



Floods, health and climate change:
a strategic review

Roger Few, Mike Ahern,
Franziska Matthies and Sari Kovats

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Roger Few

School of Development Studies, University of East Anglia,
Norwich NR4 7TJ

Mike Ahern

London School of Hygiene and Tropical Medicine, Keppel Street,
London WC1E 7HT

Franziska Matthies

Tyndall Centre for Climate Change Research, University of East Anglia,
Norwich NR4 7TJ

Sari Kovats

London School of Hygiene and Tropical Medicine, Keppel Street,
London WC1E 7HT

email: r.few@uea.ac.uk

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CONTENTS

SUMMARY	v
INTRODUCTION	1
1.1 OBJECTIVES	1
1.2 PREVIOUS REVIEWS	3
1.3 REVIEW PROCESS	5
1.4 STRUCTURE OF THE REPORT	6
GLOBAL FLOOD RISK AND RESPONSE.....	7
2.1 FLOODS AND FLOOD HAZARDS	7
2.1.1 <i>Flood disasters</i>	10
2.1.2 <i>Recent trends in flood frequency</i>	11
2.2 FUTURE CLIMATE CHANGE AND FLOODING.....	12
2.2.1 <i>Inland flooding</i>	12
2.2.2 <i>Coastal floods</i>	13
2.2.3 <i>What can we conclude about future flood risk resulting from climate change?</i>	14
2.3 RISK, VULNERABILITY, COPING, ADAPTATION.....	15
2.4 GENERAL ASPECTS OF FLOOD HAZARD RESPONSE	17
HEALTH IMPACTS	20
3.1 EPIDEMIOLOGY OF FLOOD HAZARD	20
3.2 HEALTH OUTCOMES.....	21
3.2.1 <i>Mortality</i>	22
3.2.2 <i>Injuries</i>	27
3.2.3 <i>Diarrhoeal disease</i>	27
Cholera.....	30
Rotavirus and Cryptosporidium	30
3.2.4 <i>Other faecal-oral</i>	31
Hepatitis A and E	31
Poliomyelitis	32
3.2.5 <i>Infection from helminths</i>	32
3.2.6 <i>Vector-borne disease</i>	33
Malaria	33
Arboviruses	34
Bancroftian Filariasis	35
3.2.7 <i>Rodent-borne disease</i>	36
Hantavirus Pulmonary Syndrome	36
Leptospirosis	36
3.2.8 <i>Mental health</i>	38
Common mental health disorders (anxiety, depression, stress).....	39
Post-traumatic stress disorder (PTSD)	41
Suicide and Schizophrenia	42
3.2.9 <i>Other</i>	43
Chemical pollution.....	43
Nutrition.....	44
Displaced populations (Environmental Refugees)	44

3.3 STATE OF KNOWLEDGE: AN ASSESSMENT	45
3.3.1 Summary of the findings	45
3.3.2 Knowledge gaps.....	46
RESPONSES TO THE HEALTH RISKS FROM FLOODING	49
4.1 INTRODUCTION: THE SCOPE OF THE SURVEY.....	49
4.2 REVIEW OF HEALTH-RELATED RESPONSES TO FLOODING	50
4.2.1 Action in the Home and the Community	51
Household actions	51
Community actions	52
Issues in household/community response	53
4.2.2 Health and hygiene education	56
Content and delivery	56
Issues in education activities	57
4.2.3 Warning and Evacuation	58
Integrated approaches to warning and evacuation.....	59
Organisational issues: getting an effective system in place.....	60
Behavioural issues: public response to warnings	61
4.2.4 Disease surveillance and control.....	63
Priority measures.....	63
Issues in disease surveillance and control	64
4.2.5 Health care provision	65
Emergency planning and needs assessment	66
Health care delivery	68
Mental health care	71
Issues in health care provision	73
4.2.6 Protecting health infrastructure	74
Damage risks and response	74
Issues in infrastructure protection	76
4.2.7 Water and sanitation: protection and provision.....	77
Flood impacts on water and sanitation systems.....	77
Advance protection	79
Emergency provision: water supplies and purification.....	80
Emergency provision: sanitation.....	82
Issues in water and sanitation response to floods	83
4.3 STATE OF KNOWLEDGE: AN ASSESSMENT	85
4.3.1 Summary of the findings	85
4.3.2 Knowledge gaps.....	86
VULNERABILITY AND ADAPTATION IN A CHANGING CLIMATE 89	
5.1 HEALTH IMPACTS AND VULNERABILITY	90
5.2 COPING CAPACITY: RESPONSES TO HEALTH RISKS	93
5.3 CLIMATE CHANGE, FLOODS AND FUTURE HEALTH RISKS	94
5.4 ADAPTATION PROCESSES AND POLICIES.....	96
REFERENCES.....	100
APPENDICES	118
Appendix 1 Summary of epidemiological studies.....	118
Appendix 2 Types of health-related response	124

SUMMARY

Introduction

Flooding is one of the most widespread of climatic hazards and poses multiple risks to human health, yet there has been little systematic research work on health outcomes and the means by which vulnerable populations and health systems respond to those risks. Given the prospect that flood hazards may increase as a result of climate change, it is timely now to make a strategic assessment of the existing knowledge base on health and flood risk.

The objectives of this report are:

- To present findings from a wide-ranging review of global literature on health impacts, adaptation processes and policies relating to flood risk.
- To make a critical assessment of the existing knowledge base and identify key opportunities and challenges for intervention and research.
- To assess the implications of climate change and future flood risk for health impacts, adaptation processes and policies.

Following preliminary discussion of global flood risk issues (chapter 2), the main sections of the report comprise an epidemiological review of the evidence base for health outcomes of flooding (chapter 3) and a review of literature analysing mechanisms of response to health risks from floods (chapter 4). Though the scope of the report is global, the material discussed in these sections is fairly narrow in thematic focus: the intention has been to maximise the added value of the work by concentrating as closely as possible on issues connected with health and flooding. The final section (chapter 5) then discusses the key findings in the wider contexts of social differentiation, development, hazard management, climate change and adaptation.

Global flood risk and response

Flood events can take many forms, including slow-onset riverine floods, rapid-onset flash floods, accumulation of rainwater in poorly-drained environments, and coastal floods caused by tidal and wave extremes. Both inland and coastal flooding may be associated with windstorm events. Floods also vary greatly in magnitude and impact, according to depth, velocity of flow, spatial extent, content, speed of onset, duration and seasonality. A flood event that has severe consequences (variously defined) may be termed a flood disaster, and the human impact of flood disasters is concentrated disproportionately in developing countries.

Though major limitations remain in our ability to make robust projections of future rates of climate change and its effects, increasing predictive evidence of heightened global risk of inland and coastal flooding is emerging. Over the next 100 years, flooding is likely to become more common or more intense in many areas, especially in low-lying coastal sites or in zones that currently experience high rainfall. Marginal changes in the geographical distribution of flooding are also possible. However, prediction of precise locations for increased flood risk resulting from climate change is not feasible: part of the problem is that flood risk dynamics have multiple social, technical and environmental drivers.

In this report we draw on a body of analytical work that defines flood risk to humans as a product of flood hazard and vulnerability, recognizing that vulnerability is constructed largely by social processes that shape people's susceptibility to harm and capacity to resist and recover. The converse concept of coping capacity emphasizes the positive potential and actions of people and societies to combat the adverse effects of flooding. Response to flood risk that involves a change in action or policy is referred to as adaptation.

Coping mechanisms in response to floods can apply at all phases of the hazard management cycle: mitigation, preparedness, emergency response and recovery. The last two decades have witnessed considerable rethinking on how society should approach the management of flood hazards, with a stronger trend now toward broader aspects of flooding preparedness and a less ready reliance on structural mitigation works and emergency relief efforts.

Health impacts

Floods of all magnitude have the potential to impact on human health. In order to understand better the nature of this health burden the report surveys the evidence base available on the epidemiology of floods. Chapter 3 provides the substantive results of this review, with studies grouped under the following categories: mortality; injuries; diarrhoeal disease; other faecal-oral; infection from soil-transmitted helminthes; vector-borne disease; rodent-borne disease; mental health; and other health outcomes.

Overall, the epidemiological review suggests that there is presently a weak evidence-base to assess the health impacts of flooding. Relatively few rigorous epidemiological studies have been undertaken, and it is extremely difficult to assess the duration of symptoms and disease, and the attribution of cause without longitudinal data.

Mortality statistics are generally only available for flood disasters and datasets may be subject to bias. In developing countries accurate information on the mortality impact of flood events is particularly limited. Nevertheless, data available shows that by far the greatest burden on mortality is in Asia, and suggests that incidence of death due to inland and coastal flooding is especially high in parts of Central and South America, the Caribbean and South Asia. The speed of onset of floodwaters is a key factor determining the number of immediate flood-related deaths; few deaths from drowning occur during slow rising floods. Generally, there is very weak data available on non-drowning (non-immediate) deaths that can be attributed to the flood event.

Infectious disease is a major flood-related health concern in the South, especially in settings where infectious disease transmission is an endemic public health problem. Infectious disease outbreaks have been reported following major flood events in developing countries, and these outbreaks vary in magnitude and rates of mortality. There is some evidence from India and Bangladesh that diarrhoeal disease increases after flooding. There is also good evidence of outbreaks of leptospirosis, but relatively weak evidence that flooding leads to outbreaks of other infectious diseases (e.g. cholera, hepatitis, vector-borne disease). From the studies reviewed it is clear that there is no strong evidence of outbreaks of infectious disease in countries of the North.

Mental health studies relating to flood events, by contrast, come mainly from countries of the North. There is strong evidence that flooding can have an adverse effect on common disorders such as anxiety and depressive illness, especially in the elderly. One study in the USA showed that an increase in such disorders was greatest in low-income groups. Only two studies addressed mental health impacts of flooding in developing countries. There was evidence that flooding in Bangladesh was associated with increased behavioural problems in children. The lack of research in developing countries may reflect low levels of mental health service provision as well as a shortage of research expertise on mental health epidemiology.

The knowledge gap on health outcomes relates in part to a need to improve monitoring and surveillance. This includes strengthening general surveillance systems for infectious diseases, and developing and enhancing specific surveillance following flood events. Many studies in the review also suffered from methodological shortcomings. We therefore make the following recommendations for the design of epidemiological studies that investigate the health impacts of floods: control groups for comparison with non-flooded populations; use of longitudinal data, or routine data in order to gain information on pre-flood levels of disease; use of objective measures of disease outcome; and improved use of routine surveillance information

Priorities for future research include: the impacts of flooding on long-term mental health in both industrialised and developing countries; the impact of flooding and heavy rainfall on diarrhoeal disease, and the main routes of transmission; indirect mortality attributable to flooding (in addition to immediate deaths from drowning); and impacts on health from the disruption of health services and other life-supporting systems.

Responses to the health risks from flooding

Efforts to tackle the health risks from flooding include both actions that reduce vulnerability to health impacts and measures to strengthen coping capacity in the face of health risks. Health outcomes of floods can be seen as the culmination of a series of events whereby a flood hazard leads to mortality and morbidity effects in humans exposed to the hazard. Interventions can be made at various points along this process, including structural and non-structural mechanisms of flood risk management. Since such general flood avoidance mechanisms are widely discussed elsewhere, however, this report focuses attention specifically on health-related responses: by which we mean actions geared to preventing injury and illness resulting from flooding and to promoting treatment, including the continued functioning of health services.

Chapter 4 reviews and analyses seven main categories of health-related responses: action in the home and the community; health and hygiene education; warning and evacuation; disease surveillance and control; health care provision; protection of health infrastructure; and water and sanitation protection and provision. The focus of these accounts is on assessing processes and policy-related issues. Together, they raise several generic considerations for policy and intervention, broadly relating to: information and education; planning, flexibility and organization; and commitment and support.

The chances of effective response to health risks are greatly enhanced by reliable information on the health needs of the population and the rehabilitation needs of health, water and sanitation systems damaged by floods. Good baseline data, for example, is a prerequisite for accurate disease surveillance during floods and needs assessment. However, the ideal of high-quality data has to be considered in context: there may be a trade-off between optimization of the accuracy of data gathering and the need to provide a timely response to health impacts. A related issue is the need for communication of information to the public in a meaningful and accessible manner. Social differentiation in perception of risks and cultural barriers to effective coping and take-up of interventions, highlight the need for health promotion and flood warning activity to be tailored to local social contexts.

Advance planning is key for successful health education, warning and evacuation, emergency health care provision, infrastructure protection and other aspects of health-related response to floods. At the same time, a planned approach to health-related response needs a degree of flexibility, to ensure that actions are tailored to local circumstances and needs, and to promote institutional learning from positive experiences and external examples of good practice. Efficient response to health risks from flooding also rests on effective coordination between sectors and agencies, and on effective linkage between scales of responsibility, including the relations of trust and accountability between local public agencies and communities subject to flooding.

Effective response requires considerable commitment to preparedness and risk reduction, both in time and financial support. Agencies from flood-prone areas need a long-term commitment to put strategies in place and ensure they are capable of functioning when emergencies arise. External agencies need to provide a presence beyond the immediate flood relief phase, preferably with a long-term commitment to capacity building and broad-based community involvement in intervention projects. For the South, in particular, health risk reduction from floods may require an increase and/or a shift in emphasis in external funding assistance.

The global knowledge gap on health responses to flooding remains wide, and the review indicates many issues and considerations that would benefit from greater research attention. In a

technical sense, there is a need to evaluate the effectiveness of existing and new health protection, health promotion and system preparedness measures used in flood-prone locations. It is important also to analyse responses to 'non-emergency' floods as well as to extreme events. In parallel, social science approaches can help strengthen our understanding of processes of response by people and institutions to the health impacts of flooding. That means analysing perceptions of health risk and coping strategies of affected populations and organisations, and the economic, social, cultural and political constraints and opportunities that shape capacity to adapt.

It is also recommended that research efforts should: be undertaken jointly on health impact and response, should aim to integrate findings from different spatial scales, and should inform and be informed by more generic aspects of health risk and hazards.

Vulnerability and adaptation in a changing climate

The final section of the report interprets the findings in terms of vulnerability, coping and adaptation to health risks from flooding, and sets them in the context of potential changes in future flood hazards as a result of climate change. Chapter 5 discusses a series of key points and related questions, grouped under four themes: health impacts and vulnerability; coping capacity; climate change and future risk; and adaptation processes and policies.

The major direct and indirect health burden caused by floods is widely acknowledged, but poorly characterised and too often omitted from formal analyses of flood impacts. A major distinction exists between the health burden of floods in the North and South, linked crucially to capacities within society to protect populations from flood hazard and health risks, and to provide health care services. However, this gross distinction hides important differences between regions and countries. Differences in vulnerability are also critical at the micro-scale, shaped both by differences in people's behaviour, material assets, wellbeing and access to health care, and by wider social, economic, cultural and political processes.

Diverse coping mechanisms exist in relation to flooding and health risk at a range of scales, and yet there has been little systematic research work gauging their effectiveness. It is evident, however, that there are major limitations to the application of preparedness measures for health risk reduction, many linked with issues of information and communication, organisation, funding and the mainstreaming of flood response into strategic planning.

The potential for climate change to intensify or alter flood patterns means that it is likely to become a major additional driver of future health risk from flooding. Though predictive uncertainties and timescale issues may remain an impediment to adaptive action, many such actions are also likely to provide immediate health benefits for flood-prone populations. The climate change threat heightens the need for research, both for assessment of future health burdens and for improved analysis of current and future options for health-related response. Important insights may be gained from analyses in areas currently experiencing major shifts in flooding incidence as a result of other drivers of change.

Adaptation to the increased risk posed by climate change requires a further shift of emphasis toward flood preparedness, away from an emphasis on emergency health response. For the South in particular, improvement in general health practices and infrastructure can play a vital role in reducing the specific risk from flooding: if the climate change threat were to galvanise significant improvement in health systems and related services, it could therefore be seen as a 'win-win' solution. More effort is needed to identify and communicate actions and strategies at different scales that work effectively, and adapt them to meet the needs of other contexts and regions. This may become especially important for any areas newly exposed to flood risk. Ultimately, commitment to implementing best practice in flood health risk response is likely to rest on political will, innovation in response to floods, and targeted financial support.

FLOODS, HEALTH AND CLIMATE CHANGE: A STRATEGIC REVIEW

CHAPTER 1 INTRODUCTION

The threat of changes in the pattern and intensity of hydrometeorological hazards has served to highlight how little we yet know of their implications for human health. It is not just that predicting future health challenges is difficult, but that, until recently, there has been a paucity of systematic work analysing the risk already posed by present-day hazards.

Flooding is already one of the most widespread of hydrometeorological hazards, and the Intergovernmental Panel on Climate Change (IPCC) predicts that climate change is likely to cause an increase in flood hazards in many areas of the world (McCarthy *et al.*, 2001). Floods pose risks to health, and emerging evidence from industrialised, transitional and developing countries suggests that their health impact penetrates far deeper than the immediate physical threat from floodwaters. Flooding can increase exposure to toxins and pathogens, may have implications for mental health, and can disrupt the capacity of health care systems to respond to health crises (see, for example, McMichael *et al.*, 2001; WHO, 2002).

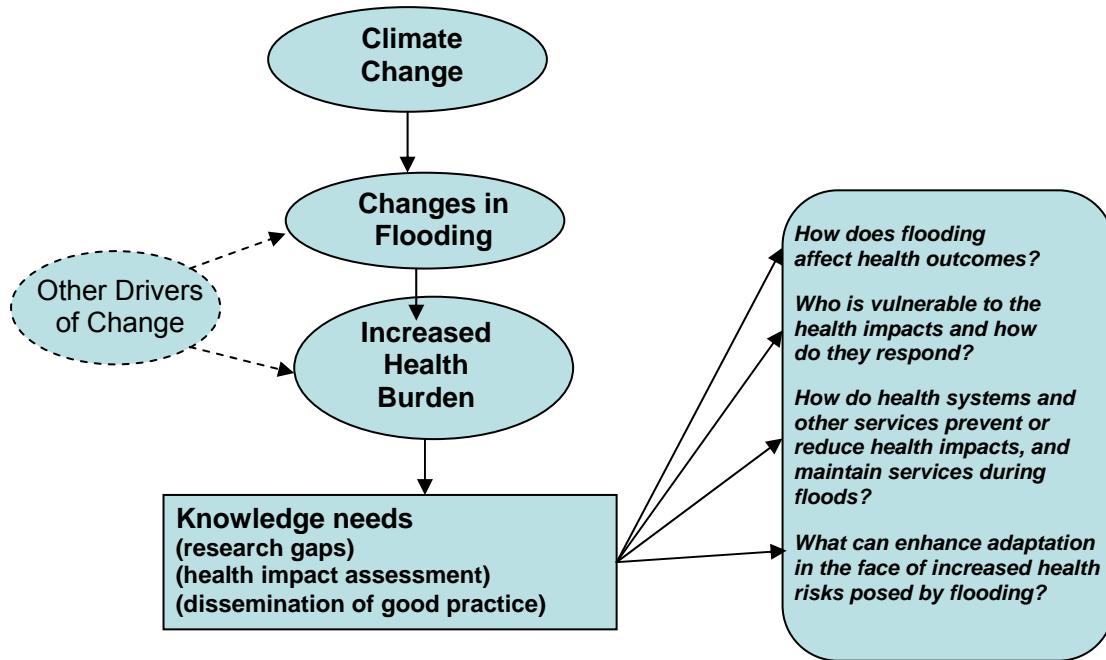
However, to date there has been relatively little scientific research characterizing the health outcomes of flood hazards and, similarly, little social science research targeting how vulnerable populations and health care systems respond and adapt to the health risks (Few, 2003). As well as improved understanding of the impacts of flood hazards on health, there is a need to focus on how people and institutions respond to health risks. How, for example, does a health system cope with the simultaneous pressures from flood-related morbidity and flood-related disruption of the system itself?

Figure 1.1 depicts the underlying rationale for the review work documented in this report. If climate change acts as a driver of change in flooding, then the future health burden from floods may significantly alter. It is therefore important that existing information is assessed now so that global knowledge gaps can be strategically addressed. Armed with this improved knowledge base, it may be hoped that society will become better able to anticipate and respond to the health threats posed by any intensification of future flooding hazards.

1.1 OBJECTIVES

A strategic approach to taking the knowledge base forward first requires a global review of the scientific and social studies that do currently exist relating to flooding, health and climate change. This document presents the results of a research project undertaken by the authors to assess and analyse the current state of knowledge.

Figure 1 .1 Rationale for the project



The objectives of the report are:

- 1) To present findings from a wide-ranging review of global literature on health impacts, adaptation processes and policies relating to flood risk.
- 2) To make a critical assessment of the existing knowledge base and identify key opportunities and challenges for intervention and research.
- 3) To assess the implications of climate change and future flood risk for health impacts, adaptation processes and policies.

The review combines two distinct disciplinary approaches. Health impacts are addressed primarily through an epidemiological review, assessing the quality of the existing evidence base for health outcomes of flooding and analysing trends in the findings. Mechanisms of response to health risks from floods are addressed via a more discursive review of literature, in which the intention is not to provide an 'inventory' of specific health-related responses but to highlight key practical and policy issues that arise in processes of response and adaptation.

To date there has been no global systematic integration of epidemiological, social and institutional studies that have addressed climate change adaptation in relation to human population health. This study therefore serves a dual purpose: taking stock of research and intervention needs in the critical field of flood risk and health; and providing the first strategic assessment of behavioural and public policy adaptation to potential health impacts of climate change. In doing so, it frames health not merely as a medical or technical matter, but, crucially, also as a social, cultural, economic and political issue.

The overall scope of the review is as follows:

- It is concerned with flood events in general: covering a variety of scales, intensities, speeds of onset and types (including riverine floods, flash floods and tidal waves) *See chapter 2 for further explanation.*
- The geographical scope of the review is global – we have attempted to bring together information from all regions of the world, for synthesis and for comparison.
- The review concentrates on literature produced over the last 30 years, although some key studies from an earlier date are also included.
- The time frame for the assessment takes into account potential climate change over the next 100 years.
- The review examines a range of health risks connected with flooding including drowning, injury, stress, communicable disease, illness from exposure to pollution, and damage to health infrastructure and water/sanitation facilities.
- It examines responses to health risks at different scales (from households to international intervention) and at different stages in the hazard cycle (before, during and after the hazard event).

In order to maximise the added value of this review, the authors have concentrated thematically on studies of health impacts and adaptation processes specific to flooding rather than to hazard or disaster events in general. We are mainly interested here in documenting response to the specific health problems that arise for populations living within or near a flooded environment. It was decided therefore not to focus on the health issues caused by displacement of populations to non-flooded refuges, since these issues tend to be of a generic nature common to all disastrous forms of hazard. Similarly, the study does not look at how economic losses to households from floods might then lead to increased health burden. We have also decided not to focus on studies relating to the disruption by flooding of food supplies, partly because these issues are again largely generic, but also because we feel there is a fairly robust body of literature already in existence on this topic. Nevertheless we do take note of the critical importance for health and wellbeing of malnutrition that may result from flood impacts on food supply systems.

1.2 PREVIOUS REVIEWS

To the best of our knowledge, this review represents the first detailed global assessment of health risks and responses relating to flooding. However, there have been a number of other works that have taken a less detailed or regionally-specific approach.

The closest forerunner to this project in terms of thematic approach has been work on flooding in Europe under the project Climate Change and Adaptation Strategies for Human Health (cCASHh). Outputs from this work - a review paper by Hajat *et al.* (2003)

and a workshop report (WHO, 2002) - analyse health risk and adaptation to floods in Europe, emphasizing the need for a stronger epidemiological information base, and a better understanding of vulnerability factors, particularly in the context of potential increased flooding under climate change (see Box 1.1).

Box 1.1 cCASHh project work on flood and health in Europe

A review of the health impacts of flooding was undertaken as part of the European Commission-funded project Climate Change and Adaptation Strategies for Human Health (cCASHh) (EVK2-2000-00070). Specifically, this work aimed to:

- ◆ Review the public health literature on the impacts of floods on human health in Europe
- ◆ Explore climate change projections of the risk of floods, and understand the possible consequences for human health
- ◆ Assess strategies to adapt to or prevent these consequences in order to reduce the health risks.

Analysis of the published literature indicates that the main health effects are drowning, injuries, and (perhaps most importantly in Europe) a long term increase in common mental disorders (Hajat *et al.* 2003). There is some evidence that common mental disorders (anxiety and depression) may last for more than six months after the flood event. Flood-related increases in communicable diseases appear relatively infrequent in Europe. A lack of co-ordinated monitoring of injuries related to flooding, including from clean up activities, meant that it was difficult to assess the true burden of ill health due to flood events.

A review of the role of health agencies in emergency planning found largely negative results, in that, any activities developed to address health impact were largely ad hoc and unreported and unevaluated. The World Health Organisation (WHO) and the London School of Hygiene and Tropical Medicine organized a workshop in 2002 to identify adaptation priorities associated with floods in the WHO European Region. The participants recommended that:

- emphasis be shifted from disaster response to risk management, including the improvement of flood forecasting and warning systems, the addition of health protection as a goal, and consideration of how climate change may increase or decrease flood hazards;
- environmental impact assessments include health risks from flooding as an issue;
- assessments be made of communities' capacity to respond to and manage flooding and its effects on health;
- governments support monitoring of and research on the health impact of all categories of flooding;
- coordination be promoted among disciplines, policy-makers and international organizations.

Malilay (1997) provides a book chapter on the public health consequences of floods, looking at factors influencing mortality and morbidity, largely in an industrialised country setting (primarily the USA). A paper by Brunet (undated) provides a parallel review on public health dimensions of flooding in developing countries. Jonkman (*in press*) combines attention to North and South in a focus on loss of life in floods, while Mooij (2002) highlights aspects of preparedness and mitigation. A range of other publications and reports provide a contextual overview of literature in connection with studies of specific flood events. However, none provides the level of detail assembled in this review.

In the climate change literature, flooding is considered an important mechanism through which climate change will affect human health, and is addressed in assessments from the Intergovernmental Panel on Climate Change (IPCC) and World Health Organisation (WHO). The health consequences of future flood risk have also been discussed at a country-specific level, for example in national assessments by the UK government (Department of Health, 2001).

1.3 REVIEW PROCESS

The hallmark of this review has been an attempt to identify, assemble and analyse as much as possible of the existing literature from around the world that relates to flooding health risks and responses. That search has by no means been confined to conventional academic sources – on the response side in particular, the documents surveyed include a variety of ‘grey’ literature. Categories of literature drawn on in this review include:

- academic studies and peer-reviewed literature;
- studies and reports by governmental, non-governmental and international organisations;
- newsletters and website texts.

In order to identify documents, the team invested at least one third of project time in undertaking formal literature searches, checking publication/document lists of organisations and consulting with key individuals. Sources for the references surveyed include:

1. Bibliographic databases
2. Websites
3. Contact with lead agencies
3. Contact with experts in the field
4. Hand search of relevant journals and conference proceedings
5. Search of the reference lists of relevant reviews, books and articles
7. Contact with the authors of relevant papers
8. Use of the citation analysis facility of the Web of Science, Science Citation Index (SCI) and Social Science Citation Index (SSCI)

A formal search strategy was developed for the bibliographic databases, with a standardised set of search terms. Results of the database searches were collated in Endnote, duplicates were removed, and then titles and abstracts were scrutinized for relevance. At the end of this filtering process a list of articles was identified for acquisition through libraries, electronic sources and direct contact with authors.

In total, the project team surveyed over 450 academic and non-academic documents relating both to flooding and health. Not all provided material of sufficient importance to be cited in this review, but a full database of references will be collated and made available in the final stages of this project.

We have attempted to be as comprehensive in our document search and acquisition as was feasible with the resources at our disposal. The result has been a major undertaking, and one that we are confident has captured most of the issues concerned

with health and flood risk. Nevertheless we recognise limitations to the scope of what we have achieved and cannot claim to have scrutinized all available document sources. For example, we have not been able to search systematically through governmental and non-governmental grey literature produced in all flood-prone countries. We also recognise that the review has concentrated mainly on English language documents and omits important contributions in other languages, particularly by hazard experts in Latin America.

1.4 STRUCTURE OF THE REPORT

The remainder of this report consists of four parts. Chapter 2 provides an initial contextual overview of flood risk, climate change impacts and a range of generic issues associated with flooding vulnerability, risk reduction and hazard response. Chapter 3 then presents a review and analysis of current understandings of the health impacts of flood, drawing predominantly on epidemiological studies. Chapter 4 then examines the available literature on response and adaptation to those health impacts – by households, communities, health and environmental health systems, and external agencies. This analysis of process and policy draws on a multi-disciplinary and multi-sectoral body of work. Chapter 5 then summarizes the key findings on vulnerability and response to health risks from the foregoing reviews and discusses their implications for adaptation to future flood threats arising from climate change.

CHAPTER 2

GLOBAL FLOOD RISK AND RESPONSE

Flooding is one of the most frequent and widespread of all environmental hazards. Floods of various types and magnitudes occur in most terrestrial portions of the globe, causing huge annual losses in terms of damage and disruption to economic livelihoods, businesses, infrastructure, services and public health. Long term data on natural disasters suggest that floods and wind storms (which frequently lead to flooding) have been by far the most common causes of natural disaster worldwide over the past 100 years. According to the International Federation of Red Cross and Red Crescent Societies, in the 10 years from 1993 to 2002 flood disasters ‘affected more people across the globe (140 million per year on average) than all the other natural or technological disasters put together’ (IFRC, 2003, p179). This chapter provides a contextual summary of the nature of flood hazard now and in future, a conceptual background to the analysis of flood risk and response, and an overview of some generic issues relating to flood risk reduction.

2.1 FLOODS AND FLOOD HAZARDS

As Parker (2000) discusses in detail, floods can take many forms and it is not easy to pin down a precise definition for the term. Broadly-speaking, however, a flood refers to an excess accumulation of water across a land surface: an event whereby water rises or flows over land *not normally submerged*. It is the ‘abnormality’ of floods that is key, and that helps to explain why the phenomena can have such a severe impact on humans and human systems.

Floods across the globe have many different causes and characteristics (see, for example, Dolcemascolo, 2004; Few, 2003; Malilay, 1997). Drawing on Parker (2000). Table 2.1 provides a simplified typology of flood causes and associated flood types.

Table 2.1 Causes of floods

<i>Cause</i>	<i>Examples of flood types</i>
High Rainfall	Slow-onset riverine flood Flash flood (rapid onset) Sewer/urban drain flood
Tidal and wave extremes	Storm surge Tsunami
Thawing of Ice	Jökulhlaup Snowmelt
Structural failure	Dam-break flood Breaching of sea defences

The leading cause of floods is heavy rainfall of long duration or of high intensity, creating high runoff in rivers or a build-up of surface water in areas of low relief. Rainfall over long periods may produce a gradual but persistent rise in river levels that causes rivers to inundate surrounding land for days or weeks at a time. In August 2002, for example, intense rainfall of long duration induced extreme flooding spanning five countries of central and Eastern Europe (Caspary, 2004). Intense rain from storms and cyclones, on the other hand, may produce rapid runoff and sudden but severe flash floods across river valleys. The flooding from these events is typically more confined geographically and persists for shorter periods, but the violence of the event can be highly damaging and dangerous. Intense rain can also cause standing water to develop in urban areas when the capacity of storm drain systems is exceeded.

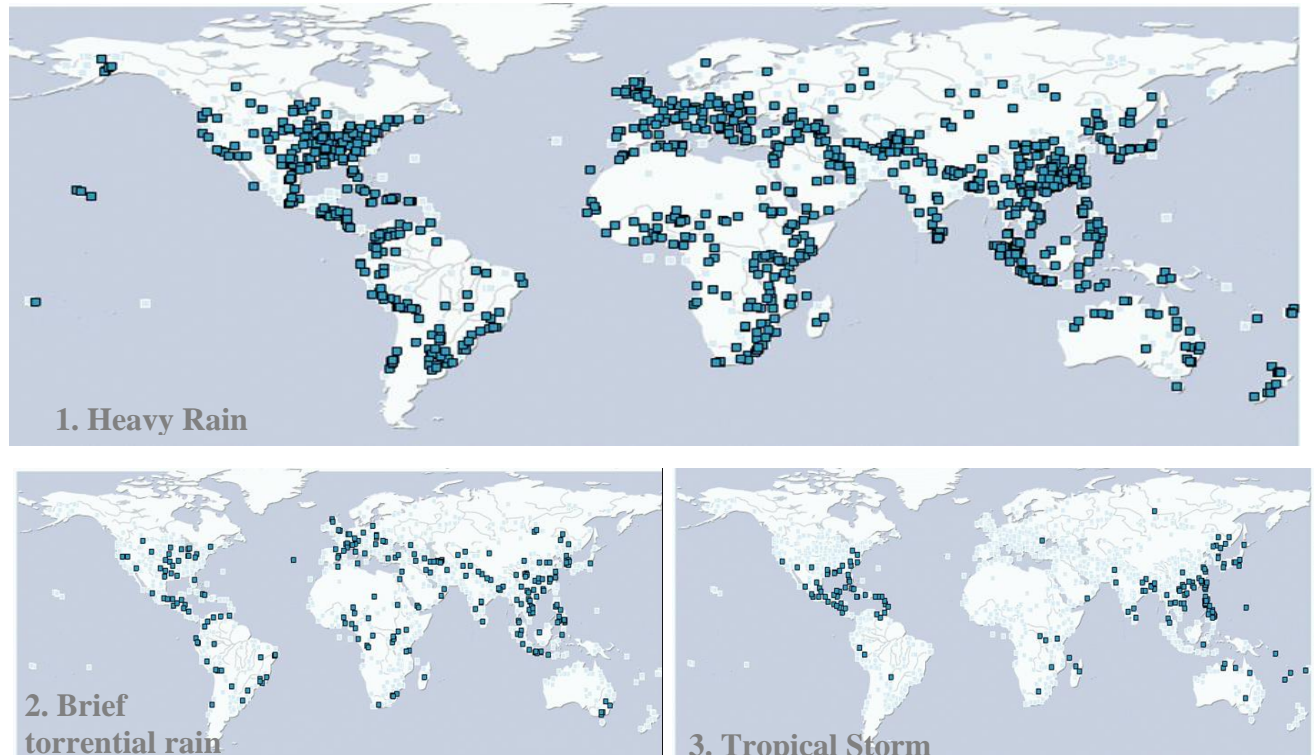
Coastal areas may face an added threat from the proximity of the sea. Tidal and wave extremes are the second major cause of floods, bringing seawater across land above the normal high tide level. Cyclonic storms may create a dangerous 'storm surge' in which low atmospheric pressure causes the sea to rise and strong winds forces water and waves up against the shore. It is important also to note that flood causes may combine. For example, winter storms in the UK may produce simultaneous inland flooding and storm surges that doubly afflict areas adjacent to river mouths.

Flood events vary greatly in magnitude, timing and impact. Handmer *et al.* (1999, p126) note that the term flooding can cover 'a continuum of events from the barely noticeable through to catastrophes of diluvian proportions'. There are a number of measurable characteristics through which events can be differentiated, including flood *depth*, *velocity* of flow, *spatial extent*, *content*, *speed of onset*, *duration* and *seasonality* (Few, 2003; Parker 2000). Floods may vary in depth from a few centimetres to several metres. They may be stationary or flow at high velocity. They may be confined to narrow valleys or spread across broad plains. They may contain sewage and pollutants, debris or such quantities of sediment that they are better termed mudflows. They may be slow to build up or rapid in onset as in flash floods. They may last from less than an hour to several months.

Floods may also be associated with regular climatic seasons such as monsoon rains and other annual heavy rainfall periods. In some locations, such as the major floodplains of Bangladesh, extensive flooding from seasonal rains is a normal, annual occurrence to which human lifestyles and livelihoods are largely pre-adapted (though such predictable flooding may still have health implications). However, seasonal flood levels vary from year to year, and such areas tend to be subject to occasional flood events that exceed the normal range of expectation. In 1998, Bangladesh experienced flooding of an unprecedented magnitude (depth and duration), surpassing the previous record flood that occurred in 1988 (Nishat *et al.*, 2000).

Figure 2.1 shows the spatial distribution of 'extreme' floods from three different causes listed by the Dartmouth Flood Observatory since 1985. Severe floods from high rainfall (of long or short duration) have occurred in almost the humid regions of the world, as well as some semi-arid zones. Tropical storms (known as hurricanes, cyclones or typhoons) are more concentrated in distribution, with hotspots around the western Pacific coasts, the Caribbean and south-eastern USA, and the Bay of Bengal.

Figure 2.1 Causes of extreme floods since 1985



(Source : NASA-supported Dartmouth Flood Observatory)

River and coastal defence engineers distinguish flood events using a statistical flood frequency measure, which uses historic data to define the probability of occurrence of a flood event of a given magnitude (Parker, 2000). Hence a '100-year flood' refers to an event of a size likely to occur once in every hundred years, while a '1-year flood' might be expected annually. However, the physical parameters of a flood are not always effectively measured and are not necessarily reliable indicators of its impacts. Differing perceptions of and terminology for flood severity make it difficult to develop a standardised categorisation of floods, and no such detailed categorisation is attempted in this paper. In any case, categorising by flood magnitude can be misleading when considering severity of impacts since the same flood may differ in its effect at even an inter-household scale (Wisner *et al.*, 2004).

The consequences of flooding are by no means solely negative. Seasonal river floods, in particular, play a crucial role in supporting ecosystems, renewing soil fertility in cultivated floodplains (Wisner *et al.*, 2004). In regions such as the floodplains of Bangladesh, a 'normal' level of seasonal flooding is therefore regarded as positive: it is only when a flood reaches an abnormal level that it is perceived negatively as a damaging event (Parker, 2000).

It is this latter sense in which we use the term '*flood hazard*' in this paper, meaning a flood event with the potential to cause harm to humans or human systems. Flood hazards may of course have varying degrees of impact, from minor or small-scale damage to damage of catastrophic proportions. This paper is concerned with all scales of

impact, because all forms of flooding can pose health risks. However, in public perception at least, it is flood ‘disasters’ that tend to be of special concern.

2.1.1 Flood disasters

The definition of what constitutes a disaster is another contentious issue, but in its most basic sense it is used to describe an event that brings widespread losses and disruption to a community. Some definitions include the notion that it exceeds the ability of that community to cope using its own resources (ISDR, 2002; Parker, 2000). A number of studies and reports discussed in this paper refer to flood disasters of different scales, and statistics on flood disaster provide a useful indicator for global flood risk.

The Centre for Research on the Epidemiology of Disasters (CRED) manages a global database on disaster impacts. CRED classifies an event as a disaster if at least one of the following has occurred: 10 or more people killed; 100 or more people reported affected; a call for international assistance; and/or a declaration of a state of emergency. According to their disaster data, floods come second only to drought/famine in recent years in causing direct mortality (as defined), and account for more than half of all people ‘affected’ by natural disasters. Since ‘people affected are those requiring immediate assistance during a period of emergency, i.e., requiring basic survival needs such as food, water, shelter, sanitation and medical assistance’ (IFRC, 2003, p180), this measure provides an indication of the scale of health impact associated with flooding.

Though they have a number of limitations regarding the quality of information (see Chapter 3), disaster statistics also provide some indication of the geography of flood risk to human populations. Tables 2.2 and 2.3 compare flood and wind storm disaster statistics for different continents using the EM-DAT data from CRED (many of the deaths attributed to wind storms are flood-related). From the tables, it is clear that flood disasters and their mortality impacts are heavily skewed toward Asia, where there are high population concentrations in floodplains of major rivers, such as the Ganges-Brahmaputra, Mekong and Yangtze basins, and in cyclone-prone coastal regions such as around the Bay of Bengal and the South China Sea. Closer analysis of the statistics suggests that developing countries in general bear a disproportionate toll – with industrialised or ‘high human development’ countries accounting for just 0.4% and 3.7% respectively of people affected by floods and windstorms (see section 2.3).

Table 1.2 Flood disasters by continent 1993-2002

<i>Continent</i>	<i>Reported disasters</i>	<i>People reported killed</i>	<i>People affected reported</i>
Africa	238	9,642	19,939
Americas	239	35,236	9,730
Asia	385	47,009	1,364,957
Europe	187	1,654	6,700
Oceania	26	20	147

Source: EM-DAT, CRED, University of Louvain, Belgium

Table 2.2 Windstorm disasters by continent 1993-2002

<i>Continent</i>	<i>Reported disasters</i>	<i>People reported killed</i>	<i>People affected reported</i>
Africa	63	1,335	5,687
Americas	285	23,703	18,117
Asia	328	34,923	277,780
Europe	90	739	6,655
Oceania	57	271	4,306

Source: EM-DAT, CRED, University of Louvain, Belgium

2.1.2 Recent trends in flood frequency

Flooding and its impacts not only vary across space but also across time. One component of this variation is simply year to year short-term change in the incidence of floods caused by variability in climate. A major periodic influence on this variability is the cyclical climatic phenomenon known as El Niño - Southern Oscillation (ENSO), which may produce large-scale shifts in storm tracks and dramatic changes in rainfall patterns and flood risk (Kovats *et al.*, 2003a). The second component, of key interest to this review, is long-term change associated with significant shifts in flood trends over multiple decades. It is important to consider the evidence for recent global flood trends and to address the notion that the incidence of flooding may already be increasing as a result of anthropogenic forcing, through alteration of greenhouse gas levels in the atmosphere leading to climate change.

To date, the evidence for recent upward trend in global flooding remains inconclusive, with no strong consensus emerging from the different global and regional studies. Robson (2002) argues that no clear long-term evidence has emerged of an increased global flood trend during the last century. Milly *et al.* (2002) report that the frequency of great floods – floods at 1/100 year levels – increased during the 20th century for large rivers in high-latitude regions of North America and Eurasia. Yet they found no evidence for an upward trend in floods of lesser magnitude. Frei (2003) explains that, though there may appear to have been an accumulation of high-magnitude floods events over the last decade in Europe; it is difficult to confirm statistically whether this constitutes a genuine trend because of the small number of actual events being considered. Rather, it is preferable to analyse lower-order ‘intense’ events that are more common and therefore make it easier to detect a trend signal out of the background ‘noise’ of random variation. In this case, for Europe, there does appear to have been a significant trend toward increased intense winter rainfall events over much of the continent in the last five decades. However, it remains unclear whether this change is related to climate change (Frei, 2003).

One of the problems of attributing a causal link between flood trends and climate change is that flood dynamics may have multiple drivers. The incidence of flooding is strongly affected by a range of environmental changes (Bronstert, 2003; Woodworth *et al.*, *in*

press). Alterations in land cover and urbanization influence the water absorption characteristics of land surfaces, in many cases increasing runoff rates and thereby exacerbating flooding from high rainfall. Loss of wetlands that can act as a buffer against tidal floods may heighten coastal flood risk. Though these changes take place at a local scale, they can combine to form cumulative trends in land use change that might be associated with trends in flood events at a regional or global scale. Human vulnerability to floods is additionally affected by other drivers of change, including population growth and settlement pattern (see Chapter 5). A final complicating matter to add to the uncertainty over present flood trends is the possibility that changes in the reporting and categorisation of flood events may influence the pattern of statistics. As Jonkman (*in press*) discusses, these include cumulative improvements in data collection on disasters over recent decades

2.2 FUTURE CLIMATE CHANGE AND FLOODING

Though information on recent flood trends is inconclusive, global trends in sea level and temperature now provide strong evidence of a climate change signature. The weight of international scientific opinion has swung decisively toward the perspective that a process of anthropogenically-forced global climate change is now under way, over and above normal background climatic variability. The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) draws on a series of modelling approaches to estimate how climatic parameters might change in future and set out a range of potential impacts resulting from these changes. The magnitude of change depends partly on whether society succeeds in reducing greenhouse gas emissions. Yet, even with strenuous efforts in climate change mitigation, some climate impacts are inevitable. Over the next 100 years, yearly average near-surface temperatures across the globe are predicted to rise by between 1.4°C and 5.8°C, causing an increase in flood hazard in some areas because of sea level rise, changes in seasonal precipitation or the pattern of wind storms (Houghton *et al.* 2001; McCarthy *et al.*, 2001).

Because of future uncertainties over greenhouse gas emissions and the complexity of hydrometeorological processes, however, confident prediction of the scale of flooding changes in specific geographical regions remains an elusive goal. The predictive picture also becomes obscured by the potential effect of other environmental changes that may exacerbate or counteract climate-induced changes, such as land use alterations, deforestation and mangrove clearance, construction of coastal defences and river channel engineering (Bronstert, 2003; Woodworth *et al.*, *in press*). For extreme events of low probability but high consequence the challenges for quantification and prediction are especially great (Goodess *et al.*, 2003).

2.2.1. Inland flooding

As Milly *et al.* (2002) state, the intensification of the global water cycle expected under climate change is likely to lead to an increased threat of riverine flooding from high rainfall over catchments. This may result in changes to several aspects of a river basin's flood regime, including changes in timing, magnitude, frequency, spatial extent and temporal duration of floods (Mirza, 2002). There may also be alterations in the timing of peak flows and the synchronicity of peaks from different tributaries of large river basins. Moving from such generalised statements to predictions for specific rivers presents a

major challenge, partly because of the coarse spatial scale (with grid sizes of hundreds of kilometres) on which most general atmosphere-ocean circulation models (GCMs) run, although advances are being made in downscaling models to a finer resolution for individual regions (Hunt, 2002). For all but the biggest river basins, grid sizes of 10km or so may be needed to give accurate simulation of precipitation and river flows, and predicting extreme flood events is yet more difficult because of their inherent rarity (Bronstert, 2003, Palmer and Rälsänen, 2002). The high uncertainty surrounding future storm patterns and extreme weather events means that future flooding can be considered a potential threat for virtually any region.

As already noted, despite recent upward trends in high river flows in some locations, it is not yet clear whether a climate change signature can be detected in present-day global flooding statistics. However, warming of the climate in the next 50-100 years is widely expected to lead to changes in rainfall and flood risk in all continents. The major problem is pinpointing exactly where levels will increase or decrease. Results from a series of different climate models analysed by Arnell (2004, p36) point toward reduced annual runoff from precipitation in 'much of Europe, the Middle East, southern Africa, North America and most of South America' and increased annual runoff in 'high latitude North America and Siberia, eastern Africa, parts of arid Saharan Africa and Australia, and south and east Asia'. Rising trends may be especially apparent in areas of maritime climate, monsoon regions and zones where precipitation is strongly associated with tropical cyclones (Hunt, 2002). Seasonality of rainfall can, however, be masked by annual totals. Predictions by Palmer and Rälsänen (2002) for northern Europe, for example, suggest that high rainfall winters (with precipitation two standard deviations above normal) will become 3-5 times more frequent than at present.

Making the link between increased rainfall and flooding is not necessarily straightforward, because the flood outcome will depend also on other river basin and flow regime characteristics. However, some authors have explicitly addressed future flood risk. Interestingly, Christensen and Christensen (2003) and Mudelsee *et al.* (2003) predict a greater frequency of flooding in summer within Europe. A major recent report for the UK produced by the 'Foresight Future Flooding' project envisages a 2-4 fold increase in inland flood risk across the country by the 2080s (Evans *et al.*, 2004). If the connection between rainfall and flooding is strong, the predictions from GCMs are particularly worrying for South Asia, already the world's leading flood-prone region. The work by Palmer and Rälsänen (2002) predicts an increase of 3-7 times in the probability of high monsoon precipitation in the next 100 years, producing increases in peak discharges of the region's major rivers. The highest rainfall increases are in the upper basin of the Brahmaputra. The study by Mirza (2002) also suggests that the predicted discharge from the Brahmaputra river is especially sensitive to mean temperature rise, with major implications for future flooding in Bangladesh.

2.2.2. Coastal floods

Rising sea level is likely to lead to an increase in flood events experienced by coastal populations (Kabat and van Schaik, 2003). This is especially likely to be the case in low-lying coastal sites, as a prelude to their eventual permanent inundation and abandonment (Nicholls, 2002). But it is not only rise in mean sea level that may heighten the risk of sea floods: the more complex effects of climate change may also bring changes in storm conditions (increasing storm surges), tide patterns and wave heights (Woodworth *et al.*, *in press*). Moreover, sea level rise may not only exacerbate the effect

of increased storm surges but also pond back the outflow from rivers during peak discharges – it has been estimated that a sea level rise of 90cm would raise flood heights in the Mekong River, Vietnam, up to 400km inland (Nicholls *et al.*, 1995).

Sea level rise has already been observed during the past century and GCMs robustly predict that global mean sea level will continue to rise over the next 100 years. The TAR estimates a rise of 9-88cm, depending on the level of future greenhouse gas emissions (Church *et al.*, 2001). In addition to this, different regions may experience further relative sea level rise owing to land subsidence and regional oceanic changes (Woodworth *et al.*, *in press*). Any increase in the frequency and magnitude of offshore wind storms will further increase the risk of floods, although, as noted, predicting the future geography of storm events is extremely problematic.

Nicholls (2004) reports on modelling work that combines sea level rise predictions with different sets of assumptions about the implications of future global political, economic, social and technical developments – the so-called ‘SRES storylines’. The model predicts that in 1990 approximately 10 million people per year worldwide experienced coastal flooding arising from storm surges. By the 2080s, depending on the SRES scenario adopted, the model calculates that between 2 million and 50 million additional people per year will experience flooding. The model generally assumes that coastal flood defence measures would be improved during this period. In an earlier paper, the same author suggests that if no measures are taken to adapt to sea level rise, the worst case scenario could see nearly 40 times more people per year affected by sea floods by 2100 (Nicholls, 2002).

Regionally, the global pattern of coastal flooding impact on human populations will relate not just to coastal topography but also to the number of people potentially exposed to storm surges. Nicholls *et al.* (1999) argue that the greatest increase in vulnerability to sea level changes lies in the coastal strips of South and South-east Asia, and the urbanised coastal lowlands around the African continent. All have high concentrations of relatively unprotected people living in low-lying (and sometimes cyclone-prone) coastal locations. In addition, though they hold relatively small populations, many of the small island states of the Caribbean, Indian Ocean and Pacific Ocean are under especially severe threat from sea level rise and tropical cyclones (Woodworth *et al.*, *in press*). A recent report by the World Bank draws attention to the potential vulnerability of major urban agglomerations concentrated in coastal areas of both North and South (Kreimer *et al.*, 2003).

2.2.3. What can we conclude about future flood risk resulting from climate change?

All in all, though major limitations remain in our ability to make robust projections of future rates of climate change and its effects, increasing predictive evidence of heightened global risk of inland and coastal flooding is emerging. It is perhaps premature and misleading to attempt to produce a future flood risk map, but it is apparent that some areas at least are highly likely to experience more intense or frequent flood events over the next 100 years – many of these are humid areas that already experience high rainfall/flood events or low-lying coastal sites that are now prone to tidal inundation (as depicted in Figure 2.1).

We contend that it is also prudent to assume that the changes may not only mean just 'more of the same'. There might not be evidence from the low-resolution GCMs of coarse regional changes in flood distribution, but we cannot take that assumption too far. It does not preclude the possibility of there being significant geographical changes in flood distribution at a smaller scale – areas not previously affected by flooding that may become newly afflicted as a result of climate change. Lack of experience could then become a contributory factor toward vulnerability.

Finally, the increasing attention being given to the possibility of *rapid* or *catastrophic* climate change should be noted (Hulme, 2003). Though such changes are generally considered of low probability, their implications for future patterns of flood risk from high rainfall and windstorms could be highly significant.

2.3 RISK, VULNERABILITY, COPING, ADAPTATION

Galvanised in part by questions of societal adaptation to climate change impacts, there has been much recent theoretical work on hazard risk and related concepts of vulnerability and resilience (see e.g. Wisner *et al.*, 2004 for a recent review). Navigating through a series of competing terminologies from different academic disciplines is a complex undertaking, but Box 2.1 provides a list of working definitions for some of these concepts to indicate how they are being applied in this paper. It draws on, but also differs from, the conceptual definitions provided by the International Strategy for Disaster Reduction (ISDR, 2002).

Box 2.1 Working definitions of key concepts

Risk = the probability of harmful consequences to a human population resulting from flooding (a function of flood hazard and vulnerability).

Hazard = a flood event that has the potential to cause harm to humans or human systems.

Vulnerability = a set of conditions and processes that determine the susceptibility of humans or human systems to be adversely affected by a flood hazard.

Coping capacity = the ability of people/systems to avoid exposure to flood hazard and avoid, tolerate or recover from harm (the converse of vulnerability).

Adaptation = change in behaviour, resources, infrastructure of the functioning of a system that reduces vulnerability.

Flood risk is defined here in terms of risk to humans and human society, and is seen as a product of the severity and probability of occurrence of flood hazard and the vulnerability of the population/system (Brooks, 2003). Vulnerability is shaped by a combination of physical, social, economic and environmental factors - the attributes of the person/system that condition the impacts resulting from flooding. In the past, physical aspects of vulnerability - the spatial distribution of populations and infrastructure in relation to flood hazard - tended to receive more attention in hazards research (Hilhorst

and Bankoff, 2004). But there is now increasing recognition given to the social aspects of vulnerability. For individuals, susceptibility to hazards depends largely on behaviour, wellbeing and the resources people have to enable them to avoid and recover from harm. These, in turn, are largely determined by wider social, economic and political patterns and processes that differentiate how flooding impacts on people and human systems (Cannon, 2000, Wisner *et al.*, 2004). Analyses of vulnerability increasingly highlight its socially constructed nature (Cutter, 1996), underlining the importance of understanding how socio-political processes can create vulnerability and thereby create 'disaster' (Hilhorst and Bankoff, 2004; Pelling, 1999).

Wisner *et al.* (2004) develop an analytical model that shows how underlying causes rooted in inequality generate a progression of vulnerability that creates the unsafe conditions in which hazard events turn to disasters. This process of vulnerability creation operates at different scales. That the impact of flood disaster is so heavily skewed to developing countries is undoubtedly linked with disparities at the global level in resources available for risk reduction by governments and citizens. Equally, at the intra-community level, poverty and marginalization can create differential vulnerability, with the poor being both more susceptible and more exposed. Flood-prone marginal land in cities of the South often becomes the site of squatter settlements for the urban poor (Bernstein, 1992; McCluskey, 2001). But poverty and vulnerability are not one and the same: floods can reach the wealthy too. Indeed, inappropriate floodplain and coastal development can generate vulnerability in all countries (see e.g. Baxter *et al.*, 2001), affecting both rich and poor. It is also important to recognise that vulnerability is differentiated by social dimensions other than wealth. In both developing and industrialised nations, health and other impacts may fall disproportionately on women, children, people with disabilities and the elderly (Guha-Sapir 1993; Tapsell and Tunstall 2001; Twigg, 2004).

Because the term has negative connotations, a focus on vulnerability may run the risk of labelling, alienating and disempowering those it describes (Bankoff, 2001; Handmer 2003). The concept of *coping capacity*, though in essence the converse of vulnerability, emphasises instead the positive potential and actions of people and societies to combat the adverse effects of flooding. As such, it too depends on policies and actions at the systems level and on a range of assets at the local level, including the knowledge and capability to utilise coping mechanisms and strategies. At the local level, for example, people accustomed to living in flood-prone environments in the North and South may follow a range of actions designed to help them avoid and manage harm from floods, including creation of dykes, raised house construction, community food stores, livelihood diversification and reliance on social networks (Buckland and Rahman, 1999; Few 2003). Response to flood risk that involves a change in action or policy is referred to as *adaptation*, and the ability of people and systems to bring about such changes is referred to as adaptive capacity. As with coping capacity, adaptive capacity of people and systems is shaped by social, economic and political processes (Adger *et al.*, 2003).

Ideas relating to adaptation and adaptive capacity have come to particular prominence in the global literature on the future impacts of climate change. Drawing on concepts from broader hazards theorization emphasizing the positive aspects of human 'resilience', the Third Assessment Report of the IPCC argues that planned adaptation to climate change impacts has to be considered by society in tandem with actions to reduce greenhouse gas emissions (climate change mitigation). In this sense:

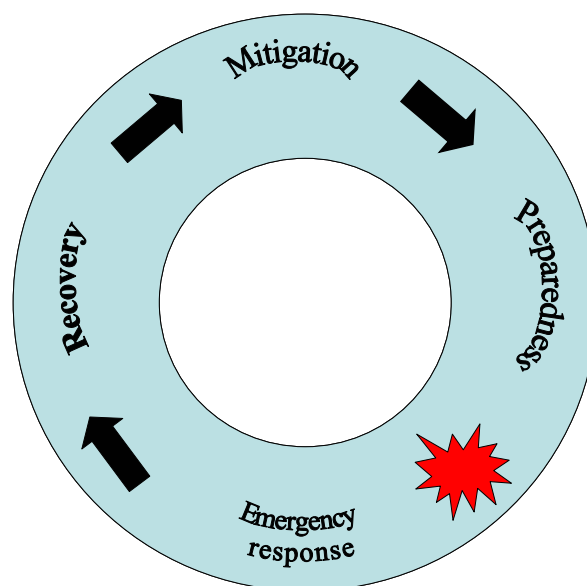
'Adaptation is adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate' (Smit *et al.*, 2001).

Coping mechanisms and future adaptive strategies that relate to health risk from floods form the prime interest of this document and are explored in detail in Chapters 4 and 5. The remainder of this section introduces broader, cross-sectoral aspects of flood hazard response.

2.4 GENERAL ASPECTS OF FLOOD HAZARD RESPONSE

Wisner *et al.* (2004) describe how hazard coping strategies may comprise preventive, impact-minimizing or post-event recovery strategies. These strategy options map on to the concept of a cycle of hazard events - a descriptive device that is influential in disaster management approaches (Wisner and Adams, 2002). Figure 2.2 depicts a simplified hazard/disaster management cycle, with stages before and after flood events relating to mitigation, preparedness, emergency response and recovery. The terms 'mitigation' and 'preparedness' are to some extent overlapping, but the former generally refers to actions in advance to limit the impact of hazards, while the latter denotes actions in advance to ensure effective response when impacts occur (ISDR, 2002). Emergency response includes coping actions by affected populations as well as relief interventions from external agencies. The recovery stage may include efforts in rehabilitation and reconstruction of services and infrastructure. (Note that the term 'mitigation' in relation to hazard has a distinct meaning from its use in relation to climate change policy, where 'mitigation' refers to the reduction of net greenhouse gas emissions).

Figure 2.2 Hazard/disaster management cycle



The last two decades have witnessed considerable rethinking on how society should approach the management of hazards. This process has, in part, been shaped by the inter-linkage between a series of international initiatives tackling disaster issues and wider concerns on global environment and development, including, recently, the International Strategy for Disaster Reduction, the World Summit on Sustainable Development, and the declaration of the Millennium Development Goals for poverty reduction (see Wisner *et al.*, 2004). In the past, flood response by governments and external agencies focussed largely on emergency relief efforts for affected populations and on 'structural' mitigation - attempts to prevent hazards through flood control engineering. Although structural mitigation measures such as dikes and tidal barriers will continue to play a major role in flood management, there is also a strong trend now toward advocating broader aspects of flooding preparedness and a less ready reliance on structural responses (Hajat *et al.*, 2003; Wisner *et al.*, 2004). Non-structural flood mitigation and preparedness options include appropriate land use planning, enforcement of building codes to avoid construction in flood prone sites, insurance schemes, and effective flood forecasting, warning and evacuation procedures (Parker, 1999). Given the threat of future climate change increases in flood intensity/frequency, and the generally prohibitive cost of local-scale structural defences, Christie and Hanlon (2001, pp151-152) stress the need for non-structural solutions in Mozambique, including clearly marked evacuation routes and better and clearer public warning systems.

Good practice in flood preparedness is widely seen to involve cross-sectoral coordination by public authorities, non-governmental organisations (NGOs) and external agencies in developing response plans at different scales that are in place before disaster strikes (Biswas *et al.*, 1999a; Hajat *et al.*, 2003, ISDR, 2002). According to IFRC (2002, p3), priority disaster preparedness activities include 'risk and vulnerability mapping, disaster awareness and education, early-warning and evacuation systems, stockpiling relief materials, training in response skills, and planning at all levels to ensure coordination of disaster response'.

In Latin America, the Red Cross has set up the Pan-American Disaster Response Unit (PADRU), based in Panama, to coordinate and strengthen capacity regionally and locally in disaster preparedness and response capability. It views the optimum scale of disaster preparedness organisation as dependent on the type of activity, with strategic relief stockpiles and international relief coordination best managed centrally, but search-and-rescue operations and evacuation procedures best organised at a local level (IFRC, 2002).

Linked with the idea of local management is the role of community participation in response to flood risks. Lambert *et al.*, (2003) advance ethical principles of open discourse on environmental health risks, arguing that communities have a right to be involved in understanding risks and in developing preventive responses. In a publication marking the close of the United Nations' International Decade for Disaster Reduction, Maskrey (1999) and Davis and Hall (1999) strongly emphasize greater community involvement in strengthening local coping capacities. As Lichterman (2000) and others demonstrate (see section 4.2.1), these arguments apply equally in the North and South. However, the principles of community involvement have perhaps been elaborated most strongly in developing country contexts.

Victoria (2002), for example, reports on community-based disaster preparedness and mitigation initiatives established in Orissa, India, after the floods and super cyclone of

1999. These included: organization of Disaster Management Committees, community based organizations (CBOs) and community volunteers; identification of response gaps observed in 1999 and development of community contingency plans; and promotion of alternative housing technologies and local radio alert networks. The project was deemed successful in building capacity in disaster preparedness, raising the profile of risk reduction, and putting local disaster management systems in place that enabled more effective response to further floods in 2001 and a cyclone threat in 2002.

Disaster relief raises further complex issues including the identification and targeting of priority groups and the creation of aid-dependency in vulnerable communities. Hossain and Koslteran (2003), for example, raise questions against targeting during large-scale disasters. Bankoff (2001) warns against creating a discourse of vulnerability that casts populations or countries as 'disaster-prone', and thereby undermines their actions and potentials. The detailed discussion of issues such as these is unfortunately beyond the scope of this introductory section, although their implications will be touched on in later chapters.

CHAPTER 3 HEALTH IMPACTS

Floods have the potential to exact a huge impact on the health of human populations. Since 1900, for example, flood disasters alone have led to at least 6.8 million reported deaths and 1.3 million reported injuries (see Table 3.1 and Table 3.2). A further, undocumented global health burden arises annually from floods that are severe in effect but not classified as full-blown 'disasters'. To date, there have been few published reviews on the health impacts of floods (Western, 1982; Seaman, 1984; Hajat *et al.*, 2003; Malilay, 1997), and these have either focused on particular geographical regions, or not involved a systematic review of the available epidemiological evidence. Therefore, in order to understand better the nature of the overall health burden from floods, this chapter surveys the evidence base available on the epidemiology of all floods.

Our review of epidemiological studies concentrates on those health outcomes that we regard as specifically related to flooding and human vulnerability. We do not survey aspects of health that can be categorised as generic to disaster situations, such as the health impacts of population displacement, economic losses and disruption of food supplies. We also recognise that there have been insightful qualitative studies on the health effects of flooding (e.g. see 3.2.8 for a note on research in Bangladesh and the UK). However, the focus of this chapter is on epidemiological evidence, and therefore we do not provide a detailed analysis of this qualitative work.

3.1 EPIDEMIOLOGY OF FLOOD HAZARD

Epidemiology has been defined as 'the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to control of health problems' (Last, 2001, p62). Epidemiological data is essential for setting priorities within health, for designing and evaluating public health interventions, and is also an important tool for advocacy. In the context of flood disasters epidemiological data is important to enable public health officials and various disaster relief organisations to gain a better understanding of the different health outcomes that may arise from these kinds of events, the various population groups that may be affected, and how best to minimise the health impacts of future events.

There are several types of epidemiological study design. Observational studies can be either *descriptive* or *analytical*, and these types of study 'allow nature to take its course: the investigator measures, but does not intervene' (Beaglehole *et al.*, 1993, p29). All the studies in this review are observational, some descriptive and others analytical. In general terms, analytical studies are given a higher rating as they analyse relationships between health status and other variables; while descriptive studies only provide a description of the occurrence of a disease in a population (Beaglehole *et al.*, 1993). In this review we have adopted this generalisation, and consider the 'most' rigorous studies to be those, which have provided details of the following:

1. Clearly stated hypothesis
2. Individuals included in the study and how they were selected (i.e. using some form of randomisation or probability sampling procedure)

3. Sample to include those who were affected by the flood event, and those who were not. The latter are often referred to as the ‘control’ or ‘comparison’ group
4. Data collection in both the pre- and post-flood period. Prospective data collection is given higher weighting than retrospective data collection, as the latter is particularly susceptible to recall bias
5. Results should include *p*-values or confidence intervals. Limitations of the study (e.g. results may be due to bias, chance or confounding) should also be included
6. Clinical or laboratory diagnosis is given greater credence than self-reported diagnosis.

These criteria are used to evaluate the quality of the various studies described in this review. However, it is difficult to fulfil many of these criteria for flood disasters, for many reasons (difficulty in collecting data, no baseline data, weak surveillance infrastructure). Points 4 and 6 (self-reporting) are particularly important for those studies focusing on mental health outcomes.

3.2 HEALTH OUTCOMES

We consider health in the broadest sense, that is, covering all aspects of physical and mental well-being. The range of health outcomes that may result from flooding is broad (see Table 3.1). The remainder of this chapter is organised according to the type of health outcome. These outcomes can be both direct (e.g. death, injuries, outbreaks of infectious disease) and indirect (e.g. destruction of health care infrastructure and loss of essential drugs), and may occur in different time periods (pre-onset, onset, post-onset).

Table 3.1 The potential health effects of flooding

Impacts on health	Pre-onset-phase	Onset-phase	Post-onset phase
<i>Direct</i>	<ul style="list-style-type: none"> • Injuries 	<ul style="list-style-type: none"> • Death (drowning) • Injuries 	<ul style="list-style-type: none"> • Faecal-oral disease • Vector- and rodent-borne disease • Respiratory infections • Skin infections • Mental health
<i>Indirect</i>	-	-	Health outcomes associated with: <ul style="list-style-type: none"> • Damage to health care infrastructure • Chemical contamination of food and water stocks • Damage to water and sanitation infrastructure • Damage to crops and/or disruption of food supplies • Damage/destruction of property (e.g. lack of shelter may lead to increased exposure to vectors) • Population displacement

Flood-related deaths and injuries are most likely to occur in the flood onset period, from drowning or from fatal injuries sustained when struck by debris in fast-flowing waters. Outbreaks of infectious disease and adverse effects on mental health are more likely to occur in the medium and longer-term. This temporal demarcation is somewhat arbitrary however. Injuries may also occur in the pre-onset, and post-onset periods during evacuation and clean-up operations. Flood events may be of long duration, creating a blurring of onset and post-onset phases, during which, for example, risk of drowning is prolonged. And it is also crucial to note that deaths may result from disease outbreaks.

The range of health outcomes addressed in this section, fall under the following broad headings:

- Mortality
- Injuries
- Diarrhoeal disease
- Other faecal-oral
- Infection from soil-transmitted helminths
- Vector-borne disease
- Rodent-borne disease
- Mental health
- Other

In addition to the detailed discussions that follow here under these headings, summary information on key studies we have surveyed is also provided in Appendix 1.

3.2.1 Mortality

According to EM-DAT (see Box 3.1), between 1900 and May 2004 there were over 6.8 million flood deaths, which represent around 20% of all natural disaster deaths, and over 98% of these deaths occurred in Asia (see Table 3.2).

Table 3.2 Summary of deaths and injuries from the main types of natural disasters

Region	Type of natural disaster									
	Droughts (1900 to 2004)		Epidemics (1900 to 2004)		Famines (1931 to 2002)		Floods (1900 to 2004)		Totals	
	No. killed	Injured	No. killed	Injured	No. killed	Injured	No. killed	Injured	No. killed	Injured
Africa	1,046	0	421	<1	38	0	19	23	1,524	24
Americas	<1	0	67	80	0	0	96	41	164	121
Asia	7,761	0	6,523	0	2,121	0	6,757	1,177	23,162	1,177
Europe	1,200	0	2,501	0	5,000	0	10	22	8,711	22
Oceania	<1	0	7	0	0	0	<1	<1	9	1
Totals	10,009	0	9,519	81	7,159	0	6,883	1,264	33,570	1,345

All figures in this table are given in thousands, and have been rounded to the nearest thousandth
Source: Based on data extrapolated from EMDAT on 15th June 2004

The vast majority of these flood deaths occurred in two catastrophic events in China in 1931 and 1959, which has seen some of the highest flood related death tolls, as well as number of persons affected by these flood events. However, these data need to be treated with caution (See Box 3.1). In the Global Burden of Disease (GBD) study, regional estimates of mortality due to flooding (coastal and riverine) were calculated for the period 1980-1999 (see Table 3.3). The total numbers of deaths for each class of event were summed for the 14 WHO GBD 'regions' (in which countries are grouped first by geography and second by similar mortality patterns). The greatest impact (per capita) for inland floods is seen in South America (Amr B and Amr D). The greatest incidence of death due to coastal flooding is seen in Amr B (Caribbean and Central America) and Sear D (which includes Bangladesh and India).

Box 3.1 EM-DAT – the Emergency Events Database

EM-DAT was established in 1988, and is the most detailed international source of information on disasters, and contains details of disasters from 1900, although the time period covered for each type of disaster varies. The database (website <http://www.em-dat.net/who.htm>) relies on a variety of sources for information, and these include United Nations agencies, NGOs, insurance companies, research institutes and press agencies. In order for a disaster to be entered into the EM-DAT database at least one of the following criteria has to be fulfilled:

- 10 or more people reported killed
- 100 people reported affected
- a call for international assistance
- declaration of a state of emergency

There are a number of general limitations to the EM-DAT database. The database was only established in 1988, and therefore it is unlikely that data from earlier disaster events is complete. For example, in countries where there is already a lack of reporting of deaths and injuries, this is likely to influence the data that is available in a disaster situation. This is particularly the case with injuries, and may partly explain the relatively low number of injuries, which have been reported. Thus, the data for deaths and injuries may be somewhat conservative.

Also in terms of the epidemiology of natural disasters, and floods in particular, the database does not provide details on the cause of death and injury, nor on the constitution of the different groups who are likely to be affected by these disasters. For instance, certain groups (children, the elderly, and those with pre-existing ill-health) are more likely to suffer the adverse consequences of natural disasters. In addition, EM-DAT does not differentiate between the different types of floods (e.g. inland and coastal).

Source: EM-DAT website (<http://www.em-dat.net/who.htm>) accessed June 2004.

In general terms, most flood-related deaths are likely to occur in the onset phase, through drowning, or from fatal injuries received when hit by objects in fast-flowing waters. The speed of flood onset is thus one of the main factors determining the number of flood-related deaths, and in this regard, flash floods are particularly hazardous as there is little opportunity to warn the relevant communities and enable them to take evasive action. Jonkman (in press) shows that the average rate of mortality, in terms of numbers killed as a proportion of numbers affected, tends to be highest for flash floods.

Table 3.3 Annual incidence of deaths per 10,000, 000 population, for the period 1980-1999 (reported data from EM-DAT database)

Region	Countries included	Inland floods and landslides	Coastal floods
Afr D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, São Tome and Príncipe, Senegal, Seychelles, Sierra Leone, Togo	2.7	0
Afr E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe	6.5	0
Amr A	Canada, Cuba, United States of America	2.2	0
Amr B	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela	52.2	2.00
Amr D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru	52.1	0.40
Emr B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates	14.9	0
Emr D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen	32.2	0
Eur A	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom	1.3	0
Eur B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia	8.9	0
Eur C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine	1.2	0.10
Sear B	Indonesia, Sri Lanka, Thailand	9.9	0.10
Sear D	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal	20.3	1.20
Wpr A	Australia, Brunei Darussalam, Japan, New Zealand, Singapore	3.7	0.10
Wpr B	Cambodia, China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam	13.8	0.90

Source: Adapted from (McMichael *et al.* 2004)

It is important however, to bear in mind that flood-related deaths can also arise from other factors, which do not occur in the onset phase. For example, flooding can increase the risk of infectious disease, (e.g. diarrhoeal disease, malaria), some cases of which may become fatal.

In industrialised countries several papers refer to increases in total mortality following flood events. After the February 1953 floods in Canvey Island Essex, UK, Lorraine (1954), compared routine deaths data for the period with the previous year, and suggested there was an increase in mortality. Also in the UK, Bennet (1970) conducted a retrospective study of the 1968 Bristol floods, and found a 50% increase in the number of deaths among those whose homes had been flooded, and the most pronounced rise was in the 45-64 age group. However, in their study of the 1974 Brisbane floods, Abrahams *et al.* (1976) found no increase in mortality after the floods. The Bristol study suggested that a flood experience might hasten death in the older age group, but Abraham's results did not support this. Also in Australia, Handmer and Smith (1983) examined death certificates for the year before, and year after the 1974 floods in New South Wales. The study compared flooded and non-flooded areas, and found no significant overall change in total number of deaths.

A total of 1,185 deaths associated with 32 flash floods (average 37 deaths per flood) were reported from 1969-81 in the USA (French *et al.*, 1983, p584). Of the 34 reports of flash flood reports covering the period 1969-81, which they reviewed, only 16 provided details of cause of death, and these covered only 190 (16%) of the deaths. In addition, these reports were incomplete. Of the 190 deaths, 177 (93%) were due to drownings (with 42% of these being car-related (see Table 3.4). Only a few of the reports contained information on the age and sex of the flash flood victims, and the authors were unable to 'draw conclusive inferences for all flash floods [as the floods reviewed] were not representative of all flash floods [and] the lack of a systematic method for collecting data, particularly the circumstances surrounding death, also poses problems in the interpretation of the data' (French *et al.*, 1983, p587).

Table 3.4 Circumstances of 190 deaths in 16 survey reports of flash floods

Circumstances of death	Number	Percent
Drownings	177	93
<i>Car related</i>	80	43
<i>Swept into water (in home, at campsite, or when crossing bridge)</i>	81	43
<i>Rafting or sailing</i>	4	2
<i>Storm water</i>	2	1
<i>During evacuation (not involving car)</i>	4	2
<i>Performing rescue</i>	6	3
Trauma	2	1
Heart attack	7	3
Electrocution	2	1
Buried in mud	2	1
Total	190	100

Source: French *et al.*, 1983

The 1993 floods in Missouri, USA resulted in 21 deaths directly related to the flood (drowning) and 6 deaths indirectly related to the flood (i.e. flood-related activity with no direct physical contact with flood water) (Donnell and Hamm, 1993). The age of the deceased ranged from 9 to 88 years (mean 37.8), and 18 (67%) were male. A further 16 deaths were reported in the autumn of the same year, and 14 of these were motor-vehicle related. In this report 75% (27/36) of the drownings that occurred were motor-vehicle related. In 1998 there were 31 deaths following floods in Texas, and 24 (77%) of these were due to drowning, with 22 of these the result of a vehicle being driven into deep water (Kremer *et al.*, 2000). Three deaths (10%) had a cardiac origin, another 10% from multiple trauma, and one (3%) from hypothermia.

Similar flood-related mortality arose in the 1994 floods in Georgia, USA, where there were 28 deaths (ages 2 to 84; mean 31 years). Twenty (71%) of these were males and the majority of drownings were motor-vehicle related (Duke *et al.*, 1994). There were 9 flood-related deaths (drowning) – including persons who tried to rescue others – in the 1988 flash floods in Nîmes, France, but an analysis of death certificates did not reveal any marked increase in mortality (Duclos *et al.*, 1991). In Puerto Rico in 1992 Staes *et al.* (1994) conducted a case-control study to determine the circumstances of the deaths [associated with the flood] and to identify potential risk factors for flash flood-related deaths' (Staes *et al.*, 1994, p969). Cases were defined as deaths that occurred as a direct result of the impact of the floods. In all, there were 23 flood-related deaths, with ages of the deceased ranging from 4 to 82 years (average 32 years); 13 (56%) were female. Autopsies were performed on 20 (the other three were swept away), and all were occupants of motor vehicles. Of these 20 deaths, 19 (95%) were due to drowning and one (5%) died from carbon monoxide poisoning, when the exhaust pipe of the victim's car was blocked by mud. The estimated risk of mortality was significantly elevated (OR 15.9, 95% CI 3.5-144) for those who occupied a vehicle, and the risk remained significantly elevated after controlling for age and sex.

Three papers report on flood-related mortality in developing countries. In Sudan, Woodruff *et al.* (1990) used surveillance data from the 1988 floods in Khartoum, and found an excess of diarrhoea mortality, but suggest that this excess may not have been due to the flood, as the data for the period May-July 1988 were also greater than in the corresponding months of 1987. In Bangladesh, Siddique *et al.* (1991) also used routine surveillance data and hospital admissions records, and found diarrhoeal disease to be the most frequent (27%) cause of death, but it was not clear if this was due to the 1988 flood or to seasonal increase. Siddique and colleagues have also compared data on drownings in the 1-4 age group, from an earlier study (no details provided) and suggest that the increased difference noted in 1988 'may have been influenced by the flood' (Siddique *et al.*, 1991, p 313).

More recently, Kunii *et al.* (2002) conducted a cross-sectional survey of the 1998 floods in Bangladesh, and out of 3,109 people within their study households, seven (0.23%) died during the flood, two of whom died of apparent diarrhoea, two were suspected of dying of a heart attack, but the causes of the other three deaths were unknown. The authors report that the slow onset of the flood 'did not seem to lead to high mortality as a result of direct causes such as drowning and injuries, as is often the case in flash floods' (Kunii *et al.*, 2002, p73).

3.2.2 Injuries

Flood-related injuries may occur in the pre-onset, onset, and post-onset phases. In the pre-onset and onset phase injuries may be sustained when individuals are attempting to remove themselves, their family or valued possessions from the approaching waters. These injuries could be relatively minor, such as cuts and abrasions, or may be more serious, e.g. fractures and punctures. These more serious injuries are a particular risk when there are large heavy objects in fast-flowing floodwaters. There is also potential for injuries in the post-onset phase, when people return to their homes and businesses, and begin the clean-up operation. In this phase particular care should be taken with buildings, which may have become unstable, and electrical power cables present a particular hazard.

Surprisingly little information on the burden of injuries due to flood events is available. Injuries are not routinely reported in most countries, and where injuries are reported, they cannot be identified as flood related. The CCASHH project found no survey information on flood related injuries in Europe (WHO, 2002). The EM-DAT database reports injuries associated with flood events, but these data are seen as much less robust than reports of deaths (Guha-Saipr, personal communication) As with deaths, the majority (93%) of flood-injuries occurred in Asia (see Table 4). The injury to death ratio is much smaller than that seen for wind storms.

In general, floods with a slow onset (such as the 1988 floods in Bangladesh) are less likely to produce injuries (Siddique *et al.*, 1991). In addition to the flooded community, rescue workers and other emergency teams are also at risk of injury. In their review of weather-related disasters in the USA, French *et al* (1983) reviewed 34 reports of flash reports covering the period 1969-81 and only three of these provided information on injuries; thus they were unable to assess injuries related to flash floods. Duclos *et al.*, (1991) report that in their community survey (108/181 households completed a questionnaire) of the 1988 floods in Nîmes, France, 6% of households surveyed reported mild injuries (contusions, cuts, and sprains) related to the flood.

In Missouri after the Midwest floods of 1993, injuries were reported through the routine surveillance system. Between July 16th and September 3rd, 524 flood-related conditions were reported, and of these 250 (48%) were injuries. The most common injuries reported were sprains/strains (34%), lacerations (24%), "other injuries" (11%), and abrasions/contusions (11%) (Schmidt *et al.*, 1993). Similar data was also reported from Iowa (Atchison *et al.*, 1993).

3.2.3 Diarrhoeal disease

Diarrhoeal disease is a major cause of childhood mortality and morbidity in developing countries, and studies have shown strong seasonal variations in numerous populations. The seasonal peaks in diarrhoeal mortality and morbidity are, in some cases, associated with seasonal rains and flooding. Diarrhoeal disease can be caused by both viral and bacterial pathogens. Due to improvements in the treatment of diarrhoea (such as Oral Rehydration Therapy), mortality has decreased in many countries, but morbidity remains high.

Infection through water-borne transmission of an infectious agent occurs when humans drink water infected with a pathogenic agent, such as *Vibrio cholerae*, but it is important to note that 'all water-borne diseases can also be transmitted by any route which permits faecal material to pass into the mouth (a 'faecal-oral' route). Thus, cholera may be spread by various faecal-oral routes, for instance via contaminated food' (Cairncross and Feachem, 1993, p5). Table 3.5 provides a summary of the main water- and excreta-related infections.

Several papers focused on non-specific diarrhoea in developing countries – Bangladesh (Siddique *et al.*, 1991; Kunii *et al.*, 2002,) India (Biswas *et al.*, 1999b; Mondal *et al.*, 2001), Mozambique (Kondo *et al.*, 2002), and Sudan (MMWR, 1989b; CDC, 1989; Woodruff *et al.*, 1990). Siddique *et al.* (1991) used routine surveillance data and hospital admissions records to quantify the impacts of the 1988 floods, and found diarrhoea to be the most common problem (35%) among the 46,740 patients treated. Diarrhoea was the major cause of illness in children, and accounted for 27% of all-cause mortality among the 154 flood-related deaths (all ages). However, data was limited to flood-affected persons seeking treatment, and it was therefore not clear if 'the higher proportion of diarrhoea was due to the flood or due to the usual seasonal increase' (Siddique *et al.*, 1991, p312).

After the 1998 floods Kunii *et al.* (2002) carried out a cross-sectional survey of health problems, and found the leading health problems among respondents to be 'fever; (43%); diarrhoea (27%) and respiratory infections (14%), and children under 5 years were more susceptible to diarrhoea, than the older age-groups. However, the study lacked a comparison group, and there were no details about pre-flood incidence of diarrhoea in the various age-groups.

In a cross-sectional study of the 1993 floods in West Bengal, India, Biswas *et al.* (1999b) report that the attack rate of diarrhoea increased from 4.5% before the flood to 17.6% afterwards ($p < 0.01$). However, there are few details on how participants were selected, there is lack of a comparison group, and there are no details on how the different age-groups were affected. In a 1999 case-control study Mondal *et al.* (2001) found the distribution of diarrhoeal disease significantly higher in the 'study' population in the post-flood period ($p < 0.001$). The attack rate of diarrhoea was also significantly higher in the flood-prone population post-flood.

After the 1988 floods in Khartoum, Sudan, and using surveillance data, Woodruff *et al.* (1990), found an excess of diarrhoea morbidity, but have suggested that this excess may not have been due to the 1988 flood, as the data for the period May-July 1988 were also greater than in the corresponding months of 1987. In Chad (Kostioingue *et al.*, 2002) report on the prevalence of intestinal parasitoses in children (aged 0-5 years), and found those districts with the highest rate of infection were subjected to flooding in the rainy season.

There is no available evidence that flooding leads to outbreaks of diarrhoeal disease in industrialised countries, and this is confirmed in studies from the former Czechoslovakia (Cervenka, 1976), Norway (Aavitsland *et al.*, 1996) and the USA (Atchison *et al.*, 1993 and Schmidt *et al.*, 1993)

Table 3.5 Environmental classification system for water- and excreta-related infections

Category	Infection	Pathogenic agent
1. Faecal-oral (water-borne or water-washed)	Diarrhoeas and dysenteries Amoebic dysentery Balantidiasis <i>Campylobacter</i> enteritis Cholera Cryptosporidiosis <i>E. coli</i> diarrhoea Giardiasis Rotavirus diarrhoea Salmonellosis Shigellosis (bacillary dysentery) Yersiniosis Enteric fevers Typhoid Paratyphoid Poliomyelitis Hepatitis A	P P B B P B P V B B B B B V B B V V
2. Water-washed: (a) skin and eye infections (b) other	Infectious skin diseases Infectious eye diseases Louse-borne typhus Louse-borne relapsing fever	M M R S
3. Water-based: (a) penetrating skin (b) ingested	Schistosomiasis Guinea worm Clonorchiasis Diphyllbothriasis Fasciolopsiasis Paragonimiasis Others	H H H H H H H
4. Soil-transmitted helminths	Ascariasis (roundworm) Trichuriasis (whipworm) Hookworm Strongyloidasis	H H H H
5. Water-related insect vector (a) biting near water (b) breeding in water	Sleeping sickness Filariasis Malaria River blindness Mosquito-borne viruses Yellow fever Dengue Others	P H P H V V V
B = bacterium; H = helminth; P = protozoan; M = miscellaneous; R = rickettsia; S = spirochaete; V = virus		
Source: Adapted from Tables 1.2 and 1.3. (Cairncross and Feachem, 1993)		

Cholera

Cholera is an acute bacterial enteric disease caused by the infectious agent *Vibrio cholerae* 01 (a more recent strain, *V. cholerae* 0139, has also been identified), and humans are the main reservoir; although in recent years environmental reservoirs have been shown to exist, apparently in association with copepods or other zooplankton in brackish water or estuaries (Chin, 2000; Naidoo and Patric, 2002). Since the 1990's there have been several reports of cholera following flood events, and these include outbreaks in Djibouti (Morillon *et al.*, 1998), the Horn of Africa (Anonymous, 1998), India (Sur *et al.*, 2000), Indonesia (Korthuis *et al.*, 1998), and Mozambique (Naidoo and Patric, 2002).

The main modes of transmission are through the ingestion of contaminated water or food. Though historically originating from Bengal, the disease is now largely concentrated in Africa, where more than 80% of the total cases worldwide are found (Naidoo and Patric, 2002). For example, in 1997 there were numerous outbreaks in Africa, and 'most of [these] followed heavy rainfalls which in some countries resulted in huge floods' (Anonymous, 1998, p201), and 'The February 2000 floods in southern Mozambique contributed more than 17,000 cases of cholera' (Naidoo and Patric, 2002, p89). In both of these statements there is an implicit assumption that floods may have played some role in the cholera outbreaks. However, neither paper provides epidemiological evidence to substantiate these statements. Morillon *et al.*, (1998) have also reported that cholera epidemics in Djibouti in 1995 and 1997 followed flooding, but do not provide epidemiological evidence of causality.

Two outbreak investigations in Asia (Sur *et al.*, 2000; Korthuis *et al.*, 1998) also suggest that flooding may have been a contributing factor in the transmission of cholera. After the 1998 floods in West Bengal, India, Sur and colleagues investigated a severe outbreak of diarrhoeal disease, which led to 16,590 reported cases and 276 deaths. Twenty eight per cent (4,645) of the patients were under five years of age, and the highest death rate (details not provided) was observed in this group. From a sample of 29 rectal swabs, 72% (21) were found to be positive for *V. cholerae* 01, biotype El Tor, and these laboratory findings suggest that this pathogen 'was the primary cause of this epidemic' (Sur *et al.*, 2000, p181). Sur *et al.* (2000) reported that in the post-onset phase tubewells were erected on an emergency basis and these 'were located in low lying areas, very near ponds, without platforms and surrounded by stagnant polluted water' (Sur *et al.*, 2000, p180). However, it is not clear how the pathogen was transmitted, and if it was due to the location of the emergency tubewells, then this would be an indirect, rather than a direct consequence of the flood. In the outbreak investigation by Korthuis *et al.* (1998) it was also unclear how the pathogen was transmitted.

Rotavirus and Cryptosporidium

Rotavirus is a common cause of diarrhoea in children and infants, and two studies from Bangladesh (Ahmed *et al.*, 1991; Fun *et al.*, 1991) focus on the floods of 1988. In a two-year study (January 1987 to May 1989) using routine surveillance data Fun *et al.* (1991) investigated the incidence and serotype distribution of rotavirus-associated diarrhoea. Rotavirus diarrhoea was evident throughout the year, and there were peaks in both years during the dry winter months (December to February). In 1988 there was also a

peak in rotavirus in September, coinciding with the 1988 floods. Although the number of diarrhoea patients remained high until December (1988) in the Fun *et al.* study, the cases associated with rotavirus declined sharply by October 1988, and the reason for this is unclear (Fun *et al.*, 1991, p1362). These results concur with those of Ahmed and colleagues (1991) who used stool specimens from three hospitals to investigate rates of rotavirus before and after the 1988 floods, and 'an increase in the proportion of rotavirus diarrhoea also seemed to correspond to the spread of the flood after August' (Ahmed *et al.*, 1991, p2275).

In Indonesia a hospital-based case-control, and community-based cross-sectional survey were conducted to understand the prevalence and mode of transmission of *Cryptosporidium parvum* infection (Katsumata *et al.*, 1998). Although exposure to flooding was found to be a risk factor for *Cryptosporidium parvum* infection (OR= 3.083; CI= 1.935, 4.912) it was not clear how exposure to flooding was measured, or whether this association referred to both the hospital- and community-based studies.

3.2.4 Other faecal-oral

Hepatitis A and E

The Hepatitis A and E viruses (HAV and HEV) are transmitted primarily through the faecal-oral route (Chin, 2000). Common source outbreaks for HEV include contaminated water and for HAV both contaminated food and water. A recent review (Piper-Jenks *et al.*, 2000) suggested that many of the large outbreaks of HEV have occurred after heavy rains and flooding. There have also been reports of flood-related outbreaks of HAV and HEV from Sudan (McCarthy *et al.*, 1994), the USA (Mackowiak *et al.*, 1976), and Vietnam (Corwin *et al.*, 1999; Hau *et al.*, 1999).

In Louisiana, USA, Mackowiak *et al.* (1976) investigated an outbreak of oyster-related Hepatitis A, but were unable to determine the precise cause of the outbreak, and hypothesised that flooding of the Mississippi valley, and discharge of faecal materials in the oyster growing areas may have been a factor.

Meanwhile, in Sudan, McCarthy and colleagues (1994) reported an outbreak of Hepatitis E following the 1988 floods in Khartoum, and a review of the riverine ecology of hepatitis E in South-East Asia by Corwin *et al.* (1999) suggested that 'heavy rainfall linked to flooding in Vietnam, or subnormal rainfall in Indonesia, have probably contributed to the favourable conditions that influenced epidemic or cyclic HEV spread, [and] anecdotal information from the Mekong Delta Region also indicates a dramatic rise in cases during the flooding of the river system' (Corwin *et al.*, 1999, p259).

In their cross-sectional study of the prevalence of Hepatitis A and E in Viet Nam, Hau *et al.* (1999) suggested that 'periodic flooding of the Mekong River and tributaries probably contributes to the contamination of water sources with human and/or animal waste material, adding to the risk of exposure [and this] regular flooding favours the epidemic potential of HEV spread' (Hau *et al.*, 1999, p279). However, such an association cannot be confirmed by this study design. In contrast an outbreak investigation in Indonesia (Sedyaningsih-Mamahit *et al.*, 2002) found no climatic influences (flood or drought) which favoured epidemic HEV transmission.

Poliomyelitis

Poliomyelitis (polio) is a viral infection, caused by the Poliovirus (genus Enterovirus) types 1, 2 and 3 – all types can cause paralysis – and is spread primarily from person-to-person through the faecal-oral route (Chin, 2000). One study (Middelkoop van, *et al.* 1992) described an outbreak in KwaZulu/Natal, South Africa between December 1987 and November 1988, in which 412 cases were reported, and 211 (51%) of these were confirmed by virus isolation. Those areas along the coast were of highest risk, and it was posited that major floods during late September and early October 1987, had caused major disruption, and that this may have been a risk factor for the outbreak. Although the primary cause of the epidemic could not be definitely determined, there was a strong correlation (Spearman's 0.56, $p < 0.01$) between flood-related mortality rates in each district – which was used as an indicator of the severity of the floods – and poliomyelitis attack rates. The authors suggest that 'it is reasonable to speculate that the scene was set for an outbreak by the massive floods which led to both a temporary breakdown in vaccination services and considerable surface pollution, including 'wild' poliovirus' (Middelkoop van *et al.*, 1992, p81).

3.2.5 Infection from helminths

Infection by helminths (parasitic worms) can be either water-based or soil-based (see Table 7). Water-based infection (e.g. Schistosomiasis - see 3.2.6) results from infection by helminths, which depend on an aquatic intermediate host to complete their life cycle. Soil-transmitted helminths are not immediately infective, but first require a period of development in favourable conditions, usually in moist soil (Cairncross and Feachem, 1993, p11). Both water-based and soil-based infections are associated with conditions of poor sanitation and hygiene, as infective eggs are passed in either human urine or (usually) faeces.

Hookworm is a chronic parasitic infection and is widely endemic in tropical and subtropical countries where sanitary disposal of human faeces is not practised and soil, moisture and temperature conditions favour development of infective larvae (Chin, 2000). In a longitudinal study of risk factors for Bancroftian filariasis in Haitian children (Lilley *et al.*, 1997), the prevalence of *Ascaris* and *Trichuris* remained relatively stable, while over the 6-year follow-up period of the study the prevalence of hookworm increased from 0% to 12-15%. Lilley and colleagues report that this increase 'may be an indirect consequence of deforestation, which led to silt accumulation in the local river, subsequent flooding, altered water drainage patterns, and saturation of soil near homes', and sandy loam soil deposited after flooding 'may also have been more conducive to hookworm development and survival, thus heightening the effects of the increased soil moisture' (Lilley *et al.*, 1997, p392).

A second study in 25 provinces of Poland (Plonka and Dzbenski, 1999) evaluated the occurrence of intestinal parasites among 7-year-old children ($n = 30,110$). Parasites most frequently found in faecal examinations included *Enterobius vermicularis* (16.45%), *Ascaris lumbricoides* (2.8%), and *Trichuris trichuria* (0.29%), and the authors suggest that these results 'confirmed the decreasing frequency of infections with intestinal parasites in Poland and indicated that the summer flood of 1997 had a little influence on the epidemiological situation of intestinal parasitoses in the affected regions' (Plonka and

Dzbenki, 1999, p338). These two studies would suggest that there is little evidence that infections caused by soil-based helminths increase during flooding.

3.2.6 Vector-borne disease

Water-related insect vectors represent an important category of diseases that can be affected by flooding (see Table 7). Many important infections are transmitted by mosquitoes, which breed in, or close to stagnant or slow moving water (puddles, ponds). Rainfall has a particularly important role to play in the transmission of malaria in areas where the climate is usually too dry to maintain a sufficiently abundant mosquito population. Flood waters can be beneficial, in the sense that they can wash away breeding sites, and in areas where mosquito-borne disease is endemic this can lead to reduced transmission (Sidley, 2000), at least during the period when water levels are high. The collection of stagnant water due to the blocking of drains in urban settings is also associated with increases in transmission. In contrast, the mosquito vectors of dengue breed in containers and so the relationship with rainfall is less established. Here we report only those papers where a flood event is also reported.

Malaria

Malaria is a parasitic disease, which occurs in humans, when one of four infectious agents – *Plasmodium vivax*; *P. malariae*, *P. falciparum* and *P. ovale* – is transmitted into the blood stream through the bite of a female mosquito (Chin, 2000). Flood-related malaria transmission has been reported from Africa, Asia and Latin America. For example, the 1982 El Nino event caused extensive flooding in several countries in Latin America, and a number of papers (Moreira Cedeno, 1986; Russac, 1986; Hederra, 1987) reported sharp increases in the number of cases of malaria following these floods.

Likewise the 1988 floods in Khartoum, Sudan were also reported to have led to an increase in transmission of malaria, which was over and above the annual rainy season increase that one would normally expect (MMWR, 1989; Woodruff et al, 1990, McCarthy et al, 1996; El-Sayed et al, 2000). However, due to a lack of baseline population data, morbidity and mortality rates could not be calculated, and while the increase in the number of cases reported in August 1988 was greater than that of August 1987 it is not clear if this was statistically significant (MMWR, 1989; Woodruff *et al.*, 1990). A second study in Africa (Kondo *et al.*, 2002) compared the number of cases of malaria after the Mozambique floods of 2000 with the number of cases in 1999 and 2001, and reported that the incidence of malaria increased 1.5 to 2 fold. However, the floods led to major population displacement, and it is not clear if Kondo *et al.* (2002) have taken these changes into account in their calculations. Also, they do not provide details on which age groups were affected, and provide no details on whether these changes were statistically significant.

Other flood-related outbreaks of malaria have been reported from Costa Rica (Saenz *et al.*, 1995), and India (Nandi and Sharma, 2000; Sharma *et al.*, 1997; Mathur *et al.*, 1992), but none provide strong epidemiological evidence of a flood-related increase in transmission.

Arboviruses

Mosquitoes are also responsible for the transmission of a number of arboviruses (arthropod-borne viruses), including dengue, and several forms of encephalitis. Dengue fever is an acute febrile viral disease and transmitted to humans by the *Aedes aegypti* mosquito, which predominates in urban environments, and whose preferred breeding habitat is in man-made containers, such as drinking-water storage containers. Dengue is unlikely to be a particular problem during the onset phase of a flood, as many breeding habitats of *Aedes aegypti* are likely to be overwhelmed by floodwaters. However, in the post-onset phase there is a possibility that receding floodwaters may provide ideal breeding habitats. Only one paper (Rigau-Perez *et al.*, 2001) made reference to dengue in the context of flooding, and reported that 'widespread flooding in 1996, did not affect the shape and height of the dengue epidemic [in the inter-epidemic period]' (Rigau-Perez *et al.*, 2001, p81).

West Nile virus (WNV) has caused outbreaks in Egypt, Israel, India and several countries in Central Europe, and is widespread in parts of Africa (Chin, 2000). Several papers refer to WNV in Europe (Hubalek, 2000; Hubalek and Halouzka, 1999; Hubalek *et al.*, 1999; Tsai *et al.*, 1998), and report that environmental factors such as flooding can facilitate the re-emergence of WNV. One case-control study (Han *et al.*, 1999) investigated the risk factors for WNV in Romania, and compared asymptotically infected persons (n=38) with uninfected persons (n=50); both samples were selected from those who participated in a serological survey. Among apartment block dwellers, 63% (15/24) of asymptotically infected persons were found to have had a flooded basement, whilst among uninfected persons 30% (11/37) reported having had a flooded basement. This difference was found to be statistically significant (OR 3.94, CI 1.16, 13.7, $p < 0.01$). Han *et al.* (1999) found 'the associations of infection with mosquito bites and flooded basements remained after controlling for age, residence in the agricultural sector, and other variables but were not consistently present in all subgroups examined' (Han *et al.*, 1999, p231); the paper does not provide details on these different subgroups.

There have also been reports of Murray Valley encephalitis (MVE) and St. Louis encephalitis (SLE) following floods. MVE is found in parts of Australia and New Guinea (Chin, 2000), and in the period 1990-1998, 14 cases of MVE were notified in Western Australia (WA); nine of these cases followed heavy rain and flooding during the 1993 wet season in WA and the Northern Territory (Smith *et al.*, 1993; Cordova *et al.*, 2000). Between January and August 2000 there were nine cases (6 definite and 3 presumptive) of MVE in WA, and this equals the previous record in 1993. Cordova and colleagues (2000) performed a case series, and described the epidemiological and clinical features of human MVE infections. Heavy rainfall and flooding were seen as possible contributory factors, and the 'marked southward migration of the virus in 2000 is of significant public health concern' (Cordova *et al.*, 2000, p370). We did not find any epidemiological study that focused on Murray Valley encephalitis (MVE).

SLE is found in North America, parts of the Caribbean, and Latin America. One study (Hopkins *et al.*, 1975) reports on an epidemic of SLE in the USA in 1966. In late April 1966 unusually heavy rains caused flooding in many areas of Dallas, Texas, and

'overloaded the drainage and sewage management system, causing back-up of water in the drains and creating pools of standing water enriched with organic waste favourable for mosquito breeding throughout the low-lying parts of the city' (Hopkins *et al.*, 1975, p2). There were 145 cases of confirmed SLE virus infection and 14 deaths over an 11-week period, and the attack rate was progressively higher in the older age groups, reaching a high of 59.9 cases per 100,000 in persons over 70 years of age. The incidence of SLE was also higher in the black population (37.1 per 100,000), and the major concentration of the cases occurred in the lower socioeconomic areas of the central part of the city.

Lauerman *et al.* (1984) describe an outbreak of *Culex tarsalis*-borne SLE in California and Arizona in 1983, and report that this outbreak was associated with flooding of the lower Colorado River. The estimated attack rate in California was 15.4 per 100,000, while that in Arizona was 2.3 per 100,000, and 64% (9/14) of the cases occurred among adults aged 50 years or older. More recently, two human cases of SLE were reported during the 1993 floods in the Midwest USA. However, only one of these occurred within the disaster area, and although sporadic cases of SLE frequently occur in the Midwest, neither of these two cases were related to the 1993 floods (Anders *et al.*, 1994).

Bancroftian Filariasis

Filariasis denotes infection with any of several nematodes belonging to the family *Filarioidea*, and *Bancroftian filariasis* is an infection with the nematode *Wuchereria bancrofti*, which is transmitted through the bite of a mosquito (Chin, 2000). A three-phase study was conducted in Lower Shire, southern Malawi between April and June 2000, when the area was still affected by the severe floods in Mozambique in 1999 (Nielsen *et al.*, 2002). Phase I assessed the geographical spread of lymphatic filariasis using a household questionnaire survey; Phase II volunteers reporting frequent manifestations of lymphatic filariasis from Phase I were tested for *Wuchereria bancrofti* circulating filarial antigens (CFA) in order to assess the extent of active infection; and in Phase III all those whose tests for microfilariae proved positive were offered treatment. Compared with other endemic areas the study found high prevalences of CFA, especially in children, and suggested that 'it is possible that [these] reflect a recent increase in transmission as a consequence of the severe flooding that affected the study areas a few months prior to the study' (Nielsen *et al.*, 2002, p136).

A number of other vector-borne diseases are referred to in the context of flooding, including *Tularaemia* in Croatia (Borcic *et al.*, 1977), and staphylinid (rove) beetle *Dermatitis* in the USA (Claborn *et al.*, 1999), Egypt (Morsay *et al.*, 1996 cited in Claborn *et al.*, 1999), and Kenya 1998 (Hugh-Jones, 1998, cited in Claborn *et al.*, 1999). However, none of these papers provide epidemiological evidence to support the link between flooding and these various health outcomes.

In summary, there is very little rigorous epidemiological evidence to support the argument that the transmission of vector-borne diseases increases with flooding. None of the malaria studies reviewed here provide epidemiological data of sufficient quality, and only two studies on arboviruses (Hopkins *et al.*, 1975; Han *et al.*, 1999) provide reasonably rigorous data to support the case that flooding may have influenced increased transmission rates. But, even these two studies do not demonstrate a casual linkage between the outbreaks and flooding.

Schistosomiasis is a water-based infection, but for convenience we have included it here. The disease is particularly associated with stagnant water (such as irrigation projects), and tends to occur in communities with inadequate sanitation infrastructure. The transmission cycle requires an intermediate snail host in which the schistosome parasite gestates. Humans become infected when the parasite penetrates skin, and is transported to the veins around the bladder or which deliver blood to the liver. The transmission cycle is completed when infected humans urinate or defecate in waters in which the intermediate snail host is found. There is increased risk of transmission when floods may inundate the irrigation project and enable the intermediate snail host to be more widely dispersed. Several papers from China focused on the changes in snail intermediate host distribution, and prevalence of human infection, which resulted from various flood events during the 1990s (Chen Minggang, 1999; Chen Jiran *et al.*, 2001; Chen Wei *et al.*, 2000; Huang YiXin *et al.*, 1998; Li Tao *et al.*, 2000; Lin DanDan *et al.*, 1999, Yang MeiXia *et al.*, 2002; Zhang YuQi *et al.*, 2002), but none of these were controlled studies or provided sufficient epidemiological data.

3.2.7 Rodent-borne disease

Hantavirus Pulmonary Syndrome

Hantavirus pulmonary syndrome (HPS) is an acute zoonotic viral disease, and multiple hantaviruses have been identified in the Americas; the disease was first recognized in 1993 in New Mexico and Arizona, USA (Chin, 2000). The natural reservoir for the disease includes various species of rodent, such as the deer mouse and other rodents, and infection in humans occurs after inhalation of aerosolized virus or direct contact with infected rodents or their excreta (Bayard *et al.*, 2000). In Panama in 1999, there were reports of an increase in the number of cases of HPS, and 12 patients with suspected HPS were identified; three died. The mean age of patients was 42 years (range: 26-58 years), and 58% were women. This increase in cases occurred around the same time as an increase in peri-domestic rodents, which was associated with increased rainfall and flooding in surrounding areas (Bayard *et al.*, 2000). Bayard and colleagues (2000) have also suggested that an increased incidence of HPS was linked with periods of above average rainfall in parts of the southwestern United States.

Leptospirosis

Leptospirosis is a zoonotic disease caused by the bacterial pathogen *Leptospira interrogans*, and is transmitted in urine from animals to humans, either directly, when urine from an infected animal (including dogs, cats, cattle, rodents and wild animals) enters the body through a break in the skin, or indirectly, in contaminated water and soil (Ingraham and Ingraham, 1995; Bharti *et al.*, 2003). The pathogen enters the bloodstream and after reaching the kidneys multiplies and is excreted in the urine. The disease occurs worldwide in urban and rural areas, and in both North and South (Chin, 2000), but there is a higher incidence of human infection in tropical regions compared with temperate (Bharti, *et al.*, 2003). There is often a lack of awareness of the disease,

and with diagnosis difficult (even in the laboratory) there is likely to be a general underestimation of incidence rates (Bharti *et al.*, 2003, p759). While leptospirosis is not solely associated with flooding, there have been reports of flood-associated outbreaks from a wide range of countries, including: Argentina, Bangladesh, Brazil, Costa Rica, Cuba, India, Korea, Mexico, Nicaragua, Philippines, Portugal, Puerto Rico, Russia, and the USA.

Several case reports highlighted the potential link between flooding and leptospirosis. In November 1967, Lisbon, Portugal experienced heavy precipitation (109mm in 24 hours), which resulted in homes being flooded. According to Simoes and colleagues (1969) similar heavy precipitation occurred in the past, but cases of leptospirosis were not reported, and this may be due to the lower density of the human population. There were 32 cases (all males aged 14 to 59 years). Park *et al.* (1989) suggest that the 1987 outbreak in Korea 'seemed to be due to the wash-out of leptospira-laden rodent urine into fields where workers were tying up fallen rice stalks after severe flooding. The outbreaks of leptospirosis in 1975, 1984, and 1985 also occurred after severe floods before harvesting season' (Park *et al.*, 1989, p348).

Leptospirosis tends to affect males more than females (Park *et al.*, 1989; Morshed, *et al.*, 1994), and this predominance in males is considered to occur due to the factors of occupation and environment, for example rice workers in Korea affected following flood event (Park *et al.*, 1989). Although Park *et al.* (1989) found the male to female ratio to be 3:2, which was 'thought to be due to increase of female workers in fields, and as many men were involved in damming up the flood or other repair work' (Park *et al.*, 1989, p348), and this concurs with other work where leptospiral antibodies were found not to be always more prevalent in males compared with females (Nutti *et al.*, 1992 cited in Morshed *et al.*, 1994). The disease is generally seen as an occupational infection in sewer workers and agricultural labourers; the first apparent outbreak in sewer workers was in 1883 (Fuortes and Nettleman, 1994). However, there have also been outbreaks among water sports enthusiasts who were infected when using flooded rivers (Reisberg *et al.*, 1997). In general, 'flooding after heavy rain is particularly favourable to leptospores; it prevents animal urine from being absorbed into the soil or evaporating so leptospores may pass directly into the surface waters or persist in mud' (Sanders *et al.*, 1999, p401).

There have been reports of flood-related outbreaks in a number of countries in the Americas, including Argentina (Vanasco *et al.*, 2000), Brazil (Barcellos and Sabroza, 2000; Barcellos and Sabroza, 2001; Correa, 1975; Ko *et al.*, 1999; Kupek *et al.*, 2000; Marotto, *et al.*, 1997; Sarkar *et al.*, 2002), Cuba (Suarez Hernandez *et al.*, 1999), Mexico (Leal-Castellanos *et al.*, 2003), Nicaragua (Ashford *et al.*, 2000; Munoz *et al.*, 1995; Trevejo *et al.*, 1998), and Puerto Rico (Sanders *et al.*, 1999). Although few provide detailed epidemiological data there is some good evidence that flooding can lead to outbreaks of leptospirosis. After a series of tropical storms in 1995, two health centres in western Nicaragua reported increased numbers of patients with a fever-like illness, and some deaths from haemorrhagic manifestations and shock (Trevejo *et al.*, 1998). Dengue and dengue haemorrhagic fever were initially suspected (Munoz *et al.*, 1995). A case-control study was conducted to identify and characterise aetiology, to describe the epidemic, and identify possible risk factors. Case-patients were found to be 'significantly more likely [no p value given] than controls to have reported walking through creeks or swimming in rivers' (Trevejo *et al.*, 1998, p1459). The authors report 'the most likely explanation for this epidemic was increased exposure to flood waters that had become contaminated by urine from animals infected with leptospira species' (Trevejo *et al.*,

1998, p1461). Although several articles (Trevejo *et al.*, 1998; Munoz *et al.*, 1995; Ashford *et al.*, 2000) indicate that contact with floodwaters was the likely cause of the outbreak none of these papers have provided details of the flood.

In Salvador, Brazil, Sarkar *et al.* (2002) conducted a population-based matched case-control study, and during the study period the incidence of severe leptospirosis for the city was 6.8 per 100,000. Risk factors included flooding of open sewers and streets during the rainy season, and cases were found to be at significantly higher risk. The odds ratio for exposure to flooded open sewers was 4.21 (95% CI 1.51, 12.83, p-value <0.001), and for flooded street was 2.54 (95% CI 1.08, 6.17, p-value <0.05).

There have also been reports of flood-related outbreaks in India (WHO, 2000; Seghal *et al.*, 2002; Karande *et al.*, 2003; Karande *et al.*, 2002), Korea (Park *et al.*, 1989), and The Philippines (Easton, 1999) but again there is limited detailed epidemiological data. After the floods of 2000 and 2001 in Mumbai, India, Karande and colleagues conducted two hospital-based observational studies, among children and found contact with contaminated flood water was significantly associated with the diagnosis of leptospirosis [and children] had either played in the flood water or waded through it while going to school, and in some cases the flood water had even entered their homes' (Karande *et al.*, 2003, p1071). However, neither of the studies in Mumbai used a control group, making it difficult to establish whether there was an association between contact with floodwaters and both outbreaks.

3.2.8 Mental health

In their 2001 World Health Report (WHO, 2001) the World Health Organisation (WHO) stated:

'mental health has been defined variously by scholars from different cultures. Concepts of mental health include subjective well-being, perceived self-efficacy, autonomy, competence, intergenerational dependence, and self-actualisation of one's intellectual and emotional potential, among others. From a cross-cultural perspective, it is nearly impossible to define mental health comprehensively. It is however, generally agreed that mental health is broader than a lack of mental disorders.'

(WHO, 2001, p 5)

Box 3.2 sets out typical symptoms and forms of mental illness. There are complex interactions between physical and mental health. In general, major life stressors, like natural disasters can influence the constitutional status of the body and increase susceptibility not only to physical illness, but may also affect mental health (Phifer *et al.*, 1988), and the mental health consequences of exposure of these disasters 'have not been fully addressed by those in the field of disaster preparedness or service delivery' (Gerrity and Flynn, 1997, p101).

Natural disasters, such as earthquakes, floods, and hurricanes 'take a heavy toll on the mental health of the people involved, most of whom live in developing countries, where capacity to take care of these problems is extremely limited' (WHO, 2001, p43). This is especially problematic as 'more than 40% of countries have no mental health policy and

over 30% have no mental health programme. Over 90% of countries have no mental health policy that includes children and adolescents' (WHO, 2001, p3).

Here, we focus on

- i) Common mental health disorders
- ii) Post-traumatic stress disorder (PTSD)
- iii) Suicide

Box 3.2 Symptoms and categories of mental illness

There are five major types of symptoms for the diagnosis of mental illness:

- ◆ *Physical – 'somatic' symptoms.* These affect the body and physical functions, and include aches, tiredness and sleep disturbance. It is important to remember that mental illnesses often produce physical symptoms
- ◆ *Feeling – emotional symptoms.* Typical examples are feeling sad or scared.
- ◆ *Thinking – 'cognitive' symptoms.* Typical examples are thinking of suicide, thinking that someone is going to harm you, difficulty in thinking clearly and forgetfulness.
- ◆ *Behaving – behavioural symptoms.* These symptoms are related to what a person is doing. Examples include behaving in an aggressive manner and attempting suicide.
- ◆ *Imaging – perceptual symptoms.* These arise from one of the sensory organs and include hearing voices or seeing things that others cannot ('hallucinations')

In reality, these different types of symptoms are closely associated with one another. There are six broad categories of mental illness:

- ◆ common mental disorders (depression and anxiety)
- ◆ 'bad habits', such as alcohol dependence and drug misuse
- ◆ severe mental disorders (the psychoses)
- ◆ mental retardation
- ◆ mental health problems in the elderly
- ◆ mental health problems in children

Source: Adapted from (Patel, 2003)

Common mental health disorders (anxiety, depression, stress)

There have been numerous studies on the effects of flooding on common mental health disorders, and most of these refer to flood events in the USA (Melick, 1978; Logue and Hansen, 1980; Logue *et al.*, 1981; Melick and Logue, 1985; Ollendick and Hoffman, 1982; Powell and Penick 1983; Phifer *et al.*, 1988; Phifer., 1990; Tobin and Ollenburger, 1996; Ginexi *et al.*, 2000; Hegstad, 2000; Ferraro, 2003) and a number of European countries including Poland (Neuberg *et al.*, 1999; Neuberg *et al.*, 2001; Bokszczanin, 2000; Bokszczanin, 2002), The Netherlands (Becht *et al.*, 1998) and the UK (Bennet, 1970). There have also been studies in Australia (Abrahams *et al.*, 1976; Price, 1978) and Bangladesh (Durkin *et al.*, 1993).

In a retrospective case-control study of the 1968 floods in Bristol, UK, Bennet (1970) found a significant increase (18% versus 6%; χ^2 7.57; $p < 0.01$) in the number of new psychiatric symptoms (considered to comprise anxiety, depression, irritability, and sleeplessness) reported by flooded female respondents compared with the non-flooded group. However, there was no significant difference in the psychiatric symptoms reported by males. These results concur with the study of the 1974 Brisbane floods (Abrahams *et al.*, 1976), except in the latter study flooded males were more affected than non-flooded males. In a follow-up of the Brisbane study, Price (1978) considered the age-related effects of the flood, and found those between 35 and 75 years of age were most affected. Women under 65 years of age had more psychiatric symptoms than men, but this sex difference disappeared in those over 65 years of age.

Meanwhile, in the USA two case-control studies (Melick, 1978; Logue *et al.*, 1981) were conducted after Tropical Storm Agnes (1972) caused extensive flooding in Pennsylvania. The first study was conducted 3 years post-flood, focused on working-class males (aged 25 to 65 years), and investigated the relationship between stress and self-reported incidence and prevalence of emotional disorders. Although respondents who were flooded demonstrated more mental health symptoms than non-flooded respondents, this difference was not statistically significant. In the second study the focus was on the long-term health impacts on females aged 21 years and over, and was carried out 5 years post-flood. As in Melick's study, respondents who were flooded demonstrated more mental health symptoms than non-flooded respondents, but again, this difference was not statistically significant. The authors report that 'the failure to find a stronger relationship between flood condition and mental/emotional status may, in part, be the result of the length of time which had elapsed since the disaster impact' (Logue *et al.*, 1981, p239)

In their controlled panel study of adults aged 55-74 years who had been flooded in 1981 and again in 1984 (Phifer *et al.*, 1988; Phifer, 1990) found that flood exposure was associated with significant increases in depression ($p < 0.005$), and anxiety ($p < 0.0008$). Those with high levels of pre-flood depressive symptoms experienced greater increases in symptoms post-flood. Flood exposure was also associated with reports of increased physical symptoms ($p < 0.003$). Those with high levels of pre-flood depressive symptoms experienced greater increases in symptoms post-flood, and these adverse effects also increased inversely with occupational status. Phifer (1990) reports 'this finding supports Logue, Melick, and Struening's (1981) assertion that low-income people are more vulnerable to the adverse effects of a disaster than are people of higher socioeconomic status' (Phifer, 1990, p417).

In a longitudinal study Ginexi *et al.* (2000) were able to compare symptoms for depression in both the pre- and post-flood period, and found that among respondents with a pre-flood depression diagnosis, the odds of a post-flood diagnosis increased significantly (OR 8.55, CI 5.54, 13.21). An increase in depression was also observed when pre-flood diagnosis was controlled for. A more recent case-control study from the UK (Reacher *et al.*, 2004) found a four-fold increase in psychological distress among adults whose homes were flooded compared to those whose homes were not flooded (RR 4.1, CI 2.6, 6.4, $p < 0.0005$).

While the majority of the papers reviewed here focused on the mental health of adults, there were a number of papers on the mental health impacts of children. In their study of children aged 2 to 9 years, Durkin *et al.* (1993) found post-flood changes in behaviour

and bedwetting. Before the flood none of the 162 children were reported to be 'very aggressive'; post-flood 16 children were found to be 'very aggressive toward others' and this represented a statistically significant increase ($p < 0.0001$). There were also significant differences ($p < 0.0001$) in levels of bedwetting with 16.8% of children bedwetting before the flood and 40.4% bedwetting post-flood. In the Netherlands, Becht *et al.* (1998) interviewed children ($n=64$) and their parents ($n=30$) 6 months post-flood, and found 15-20% of children having moderate to severe stress symptoms. After the 1997 floods in Opole, Poland (Bokszczanin, 2000; Bokszczanin, 2002) studied children aged 11-14 years, and 11-20 year olds. Results confirm long-term negative effects on well-being of children, with resultant PTSD, depression and dissatisfaction with ongoing life. (Russoniello *et al.*, 2002) studied children aged 9-12 years, 6 months after Hurricane Floyd, and the homes of 37% of children were flooded. These children who reported that their homes were flooded were 3 times more likely to report symptoms of PTSD than those whose homes were not flooded, and the girls were twice as likely as the boys to report symptoms.

There have also been a number of qualitative studies, including work in Bangladesh (Rashid, 2000; Rashid and Michaud, 2000), and the UK (Tapsell *et al.*, 1999; Tapsell *et al.*, 2003; Tapsell and Tunstall, 2001). We recognise that such studies add valuable insight to the effects of flooding on the health and wellbeing of individuals, but they are not, strictly speaking, epidemiological studies, and we have therefore not included an analysis of their findings in this section.

Post-traumatic stress disorder (PTSD)

Post-traumatic stress disorder (PTSD) 'arises after a stressful event of an exceptionally threatening or catastrophic nature and is characterised by intrusive memories, avoidance of circumstances associated with the stressor, sleep disturbances, irritability and anger, lack of concentration and excessive vigilance'. The specific diagnosis of PTSD 'has been questioned as being culture-specific and also as being made too often' (WHO, 2001, p43) [and] has been called a diagnostic category that has been invented based on socio-political needs (Summerfield 2001 cited in WHO, 2001, p440).

There have been studies of flood-related PTSD undertaken in Canada (Auger *et al.*, 2000; Maltais *et al.*, 2000), France (Verger *et al.*, 2003), Poland (Norris *et al.*, 2002), Puerto Rico (Canino *et al.*, 1990), and the USA (Moinzadeh, 1999; Waelde *et al.*, 2001; McMillen *et al.*, 2002).

Verger and colleagues conducted a retrospective cross-sectional study in adults over 18 years of age, five years after the 1992 floods in Vaucluse, France, to study the association between the severity of psychological exposure to the flood and symptoms of PTSD. A significantly higher PTSD score was observed for females, and subjects older than 35 years. However, the authors state 'the subjects' reports of their disaster-related experiences are by nature subjective and were collected retrospectively, 5 years after the event [and are therefore] not entirely reliable (Verger *et al.*, 2003, p440). McMillen *et al.* (2002) interviewed those who were affected by the 1993 Midwest floods in areas around St. Louis, and found 60 subjects (38%) met criteria for post-flood psychiatric disorder. Thirty-five subjects (22%) met criteria for flood-related PTSD. But limitations recognized by authors included retrospective data collection; individuals self-

selected; self-reporting; no control group. In Puerto Rico, Canino *et al.* (1990) found that the higher the level of exposure to the disaster, the greater the number of new depression and PTSD symptoms.

After the 1997 floods in the Central Valley of Northern California Waelde *et al.* (2001) assessed acute stress disorder (ASD) one to three months post-flood, and PTSD one year post-flood. Of the 128 participants average age 43 years (SD 12.6) who completed the ASD questionnaire 24 (19%) met the symptom criteria for the ASD diagnosis, and of the 73 participants who completed the one-year follow-up, 7 (10%) met the criteria for full PTSD. There are a number of limitations to this study, which include: no pre-flood data collection; no comparison group; self-reporting; not clear how participants were selected and if this was randomized. (Moinzadeh, 1999) investigated whether adult survivors of child abuse experienced more Acute Stress Disorder (ASD) and PTSD symptoms than a non-abused comparison group following exposure to the flood. Adult survivors of child abuse experience more ASD and PTSD symptoms following flooding, than non-abused individuals.

Norris *et al.* (2002) compared the effects of age on PTSD after disasters in the USA (Hurricane Andrew, 1992), Mexico (Hurricane Paulina, 1997), and Poland (floods in Opole, 1997), and found that 'Poles of all ages reported more symptoms than did Americans and Mexicans, and that difference was most pronounced for older adults [and] age had a clearly positive linear relation with PTSD for Polish men but a curvilinear relation with PTSD for Polish women' (Norris *et al.*, 2002, p167). Among the list of study limitations highlighted by the authors, however, are the cross-sectional nature of the study, the use of samples that are not representative, and the reliance on self-reported measures.

Auger *et al.* (2000) conducted a cross-sectional study using telephone survey of flooded and non-flooded areas, 4 months post-flood. The prevalence of PTSD in the flooded group was 20% higher than in the non-flooded group (OR= 6.08; 95% CI = 1.63, 22.64). The prevalence of emotional distress in the flooded group was 29% higher than the non-flooded group (OR = 2.42; 95% CI 1.04, 5.61). However, the study lacked pre-flood data. Another study (Maltais *et al.*, 2000) in Saguenay-Lac-St-Jean region, Quebec, Canada, involved a case-control study 2 years after the flood, and compared physical and psychological health conditions, in cases (n=177) and controls (n=168). The health status of flood victims was worse than non-victims, with the former presenting more manifestations of PTSD and higher levels of depression. There was no significant difference in terms of severe depression.

Suicide and Schizophrenia

Suicide 'is the result of an act deliberately initiated and performed by a person in the full knowledge or expectation of its fatal outcome' (WHO, 2001, p37). Two papers referred to suicides in the context of flooding. Reporting on natural disasters in the USA, (Krug *et al.*, 1998) found that flood-related suicide rates increased significantly from 12.1 to 13.8 per 100,000 ($p < 0.001$) in the four years after floods. However, these results were subsequently retracted (Krug *et al.*, 1999) after the authors found a computational error in their original findings, and the authors conceded that 'the new results for counties affected by a single natural disaster do not support the hypothesis that suicide rates increase after natural disasters' (Krug *et al.*, 1999, p148). A second paper from China

(He, 1998) reports that suicide rates in the Yangtze Basin are 40% higher than in the rest of the country. This area resembles the rest of the country in terms of socio-demographic variables, and the authors report that ‘the major difference in this region is the periodic flooding’ (He, 1998, p287). However, the paper provides no epidemiological evidence to support any link between these suicide rates and flooding. One study in The Netherlands (Selten *et al.*, 1999) focused on schizophrenia in two ‘birth cohorts’, but found no statistically significant difference between the two groups.

3.2.9 Other

Here, we briefly review a number of health outcomes – chemical pollution, nutrition, and displacement – that do not easily fit into the structure of the previous sections of this chapter. A number of other health outcomes (Acanthamoeba Keratitis (Meier *et al.*, 1998); Epilepsy (Swinkels *et al.*, 1998); Legionnaires’ disease (Kool *et al.*, 1998); Leukaemia, lymphoma and spontaneous abortion (Janerich *et al.*, 1981); and Melioidosis (Cheng *et al.*, 2003)) were highlighted by our search of the literature, but these studies will not be discussed here, as they were either weak in methodological design, showed weak evidence of an effect of flooding, or had rather implausible mechanisms in relation to flooding.

Chemical pollution

Chemical contamination may result when floodwaters inundate industrial plants and waste storage facilities, damage pipelines, or facilitate the release of chemicals from land, which may be already contaminated. Floodwaters can also cause structural damage to housing and heating systems, releasing fuel oil into floodwater, and these oils can seep into walls and stairwells, later releasing toxic hydrocarbons into indoor air (Potera, 2003). These accidental releases of chemicals may result in adverse effects on human health through various pathways – inhalation of contaminated air, and ingestion of contaminated water or foodstuffs.

In Honduras, and after the floods associated with Hurricane Mitch (October 1998), Balluz and colleagues (2001) evaluated chemical contamination of potable water and the extent of human exposure to chemicals. After conducting an environmental exposure assessment and cross-sectional survey of households with adolescents aged 15 to 18 years, the study showed that the floods had produced little contamination of water supplies, and ‘only one sample had any detectable contaminants above expected levels. This suggested that chemicals from agricultural land and chemical manufacturing and storage facilities, which were released into the water during the hurricane and subsequent flooding, were diluted or washed away with the flood water’ (Balluz *et al.*, 2001, p291). However, in contrast, all of the soil samples contained detectable levels of pesticides, and as exposure through inhalation and ingestion of food were not studied ‘these may represent significant exposure pathways’ (Balluz *et al.*, 2001, p292). For example, dust from drying fields was a major problem after the flooding.

In Grand Forks, North Dakota, fuel oil contamination led to high levels of hydrocarbons being deposited in building structures (concrete and wood), and these deposits ‘were considered to be a serious health problem’ (Potera, 2003, pA230). Floods can often lead

to a temporary loss of electrical power supply, and this shortage is often met by using petroleum-fuelled equipment. This equipment may be used in the clean-up operations. After the April 1997 Red River flood, a surveillance system was established in North Dakota, which detected an outbreak of carbon monoxide (CO) poisoning. Daley *et al.* (2001) conducted a descriptive study of these poisonings. Thirty-three patients met their case definition, and the CO source in all cases was a gasoline-powered pressure washer being used to clean flood-damaged basements.

Nutrition

Floods can influence nutritional status in a number of ways. Access to foodstuffs may prove difficult, if not impossible, when food distribution networks are unable to operate. If one assumes that most households are unlikely to have food reserves to last more than a few days, and that access is not restored within a relatively short period, increased morbidity and mortality are likely to result. Whilst the impact of these distribution disruptions will generally be confined to the area of the flood, the impacts of inundation of agricultural land are likely to be much wider in scale. The latter is likely to affect not just the local community, but those who live further away and are reliant on this agricultural land for their food production.

Two surveillance reports from the Khartoum floods of 1988 have highlighted the difficulties in measuring the impacts of flooding on nutritional status (CDC, 1989; Woodruff *et al.*, 1990). Woodruff *et al.* (1990) established that of the 17,639 children (aged 1-5 years) assessed during the period August 19-30, 1988, 13.6% were moderately malnourished, and 9.5% were severely malnourished. The second report highlighted that 'the direct impact of the flood disaster on the nutritional status of the assessed children is difficult to evaluate without prior survey information [which in this case was not available]; however, the extent of their current undernutrition is associated with an increased risk of mortality (CDC, 1989, p787).

Displaced populations (Environmental Refugees)

Although the central focus of this report is not on displaced populations it is worth noting that floods, and particularly, catastrophic floods, are liable to result in population displacement. Displacement may occur within national borders or can be cross-border. These displacements can lead to a range of health outcomes. Individuals will lose their homes, possessions and livelihoods. They may not have an alternative source of food, water and shelter. Access to essential medicines and health care may also be acutely affected. Large-scale population movements will place a particular burden on the local and national health care infrastructure.

3.3 STATE OF KNOWLEDGE: AN ASSESSMENT

The health impacts of floods are wide ranging, and depend on a host of factors. Clearly, the impacts of a particular flood event are context specific, and are also substantially different between rich and poor countries. Here, we report the main findings from the review of health impacts, which are not often generalisable due to a lack of information about exposures to the flood. This is then followed by an assessment of the key knowledge gaps and related research needs.

3.3.1 Summary of the findings

Overall, there is a surprisingly weak scientific evidence-base to assess the health impacts of flooding. Few rigorous epidemiological studies have been undertaken, and it is extremely difficult to assess the duration of symptoms and disease, and the attribution of cause without longitudinal data. In general, the incompleteness of the information entails that a) the review cannot be limited to high quality epidemiological studies; b) there is insufficient information to evaluate specific public health interventions; and c) insufficient information to address more detailed questions about vulnerability to the health impacts of flooding. A summary table providing details of the key studies that we have identified is provided in Appendix 1.

Mortality and injuries

Globally, the number of deaths due to flooding is considerable, and the greatest burden on mortality is in Asia. Mortality statistics are only available for floods defined as catastrophic. Although subject to reporting biases over time, and between countries, the EM-DAT dataset indicates that the number of deaths per event has been declining. The greatest incidence (mortality per capita per year) due to river flooding and landslides are in South America (WHO Regions Amr D and Amr B). The greatest incidence of death due to coastal flooding is seen in the Caribbean and Central America, and South East Asia (Bangladesh and India). Population growth and other factors have also increased the population at risk of flooding and so it is extremely difficult to estimate trends over time and vulnerability between countries.

The speed of onset of floodwaters is a key factor determining the number of flood-related deaths; few deaths from drowning occur during slow rise floods. There is little robust information on risk factors for drowning and age groups most at risk. However, in the USA, most flood deaths are in adult males and nearly all are car-related. In developing countries accurate information on the mortality impact of flood events is limited. Generally, there is very weak evidence about non-drowning (non-immediate) deaths that can be attributed to the flood event.

Very limited information (robust or otherwise) was available on injuries related to flood disasters. Slow-rising floodwaters are generally considered to be less of a hazard, than flash floods. There is some evidence that the burden of injuries due to floods is low in industrialised countries, and in those surveys that do report on injuries, the injuries were all relatively minor.

Infectious diseases

Overall, there are few high quality studies on flood-related infectious disease. From the studies reviewed it is clear that there is no good evidence of outbreaks of infectious disease in industrialised countries, and this concurs with previous reviews (Hajat *et al.*; 2003; Malilay, 1997).

In developing countries outbreaks of infectious diseases have been reported following major flood events, and these outbreaks vary in magnitude, and mortality. There is some evidence from India and Bangladesh that diarrhoeal disease increases after flooding (Ahmed *et al.*, 1991; Fun *et al.*, 1991; Mondal *et al.*, 2001), but this is based on only a few studies. There is weak epidemiological evidence that flooding leads to outbreaks of other infectious diseases (e.g. cholera, hepatitis, vector-borne disease). Since the early 1990s there have been numerous studies, particularly in the Americas, on leptospirosis. Although the strength of the evidence base for flood-related outbreaks of this disease is mixed, there is some good evidence (Trevejo *et al.*, 1998; Sarkar *et al.*, 2002) of flood-related outbreaks.

Mental health

The majority of flood-related mental health studies are from the USA and Europe. In general, there is good evidence that flooding has an adverse effect on common health disorders (Bennet, 1970; Reacher *et al.*, 2004; Abrahams *et al.* 1976; Price 1978; Phifer, 1988 *et al.*; Phifer, 1990), especially in the elderly. One study showed that after adjusting for pre-flood morbidity there was an increase in anxiety and depressive illness in elderly people following flooding in the USA. Further, this increase was greatest in the low-income group, and least in the high-income group. Only two studies addressed mental health impacts of flooding in developing countries. There was evidence that flooding in Bangladesh was associated with increased behavioural problems in children. Durkin *et al.* (1993) found that pre-flood none of the 162 children in their sample were 'very aggressive towards others', but after the flood 16 children (9.9%) were aggressive and this was statistically significant ($p < 0.0001$). The dearth of mental health studies from developing countries may be due to a lack of research expertise on mental health epidemiology and related services.

3.3.2 Knowledge gaps

In broad terms, we have limited knowledge of how different types of flood affect human health. Our understanding of how these types affect different populations is even more limited. The flood events reviewed in this chapter can be divided into three broad categories – 'flash flood', 'slow onset' and 'coastal' – which lead to a wide range of health outcomes that are context specific. Drawing on the evidence cited in this chapter we make some general comments about the health outcomes that result from each of these types, and highlight some of the key areas where there are gaps in our knowledge base.

Flash floods are particularly hazardous, as by their very nature they provide little warning. From the few epidemiological studies that exist, it is evident that the majority of flash-flood-related deaths are from drowning, and these tend to arise among males who drive motor vehicles through rising floodwaters. It is unclear why there have been so few epidemiological studies of this type of flood (those that exist have focused on industrialised countries), and it is even less clear why there are no epidemiological studies of flash floods in developing countries. There are many methodological challenges in studying the health impacts of floods (which probably increase in the case of flash floods), and these difficulties may be one reason for the dearth of studies. Nevertheless, it is likely that many communities (especially in developing countries) are particularly vulnerable to this type of flood, and there is a need to gain a better understanding of how flash floods affect health. Increased understanding can enable the development of programmes to prevent unnecessary loss of life and injury.

The majority of the flood events covered in this chapter are of the slow-onset type, and these are less likely to result in deaths and injuries, at least in the onset phase. The range of health outcomes described in this chapter are likely to arise in the context of a flood of this type, albeit that certain outcomes are more likely to arise in one setting compared with another. For example, the evidence cited here would suggest that flood-related outbreaks of infectious disease are less likely to occur in industrialised regions such as Europe and the USA. Such outbreaks are more likely to occur in developing countries where infectious disease transmission is an existing public health problem, and in many of these countries the public health infrastructure is less well-established, and there are many more vulnerable individuals. There is a general paucity of epidemiological studies in both North and South, and we suggest that studies need to be funded. Due to the difficulties in obtaining relevant information on flood events (including flood surveys and reports), we also recommend that an information system be created to improve access to this literature.

There is a need to improve monitoring and surveillance (see 4.2.4). On the one hand this includes maintaining and strengthening surveillance systems for infectious diseases in general. For example, leptospirosis is difficult to diagnose, and is often mis-diagnosed as dengue. There are few specialist laboratories which can make the diagnosis. On the other hand, there is a need to develop and enhance surveillance following flood events. Surveys and research should be conducted following flood events in order to determine mortality, morbidity and the associated risk factors (age, sex, housing types, socio-economic status, access to warning information, etc). Where possible, morbidity due to infectious diseases should have the infectious agent confirmed by laboratory test.

More and improved epidemiological research needs to be undertaken on the health impacts of disasters. Many studies in the review had the following methodological problems:

- Lack of pre-flood data (many collect pre-flood health data retrospectively)
- Recall bias (that is, flooded subjects more likely to report symptoms).
- Lack of control groups/individuals (that is, a non-flooded group with which to compare).
- Lack of clinical diagnosis of health outcomes (that is, objective measures of health outcome)

Most studies were retrospective in nature. Interviews were conducted post-flood and no pre-flood baseline data was available with which to compare the post-flood results. In some cases data collection was more than a year after the flood event. One study conducted a telephone survey 5 years post flood event.

We therefore make the following recommendations for the design of epidemiological studies that investigate the health impacts of floods:

- Control groups for comparison with non-flooded populations.
- Use of longitudinal data, or routine data in order to gain information on pre-flood levels of disease at individual or population level.
- Use of objective measures of disease outcome, where possible
- Improved use of routine surveillance information

Priorities for future research include:

- The impacts of flooding on long-term mental health in both North and South.
- Impact of flooding and heavy rainfall on diarrhoeal disease, and the main routes of transmission (e.g. flood waters or hygiene).
- Indirect mortality attributable to flooding (in addition to immediate deaths from drowning).
- Impacts on health from the disruption of health services and other life-supporting systems in low income countries.

CHAPTER 4

RESPONSES TO THE HEALTH RISKS FROM FLOODING

Having set out the evidence base for health impacts from flooding, this chapter turns attention to responses to those impacts, drawing on the concepts of vulnerability, coping and adaptation outlined in chapter 2. We focus on health-related responses, by which we mean actions that reduce vulnerability to health impacts and strengthen coping capacity in the face of health risks.

4.1 INTRODUCTION: THE SCOPE OF THE SURVEY

The direct health outcomes of floods can be seen as the end point of a series of events, whereby a flood event generates a flood hazard that leads to mortality and morbidity in humans exposed to the hazard. Interventions can be made to reduce risk along various points of this process, including efforts to avoid the incursion of floodwaters into the local environment and living spaces such as flood control engineering and raised house construction. Such general flood avoidance actions, however, are not the focus of this chapter, which confines its attention to health-related coping mechanisms and strategies (both private actions and external interventions). By that we mean responses geared toward the later stages of the impact process: actions geared to preventing injury and illness resulting from flooding and to promoting treatment, including the continued functioning of health services. These actions can take a variety of forms. Hence: exposure to disease can be avoided, for example, by the flood-proofing of latrines or the use of bednets; development of illness can be prevented by vaccination or social support networks; and recovery can be promoted by stockpiling medicines or ensuring health services continue to function.

The range of responses considered in this chapter loosely map on to the phases of the hazard cycle introduced in Chapter 2. Coping strategies relating to health are particularly concentrated in preparedness and emergency response, with some linkage too with mitigation and recovery phases for formal health systems. However, many of the actions cannot be too closely tied to one phase, either practically or conceptually – much preparedness for example is concerned with preparation for emergency response, recovery activities can evolve into mitigation of future floods, and there is confusion in the literature over the differences between mitigation and preparedness (e.g. early warning systems are alternatively referred to as mitigation or as preparedness). Hence, it has not been feasible to organize this section in terms of phases of the hazard cycle.

Health-related responses also take place at a variety of scales by different agents or 'actors', a variation we try to convey in the substantive sections that follow. Responses may take place at individual, household, community, city/district, regional, national and international scales. One of the most problematic of these scale categories to define is 'community', which has only vaguely defined connotations of local-scale social linkages and shared place-based identity. Warburton (1998, p15) suggests the term is perhaps best understood by 'recognising what it is not: it is not state, society, association, individual'. In applying the term it is important to avoid the simplistic idea that communities are necessarily consensual or socially homogenous entities (Leach *et al.* 1997). As with other scale categories, communities are characterised by internal differences and divisions that may become manifest in health-related response to crises.

Actions by different actors, with different sets of assets and capabilities, loosely map on to these scale categories. The principal types of actor in this context are:

- 1) Individual people (affected by floods, in proximity to floods, or subject to flood risk);
- 2) Community-based organisations;
- 3) Local health care providers (dispensaries, surgeries, clinics, health centres, hospitals);
- 4) Local service providers in preventive health (health education, public safety and environmental health teams);
- 5) Local water and sanitation providers;
- 6) Regional and national government departments;
- 7) Non-governmental organisations (NGOs);
- 8) International agencies.

As well as reflecting different hazard management stages and scales of action, we also try to depict as far as possible actions in different global regions. One of the key dimensions of geographical variation is the disparity in health outcomes between North and South that has been indicated in Chapter 3, and which is reflected further in this chapter. However, it is important to note that the disparities are more complex and less bipolar than any developed/developing country division might suggest. Differential coping capacity relates not just to the distribution of material resources but also to context-specific aspects of culture, social organisation and relations of social power that may shape human vulnerability, risk perception and risk behaviour.

Section 4.2 now discusses in detail the findings from the literature and material we have surveyed, examining a series of response themes in turn. It should be noted from the outset that relatively few of these studies or reports directly focus on health issues and that there is a paucity of analytical material by which to gauge the effectiveness of many of the responses described. However, each section raises a number of issues that feed into the further analytical discussion in Chapter 5.

4.2 REVIEW OF HEALTH-RELATED RESPONSES TO FLOODING

This section discusses in detail the scope, importance and issues associated with health-related responses to the impacts of flooding. These are grouped under seven main categories, starting with health protection undertaken by vulnerable populations themselves, and moving through aspects of health education, public safety, disease surveillance and control, health care provision, protection of health infrastructure and the protection and provision of water and sanitation systems. In each section, we first set out in broad terms the types of coping mechanisms and strategies described in the literature, before discussing some of the issues relating to them. It should be made clear that *this document does not attempt to provide a comprehensive manual of response options*: the focus of this work instead has been on assessing processes and policy-related issues regarding response and adaptation. However, a summary list of the types of responses identified is provided in Appendix 2.

4.2.1 Action in the Home and the Community

We focus first on actions undertaken by vulnerable people themselves in the home and within the community to prepare for and cope with the health risks of floods. Though it has received little attention to date from academic studies (Few, 2003), health protection coping mechanisms at the grassroots provides the frontline of defence against flood risk. In a recent report, the aid organisation Tearfund stressed: 'the ability of local people to resist the impact of disasters should not be under-estimated. In fact, local coping mechanisms must form the basis of international development support' (Tearfund *undated*, p15).

As with all aspects of vulnerability, the coping options available to people are shaped by attributes both of the society in which they reside and of the individual, including access to social networks. On the latter, Shahaduzzaman (1999, p47) notes: 'How people cope will be determined by their personal strengths, those of their families, friends and community and on the resources, which they have or receive'.

Household actions

Analysis of household coping strategies against flood has seldom concentrated on health protection. Most studies that we have identified examine efforts to maintain income and economic livelihood, which may themselves impact on health. Del Ninno *et al.* (2001), for example, report on how borrowing, selling belongings and reducing food consumption became short-term economic coping mechanisms for poor families affected by the extreme Bangladesh flood of 1998, and Skoufias (2003) points out that such actions can have adverse long term health and nutritional impacts. Few coping actions directly relating to health have been discussed in the literature surveyed, but the material that does exist suggests that this may reflect a lack of reporting.

People may make coping adjustments to their dwellings, both to resist the incursion of floodwater but also to prevent exposure and injury when floods enter (Parkinson, 2002). Placing electrical wiring high up on walls in flood-prone environments is one such example. Prior to flood seasons households may make advance purchase of medicines to tackle common diseases that arise during floods such as skin infections. In studies in the Mekong Delta of Vietnam, Few *et al.* (2004) list a number of household coping actions including avoidance of exposure to water in houses by raising furniture on bricks and creating raised walkways from planks, and removal of unused vessels where mosquitoes can breed after flooding has receded.

In countries of the South, where flooding often poses severe threats to water supplies (see section 4.2.7), evidence suggests that people make major efforts to obtain clean drinking water. An evaluation of relief efforts for the 1999 cyclone disaster in Orissa, India, suggests that mortality resulting from polluted water following the event was low and that this 'was caused as much by strong local coping mechanisms amongst the people themselves as it was by the initial relief efforts' (INTRAC 2000, p24). People generally recognised the need to avoid sources of water polluted by nearby carcasses and made widespread use of fluid in coconuts for drinking (coconuts were abundant because of the destruction of palms). Ahmed *et al.* (1999) report that after the 1998 Bangladesh floods people switched to fetching water from distant non-contaminated

tubewells and from new sources such as schools and mosques. Boiling of water, and use of alum crystals or disinfection tablets are common means of purifying water supplies at the home.

A number of studies of household-level coping responses relating to mental health come from the USA, detailing psychological coping mechanisms and the role of emotional support within the household. Smith (1996), in a study of the 1993 Midwest flood, identified how a 'problem-focused' active coping mentality was positive for mental health: active coping efforts directed to clean up and recovery were associated with lower levels of psychological distress. Russoniello *et al.* (2002) examined coping strategies of children after the flooding events of Hurricane Floyd in 1999. They noted how ineffective coping patterns such as social withdrawal, self-criticism, problem solving (unresolved) and blaming of others were strongly related to post-traumatic stress disorder (PTSD). Effective coping strategies included: 'wishful thinking (hope), distraction, social support, cognitive restructuring, and resignation (accepting the reality of the event)' (Russoniello *et al.* 2002, p69). From work with flood victims, Deering (2000) stresses the strong role that parents and significant adults play in conditioning children's response. Providing emotional support for children is key, through activities such as comfort, reassurance, restoring routine and talking through events.

Community actions

As for the household level, there is little material analysing communal activities in health risk reduction in relation to flooding, although we again suspect this may be a reflection of lack of critical attention to the subject. Surveying the material that does exist describing community-level action strongly suggests that several types of response at this level may be of key importance in influencing public health. One crucial area in terms of public safety is warning and evacuation, for which community-based activities may provide the key to survival – a theme addressed specifically in section 4.2.3. Some such mechanisms are traditional, such as the ropes with bells attached tied across rivers prone to flash floods in parts of northern Pakistan that provide last-minute warning to fishermen (Davis and Hall, 1999).

Two studies provide examples where communities have responded to the efforts of public and external agencies to foster general community preparedness for hazards, including their health aspects. Lichterman (2000) describes a number of successful community-based 'citizen disaster preparedness programs' in different parts of California, USA, which include training in reducing household hazards, preparing emergency kits, evacuation plans, first aid, and also advanced training in disaster medical aid and disaster mental health for volunteers to work alongside professional personnel. One scheme provides 'first-responder' training to make communities as self-sufficient as possible in the immediate aftermath of disasters. In Los Angeles, up to 400 people per year trained in a 7-week Citizen Emergency Response Training program. Luna (2001) discusses the work of NGOs in the Philippines in community-based flooding and disaster management, including the establishment of village committees and training in fields such as evacuation management, and health and sanitation.

In terms of emergency response to floods, there are examples of both spontaneous relief efforts by community members and efforts coordinated by external bodies. Studies of the

1998 floods in Bangladesh, for example, yield various reports of spontaneous communal coping mechanisms relating to health. Karim *et al.* (1999) note how a group of students opened a centre at a school in Dhaka for preparing oral rehydration packets to a standard WHO formula and distributed them to affected households. A study by the organisation BRAC during the same flood notes distribution of food and other materials by richer families to poor neighbours in rural areas, and people sharing boats with neighbours for essential travel. 'In one slum area, a group of ten women bought together a boat for Tk 1,800 to move about and go to private places for their personal hygiene and bathing' (Ahmed *et al.* 1999, p23). Nishat *et al.* (2000) report that volunteers often organised themselves into groups to provide relief including shelter, food, drinking water, treatment of the sick, and distribution of water tablets.

Nishat *et al.* (2000, p232) add that '...in future, this kind of cooperation from the general population may be of great help and proper planning and coordination of these efforts are required'. They recommend that formal health systems should encourage participation from the community and voluntary organisations in medical teams during crises. The potential for coordinated volunteer action was demonstrated in Orissa, India, after the 1999 cyclone, when the government appealed for volunteers to help dispose of human bodies and animal carcasses, and thousands came forward (INTRAC 2000). In Vietnam, local voluntary effort in rescue and medical assistance during floods is coordinated on a large scale by a network of mass organisations, including the Viet Nam Red Cross (Few *et al.* 2004).

Research by Gillard and Paton (1999) in Fiji notes the role that local religious organisations can play in hurricane preparation and response, particularly in providing spiritual and social support to help alleviate stress among victims (although, in certain circumstances, the direction of support may be reversed). Clemens *et al.* (1999) note that informal support networks within communities can also help lessen negative emotional impact from the experience of flooding. Social and emotional support for flood victims by fellow community members is reported in both the South and the North. According to Enarson (2001, p6), in the 1997 flood of the Red River Valley, USA, women drew on extended networks to share hazard information, make contingency plans and organise 'nonfamily or institutional care of the young, old, sick, and disabled'.

Research on the social psychology of floods and other disasters has yielded insights into the processes through which community bonds tend to be disrupted and reorganised in the post-impact phases. Gordon (2004), for example, defines stages of initial 'debonding' and then temporary high levels of social 'fusion' in the immediate emergency phase, leading commonly to a disruptive stage of social 'cleavages' in the early recovery phase (when many of the psychosocial problems associated with flooding tend to develop). Efforts to foster community preparedness, facilitate social communication and establish appropriate local organisational structures to manage recovery can all serve to smooth the rehabilitation process and minimize social disruption.

Issues in household/community response

The nature of action at the grassroots to protect against floods depends fundamentally on **how people perceive the risks**. Stephens *et al.* (1994) provide one of the few academic studies that looks explicitly at perceptions of environmental health risk from

flooding. They found that flood-prone urban communities in Indore, India, broadly understood the health effects that floods might bring and especially the relationship between sewage contamination and waterborne disease. However, they freely traded that risk off against the livelihood advantages of an inner city location, and were prepared to 'live with' flood hazard, making only simple modifications in housing and behaviour to try to avoid its worst effects. Such a 'hazards culture' oriented to living with floods is replicated in many parts of the world. It may contain within it aspects that heighten susceptibility to flood impact, but it also usually entails a series of customary coping mechanisms borne out of experience and preparedness. Perceptions of flooding and responsibility for action are likely to be highly contrasting in communities that are not accustomed to dealing with flooding, and may also vary within different cultural groups. For example, Pakistani women recently resident in the UK expressed surprise at being flooded in an industrialised country but expected it in their native country (Tapsell *et al.* 1999). Tapsell and Tunstall (2000 and 2001) found a general lack of preparedness for flood events among people in their studies of communities in both northern and southern England.

Lack of effective coping mechanisms may be a more complex matter than simply failure to perceive risk or lack of material assets. It may have reasons that relate to knowledge, education and cultural norms. In the Bangladesh cyclone of 1991, Hoque *et al.* (1993) found that many people understood the risks from contaminated water but were unable to treat their sources. Many were unable to boil water because they were displaced from their homes and possessions or could not afford fuel. But chemical treatment was also hampered by a lack of awareness of methods such as bleaching or use of alum, and though people may have received water purification tablets they had been given inadequate information on how to use them. In the 1998 floods in Bangladesh, Ahmed *et al.* (1999) note that women experienced major difficulty in accessing alternative toilet sites when household latrines were flooded. They report that many women had little choice but to squat in water, in twilight or darkness, or defecate in the home. 'During the flood, women used to drink less water and take less food so that they would have to urinate and defaecate less frequently' (Ahmed *et al.* 1999, p12). Indeed, coping mechanisms relating to sanitation generally seem to be less effective than those for water supply in several reports from developing countries. (See also sections 4.2.2 and 4.2.7).

Where coping action is taken it may also be ineffective or counter-productive. **Inappropriate coping actions** are sometime referred to as maladaptation. The long-term health and nutritional problems that may result from short-term economic coping strategies have been noted earlier, but maladaptive responses may also be directly related to health. In this sense, Hoque *et al.* (1993) caution against reliance on disaster volunteers who are inadequately trained or supervised. They note that, during the 1991 Bangladesh cyclone many relief personnel, who, for example, helped repair tubewells, remove corpses, and distribute water purifying tablets, admitted in interviews that they did not know enough about appropriate environmental health measures. Also, many were not giving adequate instruction to people on water tablets, which sometimes were emptied from packets and distributed loose to people with no storage and usage instructions.

Partly to avoid inappropriate and ad hoc flood responses, at-risk communities may be best served by advance efforts in **local capacity building** to enable them to plan for and coordinate their own emergency response effectively in the immediate post-disaster

phase. Improving community-level coping capacity, organisation and self-reliance in the face of future threats has emerged as a key aim for many agencies involved in hazard response. In their emergency work, Action Aid aim to focus increasingly on long term capacity building for poor people (Action Aid, 2002) and, in an evaluation of relief work after Hurricane Mitch in Central America in 1998, Espacios Consultores (2000, pvi) stress the need for 'a long-term commitment to developing local capacities'. Involvement and responsibility for community-based hazard preparedness also has to be broad-based within the community. Maber (1989) reports on a participatory programme of water/sanitation and health promotion in Peru that was set up as response to lack of facilities and preparedness to a major El Niño flood in 1983. Community involvement in the process he claims gave them knowledge to run and expand it themselves: 'In the long term, this reduces their dependence on outside assistance and ensures that the community will be better able to cope with the next disaster' (Maber 1989, p31). Community participation, however, can prove more straight-forward on paper than it is in practice, as experience from many fields of development amply shows (Cooke and Kothari, 2001; Pugh and Potter, 2003). Box 4.1 provides some perspectives on community involvement in relief and recovery in floods and other natural disasters.

Box 4.1 Perspectives on community involvement in disaster relief/recovery

According to Tearfund (undated, p18): 'Governments, aid agencies and local authorities should work alongside poor communities in vulnerable countries to identify and reduce the risks they face'.

An evaluation of the activities of external agencies in Orissa in the aftermath of the 1999 cyclone strongly advocated greater inclusion of affected populations in decision-making. 'Future emergency responses need to build on the innovative participatory work of some DEC agencies and their local NGO partners in increasing the involvement of poorer people in the planning and monitoring of relief and rehabilitation activities' (INTRAC 2000, p58).

The latest World Disasters Report (IFRC, 2003) notes that in the early phase following a disaster event, it is local people and organisations that take the first crucial steps in response and recovery. Moreover, once external agencies arrive, the report argues it should be local people who remain the key decision-makers: they have the necessary local knowledge and also they should be the ones directing their own recovery.

In order to facilitate community-based decision-making a crucial role for external agencies should be in capacity-building. But there is a fine line between fostering action and directing action, and before any intervention crucial questions should be asked. 'The issues can be distilled down to two very simple but fundamental questions: first, what do vulnerable people and disaster victims really want and need?; second, do our actions contribute in meeting those needs in any real way?' (IFRC 2003, p62).

Yet, a report on relief efforts after Hurricane Mitch in 1998 suggests that effective community involvement may not even be feasible in the early stages after disaster. 'Many community members recall a state of shock and disbelief that would have precluded any serious effective participation in the humanitarian assistance programs that served them' (Espacios Consultores 2000, p17).

4.2.2 Health and hygiene education

This section focuses on health and hygiene education specific to flood situations. Like section 4.2.1 it examines aspects of health promotion targeting vulnerable populations, but the prime interest here is on ‘exogenous’ efforts by non-local agencies – governmental and non-governmental – to directly advise the public on health/hygiene practices that reduce health risk.

Content and delivery

The American Red Cross provides detailed information for households and individuals on preparedness and safety measures against floods and flash floods, including how to react to flood warnings, how to evacuate, suggestions for a family disaster plan and a disaster supplies kit (American Red Cross, 1998). It is beyond the scope of this document to discuss safety and preparedness measures in detail, but is worth noting that the overall content (if not perhaps the detail) of health and hygiene guidance in flood situations is broadly similar across different regions.

The website of the Centers for Disease Control and Prevention (<http://www.bt.cdc.gov/disasters/floods/index.asp>) provides specific health advice for the US public during floods. The guidance covers: purification of drinking water, disinfection of wells, food safety, sanitation and personal hygiene, precautions during return to and cleaning up of flooded homes, mosquito control, and threats from animals, chemicals and swift flowing water. Becker *et al.* (1999) suggest education materials in the USA should include warnings to drivers not to drive in flash flood risk areas or across roads/bridges covered by rapid water, and recommendations that people with asthma returning home should guard against exposure to mould and mildew. Draft guidelines designed to reduce health risks from flooding provided by the Public Health Laboratory Service in the UK cover general hygiene to prevent exposure to contaminated water and surfaces, cleaning and drying of surfaces and materials, food and drinking water safety, and avoidance of electrical hazards (PHLS, 2000). All these sources from the North reflect general principles for hygiene practices during disaster situations listed by Wisner and Adams (2002) for both North and South (See Table 4.1).

The Sphere Handbook on humanitarian assistance suggests that hygiene promotion in general disaster response should target the key risks in each context – these are likely to relate to excreta disposal, toilet use and maintenance, hand washing hygiene, water collection and storage, and food storage and preparation (The Sphere Project, 2004). One of the most important functions of such efforts should be addressing key misconceptions about effective hygiene. Malilay (1997) similarly underscores the importance of health education addressing common gaps in public understanding, such as the link between driving and drowning deaths during flash floods.

Table 4.1 Household health and hygiene during disasters: key themes

<i>Theme</i>	<i>Consideration</i>
Water safety	Sources of water Collection and storage Use of water
Excreta disposal	Hygienic places for defecation Children's sanitation
Waste disposal	Solid waste Liquid waste
Vector control	Removal of breeding sites Personal protection
Personal hygiene	Water for washing Washing of hands
Shelter	Continued use of the home Return from shelter
Food safety	Food handling and preparation Feeding babies

Source: adapted from Wisner and Adams (2002, pp250-252)

The delivery of education messages may be by various means, depending on context and resources, including written materials, radio and television broadcasts, public meetings and demonstrations, and household visits. In Vietnam, much of this work is undertaken through conventional propaganda channels such as the local government loudspeakers sited throughout communities (Few *et al.* 2004). Following the Orissa cyclone (1999), UNICEF assisted with production of handbills and loudspeaker announcements, and supported a series of hygiene education programmes for 3,900 teachers (Palakudiyil and Todd, 2003). A newspaper article on public safety during the 2004 floods in Bangladesh illustrates the role of the media in information provision, offering specific advice for householders on topics such as use of salvaged food, disconnection of electrical appliances and the threat from venomous snakes taking refuge in homes (The Daily Star, 2004).

Issues in education activities

Health and hygiene education can be provided as flood preparedness in flood-seasonal environments or distributed as emergency response during and after the flood event. But whatever the timing of delivery the key to effective education appears to be **advance planning** to ensure information provided is accessible, appropriate and widely disseminated. For example, drawing lessons from the experience of Hurricane Floyd (1999) in North Carolina, USA, Becker *et al.* (1999, p371-372) note: 'public service announcements, educational materials, and training programs on hurricane preparedness should be made accessible to all communities before the hurricane season'. The manual for contingency planning for floods produced by Caribbean Environmental Health Institute (2003) stresses that for each aspect of environmental health a key action is to ensure not only that public advisory and education materials are developed but also that mechanisms are in place to disseminate them.

Tapsell *et al.* (2002) report a series of complaints from focus-group participants after floods in the north-east of England (2000) that public health information was delayed.

‘Flyers were sent out by local authorities a day or two after the floods, advising people to wash their hands if they were handling contaminated goods. Most people stated that these notices arrived too late as they had immediately begun to clean their homes the moment the flood waters had receded’ (Tapsell *et al.* 2002, p1517).

The participants in the study also complained that they had received conflicting advice on health from different authorities. Clarity of message also depends on the **form of the message**. The Sphere Handbook on humanitarian assistance stresses the need to ensure materials reach all vulnerable sectors of the population and are appropriate to all. In situations where literacy is low, it may be more culturally appropriate to communicate hygiene promotion through participatory techniques other than written instruction (The Sphere Project, 2004). Wisner and Adams (2002) add to this that a first step should be to establish a need for the education activity with people and involve community members in production of materials to ensure they are relevant and appropriate. To enhance receptivity to the materials, there should be an effort to encourage positive existing practices and to avoid judgemental messages that suggest people are to blame for their family’s ill-health.

With thoughtful intervention, it may be feasible to draw positive lessons from flood experience during the recovery stage to **enhance health promotion in general**. Maber (1989) reports how flood disaster highlighted poor hygiene practices and inadequate knowledge of causes and treatment of common diseases in a town in north-east Peru. Health promotion became a key parallel activity to a participatory programme of sanitation works. A community medical centre was established, which concentrated efforts on regional campaigns, education programmes and workshops on general preventive medicine and practices. In India, after the Orissa cyclone in 1999, relief agencies became involved in training programmes for local volunteers and teachers that took a similarly wide approach to the communities’ future health needs (Palakudiyil and Todd 2003).

4.2.3 Warning and Evacuation

Ensuring public safety during the onset of floods is of course a key dimension of health-related response to floods. It is not appropriate in this review to discuss general aspects of forecasting, risk mapping and warning technology, but it is important to talk here about the role of warning systems and evacuation procedures in health preparedness and emergency health response. Efforts to preserve public safety through warning and/or evacuation may not always be effective, especially in rapid onset situations. In their UK study, Tapsell *et al.* (2002) describe how the flashy nature of flooding made warning difficult and hampered people’s ability to react. Moreover, there will almost always be individuals who are ‘risk-informed’ but fail to react to warnings because of insensitivity to risk, competing priorities or an inability to respond (Glantz, 2004; Handmer, 2000). Nevertheless, well organised warning and measures to ensure appropriate response by citizens can play a crucial role in saving lives and reducing injury (Menne, 1999).

For Africa, Parker and Thompson (2000) note that making the public aware of flood-prone areas and providing warnings is important in reducing death and injury, while Tearfund (undated) emphasize the key role early warning systems (EWS) and cyclone shelters now play in protecting communities in the Bay of Bengal from tropical windstorms. Kircher *et al.* (1987) reported that in the USA, where flash floods were the foremost weather-related cause of death, studies suggested that people failing to respond to warnings were more likely to die. They advocated local disaster plans developed with the people and periodically tested with them. Becker *et al.* (1999) emphasise the need for advance information to be circulated on flood risk zones and safe vehicle evacuation routes before the US hurricane season. As Wisner and Adams (2002) note, early warning is also important for public and environmental health systems to have time to prepare and make emergency assessments.

Integrated approaches to warning and evacuation

Evidence provided by studies and reports from many sources emphasise the importance of setting up integrated emergency systems. Too often there has been an over-emphasis in investment in scientific and technical aspects of forecasting and a relative neglect of effective systems for warning dissemination (Parker, 1999). According to the Red Cross/Red Crescent, to be effective, all links in the chain from high-tech meteorological forecasting to local evacuation announcements and plans must be in place (IFRC, 2002).

Some good examples of integrated, pre-prepared warning, safety and evacuation systems have been recorded in hazard-prone regions in both South and North. Floods were a major hazard associated with Hurricane Michelle in Cuba 2001, but, though the storm was extremely powerful and destroyed 8,700 homes, only five people died (Palakudiyil and Todd, 2003; Thompson and Gavira, 2004). According to the World Disasters Report of 2002, the United Nations put the small loss of life down to high disaster preparedness. Advance planning by civil defence authorities and agencies combined with effective dissemination of emergency information through state-run media, enabled the evacuation of 700,000 people to shelters before the storm struck (IFRC, 2002).

Kircher *et al.* (1987, p119) put the lack of deaths and injury during dam-break floods in Essex, north-east USA, in 1982 down to timely evacuation, facilitated by: 'responsible monitoring, effective communication and compliance with directives'. Also, a high degree of trust existed between town officials and citizens. The town authorities identified the danger early and monitored dams for signs of failure. The evacuation was then well coordinated by the fire service, aided by a high degree of trust that the authors claim existed between town officials and citizens. Partly because of the small size of the town the fire service were able to go from door to door. The personal approach helped avoid confusion, and all people warned were evacuated.

Much of these efforts are taken on by government, and PAHO (1999) advocates that a single national agency be given responsibility for overall integration and coordination of early warning systems. However, the same report also stresses the need to ensure there is sufficient local capacity to interpret warnings and take appropriate action. Indeed, warning and evacuation activities may also be community-based. When Hurricane Mitch

struck Central America in 1998, few communities were prepared for the impact of high winds, floods and landslides. In contrast with neighbouring sites, however, there were no deaths among the inhabitants of La Masica on the coast of Honduras, where external agencies had supported a local capacity-building programme for risk reduction featuring a community-based flood early warning system (Maskrey, 1999; Tearfund, undated). Similarly, there was no loss of life along the Coyolate River in Guatemala, although 300 people perished in floods along other rivers. There, communities had jointly worked to map flood hazard, establish a high-rainfall alarm system, monitor river levels and build evacuation shelters (IFRC, 2002). Similar activities have recently been implemented after the 2000 floods in Mozambique (see Box 4.2), building on the existing efforts by Red Cross and other organisations in emergency response such as boat rescues (Christie and Hanlon 2001).

Box 4.2 Community-based warning and evacuation initiatives in Mozambique

Early in 2000 Mozambique experienced its worst flood disaster of recent decades. According to Cosgrave et al (2001) the floods caused estimated damages of £500 million, displaced over 500,000 people and killed 700 people. One of the world's poorest countries also suffered severe damage to its transport, school and health infrastructure.

One of the key lessons of the 2000 disaster in Mozambique has been the need for more effective flood warning systems that are trusted and responded to by the community (Christie and Hanlon, 200; IFRC 2002). The country has since invested in low-technology initiatives: equipping school teachers and community leaders to monitor river levels and issuing warnings during times of flood alert. In Matasse, a rural community of 2,000 people, the Mozambique Red Cross (CVM) initiated a community-based disaster preparedness project, in which volunteers are trained to analyse local hazard risks in space and time (seasons) and identify appropriate refuge sites (IFRC, 2002). The government has also now issued radios, bicycles and motorcycles in risk areas to local people involved in hazard monitoring (Palakudiyil and Todd, 2003).

In northern Cambodia the aid organisation Action Against Hunger has helped establish 'safe areas' for flood evacuation in rural areas (British Red Cross, 2001c). The agency consulted villagers to identify traditional safe areas both within the village (higher-placed houses) and external to the village (other villages on higher ground). Water supply and sanitation infrastructure was then improved at these sites, to better serve evacuees and benefit the host communities year-round.

The integrated approach has been taken a step further in Australia, with the concept of a 'total flood warning system'. This holistic approach combines planning for flood prediction, impact assessment, warning dissemination, agency response and community response, and emphasizes processes of community involvement, institutional cooperation and continuous review and improvement of procedures (Handmer, 2000).

Organisational issues: getting an effective system in place

In a series of articles, Perez and Thompson (1995a, 1995b, 1995c) discuss the major challenges that apply to warning and evacuation systems for flood-related climatic hazards. As well as noting technological issues in information gathering, they note a

series of social issues in communicating warnings to people and prompting people to respond to them.

'The capacity for nations or communities to develop warning systems is affected by population size, financial or other resources, linkage with media, use of radio and television, government-citizen relationships, frequency of extreme events, willingness of officials to risk false alarms, relationship among governmental units, and organizational capacity' (Perez & Thompson 1995b, p88).

First, effective response to the onset of flooding requires **careful advance planning** to ensure warning systems are broadcast widely and messages coordinate well with evacuation plans (Menne, 1999; Perez & Thompson 1995b). The former is aided by the use of delivery mechanisms such as radio and television announcements, telephone alerts, siren warnings and loudspeaker alerts. In the USA, public warning mechanisms for tornadoes, which are often accompanied by severe flooding, include automatic telephone warning alert systems, cable television overrides, and public education programmes (Greenough *et al.* 2001). Coordination of warning with evacuation usually requires a **presence 'on the ground'**: leaders and volunteers to help persuade people to take warnings seriously, take avoidance action and, if necessary, evacuate their dwellings (Palakudiyil and Todd, 2003; Wisner and Adams, 2002).

If evacuation is advised, it is vital that **appropriate shelter** is provided - adequate in size and accessible. The 1991 cyclone in Bangladesh revealed early problems with large purpose-built cyclone shelters (with space for up to 1500 people) constructed in the flood-prone coastal lands on the Bay of Bengal (UNICEF Cyclone Evaluation Team 1993). The population interviewed complained of an inadequate number of shelters, separated by long distances, and that some were hard to reach because the access roads to them were themselves flooded. Instead of these large shelters, the evaluation report suggested a better alternative might be the reinforcement of a series of small (multi-purpose) buildings within communities that people could reach more quickly. The ease of accessibility is especially important for people with disabilities and others with limited mobility. Chowdhury *et al.* (1993), reporting on the same event, stressed the need for more shelters and better provision within them of drinking water supplies and latrines. After the cyclone in Orissa in 1999, an evaluation recommended not only capital investment in more shelters to meet the population needs, but also investment in social capital – in work with local communities and organisations to encourage them to maintain and use the shelters (INTRAC, 2000).

Behavioural issues: public response to warnings

A system for protecting the public from flood hazard is only effective if the public takes note of warnings and acts appropriately. In a useful discussion of the constraints on early warning systems, Glantz (2004) notes, for example, that many people may develop a false sense of security and relax their self-protection mechanisms in situations where they perceive it is the government's responsibility to protect them. Human behaviour in times of emergency must therefore be a crucial consideration in overall planning of warning and evacuation systems. It is important to understand the social and cultural influences on response behaviour in designing and targeting health education and warning messages.

Because there may be a social differentiation in response to warnings it is important that the approach to communicating risk is flexible enough that it can be **targeted to the needs of different groups** (Glantz 2004). Kircher *et al.* (1987) note that the likelihood of individuals taking emergency action or evacuating their home following flash flood warnings tends to be higher than the mean for those with recent disaster experience, and significantly lower for the elderly or for people living alone.

Several authors point to the need to **ensure warnings are communicated with clarity and in accessible language** to maximise public understanding of the nature of the risk and the advised response. UNICEF Cyclone Evaluation Team (1993) report that, although almost all people in their study sites in Bangladesh had received several hours notice of the 1991 cyclone's approach from local volunteers and radio announcements, most people did not take shelter until the winds and tidal waves hit. The majority of respondents said they had not understood the warning or details of the storm's severity. Eight years later in Orissa, Palakudiyil and Todd (2003) report that the lack of a truly integrated warning system meant that communication of the approach of 1999 supercyclone was not effective. Warnings were scientific rather than user-friendly – they did not enable people to assess the risk to themselves and take appropriate evacuative action.

'Early warning must be more than a technological instrument to detect, monitor and inform. It should provide an assessment of risk in a language that is understood by a non-technical audience' (Palakudiyil & Todd, 2003, p15). Wisner and Adams (2002) stress the use of simple language, clear statements of the threat and implications, and identification of the potential victims. It is also important to avoid delivery of conflicting messages from different warning systems. Pilon (undated) further stresses that for information to be communicated effectively, the design of the message and the nature of the advice must be sensitive to differences in economic status, language, gender and cultural barriers.

Another vital consideration is **the level of trust** people have in those giving the warnings. The study by Kircher *et al.* (1987) pointed out the importance of trust between town officials and citizens in smoothing the evacuation process in the case of Essex, USA. In Mozambique 2000 flood warnings were given, but many of the deaths were from people who ignored them (IFRC, 2002). Lack of trust by communities in those delivering the warnings was thought to be a major reason for failure of evacuation, and the Mozambique president later suggested that community leaders or trusted figures such as primary schoolteachers should be given a role of both monitoring river levels and issuing community warnings. As already noted, having people 'on the ground' with sufficient influence to persuade fellow community members to heed warnings may be crucial (Wisner and Adams, 2002).

The case of the 2000 Mozambique floods also raised another very difficult issue relating to the **timing of evacuation advice**, particularly in situations of poor home security against theft and poor livelihood security against loss. It has been suggested that many of those who perished after ignoring the warnings had stayed behind to look after livestock and possessions (IFRC, 2002). The timing of warning messages and evacuation advice may have to take such concerns into account. In stressing the need for better warning and evacuation systems in Mozambique, Christie and Hanlon (2001, pp151-152) state: 'Such a system must give people sufficient advance warning to

prepare. But it must also sound the alarm in such a way that people can safely wait until the very last minute before fleeing.'

4.2.4 Disease surveillance and control

Disease surveillance refers to the systematic collection and analysis of data on communicable diseases. It is important for efficient resource allocation, planning of preventive strategies and public health interventions, and the identification of special needs (Dietz *et al.*, 1990; CDC, 1993a). Two dimensions of disease surveillance are key in relation to response and adaptation to flooding. First, a functioning well defined and documented disease surveillance system provides the baseline data against which changes in incidence can be detected after an extreme event such as a flood. Second, a specific disaster related public health surveillance system of mortality and morbidity covering endemic diseases, infectious diseases, injuries and vector populations should be established following a flood (Malilay, 1997). Also water quality should be monitored. Such a post-flood surveillance system helps to identify changes in disease patterns and outbreaks (defined as 'more cases than expected'). Noji and Toole (1997) argue that timely data collection and analysis provides the foundation for effective disaster response, and Franklin *et al.* (2000) suggest that academic medical institutions can play a key role in emergency response in this respect, providing specialist support and expertise to boost the surveillance capacity of the public health system. Both types of surveillance system need to be well defined with regard to the selection of diseases, case definitions, methods, documentation and duration. Data need to be collected, compiled, documented, analyzed and results shared with decision makers on a regular basis (Malilay, 1997).

Utilizing surveillance information, control measures can be put in place that specifically tackle disease risk associated with floods. As well as preventive control measures, responsive control strategies (including treatment) need to be in place to react as soon as possible to irregularities or outbreaks of infectious diseases. Disease outbreak control includes actions to protect susceptible populations, such as immunization and hygiene education, as well as direct efforts to combat the disease organism and its vectors, such as water treatment and mosquito control (The Sphere Project, 2004). In many cases, routine practices such as vector control may become disrupted by flood events and it is important to ensure that they are able to resume as rapidly as possible (Caribbean Environmental Health Institute, 2003).

Priority measures

As Chapter 3 has shown, literature on severe floods from countries of the North suggest that the risk of infectious diseases is very low, and hence control measures tend to be of low priority. Nevertheless surveillance relating to the range of health impacts from floods may take place. Following the floods in Iowa in 1993, the CDC assisted in implementing a surveillance system to monitor flood related injuries, illnesses and impacts (CDC, 1993b). A surveillance system for infectious diseases was established by the North Carolina Department of Health and Human Services in a flood-affected county, registering 150 reportable health effects (Booker, 2000). Data were compared with

results from 1998, underscoring the value of reliable baseline data, often missing in developing country situations.

In developing countries, however, infectious diseases pose a real threat after floods, emphasising the importance of surveillance and control systems. In Puerto Rico, following tropical storm Isabel in October 1985, a shelter surveillance system was established monitoring 19 acute and chronic conditions (such as fever, diarrhoea, conjunctivitis, upper respiratory tract infections, pediculosis, injuries, stress, vomiting, and asthma) in 28 shelters over a 5 week period (Dietz *et al.*, 1990). The authors emphasize that such a system needs to be standardized and representative for the entire hazard area (not just the most affected locations).

In the aftermath of Hurricane Mitch cholera outbreaks and increased infectious disease incidence emphasized the need for epidemiological surveillance (PAHO, 1998). Due to the physical damage to the health services, water and sanitation facilities, overcrowding in shelters and movements of populations, the incidence of cholera and other water-borne diseases, leptospirosis, dengue and malaria had increased in urban areas and in poor populations.

Biswas and colleagues (1999b), who report about increases in diarrhoeal diseases and acute respiratory tract infections as a consequence of severe flooding in West Bengal, India, also stress the need for disease surveillance and control. Reporting from their experience during the 1998 floods in Bangladesh, Hossain and Kolsteren (2003) assign top priority to the control and the treatment of diarrhoeal diseases in flood-affected areas. The WHO media centre (www.who.int/mediacentre/releases/2003/pr47/en; accessed on 9th of June 2003) recommended especially surveillance of diarrhoeal diseases and vector-borne diseases following severe floods in Sri Lanka because of the damage to water and sewage systems and displaced people in overcrowded camps contributing to the increased risk.

Risk of increase in mosquito-borne diseases is often a major concern following floods in the South. However, control spraying to kill mosquito larvae may not always be feasible during widespread flood conditions, and hence disease control may at this stage have to rest on preventive behaviour in the home. Durrheim and Govere (2002) report on effective control of a post-flood malaria epidemic in a community in South Africa through promotion of a twice-nightly application of insect repellent on ankles and feet. The pre-epidemic malaria incidence was restored, and the approach is recommended for consideration generally in areas with seasonal and unstable malaria transmission.

Guha-Sapir *et al.* (1991) address the question of strengthening existing surveillance systems following severe flooding in order to control possible epidemics of leptospirosis in Brazil (see 3.2.7). Their main recommendations included compulsory notification of disease cases and protection of susceptible groups, together with improvements in public awareness of the disease and improvements in environmental health conditions.

Issues in disease surveillance and control

Lack of **reliable baseline data** has been mentioned in many reports of severe floods as a reason for difficulties in identifying flood related changes in disease incidences, especially in developing countries. Routine surveillance data are needed to detect

epidemics after extreme events. In disaster prone areas of developing countries baseline information may be particularly important with regard to common infections such as diarrhoeal diseases and upper respiratory tract infections (Rahman and Bennish, 1993). Establishing baseline disease surveillance systems can, of course, contribute to the improvement of health care systems in general.

Linked with this is the desirability of **advance knowledge on environmental health risks** to help assessment and control teams identify priority measures (The Sphere Project, 2004). Guidelines provided by Caribbean Environmental Health Institute (2003) particularly emphasize the development of 'vector profiles' for flood-prone areas. Such profiles should include gathering knowledge on sites that are likely to develop pools of stagnant water where mosquitoes can breed, and the locations of commercial or domestic sites where food sources are likely to accumulate for rodents and other vectors.

In **selecting and designing control measures**, it is important that the utility of specific measures be carefully assessed in relation to the threat. Chosen control measures and the manner in which they are implemented should be appropriate to the specific disease, its risk and its context, and flexibility of approach is often required. For cholera control, for example, Piarroux (2002) suggests adapting general cholera control techniques to the specific hazard situations in the field, perhaps implemented by teams of volunteers supervised by professional staff. The utility of a reactive approach of mass immunization against potential disease outbreaks during flood disasters is questioned by some authors. Parker and Thompson (2000) note that, though there is often public demand for immunization, such measures can absorb critical resources and divert them from other priority relief activities. They may also give people a false sense of security in terms of hygiene behaviour and health protection. Reflecting on the situation following floods in Turkey, Beser *et al.* (1991) suggest that general vaccination against typhoid is not recommended because the development of immunity takes too long. Also, general inoculation against tetanus is not seen to be necessary in flood disasters, except for specific cases (e.g. injuries during clean up). Menne (1999) points out that heightened disease risk during floods is usually limited to diseases that are already endemic to a flooded area: the chance of new infectious diseases being introduced is generally low.

A need to ensure **compatibility** between the actions of external relief organisations and in-country health agencies emerged from recommendations for the surveillance and control of communicable diseases following windstorm disaster, given at a meeting of more than 400 professionals from 48 countries (PAHO, 1999). Surveillance by incoming medical teams needs to work in harmony with local surveillance schemes to ensure information can be effectively compared. It is also important that incoming teams ensure any immunizations they give are compatible with existing basic immunization schemes in the affected areas.

4.2.5 Health care provision

This section focuses on the provision of health care for populations affected by flood. Its principal concern is with the actions of formal health systems (from primary to tertiary level), but the discussion also brings in the actions of a range of other organisations

engaged in health sector response, including environmental and social support agencies, and NGOs and external aid organisations providing health-related services.

During hazard and disaster events the demands on a health system tend to multiply. Authorities with responsibility for public health and social care provision have to be able to organise and coordinate response to the specific needs of injured and displaced people and to changing disease patterns. The demand for health services may change after a flooding event, and these changes have been observed to persist longer than the acute phase of the event. In the USA, for example, changes in health care demand (e.g. from injuries, consumption of contaminated water and food, and the consequences of stress) were reported following the 1993 Midwest floods (Axelrod *et al.*, 1994). At the same time, ongoing provision of 'normal' health care has to be maintained as far as possible, or at least quickly re-established (Poncelet and de Ville de Goyet, 1996). This is especially the case for essential services such as care for the chronically ill (e.g. dialysis patients). All this should be undertaken on an equitable basis for the client population, at a time when access to and from health facilities may be greatly disrupted (Menne, 1999). There may also be damage and disruption to the health infrastructure itself (see 4.2.6).

The precise nature of health care provision and prioritisation during floods, as with most aspects of health-related response, varies greatly according to context. It is shaped by: i) the pre-existing health status of the affected population; ii) the health risks posed by the hazard event; and iii) the resources and capacity of the health system (The Sphere Project, 2004). Differences in terms of health care needs, response capabilities and the need for external support arise from these factors.

The following discussion looks first at emergency planning and needs assessment activities, then examines the problems and principles of general health care delivery and mental health care, before drawing out a series of issues relating to health care provision overall. Many of these concerns overlap with those raised in other parts of chapter 4.

Emergency planning and needs assessment

Well planned emergency procedures for health systems, designed and put in place well in advance of hazard events, provide the foundation for effective health care during and after flooding. Preparedness of health services for natural disasters aims at minimizing mortality and reducing morbidity. In Mozambique, for example, health sector preparedness for the February/March 2000 floods started in November 1999, when warnings of impending flood risk began to be issued (Christie and Hanlon, 2001). The Ministry of Health oversaw efforts to prepare cholera treatment plans at provincial level and to ensure health posts were adequately stocked with routine medicine supplies, and issued extra stocks of malaria medicines and rehydration fluids. The Mozambique Red Cross also distributed medicine kits in late 1999.

Preparedness can, however, be taken still further in advance – well before the advent of flood crises – and can be more comprehensive in approach. According to Quayle (1995), systematic disaster preparedness plans for health facilities form the best defence in any emergency. A well-crafted plan consists of information and guidelines on availability of

staff, decision-making structures, communication with the media, and supply and storage of medicines and equipment. The author also underlines the importance of undertaking practical drills. Menne (1999) adds the need to compile inventories of existing resources in order that they can be rapidly mobilised, and the need to undertake a public health vulnerability analysis.

Disaster preparedness plans for the health sector may apply at local, regional and national scales. Milsten (2000) provides a review of hospital level planning in the USA (where all hospitals are supposed to have a written disaster plan), indicating commonplace shortfalls in quality and staff awareness of the plans that have been produced, and cases where plans have failed to be implemented when crises strike. The author argues that detailed preparation is needed for the disaster plan to be effective in providing structure to an organisation in a chaotic situation. It needs to be specific for each facility, rather than simply generic in format, and should be modular so that different sections can be activated separately. It needs to address three disaster phases: preparation following warnings; dealing with the event itself; and recuperation. The plan needs to be evaluated and agreed upon by all sections of the hospital and it may include brief action statements, checklists and flow charts to facilitate rapid provision of information for staff.

A case study by Xiaohong (1993) describes the role of health system planning in disaster preparedness in eight flood-affected provinces in south-east China in 1991. The author reports that as a result of adequate preparedness of the health sector no infectious disease epidemics occurred in the affected areas, and a considerable reduction of mortality rates (persons killed: persons affected) was achieved compared to earlier severe flood events in the same region. To enhance preparedness it was essential to establish an organisational framework, with a detailed plan for decision-making and to provide training in techniques of rescue and treatment of victims. Intensive care units of hospitals (field hospitals, rural hospitals and city level hospitals) needed to be prepared to treat large numbers of patients. Cooperation with different sectors such as military forces, fire-fighters, civil engineers, mechanics, police force and others was another important aspect of planned response.

However, preparedness plans for the health care system can only go so far. Health care needs vary in each disaster situation, and it may not always be feasible to prepare for unanticipated or extreme-magnitude flood events. When flood events occur emergency needs assessments give the necessary information to respond adequately and effectively.

CDC (2002) underlines the usefulness of rapid needs assessment techniques (combining epidemiological, qualitative and statistical methods) for directing response measures and response planning following flood events. A rapid needs assessment is a streamlined, low-cost analysis designed to identify key health threats and minimize misinformation. Information gathered following floods typically includes population health status and medical needs, the condition of water, sanitation and electricity supply systems, and the state of health services (Menne, 1999).

Guha-Sapir (1991) has reviewed concepts and methods of rapid assessment of health needs in emergencies. The most immediate assessment following an acute disaster may be required within 24–48 hours of the event, particularly in the case of rapid-onset cyclone or flash flood disasters. Its purpose is to estimate the magnitude of the disaster,

to measure present and potential health impact (mortality and expected morbidity patterns), to assess the resources needed, and to plan appropriate responses. Inevitably in such rapid analyses, there is a trade off to be made between accuracy and timeliness: the need for scientific precision may have to be relaxed in order to permit the swift reporting of critical information.

Rapid assessments may not be limited to the immediate flood phase. Clinton *et al.* (1995) stress the need for continuous re-assessment of health and medical needs in changing conditions as an event unfolds into its post-onset phase. Assessments also should take account of the special needs of population groups such as pregnant women, children, people with disabilities and the elderly. The NGO Help Age International (HAI) draws attention to the special needs of older people in disasters (British Red Cross Society, 2001b). Differences in perception of needs between NGOs and older people have been observed, as well as shortcomings in how these needs are considered in activities. On the basis of extensive research HAI has formulated best practice guidelines, which include ensuring health relief is accessible to the frail (perhaps through outreach care or transport provision) and providing medication for chronic medical conditions. These and broader aspects of health care delivery during floods are the focus of the next part of the review.

Health care delivery

Health care activities during floods comprise actions to ensure services for 'normal' public health needs continue, as well as actions to provide treatment for flood casualties and victims of flood-related illness. Besides the medical procedures themselves, they include technical and organisational activities designed to maintain services, supplies, communication and public access to health facilities. Where transport becomes difficult, health systems and relief agencies may establish extra emergency field hospitals or dispensaries. In China, for example, disaster response of the health systems has included setting up replacement telecommunication facilities, use of helicopters and steamboats as ambulances, and use of mobile intensive care units (Xiaohong, 1993). Though there are many global commonalities in the pressures and problems posed for health care delivery during floods, broad disparities tend to exist in population needs and response capacities between North and South.

In the North, though shortcomings remain, important lessons for health care provision during crises have been learned from a series of flood and storm events in the USA. In the aftermath of the Midwest floods of 1993, a health and medical task force was formed through the Public Health Service office of emergency preparedness to coordinate a multi-state strategy to deal with resulting health and medical problems (Axelrod *et al.*, 1994). The emergency response largely consisted of restricting admissions to facilities, rescheduling of surgical services, and assuring continuity of renal dialysis and dietary services, sanitation and infection control. Other services such as hospital laundry, cooling equipment and fire protection needed also to be functional. The aim was to restore 'near-normal' facility operations as quickly as possible, and the overall emergency response was built partly on disaster preparedness and partly on improvisation and flexibility (Peters, 1996).

Clinton *et al.* (1995) summarise the important characteristics of emergency response following Tropical Storm Albert over Georgia. Disaster preparedness planning, they suggested, should facilitate continuous liaison between different levels of health care and response managers to ensure maintenance of effective health services. After Hurricane Floyd hit Pitt County in North Carolina in 1999, an emergency team ran the hospital command centre and the transportation centre to ensure continuous access to health care (Franklin *et al.*, 2000). Teamwork between community physicians and University medical services secured health care provision. Family clinics offered 24 hour medical services (triage, treatment and referral) and medical staff were sent to community shelters to provide tetanus vaccinations, treatment of injuries and the management of chronic diseases. The identification of dialysis patients and provision of dialysis was organized either at a functioning centre or in the home, and telemedicine services were established in community shelters.

The situation may be very different if countries of the South are afflicted by severe flooding. In many cases, the health care services do not have the capacity to deal with these extreme situations, on top of a generally higher baseline pattern of disease burden. In the worst cases, the health care situation following a disastrous flood in low-income countries may be marked by a temporary collapse of services owing to the destruction of facilities, disruption of transport and shortages of drugs. Nishat *et al.* (2000) report on how the formal health system in Dhaka in Bangladesh was severely disrupted in this manner during the catastrophic flood of 1998 (see Box 4.3).

Box 4.3 - Health care disruption during the 1998 floods in Bangladesh

The 1998 floods that overwhelmed much of Bangladesh were the worst on record, surpassing all previous events in scale and duration. Almost two-thirds of the country became submerged for up to two months and an estimated 18 million people required emergency food and health care (Ahmed *et al.*, 1999). Facing food shortages, environmental health risks, and emotional stress, many people had no ready access to treatment because local practitioners and pharmacies were forced to close (Shahaduzzaman, 1999). In Dhaka city, the usual health system ceased to function effectively. According to Nishat *et al.* (2000, p232), 'providers of the health care in the city were found almost unprepared for meeting the calamity', with poor levels of disaster management training and preparedness. With the normal system severely impaired, the main emergency response by government and NGOs was to extend opening times of unflooded dispensaries, set up field health posts, including diarrhoea treatment centres, and establish 200 mobile health teams to bring services direct to communities. However, the resources of these teams were limited by insufficient manpower, equipment, medicines and transport.

Both Ahmed *et al.* (1999) and Nishat *et al.* (2000) strongly recommended a more systematic approach to disaster management and preparedness planning in the health sector within Bangladesh. Because of the limited effectiveness of mobile medical teams, one of the key suggestions is for a pre-established network of local emergency hospitals built above flood level and utilised for primary health care during normal times. Some of the other actions they suggest include: mechanisms for training health cadres in emergency management and training volunteers in first-aid; provision for sufficient supply of medicines for common flood-related illnesses; establishing anti-venom stocks to treat snakebite in rural communities; and provision of motorised small boats for use as ambulances during floods.

Prior to the 1998 disaster, Rahman and Bennish (1993) analysed health-related emergency response to the devastating cyclone of 1991 in Bangladesh, and drew recommendations that can be used to improve future preparedness of the health care system. The authors identified treatment of injuries and control of infectious diseases (especially diarrhoeal diseases and respiratory tract infections) as priorities. They suggested that, in order to make up for personnel shortages, health care should be provided with the help of local recruits under professional supervision. They also stressed that ongoing health programmes such as immunization campaigns and Vitamin A distribution should continue, in order to avoid long-term effects of an extreme event through neglect of existing health issues.

Positive lessons for the South have emerged from efforts in Mozambique to cope with the health impacts of the floods of 2000 (Christie and Hanlon, 2001). Here, the formal public health system benefited from its close partnership with an NGO, the national Red Cross (CVM), which carried out emergency preparedness and response activities in parallel with those of the government. As the floods deepened, CVM set up a network of emergency health posts to treat minor wounds and common ailments. In the capital, Maputo, the city health department cooperated with these efforts by sending visiting doctors to the posts and providing transport for volunteers.

The scale of health care problems during floods in lower and middle income countries often prompts the need for assistance and relief items from outside the country, from governments and international organisations. Beser *et al.* (1991), for example, report that external health-related help following a Turkish flood disaster consisted of financial support, assistance in organization and planning, setting up of an epidemiological surveillance system and the provision of information and guidance through mobile health teams. Some external agencies are specialists in providing emergency medical assistance, including the organisation Médecins Sans Frontières (MSF).

UNICEF relief efforts provide examples of what may be needed to provide continued health care for an affected population. In the year 2000 for example, 600,000 people were affected by the cyclone Gloria in Madagascar, 50% of whom were children. Following a request from the Government the following relief items were provided: drugs for 120,000 people for 3 months, high energy biscuits for malnourished children, radio equipment for co-ordination, blankets and water purification tablets (UNICEF, 2000). Following floods in Kenya in 2003, UNICEF provided health care items such as rehydration salts, drugs, mosquito nets and cooking sets, targeting especially diarrhoeal diseases, water-borne diseases and malaria to prevent avoidable deaths and disease especially among children (UNICEF, 2003). Efforts were co-ordinated through the Kenya Red Cross and the Disaster Operations Centre, with the Office of the President identifying critical needs.

The form and quality of health assistance is important in flood disaster situations: if inappropriate external skills and resources do not meet the needs on the ground they may only add to the problems (Noji and Toole, 1997). Immediate life-saving needs, for example, tend to be covered by local populations and their health professionals, so the skills of incoming medical personnel should be closely matched to specific shortages within the country. The problem of ill-conceived assistance has been highlighted particularly in relation to donations of inappropriate drugs that are not requested by the recipient country, unable to be used in the local context, or simply out-of-date. Christie

and Hanlon (2001) argue that this applied to as much as 50% of the drugs donated to Mozambique in 2000. They describe the response to one appeal for drug supplies by the government as follows:

'The request was for 33 basic medicines worth \$1.3 million. The response included 403 different medicines valued at \$1.4 million, but of those only 15 per cent by value (\$205,000) were actually useful in the emergency, according to Ministry of Health officials' (Christie and Hanlon, 2001, p94).

According to PAHO (1998), the international response to Hurricane Mitch, which left a trail of destruction across Central America in Autumn 1998, is one example of coordinated disaster relief by international organisations and national governments. International resources were mobilized and used essentially for drugs, vaccines, epidemiological surveillance, control of outbreaks and vector-borne diseases, immediate assistance to victims and building of shelters. The Ministries of Health also received assistance for coordination of the international support. In 1999, PAHO held an international conference on the lessons learnt from Hurricanes George and Mitch regarding emergency medical care. More than 400 experts from 48 countries compiled a comprehensive document with recommendations on topics including disaster preparedness, needs assessment, coordination, supply management, emergency medical care, psycho-social aspects and issues of reconstruction (PAHO, 1999).

Mental health care

Psycho-social aspects of floods are increasingly highlighted in the literature, and it is useful to examine response in this area in a little more detail. Extreme stressors are a risk factor for mental health problems and various studies (e.g. Tapsell *et al.*, 2002; Breo, 1993) have shown that the mental health impact of both rapid-onset and long-duration floods can be significant (see 3.2.8). Flooding can both create stress-related conditions and lead to exacerbation of existing problems.

Health services need to be prepared to offer specific help to affected victims, but few national disaster plans explicitly address measures to identify or deal with psycho-social aspects of flood or other hazard events (PAHO, 1999). Tierney (2000) discusses options for methodology to assess mental health impacts of disasters. The author lists factors that need to be taken into account when planning outreach and intervention measures, such as social-systemic sources of stress, secondary and cumulative stressors, and the coping capacity of the afflicted person. NSW Health (2000) stresses that mental health care in terms of psychological 'first aid', triage, assessment (risk factors screening), referral and interventions needs to be part of an emergency health care response.

To date, discussions of mental health aspects of flood risk and response have been confined mainly to industrialized countries. Tapsell *et al.* (1999) list causes of mental health problems in the UK, as reported from the Easter 1998 floods, as: lack of awareness of flood risk and coping strategies; having to leave home; lack of practical and emotional support; stress, distress and financial worries; and lack of confidence in authorities and institutions. To deactivate these causes of mental distress the authors suggest efforts should be made to enhance early warning, information to the public, advice on coping strategies, and the provision of counselling and social support.

During the Midwest floods of 1993 in the USA, the Red Cross provided in the frame of its flood relief services mental health counselling to flood victims and caregivers through a voluntary team (Breo, 1993). However, members of this team described the limits to their crisis counselling capacity and had to refer severe cases. From Australia, NSW Health (2000) emphasises that the role of mental health disaster workers, (professionals and volunteers) requires training and experience. Well trained disaster workers establish cross linkages with other organisations and individuals involved in relief work, know policies and procedure plans that are in place, and demonstrate good post disaster work skills (such as working with children, the elderly and people in crisis). Exposure to death, heavy workload, and exhaustion are severe stressors that can also put the mental health of disaster workers themselves at risk. To mitigate these risks, specific training, working in teams, sufficient breaks, the distribution of clear roles and responsibilities, and professional follow-up and counselling for disaster workers is recommended.

Mental health issues seldom gain high profile in the South, yet there may be tremendous risk factors during flood disasters in developing countries, related to the scale of suffering. When MSF began providing medical relief in the town of Goinaves, Haiti – which was devastated by floods in September 2004 – they found that many of the survivors who attended their health centre required treatment for mental health issues alongside basic health care (MSF, 2004).

The WHO document 'Mental Health in Emergencies' (WHO, 2003b) describes principles and strategies for preventing and tackling mental health problems in emergencies in resource poor settings. National preparedness plans need to include a coordinated system of adequate social and mental health response, including training of relevant personnel well adapted to the local context. Clinical on-the-job training of health care staff supervised by mental health specialists is encouraged. These activities should be guided by a focus on long-term development of community mental health services and other social interventions. The guidelines divide mental health care needs according to two phases of disasters, the acute emergency phase and the reconsolidation phase. In the acute phase, emphasis should lie on a series of social interventions, such as: improving the flow of information to the public on the disaster and the response; organizing shelter to keep families and kinfolk together; discouraging unceremonious disposal of corpses; re-establishing cultural and religious events; facilitating inclusion of orphans, widows and widowers in social activities; offering activities for children; involving people in purposeful and common interests; and disseminating information on normal reactions to stress. There may also be a need to manage urgent psychiatric complaints, and the possibility of organising outreach and non-intrusive emotional support. During the reconsolidation phase longer-term social and psychological interventions can be organised, such as: outreach education on psychological distress and mental health care; starting economic development activities and self-help groups; training primary health care workers in mental health skills; and reinstating treatment of psychiatric cases. Activities should follow national mental health programmes and national legislation and policy, but there should also be efforts to work in tandem with pre-existing coping mechanisms and traditional healers where applicable and feasible (WHO, 2003b).

Issues in health care provision

Among the many issues connected with the overall provision of health care for populations affected by floods, several key points stand out. First, the discussion has underscored the value of **well-prepared emergency plans** for health systems. Careful and committed preparation tailored to local context not only needs to be developed, but also shared with health staff to ensure they are aware of procedures and practised in carrying them out, through drills. Bradt *et al.* (2003) argue that health care providers must enhance skills in disaster management and engage with public health and public policy officials to generate guidelines for preparedness. Their recommendations include regular drills, use of web pages for the dissemination of information, and education and training in the interdisciplinary field of disaster medicine.

When floods strike, **timely and accurate needs assessment** is important as inadequate assessment is likely to lead to sub-optimal (or even maladaptive) responses, based on rumours rather than on facts. Inappropriate relief becomes redundant, and may even create additional problems, such as the time and space needed to process and store unusable drug supplies. Though some trade-off may be necessary between scientific precision and rapidity, efforts should still be made to maximise the accuracy of rapid needs assessments. Guha-Sapir (1991) notes that common sources of bias and error in rapid assessments include small sample sizes, inattention to differences between urban and rural areas, and extrapolation from data on a few specific sites leading to over-reporting or under-reporting of injuries or diseases.

Flood casualties and disease victims are not the only people in need of medical attention during crisis periods. It is important to make provision that **regular health care practices** are not interrupted during flood emergencies (Poncelet and de Ville de Goyet, 1996). Health service responses should be consistent with normal public health principles, and essential services, such as maternity care and care for chronically-ill patients, people with disabilities and people living with HIV/AIDS, need to be maintained.

Some authors point to the need for **more attention to mental health** needs during flood disasters, especially in the South (e.g. Espacios Consultores, 2000; Herzer and Clichevsky 2001). In some quarters, mental health may be seen as a 'luxury' issue for poor countries. The inattention paid to mental health may also be a function of cultural notions of resilience in flood-prone communities and the politics of post-disaster relief. According to WHO (2003b), awareness of mental health impacts and the need for action has to be raised at all levels. Mental health interventions need to be taken up within general primary health care at the local level, and their sustainability ensured by support from communities, NGOs, government and international donors.

In many cases there may need to be a **targeting** of care toward especially vulnerable groups, both because of their susceptibility and to prioritise use of limited resources (Handmer, 2003). Vulnerability to injury and illness may be heightened by age factors, mobility, health status, income, occupation, gender and cultural practices, as well as by geographical differences in exposure to hazard. In terms of mental health, both Tapsell *et al.* (1999) and Tierney (2000) conclude that outreach and intervention efforts need to take risk factors into account and specifically target vulnerable groups of populations and areas that are hit especially hard. Highest priority, they suggest, should be given to

individuals who are already subject to chronic and acute stress, who already had symptoms and who already had difficulties coping prior to the disaster.

Health care response to floods needs careful **coordination** between agencies, especially in cases where external medical relief is provided. According to a PAHO meeting report, external cooperation is usually valued but it is best if medical relief efforts such as the establishment of field hospitals and the distribution of drugs are coordinated by local health authorities (PAHO, 1999). External agencies working on-the-ground may require logistical and technical support from agencies in flood-affected countries, which can sometimes place extra burden on them during the critical emergency phase unless activities are carefully and jointly organised. Christie and Hanlon (2001) suggest that some medical relief groups were poor in coordination with national bodies and may even have been a net cost to Mozambique in the floods of 2000, given that many personnel were only available in the field for a short period following in-country preparations. For donations of supplies, PAHO has developed a computerised system, SUMA, to enable countries to coordinate incoming drug provision and distribution during disasters (Noji and Toole, 1997).

Finally, the complexity of health care provision reveals how health system functioning during floods is highly **dependent on preparedness in other sectors**. If new medical needs are to be tackled and essential services maintained, there needs to be inter-sectoral coordination in preparedness planning to ensure continuance of transportation, communication, electricity supplies and water and sanitation systems. Poncelet and de Ville de Goyet (1996) suggest that, in this respect, health professionals can act as leaders in galvanising overall preparedness activities within society, citing efforts during the 1990s in Latin America and the Caribbean as an example. The inter-dependence of health care with other health-related response activities is reflected further in the next two sections of this chapter.

4.2.6 Protecting health infrastructure

Intact, functioning and accessible infrastructure is a cornerstone of effective health care provision for affected populations during flood emergencies. Yet that infrastructure itself is often vulnerable to flood hazards. Hospitals, health centres and related facilities may become severely damaged or functionally disrupted by flood events (Menne 1999), affecting access to health care and the quality of care. Any resulting breakdown of services thereby creates a situation of double jeopardy for client populations suffering from the health outcomes of flooding. Unless overall planning for health care response takes these risks into account, there is danger that preparedness will be rendered meaningless by floods that prevent the health system from functioning according to plan (PAHO 2001).

Damage risks and response

Milsten (2000) summarizes the common infrastructural problems that may confront hospitals responding to disasters, including: physical damage to the health facility and on-site storage facilities; communication and power failures; water shortage and contamination; damage to equipment; and release of hazardous materials. In some

cases, the physical damage to the buildings may be relatively minor but the damage to non-structural electrical, mechanical and medical components may render services inoperable. In hospitals such non-structural components may make up to 90 percent of the overall cost of the facility (PAHO, 2000).

Serious disruption of public health services after severe floods has been reported for industrialized countries. Accounts of floods affecting health systems in the North include closure and evacuation of hospitals and health facilities during the recent flood and storm events in Germany and the USA. In Saxony in eastern Germany, a total of 53 doctor's surgeries were destroyed or severely damaged during the Elbe floods of 2002. Their closure caused a loss of service that Orellana (2002) indicates reduced the capacity of the health system to respond to flood-related disease risk. The 1993 Midwest floods in the USA had severe impacts on health care infrastructure and its accessibility. Axelrod *et al.* (1994) describe the effect of the floods on primary health care services and their inability to respond to changes in health care demand due to damage to facilities, equipment, lack of drugs and supplies, and communication problems. Initial public health assessments of the disaster included analysis of impacts on the health system.

Floods caused by Hurricane Floyd in North Carolina, USA, in 1999 placed major challenges on the public health systems. In Pitt County, the storm had a severe impact on the county hospital (731 beds): the transport infrastructure collapsed and the hospital was inaccessible and the electricity and water supplies were disrupted (Franklin *et al.*, 2000). An emergency generator with additional electric generators provided by the US Army Corps of Engineers re-established electricity, and provisional water systems were established using the hospital's swimming pool as reservoir. A command and a transportation centre were created, providing helicopter airlifts for patients and staff. The consequences of damage to clinics and practices, equipment and medicines caused by the hurricane was also alleviated through voluntary efforts from physicians in the region, coordinated through the North Carolina Medical Society (Edwards and Schwartz, 2000).

Major damage to health infrastructure is often reported from extreme flood events in developing countries, linked both to the severity of events and to greater system vulnerability. Following severe floods in Vietnam in 2003, WHO compiled a detailed health sector report, noting how disruptions to the health infrastructure hampered effective response (WHO, 2003a). Some health facilities were inaccessible for several days and significant physical damage to buildings was caused, especially those that had suffered repeated incidence of flooding in recent years. In the aftermath of the floods, insufficient resources for reconstruction and repair were available, particularly at a community level, as the focus was placed largely on district health centres. As well as damage to fixed assets, floods may cause loss of equipment and drugs – particularly in rapid-onset floods when there is little time to store items safely. Christie and Hanlon (2001) note that after the Mozambique floods of 2000, loss of drug supplies damaged by flooding of local health posts was substantial enough to prompt a specific appeal for new supplies.

A particularly useful body of literature on the impacts of floods and other hazards on health systems has emerged from the Americas, largely from a series of reports produced by the Pan American Health Organization (PAHO). The region has experienced a number of damaging floods in recent years, including El Niño events in the central Andes in 1997-98, the devastating 1999 flood in Venezuela and a series of hurricanes in the Caribbean. During the 1997-98 El Niño, floods affected at least 34

hospitals and 485 local health centres in Ecuador and Peru (PAHO, 2001). Hurricane Mitch in 1998 had a particularly severe impact on the health care infrastructure in Central America, the rehabilitation and reconstruction of which required international support and major co-ordination of external aid resources (PAHO, 1998; PAHO, 1999). An estimated 50% of all hospitals in Latin America and the Caribbean are located in hazard risk areas and most are inadequately prepared for natural disasters (PAHO, 2003). Partly as a result of these risks, the protection of the health services network by reducing the vulnerability of existing and new hospitals, health centres and laboratories has become a policy priority for PAHO (see Box 4.4).

Box 4.4 Protecting health facilities in Latin America and the Caribbean

During the 1990s International Decade for Natural Disaster Reduction, protection of health systems began to assume a particularly high profile in international policy circles in Latin America and the Caribbean. Coordinated largely by PAHO, health ministries, scientists and architects began to exchange knowledge and ideas on strategies for improving design of new facilities and for the updating or retrofitting of existing infrastructure to reduce the impact of hazards (Poncelet and de Ville de Goyet, 1996). Central to this strategic formulation have been economic arguments over cost-effectiveness, as well as the potential to save lives. In hazard prone areas it is claimed that 'for each dollar invested in mitigation before a disaster strikes, enormous savings will be made in losses prevented' (PAHO, 2000, p4).

The process has continued since the close of the decade, with the publication of guidelines for the protection of new health facilities from natural disasters (PAHO, 2003). The document argues that measures to ensure continuing functionality of key areas of hospitals when they are most needed should be part of every newly built facility. The guidelines suggest that mitigation work should begin in the pre-investment phase, when protection and specific performance objectives need to be formulated for the new facility. When assessing different site options the choice of location should be informed as much as possible by existing risks from natural hazards. Facility design then needs to take an integrated approach to mitigating risks of both structural and non-structural damage: a process that requires coordination of expertise from different professions. During the construction phase, quality assurance procedures are then required to ensure protection measures are implemented. The guidelines that were compiled by PAHO for Latin America and the Caribbean could equally be applied to other regions where the need for integration of disaster mitigation in planning, construction and management of health facilities is just as great.

Issues in infrastructure protection

The **planning, design and construction** of health facilities needs to take account of and avoid likely physical threat from flood events. The examples of damage to health care infrastructure during times of emergency emphasize the need for guidelines to ensure as far as possible that health care infrastructure is built outside flood zones or designed to function effectively in a flooded environment. Existing codes and regulations on the design and construction of facilities may need to be revised and adapted to local requirements, and mitigation objectives should be integrated into every step of the project cycle for new health infrastructure, from project inception to construction (PAHO, 2003). Once appropriate guidelines and regulations are in place, they need to be effectively applied, with coordination of efforts between experts. Training and education of a variety of different professions related to the planning, construction and

management of health facilities should include disaster mitigation as an essential component.

For existing health infrastructure, a systematic **vulnerability analysis** of both structural and non-structural components can point to priority upgrading measures, as well as inform the facility's flood preparedness plans. There may even be a need for relocation and redesign of existing health facilities that are flooded on a regular basis. A key step towards this new approach is to influence perception that the financial burden for prevention and mitigation for health facilities is too high. According to PAHO (2000; 2003), on the contrary, investments in vulnerability reduction can prevent huge costs and losses in the event of a natural disaster.

After floods strike, greater attention may need to be paid by governments, agencies and donors to **damage assessment and rehabilitation** of health infrastructure, alongside more conventional disaster relief work. The WHO report for Vietnam (WHO, 2003a), for example, notes insufficient official guidelines and training for the assessment of damage. More international attention to long-term needs for health infrastructure is also recommended, building on the disaster reconstruction and future risk reduction efforts already promoted by some agencies. The activities of donors, on the other hand, will be enhanced by specific advice from flood-affected countries on losses of infrastructure, equipment and drug supplies.

4.2.7 Water and sanitation: protection and provision

Much of the communicable disease outcome of flooding events centres on the impacts of flooding on water supplies and sanitation facilities. Equally actions in water and sanitation are among the most widespread of health-related coping strategies in the face of flooding. Hence it is important to explore in detail here the nature of risks and responses in this sector and associated issues. Because waterborne and faecal-oral disease outbreaks during floods are of such low incidence in the North, the discussion here deals primarily with studies undertaken in the South.

Once again, the focus here is less on technical matters, but more on how mitigation and emergency response actions are organised and the considerations that need to be made in ensuring they have the desired effects on public health (processes and policies of adaptation). We look mainly at interventions in this sector by state organisations and NGOs that are specific to flooding and flood risk contexts (though there is inevitably some reference to generalized principles of emergency water and sanitation). Though we do not cover them here, it is also important to note other actions relating to environmental health during floods that may need to be taken in parallel with water and sanitation measures. These include strategies to reduce solid waste and hazardous waste, and to enhance food safety and de-contamination of homes, some of which are discussed in section 4.2.2.

Flood impacts on water and sanitation systems

Parker and Thompson (2000, p197) observe: 'typically floods adversely affect water supply systems including water purification plants, as well as sewerage and sewage

disposal systems'. Guidelines on the protection of water and sanitation systems infrastructure produced by the Pan American Health Organisation note that floods can cause damage to virtually every part of a supply system, including intakes, dams, reservoirs, conduits, pipelines, chambers, valves, treatment plants, engine houses, pumping equipment and electrical installations (PAHO, 1998). Components of the system are put at risk of displacement and rupture by erosion of protective soil cover, rising ground water causing flotation, excess water flow and wave action during tidal floods. Damage can also come from submergence of electrical components, and from excess sedimentation. Related disruption such as road blockages by flood debris can hamper efforts to repair systems.

According to Osorio (2003, p2), three-quarters of the population of Honduras was affected by disruption to water supplies after Hurricane Mitch in 1998 and the damage 'set the Honduran water sector back in its water coverage services to a similar level to that of three decades earlier'. McCluskey (2001) adds that flash or high-velocity floods are the most damaging for water systems because their physical force can knock out key components such as treatment stations and pumping installations. Box 4.5 indicates the destruction caused by freak floods during El Niño years in the central Andes.

Box 4.5 Effects of El Niño floods on water and sanitation in Ecuador and Peru

In late 1982 and early 1983, intense, prolonged rainfall associated with the ENSO phenomenon brought severe floods and landslides to many coastal regions of Ecuador. Hederra (1987) described how the floods caused extensive damage to infrastructure across five provinces of Ecuador, affecting drinking water systems (damage to wells, elevating plants, pipelines and impulsions; interruption of service) and sewage systems (damage to elevating plants, pipelines and impulsions, sewer networks; obstructions caused by reflux of sewage). In the city of Babahoyo, discharges from the sewerage system (via inspection wells) directly into the standing floodwaters that lay across much of the city created a level of coliform contamination that 'corresponds to raw wastewater' (Hederra 1987, p304).

Freak floods caused by the same El Niño event also afflicted the arid coastal belt of north-east Peru. According to Maber (1989, p28), the floods destroyed the well system and pumping main for the town of Sechura, forcing the inhabitants 'to buy contaminated water from water-sellers using open wells several kilometres away'. The author reports how the impact of the flood led to a special community-based project called 'Agua Para Sechura', designed to give the town better-protected but also better-quality and more sustainable water and sanitation facilities.

It is not only networks of piped water systems and sewerage that are at risk of physical damage. Wells and latrines can also be at physical risk although the structural damage caused to them may have less impact across space and time. In the 1991 Bangladesh cyclone, for example, tubewells were affected by the storm and tidal surge – official data reported that 38% of tubewells in the affected areas were damaged (Hoque *et al.* 1993). According to the UNICEF Cyclone Evaluation Team (1993), however, much of the damage was not critical and most of them were quickly brought back into service after minor repairs to e.g. platforms and pump handles.

As well as suffering physical damage, though, water facilities are also subject to contamination that may be more cross-scale in its impact. Parker and Thompson (2000)

regard large-scale contamination of drinking water as the most serious disease hazard from floods. Contamination may arise from: animal cadavers near water intakes; high turbidity making purification difficult; floodwater entering well heads; flood levels higher than well head walls or water flowing directly over wells and other intakes; fuel/chemical pollution (fuel mixed with water also makes it more difficult to boil); and physical damage to water treatment plants (Caribbean Environmental Health Institute, 2003; PAHO, 1998).

Even if the supply system itself is not interrupted there can be cross contamination from damaged sewage systems. In the great flood of 1998 Dhaka city's waste disposal system became almost completely ineffective (Nishat *et al.*, 2000): many streets became flooded with water mixed with waste and sewage, the leakage of sewage contaminated most water supply lines, and the reserve water tanks of many houses became submerged and contaminated. Water level rise in sewer outfalls can cause contamination of groundwater supplies and cause waste water to back up and flood through manholes in roads and the toilets and washbasins of homes and buildings (Caribbean Environmental Health Institute, 2003; PAHO, 1998). Shut-off valves can prevent such back-flow, but in many cases in developing countries these are not installed.

In Brazil, Philippi Junior *et al.* (2003) state the prime importance of providing clean water and managing excreta after floods. This importance is reflected in the high priority accorded to water and sanitation in the emergency response of many organisations. Commenting that millions of people suffered scarcity of drinking water and no hygienic means of sanitation during the Bangladesh floods of 1998, Ahmed *et al.* (1999) advocated that the NGO BRAC become involved in rehabilitation of tubewells and sanitary latrines, plus distribution of water-purifying tablets. During Hurricane Mitch in the same year, local NGOs such as the Madriz Community Movement organised external financing 'for a project to reconstruct latrines and wells that had been destroyed' (Richards, 1999, p5).

An evaluation of external NGO response to the Orissa 1999 supercyclone notes Oxfam, Action Aid and Christian Aid all becoming involved in water and/or sanitation provision (INTRAC, 2000). In Mozambique in 2000, 16.5% of expenditure from a joint appeal by UK-based NGOs was spent on water and sanitation, compared with 8.4% on 'health' (the largest shares were for agriculture and shelter – both accounting for just under 20% of funds) (Cosgrave *et al.*, 2001). Oxfam took the lead in these actions, with emergency repairs to water systems, sinking of new boreholes, rehabilitation and construction of wells, cleaning and repair of septic tanks and construction of latrines: combined with hygiene education. The main impetus for this, according to Cosgrave *et al.* (2001), was the threat of cholera outbreak, and the absence of an outbreak was put down in part to the agencies' water and sanitation efforts combined with hygiene promotion (McCluskey, 2001).

Advance protection

Much of the flood response literature discusses strategies such as those above for emergency water and sanitation provision, and these aspects are discussed in more detail in subsequent parts of this section. But emergency actions are only part of the water and sanitation story and may not be the most effective coping strategies against

flood risk. It is important too to stress mitigation actions that protects system infrastructure and facilities in the home from becoming damaged or contaminated in the first place. Osorio (2003) argues, for example, that emergency response such as water distribution by tankers is logistically very difficult for Central American countries. The optimum solution instead is to design supply infrastructure to consider the geography of natural hazard risk, and to incorporate measures to ensure the system can continue functioning when floods occur.

In this sense, pre-flood protection and long-term flood recovery ideally should blend into one another. Indeed action on water and sanitation can fit with all stages of the hazard cycle. Oxfam's River Basin Programme, covering the Ganges and Brahmaputra Basins of South Asia, includes water and sanitation work in: disaster preparedness – e.g. the raising of tubewell heights prior to floods; emergency relief – e.g. provision of sanitation kits and latrine repairs; and flood recovery – e.g. the replacement or rebuilding of latrines (British Red Cross, 2001a). In the recovery phase from the El Niño floods of 1983, the project Agua Para Secura in Peru involved reconstruction of the water supply system and improvements to emergency wells to provide more adequate future protection of supplies (Maber, 1989). Dunston *et al.* (2001) promote the benefits of moving from an emergency project approach to drinking water to a development project approach that emphasizes long-term safe water provision for communities at all times.

As well as making systems more hazard-proof, flood preparedness includes more temporary measures based on advance forecasts, such as the raising of tubewell heights to prevent inundation (Roger Young and Associates, 2000; McCluskey, 2001). It also includes advance development of emergency plans and response mechanisms. The latter, in particular, is emphasised in a set of planning guidelines prepared by the Caribbean Environmental Health Institute (2003), many of which relate to water supply and quality, and to sanitation and hygiene. One of the few documented examples of such preparedness actions comes from the NGO sector in Mozambique before the 2000 floods, where provincial offices of the Red Cross (CVM) did preparedness planning from September 1999 when the first warnings of floods were issued. This included advance distribution of basic kits including chlorine for water treatment to strategic locations (Christie and Hanlon, 2001).

Emergency provision: water supplies and purification

Provision of water is arguably the single most important measure for health protection of disaster-affected populations (Lillibridge, 1997). When floods strike, the agencies involved in response and relief have to consider several aspects of water supply and usage, including decontamination of supplies, providing sufficient quantities of water and hygienic collection, storage and use of water by households (see Box 4.6). The Sphere Project (2004) stresses that insufficient water for drinking and hygiene can be just as harmful as contamination of water supplies and provides a minimum target for water supply of 15 litres per person per day, equitably distributed across an affected population. Wisner and Adams (2002) affirm that the first priority is to provide an adequate quantity of water, even if the supply is of low quality. The Caribbean Environmental Health Institute (2003) recommends that a survey of all sources of public water supply be undertaken after a flood, and priority accorded not only to drinking water systems but also to proper storage (to prevent contamination and breeding sites for

mosquitoes). In the medium term, the next priority is to restore original sources. McCluskey (2001) stresses that recommissioning of water supplies requires disinfection with super-chlorination rates, and that some sources, such as wells, may need physical cleaning first.

Box 4.6 Sphere standards for water and sanitation

Guidelines on disaster response developed by The Sphere Project (2004, pp63-73) establish three international water supply 'standards' (on access and water quantity, water quality, and water storage and use) and two excreta disposal 'standards' (on access to and number of toilets, and design, construction and use of toilets). The five standards are worded as follows:

'All people should have safe and equitable access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Public water points are sufficiently close to households to enable use of the minimum water requirement.'

'Water is palatable, and of sufficient quality to be drunk and used for personal and domestic hygiene without causing significant risk to health.'

'People have adequate facilities and supplies to collect, store and use sufficient quantities of water for drinking, cooking and personal hygiene, and to ensure that drinking water remains safe until it is consumed'.

'People have adequate numbers of toilets, sufficiently close to their dwellings, to allow them rapid, safe and acceptable access at all times of the day and night.'

'Toilets are sited, designed, constructed and maintained in such a way as to be comfortable, hygienic and safe to use.'

Wisner and Adams (2002) note that where disruption or contamination of a water source happens, a number of immediate options may be considered. First, alternative sources nearby may be made available in emergencies, such as from unaffected wells or from supplies to food/drink factories. If these are unavailable, water may be trucked in by tankers or existing contaminated sources may be chlorinated before consumption - at higher levels than may be normal. Priority for provision and treatment should be given to areas that do not have alternative sources, and special priority should be given to hospitals. The authors consider household purification of untreated water should be a last resort.

During the 1998 floods in Bangladesh, one of the first responses was the raising of tubewells to prevent contamination (Roger Young and Associates, 2000). As the flood rose and many wells eventually became submerged, people waded through water or hired boats to access wells on higher ground. The supplies provided to designated flood shelters became very important. Agencies and the government also became involved in tankering water, especially in urban areas. As the flood receded, many agencies then provided bleaching powder and advice for cleaning and rehabilitating wells. The study by Shahaduzzaman (1999) in an area of Dhaka reports that people initially had great difficulty accessing fresh water because tubewells were drowned. The NGO BRAC

reacted quickly to install a new tubewell above water level, which then became heavily used. Also, the Bangladesh Army set up a mobile fresh water tank in the area.

Water supply was similarly a major issue immediately after the 1999 Orissa cyclone (INTRAC, 2000), but emergency decontamination was seen to have been a major factor in successfully preventing major epidemic outbreaks (Palakudiyil and Todd 2003). As many as 68,000 tubewells were 'rehabilitated' by cleaning and bleaching within two weeks of the cyclone with support from the state government and external agencies such as Oxfam and UNICEF (INTRAC, 2000; Palakudiyil and Todd, 2003).

In some circumstances, local, state and international agencies may also have little choice but to become involved in efforts to purify untreated water collected by households and protect stored water around houses. Much of this centres on education (see Section 4.2.2), but it may also involve free distribution of purification kits and hygienic containers, as in the Bangladesh floods of 1998 (Roger Young and Associates, 2000). In Nicaragua, during Hurricane Mitch in 1998, the local NGO Madriz Community Movement 'mobilised their health brigades to prevent people drinking contaminated water and encourage them to chlorinate drinking water' (Richards, 1999, p5). Oxfam has designed and distributed special sealable water containers with taps to prevent environmental contamination (McCluskey, 2001).

Emergency provision: sanitation

According to the Caribbean Environmental Health Institute (2003, p26): 'The importance of maintaining good sanitary conditions following a flooding event in order to protect public health cannot be overstated'. As for water, The Sphere Project (2004) establishes disaster response standards on sanitation facilities and their usage (See Box 4.6). The document emphasizes that people should have adequate numbers of toilets close to dwellings, and that these should be comfortable, safe and hygienic to use – safety and cultural acceptability may be particularly important considerations for women.

Inundation of latrines and lack of access to alternative toilets emerged as a major problem during the 1998 floods in Bangladesh, for example, and it is a problem especially heightened in congested urban areas (Roger Young and Associates, 2000). Wisner and Adams (2002) confirm that excreta disposal is particular concern in urban areas, because of the greater density of people and risk of contamination (whereas in rural areas the priority is likely to be protection of water sources).

Emergency provision of sanitation relates both to piped systems, where sewerage exists, and to household level facilities (toilets and latrines). In terms of systems, the immediate response may include the isolation of sections still functioning and bypassing of damaged or blocked sections (The Sphere Project, 2004; Wisner and Adams, 2002). This may be combined with sewage tankering services and the installation of septic tanks or containment tanks that can be regularly emptied. To ensure people have access to adequate sanitation facilities in accessible locations temporary or portable toilets may need to be provided, although Wisner and Adams (2002, p128) stress that first 'every effort should be made to allow people to use their existing toilets'. Nishat *et al.* (2002) particularly emphasize that emergency shelter houses need to have adequate number of toilets – many people sheltering during the 1998 flood in Dhaka used open latrines.

Some authors also point out the need and opportunity in the recovery phase from floods to invest in long-term sanitation provision. Hoque *et al.* (1993, p150), for example, claim: 'it is also important that aid for the reconstruction of damaged houses be used to promote the construction of sanitary latrines'. The Agua Para Sechura project, prompted by floods in 1983, provided the first sanitation system for the town of Sechura on the arid coast of Peru (Maber, 1989). However, it was not considered feasible or appropriate to install full sewerage when there would never be sufficient water for a flush-system to work. The response instead was to provide public latrines first and then offer credit for self-help groups to build domestic models.

Issues in water and sanitation response to floods

Perhaps the first issue to stress is that those planning for and managing water and sanitation systems during times of flooding need to take a **broad, integrated perspective** on response options. The paper by McCluskey (2001) neatly summarizes some key points, two of which we highlight here. First, concentrating effort on providing supplies of clean water is not enough if parallel transmission routes for disease exist because of disrupted waste disposal systems. Water and sanitation issues are so entwined, especially in urban areas, that they need to be considered together. Second, levels of contamination of water sources during floods must be put into context. Normally-safe water sources that become flooded may still remain less contaminated than alternative non-flooded, but unprotected, water sources – as shown by a comparative study of water quality in flooded tubewells and other surface sources in Bangladesh (McCluskey, 2001). This needs to be borne in mind when decisions are taken on closing down water systems for disinfection during the emergency phase of floods.

In relief interventions relating to water and sanitation, agencies also need to remain flexible in approach to ensure their actions are **properly targeted and appropriate** to the situation. In Bangladesh in 1998, though Nishat *et al.* (2000) found that most people in their study knew about water contamination and only 2% reported drinking untreated floodwater, others suggest there is a major problem for some population sectors over use of unsafe water for drinking, caused often by lack of choice rather than lack of understanding. Roger Young and Associates (2000) especially make the case for relief agencies to target elderly people who are confined to houses during high floods. They report cases where such people drank untreated floodwater because they were not strong enough to reach sources or could not afford to hire boat transport.

Lack of fuel during the 1998 Bangladesh flood in rural areas (where people are mainly dependent on firewood) also meant boiling water often was not feasible. The scale of the problem and difficulties with the taste and quality of available purification tablets, forced a rethink in relief actions by NGOs toward cure rather than prevention of waterborne disease. 'Finding that the scale of impure drinking water could not be addressed by purification measures, agencies promoted the wide-spread use of rehydration salts, distributing ORS packets with the relief supplies and mobilizing thousands of volunteers in all parts of the country to prepare and package ORS' (Roger Young and Associates, 2000, p21).

One early element of Oxfam's public health programme in Orissa in 1999 received criticism for promoting a specific single pit latrine design that had been rejected as inappropriate by other Indian NGOs and which then suffered from poor quality of construction (INTRAC, 2000). As well as providing the right technology, appropriate relief also means gearing interventions to the technological capacities of target populations. To aid people rehabilitate wells, for example, Oxfam has developed special cleaning kits designed for use by non-skilled personnel (McCluskey, 2001).

To be most effective, efforts in water and sanitation response also need to be combined with **education and social marketing** for user groups (See also section 4.2.2). The Sphere Project (2004, p56) emphasizes that provision of water/sanitation is not enough. 'In order to achieve the maximum benefit from a response, it is imperative to ensure that disaster-affected people have the necessary information, knowledge and understanding to prevent water- and sanitation-related disease.' According to Roger Young and Associates (2000), the impact of the 1998 floods in Bangladesh was lessened by the fact that, since the previous great flood of 1988, rural Bangladesh people had become used to drinking tubewell water and gained a generally higher awareness about the need for clean drinking water. The need for education and social marketing is highlighted even more in the case of sanitation provision, because of a reported lower receptivity among people to change in toilet behaviour and investment in hygienic facilities. In emergencies in India UNICEF have become involved in a twofold approach of toilet provision combined with hygiene education training for teachers (Palakudiyil and Todd 2003). Cairncross *et al.* (2003) emphasise that sanitation promotion may need to be more sophisticated than for clean water supply: there may be a need to 'market' use of toilets (pit latrines or pour-flush toilets). Dunston *et al.* (2001) suggest that such social marketing is best achieved in tandem with mobilization of community involvement in interventions.

Approaches to water and sanitation response to floods tend to work best when there is some form of **community involvement** in the design, construction, operation and maintenance of facilities (The Sphere Project 2004). Several reports stress the need for a more bottom-up approach. Hoque *et al.* (1993) describe how tubewell repairs and installation activity went on round-the-clock after the 1991 cyclone in Bangladesh, but the scale of the problem and reliance on external technical help meant there was a lack of resources and manpower to cope. They pointed to the need to train and encourage local people to maintain pumps and stockpile spare parts. Wisner and Adams (2002) suggest that implementing agencies in new latrine construction should work closely with user families in design and building to ensure methods are appropriate. They also argue that a key element of involvement is the move to more permanent arrangements for local management of facilities, such as the organization of neighbourhood committees.

Finally, sustainable solutions to water and sanitation problems seem to require **long-term commitment** of effort by intervention agencies. Cosgrave *et al.* (2001) describe how water committees were set up by some of the agencies operating in Mozambique in 2000, but there was little follow up to ensure that they became properly established: consequently maintenance of new handpump supplies generally failed. The evaluation argued that more efforts should have been put in to support long-term sustainability of the new facilities through local capacity building. Oxfam's single pit latrine programme in Orissa was similarly criticised for being too ambitious in geographical scale, with inadequate technical supervision and long term internal monitoring across the programme sites (INTRAC, 2000). This evaluation emphasises that sanitation promotion

has to be long term and involve local people in decisions on, construction and maintenance of toilets, allied with effective hygiene promotion to bring about their use (INTRAC, 2000). However, it also points out that the immediate post-disaster period may not actually be the best time to try to bring about behavioural change in sanitation habits.

4.3 STATE OF KNOWLEDGE: AN ASSESSMENT

The foregoing discussion has drawn on diverse sources of existing information to set out the nature of health-related responses to flooding and highlight some of the issues that are likely to shape the effectiveness of those responses. Here, we provide a summary assessment of the current state of knowledge on responses, picking out some of the key generic themes that have emerged from the review, and pointing toward knowledge gaps and research needs.

4.3.1 Summary of the findings

Together with general measures designed to protect human systems from floods, the survey of literature has revealed various mechanisms and strategies that serve specifically to prevent or address mortality and morbidity impacts. Such health-related responses exist in terms of health protection activity in the home and community, health and hygiene education, warning and evacuation practices, disease surveillance and control, provision of health care, protection of health system infrastructure and protection and provision of water and sanitation facilities. These responses may take place before, during and after flood events, and, in practice, the delimitation between preparedness, emergency response and recovery phases of action is often blurred. The actors undertaking these responses include affected individuals, community organisations, medical teams, public agencies, non-governmental organisations and external agencies. Though this report does not attempt to provide an inventory of specific mechanisms, in Appendix 2 we have produced a summary tabulation of types of health-related response, with selected examples.

The provision and organisation of these responses has raised a series of issues discussed in detail in section 4.2, and which we summarize here as the following set of generic considerations for policy and intervention relating to the health risks from floods.

Information and education

The chances of effective response to health risks are greatly enhanced by reliable information on the health needs of the population and the rehabilitation needs of health, water and sanitation systems damaged by floods. Good baseline data is a prerequisite for accurate disease surveillance during floods and needs assessment. However, the ideal of high-quality data has to be considered in context. In practical terms, there may be a trade-off between optimization of the accuracy of data gathering and the need to provide a timely response to health impacts.

The other key aspect of information is communication. The section on warning and evacuation has highlighted the importance of genuine communication of information to the public in a meaningful and accessible manner. This applies to health promotion in

general. Social differentiation in perception of risks and cultural barriers to effective coping and take-up of interventions, highlight the need for health promotion activity to be tailored to local social contexts.

Planning, flexibility and organisation

Advance planning emerges strongly as a key message for the successful implementation of health education, warning and evacuation, emergency health care provision, infrastructure protection and other aspects of health-related response to floods. Preparedness plans, for example, are seen as crucial for health systems in flood-prone locations, covering how the system continues to function during flood events as well as how the system responds to additional needs created by the flood.

At the same time, a planned approach to health-related response needs a degree of flexibility, not just to cope with variability in the nature of flood events but also to ensure that actions identified are appropriate to the needs of the population or system being served. It is difficult simply to lift generic responses 'off the peg', especially from North to South, or vice-versa. There also needs to be a flexibility in institutions to learn from positive experiences and external examples of good practice.

Efficient response by agencies also rests on effective coordination between sectors and, during flood emergencies where external assistance is forthcoming, between the different organisations providing medical and other care for affected populations. It also rests on effective linkage between scales of responsibility, including the relations of trust and accountability between local public agencies and communities subject to flooding.

Commitment and support

As for most aspects of hazards response, a key message from the review is that effective response requires considerable commitment to preparedness and risk reduction, both in time and financial support. Agencies from flood-prone areas need a long-term commitment to put strategies in place and ensure they are capable of functioning when emergencies arise. For example, flood risk should be factored into mainstream health system planning. External agencies need to provide a presence beyond the immediate flood relief phase, preferably with a long-term commitment to capacity building and broad-based community involvement in intervention projects. For the South, in particular, health risk reduction from floods may require an increase and/or a shift in emphasis in external funding assistance.

4.3.2 Knowledge gaps

Pin-pointing where adequate knowledge exists is probably a more difficult task than suggesting research gaps on response to health risks from flooding. Perhaps more so even than for health impacts, there are remarkably few studies that focus on health-related responses and hence the global knowledge gap is fairly comprehensive. What the often-tangential literature sources discussed in this chapter do show, however, is that there are many issues and considerations involved in reducing health risks that we suggest need specific attention from research and evaluation.

In a **technical** sense there is a need to evaluate the effectiveness of existing health protection, education, warning, evacuation, monitoring, health care, water and sanitation, and system preparedness measures used in flood-prone locations (Greenough *et al.*, 2001; Malilay, 1997; WHO, 2002). There is a need for health impact assessment of response measures. That means assessing not only the potential for measures to interrupt the pathways toward ill-health, but also assessing how readily they are taken up. Similar requirements exist for testing novel adaptation options: questions of their potential performance need to be accompanied by assessment of how feasible, appropriate and accessible they may be in different social contexts. Improved understanding of the effectiveness of options then needs to be translated into implications for policy on, and organisation of, flood response. This may need to be coupled with innovative work on improved methods for disseminating best practice response measures.

Evaluation of effectiveness can apply in all the spheres of response we have considered in the chapter. In regard to mental health care, for example: 'an ongoing goal might be to identify and explain the factors that enable an individual to creatively cope and even grow in the midst of forces that threaten to overwhelm and destroy. This knowledge might then be utilized to develop intervention programs that maximize the chances for successful coping.' (Smith 1996, no page). It is important also to analyse responses to 'non-emergency' floods as well as to extreme events. Very few studies at present examine how people cope with the health implications posed by predictable seasonal flooding.

In parallel, there is ample opportunity for **social science** approaches to strengthen our understanding of processes of response by people and institutions to the health impacts of flooding. That means analysing perceptions of health risk and coping strategies of affected populations and organisations, and the economic, social, cultural and political constraints and opportunities that shape capacity to adapt. As McCluskey (2001, p17) suggests for the household level: 'In particular there is a need to understand better the coping mechanisms of the affected populations, particularly those who are not (or chose not to be) displaced, how they adapt at the household level to diminish risk and how important underlying levels of awareness are, such as risks and what influences this (literacy, level of education, previous exposure to health promotion)'.

Social scientific analysis should target not just how resources and assets affect capacities and decisions, but also examine the role of structural factors within society at large that may define the parameters within which decisions and actions can be made. The latter might include, for example, the norms of organisation and policy within health systems, processes of risk communication to vulnerable populations, or cultural norms on gender roles within society. Two key themes of research interest in this respect are the role of community-based flood risk management approaches in relation to health in different settings, and the prospects for mainstreaming health risk more fully into disaster planning at national level.

The potential for **climate change** to intensify or alter flood patterns only serves to heighten the research need. On the one hand we need better knowledge of the nature of future risk from floods from advances in modelling and prediction that will support the development and fine-tuning of adaptation strategies. These have to take into account complexities relating to the multi-causality of ill health. In this respect, important insights may be gained from analysis of health risk and response in areas currently experiencing

major shifts in flooding incidence as a result of environmental change such as land subsidence or deforestation.

On the other hand, the increased risk that may result for existing and potentially new flood-prone areas, suggests a need for improved understanding of current coping practices (as indicated above) so that positive responses can be replicated effectively elsewhere. The climate change threat may heighten the need to develop new mechanisms for auditing preparedness and emergency response in health systems, and to re-examine the applicability of the precautionary principle to health policy development.

The concluding sections of the review discussions in Chapters 3 and 4 have highlighted research priorities relating respectively to health impacts and health response. There are also some cross-cutting integrative considerations for research work that apply across these categories and that were given special emphasis at the Workshop meeting associated with this project. First, there is a need for research that links findings on impact and response: the interactions between the two aspects makes it difficult to draw conclusions in isolation. Second, there is a need for integrated cross-scale research conducted at regional, national and local levels, in order to capture variation in pattern and process at different spatial scales. Third, there is a need to ensure flood-related work informs and is informed by health aspects of other natural hazards. This linkage includes analysis of the more generic health issues connected with hazards and disasters, such as risks associated with population displacement, economic losses and food shortages, that we have not been able to discuss in detail here (see Chapter 1).

CHAPTER 5

VULNERABILITY AND ADAPTATION IN A CHANGING CLIMATE

Chapters 3 and 4 have set out the findings of our review of existing academic literature and other documentation on the health impacts of flooding and the ways in which individuals and organisations respond to those (actual or potential) impacts. In Chapter 2 we introduced the notion of risk as a function of hazard and vulnerability, emphasizing that is shaped just as much by social processes as it is by natural forces. The degree to which a particular flood event will affect human health can therefore be seen to depend on the physical nature of the flood event and the degree to which human populations and systems are vulnerable to its impacts. Vulnerability is not just a passive state, since it is also determined by the responses of people and systems to health threats. Hence, coping capacity is seen as the converse of vulnerability. We also introduced the notion of adaptation as purposeful change to address recurrent or future risk. This concluding chapter now integrates and extends the analysis. It draws out a series of points on the dimensions of vulnerability and adaptation to health risks from flooding, and sets them in the context of potential changes in future flood hazards as a result of climate change. The points are listed in Table 5.1 and discussed in the sections that follow. In each of the sections we also pose some key questions that emerge from the study.

Table 5.1 Key points from the review

Health impacts and vulnerability	<ol style="list-style-type: none"> 1. Floods worldwide have a significant impact on human health 2. Different types of flood are broadly associated with different patterns of health impact. 3. Vulnerability to health impacts of flood hazard differs between global regions. 4. Vulnerability to health impacts of flood hazard also differs at the micro-scale.
Coping capacity : responses to health risks	<ol style="list-style-type: none"> 5. Responses to the health risks from floods take many forms. 6. Efforts are needed to improve health risk reduction from present-day floods in most areas. 7. Communication and coordination are vital aspects of risk reduction.
Climate change, floods and future health risk	<ol style="list-style-type: none"> 8. Climate change is likely to intensify future flood problems in many areas. 9. Climate change is therefore an additional driver of future human health risk from floods 10. Flooding should be included in formal assessments of climate change health impacts
Adaptation processes and policies	<ol style="list-style-type: none"> 11. There is a need to move further toward risk reduction activities in advance of flood events 12. Improvement in general health infrastructure and services will play a major role in reducing the specific risk from flooding 13. More effort is needed to identify and communicate best practice in flood health risk response 14. There needs to be a global commitment to implementing best practice.

5.1 HEALTH IMPACTS AND VULNERABILITY

Point 1

Floods worldwide have a significant impact on human health.

The health burden of floods consists not just of direct mortality and injury during onset of the flood hazard, but also of morbidity from a range of diseases and other health outcomes contracted through various pathways – some of which may lead on to mortality. These morbidity pathways and effects have to date been poorly characterised for most health outcomes in most regions. However, a number of epidemiological studies reported in Chapter 3 do provide reliable evidence to back up qualitative reports of the potential for disease outbreaks and increase in mental health disorders during or after floods.

This health burden is often acknowledged in discussions of the overall impacts of flooding, but is seldom included formally in flood risk assessments. To date, most flood risk assessments and impact studies in Europe have focused on damage to property and economic and financial losses. Unless the ‘intangible’ health impacts are taken into consideration the true costs of flooding remain unknown and there is a risk of focusing on what can be more easily measured as opposed to what may often be more important to people, particularly as these health effects may persist for long after properties have been repaired (RPA/FHRC *et al.*, 2003).

Point 2

Different types of flood are broadly associated with different patterns of health impact.

The term ‘flood’ covers a spectrum of events of different magnitude and with many different causes. Floods vary according to regularity, speed of onset, velocity and depth of water, spatial and temporal scale; they may originate from rainfall precipitation events of long or short duration or from inundation of coastal lands by storm-driven tides. We cannot make definitive statements about different flood types and levels of health outcome, but our analysis of available literature confirms some broad patterns. For example, mortality from drowning and injury tends to be low relative to the extent of inundation for slow-onset or seasonal floods, but becomes a more significant risk in the case of flash floods and storm surges in all regions. Infectious disease outcomes, on the other hand, tend to be associated with prolonged persistence of flood waters in and around homes, often arising from slow-onset events.

Point 3

Vulnerability to health impacts of flood hazard differs between global regions.

At a crude level, there is a major distinction between the health burden of floods in the North and South, linked partly to the geography of hazard, but, crucially, also to capacities within society to protect population from flood hazard, reduce health risks of floods, and provide baseline health care services. Populations in the South tend to be more vulnerable not only because of individual poverty but also because of 'collective poverty' (e.g. inability of government to invest in flood defence). A key difference lies in the accessibility, quality and capacity of health care and other life-supporting services, which is relatively low in many countries of Latin America, Africa and Asia.

However, this gross North/South distinction hides important differences between regions and countries, both in levels of general development and health service provision, and specifically in their response to environmental hazards. A recent report on hurricane preparedness in Cuba suggests that, despite relatively low per-capita income, the country has been highly successful in risk reduction because of its investment in health care, rural infrastructure, and both national-level and local-level disaster planning (Thompson and Gavira, 2004). Rather than gross patterns emerging to contrast North and South, location-specific issues such as culture, topography and local issues may be just as prominent in shaping vulnerability, adaptation, and coping capacity characteristics.

Q. Health risks in North and South – are they fundamentally different?

We can see clear distinctions in the patterns of health outcome between high income and middle or low income countries, yet there is evidence too of universality. It may be that the differences are less fundamental than they might seem. There is a clear danger, for example, in making simplistic assumptions about the geography of mental health impact as mainly confined to the North. Though most of the available evidence comes from the North, the lack of attention paid to mental health impacts in the South may mask a widespread problem. Indeed there is now gradually emerging concern for mental health impacts in the South. Could there be a reverse danger in routinely assuming communicable disease problems in floods are confined to the South?

Point 4

Vulnerability to health impacts of flood hazard also differs at the micro-scale.

The differential vulnerability and coping capacity of individuals, households and communities within countries must also be stressed. A closer analysis of the hazard-morbidity link for flood-related diseases reveals that health outcomes arise in people via a chain of vulnerability. For the presence of flood to affect health

there first has to be some form of exposure to its health-prejudicial effects – such as physical contact with waterborne pathogens. Next there has to be development of illness in the individual, a state affected by existing health status. Final health outcome then depends further on ability to recover from the condition, which is partly dependent on treatment. The differential vulnerability of people to health impact can be seen to arise from differences at all these stages: differences in behaviour, material assets, wellbeing and access to health care.

Socio-economic status is a major influence but, though relative wealth/poverty plays a key role in shaping vulnerability, other assets and resources also come into the equation, including access to social support networks (social capital may be high among certain marginalized groups). Vulnerability is also differentiated by wider societal factors such as water provision policies and cultural norms – ‘structural’ factors that shape the likelihood of health impacts and available response options. Differences in vulnerability may exist at the intra-household level: several authors point toward higher levels of vulnerability among children, the elderly and people with disabilities (e.g. Quarantelli, 2003, Parkinson, 2003). In some contexts, women may be more likely to become disaster victims because they are less likely to be reached by warning and evacuation procedures and may have access to fewer support systems. Handmer (2003), however, warns against a tendency to stereotype social groups ‘a priori’ as vulnerable or lacking in resilience.

Q. How does urban vulnerability differ from rural vulnerability?

This question is directed mainly to developing countries, where major urban/rural differences tend to exist in provision of health care. In rural areas there is less ready access to health care facilities, pharmacies, and alternative water supplies, and the chances of disruption to local health system and transportation may be greater. Relief efforts may be slower to reach rural areas than urban areas for both logistical and political reasons. Urban livelihoods and household incomes are likely to be less disrupted by floods because of greater opportunities for diversification. However, other factors may be at work. A lower disease vulnerability might be expected in rural areas, because of the lack of high population density and high faecal and waste contamination associated particularly with low-income urban areas. Rural populations may have higher resilience when infrastructures fail: urban populations may have become over-reliant on social protection rather than self-protection. Given the gap in comparative studies for specific diseases or for the overall health burden from floods, the question is at present difficult to answer. Urbanization may, however, be a significant driver of vulnerability when it takes place in high flood risk areas on floodplains and coastal strips.

5.2 COPING CAPACITY: RESPONSES TO HEALTH RISKS

Point 5

Responses to the health risks from floods take many forms.

Chapter 4 and Appendix 2 list a range of measures that are taken at different scales by different actors at different phases in the hazard cycle across the fields of health promotion, warning systems and evacuation, disease control, health system disaster procedures, water supply protection and emergency sanitation provision. These stand in addition to a wide range of actions in flood risk reduction generally such as flood control measures and land use planning policy. However, it is difficult at present to make practical statements about the utility and feasibility of different health risk reduction responses. Very few independent studies exist that gauge the effectiveness of response measures. Aside from reports on hospital system procedures in some countries of the North, most that attempt to do so are evaluation reports of general relief efforts during flood disasters.

Q. Is response to 'regular' flooding different from that to extreme flooding?

It has been very difficult to make a distinction between magnitudes of flooding in the review – either from available health impact literature or literature on responses. It seems that response mechanisms to severe events of different intensity tend to be similar in form overall, although they may differ in scale of activity. One key factor is the extent to which the health system itself is damaged and disrupted. Very little information exists on how health systems, communities and households deal with the potential health risks of predictable, seasonal floods in environments where the population 'lives with floods'. Yet this information on coping mechanisms that enable people to co-exist year-by-year with floods could be of key importance.

Point 6

Efforts are needed to improve health risk reduction from present-day floods in most areas.

The studies, reports and recommendations that do exist suggest that there are major limitations to the application of existing response mechanisms for health risks from floods in many areas – limitations broadly in terms of information, organisation and funding. Better efforts are needed to cope with floods that take place now. This is required both in terms of preparedness of health and environmental health systems to cope with emergency demands and damage to infrastructure/services, and in terms of health promotion for at-risk populations via education, mobilization and community-based health risk preparedness.

In integrating risk reduction into health system planning, it is important to recognise hazard or disaster as an inherent potential of pre-existing conditions, rather than

view it as an exogenous aberration from a 'normal' non-emergency state. In this sense, the hazard cycle may be better viewed as a spiral – one that can progress positively upward if learning from the hazard experience leads to adaptation, or downward if the post-hazard phase exacerbates previous vulnerabilities still further (Wisner *et al.*, 2004).

Point 7

Communication and coordination are vital aspects of risk reduction.

In all forms of health-related response to floods, effective response relies not just on the technical means to protect health but crucially also on the flow of information and interaction between different actors and sectors. There needs to be greater dialogue and coordination between institutions and across scales: between policy-makers, agencies and communities in flood preparedness and emergency response.

Several aspects of this theme were raised during the workshop associated with this review project. Information needs to be provided for the public on health and safety risks related to floods and on means of protection against those risks: this needs to be carefully targeted to its audience to maximise its effect. Access to operational information and evaluations of intervention programmes should be improved to promote transparency, accountability and lesson-learning. Community involvement in decision-making should be maximised wherever possible, and the development of community-based emergency management should be encouraged. Researchers too should seek to be pro-actively involved both at the micro-scale (e.g. in aiding local disease surveillance) and at the macro-scale in engaging with national decision-makers and international donors on issues related to floods and health risks, and the impacts of climate change.

5.3 CLIMATE CHANGE, FLOODS AND FUTURE HEALTH RISKS

Point 8

Climate change is likely to intensify future flood problems in many areas.

There is a growing certainty that climate change will lead to changes in flood hazard and a net increase in flood risk globally by 2100. In some locations under some scenarios of climate change there may be significant changes in flooding by 2050. Sea level rise and changes in storm patterns could affect many coastal settlements throughout the world, including many of the world's 'megacities' with populations of over 8 million (Klein *et al.*, 2003). Increases in storm precipitation and seasonal rainfall peaks will affect many river basins, particularly, but not necessarily exclusively, in existing humid regions. We cannot say precisely where, when, and by how much flood hazard will change. However, we contend

that it is reasonable to assume such changes would entail not only an increase in risk in existing flood-prone locations but also cause some coastal and river basin areas to become newly prone to severe flooding.

Point 9

Climate change is therefore an additional driver of future human health risk from floods

In the absence of effective adaptation measures, increased flood hazard as a result of climate change would be likely to exacerbate the health impact of flooding. This additional driver needs to be considered alongside other potential drivers of positive or negative change in flood hazard (such as vegetation and land use changes, and flood management) and vulnerability (such as population growth and poverty reduction). The additional hazard factor implied by climate change may place extra and potentially unanticipated demands on health care provision and other life-supporting services. This may be especially so in circumstances where other drivers such as environmental degradation in low-income African settlements already threaten to overwhelm present adaptive capacities (Parker and Thompson, 2000).

Action in response to future risk is hampered by the long time-scales and uncertainty associated with the climate change problem. Work is required to address the disparity between risk perception/decision-making time scales (typically 10-20 years) and climate change modelling time scales (50-100 years). Though uncertainty remains over the parameters of change, a precautionary approach to response would posit that proof of the effects of the climate change threat should not necessarily be required before adaptive action is taken. Moreover, efforts to build coping capacity against the health impacts of future flood risk will in many cases provide immediate health benefits for populations experiencing floods today.

Point 10

Flooding should be included in formal assessments of climate change health impacts

Only one quantitative assessment of the future health burden of flooding due to global climate change has so far been attempted. The WHO global burden of disease project will provide estimates of deaths and DALYS attributable to 3 climate scenarios, globally and by region (McMichael *et al.*, 2004). Existing national assessments of the potential health impacts of climate change tend to focus on infectious diseases, particularly alterations in the distribution and incidence of vector borne diseases. To date, flooding has not often been considered explicitly as an important mechanism by which climate change may affect human health, with the notable exception of a report by the UK Government (Department of Health, 2001).

Lack of quantifiable health outcome predictions for flooding is not a reason to omit flooding from assessments. Given the uncertainties over future projections of flood frequency and human vulnerability under climate change, the WHO method for assessing national vulnerability to the health impacts of climate change suggests instead that assessments focus on describing current health impacts of weather disasters, in terms of total and age-specific mortality and morbidity (Kovats *et al.*, 2003b). The important next step is then to assess whether vulnerability is increasing or decreasing.

Q. Will climate change bring more of the same, or will it create new threats?

The emerging pattern of climate change predictions is toward intensification of flooding in many existing humid areas. However, can the possibility be ruled out on the micro-scale and even on the macro-scale that areas previously unaccustomed to floods will experience severe events that will pose serious health risks and require some form of adaptive response by actors at all levels in those areas? In addition, given the potential multiple pathways of climate change effects on health, changes in flooding might become superimposed on changes in disease distribution brought about, for example, by rising temperatures. Hence, can we rule out changes in the disease profiles associated with floods in specific locations?

5.4 ADAPTATION PROCESSES AND POLICIES

Point 11

There is a need to move further toward risk reduction activities in advance of flood events

Given the increased risk posed by climate change, a further shift of emphasis toward risk management and preparedness is required, away from an emphasis on emergency response that still remains for many actors. This is increasingly advocated for flood risk reduction in general (such as improvement in weather alert systems and building restrictions on floodplains), which will itself reduce overall health risk 'upstream' by reducing exposure and social vulnerability. But it is also crucial in terms of 'downstream' health protection. There needs, for example, to be more planning and preparedness for the public as well as for health systems to develop health measures that will be taken both before and after events. There is a need for more good quality epidemiological data before vulnerability indices can be used operationally to minimise the effects of flooding on target groups. Flood hazard issues need to become mainstreamed into general health system planning and development. There is, as yet, little evidence of purposeful adaptation to future flood risks in health systems.

Where society in general is already undertaking flood risk reduction efforts, it is crucial that health systems are brought into the process through effective inter-sectoral or inter-institutional coordination. Indeed, given the importance, reach and political 'tangibility' of health impacts from floods there is a case for arguing that the

health sector can and should take the lead in disaster preparedness planning, impact assessment and awareness-raising.

Q. Are material resources critical to adaptation or can health impacts be offset by socio-political factors?

Greater material and economic resources can be deployed to reduce mortality and morbidity from floods in the North, but we cannot assume they are necessarily employed to best effect. The review of responses has underlined that there are important cultural, social and political dimensions to risk reduction. A culture of living with floods – oriented toward building coping capacity rather than flood prevention may have helped foster the development of creative risk reduction measures in Bangladesh and Vietnam. We have seen how efforts to build up public trust can enhance evacuation, how social capital can facilitate community level response, and how political commitment to integrated risk reduction can enhance preparedness at all levels. Given that risks may rise, together with costs of adaptation across a range of climate impacts, it may be important for all countries to reconsider response approaches that rely on capital-intensive measures. But how far can this argument be taken? External relief in the form of material resources is likely to remain crucial in disaster situations. It is important, too, not to overestimate or romanticize notions of resilience in poor communities.

Point 12

Improvement in general health infrastructure and services will play a major role in reducing the specific risk from flooding

For the South in particular, there is a strong argument that adaptation to future health risks will be facilitated most effectively by overall strengthening of health systems and life-supporting services (WHO, 1999). General improvement of health-related facilities and services, including disease control, waste management and water and sanitation provision, would go a long way to reducing vulnerability to specific hazards such as flooding. It will do so by, reducing chronic health hazards in the environment, improving the general health status of populations (so reducing susceptibility to ill-health), and improving the coping capacity of systems during emergencies. If the climate change threat were to galvanise significant improvement in health systems and related services, it could be seen as a ‘win-win’ solution – one that will provide benefits regardless of the outcome of climate change.

Point 13

More effort is needed to identify and communicate best practice in flood health risk response.

Adaptive management of risk is needed, including mechanisms for learning from past experiences. Some studies and reports draw practical lessons from current responses to health risks from hazards and advocate replicable principles for action elsewhere. Most of the recommendations are set within more general

analyses of hazard response rather than focussing specifically on health. However, notable exceptions include a series of publications produced by PAHO on hurricane preparedness (PAHO, 1999), the protection of health facilities from natural disasters (PAHO, 2003), and contingency planning for environmental health during floods (Caribbean Environmental Health Institute, 2003).

More effort is needed to identify actions and strategies at different scales that work effectively, and communicate them to other contexts and regions. This is especially important for areas that may become newly exposed to flood risk as a result of climate change effects. However, generic lessons have to be tailored to local circumstances and made context-specific. It may not always be feasible or appropriate, for example, simply to transpose Northern protection standards into a Southern context. Knowledge transfer may also be limited by the varying characteristics of floods and vulnerability in different settings.

Q Is there scope for cross-cultural learning with regard to adaptation?

Adaptation may arise automatically in new flood-prone areas as climate change effects start to bite, but it may also benefit from deliberate exchange of knowledge between countries and communities. For local level responses there could be useful exchange on customary coping mechanisms, such as avoidance of electrical hazards in flooded homes or how to organise community-based early warning and rescue systems. At a national level, for example, there may be lessons communicated on how preparedness can be better integrated across systems and how relations of trust can be built up between public authorities and citizens. Learning could most easily take place across similar cultural contexts or levels of national development, but there may be generic aspects that can be replicated in widely differing contexts (including 'South-North' and 'North-South' learning). Oxfam America (Thompson and Gavira, 2004) argues that lessons on effective governance and community mobilization from hurricane risk reduction in Cuba are applicable to many countries in the region, regardless of the system of government.

Point 14

There needs to be a global commitment to implementing best practice.

Recommendations are not enough. Putting good ideas into practice requires in many cases strong political will and financial support. It may require an ideological shift in policy-makers, donors and their constituencies toward precautionary action rather than high-profile disaster relief. At present, it is not always easy to attract funding for such activities. Luna (2001) reports on disaster work in the Philippines where, for example, it is difficult for NGOs to obtain funds for capacity building and preparedness compared to emergency relief – the need is less visible, and the impact of the work is less easy to measure. Greater resources are required, not just for health-related preparedness, but also for post-flood phases. Donor response to flood disasters, for example, often fails to continue sufficiently into the recovery period to address long term health outcomes or rehabilitation of health infrastructure and services.

However, there are limits to available funds and the work of organisations such as WHO may become stretched across a range of new health threats associated with

climate change and other drivers of vulnerability. On the one hand, there is a need to learn and communicate the extent to which adaptation may be effected through relatively low-cost efforts in community-based mitigation and preparedness, and through organisational shifts in emphasis toward risk reduction. On the other hand, there may need to be additional sources of global finance. Possible new sources of funding are coming available under the UN Framework Climate Change Convention, including a Least Developed Countries Fund for strengthening adaptive capacity in low-income countries. The fund is already financing the preparation of National Adaptation Programmes of Action (NAPAs) through which countries can set out proposed priority actions to address the potential impacts of climate change. However, it is unclear yet to what extent these new initiatives will be able to facilitate the key transformations that our review suggests are likely to be required.

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APPENDICES

Appendix 1 Summary of epidemiological studies

Table 1. Key studies that assess the relationship between flooding and health			
Author and year of publication	Location and year of flood ^a	Design	Main results
<i>Studies of multiple health outcomes</i>			
Reacher, <i>et al.</i> , 2004	Lewes, UK, 2000 ^b	Telephone interviews of 227 cases (house flooded) and 240 controls (non-matched), 9 months post-flood.	Four-fold higher risk of psychological distress in flooded group (RR 4.1, CI = 2.6,6.4). Flood also associated with earache in all age groups (RR 2.2, CI = 1.1, 4.1). Association for gastroenteritis less marked (RR 1.7, CI = 0.9,3.0).
Kondo <i>et al.</i> , 2002	Mozambique, 2000 ^c	Collection of emergency clinic data and interviews of 62 randomly selected families. No details on how families were selected.	Incidence of malaria reported as increasing by a factor of 1.5-2.0, and diarrhoea by a factor of 2.0-4.0.
Kunii, <i>et al.</i> , 2002	Bangladesh, 1998 ^c	517 persons (non-randomised selection) interviewed 2 months after start of flood.	Fever accounted for 42.8% of health problems among 3,109 family members; diarrhoea 26.6%; respiratory problems 13.9%.
Biswas <i>et al.</i> , 1999b	West Bengal, India, 1993 ^c	Survey conducted before, during, and after flood in four villages. No further details on sample.	Attack rate for diarrhoea increased from 4.5% pre-flood to 17.6% post-flood ($p < 0.01$). Rates for respiratory infections 2.8% and 9.6% respectively ($p < 0.01$).
Duclos <i>et al.</i> , 1991	Nîmes, France, 1988 ^{c, g}	108 questionnaire interviews 1-2 months post-flood. Review of medical care delivery data for Nîmes area. Active	Nine flood-related drownings, but death certificates did not reveal increased mortality. 6% of interviewees report mild injuries. No specific increase in infectious disease observed.

		surveillance in GP clinics instigated one week after flood. .	
Woodruff <i>et al.</i> , 1990	Khartoum, Sudan, 1988 ^{c, g}	Review of admissions data; 12 sentinel disease surveillance sites established post-flood.	Diarrhoeal disease most reported cause of non-fatal illness among all age groups. Population-based mortality rates could not be calculated.
Dietz <i>et al.</i> , 1990	Puerto Rico, 1985 ^g	Routine death certificate data from 12 most flood-affected municipalities.	180 disaster-related deaths. Data for 95 recovered bodies – 22% (21/95) drowned. No significant change in communicable disease post-flood.
Handmer and Smith, 1983	Lismore, Australia, 1974 ^g	Comparison of patients from flooded and non-flooded areas.	No flood-related increase in hospital admissions and this holds for all classes of flood severity. No significant overall change in total number of deaths.
Price, 1978	Brisbane, Australia, 1974 ^b	695 cases and 507 controls (no details of selection procedure).	Percentage claiming worsened health rose with age in flooded group ($r=0.9104$). Between groups analysis saw general tendency for difference to increase with age, although those >75 years least affected.
Abrahams <i>et al.</i> , 1976	Brisbane, Australia, 1974 ^b	738 cases and 581 controls interviewed. No details on how sample was selected.	No differences in mortality between control and flooded groups. Flooded males more likely to visit GP than non-flooded males ($p<0.01$). Psychological disturbances more prominent, than physical ones in both sexes.
Bennet, 1970	Bristol, UK, 1968 ^b	Survey comparison 316 flooded and 454 non-flooded homes	76% rise in flooded males attending GP more than 3 times ($X^2 10.6, P<0.01$). Hospital referrals among flooded more than doubled in year after floods ($p<0.01$). Increased self-reporting of physical and psychiatric complaints. 50% increase in number of deaths among flooded. Most pronounced rise in the 45-64 age group, and increases predominantly in those >65 years.
<i>Mortality</i>			
Staes <i>et al.</i> , 1994	Puerto Rico, 1992 ^b	23 flood-related deaths (cases), and 108 controls	Estimated risk of mortality significantly elevated (OR = 15.9, 95% CI 3.5,44) for those who occupied a vehicle, and risk remained

		(randomly selected from those seeking disaster relief).	significantly elevated after controlling for age and sex.
Siddique <i>et al.</i> , 1991	Bangladesh, 1988 ^g	154 flood-related deaths. Comparison of health centre and district level records.	Children < 5 years accounted for 38% of all deaths, and those between 5-9 years for 12%. Diarrhoeal disease most frequent (27%) cause in all ages; respiratory tract infections 13% (20/154).
<i>Faecal-oral disease</i>			
Wade <i>et al.</i> , 2004	Mississippi River, USA, 2001 ^{c,e}	1,110 persons from intervention study cohort provide flood survey health data.	Flooding of house or yard significantly associated with gastrointestinal illness for all subjects (IRR = 2.36, CI = 1.37,4.07), and children ≤12 years (IRR = 2.42, CI = 1.22,4.82).
Vollaard <i>et al.</i> , 2004	Jakarta, Indonesia ^b	93 (69 typhoid and 24 paratyphoid) enteric fever cases compared with 289 non-enteric fever patient controls, and 378 randomly selected community controls.	Flooding of house significant risk factor for paratyphoid fever. When paratyphoid group compared with community control OR = 4.52, CI 1.90, 10.73; and compared with fever controls OR = 3.25, CI 1.31, 8.02.
Heller <i>et al.</i> , 2003	Betim, Brazil, ^b	997 cases (children < 5 years with diagnosis for diarrhoea) and 999 controls	Flooding of family compound significantly associated with diarrhoea (RR = 1.39, CI = 1.09,1.76).
Prado <i>et al.</i> , 2003	Salvador, Brazil ^c	694 children aged 2 to 45 months from 30 clusters throughout the city	Susceptibility to flooding studied as potential risk factor for <i>Giardia duodenalis</i> , but no statistically significant result found.
Mondal <i>et al.</i> , 2001	West Bengal, India, 1998 ^b	Comparison of flood and non-flood areas; two villages in each area selected by systematic random sampling.	Frequency distribution of diarrhoeal disease significantly higher in flooded area ($p < 0.001$).
Sur <i>et al.</i> , 2000	West Bengal, India, 1998 ^d	Mortality and morbidity data collected from district hospital, and 4 primary health centres.	In 3 month period following flood, 16,590 cases reported, with 276 deaths (attack rate of 1.1%, and case-fatality rate of 1.7%). Laboratory results suggested that <i>Vibrio cholerae</i> was primary causative agent.

Korthius <i>et al.</i> , 1998	Irian Jaya, Indonesia ^d	Cases of diarrhoea identified from community health clinic records	Epidemic curve inconclusive as to the source of the outbreak, and no <i>Vibrio cholera</i> species isolated from water sources.
Katsumata <i>et al.</i> , 1998	Surbaya, Indonesia ^{b, c}	917 hospital patients with acute diarrhoea (cases) and 1,043 in-patients without gastrointestinal problems (controls), plus community-based study during rainy, and dry season.	Flooding independently associated with an increased risk of cryptosporidium infection (OR = 3.083, CI= 1.935-4.912).
van Middelkoop <i>et al.</i> , 1992	Kwazulu Natal, South Africa ^d	Cases of poliomyelitis identified from hospital records	Strong correlation (Spearman's 0.56, p<0.01) between flood-related mortality rates in each district – which was used as an indicator of the severity of the floods – and poliomyelitis attack rates.
Fun B.N. <i>et al.</i> , 1991	Bangladesh ^g	Data for patients seeking treatment for acute diarrhoea between June 1987 and May 1989.	Major peak for Rotavirus recorded in September 1988, coinciding with major flood. Occurrence of RV diarrhoea declined immediately after flood, but non-rotavirus diarrhoea remained high.
Vector-borne disease			
Han <i>et al.</i> , 1999	Bucharest, Romania ^b	Compared asymptotically infected persons (n=38) with uninfected persons (n=50) identified in serosurvey.	Among apartment block dwellers 63% (15/24) of infected persons had flooded basements; 30% (11/37) for uninfected (OR= 3.94, CI= 1.16-13.7, p< 0.01)
Rodent-borne disease			
Leal-Castellanos, <i>et al.</i> , 2003	Chiapas, Mexico ^c	1,169 persons aged 15-86 years randomly selected for interview, and provided blood sample.	Contact with water in puddles or from flooding was a risk factor related to <i>Leptospira</i> infection. rude
Sarkar <i>et al.</i> , 2002	Salvador, Brazil ^b	66 randomly selected	Incidence of severe Leptospirosis for the city was 6.8 per

		hospitalised cases, and 132 controls matched on age and sex, and from the same neighbourhood as the cases.	100,000. Exposure to flooded open sewers OR 4.21, CI = 1.51,12.83; and for flooded street OR 2.54, CI = 1.08,6.17
Sanders <i>et al.</i> , 1999	Puerto Rico, 1996 ^g	All patients who had negative results in an anti-dengue test were assigned to a pre- and post-hurricane period based on date of onset of illness.	24% (17/70) laboratory confirmed in post-hurricane period, compared with 6% (4/72) in pre-hurricane period (RR = 4.4, CI = 1.6,12.4).
Trevejo <i>et al.</i> , 1998	Achuapa and El Sauce, Nicaragua, 1995 ^b	61 case-patients identified from health centre records, and 51 controls randomly selected from same area and matched by age group.	Age-specific incidence significantly higher ($P < 0.05$) in 1-14 years age group, compared with other age groups.
<i>Mental health</i>			
Melick, 1978	Pennsylvania, USA, 1972 ^b	Personal interview survey (3 years post-disaster) of 43 flooded and 48 non-flooded working-class men aged 25-65	Those who were flooded had longer periods of ill health, but no significant differences in number and nature of illnesses experienced by flood and non-flood respondents.
Logue <i>et al.</i> , 1981	Pennsylvania, USA, 1972 ^b	Postal questionnaire survey (5 years post-disaster) of 396 flooded, and 166 non-flooded females (> 21 years old)	Flooded respondents had longer periods of ill health, and a statistical trend ($p < 0.10$) was noted for anxiety.
Powell and Penick., 1983	Mississippi, USA, 1973 ^e	Personal interview of 98 flooded individuals 2 and 15 months post-flood	Significant increase in short- and long-term emotional distress ($p < 0.001$), but pre-flood data collected retrospectively.
Ollendick and Hoffman., 1982	Rochester, USA, 1978 ^c	Personal interview (8 months post flood) of 124 adults & 54 children from flooded homes	Significant difference between pre- and post-flood scores for depression and stress in both groups. However, pre-flood data collected post-event.

Phifer <i>et al.</i> , 1988, and Phifer, 1990	South-eastern Kentucky, USA, 1981 and 1984 ^f	Stratified three-stage area probability design. 198 adults aged 55-74, with six waves of interviews	Flood exposure associated with increases in depression, ($p < 0.005$), and anxiety, ($p < 0.0008$). Flood exposure also associated with reports of increased physical symptoms ($p < 0.003$).
Durkin <i>et al.</i> , 1993	Bangladesh ^c	Prospective cross-sectional of children aged 2 to 9 years (n=162)	Post-flood 16 children reported to have 'very aggressive' behaviour (pre-flood = 0), and this represented a significant increase ($p < 0.0001$). Pre-flood 16% of children wetted bed, post-flood 40.4% wetted bed ($p < 0.0001$)
Ginexi <i>et al.</i> , 2000	Iowa, USA	Non-randomised quasi-experimental longitudinal interview survey, pre- and post-flood	1,735 participated in interviews 60-90 days post-flood. Ages ranged from 18-90 (Mean = 50.9, SD = 16.5). Among respondents with a pre-disaster depression diagnosis, the odds of a post-flood diagnosis were increased by a factor of 8.5 (95% CI = 5.54-13.21).
^a Where date is provided, study refers to a specific flood event; ^b Case-control study design; ^c Cross-sectional study design; ^d Outbreak investigation; ^e Cohort study design; ^f Panel study; ^g Routine data (e.g. disease surveillance, hospital admissions, clinic attendance) ** OR, odds ratio			

Appendix 2 Types of health-related response

	Type of Response	Examples
Actions by households	Avoidance of exposure to water Avoidance of waste contamination Reduction in vector abundance Treatment of water Coping adjustment to dwellings Social support Advance purchase of medicine	Raising furniture on bricks and creating raised walkways from planks Removal of waste matter, unblocking of drainage channels Removal of unused vessels where mosquitoes can breed after flooding recedes. Boiling, use of alum crystals or disinfection tablets Placing electrical wiring high up on walls in flood-prone environments Care and support for household members under stress Ensuring household supply of treatments for common flood-related ailments
Actions by the community (the organisation and preparation of which may involve external assistance)	Voluntary relief efforts Social support networks Community citizen disaster preparedness programs Community-based flood early warning system	Distribution of food by richer family to poorer, setting up of relief centres, emergency rescue Informal support networks can -help lessen negative emotional impact of floods Training and organization in reducing health risks, preparing emergency kits, evacuation plans, first aid and health care Traditional warning mechanisms and new initiatives in local river monitoring
Actions by public/private agencies relating to preventive health	Health and hygiene education on health risk during floods	Dissemination of educational material by various media and through outreach

	Integrated systems of warning and evacuation	Advance planning of flood risk communication and evacuation procedures; provision of accessible shelters and safe houses
	Disease surveillance	Activation of pre-planned surveillance system for selected flood-related diseases
	Disease control	Vaccination campaigns; vector control mechanisms
Actions by public/private agencies relating to health care provision	Emergency planning	Disaster preparedness for health systems: practical drills, information and guidelines on availability of staff, decision making channels, communication with media, supply and storage of medicines
	Need assessment	Rapid need assessment for directing health care response measures ; monitoring of health care needs among vulnerable groups
	Provision of emergency health posts and services	Field hospitals and mobile health care teams during emergencies; provision of boats for public access to health centres; coordinated distribution of medicines
	Prioritization of services	Rescheduling, admissions restrictions, continuation of essential care
	Mental health care	Provision of counselling and related support for affected populations
Actions to protect health infrastructure	Preparedness planning	Addressing issues of communication and power failure, physical damage to health care facilities, water shortage and contamination etc.
	Flood-proofing	Appropriate design and construction of new facilities
Actions to protect and provide safe water and sanitation	Advance protection	Design supply infrastructure to consider the geography of natural hazard risk, and to incorporate measures to ensure the system can continue functioning when floods occur.
	Temporary protection measures	Raising of tubewell heights; advance distribution of water treatment kits to strategic locations
	Emergency provision and restoration of water supplies	Emergency alternative water sources e.g. tankers; decontamination and recommissioning of sources
	Emergency provision and restoration of sanitation facilities/systems	Portable toilets, emergency public latrines, sewage tankering services; isolation and repair of damaged sewerage sections piped systems

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