Flood Disaster Mitigation and Management:
A Synthesis and Key Lessons

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There is an increasing trend worldwide in the number of disasters and their total economic impacts. Flooding causes over one-third of the total estimated costs and is responsible for two thirds of people affected by natural disasters. Over 90% of people affected by natural disasters worldwide live in Asia, as the countries in Asia with large populations are particularly prone to recurrent flooding. Many disaster planners, responders and also civil engineers categorically argue that 'urban flooding' is much different from 'rural flooding' and are correct to great extent - while examining their interest and roles. However, scientific and mitigation implications draw some classic but re-enforcing components of flood disaster management - that are almost same in understanding of floods as disaster - be it in the city, villages, croplands, industrial estates or other countryside areas. 'Floods' are natural disasters, undoubtedly, and as ecological factors and part of environmental dynamics, can and usually turns into 'humanitarian disaster'.

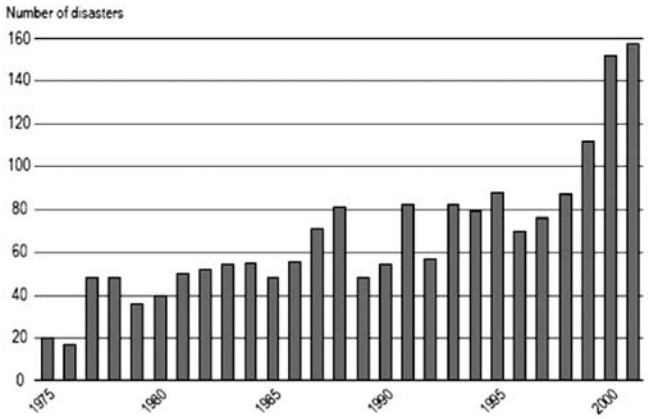

Figure 1. Number of disasters attributed to floods *(Source: EMDAT, CRED).*

* The paper is a summary synthesis from the final technical reports of Urban Flood Case Studies Project of National Institute of Disaster Management (A. K. Gupta & P. G. Dhar Chakrabarti, Disaster & Development, 3(1): 1-14, 2009).

Floods – in Making of a Humanitarian Disaster

'Flood' is excess above threshold of carrying capacity, and is the same in case of 'water' - too much, prolonged, inundating, and causing damage to property, environment and people, referring flood disaster in humanitarian response and relief context. Environmental-changes as drivers of hydro-meteorological disasters and impacts that create 'humanitarian disaster' has been summarised in the figure 2. Environmental hazards that drive the changes in climate, geo-morphological, hydrological and biological setting of the regions create vulnerability of the ecosystems thereby reducing its capacity to cope with major shifts in energy or matter (water) profiles. A structural disaster can be triggered by a natural disaster and, if mitigation fails, can develop into a humanitarian disaster. There has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. The most notable amongst them are Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat and Bhopal in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009.

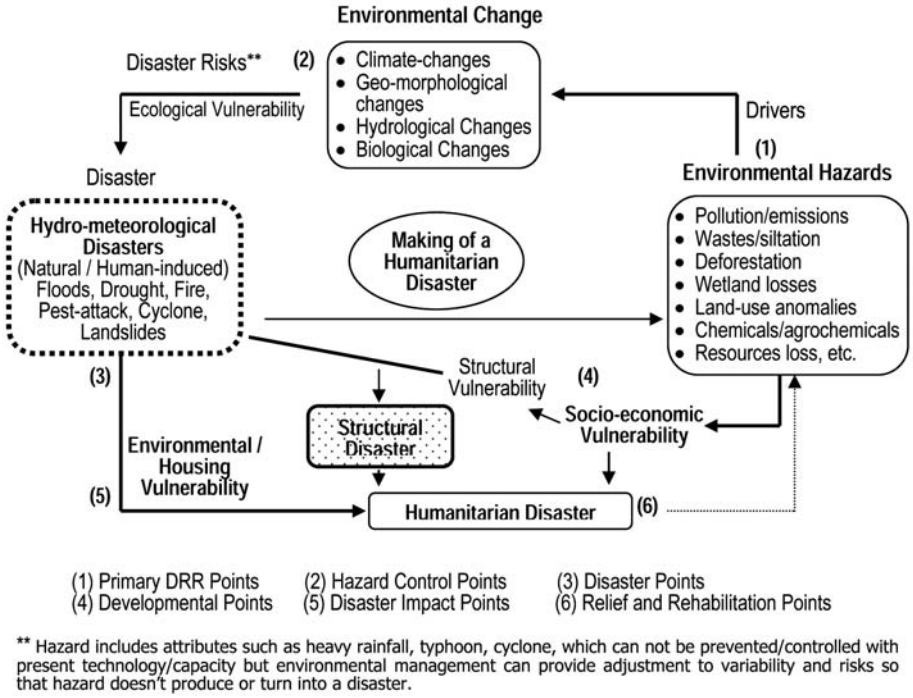

Figure 2. Making of a humanitarian disaster *(Gupta, 2010)*.

Cities may be situated on the coasts, river banks, near downstream/ upstream of dams, inland or in hilly areas. There are several cities which may fall under more than one of these categories. Mumbai city, having an area of 437 km2 with a population of 12 million, came to a complete halt owing to the unprecedented rainfall of 994 mm during the 24 hours starting 08:30 on 26 July 2005. At least 419 people (and 16 000 cattle) were killed as a result of the ensuing flash floods and landslides in Mumbai municipal area, and another 216 as a result of flood-related illnesses. Over 100 000 residential and commercial establishments and 30 000 vehicles were damaged (Gupta, 2007).

Table 1. Common factors of causing floods

	Factors leading to causes of flood	
Causes	**Natural factors**	**Man-made factors**
Silting of the river bed	Due to bank erosion Earthquake loosening the soil	Due to dams, embankments and bunds
Inadequate capacity within the banks	High runoff or rise in the water level Silting of river bed due to bank erosion	High discharge from the river due to silting Decrease in bank height – deforestation
River bank erosion	High discharge of water due to rain Shifting river courses	Decrease in vegetative cover due to deforestation
Flow obstruction and change in river course	Landslides Falling of the trees	Construction activities in the river bed
Common floods in the main and tributary rivers	Flash flood due to high discharge in the main river	Breaking of bunds constructed on the tributary rivers for irrigation purposes
Poor natural drainage	Obstruction of the natural drainage Absorbing capacity of the soil	High rate of urbanization – pressure on the drainage system
Cyclones	High precipitation Absorbing capacity of the soil	
Retardation of flow and back water effect	High runoff Topography and obstruction of the natural drainage	Inadequate drainage capacity and; Urbanization in the low lying areas
Heavy rainfall	Same as above	Decreasing vegetative cover High urbanization leads to high runoff

Harvey (2007) identified three principal types of flood:

- *Rapid-onset floods* - these include flash floods, tidal surges, floods provoked by cyclones or accompanied by strong winds, high runoff from heavy rainfall, dam bursts and overtopping, canals and rivers bursting their banks; typically water rises to dangerous levels within 48 hours. Urban growth has often happened on floodplain areas, with some areas below the flood level. Flood embankments often protect such areas, but there is a high risk that these are breached, causing devastating urban flooding.
- *Slow-onset floods* - prolonged rainfall causing low-lying areas to gradually become flooded over a period of days or weeks. Urban slum areas may be particularly vulnerable to this type of flooding because there are few drains and the ground is highly compacted, causing pathways and alleys to become streams after heavy downpours, and existing drainage channels or culverts may be blocked by refuse.
- *Annual seasonal flooding* - many communities around the world are flooded annually and may be under water for some considerable time each year. Wet season flooding may affect some areas in lowland and coastal cities for two of more months per year because rain and river water combine to raise levels in former swamp areas. Reclamation of land in such areas tends to exasperate rises in levels. Such areas are also at high risk of storm surges.

Urbanization is rapidly increasing throughout the world. There is large scale migration to cities and town. In India, during 1901 there were 1827 urban agglomerations with a population of 25.85 million which was 10.84% of the then total population, whereas as per 2001 census there are 3768 urban agglomerations/towns covering a population of 285.4 million which works out to about 27.8% of the country's population. As per the same census the cities (population of one million and above) account for 37.8% of the total urban population of the country. A total of 42.6 million people living in 8.2 million households have been enumerated in slums of 640 cities/towns spread across 26 states and union territories in 2001 Census. The slum population constitutes 4 per cent of the total population of the country. Interestingly, share of slums in urban population grown higher in major metro-cities as compared to smaller ones.

Drainage and Water Relief

The development of flood control and drainage in India started on a big scale only after the disastrous floods of 1954. Since then a total length of 26 119 km of drainage

channels have been constructed in various States upto March 1985. The National Commission on Floods assessed that a total area of about 40 million ha is liable to floods and drainage congestion (Central Water Commission, now 45 million ha). Out of this, it was estimated that only about 80% or 32 million ha could be afforded reasonable protection. However, it is a major gap that the urban areas under flooding (due to cause other than riverine) and areas affected by mountain/flash floods, coastal floods and dam breach/failure or release are not accounted and is additional to this 45 million ha.

The water storage effect of vegetation, soil, shallow groundwater, wetlands and drainage has a direct impact on the flood level in downstream areas. Each of these storage media retain certain quantities of water for various periods of time and can influence the timing of tributary flows and hence their contribution to a flood event. The storage effect can be likened to a sponge and is dependent on the antecedent conditions and the magnitude of the flood.

The impacts of land-use changes on flood events can be both positive and negative, so predictions are hard to make for a specific watershed. Generally the removal of forest and other natural cover, and the conversion of land to agricultural uses, compacts the soil and reduces infiltration rates, leading to higher flood peaks. Deforestation is believed to have been a significant cause of the catastrophic flooding. Wetlands are a critical element of national and global ecosystems and economies. At the most fundamental level, wetlands are the key part of water-cycle, playing critical roles in maintaining the general health of water-bodies, estuaries, and coastal waters. Wetlands protect the shoreline from wave action, mitigate the impact of floods, absorb pollutants and act as habitats for flora and fauna, including a number of species that are threatened or endangered. Wetlands are important for the maintenance and improvement of the quality of human life. The driving force behind the biodrainage concept is the consumptive water use of plants.

Natural water storage is also generally reduced due to the gradual loss of organic material and soil erosion, once an area is converted to agriculture. Additionally, natural vegetation may transpire moisture to the atmosphere at a greater rate than replacement crops, thereby affecting both the amount of storage available in the soil and the amount of local rainfall. Drainage of wetlands and marshes contributes directly to changes in the timing of runoff, the amount of natural storage in the basin, and the vulnerability of the channel to the erosive forces of water. Even road construction can contribute directly to increased runoff rates through improved drainage as well as the effect of reduced infiltration through the road surface.

It is estimated that in Chennai City more than half of the wetlands have been converted to other uses. Chennai City had about 150 small and big water-bodies in and around the city but today the number has been reduced to 27. There are 31 tanks located at the West, South and Northern catchment area of the swamp release the surplus water during rainy seasons to the swamp. The sustainability of this marshland is linked with vitality and sustenance of these tanks. Moreover the shrinking of wetland will have a natural death of the tanks and vice versa because they belong to a single system of water bodies. The single flow channels that would naturally help in percolation of groundwater and stands as an excellent rain water harvesting model. Evidence reveals that not only the marshland has shrunk, but also the tanks. For instance, the Adambakkam tank, one of the water sources of the swamp has reduced from its original size of 70 hectares to 20 hectares due to encroachments.

Hyderabad Urban Development authority undertook restoration of 87 lakes out of 169 large water bodies as an additional measure by formation of peripheral bund along the shore line of the lake, desilting the lakebed by dredging, strengthening and widening of main bund ,restoration of surplus weirs and sluices, construction of STP for treating the raw sewage and letting the treated water into the lake to maintain the lake water to the desired level, restoration of inflow and outflow channels, diversion of excess sewage by laying pipelines and beautification of lake bunds and periphery with landscaping and plantation.

In Hyderabad, the maximum rainfall intensity during 8?10August was 40mm per hour (Source: NY Apte, India Meteorology Department), the details of flood disaster and damages are given below.

	28-9-2-1908	**23-24 August 2000**	**8 – 10 August 2008**
Rainfall	430 mm	240.5 mm	237 mm
Property Loss/ Worth	80000 houses	35693 houses INR 1350 million	INR 495.2 million
Loss of Life	15000	26	-
Population Affected	600000	200000	150000

Certain critical observations of the disaster and post-disaster situation of the Mumbai floods 2005 have been identified for consideration in future planning and strategies for flood risk management:

- "Off-shore-Vortex" resulted in extremely localized heavy downpour in Mumbai on 26 July 2005.
- Following floods, High Court ordered for installing high-tech Doppler Radar at suitable locations in Mumbai.

- Over confidence of government on Disaster Management Plans and reluctance to synergize crosscutting sectors and stakeholders.
- Inculcation of civic sense to be induced with initial hand holding and further guidance.
- Construction on the flood plains of natural drainage channels, on top of the storm lines made things worst. In many locations, routine cleaning operations are reported to have not been fully undertaken for years.
- Continuous land relaimation in Mumbai for over 300 years (seven islands merged into single landmass) need to be checked/evaluated by experts.
- Easy to understand Costal Regulation Zoning (CRZ) legislation along with its benefits needs wider publicity among the passes.
- Reclaimation of Bandra-Kurla complex is good example of 'bad planninng'. Due to continuous neglect, Mithi river is now a open drain, carrying raw sewage, hazardous industrial waste and garbage.
- Choking of Mithi river, which is providing natural drainage to the city; substantial garbage/solid deposits in drains have major impact on drainage capacity. After the flood 2005, for three weeks, average load of waste lifted was double the normal daily load.

Table 2. Lessons learned from analysis of Mumbai flood 2005 (MCGM)*

Major issue	Causes	Role of local community	Possible solution provider(s)
Unprecedented Rain	Natural forces, global environmental changes	Nil or extremely limited in a broader sense	National/global consensus to mitigate climate change impacts
Failure of weather forecasting	Ill equipped Meteorological Department	Nil	Meteorological Department, other communication agencies
Unplanned development	Political ill-will, planners lack of vision, tremendous population growth and unchecked migration, loose implementation of existing laws, resource constraints with government agencies etc.	Very limited	Collective action from government, private sector, civil society, and community
Reclamation of low lying areas	Government agencies (without scientific approach or due to political pressure), illegal dumping/reclamation by builders and developers, unruly dumping by communities in few places	Very limited	Collective action from government and private sector, stringent implementation with regard to scientific and ecological implications.
Shrinking drainage (inadequate dilapidated drainage system)	Community, government, builders, illegal activities	Somewhat limited	Local government, planning bodies, and communities

Negligence in cleaning sewers and drainages	MCGM	Somewhat limited	MCGM (private sector may be involved if needed)
Encroaching the areas of hills and mangroves (decrease in mangroves, wetlands, forest cover)	Planning agencies; builders' lobby; in rare cases slums and squatters also	Somewhat limited	Stringent policy/legislation for protecting such eco-sensitive areas by government along with very strict implementation
Disregard for city streets, lanes and sewers	Mainly lack of civic sense among communities, also illegal activities (dumping, digging etc) by industries, dairies, restaurants, hospitals and other establishments etc.	Very strong	Communities, Civil society organizations, private sector, academic/research institutions, etc.
Violation of Coastal Regulation Zone (CRZ) rules	Politicians influencing planning and development agencies for selfish gains, sometimes communities also violate	Somewhat limited	Politicians, builders, civil society, private sector etc. with community as important partner
Choking up of rivers and drains	Communities; illegal activities of various players from formal and informal sector; illicit business activities, even politically influenced decisions of government agencies	Strong (with equally responsible other stakeholders)	Communities, civil society, private sector etc., Strict legal interventions (i.e. ban on use of plastic thinner than 50 microns)
Lack of disaster preparedness	Mainly government (specially failure to recognize communities' role)	Very strong (collectively with other stakeholders)	Disaster management require multi-stakeholder partnership
Shrinking of Mithi river (reduced to one third of its original size)	Government planning agencies, illegal activities, informal community	Somewhat limited	Time-bound intervention (both technical and non-technical) from all responsible actors government, civic society, community etc.

**MCGM - Municipal Corporation of Greater Mumbai.*

Integrated Flood Management

"Mitigation (for flood disaster risk) is expected to encompass broad framework of pre-disaster human-interventions against risk so as to minimize the disaster or its impacts. On other hand, mitigation is sum of actions to ensure overall sustainable development taking into account disaster management as a core component" and 'flood resistance' as the key objective. Resistance (to floods) has 3 main aspects:

a) Flood avoidance (prevention of occurrence and control including diversion/levee and relief, flood safe location/zoning)
b) Flood tolerance (resistant housing/infrastructure - design and materials, lifestyles)
c) Flood resilience (preparedness in place - awareness/training, warning, response and relief resources - shelters, stocks, etc.)

Definition of Mitigation as per Disaster Management Act (2005) is to quote "mitigation' means measures aimed at reducing risk, impact or effects of a disaster or threatening disaster situation" (Chapter 1, section 2.(i)). Thus, 'mitigation' is a broad framework and the plan can be developed for implementation during 'short-term', 'medium-term' and long-term' basis based on priority issues and critical concerns (figure 3).

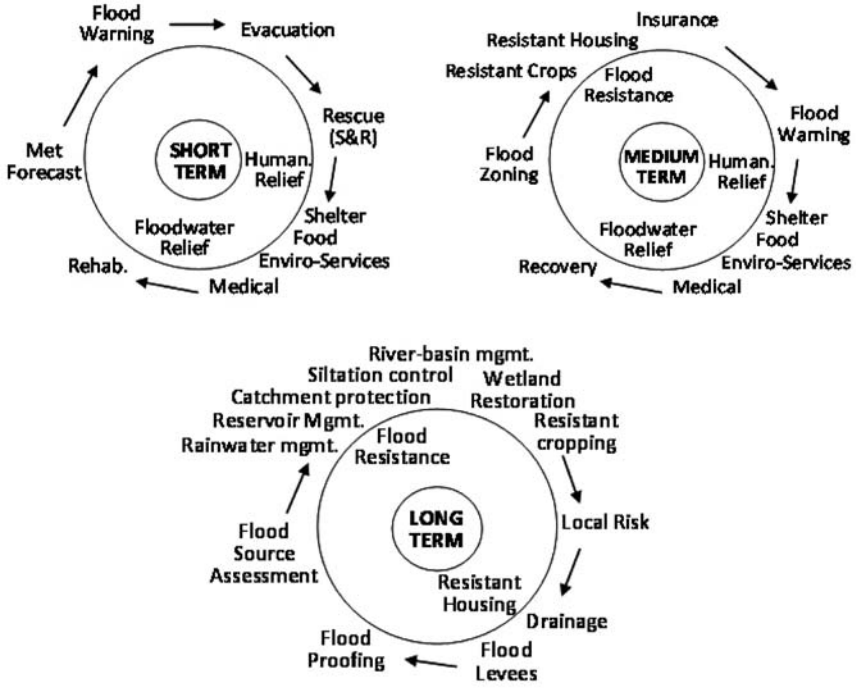

Figure 3. Flood disaster management framework

Hydro-meteorological data and accurate forecasts are of no value if the forecasts do not reach users and if decisions are not made as to the appropriate actions required. Hydrological forecasts and hydraulic conditions must be disseminated so that decisions can be made and actions taken to reduce the impact of the pending event. Decision support refers to everything from forecasts reaching decision makers such as a mayor of a flood-prone community to the operator of a flood-control structure. For decision support to be effective, advanced planning must define prescribed actions linked to forecasted values. One of the greatest advances in radar technology as far as weather

forecasters are concerned is the use of Doppler techniques which are available for operation in various frequency bands. The data sets from Doppler weather radar are available in fine temporal and spatial resolution which is critical for predicting severe weather events in near real time particularly estimation rainfall rate and its accumulation. Heavy rainfall in the range of 150 km may be estimated with a very high accuracy with calibration radar with ground truths. Most important factor is that Doppler weather radar has the capability of quick updating of rainfall data on real time and disseminate same to a centre location which may not possible with any other observing systems.

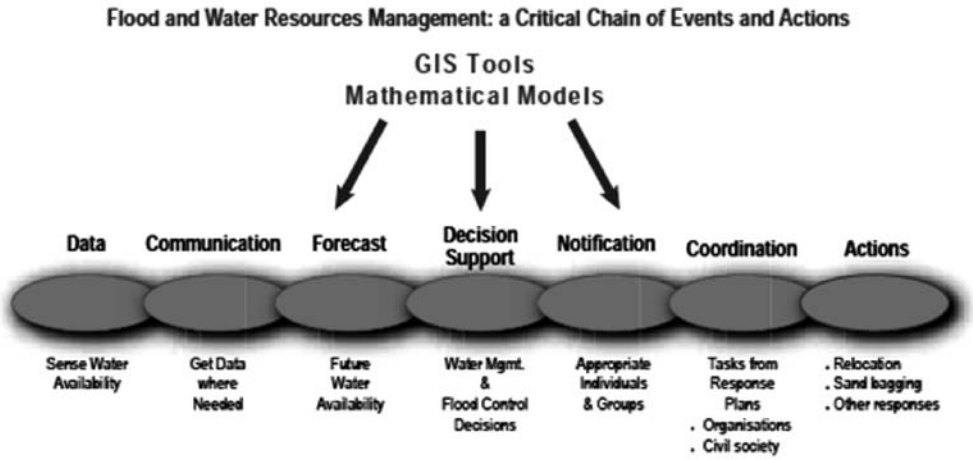

Figure 4. Integrated flood forecasting, warning and response system

Dr. Madhavrao Chitale committee (Fact Finding Mission, 2005-06. Govt. of Maharashtra) to investigated the Mumbai flood incident, in its volume 1, wrote a note on significance of ecosystem services in Mumbai floods context:

"(1) Ecosystem in and around Mumbai is under stress and is continuously deteriorating. It is necessary that a systematic aquatic ecosystem rejuvenation program to deal with the issue of "accumulated contaminated sediments" in the ecosystem is undertaken and the accumulated pollutants are systematically dredged out so that a newer healthy ecosystem gets progressively instituted. There is a great urgency of incorporating the activities of designing and commissioning the different components of the ecosystem infrastructure with a systematic river front development programs for the major rivers and the estuaries. (2) The scrutiny and investigation, which followed the

floods in Mumbai, revealed that environmental governance of Mumbai has been far from satisfactory. While the developmental and planning agencies renamed rivers and streams as nallahs and in some cases even removed them from the developmental programme's maps; environmental regulatory authorities did not take exception to derogatory treatment given to environmental and ecological systems and sub-systems by citizens, civic administrators, and elected representatives. Standards of disposal of effluents into rivers were prescribed suitable for nallahs rather than reinstating the river status to the streams. For example, India's Water (Prevention and Control of Pollution) Act of 1974 and Environment Protection Act of 1986 aim at maintaining wholesomeness of rivers. The State Pollution Control Board Shall facilitate implementation of India's environmental policy in a proactive manner and ensure compliance of environmental regulations by the municipal corporation".

Environmental Services During Flood Disasters

Specific lessons can be identified for both planning prior to a potential emergency, and response to an emergency. These are two distinct stages of a flood management programme, yet they are closely linked, as planning directly affects the effectiveness of responses. Different agencies are likely to be involved at different stages of an emergency, and it is important that they communicate and collaborate with each other, sharing information regularly. Agencies responding to an emergency need to plan their exit strategy carefully, and exchange of information is of particular importance when there is a transfer of responsibility from one agency to another, such as when relief agencies arrive or depart. Urban floods systematically affect the poorest (immigrants, new settlers, and people living in un-planned and areas vulnerable to flooding).

Vectors such as flies, mosquitoes and rats are insects or animals that can transmit disease-causing bacteria or other organisms from one host to another. Following a flood, conditions may be favourable to the survival and reproduction of vectors, and pathogenic organisms may also be widespread in the environment. Transmission of diseases by vectors is therefore likely to be a serious health risk within affected communities. Sites designated for disposal of wastes should be in uninhabited areas, away from centres of population, and with good access for vehicles. Safe water supplies, good sanitation, and effective hygiene promotion can all contribute to vector control, but additional responses may also be needed, in the form of medical diagnosis and treatment following infection, chemical or biological control of vectors, safe excreta disposal and personal protection.

Table 3. Priority responses for those affected by flooding

Those who stay in their homes	Those who relocate to official shelters	Those who relocate to unofficial shelters	Those who stay with host families
Arrange distribution of safe water during the flood phase (from regular distribution system, rainwater collection or compact water treatment unit ❶). Provide safe excreta disposal. Arrange distribution of appropriate NFIs. Provide water quality testing services, or advice and information on water quality. Communicate appropriate hygiene messages to those remaining in their homes based on ongoing dialogue to understand barriers to change and feasible actions. Rehabilitate WASH infrastructure as soon as possible (desludging wells, boreholes and latrines, repairing electromechanical equipment, etc.)	Arrange distribution of adequate quantities of safe water. Provide or procure additional latrines with handwashing facilities and ensure care and maintenance. Encourage local people to assist with clearing debris, possibly under cash for work programmes, as part of hygiene promotion response. Arrange distribution of essential and appropriate NFIs Ensure ongoing dialogue with the population to promote optimal use of facilities, handwashing and management of diarrhoea. Rehabilitate infrastructure, including electromechanical plant, as soon as possible.	Provide emergency/ temporary water supplies, and emergency/temporary sanitation (chemical toilets, for example.) but without permanent infrastructure. Provide containers for water storage. Provide advocacy assistance to obtain permissions for people to remain in unofficial locations. Arrange distribution of essential and appropriate NFIs Ensure ongoing dialogue with the population to promote optimal use of facilities, handwashing and management of diarrhoea.	Arrange distribution of adequate quantities of safe water, with increased supplies to meet additional demands. Identify host families, and provide assistance to both hosts and guests, to encourage people to continue staying. Arrange distribution of essential and appropriate NFIs Ensure those affected are aware of how to reduce hygiene risks. Provide additional, tools, materials and support to host families for water supply and sanitation (e.g. containers for storage of water). Provide tools and facilities for collection of flood debris and household wastes. Rehabilitate WASH infrastructure as soon as possible (desludging wells, boreholes and latrines, repairing electromechanical equipment, etc.)

WASH - Water, sanitation and hygiene; NFI - Non food items.

Note: If household water treatment is promoted this requires preparedness, promotion and distribution of equipment prior to the emergency.

Disaster Risk Reduction activities should attempt to identify those who are most vulnerable, and pay particular attention to them. Most publications concentrate on short-term responses, rather than addressing longer-term needs; and on providing support to those who relocate to official shelters following floods. Very little has therefore been written about resettlement after urban floods, on providing support to host families that provide shelter for friends or relatives following urban floods, or on appropriate responses to support those who remain in their homes during floods.

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