flood control strategy. In contrast, very few urban flood protection projects exist and much less is known about urban than rural, agricultural flood loss (Flood Plan Coordination Organisation, 1992). Vulnerability to floods is now rapidly increasing in the urbanising areas which are likely to present the greatest flood hazards for the future. A major challenge is faced by Bangladesh in addressing the growing flood vulnerability of urban areas, and finding a successful path towards environmentally sustainable development, given important questions over the compatibility of existing ways of life and flood control strategies with this goal (Westcoat *et al.*, 1992).

Given recent flood disasters in Bangladesh, progressively greater attention needs to be concentrated upon urban flood hazards and urban flood loss, in order to build knowledge and data networks which may be employed to enhance economic resilience. Research by Islam (1996) is concentrating upon this problem in order to construct reliable sets of potential flood damage data, which may be used to estimate the benefits of flood protection and, thereby, the economic effects of urban flood protection proposals. Only by generating reliable urban flood damage data can the necessary calculations be performed, to test the economic effects of alternative strategies and projects. In the absence of these data, efforts to allocate economic resources in order to achieve economic and social goals (e.g. economic efficiency, a redistribution of economic resources) are seriously hampered.

Research on flood damage potential is based upon detailed investigations of flood damages in 3 sub-areas of Bangladesh using 3 reference floods: Tangail (1988), Bahubal (Habiganj) (1993) and Khatunganj (Chittagong) (1991) In total, flood damage in 356 households, 123 industries, 103 other businesses and 20 offices, has been investigated by Islam. Table 3.3 presents total flood damage values for 4 principal urban house types in each of the 3 sub-areas. Per capita income is correlated with house type: per capita income is highest for house type BB and declines through BC and MC to the lowest which is MT. The potential value of these data lies in their incorporation within unit-loss flood damage models (Parker *et al.*, 1987), which are employed in estimating the potential effects of flood protection.

An important finding of the research into urban household flood damages (Table 3.3) is that low-cost houses (with their low-income inhabitants) are highly vulnerable to floods: the poorer the household is, the higher the percentage of damage to their asset values. These findings suggest that floods not only reinforce poverty but may also act to widen the income gap between rich and poor. Because flood damages may be counted as flood protection benefits, and because the rich usually generate more benefits than the poor, conventional economic efficiency cost-benefit methodologies tend to direct protection towards the rich and away from the poor. Unless checked, for example by more highly weighting the value of flood damages experienced by the poor, this problem can lead to practice which is counter to the principle of converging intra-generational equity, which is embodied within the concept of sustainable development.

Table 3.3
Urban household flood damage estimates, Bangladesh,
(in 1992/93 Taka £ values)

	TANGAIL RIVER FLOOD 1988		BAHUBAL FLASH FLOOD 1993		KHATUNGANJ TIDAL FLOOD 1991	
House Type	Total damage value	Total damage as a % of asset value	Total damage value	Total damage as a % of asset value	Total damage value	Total damage as a % of asset value
BB	23807	7.3	14069	6.2	65642	22.5
BC	24425	10.7	10781	11.6	92122	32.1
MC	16890	11.2	5500	30.7	76654	55.0
MT	11561	26.2	10714	43.2	34709	64.1
ALL	19198	10.2	10230	11.4	61908	33.6

BB Brick floor, brick wall
BC Brick floor, corrugated iron sheet wall
MC Mud floor, corrugated iron sheet wall
MT Mud floor, thatched wall

60 Taka = £1.00 Sterling

Source: Islam (1996)

Reducing the physical vulnerability of dwellings and households through flood-proofing techniques in Hong Kong

The rapid urban growth achieved by Hong Kong has generated a significant rise in the standard of living of its inhabitants, rapid population growth and the development of villages and towns in the New Territories, adjacent to the border with the People's Republic of China. There are approximately 100 villages within 10 kilometres of the border, many of which are located partly or entirely within river flood plains. Development of new towns in the New Territories has led to particularly rapid land use change, which is associated with the restriction of drainage, land filling and the reduction of flood plain storage and land reclamation which has reduced drainage gradients. All of these factors have exacerbated the flood hazard, and damaging flooding is an almost annual occurrence sometimes associated with typhoon conditions. Because living standards have increased, housing quality has improved and household durable goods are in higher ownership. Flood damages are therefore escalating and there is a growing intolerance of flooding. Various methods of reducing flood disaster potential are being employed in the Hong Kong New Territories, including river channel improvements, institution-building (e.g. new legislation to designate watercourses to bring them under planning control), improved maintenance and management of watercourses and improved flood forecasting and warning systems. The overall strategy has also included flood-proofing methods, both for villages and for selected households.

Flood-proofing is a set of techniques designed to increase the resilience of buildings, or clusters of buildings and related infrastructure, to flood damage (Laska, 1991). Systematic investigation of these techniques and their applicability originated from observed property owner self-protective behaviour - based on local knowledge and experience - within flood plains. In most cultures some occupants of frequently flooded flood hazard zones find ways of adapting their properties to reduce their vulnerability to flooding. Typical examples include the construction of steps or flood shields across doorways to prevent the ingress of water, or the elevation of houses. Both techniques can be observed in Hong Kong. The systematic evaluation of the range of feasible techniques (Table 3 4) subsequently led to their more formal categorisation and promotion, and to identification of the appropriate circumstances for flood proofing (e.g. Sheaffer, 1960) In Hong Kong bunding of small villages has already proved a valuable vulnerability reduction measure (bunding: protection by embankment).

Following serious flooding in 1987, 1988 and 1989 an impetus developed to investigate the applicability of flood proofing measures in villages and common house types in the Hong Kong New Territories (Parker, 1992). The feasibility of flood proofing is a function of (a) the type and condition of buildings and their typical contents, (b) catchment and flood conditions and (c) the socio-economic characteristics of householders. For example, dry flood proofing is not a recommended technique where river valleys are narrow and steep and flooding depth is likely to be in excess of one metre. In the case of the New Territories catchment conditions are conducive to this type of flood proofing because valleys are flat and wide and flooding is generally less than one metre in depth. In the New Territories a constraint upon 'contingent' flood proofing (i.e. non-permanent flood proofing which depends on the property owner implementing a pre-conceived contingency plan) is the rapidity of flooding. Therefore permanent methods of flood proofing are preferable, although contingent methods can work if linked successfully to flood warnings. In the New Territories villagers who are likely to be amenable to flood proofing are those who are owner-occupiers, those with some disposable income, those who have experienced multiple flooding and those for whom some flood proofing has already proved to be valuable. New Territories villages are of four principal house types; each type lending itself to particular forms of flood proofing (Table 3.5). For example, Type A is a 65 square metre house with concrete frames and concrete or brick infill, and concrete materials. Table 3.5 was prepared to provide a systematic guide to the feasibility and appropriateness of different methods of flood proofing, given the typical variation of house types, flood conditions and socio-economic circumstances in the Hong Kong New Territories. This guide was subsequently used to identify appropriate methods of flood proofing designed to reduce the vulnerability of selected flooding in villages in the New Territories (Table 3.6), and the methodology can be applied to most circumstances.

Enhancing social and system resilience through improved flood warnings in Peninsular Malaysia

Malaysia is a newly-industrialising country with a high economic growth rate and rising standards of living. These are amongst conditions in which floods and other hazards can be expected to be magnified, simply because rapid economic change can have dramatic effects on natural and social processes (e.g. upon the hydrological cycle and the rate of development in floodplain). Generally, the rather stable communities in the Peninsula's eastern agricultural region, and along the east coast, are well adapted to 'normal' floods; many of them are characterised by dwellings which are raised above the floodplain or above tidal flood zones on stilts of varying height, a further example of local knowledge being utilised to reduce vulnerability. In contrast, communities in the western part of the Peninsula, which is experiencing rapid urbanisation (e g. in the Kelang River Basin in which Kuala Lumpur is located), are generally less well adjusted to floods. This is because of the hydrological effects of urbanisation (i.e. increase in flood frequencies and magnitude and in the 'flashy' nature of floods) which is creating new flood hazards, higher levels of population mobility (leading to loss of local flood experience and knowledge), and the steady loss of indigenous coping knowledge and mechanisms such as the stilt house. As floods become more 'flashy', flood warning lead time (i.e. the time between receipt of a flood warning and the onset of flooding) is reduced.

More effective flood warning systems can enhance social resilience to floods, by delivering the benefits of either advanced, or intermediate flood forecasting technology to communities The range of choice of flood hazard reduction options can also be enhanced by introducing flood warning systems. However, research indicates that flood warning systems are only likely to be effective where the local knowledge and the needs of the community are well integrated into the flood forecasting and warning system (Parker and Neal, 1990; Schware, 1982). The same approach can also enhance system resilience by providing communities with a complementary mix of approaches to flood hazard reduction. For example, rather than relying solely upon flood embankments which may fail or be overtopped, the resilience of communities can be enhanced - and the risk of catastrophic disaster may be reduced - by adding a well-designed flood forecasting and warning system to cope with the residual hazard. Chan (1995) completed a survey of 618 flood plain occupants who had experienced recent flooding in four flood-prone areas of the Peninsula: Pulau Pinang, Kuala Lumpur (both western Peninsula locations) and Kelantan and Pekan (both eastern locations). This showed that 54 per cent of flooded respondents were not warned of flooding and the percentage of those flooded who were warned is lowest in the more urban western locations (Table 3.4). As many as 48 per cent of respondents relied more upon their own judgement than upon a formal flood warning system. Overall only one-third of flooded respondents received a flood warning, and 31 per cent of these receive their warning after the flood onset (i.e. with zero warning lead time). Normally the higher the lead time, the greater the potential for flood damage savings. The mean flood damage saved by flood warning was $705 Malaysian (the mean monthly income for Malaysian flood plain households is $917 Malaysian) (Chan, 1995, p.318). The potential for increasing flood damage savings - and thus enhancing resilience to floods - is high where flood warning dissemination systems can be improved and closely linked to local needs, in order to increase the proportion warned and the warning lead time. Research from

Table 3.4
The principal methods of flood proofing

Property relocation	Removing an existing structure and resiting it on flood-free land
Property elevation	Existing buildings can be raised in situ, i.e. 'retrofitting' New structures can be constructed above a minimum floor level, consistent with the flood potential and defined within planning controls
Bunding and walling	Individual buildings or small clusters of them may be flood proofed by constructing small bunds or walls around them: 'neighbourhood' flood proofing
Dry flood proofing	Structures that are generally impermeable to water may be modified to exclude floodwater by installing watertight barriers or closures to openings. Waterproofing sealants used on walls or floors can reduce permeability. Flood shields are an example.
Wet flood proofing	Within buildings flood damage potential can be reduced by alterations and by reorganising space use, so that the most vulnerable items are located in the least damageable place Relocation of electrical circuits and outlets from floor level to waist or ceiling level is an example.

Table 3.5
Summary of conditions in which different types of flood proofing are likely to be most applicable/successful and inapplicable/unsuccessful

	Principal Methods of Flood Proofing				
	Relocation	Elevation	Bunding	Dry Flood	Wet Flood
Village House Types					
Type A : Modern	1	1	1	2	2
Type B : Old	1	1	1	½	2
Type C : Small, old	2	1	2	½	2
Type D : Small, timber	2	0/1	0/1	0	2
Contents	1	1	1	2	2
Flood Characteristics*					
Shallow 20-100 mm	0	1	0	2	2
Moderate 100-1000 mm	1	1	1	2	2
Deep 1000 mm +	2	2	2	0	1
Low velocity less than 1 m/s	1	2	2	2	2
Moderate velocity 1-1.5 m/s	1	1	1	1	2
High velocity 1.5 m/s	2	1	1	0	1
Slow rate of rise	0	1	1	2	2
Moderate rate of rise	0	1	1	2	2
Rapid rate of rise	1	1	1	1/2	2
Short duration 1-3 hours	0	0	1	2	2
Moderate 3-24 hours	0	0	1	2	2
Long duration 24 hours +	1	1	1	0	2
Very frequent 1 + per year	2	2	2	2	2
Frequent 1 in 3 years	2	2	2	2	2
Less frequent 1 in 4 years	1	1	1	0	1
Unpolluted	0	0	0	0	2
Polluted	0	0	1	2	1
Little rainwater	2	2	2	2	2
Considerable rainwater	2	2	0/1	2	2
Socio-Economic Characteristics					
Owner	2+	2+	2+	2	2
Tenant	2+	2+	2+	1	2
Experienced with floods	2+	2+	2+	2	2
No flood experience	2+	2+	2+	0/1	0/1
Disposable income	2+	2+	2+	2	2
Low income	2+	1	2+	0/1	2
Non mobile	2+	2+	2+	2	2
Mobile	2	2+	2+	0/1	0/1
Previous flood proofers	1	1	1	2	2
Not flood proofers previously	2	2	2	1	1

0 - Inapplicable/likely to be unsuccessful, 1 - Might be applicable and successful; 2 - Highly applicable and likely to be successful

* flooding characteristics (e.g. depth, velocity, etc.) are only specified in approximate, indicative terms

\+ where socio-economic characteristics are assessed as having no significant direct bearing on the flood proofing method they are specified as 2+

0/1 or 1/2 where applicability/successfulness is assessed as either 0/1 or 1/2 the condition is marginal or may be applicable/successful only in some cases

Table 3.6
Suggested approaches to flood proofing selected new territories villages

VILLAGE	SUGGESTED APPROACHES	COMMENTS
Shui Tin Tsuen	Clearance, relocation and rehousing.	Approx 20 households in metal squatter shacks.
Ko Po Tsuen	Mixture of clearance and relation, and dry flood proofing to be extended.	Extensive wet flood proofing evident.
Sha Po Tsuen	Dry and wet flood proofing, with possibilities of using neighbourhood fortress flood proofing for parts.	Squatter shacks recently cleared by landowner: one only remains to be cleared Passageways unusually wide (1-6 metres) Seepage through house walls reported as a problem. Neighbourhood flood proofing using fortress concept likely to be problematic because of passageway widths.
Pok Wai	Neighbourhood flood proofing using the fortress concept or extend dry flood proofing or mix of both.	About 100 households reported as flooded in past year by village representative.
Chuk Yuen	Neighbourhood flood proofing using fortress concept	Many houses built in 1970s and since - in sound condition.
Mai Po	Neighbourhood flood proofing using fortress concept.	Much dry flood proofing evident, concrete flood shields and steps to doors. Narrow passageways 1-2 metres wide
Tai Tau Leng	Extend dry flood proofing or neighbourhood flood proofing using fortress concept in parts.	Complicated drains making simplification and/or sump pumping essential

Note The suggested approaches are the result of a rapid, preliminary village inspection only and in some cases extensive and detailed further investigation is required to confirm sources and routeways of flooding, to confirm the findings and to identify detailed and practicable flood proofing designs

Europe indicates that there are some important ways in which flood forecasting and warning systems can be developed to make them effective (Parker and Fordham, 1996). Although there are some obvious and important physical and cultural differences between south-east Asia and Europe, many of these research findings appear to have relevance in Malaysia (Chan, 1995). Under-developed flood forecasting and warning systems are 'forecast dominated' i.e. investment and effort in the technology and procedures leading to a flood forecast is far greater than that which is directed towards disseminating the flood warning to those occupying flood hazard zones. In advanced systems this problem will have been addressed, and methods of timely and rapid flood warning dissemination will have been proven, and their performance regularly monitored. In rudimentary systems untargeted 'blanket' flood warnings will be characteristic but in advanced systems the dissemination of flood warnings will be much more targeted, aided by high quality flood hazard zone information. Effective advanced systems will be based upon public preferences for warnings and upon the integration of formal and informal warning systems, making the best use of local knowledge and willingness to be participate, including through the employment of local flood wardens.

Resilience-building by widening the range of choice: floodplain management

One of the most powerful forces propelling increased vulnerability to floods is economic development which channels people and properties into flood hazard zones. Exposure to flood risks is growing rapidly in many parts of the world, through this process sometimes known as 'floodplain encroachment'. Systematic data on floodplain encroachment is sometimes difficult to obtain, especially in the developing world, where development is rapid and land use mapping and related data-bases are non-existent or rudimentary. Research in the United States and England and Wales has, however, demonstrated the almost inexorable urban encroachment of floodplains (Montz and Gruntfest, 1986; Parker, 1995; White *et al.*, 1958). Elsewhere, for example in Bangladesh, rural floodplains have been 'invaded' by progressively larger numbers of inhabitants, each seeking a more secure livelihood.

The most common response strategy is a protective one Flood embankments, river diversions and channel improvements are the classic forms of structural flood defence. In many parts of the world these remain the accepted and dominant approach, although serious doubts continue to be raised (Westcoat *et al.*, 1992). Beyond the USA, governments have been slow to recognise the crucial point, which was recognised by White (1945), that non-structural measures are also necessary. Progressive extension of structural flood defences, and progressive heightening of existing flood defences, tends to part of an 'escalator effect' (Parker, 1995) in which higher levels of security induce further flood plain development behind flood defences. Rising flood damage potential is commonly used to justify more extensive and higher flood defences and so on. The effect is to raise the potential for catastrophic flood loss in the event of structural defences failing (i.e. through overtopping, breaching or failure to close floodgates), and to progressively increase the maintenance and replacement costs associated with structural flood defences. The sustainability of this approach, in terms of mounting costs of maintenance and progressive replacement of high technology structures, especially in the developing world, is highly questionable.

The principal form of non-structural flood hazard reduction is regulation of floodplain development, although flood warning systems are a further example. The aim of regulation is usually to prevent undeveloped floodplains becoming unwisely developed and to constrain further development in already partly developed floodplains. Wise use of floodplains can be defined in various ways but it might include development decisions which minimise the risk of loss of life.

The concept of 'floodplain management' has reached its highest articulation in the USA (Association of State Floodplain Managers, 1990). Floodplain management embraces regulation of floodplain development through planning controls and through insurance-based incentives. However, it also embraces a wide range of flood hazard reduction options including flood proofing, flood warning, and flood information dissemination and education. Appropriate combinations of flood hazard reduction methods are selected for use in particular floodplains, employing the full range of choice of options and thereby enhancing resilience.

Conclusions

Disaster vulnerability is growing over time owing to a host of factors, including (a) socio-economic and political forces which exclude and deny access to resources, and which reinforce poverty and the growth of the income-gap, (b) the perpetuation of environmentally degrading and non-sustainable resource use practices, (c) urbanisation and the spread of people and development into hazard zones and (d) the negative feedback effects of human activities on biophysical systems (e.g. greenhouse gases contributing to global warming and the consequent hazards of global climate change). In this context post-disaster reconstruction provides important opportunities to slow and to subsequently reverse the process of vulnerability growth.

This chapter provides a conceptual framework for thinking about how vulnerability to flood disaster - indeed any hazard or disaster - might be slowed and reversed, together with a number of examples. Because hazard vulnerability extends well beyond the immediate causes and effects of disasters, the scope for vulnerability reduction is enormous and extends into most aspects of the development process. An important theme is the need to identify paths of sustainable development in order to reduce the incidence of disaster and hazard-proneness. In turn this highlights the need to develop and utilise analytical methods (e.g. flood impact estimation methods), which are capable of identifying the distribution, as well as the economic efficiency, impacts of post-disaster reconstruction projects so that intra-generational equity issues which are fundamental to sustainable development are addressed. Another theme of importance is the role of local knowledge and experience in hazard reduction, and the need to build upon indigenous hazard-coping mechanisms which are all too often supplanted by external ones which prove to be ineffective.

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