - Introduction of basic health care waste segregation practices (hazardous/ non-hazardous) and standardized 'sharps' management. The MoH, with support from WHO, is currently working to introduce coloured bags for segregation and bins for sharps at all healthcare facilities. These efforts should be fully supported.
 - Treatment and disposal of health care and ordinary wastes, including development and implementation of an incineration action plan
 - General health care waste capacity building
 - Waste reduction at source (e.g., mercury, polyvinyl chloride)
- *National health care waste management strategy:* A stakeholder-driven national strategy for health care waste management is needed to establish broader and better understanding of the risks associated with health care waste and the options available for its safe and environmentally sustainable management. In order for the strategy to have impact it should involve key health care decision-makers and contain performance benchmarks and timetables for action. Key elements: health care facilities should earmark adequate funds (preferably 2-5% of operating budgets) for health care waste management; health care waste management should be included in all staff task descriptions. WHO has developed readily available reference documents that have provided useful guidance in the development of national health care waste management strategies in many countries throughout the world. See, e.g., WHO-SEARO, 1996, *Action Plan for the Development of National Programme for Sound Management of Hospital Wastes*.

Hazardous waste

- *Short-term management:* Hazardous waste components are not easily identified and their risks are not well understood by national and community level officials. As a first step, a task force should be trained in hazardous waste identification and handling. Uncontrolled dumping and open burning of waste containing hazardous materials should be stopped

immediately, consistent with MEC guidance, and safe interim storage sites identified. MEC is working to develop a notification and reporting system that would eventually enable monitoring of the distribution, use, treatment and disposal of hazardous materials. These efforts should be fully supported. Local capacities will need to be strengthened and accompanied by intensive public awareness raising and participation.

- *Medium-to-long term management:* Guidelines are needed to promote hazardous waste reduction (including at resorts) and to ensure the safe collection, handling, transport, and storage of fuel and oil. The burning of waste oil and other hazardous waste components should be stopped immediately. Hazardous components (e.g., oil, fuel, fertilizers, pesticides, refrigerants) should be labeled and registered in a database and properly managed. Hazardous waste policies and regulations need to be developed, and public participation and awareness will need to be promoted.
- *Hazardous waste landfill:* There is an urgent need to identify and construct hazardous waste disposal facilities. In the near term, Thilafushi landfill should be prepared to provide safe storage and monitoring of tsunami-related hazardous waste until a long-term secure hazardous waste landfill can be sited. The hazardous waste storage facility at Kulhuduffushi is a second site that could also be prepared in the short term. Over time, an atoll-based approach to disposal/storage facility siting should be explored.

Asbestos

- *Short-term management:* National experts and community members should be trained in identification and proper handling of asbestos materials. Asbestos waste should be separated from general demolition waste before disposal at landfill sites or reuse in building products and should be stored on an interim basis in designated safe storage areas.
- *Medium-to-long term management:* Asbestos waste disposal standards (for identification, segregation and designation) should be developed and, following training, implemented by the MEC in cooperation with the Ministry of Home Affairs's Waste Management Section. The disposal method at Thilafushi, where waste is being used for reclamation, is acceptable in the short term. Asbestos waste, however, needs to be kept wet and asbestos disposal areas need to be designated and not subsequently excavated. The MEC and the Ministry of Employment and Labour should work closely to implement guidance on asbestos usage. Ultimately, the import of asbestos should be banned, as should the use of asbestos-containing materials in government projects and resorts.

Surface water, groundwater

- *Surface water quality:* Surface waters should be surveyed to determine ecological impacts, probable rates of recovery and needed conservation and management actions.
- *Groundwater management:* The most significant tsunami impacts on groundwater quality were elevated levels of salinity and biological contaminants. The duration and the reversibility of these impacts are uncertain. Below are a number of short and medium-term measures are needed to improve groundwater quality and preventing risks in the event of future flooding:
 - *Boil/chlorinate groundwater:* To reduce risks of waterborne diseases, supplies should be chlorinated and routinely boiled (for five minutes) before consumption or use for food preparation.

- *Clean all wells:* All private and domestic well in affected areas should be cleaned of demolition and household waste and chlorinated to prevent further spreading of contaminants to the water body.
- *Cover all groundwater wells:* All private and domestic wells should be enclosed with a fixed cover and equipped with hand pumps to prevent potential contaminants (domestic waste, leaves, bird dropping, etc.) from entering the water supply.
- *Feed rainwater overflow into wells:* The overflow from private and communal rainwater collection tanks mainly discharges to the ground surface. Because of a high evaporation rate (>70%), only 30% or less of the rainwater will reach the groundwater. To dilute salinity in the wells and accelerate freshwater lens restoration, overflow from the collection tanks should be fed directly into the wells or into an infiltration well.
- *Feed desalinated water overflow (5m³/day) into wells:* In order to reduce risks of waterborne disease from contaminated groundwater, impacted islands should be provided with temporary reverse osmosis desalinations plants whenever possible. The desalination plants should be fed from wells and not seawater. Overflow from the plants should be fed directly into nearby wells to dilute salinity and accelerate restoration of the freshwater lens. This approach would require a preliminary mapping of wells, groundwater tables and well flow rates in order to prevent intrusion of seawater into aquifers.
- *Monitor water quality:* A nationwide groundwater-monitoring programme is urgently needed not only to gauge post-tsunami improvements in water quality but also to create a baseline against which future conditions can be measured. The monitoring programme should sample and map all water tables, individual wells and collection tanks, both household and communal.
- *Long-term groundwater management:* A national water resources management plan (NWRMP) should be developed to ensure safe groundwater supplies for the future. An NWRMP would provide an overall framework for the restoration, protection and preservation of the country's precious groundwater resources. The development of a NWRMP should educate and strengthen national and local capacities; build public awareness; and provide guidelines for the management of sewer systems, hazardous materials and land use.

Soils

- In the short term, farmers need guidance regarding the use of fresh water (from wells) to desalinate topsoil and restore opportunities for successful planting. Such guidance should be published on mass media and used in public awareness campaigns. In the longer-term, detailed soil profiles are needed for a representative sampling of impacted islands in order to inform recovery plans for soil and vegetation as well as future planning decisions.

Water supply

- *Supply households with rainwater collection systems:* To meet current and future demands for clean drinking water, each household should be equipped with an individual rainwater collection system. This would increase overall capacity and decrease water supply vulnerability to future flooding. Existing and new rainwater collection system should

be equipped with filters on the inlet in order to prevent foreign bodies and contaminants from entering collection tanks, and regular maintenance is needed.

Wastewater and sanitation

- *Survey and desludge septic tanks:* In extensively affected areas, where islands were subjected to flooding for an extended period of time, septic tanks should be inspected to identify physical damage and the possible need for repair/replacement. Tanks should be desludged to ensure desalination and adequate bacterial anaerobic digestion conditions. Despite elevated salinity levels, the sludge should be collected, dewatered, composted and applied as fertilizer on affected agricultural areas.
- *Repair/replace of damaged infrastructure:* Rehabilitation and replacement of damaged infrastructure (toilets and septic tanks) is urgently needed in households and communal buildings on the islands most impacted by the tsunami. The GOM is seeking assistance for construction of permanent septic and hygienic sludge-drying beds. Damaged or undersized small bore sewers and sea outfalls also require attention.
- *Sewerage systems:* Although it will not be a short-term undertaking, islands relying solely on septic tanks/soak pit systems will need sewerage systems and the introduction of cost-effective sewage treatment facilities. Ultimately, soak pits should be closed. Development of these facilities can occur in two phases: first, collection of wastewater for centralized sedimentation and distribution to a sea outfall, followed by bypassing of the sea outfall and the delivery of wastewater to sewage treatment facilities (reed bed, sun drying beds, aerobic activated sludge system, etc.) according to feasibility and affordability. Testing and piloting of reed bed systems should be further explored. Sanitation and wastewater collection and treatment systems should all be subject to prescribed standards that are part of the country's physical planning, building and construction codes. To ensure the long-term sustainability of these facilities, capacity building within relevant authorities will be needed.



UNEP team conducts water sampling on farm in L. Fonadhoo.
Credit: J. Bennett

- *Sea outfalls:* Sea outfalls should be reactivated as soon as possible. The chronic problem of sea outfalls being located too near shorelines also needs to be addressed. Liquid septic waste is very probably infiltrating groundwater supplies near the shorelines. Ultimately, unprotected sanitation facilities should be closed. Sea outfalls connected to IDP and relief camps should be extended, at minimum, to offshore lines.

LIVELIHOODS RECOVERY

Agriculture

- *Short-term management:* A campaign is needed to replace the very large numbers of dead trees as quickly as possible in order to minimize the impacts on the incomes of rural poor households, island microclimates and tree-dependent biodiversity. This campaign should begin as soon as possible after the onset of the next monsoon, when soil salinity has begun to fall. Advice and guidance should be provided to owners of farms and home gardens on the safe use of pesticides, particularly on safe application methods, appropriate dose rates and safe storage. Farmers should also be guided in the use of compost as a soil amendment to increase soil organic matter, increase aeration, drainage and soil and water holding capacity. A programme is needed to produce a more productive, more salt-tolerant planting stock. In view of the likelihood of future flooding, the long life span of most fruit trees and their economic importance to low-income families, such improvements should be assigned a high priority.
- *Agro-forestry:* Agro-forestry is a land-use system in which woody perennials are deliberately grown on the same land as agricultural crops and/or animals. Trees and shrubs provide shade, organic matter, and soil stabilisation and reduce damage from salt spray. The development of small-scale collaborative agro-forestry projects could involve rural poor families in the production of fruit and vegetables. Such projects would have a much smaller environmental footprint than intensive large-farm horticulture and would offer a more resilient form of production and important development benefits.
- *Coastal zone:* Integrated coastal zone management planning should provide for sustainable agricultural production, including minimizing run-off of pesticide residues and nutrient rich water.
- *Resort markets:* Most resorts import fruit and vegetables from countries in the region such as Dubai, India and Sri Lanka, because, among other reasons, supplies can be reliably delivered. The resort market holds tremendous and, at present, under-realized potential for further development of the country's agriculture sector. Assistance would be needed to establish the techniques and transport modalities necessary for successful development of these markets.



Construction of septic system on HA.Filadhoo
Credit: E. Spitaler



Fishing boat swept ashore on Th. Vilifushi. Credit: J. Bennett

Fishing

- *Phased recovery:* The GOM's goal is to rehabilitate the fisheries industry in two phases: a six-month, short-term phase providing immediate repair work, and a two and a half year phase (until December 2007) that would replace damaged fishing vessels and fishing gear. The GOM envisions a similar two-phase programme for restoration of maritime infrastructure. International partners should support these efforts.
- *Sustainable fisheries:* Live bait and reef fish fisheries should be incorporated into the national fishery data collection system in order to be able to detect the effects of major environmental perturbations or excessive catch. As the country's fishing sector becomes more commercialized and turns to more advanced technologies, it would be useful to monitor annual fish catches and to compare them against science-based estimations of safe yields.

Tourism

- *Short-term management:* Continued marketing and outreach will be crucial to ensure that tourists understand current conditions and holiday opportunities in Maldives. Unemployed staff and communities suffering from declines in tourism will need assistance.

- *Medium-to-long-term management:* Resorts will need guidance and encouragement to improve disaster/crisis management planning. Training, protocols and procedures need to be elaborated together with training and advice for hotel owners on insurance matters.
- *Best environmental practices:* During the reconstruction process, environmental protection and conservation values should be emphasized to the tourism industry, and the industry should be encouraged to adopt best environmental management practices to the greatest extent possible.
- *Marketing Maldives:* Maldives has the potential to more fully exploit its natural environment for marketing purposes by, e.g., committing itself to the use of best environmental practices and working toward the creation of a ‘green state’. With improved environmental management and the development of local capacities the country’s 199 inhabited islands have the potential to become eco-tourist destinations, which could provide livelihoods and greatly strengthen local economies.
- *Eco-tax:* The close relationship between the protection of nature and the benefit that such protection provides to the tourist sector should be more fully acknowledged and formalized. To provide a stronger revenue base for environmental protection and nature conservation, consideration should be given to imposing a nominal ‘eco-tax’ on tourists visiting Maldives. A \$3 eco-tax, e.g., could drive significant revenues into a dedicated fund for much-needed implementation of environmental protection measures.

Construction

- *Building code:* Without adequate building and design standards, efforts to limit disaster vulnerability will fall short. The country’s building code needs to be upgraded to require the use of durable, tsunami-resistant materials and design standards. Various building codes around the world (e.g., Hawaii) have incorporated tsunami-proof requirements. Because the tsunami was found to have had the greatest impact on buildings using unwashed aggregate and not using ring beams or other forms of reinforcement (e.g., steel), strong consideration should be given to establishing nationwide minimum standards and, at the same time, providing assistance that will enable communities to bear the additional costs of compliance.
- *Best environmental practices:* The expeditious implementation of recovery measures should not come at the expense of Maldives’ long-term interests. International partners and the GOM will need to plan carefully to ensure that natural resources are not degraded and that new forms of vulnerability are not created as other forms are remedied. All reconstruction and longer-term development plans should be subject to environmental impact assessments and should seek to employ best environmental and energy-saving (‘green design’) practices to the very greatest extent practicable.
- *Reuse of demolition waste:* Guidance is urgently needed on the national and island levels to identify opportunities to reuse metal and concrete demolition waste components during reconstruction.
- *Health & safety standards:* Health and safety standards should be created through a process that actively involves national stakeholders, island committees and resort management.

Energy

- **Renewable energy:** Efforts should immediately begin to tap the vast supply of renewable energy – e.g., solar, biomass – that is available to Maldives. Technical assistance will be needed to identify strategic opportunities to introduce these technologies. Many of the solutions could quite possibly be developed through local small business development.

Early warning

- *Early warning systems:* A regional tsunami warning system needs to be established in the Indian Ocean. The establishment of an Indian Ocean Tsunami Warning system, however, could take an estimated 2-3 years. During the transition period, a National Tsunami Warning System linked with a national tropical cyclone and storm surge (high wave) alert is needed within the Department of Meteorology. This system could be linked to the warning systems of neighbouring countries, particularly India and Sri Lanka.
- *Climate change:* Strong links must be developed between efforts to adapt to climate change and strategies to reduce risks from natural hazards. Many hazards experienced by the Maldives are related to the sea. Projected sea level rise may result in enhanced severity of some hazards and their impacts. Efforts focused on natural hazard mitigation alone might not prove ineffective in the absence of linkages with climate change impact reduction.
- *Vulnerability assessment:* A vulnerability assessment of the Maldives is needed from various aspects. A community-based assessment through island-level task forces would strengthen preparedness planning. A national process would help assess mitigation options and identify new assets/infrastructure. The vulnerability assessment process should be linked with vulnerability assessments of ecosystems and natural resources that are serving as natural protection. The vulnerability of the country's coral reefs could be assessed with specific reference to the long-term implications of coral bleaching that occurred in 1998.
- *Multi-hazard preparedness:* Preparedness planning is recommended for the atolls. Preparedness plans would equip government officials and community members to know their roles before, during and after disasters. A feasibility study on the establishment of a multi-hazard early warning system is recommended. The feasibility study would provide an outline of the system including institutional and technical details, capacity building and training needs, awareness programmes, phased work plans, and proposed financing arrangements for the establishment and operation of an integrated national early warning system on a sustainable and continuous basis. The national system could be built on the existing observatories of Atmospheric Brown Clouds (ABC) and the Male' Declaration on Control and Prevention of air pollution and its Transboundary Effects for South Asia.

Disaster management

- *National Disaster Management Strategy:* Disaster management efforts are closely interwoven with sustainable development goals. Development processes aimed at social and economic improvement could generate significant new disaster risks if not properly planned. Major development programmes and projects need to be reviewed for vulnerability and hazard and their potential impacts on the environment. The GOM should initiate an effort to develop a national policy for disaster management. The disaster management roles and responsibilities of various ministries should be clearly delineated. A national disaster management authority could function as lead agency.

- *Atoll and island disaster management plans:* Community emergency protection plans should be developed with guidance from relevant state authorities and early and active participation of local community members. Emergency shelters should be established on high ground (perhaps reusing appropriate components of demolition waste). Technical and environmental guidance will be needed for appropriate shelter designs.
- *Disaster education:* The impact of the tsunami serves as an indicator of the vulnerability of the Maldives to external forces of nature. On the community level, there was poor public awareness of what to do in response to the tsunami. The tsunami provides an opportunity to better educate citizens through locally based outreach and information initiatives.
- *Reef top hydrodynamics:* A study of the hydrodynamics around reef-top islands would provide valuable information for the design of coastal engineering and disaster management structures.

STRENGTHENING ENVIRONMENTAL CAPACITIES

The country's environmental protection capacities need to be expanded and strengthened on an urgent basis. With a national economy based largely on nature tourism, the risks of deferring action to prevent and mitigate pollution and resource depletion are too great for the country to assume.

Ministry of Environment and Construction

The GOM should give serious and immediate consideration to separating the MEC's environment and construction functions and creating a separate, independent Ministry of Environment with clear lead authority to protect the country's environment. Such a step would signal the GOM's serious commitment to environmental protection and would greatly assist the process of clarifying the Ministry's role and strengthening its capacities.

- *Administration of the MEC:* The MEC should more effectively use its staff and their technical expertise by assigning specific roles and functions. To this end, the proposed organisational structure for the MEC should be implemented, with clearly defined roles and responsibilities provided for its different departments and divisions. As soon as possible, the MEC should also expand its presence in the atolls to monitor environmental conditions, implement policies and, following enactment of relevant legislation, conduct inspections and enforce environmental laws.
- *Capacity building:* The MEC urgently needs additional technical, managerial and administrative staff. Training and education is needed to strengthen staff capacities in environmental protection and the sustainable management of natural resources. In particular, staff responsible for the management of divisions and units should be trained to develop basic management skills as well as environmental management methods. A number of sectors require specific capacity building:
 - *Planning/EIA:* Urgent capacity building support and technical assistance is required by the MEC and the Ministry of Planning and National Development to jointly review all reconstruction plans and projects, and, under the MEC's leadership, to thoroughly and properly assess environmental impacts and options for mitigation.
 - *Waste management:* Legal, institutional, technical and financial support is urgently needed within the MEC and other relevant institutions to plan implement and ensure the long-term sustainability of waste management services.

- *Compliance and enforcement:* Compliance and enforcement of environmental laws and regulations should be strengthened by building the capacity of staffs from the MEC and other relevant government bodies to carry out environmental monitoring and inspections.
- *Coastal management:* Capacity building in the field of coastal engineering is needed, as are studies of erosion management techniques and the development of technical guidelines and procedures for shoreline protection. These activities could be spearheaded by a MEC-based coastal zone engineering unit that could prepare studies and guidelines.
- *Marine resources:* MoFAMR's capacity to monitor, analyse and protect marine resources should be expanded and strengthened.
- *Seismology and oceanography:* The Department of Meteorology's capacity should be enhanced, in particular in the fields of seismology and oceanography. The Department's working relationships with counterpart agencies and regional and national organisations should be strengthened. The participation of Meteorology Department officials in regional planning and consultation meetings would facilitate the strengthening of an early warning system. A regional EWS meeting in Male' would help network GOM agencies with international counterpart agencies.

Local environmental capacity

- Environmental governance at the local administrative level – atolls and islands – should be expanded and developed to improve implementation of environmental policies. The awareness of the local government level should be strengthened through training on existing environmental laws and regulations as well as compliance and enforcement. The MEC should take the lead on these activities, in cooperation with the Ministry of Atolls Development. A broader public awareness strategy should be developed and implemented in close cooperation with atoll and local chiefs and local educators. Consideration should be given to the distribution of environmental roles and responsibilities to the atoll and island levels.

Inter-ministerial relations

- There is a need for operational guidelines to clarify the existing mandates of the different Government bodies responsible for environmental protection. The development of guidelines could be achieved by performing a detailed institutional capacity analysis of the existing institutions and organisations responsible for environmental protection and natural resources conservation. The assessment should review institutional mandates, policies, legislation, and inter-institutional relationships. In addition, environmental units should be established within ministries and government bodies responsible for environmental protection. These units should ensure that GOM environmental policies are fully integrated into the programmes of their ministries and that environmental issues are given due considerations in the development of policy.

Policy development

- Most of the country's environmental plans have been prepared with international financial and technical support. Policy development projects are separated from policy implementation projects, creating the very common problem of good policies that are being poorly implemented. The MEC, in cooperation with other ministries with environmental

competence, should create a unified national environmental policy that harmonizes the ministries' and agencies' environmental policies. Implementation of NEAP II and other environmental policies should be accelerated through development of an implementation plan with responsibilities and actions tied to clearly identified timeframes and resource requirements.

Legislative development

- The EPPA should be revised and strengthened to address current environmental priorities. The Act needs proper implementation and enforcement. Sectoral laws that relate to environment and natural resources management should be harmonized with the EPPA. Relevant by-laws and regulations under the EPPA should be developed on an urgent basis – particularly in the areas of waste management and water quality protection. Also urgently needed is a national physical planning law.

Environmental impact assessment

- There is an immediate need to review and strengthen the country's EIA process to enable effective assessment and mitigation of the possible environmental impacts of planned reconstruction and longer-term development activities. In particular, there is a need to establish a regulation on EIA that outlines project categories requiring EIAs as well as the specifics of the process and the role of the public. The regulation should be developed with active participation of relevant ministries to gain their support in ensuring that projects covered by the law undergo the EIA process. Public participation should be integrated from the early stages of the process and should allow public concerns and objections to be raised before final decisions, including project site selections, are made. The monitoring of environmental impacts and mitigation measures identified in EIAs needs to be greatly improved.

Environmental inspections and licenses

- When capacity is improved in the area of compliance and enforcement, a national environmental enforcement body/inspectorate should be established and trained. The current licensing procedure for the use of natural resources needs to be improved through the preparation of clear procedures and guidelines, and, when necessary, amending relevant legislation. The MEC should always have at least an advisory role in procedures for licensing the use of natural resources.

Public awareness

- In order to build public awareness and a broader constituency for environmental protection, the MEC should aim to strengthen its communications capacity by dedicating staff to media relations, environmental education and public awareness activities. Training will be needed in these areas.

Access to information

- The public's right to environmental information and to participate in environmental decision-making should be acknowledged and reinforced in all MEC policies and programmes. Similarly, the MEC should encourage and seek to develop an active and independent environmental NGO community by involving NGOs in projects and activities to the extent possible and by providing full and open access to environmental information.

ANNEX I

UNEP field mission, 21-27 February 2005: Atolls/Islands Visited

Date	Atoll	Island
21 February	Haa Alifu	Filadhoo
22 February	Haa Dhaalu	Kulhudufushi Theefaridhoo
23 February	Meemu Thaa	Kolhufushi Vilifushi Kalhufahalafushi
24 February	Laamu	Fonadhoo Maandhoo Gan
25 February		Kalhaidhoo
26 February	South Male' Kaafu	Fun Island Resort Guraidhoo Huraa Bandos Resort
27 February	Alifu Dhalu	Hurasdhoo Angaga Resort

UNEP waste management experts investigated twelve additional islands prior and subsequent to the 21-27 February 2005 field mission: Banyan Tree Resort, Dhiggaru, Dhoonidhoo, Ganu, Funadhoo, Kolhuvaariyaafushi, Madhifushi, Mulah, Muli, Naalafushi, Rakeedhoo and Thilafushi.

ANNEX II

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ADB	Asian Development Bank
ATDTF	UNEP Asian Tsunami Disaster Task Force
AusAID	Australian Agency for International Development
EIA	Environmental impact assessment
ERC	Environment Research Centre
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GIS	Geographical Information System
GOM	Government of Maldives
HABITAT	United Nations Human Settlements Programme
IFRC	International Federation of Red Cross and Red Crescent Societies
ICZM	Integrated Coastal Zone Management
IDP	Internally Displaced Person
IMO	International Maritime Organization
IUCN	World Conservation Union
JICA	Japanese International Cooperation Agency
JSCE	Japanese Society of Civil Engineers
MWSA	Maldives Water and Sanitation Authority
MAD	Ministry of Atolls Development
MCST	Ministry of Communication, Science and Technology
MDNS	Ministry of Defense and National Security
MEC	Ministry of Environment and Construction
MoFT	Ministry of Finance and Treasury
MOFOR	Ministry of Fisheries, Agriculture and Marine Resources
MOH	Ministry of Health
MHUP	Ministry of Housing and Urban Development
MPND	Ministry of Planning and National Development
MOT	Ministry of Tourism
MPA	Marine Protected Area
NDMC	National Disaster Management Centre
NRRP	National Recovery and Reconstruction Plan
NGO	Non-Governmental Organization
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
ROAP	UNEP Regional Office for Asia and the Pacific, Bangkok
SEA	Strategic Environmental Assessment
UNCED	United Nations Conference on the Environment and Development
UNDAC	United Nations Disaster Assessment and Coordination
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
UNDAC	United Nations Disaster Assessment and Coordination Team
USGS	United States Geological Survey
WB	World Bank
WFP	World Food Programme
WHO	World Health Organization

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