Culverts tend to increase flood risk, especially if they are either too narrow in diameter or become blocked by debris. An urban structure or development that has been facilitated by the routing of a natural stream within a culvert may be at risk of flooding from that same culvert. Compared with an open stream, access for maintenance of culverted watercourses is also limited. Reopening culverts (sometimes termed 'daylighting') can be part of the integration and enhancement of watercourses in urban areas, with benefits in terms of biodiversity, water quality and amenity as well as flood risk reduction.

An example of this approach is the elevated freeway constructed above the Cheonggyecheon River in Seoul, South Korea, in the early 1970s. At the time, it was considered a symbol of progress, but by the early 2000s, the Cheonggyecheon area was the most congested and noisy part of Seoul. A river restoration project was therefore initiated to remove the freeway and restore the stream. This was completed in 2005 and is considered a major success.

3.4. Flood storage

As stated in Section 3.3.2 above, storage has the effect of attenuating (reducing the peak) of flood flows. This is especially true when there is a significant volume of storage available and the outflow is controlled. There is storage in all parts of the natural water cycle, which can be enhanced by creating additional opportunities for storage within a catchment. Storage, preferably semi-natural storage, is also a key to modern urban drainage design (see Section 3.5). Storage is likely to be one component in an overall strategy for flood risk reduction.

Storage occurs naturally in a catchment, for example within the floodplain or, more locally, in ponds. Artificially created storage facilities include flood storage reservoirs, retention ponds and detention ponds; deliberate flooding of farmland, or urban areas like playing fields or car parks, may also be utilized. This aspect is covered in more detail in Sections 3.4.2 and 3.5.2 and is also illustrated in Case Study 3.3, with an example of a retarding basin in Japan.

Some major reservoirs on river systems, while providing attenuation that is relevant to flood risk, may have additional functions such as water supply or hydroelectric power generation. Traditional approaches to managing reservoir operations, based on purely hydraulic considerations relating to the main function of the reservoir, may need to be widened within a context of integrated water resources management to achieve environmentally sensitive reservoir operation.

Another important consideration concerns sediment flows, as there is a risk that reservoirs can lose capacity as a result of long term deposition.

Where several flood storage reservoirs are provided in a catchment, the overall effect must be considered: reservoirs on separate tributaries may cause attenuation individually, but if the downstream attenuated peak flows are allowed to join the main river at the same time, the benefit may be lost.

3.4.1. On-line and off-line

On-line storage forms part of the line of the main channel and all flow passes through it. Typically located in the upper catchment of a river, on-line storage normally consists of an impounding structure, a flow control arrangement at the outlet and a spillway or overflow, to bypass the controlled outlet in extreme events.

Off-line storage, by contrast, is filled by water diverted from the main channel and subsequently released back to it. It is usually associated with larger rivers with wide floodplains, and typically consists of an intake structure (most often a weir) to divert water from the main channel; the storage area itself (frequently a reservoir formed from low or excavated ground, or by means of retaining structures); outlet flow-control returning water to the river (by gravity or pumping); and a spillway or overflow.

In both cases, controlled emptying soon after a flood event is necessary, in order to make storage available for subsequent events. Outlet flow control devices include orifices, throttle pipes and devices that induce vortex motion to control flow (making flow control less dependent on varying water heads). The greatest effect of storage on reducing flood risk can be realized through the control of inflow and outflow to ensure that the storage is not filled too early or too late in a storm, but this requires a complex system of real-time control.

Case Study 3.3: A multi-purpose retarding basin in Japan

The Tsurumi River Basin spreads from Machida City through to Tokyo Bay. The area has always been prone to river flooding. In the 1980s a comprehensive flood control plan was implemented with a protective level of a 150-year flood event. Part of the plan was the construction of a multi-purpose retarding basin which stores flood water from the river, releasing it via controlled outflows (as illustrated in Figures 3.7). At other times, this area is used for leisure purposes and includes an international sports stadium, as shown in the aerial photograph in Figure 3.7.

Figure 3.7: An outflow control facility and Tsurumi multi-purpose retaining basin. Source: Ministry of Land, Infrastructure and Transport, Japan; Tanaka 2011.

The height of the levee between the river and the retarding basin is set to allow water flow over the levee as it reaches flood height, thus preventing overtopping on the other side. The stadium itself is raised on piles which ensure that the sports venue and the main roadways could still be used during a flood event. The total water storage capacity of the basin is 3,900,000m3. After a flood event, the water is drained away through a spillway into the Tsurumi River.

An information center as well as notice boards in the retarding basin serve as a communication mechanism for the general public and provide early warning information. Other measures that were carried out on the Tsurumi River included dredging, the construction of levees, regulating reservoirs and greenery reservoirs.

The most important lesson learnt, therefore, is that measures must effectively utilize the limited land available in what is a very densely populated city, and be integrated within land use plans and procedures.

Source: PWRI 2009; Tanaka 2011.

3.4.2. How to utilize temporary storage in an urban area

There significant scope for providing temporary storage for stormwater in urban areas by making use of areas with other primary functions, for example, parkland, playing fields or car parks. Water can be diverted from rivers or channels to this storage, typically via a weir; alternatively urban runoff may enter the storage as ‘exceedence flow’ when the capacity of the urban drainage system (the ‘minor system’) has been exceeded

Method

The method given below covers the main aspects of identifying suitable locations for temporary storage and planning their use. Detailed design considerations are not included here.

1. **Identify suitable locations for temporary storage**
2. **Determine maximum flood depth for each location**
3. **Estimate volume of storage provided and include in a hydraulic model if appropriate**
4. **Specify outlet arrangements**
5. **Consider health and safety issues.**

1. Identify suitable locations for temporary storage

Typical urban features used as temporary storage are given in Table 3.1. It should be borne in mind that the location:

– Will be used relatively infrequently for storage of flood water

– Will normally have a different primary use (car park, playing field etc)

– Will probably not have the primary use available while the location is being used for storing stormwater.

2. Determine maximum flood depth for each location

Recommended maximum flood depths are given on Table 3.1.

Table 3.1: Types of temporary storage in urban areas.

Storage type	Description	Maximum water depth
Car parks	Used to temporarily store flows. Depth restricted due to potential hazard to vehicles, pedestrians and adjacent property.	0.2 m
Minor roads	Roads with speed limits up to 30 mph where depth of water can be controlled by design	0.1 m
Recreational areas	Hard surfaces used typically for basketball, five-a-side football, hockey, tennis courts.	0.5 m; but if area can be secured, 1.0 m
School playgrounds	Playgrounds can provide significant flood storage. Extra care should be taken to ensure safety of the children.	0.3 m
Playing fields	Set below the ground level of the surrounding area and may cover a wide area, offering significant flood volume.	0.5 m; but if area can be secured, 1.0 m
Parkland	Has a wide amenity use. Often may contain a watercourse. Care needed to keep floodwater separate and released in a controlled fashion to prevent downstream flooding.	0.5 m; but if area can be secured, 1.0 m
Industrial areas	Low value storage areas. Care should be taken in the selection as some areas could create significant surface water pollution.	0.5 m

Source: adapted from Balmforth et al. 2006.

3. Estimate volume of storage provided and include in a hydraulic model if appropriate.

Maximum flood depth and topographical data on the storage location can be used to estimate the volume of storage available at different locations. Where a hydraulic model is being used to simulate flood flows, the beneficial impact of temporary storage can be determined from the model for different flood events.

4. Specify outlet arrangements.

The temporary storage may empty to the urban drainage 'minor' system or to a river or flood channel passing through an outlet flow control device. In some circumstances it is necessary to empty the stored water by pumping. In other circumstances it is possible to rely on infiltration, and even evaporation, though in these cases emptying times are longer, creating a significant delay in returning the area to its primary function.

5. Consider health and safety issues.

The main health and safety considerations are likely to be:

- Access and escape routes for people
- Water depth (as seen in Table 3.1)
- Water velocity, as a potential hazard for people needing to walk through moving water
- Tripping hazards (especially when the hazard is submerged)
- Clear public information on the dual use of the area
- Maintenance to clear debris.

3.5. Drainage systems

Urban drainage systems need to be able to deal with both wastewater and stormwater whilst minimizing problems to human life and the environment, including flooding. Urbanization has a significant effect on the impact of drainage flows on the environment: for example, where rain falls on impermeable artificial surfaces and is drained by a system of pipes, it passes much more rapidly to the receiving water body than it would have done when the catchment was in a natural state. This causes a more rapid build-up of flows and higher peaks, increasing the risk of flooding (and pollution) in the receiving water. Many urban drainage systems simply move a local flooding problem to another location and may increase the problem. In many developed counties there is a move away from piped systems, towards more natural systems for draining stormwater. This is considered in detail later in this section. In many locations throughout the world, however, main drainage systems have never existed.

3.5.1. Sewers and drains

Where the drainage system of an urban area is piped, by a 'sewer system', there are two approaches in use: 'combined' or 'separate'.

The older parts of many cities (New York being an example) are drained using the combined system, whereby wastewater and stormwater are mixed and are carried together. The system takes the combined flow to the point of discharge into the natural water system, commonly via a wastewater treatment plant that discharges treated effluent. During heavy rainfall events, the stormwater flow will greatly dominate the wastewater flow in terms of volume, but it is hardly ever viable to provide sufficient capacity throughout the system for stormwater resulting from heavy rainfall, as the system would operate at a small fraction of its capacity during dry weather. Instead, structures are included in the system to permit overflow to a nearby watercourse. During significant rainfall events a significant volume of the flow is likely to overflow, rather than to continue to the wastewater treatment plant. As the overflowed water is generally a dilute mixture of wastewater and stormwater, these structures are designed hydraulically to prevent larger, visually offensive solids from being discharged to the river. However, the inescapable fact is that combined sewer overflows inevitably cause some pollution (Butler and Davies 2011).

In the urban areas served by a combined system, capacity is similarly exceeded by extreme stormwater flows. Under these circumstances, the 'surcharging' of the system may cause flooding of the urban surface and, as the flood water will include wastewater, there are associated pollution and health implications.

In a separate system, wastewater and stormwater are drained by separate pipes, often constructed in parallel. Wastewater is carried to the wastewater treatment plant, whereas stormwater is usually discharged direct to the nearest watercourse. The problem of combined sewer overflows is thereby avoided, but there are still challenges: stormwater discharge is usually untreated, and this may cause pollution. Stormwater may enter the wastewater pipe either through mistaken or unauthorized connections; there may also be infiltration of groundwater at pipe imperfections. Because of the relative proportions of wastewater and stormwater during heavy rainfall, these additional inputs may significantly reduce the capacity of the pipe for the wastewater it was designed to carry. Figure 3.8 is a highly simplified representation of a combined and separate system showing only a few branches.

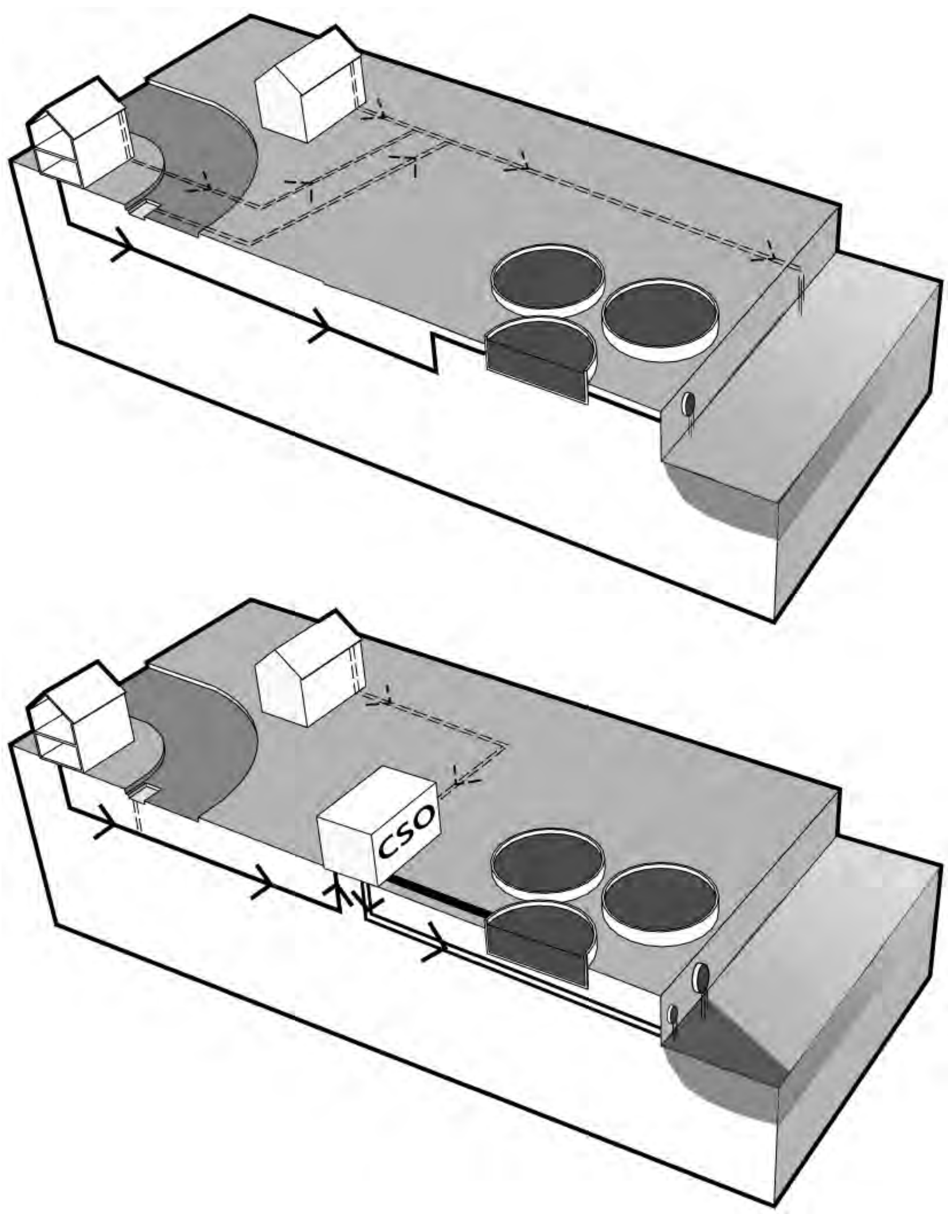

Figure 3.8: Combined system (top) and separate system (below). Source: BACA, Adapted from Butler and Davies 2011.

In urban areas without conventional piped sewer systems, disposal of excreta and wastewater is likely to be localized, though in some cases simplified (shallow and small diameter) pipes are used. Stormwater is most likely to be carried by open drains, typically unlined channels along the side of the street. Better constructed channels may be lined with stone or concrete (Photo 3.5), and may be integrated into the urban landscape (Photo 3.6). Open drains are far cheaper to construct than stormwater sewers, and although they can easily become blocked by debris or refuse from the surface, such blockages are more easily monitored and removed than in piped systems.

Maintenance is vital, not only to remove obvious obstructions, but also cleaning out deposited sediment, and then disposing of the material so that it does not go back into the drain. In heavy rain, the capacity of an open urban drainage channel may quickly be exceeded; in a well planned system, overflow should be to a specified 'major system' (described in Section 3.4.2) such as a road which can act as a drainage channel.

Where there is no adequate system for disposal of wastewater, there is a high likelihood that open drains will be contaminated by foul sewage. This could come from contributions from areas without sewers, or from discharge from simplified sewerage which does not lead to an adequate treatment facility. Open drains may also be misused for the disposal of domestic solid waste. Where the quality of stormwater carried in open drains is an issue for these reasons, there may be limited opportunities for using semi-natural systems of urban drainage that rely on the storage or infiltration of stormwater (considered in Section 3.4.4) because of public health issues.

Photo 3.5: New urban drainage in Mafalala neighborhood, Maputo, Mozambique.
Source: BBC News

Photo 3.6: Reconstructed urban drainage in Acapulco, Source: UN-HABITAT

3.5.2. Major versus minor systems

As discussed above, when the capacity of a drainage system is exceeded, the resulting 'exceedance flow' is generated on the urban surface. Under these circumstances the drainage system may be seen as consisting of two components: the 'minor system' (consisting of the sewer pipes or open drains described above) and the 'major system' (on the surface). The latter may consist of 'default pathways' taken by the flood flow, such as roads, paths or incidental storage areas. Alternatively 'design pathways' may have been created specifically to cope with exceedance flow. Design pathways include floodways, retention basins, or designated areas of public open space for temporary storage. On a small scale, some adaptation to existing urban features like road profiles and curb heights can improve the effectiveness of pathways for extreme events.

Significant components of a design pathway can be elements of urban infrastructure that have a dual role: for example, as a road (at times when there is no flood) and as a flood channel. The Kuala Lumpur Tunnel discussed in Case Study 3.4 is an example of this approach to infrastructure.

Another large scale project of this type is the refurbishment, upgrading and extension of the system of floodways in Jakarta which is presented as a Super Case Study elsewhere in this volume.

Case Study 3.4: Kuala Lumpur SMART Tunnel, Malaysia

Kuala Lumpur, the capital of Malaysia, is situated in the mid-upper reaches of the 120 kilometer long Klang River which drains a catchment of some 1,288 square kilometers. In the 1970s, a flood mitigation master plan was developed which incorporated a number of engineering options, including upstream storage, poldering, pumped drainage, and improvement of the drainage capacity of the Klang River and its major tributaries.

The Stormwater Management and Road Tunnel (SMART) project was designed both to divert stormwater and to re-route traffic away from the inner city. The scheme consists of a 9.7 kilometer long tunnel, nearly 12 meters in diameter, which runs to the east of the city centre of Kuala Lumpur. During moderate storms, the bottom section of the tunnel channels excess water without stopping the traffic flow. In case of severe storms, all traffic is evacuated and automatic watertight gates opened to allow floodwater flow. The tunnel has combined storage capacity of three million cubic meters.

The construction cost of the SMART Tunnel project was approximately US$515 million. As it was recognized that as well as the need to mitigate flooding there was an equally urgent imperative to relieve traffic congestion in the city, an innovative solution was proposed in which a tunnel would be used to carry road traffic except during flood events. Part of the total cost of the stormwater relief was offset by tolling the traffic congestion relief. Through this approach, one tunnel will provide flood and traffic improvements to Kuala Lumpur at a cost that is far less than two separate measures. The case demonstrates the potential of flexible, multi-purpose approaches to infrastructure design.

Sources: Wilson 2005; Krause et al. n.d.

Photo 3.7: Roadway/flood channel Yemen. Source: Bill Lyons/World Bank

3.5.3. Interface with river systems

Urban drainage systems are a subset of flood conveyance. Whichever way they are designed, they must discharge to rivers or other flood conveyance systems. It was reported that over 55,000 properties were flooded during the summer 2007 floods in England. Two-thirds of the properties flooded were affected because drains and sewers were overwhelmed (Defra 2008). However, the sewer system cannot be considered in isolation, since its capacity is reduced by rising levels in the receiving waters. Where capacity of an urban drainage system is the dominant cause of flooding, the flood risk can be reduced by increasing capacity (for example, by increasing the size of pipes or channels), but this is appropriate only where there is sufficient capacity in the system downstream.

A practical example of urban drainage in context can be seen in Case Study 3.5 below and also in the Mozambique Super Case Study elsewhere in this volume.

Case Study 3.5: North and East Greater Tunis Flood Protection

In Tunisia, two-thirds of the total population lives in urban areas, with about 20 per cent living in Greater Tunis. Major flood events caused by heavy rainfall have been recorded in 2003, 2004, 2006 and 2007. The most recent floods in 2006 and 2007 caused significant economic damages, and disruption of vehicular traffic. Drain blockages lasted for several days.

Water sector management ranks high in the country's economic and social development agenda. In response to these problems, a flood protection scheme is being implemented and is scheduled to be completed in 2014. The scheme consists of the following three components:

- Remote protection - construction of large and small dams, with catchment ponds to control runoffs - designed to protect the urban areas and farmlands and to store the water to be used for both irrigation and domestic consumption
- Close protection - deviation of wadis and watercourses outside the urban areas; development of wadis and watercourses crossing urban areas; and construction of flood reducing basins upstream of urban areas
- Stormwater drainage within urban areas - construction of sanitation networks, made of primary and secondary collectors for the drainage of stormwater.

Rapid urbanization in Greater Tunis has altered the physical environment generating higher surface runoff that often exceeds local drainage capacity, thereby causing localized flooding problems. Construction and rehabilitation of drainage systems can be successful in reducing both flood risk and flood impacts.

Source: AfDB 2009.

3.5.4. Semi-natural systems, 'SUDS'

As discussed above, a key characteristic of many artificial urban drainage systems, as compared with natural systems, is a more rapid build-up of flows and higher peaks, causing an increase in flood risk. It is possible to return the catchment response to a more natural state by using more natural methods of drainage. These use the infiltration and storage properties of semi-natural devices such as infiltration trenches and swales (both discussed in Section 3.6.2) or ponds, all of which slow down the catchment response, reducing the peak outflow and thus lowering the flood risk.

Such drainage systems not only help in preventing floods, but also improve water quality. In addition they can enhance the physical environment and wildlife habitats in urban areas. In the US and other countries, these techniques are termed ‘best management practices’ (BMPs), as a subset of Low Impact Development (LID). In Australia the approaches are part of ‘water sensitive urban design’. The term SUDS (Sustainable Urban Drainage Systems) is well-established in the UK (Woods-Ballard et al. 2007; Butler and Davies 2011).

SUDS devices are most effective in combination, in the form of a ‘management train’, as illustrated in the How To section 3.5.7 which shows the arrangement and components of such a sequence.

Wherever possible, stormwater should be managed in small, cost-effective landscape features located within small sub-catchments, rather than being conveyed to and managed in large systems at the bottom of drainage areas. Water should be conveyed elsewhere only if it cannot be dealt with locally.

Like all drainage systems, SUDS are designed to provide capacity for a storm event of a particular frequency. For more extreme events, exceedance flows are likely to be generated and must be carried by the major drainage system, as discussed above in Section 3.5.2.

Many SUDS devices are based on infiltration to the ground, the risk of groundwater pollution is an important consideration, especially where surface runoff is likely to be polluted and the groundwater is used for drinking supplies. The design of a permeable pavement system, for example, can be adjusted to allow infiltration, or not, in order to account for this (discussed in Section 3.6.3 below).

The main types of SUDS devices, all of which are discussed later in this chapter, can be listed as:

– Inlet control
– Infiltration devices
– Vegetated surfaces
– Permeable paving

- Filter drains
- Infiltration basins
- Detention ponds
- Retention ponds
- Constructed wetlands.

Inlet control devices provide storage close to the point where the rainfall is first collected. Rooftop ponding uses the storage potential of flat roofs; as this creates an additional load there is an increased need for water tightness, as well as good maintenance of outlet control devices. A green roof is a planted area that provides storage, encourages evapo-transpiration and improves water quality. A water store, consisting of a water butt or a tank near to ground level, can store rainwater and make it available for garden use, though some outflow must be assured to provide capacity for subsequent rainfall.

Instead of connection to the drainage system, water collected from roofs can be diverted at the bottom of the downpipe to infiltrate in nearby stable pervious areas. Paved area ponding, to accommodate heavy rainfall, can be achieved by restricting inflow to the piped drainage system, thereby reducing flood risk downstream.

Detention basins are storage facilities formed from the landscape with controlled outflow. They store stormwater temporarily, and are dry between storms.

Retention ponds provide storage within a permanent body of water. They allow natural treatment of the water and provide environmental and amenity benefits.

Where there is a danger that ponds may become mosquito-breeding areas, a permanent open body of water is not appropriate. Detention basins must, therefore, be designed to dry out before the larvae have time to mature (one week or less) (Reed 2004).

The benefits of SUDS can be realized in existing urban areas by retrofitting. Its challenges tend to be associated with availability of space, and the difficulty of adapting existing systems. Local application of inlet control may be the most feasible approach.

3.5.5. Surface water management plan

The concept of a surface water management plan is to consider all aspects of localized surface water flooding, including urban drainage, groundwater, and runoff from land. On the wider scale this would be a component of a catchment wide management plan: this approach looks at the scope for reducing flood risk by identifying appropriate measures that could be taken upstream of the urban area. As seen in Case study 3.6 below, surface water management can be considered at a city scale and incorporated within wider city plans.

Case Study 3.6: New York City Green Infrastructure Program

As part of its 'Green Infrastructure Plan', the Department of Environmental Protection (DEP) in New York City incentivized green infrastructure projects to improve the quality of the city's waterways by capturing and holding stormwater runoff to reduce sewer overflows. Green infrastructure projects can include green roofs as well as tree pits, street side swales, and porous pavements for roadways. As explained in more detail in 3.5.4, these reduce the flood risks associated with piped urban drainage systems by using the infiltration and storage properties of more natural drainage systems. Private property owners, businesses, and community organizations are eligible for project funding that use green infrastructure, with particular preference given to projects that can create further benefits such as decreased energy use for cooling buildings and increased community ownership.

Green infrastructure has the potential to be cost-effective as DEP modeling showed that combined sewer overflows (CSO) volumes will be reduced at significantly less cost than using conventional measures. The success of the initiative will depend on considerable support from local communities and businesses in developing and introducing innovative ways to deal with stormwater.

Sources: NYC Department of Environmental Protection (DEP); NYC Green Infrastructure Plan: http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_ExecutiveSummary.pdf

3.5.6. Further reading

Butler, D. and Davies, J.W. 2011. Urban Drainage, 3rd edition. UK: Spon Press.

3.6. Infiltration and permeability of urban areas

Urbanization affects the natural water cycle. When rain falls, some water returns to the atmosphere (through evaporation or transpiration by plants); some infiltrates the surface and becomes groundwater; and some runs off the surface. Since urbanization increases the proportion of the surface that is impermeable, it results in more surface runoff and reduced infiltration (Figure 3.9). As we have seen, surface runoff finds its way to a watercourse far quicker than groundwater and therefore increases flood risk, and if the surface runoff is conveyed via a piped drainage system the effect is even more pronounced.

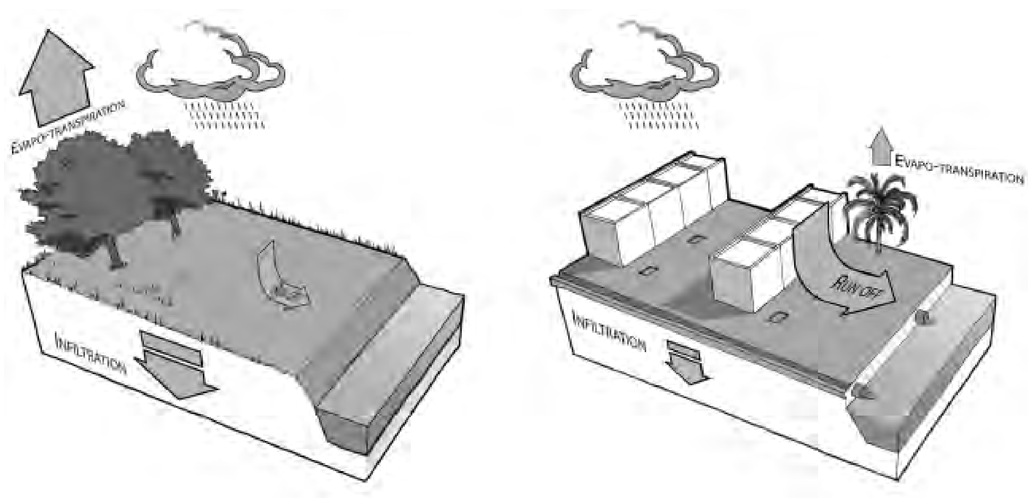

Figure 3.9: Effect of urbanisation on infiltration and runoff. Source: BACA, adapted from Butler and Davies 2011.

Increasing infiltration via improved permeability in urban areas can reduce flood risk, but in many cities the opposite is occurring. The increasing densification of towns and cities implies that every space is utilized to the maximum for the use of urban dwellers. This leads to an increase in hard surfaces and a decrease in permeability of any open space left after the construction of buildings. An example of this is the paving of front gardens in the UK to allow for parking spaces: in one part of London, 68 percent of the area of front gardens is now hard-surfaced, and the figure is rising. Leisure and recreational uses also tend to involve impermeable surfaces. Cost-cutting measures designed to limit the regular maintenance of green spaces can also lead to the concreting or de-greening of spaces.

A major characteristic of most SUDS systems (as discussed above) is to increase permeability and therefore infiltration. The use of SUDS is promoted in the UK via formal Building Regulations, which state that 'surface water drainage should discharge to a soakaway or other infiltration system where practicable'. Planning guidance in England, specifically related to development and flood risk, also strongly favors the use of SUDS in new developments. Measures like these have the effect of increasing infiltration, and are steps in the right direction in terms of preventing flood risk from increasing as a result of urbanization.

3.6.1. Infiltration devices

These include soakaways and infiltration trenches. A soakaway is an underground structure, typically circular in plan, which facilitates infiltration into the ground. An infiltration trench is a linear excavation, usually stone-filled, achieving the same aim with a greater area of exposure to the ground. These devices are only suitable in ground with suitable infiltration properties, positioned above the level of the water table at any time of year. Filter drains are perforated or porous pipes laid in a trench containing granular fill and are typically located in the verge of a road to collect water from the road surface and carry it away. Infiltration basins are open depressions in the ground which collect water and allow it to be absorbed gradually.

Photo 3.8: Infiltration through greening of car park in Washington, DC. Source: J Lamond

3.6.2. Vegetated surfaces

Swales are grass-lined channels which allow the infiltration, storage and conveyance of stormwater. Small swales can run beside local roads, large swales beside major roads, and swales may also form landscaped channels for conveyance of stormwater. Filter strips are gently sloping areas of vegetated land. Swales and filter strips delay and reduce stormwater peaks, and trap pollutants and silts. See Photo 3.8 above.

3.6.3. Permeable paving

Permeable paving creates a surface that allows infiltration, either because it is porous, or because specific openings have been provided (for example, the spaces between paving blocks). The most common applications are for car parks, but lightly trafficked roads and driveways are also suitable. The sub-base (Figure 3.10) provides storage for rainwater, typically in the voids between granular particles. The collected water may then be allowed to infiltrate into the ground; alternatively, where it is important to protect groundwater from pollution, the base and sides may be sealed, and water flows to a piped outlet, but far more slowly than it would in a piped system.

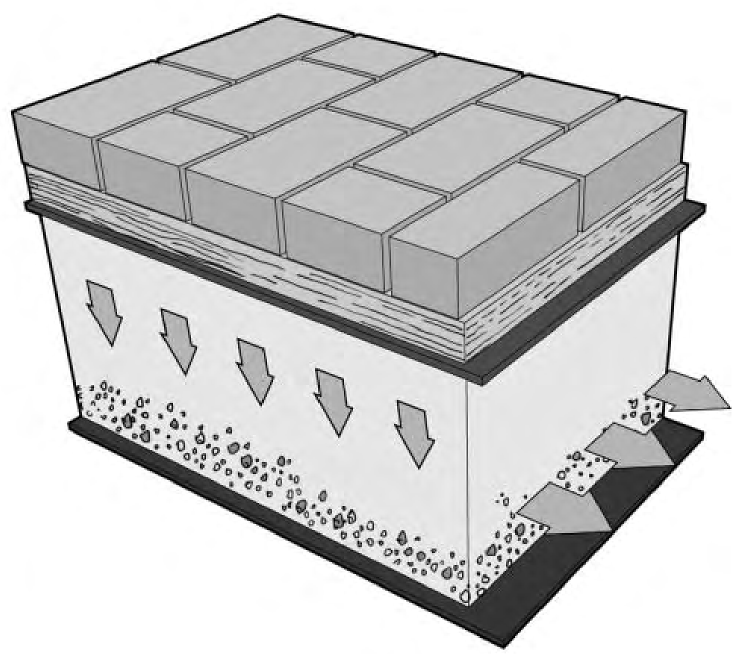

Figure 3.10: Permeable pavement – typical vertical section. Source: adapted from Butler and Davies 2011.

The only serious restriction on infiltration in urban areas is where there may be a risk of polluting groundwater that is used as a water resource.

A significant solution to the problem of increased and more rapid rainfall runoff is by using the system of development permitting. Guidelines need to be issued giving examples of how urban design can maximize infiltration into groundwater. Permits are then only authorized if such appropriate measures are included in the construction works. On a wider level, urban area administrations need to draw up a land use management and zoning plan, which recognizes the need for open spaces that can act as temporary rainfall storage, as well as being an urban recreational amenity.

Some agricultural practices reduce infiltration, and these increase flood risk to urban areas downstream. Adapted agricultural practice to reverse these effects includes conservation tillage, ploughless cultivation and avoiding bare soil. The preservation and extension of existing wetlands and forests in the upstream areas of a catchment enhances infiltration, and in addition reduces runoff through evapo-transpiration. Primary forests with broad-leafed trees are much more effective in reducing runoff than planted pine species.

3.6.4. Further reading

CIRIA. 2007. The SUDS manual. London, CIRIA.

3.6.5. How to maximize the effectiveness of SUDS

Sustainable urban drainage systems (also, as seen above, known as Stormwater Best Management Practices (BMP) or water sensitive urban design) have been seen as an effective and attractive alternative to conventional drainage schemes because of their advantages in handling runoff and urban stormwater at source and reducing the burdens of flow and pollutants on receiving systems.

SUDS devices are most effective when arranged in a series which mimics natural catchment processes, in the form of a 'management train'. In this way, the passage of water through the urban environment is slowed, maximizing the opportunity for infiltration and pollution control before the release into artificial channels or watercourses. In planning a management train, progressive stages in the management of runoff can be identified: inlet control, source control, site control and regional control. Particular SUDS devices are suitable at each of these stages (Figure 3.11). Devices at the top of this sequence should be used wherever possible as inlet control and source control can provide the most benefits.

Method

1. Identify appropriate SUDS devices

2. Link them in the form of a management train

3. Ensure that the plan increases permeability and optimizes infiltration

4. Consider the potential for SUDS to enhance the urban landscape

5. Detailed design stage

1. Identify appropriate SUDS devices

In order to select an appropriate set of devices it is necessary to understand characteristics of the urban area or development site in terms of land use, hydrology, geology and flood risk and environmental assessment. The requirements in terms of surface water management and pollution control and the capacity of downstream systems must also be taken into account. This will usually require extensive surveys. Once the requirements have been determined the appropriate devices that best meet the requirements can be selected using their particular characteristics as described in 3.4.4 and Table 3.2 below.

Table 3.2 SUDS selection matrix

SUDS group	Technique	Net Land Grab	Cost	Runoff volume reduction	Suitable for flow rate control 100 year event	Maintenance	Habitat creation potential
Retention	Retention Pond	H	M	L	H	M	H
	Subsurface storage	L	M	L	H	L	L
Wetland	Various	H	H	L	L	H	H

	Submerged gravel	M	H	L	L	M	M
Infiltration	Infiltration trench	M	L	H	L	L	L
	Infiltration Basin	H	L	H	H	M	M
	Soakaway	L	M	H	L	L	L
Filtration	Surface sand filter	L	H	L	L	M	M
	Subsurface sand filter	L	H	L	L	M	L
	Perimeter sandfilter	L	M	L	L	M	L
	Bio-retention / filter strip	H	M	L	L	H	H
	Filter trench	L	L	L	L	M	L
Detention	Detention basin	M	L	L	H	L	M
Open channels	Conveyance swale	H	L	M	H	L	M
	Enhanced dry swale	H	M	M	H	L	M
	Enhanced wet swale	H	M	L	H	M	H
Source control	Green Roof	L	L/H	H	L	M	H
	Rainwater harvesting	L	H	M	L	H	L
	Pervious pavements	L	M	H	L	M	L

Further matrices showing the suitability of SUDs devices by land use, site characteristics, catchment characteristics and amenity and environmental requirements can be found in The CIRIA SUDs manual.

2. Link them in the form of a management train.

Figure 3.11 presents the stages of a SUDS treatment train and the recommended devices at each stage.

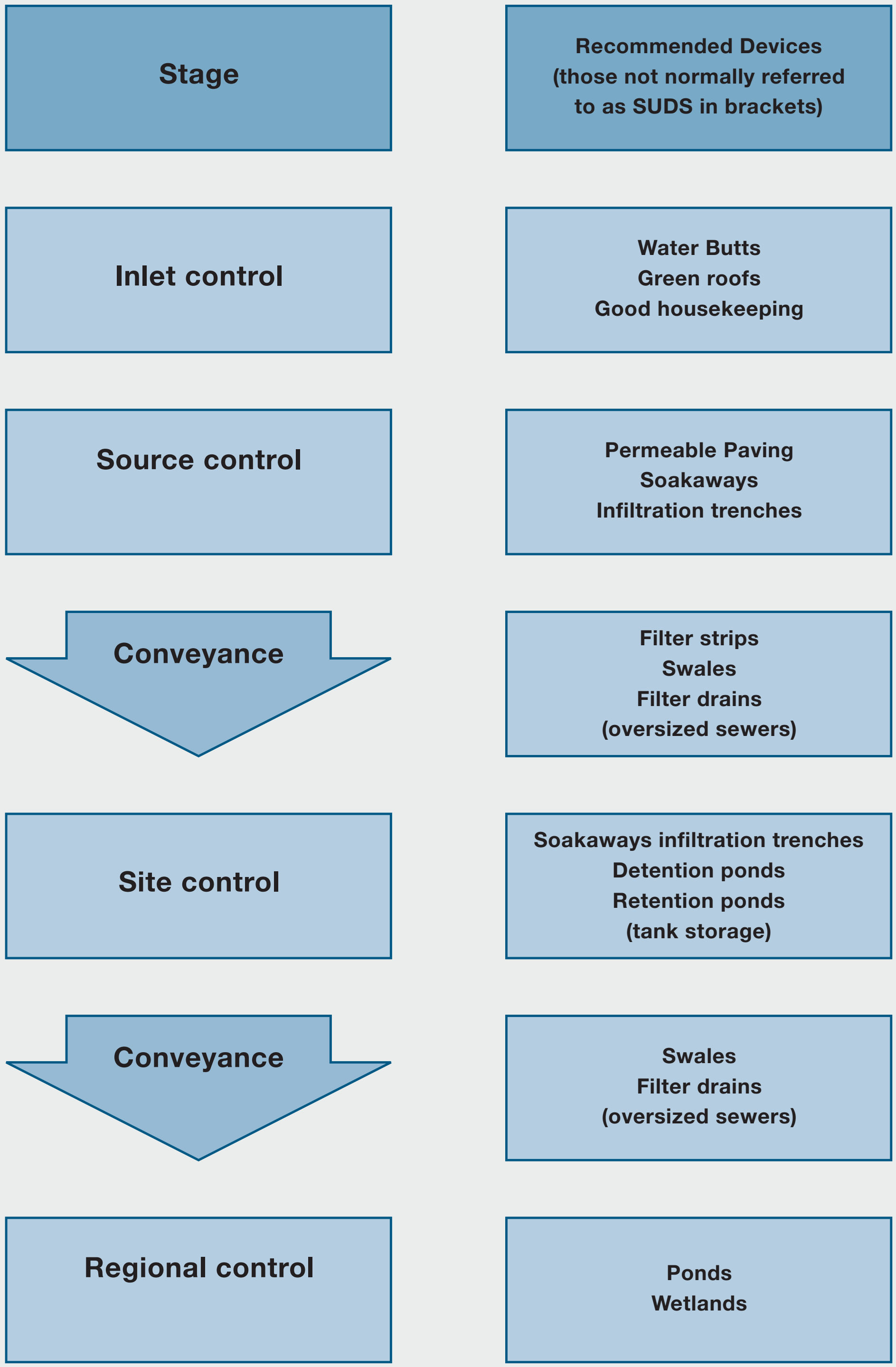

Figure 3.11: SUDS management train. Source: adapted from Butler and Davies, 2011.

3. Ensure that the plan increases permeability and optimizes infiltration

This is achieved through land use planning and control, ensuring that new developments maximize infiltration (see Section 3.5), and by greening urban areas (see Section 3.6.1). Relevant SUDS devices are identified below. For areas without serious pollution concerns the maximization of infiltration replenishes the water table and reduces peak run off.

Devices whose aim is specifically to facilitate infiltration:

- Soakaways
- Infiltration trenches
- Infiltration basins

Devices which encourage infiltration as part of their function:

- Swales
- Filter strips

Devices which encourage infiltration in specific applications:

- Permeable paving

4. Consider the potential for SUDS to enhance the urban landscape.

This can be achieved in a number of ways:

- By ensuring that ponds and other SUDS features are designed to be aesthetically pleasing, offer amenity value and are integrated effectively in the landscape
- By integrating water features that have a drainage or flood risk- reduction function into urban design
- By restoring streams that have been heavily engineered as urban channels to a more natural state
- By reopening ('daylighting') culverts (see Section 3.2.5).

5. Detailed design of system

Having selected appropriate devices and designed a management train, it is then appropriate to proceed to a detailed design of the individual features, including their inflow and outflow to the next feature to determine whether the whole system fulfils the original requirements in terms of flow and pollution control. Standard drainage software is acknowledged to be a poor approximation for SUDS devices particularly for infiltration devices which are highly sensitive to prior soil conditions and permeability.

Common Problems

The maintenance of SUDS is just as important – maybe more so – than traditional systems. The sustainability of the train depends on the functioning of every element and the ownership and responsibility for maintenance of all features should be established in advance. As SUDS trains often involve open systems, the potential for use for waste disposal and blockage is high, but the advantage of open systems are that any problems are more readily apparent and the users can see and deal with many problems quickly and easily.

In dense urban areas, competing land use requirements may make the installation of features unacceptable or too costly. Devices with low net land requirements such as soakaways or devices with dual purpose are preferred in such circumstances, such as permeable pavements, rainwater harvesting, green roofs and amenity features.

Resources and Costs

Costs of SUDS are of the same order as that for conventional drainage systems but it is of course important to take into account the whole life costs of regular maintenance and operation costs. Construction costs for simple devices such as infiltration basins and swales can be very low and use local labour and materials. More expensive options such as soakaways, filter drains, green roofs and permeable pavements require greater expertise and higher capital costs to install – up to ten times the cost of simple devices for equivalent storage capacity. However increased construction and maintenance costs must be balanced against land costs which are likely to be a significant component of the total costs for simple devices such as swales and ponds.

As an example the cost of installing permeable paving varies widely depending on the system, for example concrete blocks or permeable asphalt. However they are generally more expensive than typical asphalt (it can be up to 50% higher than non-permeable equivalents according to Boston MAPC (2011)) and the maintenance costs will also be higher. Despite this a study for the UK concluded that retrofitting permeable paving would be highly cost beneficial (Gordon-Walker and Harle, 2007) and the cost benefit for new installations would be higher.

Expertise to design and install SUDs systems is less commonly available than for conventional drainage and the availability of design software is lower implying that the design costs for SUDs may be higher than for conventional systems. However the potential for dual benefits in terms of treatment and amenity make these systems worth the consideration.

3.7. Groundwater management

In unsaturated ground, rain infiltrates into the ground and percolates downwards until it reaches the water table, below which the pores and cavities of the ground are saturated with water. Here the water moves laterally, generally slowly, under the influence of the gradient of the water table and the form of any underlying impermeable stratum. The water-bearing strata, or 'aquifers,' may consist of unconsolidated materials like sands and gravels, or consolidated materials like sandstone and limestone. Where the vertical space between two impermeable layers is saturated the aquifer is said to be 'confined'.

Aquifer recharge is enhanced by infiltration created through interventions like SUDS. In urban areas additional recharge may result from leaks in water supply pipes or drainage systems.

Groundwater discharge provides the base flow in rivers and continues during long periods without rainfall. Where the water table, or the surface of the aquifer, intersects the ground surface, groundwater is released via springs. During floods there can be rapid changes in groundwater outflow especially from confined aquifers.

In addition, groundwater management is necessary to prevent land subsidence, which leads to even greater problems in low-lying areas.

3.7.1. Groundwater flooding

Groundwater flooding is most likely to be a problem in areas that are low-lying and have water-bearing rock strata at the ground surface. An example is the Argentinean capital city of Buenos Aires: groundwater causes flooding of basements, rising damp in domestic dwellings, malfunction of in-situ sanitation systems, overloading and overflowing of sewers, and disruption to the urban infrastructure (Foster 2002). Flooding by groundwater can be hard to model and, therefore, hard to predict because the below-ground processes are complex and the properties of the ground can be highly non-homogeneous. Groundwater flooding is also characterized by the fact that the effects may be of long duration, lasting for weeks or months before groundwater levels lower sufficiently to alleviate the problem.

As some of the strategies for reducing flood risk involve increasing infiltration, the levels of groundwater may rise: this may have both positive and adverse impacts on flooding, for different areas and communities. The main method of controlling groundwater flooding is by pumping; the level of groundwater can be reduced by sustained abstraction and disposal of the water in a location where it will not infiltrate directly back into the aquifer. If the water is of sufficient quality it can be piped into the main supply, where this exists, either with or without treatment. Extracted water may also be used for low-grade industrial purposes, cooling, or irrigation of non-agricultural land elsewhere, although care needs to be exercised to ensure that the quality of such groundwater is fit for the intended purpose, following WHO and the Food and Agriculture Organization of the UN (FAO) guidelines and standards. Energy for pumping, treatment and the cost of transportation of water to the intended usage site are also major considerations.

3.7.2. Land subsidence

Where groundwater levels are lowered as a result of abstraction there is a risk of land subsidence. This can be a particular problem in coastal areas as has been identified by the World Bank Coastal Megacities report: large deltas are sinking at rates at up to six centimeters per year due to land compaction or extraction of groundwater. The Pearl River and Mekong deltas are noted as being particularly vulnerable (World Bank 2010a).

The regulation of groundwater abstraction can be a thorny legislative issue, involving the consideration of who currently owns the rights to abstraction and how they may be restricted, as well as pricing issues (IGES, 2008). Charging for groundwater has been implemented for example in Jakarta, Bangkok (see Case study 3.7 below), Bandung and Tianjin. However the effectiveness of such measures is often undermined by low pricing and the exemption of agricultural use.

Case Study 3.7: Combating Land Subsidence in Bangkok

Greater Bangkok, Thailand, witnessed widespread exploitation of groundwater starting in the 1950s, leading to significant land subsidence and damaging to urban infrastructure, as well as concerns regarding sea intrusion into the aquifer. Measures such as banning the drilling of water wells in critical areas, together with licensing and charging for metered or estimated groundwater abstraction, were all introduced but took some years to be implemented. Measures undertaken by the Government (costs stated in Thai Baht):

- 1969: Land subsidence given public attention

- 1978: Enforced Groundwater Act, B.E. 2520 (1977); the start of licensing for groundwater activities
- 1983: Critical Zone identified (four provinces)
- 1984: Groundwater tariff of 1 Bt per cubic meter imposed (six provinces)
- 1992: Groundwater act amended
- 1994: Tariff increased to 3.5Bt per cubic meter (six provinces)
- 1995 All provinces must pay groundwater charge; critical zone expanded (seven provinces)
- 2000-03: Tariff increased to 8.25Bt per cubic meter (in critical zone)
- 2003: Groundwater Act amended
- 2004: Tariff increased to 8.5Bt per cubic meter (in critical zone). Groundwater preservation charge imposed in critical zone

The groundwater pricing mechanism in Bangkok can be seen as a successful example. Charges were slowly increased until 2003, and an additional charge entitled "groundwater preservation charge" was introduced in 2004. Groundwater is now more expensive than water from the piped public water supply scheme. By combining a strict pricing system with expansion of public water supply, total abstraction was reduced from 2,700 million liters per day in 2000 to 1,500 million liters per day in 2005, and land subsidence was also significantly reduced. The groundwater preservation charge is innovative because it is earmarked for research and groundwater conservation activities by the Groundwater Act.

This example illustrates the difficulties encountered in trying to control groundwater levels; it is not easy to find the right balance of tariffs to achieve a reduction in abstraction. However the measures undertaken by the Bangkok municipality have resulted some positive outcomes and similar measures could yield benefits elsewhere.

Sources: Babel 2008; World Bank 2010b; IGES 2008.

Provision of alternative water sources is an essential element of any program to prevent groundwater extraction. An increase in the number of water treatment facilities and the encouragement of rainwater harvesting, or other surface water management techniques, can assist somewhat here, although this will reduce replenishment of the aquifer. Addressing water demand is another alternative strategy.

3.7.3. Rainwater harvesting

The term rainwater harvesting refers to reuse of stored water, including water purification, and can form part of a sustainable drainage system as described in Section 3.5.4. Most commonly, reuse will be for purposes which are less sensitive to water quality (such as irrigation, washing or toilet flushing). In this case, water from a roof may be diverted to a large underground tank; in some regions the stored water is used for drinking, though it must usually be filtered or treated if it used for this purpose. Case study 3.8 below gives an example of the successful implementation of such a system in Korea. In cases where water quality is important, the 'first flush' of rainfall, which can be particularly polluted, should be diverted away from the storage facility. Water from rainwater harvesting schemes can also be used for groundwater recharge.

The process is seen as having multiple benefits (UNEP/SEI 2009):

Provisioning

- Can increase crop productivity, food supply and income
- Can increase water and fodder for livestock and poultry
- Can increase rainfall infiltration, thus recharging shallow groundwater sources and base flow in rivers
- Can regenerate landscapes increasing biomass, food, fodder, fiber and wood for human use
- Improves productive habitats, and increases species diversity in flora and fauna

Regulating

- Can affect the temporal distribution of water in landscape
- Reduces fast flows and reduces incidences of flooding
- Reduces soil erosion
- Bridges water supply in droughts and dry spells
- Can provide habitat for harmful vector diseases

Cultural

- Rain water harvesting and storage of water can support spiritual, religious and aesthetic values
- Creates green oasis, or 'mosaic' landscape which has aesthetic value

Supporting

- Can enhance the primary productivity in landscape
- Can help support nutrient flows in landscape.

In the specific context of flooding, there are three potential direct benefits:

- Harvesting water can reduce peak flows. When implemented on a grand scale this is sometimes known as stormwater harvesting, but small scale collection of rainfall can also reduce flooding, if adoption is widespread within a community.
- Harvesting water can assist with replenishing groundwater levels, thus helping to prevent ground subsidence. Many documented cases exist where rainwater harvesting has conserved groundwater. Recharging is seen in India where the Central Groundwater Board oversees artificial recharge of groundwater both in rural and urban areas. An example is the Ghogha project in rural Gujarat, which uses 276 recharge structures in 82 villages (Khurana and Seghal 2005).
- In a flood situation, when water supplies may become disrupted or contaminated, the collection of rainwater may be a more reliable and potable supply, as is seen in northern Bihar in India. If storage tanks are provided at emergency evacuation points, then the problems of water supply for evacuees may be alleviated.

Case Study 3.8: Rainwater Harvesting at Star City, Seoul

Rainwater harvesting was incorporated into a major real estate development in Seoul. Star City is a shopping and housing project consisting of more than 1,310 apartments and provides accommodation for more than 4,000 people. The basic design idea was to collect up to the first 100 millimeters of rainwater falling on the development and to use it for gardening and sanitation purposes, as well as tap water.

An entire floor below the ground with a total area of 1,500 cubic meters is used as a water storage area which can store up to 3,000 cubic meters of water in three separate tanks. Two of the tanks are used to collect rainwater from the rooftop and the ground. This reduces flood risk in the area during the monsoon season, while simultaneously being used for water conservation. The third tank is used to store tap water in the case of emergency. It is expected that the system will save about 40,000 cubic meters of water per year, which is about 67 percent of the annual amount of rainfall over Star City.

Moreover, because the system harvests rainwater on site, it reduces the energy required, and therefore the CO2 emissions for water treatment and transportation. This project is considered very successful and the local government passed a city-wide regulation to further promote rainwater harvesting in new developments.

Source: UNEP 2009.

The technique for single household roof rainwater harvesting systems is the simplest of all. Its sophistication depends on the level of capital investment. The main component of such a system is collection of water through roof catchment and piping it to a tank underground or to the cisterns directly. The main materials used for roof rainwater harvesting system are concrete, tiles, fiberglass, slates, galvanized iron, and aluminum sheets. The pipes used for conveyance purposes are mainly PVC, which is cost effective. However they have their own negative effects in terms of health hazards. Therefore regular cleaning and monitoring of such systems are recommended. Some systems have options for filtration and disinfection of collected water.

Similar systems are also used in larger institutions for example schools; and company buildings, and the collected water is sometimes stored separately in different storage tanks and then supplied for non-potable purposes which are quite effective. In case of collection of rainwater through runoff from stormwater or heavy rainfall, the techniques like storing it in low-lying ponds or reservoirs are cost effective. However these reservoirs need regular cleaning and monitoring for effective use of the water afterwards.

The material of construction for storage tanks are generally concrete, polythene, steel, and fiber glass. The quality of the water collected may be significantly affected if tanks are not properly cleaned at regular intervals, as pollution from debris, dirt, animal droppings, rodents, insects and other solid materials can occur. The technique of rainwater harvesting in natural reservoirs helps in restoring water to its natural hydrological cycle, to some extent through underground seepage which is minimal in urban areas because of asphalt cover. Such techniques not only help cities to be self-reliant with their water storage capacity but also assist in the restoration of city drainage systems by not letting them overflow to cause urban floods.

Examples of successful implementation of rainwater harvesting are seen in Australia where commercial rainwater harvesting concerns are profiting from concerns about water availability. The potential exists for flood-prone areas to develop community-based commercial harvesting programs.

3.7.4. Further reading

LILLYCROP, W.J., PARSON, L.E., and IRISH, J.L. (1996). Development and Operation of the SHOALS Airborne Lidar Hydrographic Survey System. SPIE Selected Papers, Laser

Remote Sensing of Natural Waters: From Theory to Practice, 2694, 26-37.

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Wang, M., Zhou, Y. and Nie, L. 2009. Storage Capacity Analysis of Rainwater Tanks For Urban Flood Mitigation. Paper presented at COST22, Paris, November 26-7, 2009.

UN-HABITAT. n.d. Rainwater Harvesting and Utilization. Blue Drop Series Book 2: Beneficiaries & Capacity Builders. UN-HABITAT.

3.7.5. How to optimize a rainwater harvesting system for flood control

Rainwater harvesting is a green and sustainable option for increasing the supply of water in areas of water scarcity where the conventional water supply has failed to meet the demand of the community. This system has been used since ancient times. However in many cases it has declined in importance partly due to lack of need as piped water supplies improve and because of the lack of information and technology within rapidly expanding urban environments.

However it is now recognized that as well as providing a relatively clean and reliable source of water, rainwater harvesting can also prove to be an important technique for flood mitigation.

The traditional “linear” approach of managing large amounts of water in times of peak rainfall over a wide area involves diverting the water using sewers or rivers consisting of a line of conveyance. The “areal” approach of managing rainwater at source within a watershed, especially in urban areas, by collecting and then storing the water in numerous tanks and storage structures, can reduce peak runoff and help in reducing peak flow. The water thus stored can be used for non-drinking purposes resulting in water conservation. It can also be used for drinking purposes if proper purification measures can be installed. Rainwater harvesting can be treated as an innovative solution to prevent urban flooding.

Method

1. Understanding the rainfall patterns

2. Determining the technique

3. Delegation of roles and responsibilities

1. Understanding the rainfall pattern and the flood objective

To construct any effective rainwater harvesting system for secure water supply it is important to understand the physical factors affecting the rainfall regime of the area, for instance to have an idea of the total inflow and outflow of water. In an urban area, and with the added aim of flood mitigation, it is very important to have proper knowledge of the total cycle of water input and output. This involves quantity of rainfall in mm/year, pattern of rainfall i.e., type and total amount of rainfall, peak discharge rate and time, total runoff, the capacity of collection surface area (m2), storage capacity (m3), daily consumption rate, number of users, and the costs and alternative sources of water. A total system approach integrating rainwater harvesting into water treatment and supply should be subject to the same stringent hydraulic design as conventional piped systems.

For the purposes of flood control, the major considerations of the design should be to ensure that sufficient storage is available at times of peak flow to reduce the run off and prevent flooding, and that this storage is quickly made available to accommodate the next peak event. This is complementary to but could also conflict with the aims of a harvesting system solely for water supply where overflowing may be less of a problem and heavily polluted run off would not be acceptable. Ideally if a rainwater harvesting system has flood mitigation as a primary part of the purpose there should be storage and uses of the water that can accommodate or treat polluted run off.

However one useful advantage of rainwater harvesting is that much of the technology used is flexible and incremental with relatively little effort required for construction, operation and maintenance. In addition, such systems tend to fail gracefully: that is, if water is initially stored in a dispersed way at source, overtopping will probably not cause more problems than if the system were not installed. Therefore some improvements can be achieved quickly and cheaply even without full understanding of the system.

2. Determining technique

There are different types of rainwater harvesting systems. Techniques used for such purposes are determined by the type of rainwater harvesting system suitable in an area depending on the size and nature of the catchment available. The main components of rainwater harvesting for optimal flood control are primarily water collection, conveyance and storage. Therefore the most important aspect of consideration is to understand the impermeable surfaces generating run off relative to the storage capacity in the area.

Collection Options

Roof systems are the most common. They can be simple small roof collection systems for single households, larger roof collection systems for large commercial buildings, and collection systems in high rise buildings.

Suitable materials include:

- Galvanized corrugated iron or plastic sheets, or tiles.
- Thatched roofs made from palm leaves (coconut and palms with tight thatching are best). Other thatching materials and mud dis-color and contaminate the rainwater, often by allowing access to rats.
- Unpainted and uncoated surface areas are best. If paint is used it must be non-toxic (no lead-based paints).
- Asbestos-cement roofing does not pose health risks – no evidence is found in any research. However, airborne asbestos fibers (from processing and cutting) do pose a serious health risk of mesothelioma (asbestos-related cancer) if inhaled.

Land surface catchment systems and stormwater collection systems in urbanized areas are also possible. They are important for flood control but less common and tend to have a higher pollutant content.

Conveyance Options

Water can be stored at the point of collection, for example in roof tanks, which can be a great advantage if these tanks are situated in safe locations. Normally the water is channelized by installing rainwater channelization systems ranging from simple gutters to sophisticated filtration devices.

Timber or bamboo is also used for gutters and drainpipes; for these materials regular replacement is better than preservation. Timber parts treated with pesticides to prevent rotting should never come into contact with drinking water.

Storage options

Storage needs to be appropriate for different reuse types and may also be linked to mains systems for security of supply during dry periods. Simple home-based systems can be jars and water barrels. Larger systems use roof tanks, surface tanks or underground storage.

Materials for surface tanks include metal, wood, plastic, fiberglass, brick, interlocking blocks, compressed soil or rubble-stone blocks, ferro-cement and concrete. The choice of material depends on local availability and affordability – and weight if they are to be situated on the roof. In most countries, plastic tanks are also commonly available.

Sub-surface tanks require a water lifting device such as a pump for emptying. Materials and design for the walls of sub-surface tanks or cisterns must be able to resist the soil and soil water pressures from outside when the tank is empty (upward pressure can cause tanks to float in high groundwater areas). Damage can also be caused by tree roots and heavy traffic. Usually concrete is used, strengthened with steel. While there are experiences of using green materials such as wood, bamboo and basket work as alternatives to steel for making concrete tanks, these have not always been successful.

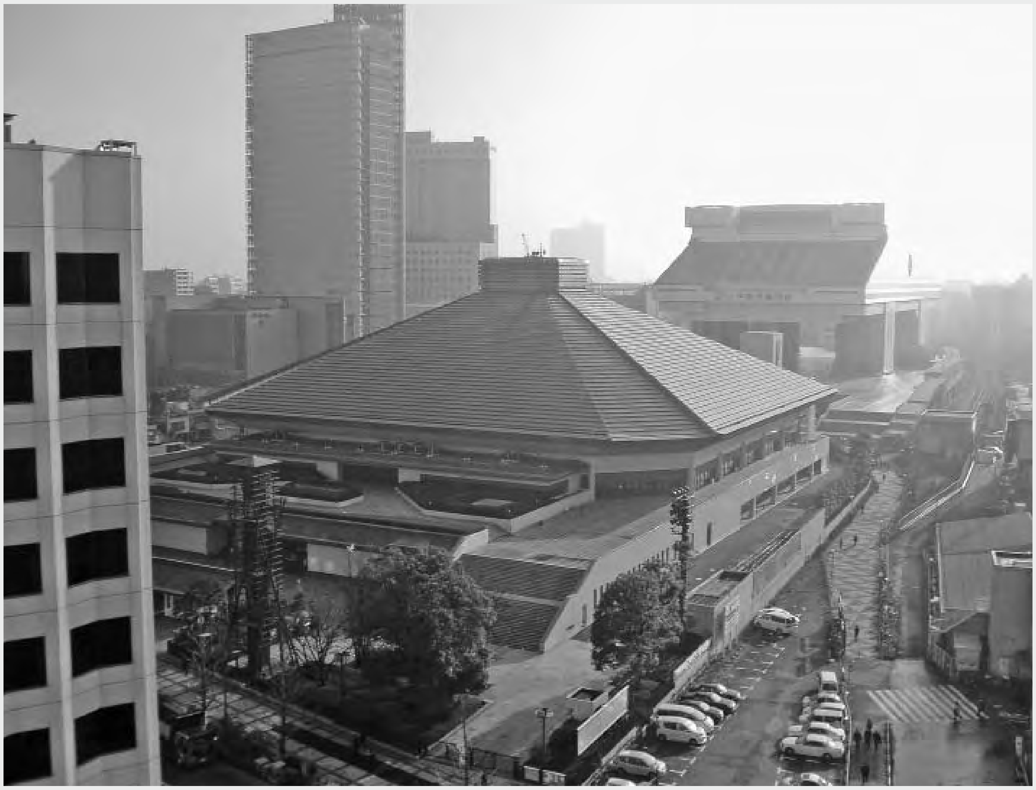

Photo 3.9: The Kokugikan sumo wrestling arena rain water harvesting system in Tokyo, Source: Japan Wikicommons

The storage of rainwater in numerous small tanks and reserves helps in reducing peak runoff and controlling overflowing of drainage infrastructure. This is more cost effective than storing rainwater in larger reservoirs or improving the carrying capacity of the drainage infrastructure through upgrading in urban areas. This however requires effective public participation and awareness generation.

3. Delegation of roles and responsibility

As mentioned earlier, the success of water harvesting systems rests on how well the system is organized and managed. Delegation of responsibility to undertake the smooth running of the system is crucial. It is important that roles and responsibilities are allocated at both individual and community levels. Participation from different stakeholder groups, for example from both from the community and commercial sectors, is essential too. Proper mandates for new constructions based on size and storage capacity of buildings should be released beforehand, and permission should be sought and granted before construction.

The role of local government is not only to develop incentives and help the participants to organize but also to keep a close eye on the entire process in the long term. A special role could be assigned to the disaster management authority in monitoring the water levels within the storage systems to ensure adequate capacity for extreme rainfall and also water availability during emergencies. An online GIS system based on manual measurement or remote sensing can be installed for management of such a system.

Public participation and technical control from different organizations are necessary for effective performance of the system, and therefore central monitoring is useful for such purposes. Monitoring and management of the system by the public and local authorities coupled with modern techniques can be very useful for mitigation of urban flooding. Such a system is successfully running in Seoul metropolitan area where the changing increased range of rainfall created the problem of urban flooding. The case of Kobe city (Japan) and Sumida city are also important examples of using rainwater harvesting as a response to natural disasters (UNEP, 2005)

Further reading

UNEP (2005) Rainwater Harvesting and Disaster Management, http://www.unep.org/pdf/RWH/disaster_management.pdf

3.8. Wetlands and environmental buffers

3.8.1. Introduction

Measures for reducing the amount and speed of rainwater runoff in urban areas can include utilizing wetlands, both natural and man-made, and increasing the amount of green vegetation. From the flood management point of view the key purpose of wetlands and environmental buffers is to act as flood retention basins and hence reduce the flood risk to built-up urban areas.

These 'greening' measures can be at a micro level, such as gardens and grass verges of streets. On a wider scale, there is the provision or designation of managed green areas within the urban space, such as an interconnected network of designated wetland areas, linked to existing natural wetlands through a program of tree and hedge planting. Such steps have a multitude of other benefits, apart from retarding and reducing the volume and timing of rainfall runoff and flooding to surrounding areas. These benefits include reducing the 'urban heat island' effect, reducing the level of CO2, as well as the reduction of run-off together with the enhancement of ground water storage by more infiltration through the soil.

The creation of green spaces such as riverside corridors, parks and tree-lined streets also assists in responding to climate change and could indirectly further reduce flooding in urban areas. It has also been observed (Faculty of Public Health/Natural England. 2010) that with a higher percentage of green space and green infrastructure, post-flood human psychological pressures are reduced as they create a healthier urban environment and promote recreation.

The study by the Faculty of Public Health in association with Natural England (ibid) also estimated that 1.3 million trees could catch 7 billion cubic meters of rainwater per year, which would significantly reduce the load on stormwater drainage, thereby preventing flooding. Some of the established practices of such green infrastructure and green space are the creation of green roofs, community woodlands, landscaping around buildings, tree-lined streets, urban parks and gardens.

Within the context of wider urban planning, policies can be drawn up which address the need to zone natural or man-made buffer zones within and around urban areas. Policies have to adequately address the differing functions of such buffer zones, including their role in flood management. Other functions include benefits to flora and fauna habitats, the ability of such areas to allow any sediment in the flow to be deposited and also the ability of such wetlands to remove nitrate by the take up of vegetation. Case Study 3.9 of Ghana illustrates the functions that such buffer zones can perform and also how zoning can be related to distance from a river or water-body. An inter-disciplinary approach has to be followed which involves all parties that have vested interests, including local people as well as institutions with remits for flood management, wetlands, forestry and protected areas and also those for water quality.

Case Study 3.9: Buffer zone policy for managing river basins in Ghana

The Water Resources Commission (WRC) in Ghana formulated a policy document in 2008 on how buffer zones are to be created, protected and maintained. It is important to emphasize that the preparation of this new policy involved a wide range of stakeholder participation. The policy follows a decentralized approach that gives the city authorities more responsibilities in relation to water resources management.

The way in which development has been taking place entailed a shift from the traditional buffer zone practices towards usages of river banks that can enhance economic growth. Such economic-driven approaches have often resulted in pollution and degradation of the buffer strip along the rivers. This is particularly the case when they are close to, or flow within, high density urban settlements. It was, therefore, suggested that customary bylaws on buffer zones be enforced by the local communities.

Over the years, various departments and agencies in Ghana have introduced policies, bye laws and regulations in relation to the width of buffer zones. However, in most cases they were introduced without any stakeholder engagement and they adopted a sectoral point of view.

Existing buffer zone widths in Ghana vary from 10 meters to 100 meters. This range determines the minimum buffer width that is necessary to sustain the river ecosystem and corresponds to the various organizational conditions in the buffer zones. The main objectives of the policy were the introduction of a regulation which incorporates the various specifications as given in existing regulations, and at the same time is flexible in its conditions to fully accommodate the real needs and priorities of the local population.

Source: Water Resources Commission 2008.

River floodplains within or immediately upstream of urban areas can be managed as periodic wetlands. This can allow for diversion or natural flooding, providing storage in the floodplain, thereby attenuating the flooding peaks of the river system.

The appropriate management of existing wetlands upstream of urban areas can go a long way to reducing flood risks. At the same time it is possible to manage the wetland in a sustainable manner for flora and fauna as well as the human use of resources. A good example of this approach can be found on the Agusan River in Mindanao, the Philippines. The city of Butuan lies at the mouth of the river and is at risk from flooding from both the river and also the sea. The Agusan wetland area lies upstream of Butuan City and has a difference in water level of six meters between the wet and dry seasons, as shown in the comparative photographs in Photos 3.10 and 3.11.

Photos 3.10 and 3.11: Agusan wetland area dry and in flood, Source: Alan Bird

The wetland area was registered under the Ramsar Convention in 1999 and is the most important freshwater site in the country. The indigenous inhabitants of the wetland have adapted their way of life to cope with such a wide seasonal range in flooding, living on floating homes and carrying out seasonal fishing. Management plans need to be drawn up for such areas and a mechanism for achieving compliance with the plan needs to be established. A model wetland management plan can be found on the website of the SPCW (n.d.).

3.8.2. Key components and data requirements for implementation

The key components of managed wetland and environmental buffers are:

- Natural wetland areas within or upstream of the urban area that can be managed by controlling water inflow and outflow.
- The construction of man-made managed wetlands with inlet and outlet control structures.
- The linking of existing natural or man-made wetlands by creating a network of link channels. These channels can be planted with appropriate species of vegetation.

– The zoning of land use within the urban area and also any wetland upstream of it. The zoning will restrict the type of development and human activity that can take place in the wetland and buffer areas. An effective system for ensuring compliance has to be in place.

– The drawing up of a planting program for the urban area with the objective of maximizing vegetation cover.

All of the above items should be carried out in a participatory manner involving all people who have vested interests within the area.

Accurate topographic mapping of the area will be needed. This can be superimposed upon a satellite imagery base such as that found on Google Earth (n.d.). In addition, it will be necessary to have rainfall data and river flow measurements and, ideally, to produce a hydro-dynamic flood model of the area.

3.8.3. Use and benefits

The development of existing natural wetlands upstream of an urban area is best carried out as part of an overall catchment management plan. The locations where man-made wetlands can be established will become apparent when the results of the hydro-dynamic model are analyzed. Within urban areas there may be difficulties and conflicts of use, as land values are likely to be higher than those wetland locations upstream.

As discussed above, the direct benefits of appropriately designed and operated managed wetlands are to reduce the impacts of flooding within an urban area. The direct benefits of vegetation planting are an improved urban landscape and provision of recreation and amenity areas.

The indirect benefits of managed wetlands, however, are to allow sediment to settle out of the floodwater and also increase surface water quality by reducing nitrogen levels. However, this requires careful management to reduce the risk of algal blooms during the warmer times of the year. In addition, wetlands can provide flora and fauna habitats, and greater overall bio-diversity of the urban and surrounding areas. The planting of vegetation should contribute to a reduction in CO2 levels.

The risks involved with the provision and management of wetland areas are increased if there is insufficient understanding of the present flooding pattern. A worst case scenario would be where additional or other areas of developed urban land are flooded if the capacity of the wetland is insufficient to safely hold the flood water. The question of land tenure is critical, however, especially if the identified sites for managed wetland require acquisition from non-government owners.

3.8.4. Essential and key considerations

A good knowledge of the existing flooding pattern is essential before drawing up a network of wetlands and interconnecting channels. An inter-institutional planning approach is required with a clear understanding of which institutions have what responsibilities. The selection of potential wetland sites will need to consider their present ownership and land value.

The construction and management of wetlands for the purpose of reducing the risk of urban flooding can be carried out as a stand-alone intervention. However, increased benefits are likely to occur if these measures are carried out as part of a basin-wide (catchment) management plan. Similarly, the planting of vegetation within urban areas could be carried out as a stand-alone measure, but would have increased benefit if it were planned and implemented as part of an overall management plan for the urban area, which would include a land use planning and zoning component.

3.9. Building design, resilience and resistance

Where buildings are situated in the floodplain, even if they are protected to some extent by structural flood defenses, there will still remain some residual risk of flooding. Careful design of buildings can reduce the vulnerability of buildings to flood damage and can therefore reduce the residual risk and enable occupation of floodplain areas. This can be particularly important for existing settlements which cannot be relocated, or where the advantages of floodplain occupation outweigh the cost of building design.

3.9.1. Description

There are a number of building design improvements that can be used to reduce the effects of flooding. Different approaches can be implemented, depending on whether they are added to an existing building or constructed as part of a new building. Three main approaches are flood resilience or wet flood proofing, (which allows the water in to a building); flood resistance, or dry flood proofing, (which keeps water outside a building); and flood avoidance (such as raising buildings on stilts or raising the land below the building, thus vertically removing the building from the risk of flood).

Generally flood avoidance is most appropriate for new builds, but it is possible to retrofit stilts or plinths below existing buildings dependent on the construction technique.

Photo 3.12: Housing raised to avoid flooding in Shrewsbury, UK. Source: J Lamond

Each of these design solutions may be more or less appropriate depending on the level of the risk and the background environmental conditions of the location, such as climate, soil conditions, pollution, and seismic activity. These strategies will not, however, be available to low-income groups living in informal settlements. Such groups may be particularly susceptible to flooding because they may located in low-lying flood-prone land, where any drains are less likely to be maintained either by the municipal authorities or by the community.

3.9.2. Purpose

Typically a building design solution to flooding is aimed at reducing the damage that occurs to the building fabric, fixtures and fittings from the impact of the flooding (floodwater, debris); the after effects of the floodwater (subsidence, corrosion, rot, mould, swelling); and the repair of the building for resumed habitation (cleaning, sanitation, repair and replacement, electrical or structural testing).

Floodwater can have a significant impact on both building integrity and recovery. At its worst it can cause structural collapse, potentially resulting in loss of life as well as property. Furthermore the building itself can become a hazard, as debris can cause damage to other buildings or injure people. Overall, as described in Chapter 2, floodwater damage to a building can be costly to resolve, carry long-term health risks, take a long time to complete, and cause social trauma.

Three approaches are indicated:

- Flood resilience (wet proofing) helps to reduce the damage when floodwater enters the building, particularly structural damage, but it does not prevent floodwater entering.
- Flood resistance (dry proofing) seeks to prevent water from entering the building, to reduce damage to the building, the fixtures and fittings, possessions and reduce the effect on occupants.
- Flood avoidance aims at avoiding the floodwater entirely, by locating buildings above the flood level, elevating or raising buildings above the flood level, or to allow buildings to rise with the floodwater.

3.9.3. Key components

Vernacular and contemporary architecture varies with local climate, available materials and long standing traditions. It is not practical to propose a generic design which will suit all flood prone areas, but in considering flood-proof building design, the key components relate to the main construction elements of a building, the rooms and furnishings:

1. Sub-structure (foundations) and basement construction
2. Super-structure (the building frame or envelope, including walls, floors, roof, windows and external doors)
3. Services (the electrics, plumbing and heating)

4. Fixtures and fittings (internal partitions, doors, appliances, floor-coverings)

5. Furnishing (any loose laid items, such as chairs and tables)

6. Safe refuge (above flood level)

7. Provisions (first aid kit, torch, blankets, clean water etc).

All components must be considered. For example, building design which prevents damage to the building by restricting access to the building using barriers also needs to allow for safe refuge on an upper floor, otherwise lives may be endangered because escape from the building is hampered.

It is also important to consider all the ways in which floods can act on these building components. Flood actions can be categorized as:

- Hydrostatic (lateral pressure and capillary rise)
- Hydrodynamic (velocity, waves, turbulence)
- Erosion (scour under buildings, building fabric)
- Buoyancy (lifting the building)
- Debris (items in the water colliding with the building)
- Non-physical actions (chemical, nuclear, biological).

(Kelman and Spence 2004)

In a high-velocity flood, these actions, particularly the hydrodynamic and debris types, are likely to overwhelm many building design features. Therefore, design should always take into account the likely flood attributes. An example of flood and typhoon resistant housing is examined in Case Study 3.10.

Case Study 3.10: Flood and Typhoon Resilient Housing in Vietnam

A disaster risk reduction initiative aimed to reduce the impact of typhoons and floods on housing was implemented in the Thua Thien Hué Province in Central Vietnam by the Development Workshop France (DWF), funded by Canadian International Development Agency (CIDA) and EU Humanitarian Aid department (ECHO).

The program which ended in 2008 involved individual households and the local community throughout the process. Each year, the program targeted more than 4,000 direct beneficiaries and reached over 100,000 people through awareness campaigns. The aim was to reduce vulnerability through the integration of storm resistant techniques in existing and future buildings. The program presented specific design principles, including:

- The balcony roof, which is a high risk item, should be structurally separate from the main roof of the house
- The connections between all individual parts of the structure, from the ground to the ridge, have to be very strong to withstand adverse weather effects
- Doors and shutters should allow the building to be closed up
- All parts of the roof and wall structures must be tightly connected
- Roof sheets or tiles must be held or tied down
- Trees should be planted to form windbreaks.

The Xangsang Typhoon in 2006 confirmed that this approach is broadly correct. Some characteristics of the program are context specific, but the approach can be adjusted to work in other countries and different contexts. In particular, the transfer of responsibilities to the local community needs to be emphasized, given that this significantly contributed to the effectiveness of the initiative.

Source: UNISDR 2007.

Resistant and resilient measures include items such as door barriers to prevent water ingress and actions such as moving power sockets higher up on a wall, in case water does enter the property. Components can be either temporary (door and window guards) or permanent (backflow prevention valves). However, in new buildings it is usually preferable for measures to be permanent.

Flood resilient design seeks to prevent flood damage to the components of the building including the effect that floodwater has on the sub-structure and superstructure. It may also include sacrificial elements of a building, for instance wallboards that can be removed and replaced. Sub-structure and superstructure should be designed to allow water to drain away, such that the building can dry out quickly. Services should be located above the potential flood level: this means all electrical outlets, fittings, junctions (including within wires), and distribution boards. Fixtures and fittings should be designed to avoid complete damage when inundated by water, and consideration should be given to furnishings that will not cause an obstacle during a flood. Safe refuge should be provided above flood level; this can be on the first floor, but for greater flood depths an access hatch out of the roof may be needed for rescue purposes.

The final key component of flood resilience is to consider provisions that will be required during a flood: quantities will depend on the potential duration of the flood, but would include things like preserved food, clean water, a torch (wind-up type, or spare batteries will also be needed) or candles and matches, blankets and a first aid kit, including drugs for diarrhea and dysentery.

Flood resistant design seeks to prevent water entering the building. There are many entry points which need to be considered: windows and doors, floor voids (particularly suspended floors), cracks or gaps in walls, air vents or air bricks (designed for ventilation), service ducts and pipes, such as toilets and drains, or seepage through floors (particularly earth or stone floors where there is no damp proof membrane). A flood resistant design must tackle all of these elements. In addition, the quality of building components is critical, as failure of any one element can compromise the whole design.

Flood avoidance, for an existing building located in the floodplain, would seek to raise the building above the flood level. This approach is illustrated in Photo 3.13 as applied to housing and in Photo 3.14, showing a municipal building in the UK that has ground floor garaging and a raised escape route.

If the ground level of a building is to be raised, the structural integrity of the earth and foundations, which the building is to rest on, must be considered. If, however, a building is to be elevated as a whole, the integrity of the columns or structure, that the building is to be raised on, must be considered. In both cases debris, weight of the floodwater and scouring can affect the building sub-structure.

Photo 3.13: Houses raised on stilts to avoid flooding in Bangladesh. Source: Alan Bird.

Photo 3.14: Municipal building in the UK with ground-floor garaging. Source: J Lamond.

3.9.4. When and where to use the 'solutions'

Building design solutions are most appropriate where there are no other means of flood prevention or where flooding would affect the functionality of critical infrastructure: power stations, communications centers, hospitals and emergency services facilities all need to continue operating during floods. This approach may also be appropriate where there is a high risk that other flood protection measures may be ineffective or prone to failure.

Ideally buildings should be located to avoid flood risk. However, many thousands of buildings are already located in floodplains, and in this case flood resilience measures could help to reduce risk.

As a rule of thumb, flood resistance should only be used where flood duration is short and flood depths are ideally below 1m, although some guidance places the acceptable depth lower, at 600mm. It is wise to assess the structural integrity of a building before installing resistant measures. This is because the pressure from flood water could cause walls and windows to collapse, water flows can erode the surrounding ground, and deep water can cause floating debris such as trees and cars to collide with the building. Flood resilience is, however, feasible at higher depths of water and for longer duration floods. It is also easier to apply to existing buildings where resistance is inappropriate, but can be less acceptable to occupants

Table 3.3 shows where and when it is appropriate to consider flood proofing measures, for existing buildings, based on flood depth, velocity and construction types.

Flood Proofing Matrix	Measures								
	Elevation on foundation walls	Elevation on Piers	Elevation on posts or columns	Elevation on piles	Relocation	Walls and levees	Floodwalls and levees with closures	Dry flood proofing/ resistance	Wet flood proofing/ resilience

Flood Characteristics										
Depth	Shallow (<1m)	√	√	√	√	√	√	√	√	√
	Moderate (1-2m)	√	√	√	√	√	√	√	X	√
	Deep (>2m)	√	√	√	√	√	X	X	X	X
Velocity	Slow (<1m/s)	√	√	√	√	√	√	√	√	√
	Moderate (1-2m/s)	√	√	√	√	√	√	√	X	X
	Fast (>2m/s)	X	X	√	√	√	X	X	X	X
Flash Flooding	Yes	X	√	√	√	√	√	X	X	X
	No	√	√	√	√	√	√	√	√	√
Ice & debris flow	Yes	X	√	√	√	√	√	X	X	X
	No	√	√	√	√	√	√	√	√	√
Site Characteristics										
Location	Coastal floodplain	X	√	√	√	√	√	X	X	X
	Riverine floodplain	√	√	√	√	√	√	√	√	√
Soil type	Permeable	√	√	√	√	√	X	X	X	√
	Impermeable	√	√	√	√	√	√	√	√	√
Building Characteristics										
Foundation	Slab	√	√	√	√	√	√	√	√	√
	Sub-floor void	√	√	√	√	√	√	√	√	√
	Basement	√	X	X	X	√	√	√	X	X
Construction	Concrete / masonry	√	√	√	X	√	√	√	√	√
	Wood/ other	√	√	√	X	√	√	√	X	X
Condition	Excellent to good	√	√	√	√	√	√	√	√	√
	Fair to poor	X	X	X	X	X	√	√	X	X

Table 3.3: Flood Proofing Matrix. Source: Adapted from USACE.

Individuals or businesses may use these measures to protect their property, without reliance on state support and can do so to the standard of protection and longevity that they wish.

3.9.5. Benefits and risks

Flood resilient, resistant or avoidant building design can help buildings to survive a flood, reducing financial loss and improving the likelihood of survival for occupants by providing safe refuge. These approaches can reduce the recovery time, allowing people to continue to occupy a building during a flood or to evacuate and return to a building after a more severe flood.

Improvements to the building design may also reduce secondary risks, such as fires, (particularly those caused by the inundation of electrical systems by floodwater or debris); pollution (from fuels and other materials leaking into the floodwater); health problems (from sewage polluting the floodwater); and the growth of mould.

Better building design may also reduce the need for and therefore the cost of evacuation. If buildings can be occupied during the flood, this will reduce the disruption to businesses and therefore the financial losses incurred. Appropriate building design can also make properties more insurable, and, where relevant, reduce premiums by reducing the payout costs borne by the insurance companies. This should also provide more stability in the insurance sector, which otherwise may be unable to resource payouts following major flood events. It may also form the last means of flood protection, but if it should this fail then the building or occupier could still be at risk. This form of flood risk measure may, however, reduce the perception of risk by occupiers, leading to issues such as a 'false sense of security'.

Building occupants typically prefer resistant or avoidant building design strategies, as they protect the interior of the property from damage. These are only effective, as discussed above, with relatively shallow flood depths or with high quality reinforced construction that can resist hydrostatic pressures. In urban situations, floodwater is likely to carry debris and contaminants, increasing the risk of damage, particularly to resistant buildings, but equally increasing the preference for resistant or avoidant construction.

Building design solutions, particularly flood resistance, require an adequate standard of workmanship to be effective.

3.9.6. Key considerations

It is essential to have a good understanding of the flood hazard (as discussed in Chapter 1) when choosing the most appropriate building design solution. It is also important to understand any relevant planning regulations or building codes which may prevent the implementation of a building design solution, (such as restriction on the height of the building, or choice of materials), or conflicts with other codes relating to construction in earthquake or hurricane prone areas.

The cost of incorporating building design solutions will depend on the complexity of the intrinsic construction, although it is often found that the payback for the additional investment will be recovered after a single flood event (Bowker et al 2007).

As a part of integrated flood risk management, building design relies to some extent on the accompanying implementation of non-structural measures such as land use planning and flood zoning; flood awareness campaigns; forecasting and early warning systems; evacuation planning; emergency planning and rescue; damage avoidance actions; temporary shelter (safe havens); business and government continuity planning; flood insurance; compensation; and tax relief.

3.9.7. Other sources of information and further reading

Asian Disaster Preparedness Center (ADPC). 2005. Handbook on Design and Construction of Housing for Flood-Prone Rural Areas of Bangladesh. Pathumthan, Thailand.

Bowker, P., Escarameta, M. and Tagg, A. 2007. Improving the flood performance of new buildings. Flood resilient construction. Defra. UK.

CEPRI. n.d. Construction in flood-prone areas. Vulnerability of building structures. CEPRI

CEPRI. n.d. Construction in flood-prone areas. Diagnosing and Reducing the Impact of Flood Hazards. CEPRI

FEMA. 2009. Building Science for Disaster-Resilient Communities: Flood Hazard Publications FEMA I-782. http://www.fema.gov/library.

3.10. Flood defenses

The threat of flooding has been present since people began to settle close to rivers and coasts in order to maintain trade and communication links. For centuries, therefore, it has been necessary to protect these areas from flooding, by building defenses that supplement natural features such as river banks.

Flood defenses are intended to reduce the risk to people and the developed and natural environment from flooding. They are constructed to protect against flood events of a particular magnitude, expressed as risk in any one year: for example, defenses in urban areas may be built to provide protection against flood events of a size which might occur, on average, once in one hundred years. It is important that flood defenses are considered as part of a strategic, integrated approach to flood risk management that considers the knock-on impact on the risk of flooding along the remainder of the river.

3.10.1. Inland flood defenses

There is no absolute definition of 'inland' but by implication it includes all river (or fluvial) defenses and excludes those defenses located on the coastline and in the sea. Tidal and estuary areas where rivers and the sea interact by their nature fall between inland and coastal defenses.

Flood defense seeks to reduce the risk of flooding and to safeguard life, protect property and sustain economic activity. Walls and embankments (levees or dykes), placed strategically around settlements or adjacent to water courses, can prevent ingress of water to inhabited areas. The construction of earth embankments is a long established method for confining river flows within the channel, as in Bangladesh where over 5,600 kilometers of earth embankments have been constructed (Haider n.d.).

The height of such structures is calculated to resist the majority of floods but total protection can never be guaranteed. Failure of these defenses can cause rapid flooding of often intensively used areas. The structure of flood walls and embankments has been described above in Section 3.3.3.

Maintenance work needs to be carried out on flood defense structures, but other work is also required to control rivers and bank-sides such as annual removal of channel vegetation and regular dredging.

Flood defenses can be very costly to design, construct and maintain and will, therefore, usually require significant investment by governments. Schemes will require careful design by experts, including structural and hydraulic engineers with a good understanding of the risks and nature of the floods anticipated. Schemes will also, normally, be required to be fully evaluated and appraised to ensure they are not only technically, but also environmentally and economically sound.

Hard-engineered defenses and levees require the construction of permanent structures, which can occupy land that is in short supply. Many such systems are also very expensive, although earth systems may often be multipurpose structures and may form the basis for other infrastructure or even residential or commercial development. In Japan, for example, super levees provide both flood defense and community development (APFM 2007).

3.10.2. Demountable and temporary flood defenses

Within an urban environment, where space is limited and access to river spaces, roads, infrastructure and buildings is essential, there may be a need for demountable and temporary measures. The advantage of such measures is that they can be installed just before or during a flood, but under normal circumstances the space and access is unchanged.

Demountable flood defenses are structures that have permanent and temporary elements. They normally have permanent foundations, with guides or sockets to install barriers when there is a risk of flooding. The barriers are then removed when there is no risk of further flooding, as in the Super Case Study on Cologne in this volume.

By contrast, a temporary flood defense is a system that can be installed during a flood event and then completely removed when no longer required. Sandbags are the most common form of temporary flood defense; however, they take time to fill and lay, and are difficult to handle. Even when properly installed, water may seep through sandbags, making them less effective than other temporary flood protection products, such as free-standing barriers designed specifically for the purpose. An example is illustrated in Photo 3.15.

Photo 3.15: temporary flood barrier deployed. Source: J Lamond

3.10.3. Property level defenses

Placing barriers across openings can be an effective defense against flooding if the structure is otherwise watertight, and both velocity and flood level are low. For regular urban flash flooding, the installation of such products can protect otherwise vulnerable buildings. Home-made boards and sandbags (such as those illustrated below in Photo 3.16) are often used but these are less effective than purpose-designed fittings. There is now a wide range of removable products available (including. flood skirts or guards, and air brick covers) that are designed to seal potential flood routes into a property, such as doors, windows, air bricks, sewers and drainage systems. These may be installed fairly quickly by property owners immediately before a flood (upon receipt of a flood warning, for example) and should be removed as early as possible after the flood water has receded. Products vary in their effectiveness and cost.

Photo 3.16: Homemade door guard. Source: J Lamond

Both demountable and temporary flood defenses are only functional when in a closed position and both require operational procedures for putting them in place.

3.10.4. Critical infrastructure

Critical infrastructure can be defined as the sites, facilities, systems and networks necessary for the functioning of a country and the delivery of essential services. The concepts of flood resilience and flood resistance are both important (as discussed in Section 3.9.1) here.

In the context of critical infrastructure, flood resilience involves designing or adapting an infrastructure asset so that, even if it is affected directly by flood water, it can still function or be quickly restored to normality. Flood resistance involves excluding water during flood events so there is no impact on normal function (McBain et al. 2010). Critical infrastructure should have protection to a standard that will withstand extreme events.

In the UK, the Pitt Review into the 2007 flooding, recommended protection from 1 in 200/0.5% chance of flooding in any one year as a minimum, and Balmforth et al. (2006) recommend a level of once in 1,000 years for highly critical facilities. As an example, in the UK the privately-owned electricity distributor Yorkshire Energy Distribution Ltd have assessed all their sub-stations and identified those critical to the network located in the floodplain. Protection of more than 24 substations involved installed flood walls with openings protected by floodgates (Flood Protection Association n.d.). Future protection from climate change, as discussed in Chapter 1, should also be considered.

3.10.5. How to select appropriate protection systems

The selection of appropriate flood protection schemes is an important part of any flood risk management strategy. Well-designed flood protection systems can help provide protection to entire communities, individual public buildings (such as hospitals and schools) and private residential property. Such systems can be used to safeguard property, homes and businesses and critical infrastructure as part of a coherent flood risk management strategy.

Poorly designed and selected systems can, however, result in even more damage due to what is known as the ‘levee effect’. This is where development proceeds behind a flood protection system in what is believed to be a safe area. If such systems are breached or overtopped because of improper design or inaccurate assessment of the depth of flood water anticipated, then the consequences can be much worse. It is important that a full understanding of the flood risk and the residual flood risk (i.e. that remaining beyond the capability of the flood protection system) is developed when designing such systems.

There are many different systems and solutions available and selection will depend on the specific circumstances of the property (or group of properties) being protected. Larger community-wide systems will require the design input of experts, including civil engineers and hydraulic engineers. The costs of such systems will need to include the manpower needed for deployment, as well as maintenance and storage facilities, where required.

Where systems are designed and selected appropriately, these can help protect people and property in the event of flooding and also provide some level of confidence in the intervening periods of a suitable level of protection, allowing for suitable investment and development to continue.

Method

1. Assess risk

2. Consider community preferences

3. Consider effectiveness and suitability of protection systems

4. Consider cost and manpower for deployment

1. Assess Risk

Protection of settlements already located in the floodplain and at risk from flooding as always starts with an assessment of the risk from flooding. Relevant features are the type, severity, frequency, depth, duration and speed of onset, as these all impact on the suitability of various flood protection options. A risk assessment appropriate to the level of protection considered may include detailed topographical survey, building assessment and hydrological modeling.

2. Consider community preferences

It is very common that multiple solutions are possible which may or may not meet with community approval and may be more or less difficult to implement. For example in a historic town centre the provision of a concrete wall will be likely to meet with opposition from local residents and wetlands may be poorly regarded in an area of high vector borne disease risk.

3. Consider effectiveness and suitability of protection systems

The suitability of various systems for classes of protection is shown in Figure 3.12 below.

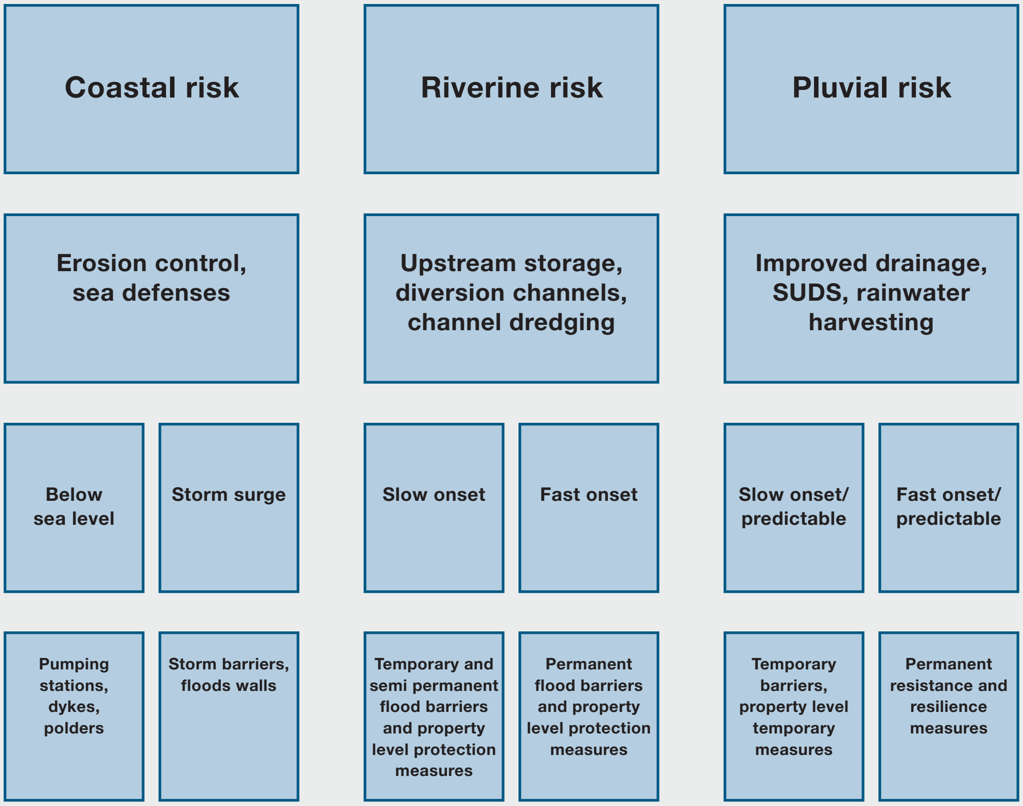

Figure 3.12 Suitable protection systems.

4. Consider cost and manpower for deployment

The variation between the costs of protection systems is vast. In developed countries, estimates for earth bunds are about half that for concrete or brick walls and one third that of typical proprietary demountable or temporary barriers. This is especially important for developing countries where the main costs of low technology solutions – i.e. labor – may be much lower than in developed nations rendering the cost discrepancies even greater. Using low-technology solutions and local labor and resources where possible can add to the sustainability of flood protection schemes, generates ownership and feelings of empowerment and provide employment for local people. However the limitations of such systems, particularly in urban environments may include increased land requirements (for earth bunds over concrete walls), lower protection levels (for sandbags over proprietary door guards) or lower durability (for earthworks).

3.11. Barrier and embankment systems for estuary and coastal flood protection

Defenses against estuary and coastal flooding from tides, storm surges and tsunamis form a key aspect of coastal area (or zone) management, and need to be considered within its context.

3.11.1. Coastal management

It is probably even truer for coastal protection than for other areas of flood management, that protection comes more from understanding the natural system than from intervening in it. Breakwaters and groynes are 'structural solutions' but their contribution to coastal protection is indirect not direct. Areas of coast that are most susceptible to change, so-called 'soft coasts', are influenced by coastal forcing (for example, by wave activity and tides) and by geology. Some areas of coast may have achieved relative equilibrium in response to these influences, whereas others may be undergoing significant change. Artificial intervention can easily disrupt any equilibrium, and factors like rising sea levels can potentially affect all coastal areas.

'Integrated coastal management' is a general term to describe an approach which aims to consider the combined effects of all activities taking place at the coast, and to seek sustainable outcomes. It considers the coastal environment as a whole, including coastal land, the foreshore and inshore waters. 'Shoreline management' refers more specifically to approaches to managing the actual coastline taking into account the risks of flooding and coastal erosion.

In cases where it is technically unfeasible, or unjustifiably expensive, to provide engineered solutions to coastal flooding, (due to severe erosion processes, for example) then there may be no option but to arrange a managed retreat. This is particularly the case in countries like Bangladesh where the river and coastal morphology processes are very dynamic. Such a decision can be hard to implement as, in effect, it admits human defeat in trying to engineer nature; it is often done by default, by taking no action.

In coastal parts of Bangladesh the rebuilding of the embankments after the 1991 Cyclone faced this issue. In some places a managed retreat was formalized by building new multi-purpose flood embankments that doubled as roads and linear resettlement locations for displaced people. Decisions had to be made as to the likely rate of future erosion and the number of years in which it was deemed economic to build a new flood embankment before it too was eroded away.

3.11.2. Coastal structures

Many coastal engineering structures are aimed at both providing flood protection and arresting coastal erosion. Groynes are shore protection structures typically of timber, rock or masonry, constructed perpendicular to the shoreline, to retain or increase beach material that is subject to long-shore transport. Breakwaters may be connected to the shore, detached, or constructed at ports or harbors. They reduce the impact of wave action through their mass and shape and thereby exert an influence on coastal erosion and deposition. A sea wall is fundamentally designed to dissipate wave energy. Traditionally they have been the dominant form of coastal defense to the upper shore, but they have a significant impact on the natural processes and are therefore now seen as a solution of last resort.

Where sea walls are still needed, modern designs aim to avoid problems that result from any direct reflection of wave energy by including features such as a sloping face, a curved top, and rock armoring (rap-rap) at the toe. Embankments in coastal areas with the primary function of flood defense, but not wave energy dissipation, can be classed with embankments, levees and dykes and are covered in Section 3.3 and 3.10. Case study 3.11 gives an example of dykes used as a flood protection measure in a coastal zone.

Photo 3.17 shows what can happen if unplanned informal development occurs. It is obviously better to design any embankment with the participation of local people with the aim of maximizing their use.

Photo 3.17: Multipurpose embankment with erosion. Source: Alan Bird

Protection against tsunamis has been attempted using substantial sea wall structures, but significant re-evaluation of the approach taken to design is taking place following the March 2011 tsunami in Japan.

Case Study 3.11: Camanava anti-flood project 2003-2011, The Philippines

The cities of Caloocan, Malabon, Navotas, and Valenzuela, collectively known as the Camanava cities, in the Philippines, sit on top of centuries of prehistoric alluvial deposits built up by the waters of the Pasig River and on land reclaimed from Manila Bay. The Pasig River bisects the city of Manila and features considerable land reclamation along the waterfronts. Some of the natural variations in topography have been evened out due to the urbanization and development of the city.

Flood risk in the area is high and increasing. To begin with, an estimated 20 typhoons impact upon the Philippines every year from the Pacific. In addition the coastal plains around Manila Bay are so low and flat that the one meter elevation extends 10-20 kilometers inland and normal spring tides only 1.25 meters high extend many kilometers inland.

Even small rises in relative sea level will, therefore, translate into large inland encroachments. It is estimated that the area is facing a sea level rise of one to three millimeters per year due to global warming. There are also issues of land subsidence, caused by excessive groundwater extraction, which is lowering the land surface by several centimeters to more than a decimeter per year.

Camanava cities were severely hit by Typhoon Ketsana/Ondoy which was the most severe typhoon in the 2009 Pacific typhoon season. A week after Ketsana, Typhoon Parma also hit the northern Philippines, worsening the situation. Together, the storms killed over 1,000 people and caused damage and losses amounting up to US$ 4.4 billion (2.7 percent of the country's GDP).

The scope of the flood protection work planned comprises:

- A 8.6 kilometer long, 2 meter high earth polder dike to enclose and protect the Malabon and Navotas areas that are already at or below mean sea level
- Five pumping stations with ancillary floodgates
- Six independent floodgates
- One navigation gate
- One rectangular box culvert
- Some river improvement works.

The designers plan to pump floodwaters out of the polder during low tides. However, it is already recognized that in extreme conditions sustained southerly winds can raise sea level significantly for days, which will render the structure ineffective. Even discounting storm waves, surges driven by typhoon winds can reach sea level to overtop this height. Changes to the original plans have been blamed for recent flooding, however delays have been caused to the project by funding difficulties and the need to resettle residents to facilitate construction may also have contributed.

This example illustrates the fact that even with significant investment of $100 million dollars or more, flood risk can be reduced but not completely eliminated. Further measures will still be needed to address this residual risk.

Sources: Frialde 2010; Antonio 2011; Rodolfo and Siringan 2006; Antonio 2009; DPWH 2009; Echeminada 2010

3.11.3. Flood barriers

A flood barrier provides temporary protection from particularly high tides, or storm surges, at a point where water flow or shipping would otherwise be allowed to pass freely. It is usually just one component in an artificial or natural flood protection scheme. Flood barriers are major and often innovative civil engineering structures. Well-known examples include the Delta Works in the Netherlands and the Thames Barrier in London (Photo 3.18).

Photo 3.18: The Thames barrier, Source: Nick Dennison

Daily high tides and those on a lunar 28 day cycle not only threaten coastal flooding but also affect the ability of rivers to discharge flood waters resulting from rainfall inland. The design and operation of flood barriers must take into account the possible coincidence of high tides and upstream flooding. Storage in coastal urban areas may be needed to control the timing of discharges in relation to tides, rather than to achieve flood peak attenuation.

An additional potential benefit of barriers is the opportunity to generate significant quantities of sustainable electric power through a flood barrier. This is starting to look more feasible than previously, now that existing sources of non-renewable power are rising in cost.

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Community activists in the flooded Chatuchak District set up a large barrier of sandbags along with pumps in an attempt to protect the Moo Baan Kredkaew housing development from being inundated, Bangkok, Thailand (2011). Source: Gideon Mendel

Chapter 4

Integrated Flood Risk Management: Non-Structural Measures

Chapter 4. Integrated Flood Risk Management: Non-Structural Measures

4.1. Introduction 288

4.2. Flood awareness campaigns 290

4.2.1. Introduction 290

4.2.2. Awareness campaign design 291

4.2.3. Communications channels 292

4.2.4. Visual clues in the landscape 295

4.2.5. Monitoring awareness 295

4.2.6. Considerations for a successful flood risk awareness campaign 296

4.3. Health planning and awareness campaigns 298

4.3.1. Description 298

4.3.2. Key Components of Health Awareness Campaigns 300

4.3.3. When and where to use Health Awareness Campaigns 303

4.3.4. Benefits 304

4.3.5. Risks and weaknesses 304

4.3.6. Essentials and key considerations 305

4.3.7. Further reading 306

4.3.8. How to conduct a health awareness campaign 307

4.4. Land use planning and flood zoning 311

4.4.1. The inter-relation between land use planning and flood risk management 311

4.4.2. Integrating land use planning and flood risk management 317

4.4.3. How to produce urban land use plans that incorporate flood risk management 329

4.5. Flood insurance, risk financing, compensation and tax relief 339

4.5.1. Introduction 339

4.5.2. Level of insurance coverage worldwide 340

4.5.3. Requirements for market-based insurability 341

4.5.4. The dangers of adverse selection and moral hazard 342

4.5.5. Micro-insurance 343

4.5.6. Risk financing mechanisms 344

4.5.7. Compensation and tax relief schemes 347

4.5.8. Essential considerations to support the introduction of effective flood insurance 348

4.6. Solid and liquid waste management 350

4.6.1. Introduction 350

4.6.2. Solid waste 351

4.6.3. Management of solid waste 353

4.6.4. Pre-emptive actions to minimize the effects of flooding on waste collection 362

4.6.5. The management of liquid waste and drainage 363

4.6.6. Pre-emptive actions to minimize the effects of flooding on liquid waste systems 366

4.6.7. Flood Waste 367

4.6.8. Solid waste management in informal settlements 367

4.6.9. Further reading 370

4.7.	Emergency planning, rescue, damage avoidance actions and temporary shelter	371
4.7.1.	Emergency planning	371
4.7.2.	Damage Avoidance	374
4.7.3.	Flood emergency preparedness activities	374
4.7.4.	Evacuation and Rescue	377
4.8.	Business and government continuity planning (BGCP)	381
4.8.1.	Relevance to the private sector or the public sector	382
4.8.2.	Minimizing flood damage risks	385
4.8.3.	Further reading	387
4.9.	Early warning systems	387
4.9.1.	Essentials for an effective EWS	389
4.9.2.	Needs of responders	391
4.9.3.	Organizational aspects of flood warning dissemination	392
4.9.4.	Appropriate message content	393
4.9.5.	Further reading	399
4.10.	Evacuation planning	400
4.10.1.	Organizational aspects of evacuation planning	400
4.10.2.	Provision of flood shelters and refuges	401
4.10.3.	Location and size of shelters and refuges	402
4.10.4.	Water supply and sanitation facilities for flood shelters and refuges	403

4.10.5.	Stockpiles of required materials	404
4.10.6.	Communications between shelters and refuges	404
4.10.7.	Further Reading	406

4.11. Flood recovery and reconstruction 407

4.11.1.	Access and solid waste clearance	407
4.11.2.	Mitigating damage	411
4.11.3.	Assessment and prioritization of needs	413
4.11.4.	Post-disaster reconstruction and resettlement	415
4.11.5.	How to restore flood damaged buildings	421
4.11.6.	Further guidance	426

4.12. References 427

4.1. Introduction

Chapter Summary

This chapter describes non-structural measures used to manage the risk of flooding for cities and towns and their inhabitants. These measures do not require extensive investment in hard-engineered infrastructures, as typically do structural measures, but rely instead on a good understanding of flood hazard and adequate forecasting systems. There are four main categories, as follows:

- Increased preparedness
- Flood avoidance
- Emergency planning and management
- Speeding up recovery and using recovery to increase resilience.

Many of the measures, such as early warning systems, will form part of any flood risk management scheme. They can be seen as a first step in protecting people in the absence of more expensive structural measures, but they will also be needed to manage residual risk where such schemes have been constructed.

The key messages from this Chapter are:

- Engagement of the community at risk and encouragement of citizen preparedness is critical to the success of non-structural flood risk management. Communication is, therefore, a key element.
- Land use planning and regulation of new development is a central measure for reducing future flood risk, particularly in rapidly urbanizing emerging economies.
- Many non-structural measures have multiple benefits, over and above their flood management role.

Chapter 3 described a number of structural measures for reducing the risk of urban flooding, within an integrated strategic approach. However it was noted that structural measures can never entirely eliminate flood risk – and may not always be an appropriate response to such risk. Problems with structural solutions include their high cost, the fact that reducing flood risk in one location may increase it in another, the possible complacency it produces in populations and the potentially increased impact if such structures fail or are overtopped.

These considerations, together with the need to address residual flood risk, have led to the development of non-structural solutions to flooding. Often described as ‘soft’ solutions, non-structural approaches are defined here as measures which are designed to keep people away from flooding and to reduce the impact of flooding on those people and assets still exposed to risk. They generally require little in the way of construction of physical infrastructure, and may therefore be less costly and quicker to implement than structural measures. In some circumstances, non-structural solutions can prove to be the most effective method of avoiding flooding and reducing its consequences.

This chapter describes non-structural measures in terms of four principal purposes: preparing for flooding, avoiding flooding, planning for and managing flood emergencies, and recovering from flooding. Section 4.2 considers the creation of better awareness of flooding through the medium of campaigns, which is vital for minimizing the impacts of urban floods. Flooding has specific and harmful impacts on public health: accordingly Section 4.3 details the ways by which health awareness campaigns can contribute to enhanced preparedness. Section 4.4 deals with the discipline of land use planning, which is a key to the avoidance of flood risk and to the reduction of impacts. The incorporation of flood zoning into land use planning procedures is highlighted. Section 4.5 covers flood insurance, risk financing, compensation and tax relief which all serve to reduce risk and damage through risk assessment – and to offset the financial risks of flooding. Section 4.6 covers the crucial practice of urban waste management. Improvements to the collection and disposal of solid and liquid waste can result in significant gains for mitigating flood risk and reducing impacts.

The chapter then discusses measures which result in the limitation of flood damage and the after effects of flooding. Section 4.7 details emergency planning, rescue and temporary shelter measures; Section 4.8 continuity planning for business and governments; Section 4.9 early warning systems; and Section 4.10 evacuation planning. Finally, Section 4.11 provides an overview of flood recovery and reconstruction methods and processes.

4.2. Flood awareness campaigns

4.2.1. Introduction

Flood risk awareness is the cornerstone of non-structural flood risk management. All actions to minimize the impact of flooding hinge upon stakeholders becoming aware these are both necessary and desirable. Ignorance of flood risk encourages occupation of the floodplain, in the first instance, and can allow appropriate building design practices to fall into disuse. In the event of a flood, the lack of awareness of risk can result in a failure to heed warnings to evacuate, thereby endangering lives. Many studies detail the low level of flood awareness exhibited by occupants of floodplains and other flood-prone areas (Waterstone 1978; Siegrist and Gutscher 2006; Ibrekk et al. 2005; Burby 2001; Lave and Lave 1991). Awareness may be naturally high in areas where flooding occurs regularly, but is often deficient in locations subject to low frequency but high impact events.

In an ideal world, heightened awareness of flood risk would lead to mitigation activities and to preparedness, which in turn reduce the impact of flood events as shown in Figure 4.1. In Afghanistan, for example, a drama-based disaster awareness campaign was conducted via the medium of national radio. This was found to have been very successful in raising awareness of flood risk and in maintaining natural forest flood barriers (United Nations 2007). The 'secret of success' in such campaigns is to trigger local debates around issues that are relevant to the communities at risk.

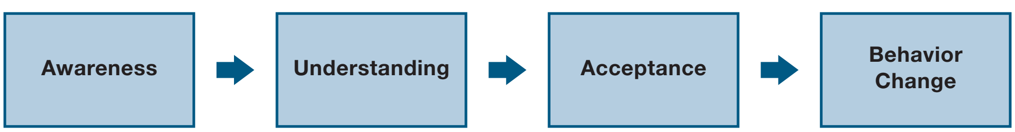

Figure 4.1: Communications continuum, Source: University Corporation for Atmospheric Research 2010

Raising awareness is only one part of a wider strategy of flood risk interventions. It should be accompanied by information on measures and steps which will mitigate the flood risk. This is illustrated in a Vietnamese scheme, which was targeted at a range of interest groups (including builders, teachers and school children); this proved successful in encouraging home owners to invest in flood- and typhoon-resistant buildings (United Nations 2007). Studies have shown, however, that to raise awareness of risk which cannot be reduced, is to engender a sense of helplessness which may lead to panic or risk denial (Waterstone 1978).

A focus on the practical actions to be taken in the event of a flood was, therefore, central to a campaign conducted in Algeria. The aim was to prevent a repetition of the fatalities that had occurred in the 2001 floods, when 700 people lost their lives. As one in three communes nationwide are at risk of total or partial flooding, the Algerian Civil Protection Agency (DGPC) needed to convey simple messages about things the public need to do. This involved open meetings at schools and community centers, followed by information disseminated via television, radio, text messages, and vehicle-mounted loudspeakers, all of which reach people in a very direct manner (ICDO 2009).

4.2.2. Awareness campaign design

Different interest groups need to be made aware of the risks they face and the steps that they can take to reduce these risks. The range of interest groups involved includes governments (at different levels), local agencies, businesses and individuals. Many people will fall into more than one of these groups, so the messages need to be consistent across interest groups and yet be targeted to the knowledge requirements of each group.

As a guide, the basic principles are that:

- Implementation should be sensitive to local cultures, conditions and perspectives.
- All sectors of society should be targeted, including both decision makers and members of the public, including children.
- Messages should be targeted at the appropriate level for each interest group.
- Campaigns should be sustained over time, with regular monitoring of their success.

As an example, an awareness raising campaign developed by the Environment Agency (the institution responsible for such work in England and Wales) which was first launched after severe flooding in 1998, had the following communications objectives:

- Keep flooding in the national consciousness
- Ensure people understand the impact of flooding
- Make flooding relevant to everyone who is at risk

- Break complacency and encourage action
- Demonstrate that the Environment Agency is a proactive partner in flooding for those at risk.

These objectives were achieved by using both a ‘top down’ and a ‘bottom up’ approach: national awareness campaigns were backed up by local flood fairs and activities designed to reach the population most at risk.

By contrast, a flood awareness campaign in Cambodia was more rooted in the community from the outset (MRC and ADPC 2007). Local stakeholders were involved in adapting materials for local conditions, and used stage plays and folk songs to disseminate information. Specific lessons learned from the project included:

- Increased capacity identified by local stakeholders
- Use of existing social and cultural practices yields better results
- Existing materials can be used – they just need adapting
- Creativity is a key in making the message heard
- Using local stakeholders to build capacity in itself generates awareness
- Focusing on the most vulnerable means that these sectors will be included.

4.2.3. Communications channels

The suitability of different communication channels will be dependent on the target audience and cultural considerations. It is important for communicators to realize that messages regarding flood risk are competing in an environment of ‘information bombardment’; this means that single messages are unlikely to make an impact. The literacy and language skills of the intended audience are also critical factors in campaign design. Examples of communication media include:

- Posters
- Brochure and leaflet drops
- Newspaper and magazine articles
- Home visits
- Television and radio (including ‘soap opera’ storylines).

- Art and photography exhibitions
- School art competitions and events
- Signage of past flood levels using flood poles
- Examples of appropriate building design
- Flood wardens
- Demonstrations
- Training
- Disaster day campaigns
- Adverts
- Merchandising
- Engagement in flood risk planning
- Songs and drama including street theatre
- Promotion by celebrities
- Mock exercises and preparedness activities
- Flood 'fairs' (where, for example, property-level resilience measures can be demonstrated by suppliers).

Case Study 4.1: Raising awareness of disaster risk through radio drama in Afghanistan

Afghanistan is prone to earthquakes and drought, as well as floods. Partly because of its mountainous geography, the country has some of the most isolated villages in the world. As around 80 percent of Afghans have radio sets in their homes, the approach adopted was to integrate disaster risk reduction (DRR) messages into a BBC World Service's educational radio program called 'New Home, New Life'.

It was anticipated that, once made aware of DRR, communities along with formal institutions would be able to actively participate in the development of local disaster management plans. The overall goal of this initiative was to support the development of disaster-resilient communities. To make the program as accessible and acceptable as possible to the listeners, comprehensive research on the context of the issues faced by the communities was first carried out.

To ensure relevance and effectiveness, the design team had to build a clear understanding of dialects, accents and people’s motivations. The involvement of external partners with relevant experience such as the charitable organization Tearfund also supported the program in identifying key messages.

The initiative is supplemented by other interventions which go into more detail on some of the issues raised in the radio dramas. This includes a quarterly publication, which repeats the messages in cartoon format and is circulated by the partners to the local communities. In addition, the BBC World Service Trust produces children’s publications to disseminate key messages, which can be used in formal and informal learning methods.

The program has been found to be a cost-effective and efficient way to reach the large section of the population who have radio sets in their homes, given that direct engagement with isolated communities is otherwise extremely difficult. Background research provided an accurate understanding of the real needs of communities and helped to identify relevant messages. The implementing agencies suggested that the project could be easily replicated, through state-funded radio programs, as part of DRR initiatives at community level.

Sources: UNISDR 2007; Tearfund n.d.

Care should be taken to select media which will not only reach the sectors of the population most at risk, but also those best able to target ‘hard to reach’ audiences. This may be due to the nature of the audience or their locations; an example is the targeting of women-led households in Cambodia (MRC and ADPC 2007).

In Senegal the methods used to communicate included plays, exhibitions, media broadcasts, teatime ‘chats’, interviews, photo exhibitions and open air conferences (Diagne 2007; IFRC 2010).

It is also a matter for debate whether the awareness of flood risk should be part of a general disaster awareness program, or should stand alone. In coastal areas there is a need to include earthquake risk with seismic induced tsunami coastal flooding. In communities at risk from multiple hazards, or cascading risks, a general ’hazard preparedness’ approach may be appropriate. A balance has to be struck between the reduced cost on the one hand and dilution of focus on the other.

4.2.4. Visual clues in the landscape

Building awareness into the fabric of the community can be a way to alert both local and transient populations to the dangers they may face. In coastal resort areas in particular, the presence of large numbers of visitors may put those unfamiliar with the area at risk: this was the case in the December 2004 Indian Ocean Tsunami. Visual clues can include flood markers on buildings, bridges, poles or marked boundary lines. Visual clues to risk can be incorporated in awareness campaigns, but these need to be backed up by national or international acceptance of the meanings of the clues and symbols used.

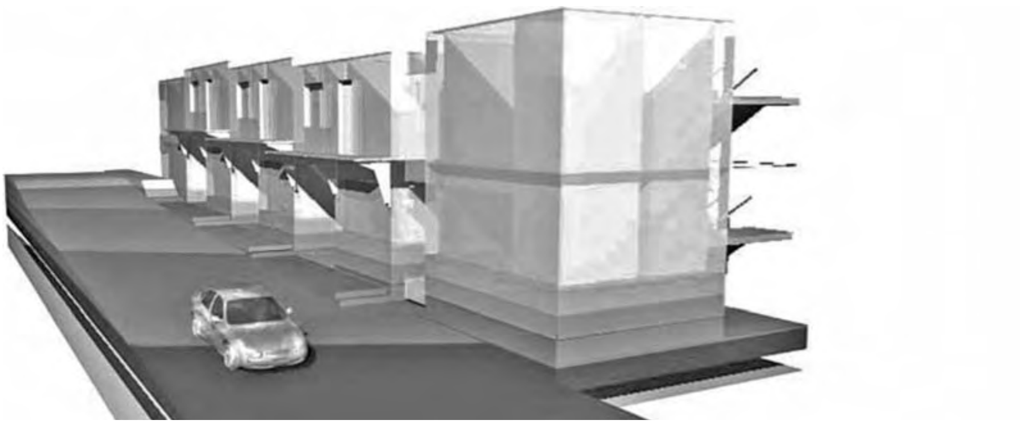

Figure 4.2: Intuitive landscapes highlight flood hazard areas within a development. Source: Baca Architects

4.2.5. Monitoring awareness

The awareness of flood risk is likely to be heightened after an event or a flood awareness campaign. However, some communities can soon forget about flooding, or the effects of it on those who have survived a serious event. Measuring outcomes of flood awareness raising activities is, therefore, important, as the benefits will not be realized until a flood event occurs. It is also important to regularly monitor the level of flood awareness, so that new or heightened campaigns can be introduced as necessary. The impact of a campaign will inevitably diminish over time; new materials and channels may need to be introduced to get the messages across. Surveys of awareness not only serve the purpose of monitoring but can also be used to heighten awareness again. Occasionally, a flood warning and evacuation is activated but the ensuing flood is not as serious as predicted. These situations may undermine the credibility of awareness campaigns.

The immediate success of a targeted campaign can be measured against its objectives – did it reach the right audience and did they get the message? This can be expressed qualitatively (in that the audience now understands risk more fully) or quantitatively (in that individuals took specified actions, such as signing up for a warning service, or putting together a flood pack) (Emergency Management Australia 2000). For longer-term awareness programs, a longitudinal survey is appropriate to ensure that the level of awareness and activity is maintained. In England, for example, the Environment Agency regularly conducts a general survey on environmental issues which includes questions on the level of awareness of flood risk, as well as a checks on whether the population knows what to do, and who to ask, about flood mitigation. Drills and exercises are another useful way to monitor and maintain awareness within a community.

4.2.6. Considerations for a successful flood risk awareness campaign

For the success of any risk assessment program it is essential to reach every corner of the society and the people who are at risk. An awareness campaign is an instrument which helps in reaching the groups who are not easily reachable. It brings a total awareness in the society and helps in building risk resistance among community.

City managers are responsible for understanding the needs of every part of the urban society and making people aware of both the potential disasters and their associated risks. Such awareness can be made achieved by promoting awareness campaigns. Generally, the focus of such a campaign differs from one area to another, based on the needs of the local people. It is important for any awareness campaign to try and engage local communities so that maximum benefit can be obtained for the people at risk. The key is to prepare the people for future flooding and reduce the level of vulnerability as seen in Table 4. 1.

Table 4.1: Actions for flood risk awareness

Actions	Considerations/operations	Outputs
Defining target audience (s)	Public, professionals, hard to reach groups	Identified group of audiences

Audience need assessment What do they already know?	What do they need to know? Who do they trust? Any specific communications difficulty, language, formats?	Output brings together the knowledge and information about what exists and what is to be done to further improve awareness
Choose the message	A general risk awareness or specific actionable knowledge? The message will depend on the audience and objectives of the campaign.	Messages taking into account social, economic political and cultural factors are more effective
Set measurable objectives and specify what indicators to use	Examples are: Increased percentage awareness of risk Increased registration for warnings At-risk households having an emergency plan Businesses having a flood evacuation drill	Specific objectives are necessary for future operations, which will be carried out based on the results obtained
Determine communications channels	Use more than one channel, e.g. posters, brochure and leaflet drops, newspaper and magazine articles, home visits, television and radio (including, soap opera storylines), art and photography exhibitions school art competitions and events, signage of past flood levels using flood poles, examples of appropriate building design, flood wardens, demonstrations, training, disaster day campaigns, adverts, merchandising, engagement in flood risk planning, songs and drama including street theatre, promotion by celebrities, mock exercises and preparedness activities and flood fairs.,	Different communication channels will help in reaching a higher number of people and have a greater overall effect
Enlist support	Engage the local community and other agencies or voluntary organizations It is particularly important to enlist the support of the trusted advisers to communities	Inclusion of local community helps in engagement of the local people and giving proper attention to their specific needs

Disseminate	Implement the plan, perhaps several times, or on a continuous basis Care should be taken to actualize the aims which were intended at the planning stage.	Proper implementation of the plan as framed is important for effective results
Monitor awareness	Check against objectives	Continuous monitoring by the local community, and occasionally by higher authorities, can keep the system going and bring in more awareness among people.

4.3. Health planning and awareness campaigns

4.3.1. Description

An urban flood event requires immediate measures to ensure that citizens have safe drinking water, including appropriate excreta disposal, disease vector control and waste management. However, during and after a flood event is not necessarily the best time to communicate health messages to individuals and organizations, as they may be dispersed and not have access to the necessary resources. Health Awareness Campaigns are vital 'soft' interventions alongside hardware provision (waste water treatment, for example); together they can help preserve public health by increasing preparedness. Health awareness and hygiene promotion campaigns must not be carried out independently from water supply and sanitation, and vice versa.

Floods can make it difficult to maintain dignity and hygiene, and lead to an increase in the risk of disease in the following ways:

1. Widespread contamination by fecal material due to destruction, breakage or damage to sewage systems and latrines, and subsequent open defecation
2. Contamination of drinking water
3. Thick layers of silt, debris and other materials
4. Loss or lack of key hygiene items

5. Standing pools of contaminated water or sewage
6. Rotting corpses (human and animal) can lead to excessive fly breeding or contamination of water sources from insect feces
7. Increase in vector breeding
8. An adverse psychological impact due to loss, and a sense of despair.

An effective health awareness campaign will provide clear timely advice on how best to protect individual and public health during a flood and will facilitate a two–way dialogue such that feedback from the affected persons directly informs priorities and decision making.

Pre-flood campaigns are vital for risk mitigation and preparedness. Campaigns during, or post-flooding, will reinforce messages and mobilize communities into action to preserve public health.

Box 4.1: Public health priorities in the event of a flood

- Provide a minimum amount of water for drinking, cooking and washing
- Provide facilities for people to dispose of excreta safely, in places which young children and babies cannot access
- Ensure people have key information to prevent water and sanitation related diseases: focus on the diseases that pose the most serious threat, include the provision and use of oral rehydration therapy (ORT).
- Protect water supplies from contamination
- Publicize emergency contact details and sources of advice and information
- Ensure people have enough water containers to collect and store water cleanly
- Ensure that people have soap or alternatives for hand washing
- Ensure that public spaces such as markets have adequate water and sanitation.

4.3.2. Key Components of Health Awareness Campaigns

Urban residents may have received little or no previous hygiene education or health awareness training and are likely to be ill-prepared to respond to a flood. When this condition is combined with weak local or municipal government and staff who are themselves ill-prepared, a flood event can result in a complete breakdown of basic public services (water, sanitation and solid waste management) alongside a significant increase in the risk of accidents and disease. As a consequence, even a relatively minor flood can result in a dangerous increase in morbidity and mortality.

It is important to plan health awareness campaigns with an understanding of the type of flooding involved, its anticipated effects, probable duration and the likely impact on the urban population. This planning also has to take into account the current status of public understanding and awareness of health issues, as no two urban situations will be the same. Both the messages and modes of communication should be adapted for the particular situation and for different audiences. The messages should take account of beliefs and attitudes that regarding health, disease and hygiene and should appeal to the interests and priorities of different groups.

The health awareness interventions should be designed with participation and collaboration of all key stakeholders, to ensure that effective messages are developed, and that both clarity and consistency apply to the communication strategy. The relevant government ministries (such as environmental health, social welfare, health, education) should be involved, as well as influential leaders, opinion formers and agencies working in the WASH (the now commonly used acronym used for water supply, sanitation and hygiene promotion) or health cluster. Different sections of the community should participate, including the more vulnerable groups such as low-income groups, women, children, aged and disabled people.

Health awareness is required by three distinct groups of people:

- Municipal staff, volunteers and health professionals
- The general public and in particular vulnerable groups
- Media workers.

4.3.2.1. Municipal Staff, Volunteers and Health Professionals

In flood-prone urban areas, pre-flood campaigns should be undertaken to prepare staff to deal with the changed public health conditions which are likely to ensue post-flood. Municipal staff and volunteers should receive training on how to carry out an initial rapid assessments (an example of which is shown in Box 4.2); prioritize actions; quickly install appropriate technologies to contain excreta (particularly in areas of high population density, such as flood shelters); and establish effective coordination within the WASH sector.

Box 4.2: Essential Questions for the Initial Rapid Assessment of Water Supply

- What type of water resources do people in the different parts of the city rely on and which are the main affected zones?
- Is water mostly supplied from modern water treatment works through pipeline distributions, or through other systems? (e.g., private boreholes, open wells or similar sources)
- Which areas of the city are most affected by the disruption to water services?
- Which public or private services are still working or could be rapidly rehabilitated?
- How to identify strategic locations (such as health centers, shelters) or other areas requiring rapid assistance with supplies of bottled water, water tankering or water treatment kits.

Source: adapted from: Global WASH Cluster 2009(a).

The training should also include post-flood responsibilities to disseminate appropriate priority messages to the public and special vulnerable groups to preserve health and hygiene. One important outcome of a pre-flood health campaign is that it should identify those valuable partners – government, non-government and volunteer – who, with training, will enhance available manpower for the post-flood relief activities and awareness campaigns to preserve public health.

Health professionals should be trained and motivated to carry out a flood risk assessment of their own facilities such as health posts and hospitals so local flood mitigation measures are undertaken to reduce the risk of these facilities becoming dysfunctional during a flood. With pre-flood health awareness training, health professionals will be better able to maintain basic curative health services and respond effectively to the new demands created by the floods. They should know what to expect and have the necessary knowledge, awareness and capacity to provide specific advice and support to protect public health during a flood.

4.3.2.2. Public

Pre-flood Health Awareness Campaigns for the public need to provide at least a minimum level of awareness to reduce the uncertainty and risk in the event of a flood. They should target the most vulnerable, for example by working through women's groups, especially in the poorer communities and reaching children through campaigns in schools. Developing links with concerned agencies and training volunteers should ensure resources are available for the health awareness campaigns and other relief activities that will be needed.

4.3.2.3. Media

As important stakeholders in health awareness campaigns in the event of a flood, it is valuable to work in advance with the media – newspapers, radio, TV, and the Internet – to prepare materials for subsequent campaigns. There are numerous tools available for rapid assessment and communication planning for health awareness campaigns in an emergency; these may include guides for developing print materials, radio spots and other interventions (examples are in UNICEF 2006; Global WASH Cluster 2009(b),(c) and (d); Oxfam 2001).

4.3.2.4. Post-Flood Health Awareness Campaigns

The staff resources required for campaigns include public health promoters for water, sanitation and vector control; children's health promoters; and both water point and latrine attendants. Examples of job descriptions and training modules are available (Oxfam 2001), along with other useful information such as notes for teaching about oral rehydration and the materials required for family hygiene kits or clean up campaigns (examples in UNICEF 2006).

When using volunteers or outreach workers for hygiene promotion, additional monetary incentives should not be paid. If a larger number of volunteers are trained their workload will be less and the system stands a greater chance of being sustainable. Incentives in kind (soap or oral rehydration salts kits) however, may be used to motivate volunteers initially. In the event of a serious outbreak of disease, it may be appropriate to include payment for a finite period of time for additional work that may be needed to halt the spread of the disease (Oxfam 2001).

During a flood it will be important to focus efforts. Very early in any flood event, a rapid needs assessment will enable this focusing to be appropriate to the specific needs; for example, it may be identified that effective excreta disposal in flood shelters and improvements in hand washing are likely to yield the greatest benefits. Raising awareness about ORT may also be extremely effective to mitigate an outbreak of diarrheal disease (Oxfam 2001).

Post-flood, the media can play a major role in public outreach, with carefully selected messages that are consistent and targeted. Messages should be kept to a minimum, as experience shows that too many messages dilute available resources, confuse the community and may reduce the likelihood of achieving changes in practice (Global WASH Cluster 2009a). Hand washing with soap is likely to be a priority, as hygiene behaviors can achieve the greatest health impact. The safe disposal of excreta and the use of clean water for drinking will also be essential. The actual message will need to be defined according to each situation.

The public – men, women and children – can take action themselves to reduce public health risks by, for example, appropriate point of use (POU) treatment of water, and practicing effective hand washing at key times. All sections of the affected population should make the best use of, and realize the need to maintain in good order, the water and sanitation services provided as explained by IASC (2008). There should be distribution of appropriate hygiene items including, for example, household sanitary kits and sanitary materials for women.

4.3.3. When and where to use Health Awareness Campaigns

Any flood-prone city or town would be well advised to invest in a health awareness campaign, both pre-flood and post-flood, irrespective of what type of flood is anticipated. An assessment in advance of the likely public health risks during a flood in that location (including, for example, impacts on water treatment works, or probable disease vectors where appropriate) will guide the design and prioritization of any campaign to make it more cost effective.

4.3.4. Benefits

An effective public health campaign will reduce death and disease caused by flooding. Specifically, pre-flood health awareness campaigns will:

- Develop knowledge, understanding and build the capacity of municipal staff and volunteers to work effectively and efficiently post-flood, to preserve public health and reduce mortality and morbidity.
- Provide guidelines on key elements of an initial rapid assessment of public health risks and build capacity to institute an appropriate, rapid and coordinated WASH response.
- Protect health service capacity from the impacts of flooding.
- Post-flood campaigns will help preserve personal and public health by giving the public immediately relevant knowledge and awareness to complement the hardware relief interventions.

The health and hygiene information is also applicable in non-flood situations and, as such, will have a knock-on effect of improving public health in general. Health awareness campaigns to deal with urban floods sit very comfortably alongside other, more traditional, health campaigns such as mother and child health, anti-malaria and HIV/AIDs awareness. The same professional staff and volunteers can and should be involved.

4.3.5. Risks and weaknesses

There are few risks associated with promoting health awareness in urban areas prone to flooding. The challenge is to ensure that this is carried out effectively, as far in advance of floods as possible and in close coordination with the structural mitigation and relief interventions.

Cities may face particular challenges, such as providing sanitary excreta disposal options for low income settlements, or maintaining waste disposal services during the flood. Given the relative poverty of many affected municipal authorities and local governments, there may also be issues around obtaining resources to invest in public health flood preparedness, when structural interventions could appear more politically advantageous.

4.3.6. Essentials and key considerations

The affected population should be made aware of their rights and entitlements to relief and recovery operations; this is particularly relevant to the rights to protection for specific groups of persons (such as internally displaced persons; women, children and adolescents; the aged; people living with HIV/AIDs; persons with disabilities; single parent households; ethnic and religious minority groups; and indigenous peoples). IASC (2008) discusses these issues in more detail. Case Study 4.2 demonstrates an instance of how children can be involved.

Public health campaigns can only provide knowledge and understanding, which may do little practical good without tangible interventions such as provision of clean drinking water, chlorine tablets or safe waste disposal sites. However, as stressed in this section, without pre- and post-flood 'soft' interventions (specifically aimed at promoting awareness of how to preserve health and hygiene during floods), the 'hard' interventions are unlikely to be effectively mobilized or, even if mobilized, will by themselves be of minimal use.

Catastrophic outbreaks of diseases are not inevitable after a disaster: they do not spontaneously occur. However, the keys to preventing disease are to be prepared, to educate and motivate both the appropriate officials and the public, and to promote the meeting of basic sanitary needs.

Case Study 4.2: Flood risk management and children's participation in Mozambique

During disasters, children are usually among the most vulnerable groups within the affected population, while at the same time they tend to be the least informed. In the Morrumbala and Mopeia settlements in Zambezia Province, the second-most populous of Mozambique's ten provinces, community leaders, teachers, and local education authorities, along with the government agencies responsible for disaster response, were supported by Save the Children, UNICEF and ECHO to carry out a DRR project that actively involved the children living in flood-prone areas.

The project aimed to increase the understanding of flood risk in children between the age of 12 and 18. A number of communication methods, including an educational game called 'The River Game', brochures, a school magazine, radio slots and theatre were used to inform children about disasters. They were also encouraged to share their concerns and understanding about disaster risk with their peers, parents and other community members.

During the 2008 floods, communities along the Zambezi River showed better preparedness and response than in previous years, partly because of the project. In particular, it was observed that:

- When flood warning was declared families were moved to higher ground;
- During the evacuation people took with them key documents such as, ID cards, social welfare documents and birth certificates;
- Communities showed better health and hygiene practices in the resettlement camps;
- Communities developed systems to ensure the protection of children from exploitation and abuse; and,
- Children avoided dangerous routes on their commute.

The project influenced behavior change at the individual and community level which lead to the adoption of more appropriate disaster responses to flood risk. Children have been empowered to engage in disaster preparedness and response in their communities, while multi-stakeholder partnerships at the local, provincial and national levels promoted replication of the initiative to other affected parts of the country.

Source: Dale et al. 2009.

4.3.7. Further reading

CDC. 2008. Re-entering your flooded home (Emergency Preparedness & Response) http://www.bt.cdc.gov/disasters/mold/reenter.asp.

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WEDC. 2005. Essential hygiene messages in post-disaster emergencies, WHO Technical Note no. 10 http://wedc.lboro.ac.uk/who_Technical_notes_for_emergencies/10%20%20Essential%20hygiene%20messages.pdf.

WHO Technical Notes for Emergencies, N° 6. Prepared by WEDC. http://www.searo.who.int/LinkFiles/ List_of_Guidelines_for_Health_ Emergency_Rehabilitating_water_treatment_works.pdf.

WHO. 2006. Guidelines for drinking-water quality, third edition, incorporating first and second addenda. http://www.who.int/water_sanitation_health/dwq/wsh0207/en/.

4.3.8. How to conduct a health awareness campaign

It is essential to provide clear advice to the public and groups that are particularly vulnerable, on how best to protect their individual and public health during a flood. In urban areas where floods are anticipated, or which regularly flood, campaigns should be undertaken in advance. This will prepare people for the likely changed public health conditions which will ensue during a flood and post-flood.

The focus of an awareness campaign will differ from one area to another and from one disaster to another. It must be designed to meet the specific needs of the people. An awareness campaign must engage local communities so that maximum benefit can be obtained for the people at risk.

Method

1. **Campaign design**
2. **Pre-flood preparedness for municipal staff, volunteers, media and health professionals.**
3. **Pre-flood basic public health awareness.**

4. **Immediate flood onset public mobilization and information dissemination.**
5. **Flood public health awareness (i.e. during a flood).**
6. **Campaign monitoring, evaluation and improvement.**

1. Campaign design

For any awareness campaign it is essential that both the message and the means of communication are chosen to meet the specific needs of the target audience. This means that for different groups (eg. health professionals, media professionals, general public, hard to reach groups) both the messages and the communication tools used (e.g. formal training sessions, posters/brochures, leaflet drops, newspaper and magazine articles, home visits) will be different. Awareness is required before the flood (i.e. preparedness); other different messages are needed at the immediate flood onset (i.e. emergency awareness) and still others during the flood (relief, recovery and rights).

A 'Core Team' of public health champions needs to be established to guide the awareness campaign and ensure coordination between sectors and agencies. This team should meet with and motivate key senior municipal and appropriate government department staff (e.g. water supply, sanitation, health etc.) and leaders of concerned volunteer agencies (e.g., the Red Cross/Crescent, community resident associations) – as well as work with them to develop a strategy for a coherent and comprehensive pre- and post-flood health awareness campaigns. Media representatives should be included, as is appropriate (see below).

2. Pre-flood preparedness for municipal staff, volunteers, media and health professionals.

Senior water supply, sanitation and public health staff of the municipality should receive training in a range of topics including probability of flood; likely type of flood; warning and duration; probable impact; possible evacuation needs and implications for mortality and morbidity public health priorities in the event of a flood; action planning; the importance of both hardware (emergency water supply, distribution of hygiene kits etc.) and software interventions (community mobilization, personal hygiene awareness, public campaigns etc.) and the need for coordination. Action plans should be developed during the training that include initial rapid assessment, identification of immediate priority actions, basic service provision during floods, normal service rehabilitation, monitoring and reporting. Participative discussion of previous flood experiences will bring out useful information and also encourage ownership of the agenda.

This detailed preparedness training will be carried out by sector technical staff to ensure appropriate action plans are developed and understood by concerned staff. Mock exercises should be included in collaboration with volunteer agencies, wherever possible, to enhance preparedness and practice essential collaboration and inter-agency communication.

To motivate and mobilize health services it is vital to organize and run training for health professionals in both government and private health facilities to ensure understanding of anticipated health implications of flood and encourage preparedness. Health administrations must be motivated to carry out flood risk assessments for health centers and hospitals, and support flood mitigation actions so as to help ensure health facilities stay operational during flood events.

Identify the most appropriate champions in various media (e.g. newspapers, TV, radio and internet) and motivate them on the important role of the media in raising public health awareness during a flood. Prepare and run training with media representatives to inform and prepare them for their role. Share available tools and encourage them to pre-prepare messages, print material, radio spots, etc.

3. Pre-flood basic public health awareness.

Work with concerned agencies to design a training strategy to reach a cross-section of the public with basic public health awareness and personal hygiene messages in event of a flood. Prepare training materials and train ‘health awareness trainers’ from both official and voluntary agencies. The awareness program should be rolled out, piggybacking activities wherever possible onto on-going programs such as anti-malaria or HIV/AIDs awareness, and using existing structures such as schools and neighborhood organizations. Ensure inclusion of vulnerable groups, such as the aged, disabled, and poor communities.

Monitor and review pre-flood public health awareness activities. Depending on the periodicity of floods, the public health awareness may require regular repetition and would not be a ‘one-off’ event but an on-going activity.

Concerned voluntary agencies should be encouraged with advice and training to work with communities, especially the most vulnerable communities, to prepare flood risk management plans.

4. Immediate flood onset public mobilization and information dissemination.

The immediate emergency information dissemination campaign should coordinate and disseminate information to public through appropriate media, volunteers and public officials. Information and messages will be prioritized to preserve life, ensure safety and promote public health This will include messages on flood severity, evacuation arrangements, status of basic services including water supplies, location of relief centers and operational health facilities, information on distribution of emergency relief food and non-food items, etc. Publicize emergency telephone contact numbers and ensure adequate and well informed response capacity to provide up to date information (eg. evacuation, drinking water, medical aid etc.). Monitor the process and ensure messages effectively reach particularly vulnerable groups.

Continue for as long as the emergency situation pervades. It will be vital to coordinate effective feedback from field agencies to inform the emergency response. It needs to be a two-way communication strategy. Develop and adjust messages as information arrives from rapid assessments (water, sanitation, health services etc.) and as evacuation and relief programs get underway.

5. Flood public health awareness (i.e. during a flood).

Based on the pre-flood preparations and working with government, media and volunteer partners (refer 1. and 2. above), carry out the pre-prepared flood health awareness campaign. Prioritize key messages such as preventing contamination of and treating drinking water and effective hand washing at key times. Coordinate messages with relief and recovery programs such as health and safety advice for clean-up campaigns, advice for families to return safely to flooded homes etc. Use the campaign to promote dialogue with communities to make decisions about providing and managing WASH facilities during the flood event (refer WASH Cluster 2008a).

Ensure continued coordination of effective feedback from field activities to identify needs and priorities (for example disease outbreaks, new pollution risks etc.). The campaign should ensure that the affected population is aware of their rights and entitlements to both relief and recovery operations (Refer IASC 2008).

6. Campaign monitoring, evaluation and improvement.

A well-designed health awareness campaign strategy will clearly define anticipated outputs; incorporate a monitoring system to ensure effective implementation; and include an evaluation process to assess impact and guide subsequent improvements.

4.4. Land use planning and flood zoning

In growing and expanding urban settlements, flood hazard may be seen to be of lesser importance than other land management concerns, such as providing land for existing or new businesses or housing. Ongoing development and encroachment of floodplains and other flood-prone areas is a consistent problem throughout the urbanized world. The need to integrate flood risk management into land use planning is vital in order to minimize the rise in exposure to hazard, and to seek to manage the consequences of flooding.

Two of the most effective regulatory systems are land use planning and the finance and insurance sector, which is discussed in the next section. Both seek to control unregulated development of the floodplain, the former by land use plans and development frameworks to guide and control development and the latter by imposing minimum design standards for finance and insurance provision.

Understanding potential flood hazard risk, natural processes of water catchment areas, watercourses and floodplains enables planners and decision makers to develop appropriate land use frameworks. The control of development through such frameworks can reduce flood hazard by allowing natural processes to occur such as storage or the flow of floodwaters within the floodplain and in turn, reduce the exposure of communities to the hazard. Conversely, lack of guidance may put communities at risk through inappropriate development that prevents natural processes and intensifies the flow of water through increased hard surface areas, particularly those located in high risk areas.

4.4.1. The inter-relation between land use planning and flood risk management

Land use planning provides a policy and regulatory mechanism that enables diverse and often conflicting objectives to be integrated and addressed in a development framework – with this process and its output, is referred to as 'integrated land use planning'. Integrating flood risk management objectives and principles into land use planning is an essential component of contemporary flood risk management. Through its formulation and implementation, land use planning:

- Identifies appropriate area(s)/location(s) for specific land uses
- Determines what risks are associated with specific land uses in specific locations

- Determines and identifies sensitive or important societal or environmental features
- Details minimum requirements/expectations of particular land use types.
- Put simply, it determines what urban development is required and where it should go.

Land use planning is understood in many ways. This book differentiates between the terms land use planning and spatial planning. Land use planning, which is often also referred to as physical planning, although this term is passing out of use, refers to the detailed planning of the ways in which buildings and land are used. It usually incorporates the regulatory dimension by which land use is overseen. Spatial planning is typically seen as a broader set of ideas and practices which give geographical expression to a polity's social, economic and other policies. Spatial planning occurs at the strategic level of overall guidance and encompasses land use planning.

The interaction between land use planning and flood risk management is mutual. Urban land use plans should ideally be integrated within a suite of flood management plans which may include river basin management plans, coastal management plans and surface water management plans. Such plans are likely to be the responsibility of different governmental departments or agencies and the urban use plan will be informed by these dedicated flood management tools. Land use plans, on the other hand, will incorporate flood risk alongside other priorities, land availability and environmental hazards while broader spatial plans will need to balance the need for urban growth with the desire to limit flood risk.

Spatial planning is undertaken at scales from national through to municipal or city level; detailed land use planning takes place at neighborhood down to plot level. This broad structure of how these respective plans relate and interact with one another is referred to a hierarchy of plans, and reflects a concept in planning known as comprehensive planning. Spatial planning enables the preparation of land use plans that are intended to facilitate and direct development over a period of time. Often strategic plans at a national level will set out a development vision or objective that aims to cover a longer development period of say 10-15 years while more detailed or operational level plans at either municipal or city level plan may only work on a 5 year cycle. That said, these time periods are arbitrary and largely informed by the legal apparatus and structure of government(s).

Very importantly, flood risk management needs to be first embedded at the urban or land management policy level in order to ensure that plans are prepared with due consideration to such matters. Situating particular objectives at a policy level within multiple institutions requires integrated governance and operational frameworks to be in place. In the first instance, the development of a policy position or objective is required. For flood risk management, a water or environmental department of a relevant authority may be responsible for this. This agency/department would normally then be responsible for setting out a series of statements (complemented with spatial maps) that provide guidance to other government/decision making agencies and the community. Guidance may include information about high risk flooding areas, anticipated changes over time, minimum height levels for development and environmental management principles. From a land use planning perspective it is the integration of these broader principles that are determined at a policy level into the planning process that is vitally necessary.

Cross-institutional working, integration and locating policy positions into the planning process is, however, often not achieved. Competing objectives coupled with 'silo' working practices often mean that one arm of government is at odds with another: spatial planning often in fact draws out or highlights these challenges.

Contemporary planning practice requires consideration of numerous and often conflicting objectives. The need to accommodate rapidly growing populations, and provide adequate infrastructure, appropriate land for commercial and industrial development, open space, and adequate protection of the environment all in a constant state of flux and change is challenging. The level of complexity continues to evolve as rates of urbanization increase in developing countries, and consideration of natural disasters and climate change becomes more pronounced. In response to this, planners and decision makers have begun to incorporate the concept of 'risk' into planning practice and developed the approach of risk- based land use planning. Risk-based land use planning is a spatial risk management approach that prioritizes risk mitigation and adaptation objectives by using conventional land use planning tools. It is broadly captured in three main stages: appraising risk, managing risk and reducing risk.

Spatial and land use planning incorporates many factors and datasets. The concept and approach for preparing an integrated land use plan is layered. In the first instance, a base map/plan is developed. Generally this is a topographical and natural features map and where available it also incorporates cadastral data. This base map is then incrementally built upon to enable a spatial understanding of all other features such as the location of infrastructure, buildings, open space, green belts, coastal areas, nature reserves and watercourse or catchment areas. It is this layering approach that enables policy makers to adequately plan for community needs and aspirations while also acknowledging and addressing potential hazards and risks.

Technology now also aides land use planning and management. In particular, the use of Geographical Information Systems (GIS) provides the ability for government authorities to capture relevant urban data and present this in a spatial manner. GIS enables the creation of databases that can include information about natural and built assets, and the extent of a natural feature such as watercourse or catchment area, and presents this information spatially. For example, a government authority may create a natural features database with one component representing all available data on the floodplain. This data is then converted to a spatial format so the outcome is that a relevant municipal official can, by loading an electronic map of an area, select a specific location and be able to access all the relevant information about the floodplain for that particular location. The benefit of this to both government employees and the community is significant as it provides swift and concise information at the 'click' of a button. Obviously, in the context of rapidly growing cities and towns with a high level of informal or less formal land development, there are limits to data availability and the capacity of staff and authorities. The potential however for GIS to be a positive support tool for decision makers and the community is great. The following case study presents the functionality of GIS in the aftermath of the 2010 Queensland floods.

Case Study 4.3 GIS Queensland Flood

The Queensland Reconstruction Authority, the agency responsible for reconstruction following the 2010/2011 floods, together with the Department of Environment and Resource Management (DERM) has used GIS and satellite imagery to aid the reconstruction effort. Mapping products have been developed and are supporting the formulation of policy and tools for decision makers and members of the community.

A number of GIS mapping outputs have been created. These include the 2010/2011 captured interim floodline which was developed using spot aerial imagery, available satellite imagery and local information captured during the 2010/2011 events. The interim floodline is publically available on the Authority's website, and feedback was encouraged to ground truth the interim floodline.

In addition to capturing the actual event, the Authority has led a body of work to ensure a better understanding of Queensland's floodplains and to establish a better correlation between floodplain management and land use planning. This two-part guideline entitled Planning for stronger, more resilient floodplains provides planners and decision makers with specific guidance to ensure that flooding potential is considered in the land use planning process.

Through a layered and integrated approach, the Authority and DERM developed a unique methodology to geospatially identify Queensland's floodplains. This is particularly important in areas where flood studies have not yet been undertaken in order to provide high level guidance in land use planning processes. A number of state-wide datasets including soils data, stream ordering, pre-cleared vegetation, contour information and recorded gauging station information were combined with satellite imagery and available aerial photography, including that of the 2010/2011 floods, to understand potential areas of flooding across every relevant river catchment in Queensland.

Figure 4.3: Example of GIS map. Source: Queensland Reconstruction Authority and Department of Environment and Resource Management.

Through the use of this technology and information, a state-wide mapping product known as the Interim Floodplain Assessment Overlay was developed. In all, 116 river catchments in Queensland have been mapped. This represents all relevant areas of the state. Part 1 of the Guideline – Interim measures to support floodplain management in existing planning schemes included the mapped product both electronically and in a hard copy, alongside a supporting guideline and a development code. The aim of the toolkit is to provide an interim response for municipal bodies, specifically Councils, to be able to incorporate the mapping and the development code into their existing planning schemes. It will therefore be used by planners and decision makers to ensure there is a consideration of flood potential when preparing or assessing development proposals. The voluntary toolkit is provided to Councils for local verification and refinement based on any more readily available data at the local level.

The Authority has also prepared Part 2 of the Guideline – Measures to support floodplain management in future planning schemes. Part 2 is focussed on providing Councils with floodplain management guidance in the preparation of their new generation planning schemes – and specifically to help ensure policy can be developed and embedded from the strategic framework into appropriate land use zones and therefore to support informed decision making through the development assessment process. Part 2 also provides specific fit-for-purpose approaches to undertaken flood investigations and studies that are targeted and suitable to the local catchment needs and priorities.

Planning for stronger, more resilient floodplains is ensuring that the lessons learnt from the summer of 2010/2011 are being translated into the land use planning process now and into the future.

Source: Queensland Reconstruction Agency.

Drawing the principles and approaches outlined above, and as an illustrative example, a concept plan will often be prepared for a particular area. A concept plan enables a graphic presentation of the desired form of development for the area. It is not detailed planning and does not specify the form of development at individual plot level but provides information on desired development patterns in relation to major environmental and infrastructure features. The preparation of a concept plan is not possible in all situations. It is a very practical and useful tool, however, to communicate preferred types of development and their locations. It can also be integrated into GIS format, so it is possible for a decision maker or government employee to select a particular location (for example, a flood plain or catchment area) for information on the environmental considerations for the desired development.

A concept plan needs to highlight major infrastructure (existing and future), transport corridors, environmental features such as water courses, and areas that are suitable for particular land uses such as residential, commercial, open space, community and education. The Figure below represents an Australian Local Government example whereby a concept plan that incorporates flood data has been prepared for a township area.

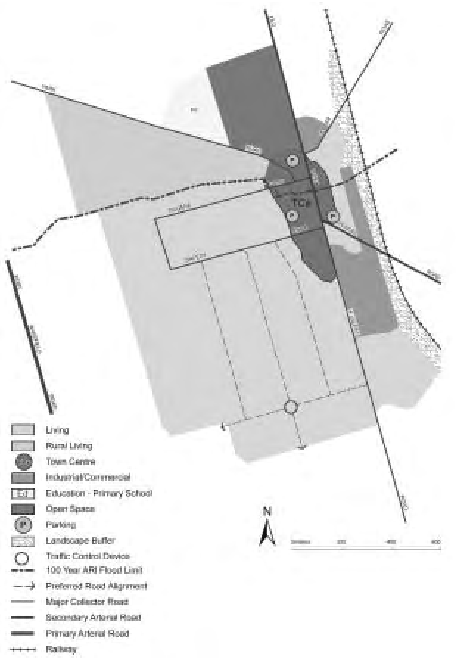

Figure 4.4: Concept plan map, Source: Department of Planning and Local Government, South Australia

4.4.2. Integrating land use planning and flood risk management

4.4.2.1. Embedding policy: Cross-Institutional working

Flood risk management needs to be embedded at a policy level. This requires relevant and responsible agencies/departments/institutions to establish policy positions that provide guidance to other arms of government and the community. Like land use planning and the concept of a hierarchy of plans, policy adopts a similar principle. At the strategic level, policy is articulated in broad statements and sets out a vision or strategic direction of a particular issue. In the instance of flood risk management, this may include policy on the long term management of the flood plain and achieving appropriate flood risk management. As policy documents move from the strategic to operational, and like spatial plans, greater detail is provided and may include specific policy objectives to achieve environmental management or appropriate standards for buildings to improve a community's resilience to flood risk.

The integration of policy at a cross-institutional level of government requires governance frameworks that encourage coordination and communication. As outlined previously, this is often difficult and in many cases is not achieved. To achieve this cross working and integration of policy often requires legislative provisions. That is, a land use planning Act/regulation should include reference to water resource legislation and that consideration of a particular plan/objective of this legislation must occur for development to proceed.

Again, it is often the reality that legislative reform is required in order to achieve this level of integration. Even when the appropriate legislative and policy frameworks exist, urban planning often highlights the inherent conflict between various and competing objectives. Flood risk management in particular has the capacity to highlight this through seeking to remedy/manage development in high risk areas from flood events that may be considered highly valuable for residential or commercial development. Despite these challenges, embedding policy and cross-institutional working is essential for effective spatial and land use planning to take place. Where such arrangements are absent, silo working practices will persist and the relevance of urban planning diminished.

4.4.2.2. Understanding flood risk and determining flood zones

Understanding how an area may be affected by a flood event enables policy and decision makers to design appropriate development frameworks and undertake development that takes into account the potential impacts of flooding. Understanding flood event(s) is often framed within the context of risk or the probability of a particular type of event occurring. This risk or likelihood of an event is then expressed spatially to detail the anticipated extent of floodwaters. Chapters 1 and 2 provide greater detail on understanding flood hazard mapping and flood risk.

The preparation of flood zones is the most common method to categorize particular thresholds of probability and the associated spatial implication or extent. For example, common storm probability thresholds are:

a. Less than 0.1 percent (low probability of flooding)

The chance of flooding in this area is less than 0.1 percent (1 in 1000) per year

b. Between 0.1 percent and 1 percent (medium probability of flooding)

The chance of flooding in this area is greater than 0.1 percent (1 in 1000) but less than 1 percent (1 in 100) per year

c. Between 1 percent and 5 percent (high probability of flooding)

The chance of flooding in this area is and greater than 1 percent (1 in 100) but less than 5 percent (1 in 20) per year

d. Greater than 5 percent annual exceedance probability (AEP) (functional floodplain, or floodway)

The chance of flooding in this area is greater than 5 percent (1 in 20) per year.

These thresholds provide a framework for planners and decision makers to determine appropriate development policy using a risk based planning approach. Understanding these thresholds and how they relate to a geographical area represents the 'appraising' risk step. It is important to note that these thresholds are influenced by a range of factors both natural and human-induced. Areas that have a greater probability of being affected by flooding, as described above, are often situated within a natural catchment area near a watercourse. Human-induced factors may include the level of development in a particular level and the hard surfaces present which impact the flow of urban runoff and in turn an areas ability to cope with a particular type of flood event. Land use planners need to understand that all areas will fall within one or other of these flood zones and that there is relationship between each of the zones. These relationships will continue to change over time as natural processes evolve and human settlement and development increase.

Flood zones provide a spatial framework in which development can occur and are developed on the basis of flood hazard mapping and risk. Flood zoning allows greater flexibility in planning by restricting the development of highly vulnerable uses (such as residential houses) in high risk areas but permitting less vulnerable uses in lower risk areas.

4.4.2.3. Determining appropriate land uses

Reducing the exposure of vulnerable people and property is one of the components required to reduce flood risk. The concept of appropriate is determined by identifying the vulnerability of different land uses to flooding. The appropriateness of any given use is determined based on the vulnerability to flooding of the building type or its occupational use. For example, a hospital is typically considered a highly vulnerable use and, therefore, it is more appropriate to locate hospitals in areas at lower probability of flooding.

Although the predominant approach to vulnerability is considered from a human and economic perspective, in determining appropriate land use(s) consideration must be given also to potential environmental impacts. For example, as the UK example below details, hazardous waste facilities are highly vulnerable as are any land uses that have the potential to have a damaging impact on the environment should the required environmental protection measures be compromised by flooding.

A list of land uses should incorporate current and projected land uses. These can be grouped into categories.

Table 4. 2 is an example of the UK categorization and the uses according to vulnerability.

Table 4.2: Flood risk vulnerability classification, Source: CLG 2006

Essential Infrastructure	Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk, and strategic utility infrastructure, including electricity generating power stations and grid and primary substations.
Highly Vulnerable	Police stations, ambulance stations, fire stations and command centers and telecommunications installations required to be operational during flooding. Emergency dispersal points. Basement dwellings. Caravans, mobile homes and park homes intended for permanent residential use. Installations requiring hazardous substances consent.

More Vulnerable	Hospitals. Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels. Non–residential uses for health services, nurseries and educational establishments. Landfill and sites used for waste management facilities for hazardous waste. Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.
Less Vulnerable	Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non–residential institutions not included in 'more vulnerable'; and assembly and leisure. Land and buildings used for agriculture and forestry. Waste treatment (except landfill and hazardous waste facilities). Minerals working and processing (except for sand and gravel working). Water treatment plants. Sewage treatment plants (if adequate pollution control measures are in place).
Water-compatible Development	Flood control infrastructure. Water transmission infrastructure and pumping stations. Sewage transmission infrastructure and pumping stations. Sand and gravel workings. Docks, marinas and wharves. Navigation facilities. Defense installations. Ship building, repairing and dismantling, dockside fish processing and refrigeration, and compatible activities requiring a waterside location. Water-based recreation (excluding sleeping accommodation). Lifeguard and coastguard stations. Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

4.4.2.4. Creation of regulations and enforcement procedures

Land use plans incorporating flood risk management through the creation of flood zones, and development frameworks that specify appropriate land use(s) and patterns of development on this basis and that of vulnerability to flooding, provide guidance and clarity to individuals, organizations and businesses about what type of development can and will occur and where. However, this guidance is of little benefit in the absence of appropriate regulation(s) to legally control or restrict development. Such regulations will need to interface with existing land use control, planning and building control legislation and will be naturally limited by the strength of current land use planning procedures. For example, flood legislation in Germany (Case Study 4.4) was built upon an already stringent planning control system with good compliance, and is expected to have a long term impact on flood risk.

Typically regulations may cover:

- The appropriate uses for new development permitted in a designated zone
- The requirement for flood risk assessment for all new developments on site and downstream of it
- Minimum design standards (such as materials, access points, minimum floor level) for permitted development within a designated zone
- Compulsory drainage and surface water management plans
- Presumption against reconstruction of damaged dwellings within designated zones
- Compulsory retrofitting of flood protection measures.

Case Study 4.4: The German Flood Act 2005

National policies can contribute towards flood management and legislation forms a vital part of this approach. The flood control sections of the 2005 German Water Act exemplify good practice in this area, and have many features in common with other water and flood protection acts. The act embodies three core principles, which place stringent flood control obligations on government and individuals to manage flood risk in advance of flooding, as well as on the way flood zoning is managed and how warnings are issued:

- Surface waters have to be managed in such a way that (as far as possible) floods are held back, non-harmful water run-off is ensured and flood damage is prevented. Areas that may be inundated by a flood, or where an inundation may help to alleviate flood damage, have to be protected;

- Within the bounds of possibility and reasonability, any person potentially affected by a flood is obliged to undertake adequate measures to prevent flood-related risks and to reduce flood damage, particularly to adjust land use to a possible risk created for humans, the environment or material assets through floods;
- A land law shall stipulate how the competent state authorities and the population in the areas affected are informed about flood risks, adequate preventive measures and rules of behavior, and on how they are to be warned of an expected flood in a timely manner.

In practice this means that:

- Extensive improvements to flood zoning and mapping are occurring in accordance with this Act, as well as the European Water Directive. Importantly, public consultation is built into the process;
- New building in the floodplain is forbidden in most cases. Where it is permitted, the design of new construction is strictly controlled (for example, the placement of oil heating systems and computer control centers);
- Flood protection plans have to be drawn up for the 100 year flood and there must be consultation with both upstream and downstream riparian owners; and,
- Flood zone maps are to be integrated into all spatial maps and plans (such as land use plans and development plans).

Commentators have noted that for German flood risk management this Act is a promising shift away from the 'protection' mentality towards 'adaptive risk management.' However, the success of this shift in practice has yet to be realized.

Sources: Government of Germany 2005; Garrelts and Lange 2011.

In cities and towns where the compliance with land use planning regulations is lower, notably in burgeoning informal settlements, the regulations may need to be supported with community engagement, incentive schemes and strong enforcement regimes. Occasionally it may be possible or necessary to demolish high risk settlements and re-house the inhabitants via resettlement programs. The usual guidance and consultation procedures should apply and such programs should seek to target more than one development goal. The case study on Chengdu below illustrates how this has been achieved in China.

Case Study 4.5: Chengdu Urban Revitalization, China

As part of a revitalization scheme of informal settlement districts initiated in 1997 by the Chengdu Municipality and finished after five years, residents were moved away from the river bank into new accommodation. About 30,000 households were moved, which created space for a green buffer zone along the riverside.

The plan had several best practice features, including a clear target to reduce flood risk. In the past, houses in the informal settlements projected over the river and were often swept away by floods in the rainy season; this necessitated constant vigilance so that evacuation could be effected. After the rains stopped, families had to deal with the chaos brought about by the flood, resulting in great hardship, suffering and economic loss.

As part of the scheme, the two rivers, Fu and Nan, were de-silted and widened thus reducing flood risk to a 200-year return period expectation. Crucially, engagement of the local community ensured that the public participated in the scheme and resettlement was completed without litigation. Per capita living space rose by a factor of 1.4 and the relocation of the informal settlement dwellers significantly reduced congestion in the city. There was also the benefit of some 30 to 35 percent of owners also gaining property rights, which they had not held before. Green zones were created which improved the environment greatly and allowed for the construction of an award winning natural park area with water purification facilities which is now on the national tourist register.

The Chengdu case shows how land use planning which integrates flood risk considerations can be effective in both reducing flood risk and improving conditions for people living in informal settlements. It is important to highlight the fact that the participatory approach adopted in the resettlement scheme was a key contributing factor to its success.

Sources: UN 2001; UN-HABITAT 2002

Increasingly, there is also interest and much innovative thinking about how flood risk management concerns can be integrated within planning for new urban development in the 21st Century in ways that meet flood management objectives while simultaneously maximizing the utility and amenity of sites both large and small. The case study which follows illustrates a prominent UK example of such work.

Case Study 4.6: Long-term initiatives for flood risk environments: The LifE Project – Making Space for Water

In designing and building new urban developments, space for water needs to be integrated with sustainable design so that the means of managing flood risk become an asset for residents and to the wider urban community. Multi-functional land use that makes space for water, energy and play within built developments will become fundamental to adapt to the challenges of rapid urbanization and climate change. The LifE project, which received funding from the UK's Defra Innovation Fund as part of its Making Space for Water program, sought to identify how new development in flood risk areas could help to reduce flood risk overall and deliver zero carbon communities. The LifE project adopted a non-defensive approach to flood risk management, which marked a shift from traditional thinking by permitting water into sites in a controlled manner to make space for water.

Sustainability and climate change are amongst the main drivers for change in the way development in the UK is planned in the 21st century. These are manifested in the need to make developments zero carbon, conserve water, reduce unsustainable transport use, reduce overheating and manage flood risk.

There are potential benefits from measures introduced to respond to these issues but understanding which to prioritize is fundamental to good planning. Of these issues, flooding is the main risk to life and therefore should be the priority. However, simultaneous assessment of the other requirements helps to develop integrated proposals.

The LifE approach was based on integrated design and planning approach, through which:

- Buildings and uses are organized according to risk
- Land which is allowed to flood has multiple functions and is also used for less vulnerable activities, such as recreation, parking and renewable energy generation
- Neighborhoods are organized around public transport infrastructure and short walking distances.

Three principles apply:

- Living with Water: Adapting to increased flood frequency and severity, likely to happen with climate change
- Making Space for Water: Working with natural processes to provide room for the river and sea to expand in times of flood and reduce reliance on defenses, where possible.
- Zero Carbon: Providing all energy needs from renewable resources on site, such as wind, tidal and solar power.

Three sites in the UK that all suffered from various forms of flood risk were considered with the LiFE approach. Each site was located within a different part of the river catchment:

- Hackbridge within the upper catchment of the River Wandle
- Peterborough within the middle catchment of the River Nene
- Littlehampton within the lower catchment of the River Arun.

Figure 4.5: Hackbridge (Site 1), Source: BACA Architects

In Hackbridge (Site 1) an area of land at the heart of the development was ascribed multiple functions. The 'village/blue green' would provide a flexible informal recreation area that would provide current and future flood storage potential and space for an array of boreholes for ground source heat pumps. This area creates a focus for the development, increases the sales value of properties and improves access to the river for the wider neighborhood.

Figure 4.6: Peterborough (Site 2), Source: BACA Architects

In Peterborough (Site 2) ‘rain and stream corridors’ were introduced between buildings to create areas for rainwater attenuation and to create drainage and flood paths away from homes. The corridor widths were designed to allow generous daylight into taller buildings and provide separation from small wind turbines located at the centre. Striating (or ‘striping’) the master plan with soft landscaping to manage flood risk would provide a high quality environment and reduce air temperature in and around buildings, mitigating the urban heat island effect.

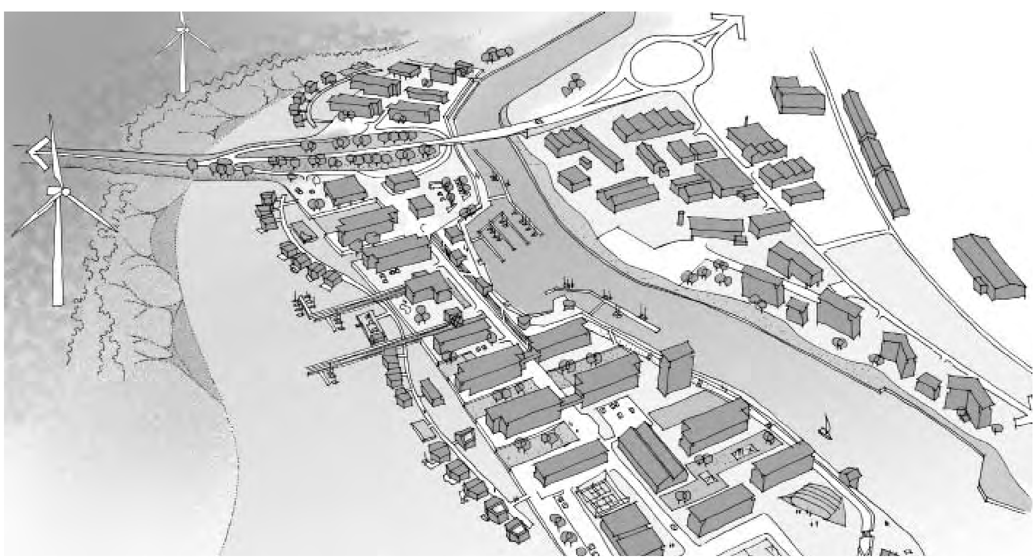

Figure 4.7: Littlehampton (Site 3), Source: BACA Architects

In Littlehampton (Site 3) a large area of land to the rear of the development site was designed for controlled flooding, to reduce water levels in the river and reduce the strain on existing defenses. This inland lagoon would provide water recreation adjacent to the development and habitat for wildlife in intertidal regions (mudflats and salt marsh) beyond. Twelve tidal turbines would generate energy for five hours during each successive ebb tide. The lagoons would be an attractive backdrop to the development and unique regional attraction.

The project had a number of policy lessons:

Flood risk management

Using modeling data it was possible to map the areas where flooding from the river would occur on each site in an extreme flood (1 in 100 or 1 in 200 year event) and also the extent that may occur with climate change. Overlaying this with topographical data allowed the depth, velocity and hazard to be assessed for differing flood events.

Having assessed those areas most likely to be flooded or most susceptible to change it was possible to plan to avoid building on the existing floodplain, to ring fence land that should be maintained as future floodplain and to identify surrounding land that could be set aside for reducing flood levels in the future. Land was planned to locate the most critical uses (hospitals, emergency services, power) in the least susceptible areas and the less vulnerable uses in more susceptible areas. At a higher resolution, development was organized so that landscapes would be affected by flooding first, followed by secondary paths and roads, then by parking, then less vulnerable buildings, then primary roads, then more vulnerable buildings – all before emergency escape routes and people would be affected. This enabled non-defensive flood risk management to be incorporated at a capital cost of between one and nine percent of the total development cost.

Renewable Energy

All three development sites included a combination of renewable energy solutions, notably biomass Combined Heat and Power (CHP) and solar photovoltaic panels (PVs), that would best suit the individual conditions.

Development and Amenity

Quality of life factors were integrated that help to make development sustainable, successful, thriving and improve the health of occupants. Minimum standards for outdoor playing space equates to approximately 36m2 per person. Higher density developments can have a requirement of 50 percent of the developable area to be for open space. This means, particularly in areas with high land values, that open space is often underprovided.

In each of the sites, use of the floodplain was the only feasible solution to meeting the open play standards. By considering the spatial needs for water, energy and open play from the beginning, these functions could be integrated into the design and layout of the site, to create more attractive and successful development plans. It also allowed more efficient planning, helping to reduce capital cost.

Source: Baca Architects with BRE and consultants.

4.4.3. How to produce urban land use plans that incorporate flood risk management

Integrated land use planning should be considered as an iterative process, and one that requires regular review and update. Land use planning that incorporates flood risk management principles requires planners and decision makers to think at macro and micro scales and across short, medium and long term time frames. The changing complexity of human and urban settlements means that if regular consideration, review and enforcement are not undertaken, land use plans lose their relevance and usefulness. It is essential therefore that land use plans can respond to the dynamics of human and urban settlements and are seen as an integral and constructive component of an area's development and future.

The following method will assist planners in the preparation of land use plans that incorporate flood risk management.

Method

There are eight broad stages to prepare a land use plan. It is possible that several of these steps are combined or carried out contemporaneously. The steps are as follows:

1. Determine the Study Area

2. Site Analysis

3. Flood Hazard Mapping

4. Land Use constraints/inventory plan

5. Development Framework

6. Development Parameters

7. Consultation

8. Regulation/Implementation/Enforcement.

1. Determine the Study Area

Land use planning can be undertaken at many scales from strategic national level planning through to detailed planning at individual plot scale. This method is applicable across all levels/scales of planning but largely deals with urban and town scale planning.

Determining the study area is a crucial first step in land use planning. The spatial extent of the plan enables the following steps in the method to be framed and the context understood. It is important to note, however, that while a spatial extent may be set this does not limit wider considerations such water catchment areas, water courses and inter-relationships with adjoining and adjacent administrative or political boundaries.

Spatial extent is usually determined by administrative boundaries. As land use planning often transcends these administrative boundaries it is necessary to understand how particular urban areas interface with other land uses, natural features and administrative/regulatory frameworks. A wider spatial plan may also be prepared that highlights strategic links or important considerations in relation to other administrative boundaries and the study area.

To determine the study area, first identify relevant administrative boundaries. These boundaries can be a national, municipal/district, city and local level. Integrated land use planning occurs at all levels.

The output of this step is an outer boundary that delineates the extent of an affected/relevant area.

Figure 4.8 below is one example of a study area. In this instance, the information shown includes the relevant administrative boundary but also the topographical features of the area. Inclusion of base data such as this is a useful and good contextual layer to include. Further, the map also includes a reference grid, whereby the viewer can ascertain very quickly where the study area is situated in relation to other areas.

Figure 4.8: Example of a study area. In this instance, the information shown includes the relevant administrative boundary but also the topographical features of the area.
Source: Department of Planning and Local Government, South Australia

2. Site Analysis

Once the study area has been determined, it is necessary to undertake a strategic assessment/analysis of the area. Its purpose is to record and evaluate information within the relevant area (in its relationship to surroundings), and to use this information to inform an appropriate policy response. This process is to develop an understanding of what land uses exist within the area, identify natural features, identify major infrastructure, obtain where possible topographical data, identify the location and footprint of built form including both legal and illegal structures. The latter is especially important, as regardless of the legal status of development the impacts from and to such developments in a flooding event need to be considered.

The level of detail that may be captured at various scales of planning will differ. For example, at the municipal or city level planning scale major infrastructure such as roads and water facilities will be identified along with the location of natural features. However, unlike the more detailed neighborhood scale of planning, this may not show building envelopes but rather will include areas that are known to be built upon and, where available, cadastral boundaries.

3. Flood Hazard Mapping

Flood hazard mapping allows planners and policy makers to understand flood risk and make informed policy decisions. As seen previously, flood risk is determined by both historic data and modelling to determine the probability of a particular type of event over time.

For land use planning, it is necessary to determine what level of probability will be planned for. This assessment may change depending on the location and the types of land uses that are present or intended. This ‘risk’ assessment is largely informed by human considerations and a desire to protect residents from harm and disruption. This concept is embedded in risk-based planning whereby the initial risk assessment will inform the following planning process. This assessment establishes the acceptable level of risk which then determines planning policy, standards and development priorities.

To enable policy makers in the assessment and decision making process it is necessary to obtain the most up to date flood hazard data. Chapter 1 outlines the process for preparing flood hazard maps. For land use planning, understanding the data is essential as the incorporation of flood risk management principles to land use planning is largely based on this data. Flood hazard zones are categorised based on the probability of a particular flood event. These categories are as follows:

- Less than 0.1% (low probability of flooding)
- Between 0.1% and 1% (medium probability of flooding)
- Between 1% and 5% (high probability of flooding)
- Greater than 5% (functional floodplain, or floodway)

Understanding the implications of each category is a critical tool in the planner’s/policy maker’s toolkit. These categories enable planners/policy makers to identify and understand the severity, spatial distribution and frequency of a hazard. Understanding the flood risk represents the first guiding principle of land use planning and flood risk management as it is ‘appraising risk’

The practical translation of this step is further developed in the following sections. However, it is important to note how this risk assessment is embedded into planning policy and the significance of this initial assessment to the wider planning process. The assessment at this stage determines what level of risk will be planned for and is considered acceptable and, in turn, what areas need to be protected, adapted or development restricted.

4. Land Use constraints/inventory plan

A constraints plan provides an important layer in the land use planning process. It details both the natural and human made constraints that will affect where development can and cannot go. It takes the information obtained in the proceeding steps and develops a spatial picture on how particular areas are affected or constrained. This can include highlighting areas within a floodplain; it can also include other natural features such as steep terrain, cliffs, coastal areas, open space reserves and nature parks. A constraints plan should also include other environmental assets or human development that may represent constraints such as hazardous industry and contaminated land.

A constraints plan provides the basis for which appropriate planning policy or a land use plan can be developed and informs the 'managing risk' step of integrating land use planning with flood risk management.

Figure 4.9 below provides an example of where by a base map that shows cadastral data that is overlain with data that shows the extent of a floodplain. This example, taken from and Australian Local Government Development Plan clearly shows how flood risk management is integrated into land use planning policy.

Figure 4.9: Base map that shows cadastral data that is overlain with data that shows the extent of a floodplain. Source: Department of Planning and Local Government, South Australia

5. Development Framework

A development framework incorporates the data compiled in the preceding steps and commences identifying particular areas that may be suitable for particular types of land uses. These identified areas can be referred to as zones. Zones do not have to include only one type of land use they can accommodate a range of uses. Contemporary planning practice encourages mixed use, responsive and adaptable urban spaces. For the purposes of integrated land use planning, this step in the process is particularly useful to identify areas that present mixed use or multi-functional opportunities, such as environmental features that may provide a dual function of flood hazard management and development of recreation areas or open space – and as seen in the LifE project above.

A development framework will also incorporate the preparation of flood hazard zones, based on the initial risk assessment. These zones provide a spatial presentation of flood risk. This information needs to be presented in a clear, concise and understandable manner. As such, it is common to see flood risk referred to through a numeric system, for example, flood risk 1 through to 3. This numeric system is then complemented through the use of graduated colour. A flood hazard map may have three hazard zones with 1 representing the least risk through to 3 representing the greatest risk. This level of risk presented visually through colour graduation.

A development framework or policy framework is the instrument that integrates all the information compiled in the preceding steps with principles of land use planning and management. A development framework needs to outline the development objectives or vision for an area(s) at a strategic level or policy level, that is, it details what the desired objective or aim over a particular time period of an area, for example an area identified to allow for future population expansion and development in the form of a residential area. Broad principles of development control or mechanisms for managing the urban environment should also be outlined. A comprehensive land use plan will balance the development objectives of an area/community with those also of the environment and long term sustainability.

A development framework needs to be reviewed and updated regularly. A common critique of land use plans is that they are static and non-responsive. Contemporary land use planning takes some steps to addressing this through the integration of infrastructure planning, hazard risk planning and community participation.

There are often many reasons why the preparation and management of land use plans is delayed. However, the preparation of land use plans provides an important mechanism for policy and decision makers to understand a wide range of issues, including flood risk and develop an appropriate strategy to facilitate land use planning and urban development. The capacity to develop, implement and enforce such plans whilst essential to the overall success of land use planning, should not prevent or stop attempts to prepare land use plans that encourage forward planning and preparation – particularly as it relates to flood risk.

6. Development Parameters

Development parameters provide a more detailed framework for which development can occur. It provides the overall objective(s) for an area. For example, the objective for a mixed use zone or area may be to provide residential, community and some retail facilities. This objective is then supported by guidance on minimum requirements or principles of development control. In the instance of flood risk management, these measures include minimum floor levels, specifying locations where particular forms of development are appropriate, and in some instances building materials.

Development parameters should also relate to natural or environmental features. The objective(s) for such features should include preservation and management and be supported by appropriate principles of development control. In the instance of an identified flood plain the objective should include allowing the natural flow and processes of the flood plain to function, and development control measures such that permanent structures and other development that will impede the flow of flood waters should not be developed. Appropriate land uses for such areas need to be specified, and may include open and recreational space and low impact farming.

In developing parameters for development it is preferable that consideration be given to how the land use over time may change. Land use planning will highlight areas where land may be attractive for particular types of development such as residential, but may be inappropriate for such development due to flood risk. The land use planning process provides a mechanism to redirect development to more desirable or appropriate locations by developing appropriate policy and development guidance.

Development parameters also need to include on site management techniques and reference to the inter-relationships of development off site. That is, if a large residential development is proposed what measures ought to be in place to manage the impacts of that development? For example, where should storm water run-off be directed? Is there a mains system whereby developments can discharge directly to or can the run-off be accommodated on site through the use for sustainable urban drainage system (SUDS) and the use of swales, landscaping, and water recycling?

A series of questions helps shape the preparation of development parameters. These questions provide the next layer of detail to the spatial data, constraints and risk mapping exercise and development framework. This thought process which enable the preparation of appropriate policy that incorporates all the layers of information and presents, through policy, clear requirements for development in particular locations and are often referred to as ‘principles of development control’.

Questions that assist this process for both steps 5 and 6 include:

1. What is the development objective?

2. What environmental assets are present?

3. What development constraints exist?

4. What and where is major infrastructure located/exist?

5. What type of development is appropriate in this area?

6. What opportunities exist to encourage multi-function or mixed use areas?

7. What types of changes are likely to occur over time e.g. pressure for urban land, informal development areas and climate change impacts?

8. What types of management controls are necessary?

Once this through process has been undertaken, it is possible to devise appropriate policy or development parameters. Development parameters do not need to be complicated and are often viewed as a tool to restrict development. Although restricting development in some situations is appropriate, in managing flood risk development parameters combined with a sound development framework can act as an enabling and pro-development tool. By preparing a land use plan that integrates the full breadth of issues affecting urban areas from urbanization and population growth, infrastructure planning, hazard risk management including flood risk it is a mechanism that provides certainty and legitimacy to the development process. Where frameworks and land use plans are absent it is difficult for authorities and communities to participate effectively in the planning process and/or development sector. Participation does not necessarily mean acting as a large scale developer, but rather members of the community understanding what influences and shapes their environment and having the opportunity to engage with this process and its outcomes.

7. Consultation

Developing a land use plan that is accepted by the community requires policy makers to engage with residents to understand views within the community and also identify challenges to implementation.

The consultation stage should clearly outline the development process and display the range of options that have, or are being considered. The options as presented through the consultation phase(s) should not be fixed and this needs to communicated during consultation to demonstrate to participants that their views are can be incorporated into the land use planning process. Land use planning is by its nature an iterative process and community consultation provides one means of contributing to this process.

Community consultation also provides a mechanism whereby natural assets and environmental features and their relationship to urban settlements can be highlighted and explained. Although land use planning considers many development scenarios and pressures, it provides an opportunity to raise awareness about flood risk and how this risk has been considered in the land use planning process. While pressure for housing or commercial development may be at the forefront of the community's mind, the implications of development being situated in high risk areas should provide the platform for engagement and the basis for developing land use plans that respond to both the economic and community needs as well as hazard management.

8. Regulation/Implementation/Enforcement.

Land use planning and policy and spatial plans are of no benefit to the community if they are not adequately enforced, or if the planning system is not seen as an effective mechanism for managing urban development issues.

In implementing a land use plan appropriate approvals or permissions need to be in place for persons wishing to undertake development. The process of obtaining permission needs to include the initial application phase whereby the proposed development type is put forward. The proposal should then be assessed against the relevant land use plan and policy framework to ascertain if what is proposed is an appropriate form of development in an appropriate location. Proposed development that is considered appropriate requires further scrutiny in the form of assessing if it meets the minimum design standards such as, siting, floor levels and building materials. Once all of these factors have been considered and the development deemed in accordance with the land use plan, permission should be granted.

Once planning permission has been obtained the development process does not cease. The construction of the proposed development and the monitoring of this activity are essential if the land use plan as devised is to be adhered to. Building inspectors have an important role in ensuring that approved development is implemented in the manner in which it is proposed, such as the correct location and finished/constructed to the appropriate standard. Construction and an inspection represent the final stage in the land use planning process. Should the development be compliant and consistent with the original permission, a 'certificate of compliance' or similar can be issued. This final stage is very important in regularising the development process but also in embedding standards and consistency. It also provides a mechanism whereby land and legal development are afforded some protection, as ensuring the appropriate permissions are in place and checking this becomes a pre-requisite for future purchases and land/development transactions. Compliance and enforcement of development standards represents the 'managing risk; step in risk-based planning.

The above outlines a land use planning system that functions in an integrated and efficient manner. In many circumstances however, the planning system and the ability for governments to discharge their duties effectively is severely challenged, particularly in the cities of developing countries. These capacity constraints need to be acknowledged and bridging mechanisms devised. Central to an effective land use planning system is the enforcement of relevant legislation and regulations. However, if the legislative framework is outdated and not reflective of current circumstances or the wants, needs and aspirations of the community it is very difficult for land use planning to be effective.

The practical reality of many planning systems in the developing world is that there is little government department integration, limited budgets, outdated office equipment and resources, limited data availability, conflicting legislative frameworks particularly as they relate to land tenure and land rights and finally, extended periods and often complicated decision making processes. These factors coupled with the rapid rate of urbanization and pressure on urban centres to provide for its population create a system that is under enormous pressure and is often rendered obsolete/irrelevant.

This how to guide provides the basis for preparing an integrated land use plan that incorporates flood risk management. It outlines the necessary steps, data requirements and necessary considerations when preparing a land use plan underpinned by an assumption that the planning system is effective and efficient. As acknowledged though, this is not always the case. However, preparation of land use plans should not be avoided because of these factors. Rather appropriate modifications and adjustments employed to reflect the local situation and acknowledging that this will continue to change over time. To inform this process the key points of integrated land use planning and flood risk management can be summarised below:

- Risk based assessment(s) is essential to all levels of planning
- Integrated land use planning is an iterative process
- Development frameworks and parameters do not need to be complicated
- Enforcement of land use plans is essential.

4.5. Flood insurance, risk financing, compensation and tax relief

4.5.1. Introduction

Insurance, risk financing, compensation and tax relief have two main purposes in the management of flood risk. Firstly, and most obviously, the provision of these financial mechanisms can be used by those at risk to offset their financial risk from flooding. Although these financial tools obviously do not prevent flooding, they allow recovery without placing undue financial burdens on those impacted by flood disasters. The advantages of flood insurance are clear, as recovery can be expedited and funds are not diverted from other priorities such as development. For low frequency but high impact events, the provision of insurance in particular spreads the risk of financial loss, centralizes the holding of disaster reserves, and should therefore be a more efficient method of financing disaster recovery. Because of this, governments are increasingly beginning to examine insurance as a risk management option: reinsurers such as Munich Re have identified the provision of insurance within developing countries as a major opportunity for the twenty-first century (Spranger 2008).

The second major function of disaster insurance, compensation and tax relief schemes is to reduce risk and damage, via the need for risk assessment and encouragement of risk mitigation (Cummins and Mahul 2009; Kunreuther 2002). If risk is correctly priced (in an actuarial sense) then the incentive to mitigate risks exists via premium pricing; many insurance contracts also implicitly require the policyholder to undertake reasonable risk reduction and mitigation activities and this obligation can be made more explicit, or mandatory, for coverage to apply. Similarly, compensation can be targeted to resilient reconstruction, whilst tax schemes have the potential to influence many aspects of reconstruction, including the use or set aside of flood-prone land.

As disaster relief funds are increasingly overstretched, and tend to divert finance from other important development programs, the main focus of this section is the potential to move towards insurance.

4.5.2. Level of insurance coverage worldwide

The coverage of natural disasters in general, and flooding in particular, varies a great deal across nations. For buildings, there is an estimated coverage of 40 percent of high income country losses, falling to 10 percent in middle income countries and less than five percent in low income countries. The UK is one of the best covered countries with 95 percent coverage; by contrast, Taiwan's coverage is below one percent. Although, following this, there is a perception that, flood insurance coverage is universally high in developed countries and the converse in developing countries, this is in fact not the case. Swiss Re has estimated, for example, that in the Netherlands flood insurance coverage is typically very low, whereas in Indonesia it may be as high as 20 percent (Gaschen et al. 1998).

Purchase of insurance is highly dependent on a number of factors, including its availability and cost, the level of the provision of disaster relief, general risk awareness, and attitudes to collective and individual risk (Lamond and Proverbs 2009).

In the UK there is a privately provided insurance cover enabling individuals to mitigate their flood risk. Flood cover is 'bundled' into standard insurance policies (as opposed to being sold as a separate policy, the method applying in the US for example) and is currently available almost universally. This state of affairs is due to a 'gentlemen's agreement,' known as the 'Statement of Principles' between insurers and the UK government (and Devolved Administrations in Wales, Scotland and Northern Ireland). The current agreement runs until June 2013 and is based on a division of responsibility whereby the government primarily funds flood defenses and in return insurers agree to pick up the residual risk and provide insurance cover to most properties at flood risk.

As a result, the majority of people who insure their property against fire and theft are also insured against flooding with an estimated 95 percent of domestic buildings covered. The advantage of this system is that domestic flood risk is transferred to the private market. Commercial flood risk is also potentially insurable in the UK and public infrastructure can be insured or self-insured by local authorities and infrastructure companies.

This leaves the central government supporting local authorities in the cost of emergency management, a fraction of the total costs from flood events. However, commentators have noted that this leads to complacency and lack of preparedness among residents at risk of flood and can lead to lack of incentive for the government to invest fully in flood defense (Lamond et al. 2009).

4.5.3. Requirements for market-based insurability

To qualify for insurance, risks have to be insurable. From an insurance provider's perspective insurability equates to:

- Risk that is quantifiable
- Risk that is randomly distributed
- A high enough number of policy holders to diversify risk
- Sufficient chargeable premium to cover the expected claims, and transaction costs, whilst remaining affordable to policy holders.

For market-derived insurance, a profit margin is also necessary.

In the context of flood risk, particularly in developing countries, the quantifiable aspect of insurability is problematic. Flooding is less predictable in its onset and outcomes than for other natural hazards; the availability and reliab of historic data in developing countries is low. The cost of insurance may also pose a problem for prospective policy holders in lower income countries. Many households already exist below economic subsistence level and have no money to spare for the purpose. Randomness and number of available policyholders are linked. In a mature market with good information and well-priced risk, the spread of risk should be appropriate. Even in the developed world, however, the steps in development of a mature market may involve insurers accepting patterns of risk which are less diverse and therefore have unaffordable premiums.

4.5.4. The dangers of adverse selection and moral hazard

Highly relevant in the context of flood insurance, adverse selection and moral hazard are two behavioral phenomena which undermine the efficient operation of insurance markets where there may be information asymmetry (i.e., policy holders know more about the risk they face than the insurer does). This leads to the potential for adverse selection. Those people who are poorer risks than the average will tend to insure; the informational problems imply that the risk will not be priced correctly.

As an example, flood risk is often assessed on an area basis, such as the average damage per property in a postal or zip code. But within a particular code some properties may be on raised ground whilst others are not. If insurance is not mandatory, then it is the residents on low ground who will buy insurance and their average claim will be higher than the code average. This results in an under pricing of risk and, potentially, claims which cannot be met from reserved premiums. The adverse selection problem is minimized where insurance coverage is high, or where cover is mandatory.

Moral hazard exists if there is no reward for risk mitigation behavior built into insurance products. Policy holders will therefore rely on insurance to offset their risk and undertake no self-protection. Policy holders will therefore rely on insurance to offset their risk and undertake no self-protection. This has been observed to be the case in the UK, where there is no effective mechanism for premium adjustment in the domestic market in consequence of self-protection, partly due to competition but also to transaction costs. The action of moral hazard results in increased damage costs and higher premiums for all. The use of excess charges, regulation and policy exclusions could potentially encourage self-protection (Kunreuther 2002) but may be difficult to enforce in a market-based system. Alternatively, awareness raising and education regarding the intangible and indirect impacts of flooding which can be avoided may also have a role here.

To avoid both adverse selection and moral hazard, insurers can employ rigorous and accurate risk pricing and take into account any mitigating activities. In developing countries, this may be difficult to do with certainty if they are in the early phases of insurance market development. It is unlikely to be cost effective for individual market based insurers to develop the information base necessary to price risk. This approach has often led to flood risk being regarded as uninsurable. Governments, donors and international financial institutions may have to play a role in generating information. It is also apparent that aggregating risk is liable to make the pricing easier, as the necessary level of detailed information reduces. Schemes which enforce insurance on individuals, or that insure a group of individuals – even to the level of nation states – will be easier for insurers to price and therefore be more attractive to them. It then becomes the role of the nation, or community peer pressure, to encourage risk mitigation in order to reduce their collective insurance premiums.

4.5.5. Micro-insurance

At the other extreme to market-based insurance is the increase in micro-insurance as a solution offered to the urban poor. Swiss Re maintains that micro-insurance on a commercial basis is the appropriate instrument for individuals above the international poverty line and living on up to US$4 per day. Below the poverty line, micro-insurance schemes will need some government or donor intervention. About half of current micro-insurance is offered commercially, with markets in Latin America the strongest. However, the non-life element of these schemes is very small compared to life insurance.

Examples of micro-insurance schemes for property loss from natural hazards include the Indian Afat Vimo or the mandatory Gujarat group-based housing insurance scheme (Swiss Re 2010). Sharia-compliant micro-insurance is also available and clearly relevant in nations with substantial Muslim populations where it is known as Microtakaful. Rheinhard (n.d.) defines the key elements of micro-insurance schemes as follows:

- Products should be easy to understand
- Premiums should be low
- Frequent payment plans should be available

– The insured population should be aggregated

– Distribution channels should be cost effective.

Distribution channels are one of the most important aspects of designing innovative micro-insurance solutions: they include retail outlets, municipal offices, energy suppliers, existing micro-finance institutions, and NGOs. Instituting an insurance mentality is another challenge, as the requirement for pooling risks requires a high level of buy-in from the insured community and some element of social solidarity.

4.5.6. Risk financing mechanisms

Catastrophe bonds and catastrophe pools are examples of alternative risk financing mechanisms where market insurance is not available. The French and Spanish insurance systems, for example, are based on catastrophe pools: policies delivered by private companies are backed by a state guarantee that is triggered by a national disaster and prevents the insurance companies from insolvency. US flood insurance is also state-backed. As a result, the US Treasury had to find around US$18bn to cover the losses after Hurricane Katrina. Nations which can self-finance the risk from flooding may find this a highly cost effective route to providing cover. But usually the level of cover offered has to be limited and often does not include such attributes as alternative accommodation. Australia is considering a move to such a system after the 2010 Queensland flooding, as seen below.

Case Study 4.7: Australia reviews disaster insurance and considers national disaster fund

As previously discussed, in the three consecutive years beginning with 2009 serious flooding and cyclones affected large parts of the state of Queensland, located in the north-east of Australia. It is estimated that the total cost of the recent floods and cyclones during these three years is around US$ 10.46 billion. One month after the severe floods of 2011, only 10 percent of the total of US$ 2.1 billion worth of private claims had been paid. The significant volume of insurance claims and the costs that insurers and reinsurers are expected to pay have also raised concerns that insurance premiums will rise.

In January 2011 the Government of Australia ordered a review into disaster insurance and the need for a national disaster fund. The report intends to examine all aspects of the response and the aftermath of the 2010 and 2011 flood events. With a focus on the insurance sector, the review reports on:

- The performance of private insurers in meeting their claim responsibilities for floods and other natural disasters
- The possible impact of any national government intervention in disaster insurance, as for example, by subsidizing insurance premiums for individuals and small businesses in high-risk, high-premium areas
- The need for a national disaster fund.

The Queensland Floods Commission held a second round of hearings in September and October 2011 at which questions of insurance matters were heard. The final report with recommendations relating to flood preparedness is due to be delivered by early 2012.

Sources: Queensland Floods Commission of Inquiry 2011; Taylor, R. 2011.

Nations which would struggle to guarantee their probable maximum flood loss may extend the risk to the market via catastrophe pooling across countries, or by moving to market catastrophe bonds. The Mexico case study below (Case Study 4.6) shows how this can be achieved and even how this type of arrangement may be used to support flood mitigation as well as recovery. It is, however, an expensive financing mechanism.

Other potential routes include nations getting together to provide catastrophe pools, thereby spreading the risk and reducing the ratio of Probable Maximum Loss (PML) to the GDP of contributing countries as in the Caribbean risk financing pool. Care must be taken to ensure that the risks are complementary so that the combined PML is not the sum of the individual PMLs. A thorough understanding of the sources and interaction of risks is therefore necessary.

Case Study 4.8: Mexican catastrophe bonds

The Mexican government has an innovative approach to all natural catastrophes which it developed with the World Bank, whereby investors' funds are used at agreed trigger level events. Mexican catastrophe bonds started with earthquake bonds in 2006, followed in 2009 by an issue of US$290 million in a broader bond covering earthquake and hurricane risks. The Goldman Sachs Group and Swiss Re managed the bond sale, which will pay investors unless an earthquake or hurricane triggers a transfer of the funds to the Mexican government. The World Bank program, called MultiCat, cuts the cost of issuing the bonds and allows the countries to lock in funding to meet emergency relief. The bonds are due to mature in 2012.

The bonds are used to protect the capital reserves in the Mexican 'FONDEN' and 'FOPREDEN' schemes, which are, respectively, a catastrophe pool covering all natural disasters and a disaster prevention scheme.

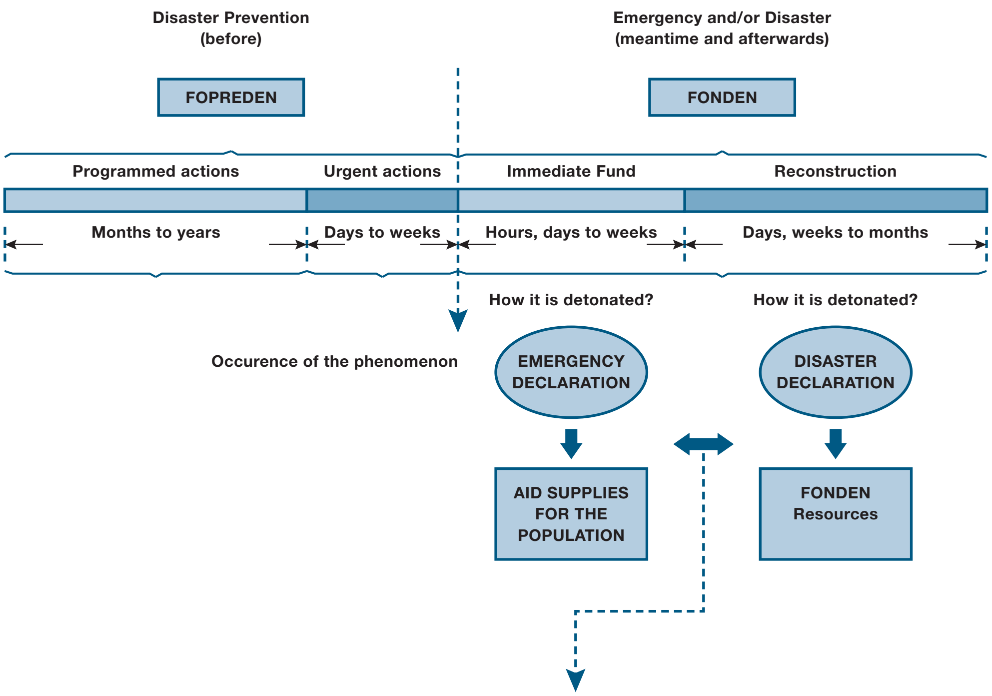

Figure 4.10: Disaster time line SOURCE: Adapted from SEGOB 2009

Preventative actions financed by the FOPREDEN include:

- Actions focused on the identification and evaluation of hazards, vulnerabilities and risks
- Actions focused on risk reduction and the mitigation of the damages caused by the impact of natural phenomena
- Actions to strengthen the preventive capacities of the population and self-protection before risk situations develop.

Buyers of this kind of catastrophe bond, which are most often sold by insurers seeking to reduce their own exposure to catastrophe costs, may be willing to settle for riskier returns after finding dwindling profits elsewhere in the fixed-income bond market. However, at the moment this is a small market, as there are prerequisites in terms of adequate risk assessment information and for the creditworthiness of issuing governments. The involvement of the World Bank helps reduce the cost of issuing the bonds and makes it easier for developing countries to sell them.

This case study illustrates a possible risk transfer mechanism whereby funds set aside for disaster prevention and management can be protected. It has two advantages in that the bond can operate before a catastrophe pool has accumulated sufficient funds to cover probable maximum loss and it can allow expenditure from the pool on a needs basis for smaller events – and provide risk prevention without concern that a larger event will leave the population without resources. It is an expensive alternative though, and may be beyond the capacity of many developing nations.

Source: Swiss Re 2010(a); SEGOB 2009

4.5.7. Compensation and tax relief schemes

The main function of compensation and tax relief schemes is to encourage self-protection activities by individuals. For example, a compensation scheme might incentivize evacuation of the floodplain or other flood-affected areas by buying property at market price, thus allowing individuals to move without financial loss. Such a scheme exists in France, in the form of the "Major Natural Risk Prevention Fund" (a.k.a. the "Barnier Fund" from the name of the Minister who attached his name to the law creating this fund, passed in 1995). The fund is financed through a mandatory contribution on natural disaster insurance premiums paid by property owners. It is used to finance the compulsory purchase of properties ("expropriation") when it is necessary to do so to stave off substantial threat to human lives, by paying the difference between insurance compensation received for property damage from the pre-flood value, thereby compensating the property owner for the full value. In rare instances, the Barnier Fund can also be used to provide incentives to displace homes or finance transactional (rather than compulsory) sales of properties. Owners can therefore buy an equivalent property elsewhere. (Darling et al 2006).

These mechanisms can also be used to relieve the financial pressure on flooded households. Although there is no official fund for private households to gain financial support, after severe flooding in the UK in 2007, many residents were granted tax relief from local council tax. In the US, residents without flood insurance who live outside designated floodplains can claim some of their post-flood property losses back against taxes. Another example, from Brazil, is described in Box 4.4.

Box 4.4

"In Estrela … a study was prepared for the city together with the Urban Master Plan and implemented in the municipal regulation. After the legislation was implemented the risk areas were preserved and gradually the remaining population was removed to safe areas using tax incentives. The tax incentives were the exchange of building construction area permits downtown with flood risk areas. Flood damage losses and population affected have decreased over the years since 1979."

Source: Tucci 2004.

Tax relief for the purchase of flood mitigation products such as door guards and toilet bungs has also often been advocated as a cost-neutral incentive to encourage self-protection, as for example in the British Property Federation response to the Thames Estuary 2100 (TE2100) Plan Consultation Document.

4.5.8. Essential considerations to support the introduction of effective flood insurance

An effective flood insurance regime can provide the necessary financial resources to effect a fast recovery and reinstatement after a flood. Insurance can form part of individual and collective strategies to handle residual risk, high impact but low probability events, and events with impacts which are high with respect to national GDP. Effective insurance regimes can also encourage prevention and mitigation.

Identify those at risk	First identify areas at risk Identify assets and receptors at risk Identify individuals, companies, owners of public assets and infrastructure who could be responsible for reinstatement.
Quantify Risks	As it is described above, the assessment of expected damage is part of a wider FRM agenda. Insurance risks may be different to economic losses due to policy terms and exclusions from cover.
Map distribution of risk	If risk is diverse then it is more insurable. Risk concentrated in just one area will be more difficult to insure. Insurers will require this information to price policies.
Explore level of solidarity	This may have legal, constitutional, regulatory or cultural aspects.
Choose appropriate pooling categories	Risk can be pooled to reduce transaction costs, increase affordability, cross-subsidise premiums or to diversify risk. Consider diversification options such as international pooling or combination with other perils.
Identify/support primary insurer	Primary insurer can be market insurer, state or Public Private Partnership. Market-based insurance may need an initial incentive to develop the market.
Identify/support cost effective distribution channel	Options are to use existing insurance channels, but where insurance penetration is low other more creative schemes may be needed through channels collecting other revenues. Intervention to support set up of new channels may be needed.
Explore reinsurance and securitisation of risk	State-backed insurance schemes may need to be reinsured or backed up with secure finance. Nations may spread risk temporally using future tax revenues or rely on the markets.
Communicate risk	To encourage the take up of insurance, risk reduction should be part of a wider FRM agenda.
Communicate benefits of insurance	To increase take up and ensure continued insurability.

4.6. Solid and liquid waste management

4.6.1. Introduction

The inadequate collection and disposal of waste is often a significant contributor to flooding. An understanding of the role of waste management in the context of flooding is therefore important for the following reasons:

- Existing waste disposal practices may cause or exacerbate flooding, by impeding the flow in drains and watercourses, or by filling low-lying areas which may otherwise act as temporary storage lagoons during floods.
- Debris will be created by the flood and by the clearance of flood debris.
- The waste generated by the existing population will be augmented by that generated by the relief agencies and the flood.
- The existing equipment and waste management practices will form the basis of the post-flood emergency measures.
- There may be opportunities, as part of flood risk management planning, to improve waste management practices.

Poor waste collection is endemic in cities and towns in the developing world and has the following adverse impacts:

- It is an impediment to drainage, often blocking drains and causing flooding.
- It is a source of disease (for example, providing material on which flies can lay their eggs or food for rats, both of which are disease vectors).
- It is a source of infection, especially from clinical waste and sewage.
- It is a source of chemical toxicity, especially from discarded medicines along with commercial and industrial waste.
- It acts as a contaminant of surface and groundwater, which may be used for human activities including consumption.
- It is a contaminant of surface water which, through bioaccumulation by aquatic plants, animals and fish may then enter the human food chain.

The principal concern in being prepared for flood events in urban environments is the blockage of drainage, and also the infilling of storage areas and ponds which may provide temporary storage for flood waters. Uncollected solid waste blocks drains, and causes flooding and subsequent spread of waterborne diseases. This was the cause of a major flood in Surat in India in 1994, which resulted in an outbreak of a plague-like disease, affecting 1000 people and killing 56 (UN-HABITAT, 2010). This section covers this wider aspect of both solid and liquid waste management in the pre-emptive capacity of reducing flood risk. The impact of and disposal of debris (the significant quantity of solid material generated by flood events) is covered in Section 4.11.

4.6.2. Solid waste

Solid waste may be categorized broadly according to its source of generation as follows:

- Municipal waste or household waste is likely to be the greatest quantity of waste generated in urban areas. It consist of general wastes discarded by households and will include food items (both vegetable and meat), paper, plastics, household sweepings and broken domestic items. The annual floods in Kampala, Uganda, and other East African cities are blamed, at least in part, on plastic bags, known as 'buveera' in Uganda, which block sewers and drains (UN-HABITAT, 2010).
- Commercial waste is generated by any commercial activities including offices, shops small manufacturing businesses and is composed of any material relating to the commercial activities
- Industrial waste. This is waste generated by industry and may range from solids liquids and sludges, inert, reactive (substances which are not inert but may react with each other or with water) and hazardous waste depending the type of industry.
- Clinical waste. The majority of urban areas will have doctor's surgeries and clinics with dedicated hospital in the larger towns. They generate household types waste, commercial waste, pharmaceutical waste and organic waste (such as body parts). It may also be the site of the local mortuary. Some clinical waste is highly infectious.
- Animal waste. In many developing countries large herds are retained in urban areas to provide milk. These will often be in the poorer areas and the manure may or may not be removed as field fertilizer and or fuel.
- Other, such as dust and construction materials generated by the sweeping of streets, for example; this is often the responsibility of the municipal authorities together with waste collection.

The type and quantity of waste differs significantly between countries and within urban areas. Industrialized countries and urban areas will tend to generate greater quantities of waste compared to developing countries and rural areas.

The composition will also vary according to season when particular crops are harvested and also factors such as religious festivals when, for example, animal slaughtering may reach a peak.

There may also be significant geographical variations relating not only to the size of the urban population, but also the location within the urban area. There are also differences in the composition of waste between low and high income countries' gross national product (GNP). As might be expected, low income countries generate less waste per capita than higher income countries. In Asia the amount ranges from 0.5 kilogram per person per day in Nepal, whilst in Hong Kong this increases to more than 5 kilograms per person per day (World Bank 1999).

Due to the rapid urban expansion and unplanned development in urban areas the amount of solid waste is increasing day by day and the disposal capacity is diminishing thus providing fewer people with collection services. For instance in cities like La Paz in Bolivia, and Brasilia in Brazil the total collection of solid waste is up to 90%, while on the other hand in Santiago, Chile, the total collection is less than 57% (USAID, 2006). The situation is worse in other countries. In most of the cases treatment plants are non-existent or non-operational due to lack of maintenance. This results in large-scale dumping of waste in open landfills, water bodies and river courses.

Table 4.3: Waste composition related to scale of urban area

Sources of waste	Small Town	Medium Town	Larger town	Informal settlement
Household waste	Predominantly food processing and dust.	Wider range of wastes and greater quantity.	Wider range of wastes and greater quantity.	Predominantly food processing and dust
Commercial	Limited range of waste mixed with household wastes.	Wider range of wastes may be collected separately collected from commercial area housing.	Wider range of wastes and more likely to be separately collected from commercial area housing.	Very limited range probably only form small neighborhood shops.
Industry	Limited range.	Limited range often related to agriculture i.e. crop processing or equipment manufacture.	More specialist manufacture grouped into identifiable areas	Industry unlikely limited as the informal settlements act as commuter areas.

Clinical	Very limited as few clinics. More serious cases are sent to local towns if finances allow.	Very limited as few clinics. More serious cases are sent to local towns if finances allow.	A range of doctors' surgeries, local clinics and potentially a number of specialist hospitals depending on the size of the population.	Clinics unlikely as population have insufficient funds.
Animals	Household animals only.	Household animals and perhaps herds on the perimeter because travel distances are short so that proximity does not confer an advantage.	Potentially large herds in the poorer areas.	Animals unlikely as population have insufficient funds.
Dust from roads	Mostly dirt roads	Mostly dirt roads some paved roads.	Main roads, those in the city center and in expensive residential areas are hard surfaced.	Always dirt roads.
Liquid waste drainage and sewerage	Open drainage channels.	Open drainage channels	Open drainage with enclosed drainage	Open drainage channels

4.6.3. Management of solid waste

The management of solid waste in developing countries is generally the responsibility of the relevant municipal government and may not be considered a priority for the following reasons:

- Lack of public education in the health implications of poor waste management;
- Absence of pressure from civil society to improve waste management practices;
- A lack of expertise in waste management within municipal authorities: employment in managing waste is generally considered menial and of low status;
- Lack of training facilities for waste managers;
- Lack of finance to purchase plant and equipment;
- Poor wages encourage absenteeism;
- Diversion of resources to non-waste management activities;

– The generation of waste owing to population growth exceeds the financial resources available for managing it.

These factors will often result in inadequate collection and disposal of the waste, as well as the concentration of resources in high profile areas (for example, city centers) and the absence of any service in informal settlements.

Waste management comprises a series of steps from the household to a collection point (primary collection); from there it is taken to a larger collection point (secondary collection); from this location it is then taken to its final disposal point. The waste hierarchy can be applied to minimize waste both before and after flooding.

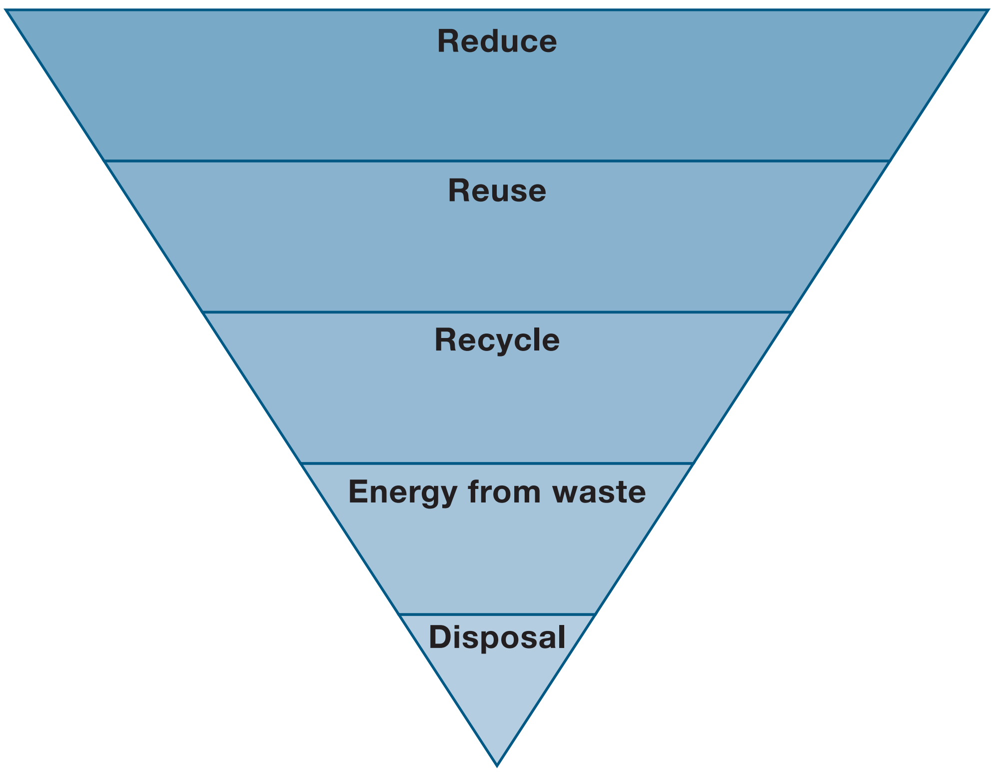

Figure 4.11: The waste hierarchy is applicable to waste management before and after flooding

Reduction of waste is often dependent on a culture of awareness of the importance of solid waste management and conservation of resources. Plastic bags and other plastic products such as drinking bottles are seen as prime culprits in the clogging of drainage and are seen as a relatively simple target in the drive to reduce the amount of waste produced. Simple alternatives such as reusable bags and drinks containers are available. After frequent floods in Mumbai, the state of Maharashtra in India banned the manufacture, sale and use of plastic bags in 2005; unfortunately, poor enforcement means that the ban has so far been less effective than hoped (UN-HABITAT, 2010).

Reuse of waste is seen as a method to remove items from the waste stream and also to generate income and employment from resale of usable items. Reuse strategies include the donation to charity of unwanted items, reuse within the home, and repairing rather than replacing defective household goods. Municipalities can encourage such practices through instituting schemes to collect and distribute unwanted furniture, clothing and other useful commodities, or by local tax incentives for reuse. Reuse can also be implemented once items have entered the waste stream via waste sorting as discussed below.

Recycling involves removing items from the waste stream by transforming items into other useful products. Composting, textile reprocessing and wood recycling are examples of activities that households commonly undertake spontaneously. Municipalities can institute sorting schemes which collect recyclable goods separately from the main waste or can undertake sorting post-collection.

Energy from waste can be a household based activity if paper, wood and other easily combustible products are removed from the waste and used for domestic heating purposes. On a city wide scale, post collection, energy can be generated from waste via incineration or the collection and use of landfill gases.

Finally disposal should be seen as the final alternative for unwanted and unusable items and will still represent a significant challenge for urban authorities to manage.

The improvement of municipal waste services can also benefit from market-based activities such as those listed in the box below (Cointreau 2003).

Box 4.5: Improving municipal waste services

- Tax credits and tax relief, allowances on property taxes, customs duties, or sales taxes to motivate investments in waste management improvements
- Charge reduction, based on proof of recycling or reuse in reducing wastes or requiring collection or disposal
- Tax rebates for pollution savings or energy efficiencies
- Environmental improvement funds, established to support pollution

reduction, resource protection and energy efficiency

- Research grants to stimulate technology development
- Host community compensation, incentives given by host communities to allow waste transfer or disposal facilities to be built there
- Development rights, long-term leases of land and development rights provided to private companies building waste treatment and disposal facilities, or to those remediating and reclaiming old disposal sites
- Tipping fees, changes to generators based on volumes of waste disposed
- Waste exchanges, facilitated exchanges or waste materials
- Trade Associations encouraging industries to join together to provide common inputs to waste management issues
- Product life cycle assessments predicting the overall environmental burden of products which can be used in certification programs
- Deposit-refund, deposit paid and refund given upon product return for reuse, e.g. beverage containers
- Take-back systems whereby manufacturers take back used products or packaging
- Tradable permits allow trading of emissions among various polluters
- Bans on materials or wastes causing disposal problems, e.g. mercury batteries
- Procurement preferences, with evaluation criteria adding points for products with recycled content or reduced resource demand
- Eco-labeling noting a product's recyclable content and whether a product is recyclable
- Recycled content requirements, laws and procurement specifications noting the precise recycled content required
- Product stewardship encouraging product designs that reduce pollution, including the full cost of solid waste recycling and disposal, the reduction of wastes and recycling
- Disclosure requirements: waste generators are required to disclose their pollution
- Manifest systems, precise cradle-to-grave tracking of hazardous wastes
- Environmental rating of industries: published lists enable consumers to consider whether to buy from polluting companies, e.g. Indonesia's PROPER program

- Liability insurance, liability assurances by contractors and private operators
- Bonds and sureties: guarantees for performance by contractors and private operators
- Liability legislation: laws defining environmental restoration settlements
- Insurance pools restructuring insured parties to enable pollution risks to be covered
- Liens placed on land where government remediation is required
- Procurement transparency and competition to encourage bidding on a level playing field
- Performance-based management contracting: oversight contractors commit to overall service improvements
- Clean city competitions rewarding neighborhoods and cities that have improved cleanliness.

4.6.3.1. Collection

Waste collection is the primary step of an integrated waste management system. Municipal authorities rarely, if ever, have capacity to collect all the municipal waste generated. Although targets are set and claims are made that up to 80 percent of waste is collected and recycled (World Bank, 1999) this is often based on inappropriate and invalidated assumptions: 50 percent may be a more accurate estimate. The volume of uncollected waste will increase with expanding populations and migration into urban areas

In many parts of Africa, Latin America and the Caribbean a significant proportion of the population do not have access to regular waste collection. However in many parts of Asia, waste collection has been given priority and regular collection is organized by the local municipalities. Initiatives have also been taken in both Latin America (USAID, 2006) and Africa (UN-HABITAT, 2008).

Considerations for city, climate and local culture should be taken into account in planning adequate collection. For example, in Delhi, India, the city wished to contract out waste collection to a single private company but encountered opposition from the many micro- collection enterprises already existing. Integration of the informal sector can also be very helpful (UN-Habitat 2010). The case study below of Bamako, Mali, shows how efficient community-based collection systems can help in the mitigation of the impacts of flash flooding.

Sometimes in smaller communities, primary and secondary collection may be combined. With increased urban populations and distance to the disposal point, secondary collections become essential and tertiary systems may also be required.

Case Study 4.9: Solid waste disposal in Bamako, Mali

Bamako is the capital of Mali and has a population of approximately two million. The city is located on an alluvial plain between the Niger River and the Mandingo Plateau. Some 45 percent of the population lives in informal, unplanned settlements in the peri-urban areas of the city. Some of the most important environmental problems that Bamako faces are inadequate or non-existent wastewater collection and treatment, inadequate solid waste management, unhygienic individual behavior, and poor urban management;

Due to the success of locally-based initiatives and the setting up of profit-seeking bodies called Groupement d'Intérêt Economique (GIEs) in the 1990s, coverage for primary collection of waste is stronger. GIEs started with sensitizing the community, making clear what their task was and the fee they expected from each household. GIEs have to be entitled by the communes of Bamako, which have institutional responsibility for waste collection, to operate within specific collection zones. Furthermore, they have to make individual contractual arrangements with households within the perimeter then put under their responsibility for collection and transportation of waste to transit sites. Other informal arrangements also exist. Much of the waste is used by farmers (up to 60% of that collected during the rainy season).

The District of Bamako is in charge of final disposal of waste through transportation from transit sites to landfills and further management of landfills. Currently, there is no land filling as such in Bamako. Rather, some dumping sites exist within the city but do not work as planned. This situation has resulting in unauthorized dumping sites and small piles of waste all over the city. The World Bank supported the preparation of a solid waste management strategy for the city of Bamako in the early 2000s. The strategy was approved but has not produced tangible outcomes because of the District having failed to put in place the appropriate staffing and adequate financial resources in support of its implementation.

In 1999 flash flooding throughout Bamako caused death and destruction. Analysis showed that the poor disposal of waste was a significant contributory factor in the scale of the impact of the severe weather event and a four year project to improve stormwater management and solid waste management was undertaken in one of the most flood-affected areas of the city.

The District of Bamako sought to establish partnerships with civil society for environmental management. An NGO known as ALPHALOG supported the creation of a partnership between the city administration and a set of NGOs, CBOs and informal sector groups, to conduct a study to determine why the District had been suffering from a lack of sanitation. This was the basis for initiating an Environmental Planning and Management (EPM) process. The project focused on the following five objectives:

- Watershed management, including retention strategies (such as slip trenches and diversion efforts) and waterway bank restoration
- Refuse removal, collection, and disposal, including removal of backlogged refuse in waterways, and the establishment of a refuse collection system and landfill operation
- Livelihood generation related to drainage and retention improvements, refuse collection and disposal, and the initiation of a composting operation
- Public health and sanitation improvement, through enhanced water management, training and awareness raising
- Decentralization support, to promote democratic governance, by engaging local government authorities and project area residents in a process of identifying needs and priorities.

Stakeholder participation, combined with a comprehensive planning framework, was used for the first time in the city. This helped to build consensus at the action planning workshop. The capacity of NGOs, CBOs and informal sector groups involved in the process has also been enhanced. The institutions are now capable of preparing terms of reference and undertaking their own studies, and they also developed capacity to conduct public information campaigns through their involvement in the process.

In addition to promoting decentralization, other project outcomes included:

- Restoring channel volume in key project area waterways through the removal of several hundred tons of accumulated refuse and debris, which improved drainage capacity and reduced flood risk;
- Improving water retention capacity in selected sites throughout the project area by constructing slip trenches (a.k.a., soak pits), thereby reducing both runoff volume and flood vulnerability;

– Establishing a refuse collection and disposal service through the creation of eight collection routes, each served by a collection team using tractor-trailers, with disposal at a nearby dumping site established by ACF.

Bamako has not experienced a similar flood disaster since 1999, partly as a result of these measures. The main challenge the City of Bamako still faces for waste disposal is the lack of a designated landfill for waste final disposal. There is a site designated for controlled land filling about 30km outside the city limits in Noumoubougou. The construction of the landfill was launched some time ago but has not been completed yet. Two important issues still need to be resolved in terms of which authority will be responsible for paying for the operation and maintenance of the landfill and which will be paying for transportation of the waste to the landfill. The situation is further compounded by the perspective of the creation, in a next future, of a new decentralized entity as result of merging of the District and the six communes of Bamako as well as many other local governments within the Bamako conurbation.

Source: UN-HABITAT n.d.; UN-HABITAT 2010;
AfDB 2002; Jha 2010 ; Setchell 2008.

4.6.3.2. Disposal

Current disposal practices in most developing countries leave much to be desired. The result is that as little as 10 percent of the collected waste may be deposited at an official disposal site there being much greater incentives to dispose of the load before reaching the site. Table 4.4 indicates typical following disposal practices.

Table 4.4: Disposal practices

Households	Municipal authorities
Removal by a sweeper who scavenges useful items Dumping on empty land Dumping in watercourses and river valleys.	Dumping in streams On land that requires raising prior to construction Infilling of holes in the road Spreading as a soil improver on agricultural land Land reclamation Infilling of the sides of river valleys Unofficial dumps with no legal entitlement Official dumps Properly operated landfills (rare).

Clinical waste from small industries and hazardous waste are rarely collected separately, but are usually mixed with municipal waste. Large industries, often located outside of the urban area may have dedicated disposal, often incorporating energy recovery as part of the process.

Inappropriate disposal practices may result in visual, chemical and biological contamination of surface and groundwater water resources, typically downstream of the origin of the waste, and are also a significant contributor to flooding, through the blockage of natural and human-made drainage channels. Municipal waste should not be deposited in flood prone areas as this may result in water contamination and the spreading of diseases (Diagne 2007).

4.6.3.3. Waste treatment

More technical treatment processes (such as incineration and composting) require capital resources, which are often beyond the technical and financial capability of municipal authorities to provide and operate. Industrial processes are often far more efficient, frequently incorporating energy recovery from the waste generated.

Treatment for different types of wastes is different and therefore a comprehensive program is required for proper waste treatment after collection. If waste collection is not facilitated with separate collection bins, then sorting should be done. Sometimes composting might not be the best option with mixed waste products. Similarly hazardous wastes should be removed and disposed of as soon as possible so that it does not affect the health of the surrounding areas. Proper training is required for such purpose.

4.6.3.4. Waste Reuse and Recycling

The removal of reusable and recyclable materials reduces the bulk of waste and can provide employment and revenue to offset the cost of the recycling process. In many developing countries, an efficient and structured scavenging system already operates, which provides a basic level of employment for minorities and migrants. Any formal recycling schemes, especially removing the most valuable waste from high income households and from hospitals, would need to seriously consider the impact on the income of existing scavengers.

4.6.4. Pre-emptive actions to minimize the effects of flooding on waste collection

Flooding may quickly render an existing waste collection system ineffective, by destroying vehicles, restricting vehicular access, making existing working routines redundant and though the absence of personnel whilst they see to their own domestic affairs. An effective waste management is critical after a flood; an already well-managed waste collection and disposal system can be modified, however, by considering the following options:

- Locating depots and garaging and equipment on higher ground away from flooding so that they remain accessible.
- Maintaining fuel reserves to be used when commercial fuel supplies are unavailable.
- Identifying a number of disposal sites in different parts of the urban area that can continue to be used if access is restricted by flooding.
- Operating a recycling and hazardous waste collection system that can be easily adapted to take an emergency into account.
- Avoiding the disposal of non-inert waste in flood prone areas.
- Avoiding infilling of low-lying areas, which may act as temporary storage areas during flooding.
- Regular clearing and dredging of drainage channels and waterways.

One example of such practice is in the megacity of Dhaka, Bangladesh, where over a period of two years, the main landfill site, Matuail, was transformed. What was once and open dump subjected to closure during flooding is now a controlled landfill, with perimeter drainage, site roads, leachate management, landfill gas venting, site control offices and an electronic weighbridge (UN-HABITAT 2010).

4.6.5. The management of liquid waste and drainage

4.6.5.1. Sources of liquid waste

In most developing countries, liquid waste is generated by:

- Run off, especially during heavy rainfall events such as monsoons
- Human sources
- Industry, such as textiles and tannery processing.

Sewage is also a significant contributor, as it often provides a significant proportion of the base flow in rivers and drains.

The majority of drainage systems are combined, receiving both sewage and drainage water. The waste is often discharged into open unlined roadside drains, passing into enclosed drains and in larger cites into sewers, before being discharged (untreated) into the nearest water course. In many countries the open drainage water is diverted to irrigate crop fields, even in urban areas.

Drains can become blocked for a variety of reasons:

- Accumulation of sediment from runoff and sewage.
- Encroachment by vegetation.
- Disposal of household waste.
- The construction of unofficial encroachments and the poor design of civil engineering works
- Disposal of household sweepings, road sweeping.
- The disposal of waste by municipal employees.
- The disposal of industrial and commercial waste.
- Inaccessibility because of new development (for example, the construction of new roads).

Larger urban areas are likely to have well developed enclosed drainage systems in both the higher income areas and in the central commercial district. The drains through the outer suburbs and informal settlements are unlikely to be covered, however, and will typically discharge directly into the nearest watercourse. In developing countries, sewage treatment is often both rare and inefficient. The enclosed systems in the higher income and commercial areas are most susceptible to drain flooding because blockages are less noticeable and less easy to clear. The drains in poorer areas are the most susceptible to blockage because these areas are less well served by collection and drain cleaning systems, sometimes as a result of their remoteness or because narrow streets restrict access.

4.6.5.2. Treatment and disposal

Sewage in developing countries is often untreated and is discharged to the nearest water course; the water may be subsequently used downstream for irrigation or for domestic use, leading to further problems in these areas.

4.6.5.3. Drain cleaning

Cleaning and clearing of drains and other urban waterways is often undertaken by the same department responsible for street sweeping. The two functions, because of the lack of resources, tend to be concentrated in the central commercial district, with other less important areas having to provide for themselves. Such tasks are labor intensive and, typically, will only have rudimentary equipment. Perversely, the greatest contributors to blocked drains may be the same departments responsible for clearing them, because of improper sweeping and waste disposal practices.

An example of an innovative approach to the problem is seen in the city of Managua, the capital of Nicaragua. The city is sited on steep rugged terrain and formed of dispersed urban centers with areas of lower population in between. The recent accelerated growth led to deficits in basic facilities and services. In particular, the city identified that weak urban governance led to shortcomings in the refuse collection service. Since 1980 a system of micro-dams has been established with the dual purpose of attenuating floods and retaining refuse. Over 16 dams have been constructed, and research shows that these dams extract in excess of 500 cubic meters of sediment from the river system (Tucci 2007). However, the micro dams are poorly maintained, and there is no effective ordinance for land use planning to regulate new urban development as well as a lack of a Drainage Master Plan. This means that flooding problems continue to be a yearly event in several neighborhoods of Managua.

The reduced flood risk resulting from practices to both reduce the waste accumulating in waterways and to remove the waste already in a river is shown below in a case study drawn from a metropolitan Manila example.

Case Study 4.10: Save the Marikina River Project, Marikana, the Philippines

The Marikina River is a tributary of the Pasig River. It is one of the most important natural water systems in Metro Manila, and serves as the city of Marikina's main waterway. For decades the river was subject to uncontrolled encroachment, and also served as a disposal site for both domestic and industrial waste, causing significant environmental degradation and increasing flood risk.

In 1993, the 'Save the Marikina River' project was launched, with the aims of rehabilitating the watercourse and developing the city's largest recreational area. The project consisted of the following components:

1. Removal of informal settlements, commercial buildings and other industries from the riverside;

2. 109 hectares of land and a community mortgage program were provided for the resettlement of 10,500 families;

3. A strict disposal collection policy was introduced, which forbade solid waste being put out of houses at days and times other than that of collection; with a penalty for non-compliance, and;

4. Regular river dredging.

With regards to flood risk, areas that are prone to flooding have been reduced and floodwaters recede faster now. In 1992, before the implementation of the project, land exposed to flooding was assessed to be 6.36 km^2. By 2004 it was reduced to 4.4 km^2. In addition, property values have risen around tenfold in areas previously vulnerable to flooding with indirect benefits for the Local Government Units (LGU) in the form of higher property tax revenues. Although the project was successful in removing and relocating informal settlements in areas with improved access to basic service and infrastructure provision, water quality and the inflow of garbage from upstream areas still remain to be resolved.

The Marikina case provides a useful illustration of the effects of urban rehabilitation on urban flood risk management. Urban rehabilitation can form part of urban flood risk management schemes and help cities adapt to long term changes, to correct past mistakes and to increase flood resilience.

Sources: World Bank 2005; ADPC 2008.

4.6.6. Pre-emptive actions to minimize the effects of flooding on liquid waste systems

Sewage and drainage systems may exacerbate any flooding through:

- Insufficient capacity of the drainage design
- Blockages
- Contributing to water pollution.

Pre-emptive operations may include the following:

- Appropriate design capacity, especially of trunk drains
- Avoiding overloading existing drains with sewage and industrial discharges.
- Regular clearance of sediment and bank maintenance
- The use of open drains where appropriate. Whilst perhaps not always desirable on health grounds, blockages in open drains are more easily detected and easier to remove.
- Raising the ingress points of wells above predicted flood levels
- Raising pit latrines above the predicted flood levels, or fitting them with liners or concrete rings to minimize the ‘flushing’ of sewage into groundwater
- Constructing embankments around any treatment plants and fitting flap valves to sewer discharge pipes to prevent flood water accessing the sewers and causing secondary flooding.

4.6.7. Flood Waste

The principal objectives of managing waste deposited during a flood are as follows:

- To create or restore access to and within the flooded area.
- To facilitate reconstruction.
- To access buildings needed for flood emergency activities, such as hospitals and schools.
- To avoid obstructing later development because of poor disposal practices.
- To provide materials for post flood development.

In order to prevent waste from disasters rapidly consuming available landfill volume, practical diversion is a high priority. The waste hierarchy (Figure 4.11 above) provides a useful framework that may be applied to flood material, if segregation can be implemented at the point of clearance. Failure to do so will result in a waste of resource and considerably increase the volume of material for disposal. This topic is covered further in Section 4.11.

4.6.8. Solid waste management in informal settlements

Informal settlements are particularly prone to the general lack of solid waste services by the community and local government. These areas are also neglected when waste management plans are implemented, as municipal authorities may not see them as their responsibility or even as falling within their jurisdiction. Situations like this are aggravated further by the prevailing conditions in informal settlements such as a lack of access to dustbins; irregular collection from the dustbins which exist, resulting in overflowing; massive continuous dumping of daily wastes in nearby water bodies and drains; and low-lying and vacant lands and narrow roads and passages making the areas unsuitable for healthy living. There are many instances when, due to rain and overflowing of drains, wastes spread and cause diseases which give rise to health problems and render informal settlements uninhabitable. This problem requires a long-term solution. It is therefore important to know how such situations can be managed with the help and support of the local community and municipal government.

As seen above, municipal solid waste management incorporates planning, engineering, organization, administration, and financial and legal activities associated with the generation, collection, growth, storage, processing and disposal of waste materials, this occurring usually in medium to high income areas. However the same procedures are often not followed in informal settlements. Even when government has accepted the importance of solid waste management in informal settlement areas and provided community bins, their number is often insufficient, with up to 10 to 25 households sometimes sharing one bin (Chowdhury, 2007). There are also occasions when these bins are stolen.

Some of the proven methods for solid waste management in informal conditions are as follows:

Low-cost methods for solid waste collection from informal settlements

Many regular waste disposal systems are expensive and require regular payments for service providers. The effect of operational cost recovery for such systems and lower incomes in informal settlements are partly responsible for the lack of initiative towards paid waste disposal programs. Some low-cost methods have proven to be effective in many informal settlement areas:

- Door to door collection using hand carts, donkeys, and tricycle carts
- Take away bins in narrow lanes, shared and community bio-bins,
- Collection by lorry at the settlement entrance
- The setting up of collection centers outside shops and supermarkets

Door to door collection is easier in areas where roads are wide enough for movement. In other areas, community collection points are effective. Such systems are prevalent in Mumbai and Calcutta in India and Dhaka in Bangladesh. It is however important that the pickup timing, frequency and regularity should be maintained for the success of such processes.

Participation of informal settlement dwellers

Research shows that the majority of informal settlement dwellers has knowledge of waste management and is willing to pay for a cleaner, healthier environment.

Community members' willingness to pay generally increases when collection methods are flexible and inexpensive. These features are best delivered by the informal sector. Engaging informal settlement dwellers in the management of their own waste is a way to capitalize on this willingness to contribute – and also to design schemes suitable for the conditions. For example, the routine of waste collectors often does not match with the working schedule of residents. Establishing the best collection time or allowing waste disposal at the most convenient time is helpful. This solution requires adequate number of bins and frequent cleaning and restoration of the bins in case of theft or destruction. Giving responsibility to the local people for the safety and security of the dustbins can also be useful. Providing large waste bins can also stop theft and encourage community ownership.

Incentives can be offered for responsible waste disposal or recycling, as seen for example in Curitaba, Brazil, where fresh vegetables were offered in return for waste brought to disposal centers. Such practices can yield double benefits in also increasing the nutritional intake of informal settlement residents.

Incorporating informal rag pickers can be another way of motivating residents by generating income and increasing collection efficiency. The local municipality can encourage this activity by making such practices feature as a source of extra income. The sustainability of proper waste management systems depends on the maintenance arrangement of the authorities.

Reuse and recycling of wastes and generation of income

It is essential that waste materials collected from any source are converted to usable products: and this principle is no different in informal settlements to other areas. Collected wastes should be sorted and recycled based on their value. Sorting points should not be at the collection points as this increases littering and contamination (Jha, 2011). It is preferable to have separate collection systems or disposal points for recyclable and reusable wastes. Degradable and non-degradable wastes should be handled separately and composting should be encouraged. Local informal settlement dwellers should be trained and involved in such activities; payment arrangements can be made so that they can remain motivated.

The social status of waste collectors is generally low. To raise this status and generate awareness of the importance of such activities, cooperation among different governing bodies at the local level and with NGOs is required. Regulated fixed pricing of the collected waste and organized dumping are some of the important aspects that local authorities can consider. While doing so, informal settlements should be included in the system and proper information should be disseminated within the areas so that the residents are fully aware of the system.

Strengthening public private partnership for developing solid waste service delivery

Although the gaps between the problems and their solutions are often recognized, in many cases factors such as the supply of funds, manpower and organization of management bodies become major limitations. Capacity building to allow informal settlements to use their own resources and manpower, and utilizing institutional frameworks like those provided by local municipalities and NGOs can help in reducing these gaps.

Strengthening community services with cooperation from the local government can bring substantial changes to the level of solid waste management. The high density of populations in informal settlements can help in charging lower price for such services.

Cooperatives and micro-enterprises can effectively collect waste from hard-to-reach areas at low cost, using appropriate vehicles (USAID 2006). There are examples of small municipalities in Bolivia, Colombia, Costa Rica, Guatemala, and Peru that use informal arrangements, contracts and concessions to encourage waste collection and recycling activities by microenterprise and cooperative associations. The micro-enterprises or cooperatives can then bring waste to a centralized area for pick up by private or municipal trucks. Although these microenterprises or cooperatives are commonplace throughout the region, the arrangements with the municipalities are still at the incipient stage regionally, with some municipalities implementing them and others contemplating them.

4.6.9. Further reading

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4.7. Emergency planning, rescue, damage avoidance actions and temporary shelter

It is vital to recognize that even after the implementation of non-structural flood mitigation measures – as combined with the structural measures covered in Chapter 3 – residual flood risk will remain. It is of paramount importance to make plans to deal with flood events and their aftermath. This involves multiple activities which can be included as part of a flood emergency plan. In this section there is an overview of the elements central to emergency planning. Further details on other measures that deal with flooding and its consequences follow in Sections 4.8, 4.9, 4.10 and 4.11.

4.7.1. Emergency planning

Flood mapping as described in Section 1.4 will have already identified those areas susceptible to flooding. An appropriate and implementable emergency plan will:

- Facilitate emergency response.
- Minimize the impacts of flooding.
- Allocate resources efficiently.
- Reduce confusion.
- Facilitate recovery.

4.7.1.1. Identifying existing internal organizations

All countries possess existing institutions and organizations that, if coordinated, may be mobilized to meet individual emergencies. The purpose of the emergency plan is to identify these institutions prior to the emergency in order to:

- Identify roles and responsibilities.
- Identify command structures.
- Facilitate inter-agency cooperation.

The following organizations should be considered:

Table 4.5: Organizations involved during an emergency

Government organizations	
Police	To maintain order
Military	For security Evacuation by land, water and air Heavy machinery for the removal of debris
Other rescue services such as Fire, and Search and Rescue (if present)	Rescue Evacuation by land, water and air
Hospital authorities	To provide health facilities
Central or regional government	To manage the emergency relief effort
Municipal government	Local knowledge Waste management
Private sector	
Train companies (if present)	Provision of transport for goods and people into and out of the affected area
Transport companies	Provision of transport for goods and people into and out of the affected area
Bus companies	Provision of transport for people into and out of the affected area
Construction companies	Heavy machinery for the removal of debris
Mining companies (if present)	Heavy machinery for the removal of debris Specialist debris removing knowledge e.g. explosives
Civil Society	
Non-governmental authority structures (e.g. tribal if applicable)	Meeting specific needs Contributing to community cohesion Mobilizing communities Communication route
Civil society	Meeting specific needs Mobilizing communities
Religious groups	Meeting specific needs (although they may be more concerned with debating the theological implications of the disaster than assisting the victims)

The preparation of the emergency plan will help to identify barriers to cooperation, including authority structure and finance, which need to be resolved before flooding occurs.

4.7.1.2. Identifying appropriate external agencies

Some flooding events may be addressed using existing national resources but many countries do not have sufficient physical and human resources to address regional and national emergencies. It would then be appropriate to invite the assistance of external agencies.

There are numerous international agencies which can assist in the emergency phase of a flooding event. These include the following:

Table 4.6: Some international agencies which can assist in an emergency

United Nations (Coordination)	UN High Commission for Refugees (for those displaced in other countries). Office for Humanitarian Affairs and Emergency Relief Coordination of UN agencies for Internally Displaced People (IDPs).
United Nations (Specialist agencies)	World Food Program (WFP). UN Children Fund (UNICEF). UN Development Program (UNDP). Office of the High Commissioner for Human Rights.
International organizations	International Federation of the Red Cross and Red Crescent Societies (IFRC).
International Charities	These are too numerous to list but many may have in-country representatives.

The presence of international agencies may, however, overwhelm the host government with the risk that the latter may lose control of the relief effort. This, in turn, can result in the deskilling of local people who may feel it necessary to defer to the external agencies. It should also be recognized that the objectives of external agencies may conflict with those of internal agencies: for example, to 'showcase' their charity in high profile emergencies. Managing these agencies is both difficult and time consuming and may require considerable diplomacy.

The emergency plan should therefore contain detailed policies, identifying the roles and responsibilities and restrictions on invited agencies.

4.7.2. Damage Avoidance

Actions taken before a flood arrives can significantly reduce the loss of life and the amount of damage suffered. Pre-warning and evacuation planning should therefore be part of an emergency plan. It follows that an early warning system (see Section 4.9) is a central requirement for damage avoidance. Local flood emergency planning could involve, for example, the installation of temporary flood barriers, or the removal of zoo animals (as in the Cologne case study elsewhere in this volume). Deployment of some building design features, as described in Chapter 3, may also be dependent on warnings being issued.

It is necessary to mobilize personnel and machinery, where available, to protect infrastructure (such as dikes, levees and retention basins); to remove individuals from facilities at risk (such as hospitals, schools, industrial sites, bridges, or individual houses); and to prevent landslides and riverbank erosion. Strengthening and rehabilitation of existing structures and flood-proofing measures can also protect critical infrastructure. Such measures may include sandbagging or establishing temporary earth, wooden or other flood barriers, including mobile flood barriers (WMO 2011).

4.7.3. Flood emergency preparedness activities

To coordinate emergency procedures, a flood management unit (FMU) needs to be set up. Representatives from the local community should be included as members. The FMU will be responsible for developing a business and government continuity plan (BGCP) and for coordinating emergency procedures in a secure flood free location, as identified in the evacuation plan (see Section 4.10). The FMU can also be organized to serve as the local representative, focal point or community partner for wider river-basin level planning. Government continuity planning requires the community to effectively participate throughout the planning process. Participatory planning for emergency situations can help build trust and confidence among stakeholders, enhance cooperation, facilitate information sharing and encourage regular communication (WMO 2011).

Table 4.7: Flood emergency preparedness activities at various levels

Individual and household level
Build awareness about the risks: drowning, waterborne diseases, electrocution, poisonous animals
Install protective railings around houses, to protect children from falling into the water and to provide support for the elderly
Identify potential safe areas and potential routes to get there
Know what to do when a warning is received
Know whom to contact in case of emergency
Keep life jackets or buoys or tires
Keep first aid kits
Store clean water and food in a safe place
Listen to daily flood forecasts
Move valuable items to higher ground
Be prepared for evacuation
Protect livestock and other important assets
Community level
Identify and maintain safe havens, safe areas and temporary shelters
Put up signs on routes or alternate routes leading to the temporary shelters
Inform the public of the evacuation plan, and the location of safe areas and the shortest routes leading to them
Keep a list with important contacts such as district or provincial and national emergency lines, and identify a focal point in the community or village
Make arrangements for the set-up of teams in charge of health issues, damage and needs assessment
Set up community volunteer teams for a 24-hour flood watch
Improve or keep communication channels open to disseminate warnings
Distribute information throughout the community

Municipality, district, provincial or regional and national levels
Determine roles and responsibilities of each agency during response, relief and recovery
Prepare maps (flood risk, inundation, vulnerability and resource maps) to provide essential information and data on current situation, and to plan for assistance in those areas
Make sure that critical roads are built up to an appropriate height, to create safe areas for flood-affected communities and to ensure continuous transportation critical for flood relief
Identify safe areas and maintain existing shelters, making sure they have sanitary and other basic necessities
Implement public awareness activities; be pro-active
Educate the public on what to do, and what not to do, to prevent harmful activities in floodplains and other flood-prone areas
Prepare resource inventories, identifying how much is available locally and how much is needed from outside
Plan resource mobilization
Set up emergency teams (for example, health, search and rescue teams)
Conduct drills (exercises) for search and rescue teams
Make sure that communication channels to the community are functioning well
Check flood mitigation infrastructure (e.g., dykes, levees and floodwalls) as well as other key infrastructure (e.g., roads, dams)
Disseminate public safety information through the establishment of early warning systems
Specify the source and actions to be taken immediately after receiving warnings.

Source: Adapted from WMO 2011: 6-7

At a household level a number of strategies can be adopted which will reduce damage as a result of flooding. Including the following:

- The identification of household escape routes
- Installation of temporary flood proofing
- The identification of elevated buildings (or even mature trees) that can be used as safe havens
- The moving of property to higher levels
- The storing of emergency provisions
- The use of non-flood impacted communications such as radios, mobile phones or even prearranged signals in order to share information
- The removal of vehicles from the area: their use in the post-flood situation is invaluable.

4.7.4. Evacuation and Rescue

Before the event, and during the first stages of the emergency, the rescue of those affected by the flood will be dependent on existing resources. The emergency plan should identify those resources, including transportation, fuel supplies, and available high ground not threatened with subsequent flooding on which those rescued may be left, along with the equipment required, and how to store and secure it. Evacuation planning is described in Section 4.10.

4.7.4.1. Flood shelters and refuges

The flooding event is likely to have destroyed the homes and livelihoods of a number of people. An estimate of the number of people requiring shelter should be made, taking into consideration the resilience of the housing in the areas affected, the extent and type of flooding and the likely survival rate. The methodology for updating this estimate immediately after the emergency should also be defined. It should be remembered that, depending on the length of time by which the warnings preceded the event, and on the available resources, many families will have left the area to stay with friends and relatives. The number of survivors is likely, therefore, to be greater than those requiring assistance. In the short to medium term, this number is likely to increase as families may return to protect their property even when conditions may be unsuitable.

Alternative accommodation will be required for the survivors as described in Section 4.10.

4.7.4.2. Emergency food supplies

Flooding is likely to have destroyed existing food supplies and local agricultural produce. Prices are likely to rise locally and even nationally in response to a significant flood event.

The emergency plan should identify:

- The most appropriate types of food considering local tastes, culture and the available equipment and fuel for cooking.
- The likely quantities based on the calculated number of survivors.
- The food suppliers and the likely cost.

The food allocation should seek to meet SPHERE standards (The Sphere Project 2011).

4.7.4.3. Emergency water supplies and sanitation

The flooding will have destroyed existing water supplies and sanitation infrastructure, where applicable; any overflow of sewage will also have polluted water supplies. The emergency plan should therefore identify alternative water supplies, preferably gravity-fed to avoid the need for pumping. The tankering of water is a very short-term solution which uses vehicles and fuel which could be more beneficially employed elsewhere.

Similarly, sanitation should be provided close to the displaced population, away from the source of water supply and on unsaturated permeable strata to allow sufficient drainage. These factors should be taken into account when locating refuges and other areas of residence.

4.7.4.4. Social dislocation

In the disruption following a severe flooding event, many families and communities will be separated, often leading to a lessening of social cohesion. The emergency plan should identify the responsible organization and methodology for families and communities to locate and communicate with each other; all the media available after the flood should be utilized, such as notice boards, mobile phones, land lines, news-sheets and radio as applicable.

4.7.4.5. Access

Flooding may affect both roads leading to the flooded area as well as those within it. This can include blockages of debris and silt, as well as flooding or washing away.

The emergency plan should therefore identify the following:

- Access roads to and within the flood zone, avoiding low bridges over rivers, low-lying areas, roads susceptible to land slippage (in cases of flooding caused by heavy precipitation) and highlighting those not susceptible to crime and insecurity.
- The design and location of permanent signage on principal road routes. The use of symbols avoids the difficulties of literacy and language.
- Suitability of road, railways and airfields, where available, for longer distance transport of supplies.
- Suitability of ports near main shipping lanes, with sufficient depth and with suitable loading and unloading facilities for international vessels.

4.7.4.6. Clearance

Floods deposit large volumes of debris and mud, the clearance of which is essential for the relief effort. The emergency plan should identify how the debris and mud is to be cleared, by whom and where is to be deposited. This is dealt with in greater detail in Section 4.12.

4.7.4.7. Emergency health facilities

Flooding may generate a range of injuries. The emergency plan should identify:

- The suitability of public buildings to act as preliminary treatment centers (such as schools, government offices or similar).
- Existing hospital facilities, away from the likely flood area, that may be developed with specialist services and equipment.
- The method of evacuation for those with more serious injuries.
- A system of vaccination.
- The suitability of public areas (such as parks and schools), for the siting of mobile clinics units, temporary camps and distribution centers.
- The provision of power, as electricity supplies (where these exist) are likely to have been severed.

Photo 4.1: A school is used as an aid center. Haiti 2004. Source: Peter Lingwood

4.7.4.8. Energy

It is likely that the floods will destroy access to energy resources, be they electricity or, in less developed areas, other forms of fuel including wood and animal dung. The emergency plan should identify:

- The local fuel resources and their continued accessibility during and after a flood.
- Alternative sources of energy (for example, generators) and the fuel to run them.
- Key institutions such as hospitals which should be supplied with these alternative sources and the methodology for ensuring their continued availability between floods.

4.7.4.9. Security

Emergency situations, and the breakdown of the normal standards of society and their enforcement, often create opportunities for theft and corruption.

The emergency plan should therefore include:

- The securing of the facilities identified in the emergency plan, between and during flood events.
- The visible deployment of reliable security forces immediately post flood to deter looting.
- External auditing of government functions for efficiency and probity.

4.7.4.10. Preparatory exercises and maintenance

Between flood events both an annual audit, and an exercise to implement the flood emergency plan, should be undertaken. This will help to identify changes since the previous year and assist in institutional preparedness. The problems identified should be rectified and the emergency plan comprehensively revised, at least every five years.

The maintenance of relevant systems is discussed in Chapter 6..

4.7.4.11. Further reading

Corsellis, T. and Vitale, A. 2005. Transitional settlement: displaced populations. Oxford: Oxfam Publications.

The Sphere Project. 2011. Sphere, humanitarian charter and minimum standards in disaster response.

4.8. Business and government continuity planning (BGCP)

After a flood disaster, some organizations, mechanisms and sectors may be able to continue to deliver their most critical services. Others may find it much more difficult to perform effectively under the adverse consequences of a flood disaster. It is important to assess the ability of individuals, government and non-government organizations, mechanisms and sectors to continue to perform critical functions under different flood scenarios. Depending on the result of this assessment, priority should be given to repair public infrastructure or maintain services that would experience a higher degree of operational problems in an emergency.

For example, the 2011 Mississippi floods in the US caused supply chain problems when freight terminals along the Lower Mississippi had stop their operations because of high water. Flooding in 2011 in Brisbane, Australia, left thousands of households without power; the electricity providers had to deploy backup generators in some of the flood-affected areas to respond to power outages. Business continuity is not only important in terms of serving immediate public needs but also to ensuring the continued economic prosperity of a flood affected area and avoiding the long- term economic impacts associated with flood-induced business failure.

BGCP ensures that essential services and critical infrastructure will continue to operate should the impact of the flood become more severe. It is a planning process which provides a framework to ensure the resilience of an organization, mechanism or sector to a disaster, and ensures that, when faced with disruption they can carry on, or resume operations with minimum delay. It is better to plan ahead for a flood disaster which may affect the operational integrity of an organization or sector, rather than having to react to a disaster when it occurs.

The objective of a BGCP is to make an organization or a sector less vulnerable to and reduce the impact of adverse events such as floods. Most importantly, the plan ensures to the maximum extent possible the continuity of critical operations to:

- Provide public safety
- Reduce disruption to essential government functions
- Minimize loss or damage to public and private infrastructure, as well as individual property.

Figure 4.12 illustrates the process for developing a business and government continuity plan.

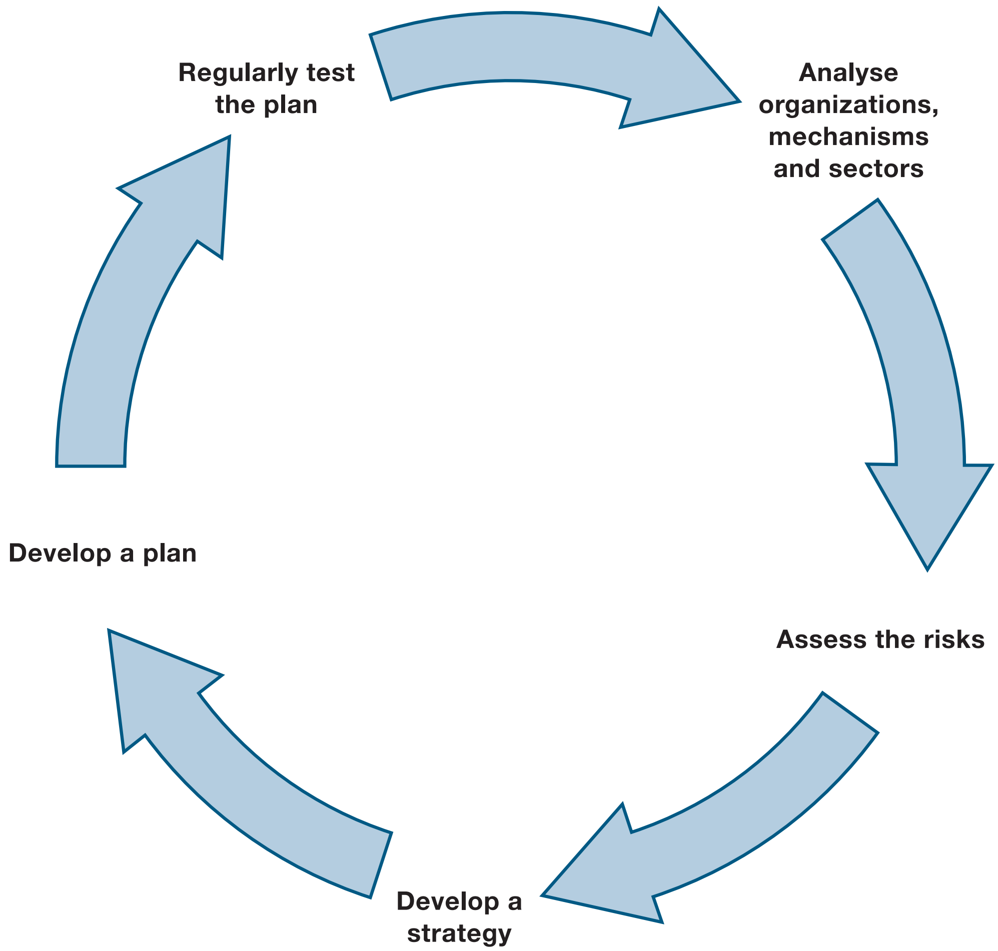

Figure 4.12: Business and government continuity planning process

4.8.1. Relevance to the private sector or the public sector

Emergency action plans are necessary for both the public and the private sectors in order to reduce their exposure to flooding. These plans can increase their resilience to cope with adverse consequences both during and after a disaster.

Government and business continuity plans should be adequately linked to disaster management institutions and mechanisms at the local, district, state and national levels. Local communities should be allowed to be active in developing and enacting flood emergency plans and to implement their own measures to reflect local conditions, real needs and priorities on the ground. Flood emergency preparedness activities vary from the individual to the national level. In addition to government bodies, the private sector and NGOs, as well as other aid organizations, are strongly encouraged to prepare continuity plans and incorporate flood risk components within them.

The initial investment required for flood risk reduction may, however, be considered as a costly and non-profitable activity for many businesses and governments. Investing in contingency planning may require cutting or reducing funding for other routine activities and this often discourages businesses (particularly smaller enterprises) and governments, from putting such plans in place. For this reason, coordination amongst all stakeholders, including between the public and the private sectors, is important in order to develop BGCPs that will effectively reduce the impacts of flooding to their vital assets, and at the same reduce the cost for contingency planning for all individual actors.

Continuity planning, however, should not be considered as an activity that only businesses and governments have to undertake. Individuals and households should also develop their own action plans, and most importantly, they should actively participate in all processes undertaken by other actors to develop such plans. It is also important to bear in mind that different actors exhibit varying levels of vulnerability; action plans will, therefore, be required to appropriately integrate individual needs and priorities in an adequate and effective manner. The factors shown in Figure 4.13 can be used to inform the basic process of action planning, to reduce vulnerability to flooding, and maintain continuity of critical operations.

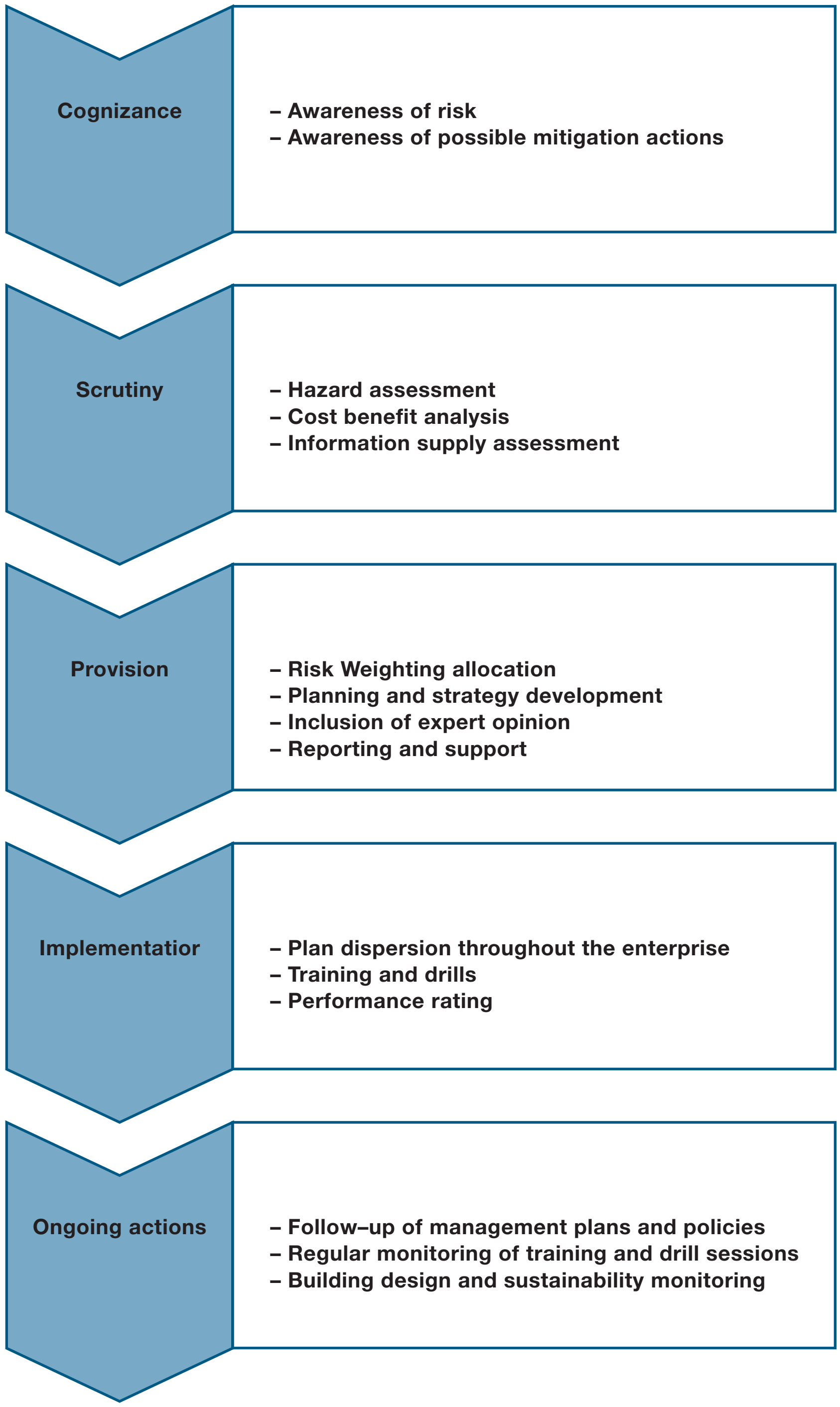

Figure 4.13: Components of an action plan for business and government continuity planning, Source: adapted from Bhattacharya et al. 2011

4.8.2. Minimizing flood damage risks

To minimize the risk of flood damage, public and private infrastructure should adopt appropriate architectural design, as covered in Section 3.9. Moreover, relocation of infrastructure and property built in locations exposed to floods should also be considered. However, decision makers and technical personnel require tools which can help them to consider the costs and benefits of such measures, which is covered in Chapter 5.

Protection of critical infrastructure is likely to be the most important task that businesses and local authorities have to consider. Providers, of essential services that are exposed to flood hazards, whether state-run or private companies, should adopt a range of measures (both structural and non-structural) to manage the risks. In the UK (CLG 2006), use is made of the following hierarchy of flood risk management measures:

- Assess
- Avoid
- Substitute
- Control
- Mitigate

Avoidance is a key non-structural mitigation measure for development of new infrastructure and should be a fundamental part of the land use planning process discussed earlier. Other non-structural measures available to an infrastructure asset manager's toolkit include redundancy reserve capacity, flood forecasting and warning, incident management, and emergency exercises.

Designing infrastructure that is robust to flooding, and can therefore be sited in the floodplain without increasing risk, is a possible approach to reducing damage. It can be seen as robust to the uncertainties of future risk assessments. If such adaptations can be made cost neutral for new infrastructure, this could make a major contribution to reducing future risk. The use of raised construction and services, micro-generation (also raised) and resilient materials may help.

The protection of infrastructure via structural measures in the form of fixed defenses which can include floodwalls or embankments (as covered in Chapter 3) also requires consideration. Design and construction of flood defenses is a specialized field requiring input from hydrologists and geotechnical and civil or structural engineers. Temporary and demountable flood defenses are another form of structural measure that can be used to protect infrastructure, but there are important issues around understanding and minimizing the obstacles to their successful deployment. It must also be recognized that the whole-life costs, including operational and maintenance costs, are likely to be higher for these systems than they are for fixed structures.

Businesses are disrupted not only by the direct physical impact of flooding but by the wider effects of damage caused to infrastructure, inventories, vehicles, equipment, and documentation. In addition, there is disruption of services like electricity, gas, telecommunication and transport facilities. Smaller and often economically more vulnerable enterprises suffer more, the reason being financial incapability to build flood resilient infrastructure, dependency on smaller markets for profitability and the lack of resources and knowledge for capacity building. Sometimes it is possible for certain enterprises to let their employees work from another location, but it is industry specific and not suitable for many businesses. An enterprise with higher efficiency of employee replacement will succeed in such situations.

Businesses having a larger market and higher financial capability are in a better position to recover from disaster than their smaller counterparts. This is because they can disperse their risk factor across multiple locations due to larger market capacity. The resilience factors for large enterprises work well since they are financially capable of building high priced resilient infrastructures for enhanced protection. They are also better able to afford hazard insurance, separate contingency funds and other insurance which are the prerequisites of any business continuity plan to cope during the disruption period and get back to a pre-disaster situation as soon as possible. This attribute is sector-specific in nature and differs largely on the level of exposure and vulnerability of the specific businesses towards flooding.

Insuring those properties that are under-insured, or not insured at all can help speed recovery. Organizations at higher risk may face problems in getting insurance, due to the high rate of premiums; others do not have the option of obtaining insurance at all, especially in developing countries. Receiving early warning of potential flooding lessens dependency on insurance companies for total recovery. Individual reactivity in reducing vulnerability from flooding by adopting resilient measures, together with proactive organizational and governmental help in recovery, are factors that can help with early recovery from business disruption.

4.8.3. Further reading

WMO. 2011. Flood emergency planning: A tool for integrated flood management. Associated Program on Flood Management.

4.9. Early warning systems

The purpose of early warning systems (EWS) is simple. They exist to give advance notice of an impending flood, allowing emergency plans to be put into action. EWS, when used appropriately, can save lives and reduce other adverse impacts. Actions taken after flood warnings which can yield direct benefit are summarized in Table 4.8.

Table 4.8: Actions after warning that yield direct tangible benefit. Source: adapted from USACE 1994

Action	Description
Temporary removal of property from floodplain	Floodplain property owners can move belongings such as televisions, stereos, computers, important documents and personal memorabilia
Moving property to a safe elevation within the floodplain	Residents and businesses occupying multi-storey buildings may have the opportunity to protect moveable property by relocating it from basements and ground floors to higher levels
Temporary flood proofing	Warnings issued with sufficient mitigation time allow property owners to temporarily flood proof property with, for example, temporary closures of windows and doors. These activities can reduce flood damages by preventing inundation.
Opportune maintenance	A warning system can provide officials and individuals with more time to undertake opportune maintenance such as closing a shut off valve on a gas line, halting discharge of certain materials into the sewer system or safeguarding water supplies and sewage treatment plants.
Early notification of emergency services	Increased warning time can reduce the cost of emergency shelter and emergency care as individuals have more time to arrange to stay with relatives, friends or elsewhere. The cost of public assistance and long-term emergency can be reduced if the evacuees have time to secure their property and prepare before evacuation. Communities with limited emergency personnel and other resources will benefit from additional time to ready emergency services.

Orderly disruption of network systems	Warning and response systems offer opportunities for network systems (phone systems, utilities, pipelines, cable TV services, transportation patterns and traffic levels, and local area networks) to prepare for disruption in a more orderly and cost-effective manner. With sufficient warning time, businesses may make alternative plans for their network services.
Suspension of sensitive works	For products that require lengthy production processes, sufficient warning times may provide the opportunity to suspend the production processes to minimize the destruction of the product or minimize the possibility of hazardous materials seeping into the floodwater. Similarly sufficient warning may allow crews to sequence repair work in a way that minimizes disruption to a utility.
Related effects of emergency cost, cleanup cost and business losses	Warning systems may reduce emergency costs and cleanup costs by allowing emergency responders and residents to take preventative actions. Similarly, warning systems may allow for reduced unemployment and income loss, smaller losses in sales, and smaller reduction in taxes collected by increasing the chances of a quick recovery. The costs for flood insurance may be reduced as warnings result in decreases in the amount of coverage required by residents and businesses
Traffic Control	Advance flood warning may provide the opportunity for authorities to decide which roads to close and which to keep open before flooding begins. Traffic can be re-routed in a more efficient manner and personnel can be deployed in a timely manner to block access to potentially dangerous areas as well as to direct traffic onto safe detour routes.

An example of an EWS saving lives and reducing impacts is the Binahaan River Local Flood Early Warning System in the Philippines. Since the system became operational people believe that the low level of damage is due to the warning system (Neussner et al. 2008). The Binahaan River Local Flood Early Warning System Operation Centre (2009) noted that in 2008 there were five uses of the system and three floods, which involved no loss of life due to timely deployment of boats for evacuation.

Another example comes from a teacher, quoted by Gautam and Khanal (2009):

"With the careful use of EWS devices and application of the skills and knowledge we gained through various trainings and exposures, we made sure that no human casualties were reported in our communities although 24 people died in adjoining communities where EWS was not in place. These figures show that if local communities are prepared sufficiently in advance, the impact of flood can be reduced dramatically."

Although it did not involve the use of a meteorological forecast, a successful example of Togo's early warning communication system, which was developed in response to 2008 seasonal forecasts, was demonstrated by the small community of Atiégou Zogbédji located north of Lomé. When river levels were identified as dangerously high, the community leader went through the flood-prone community with a loudspeaker, spreading the message that floods were coming and asking people to evacuate. With just an hour and a half's notice, the population of 2,000 was able to leave. When the floodwaters arrived, physical damage occurred, but not loss of life.

Developments in forecasting and risk assessment which have been discussed in previous chapters have laid the groundwork for developing increasingly timely and accurate warnings with longer lead times. Warning systems can be used to alert relevant authorities or the public or both. The scale of a warning system can be national, based on a river basin, or local and run by volunteers. Most are stand-alone national operations, but warning systems have been developed covering several international rivers, such as the Rhine, Danube, Elbe and Mosel in Europe, the Mekong, Indus and Ganges-Brahmaputra-Meghna basins in Asia and the Zambezi in Southern Africa (United Nations 2006). However, the utility of EWS is crucially dependent on the underlying forecasting system, the quality of emergency plans and the level of preparedness of the community at risk. The quality of forecasting is also dependent on the nature of the hazard. Warning systems related to river flooding have a longer lead time than those for cyclonic events; seismic induced tsunamis may have very short warning periods. Forecasting flash flooding is also very problematic; this has implications for developing nations which are more exposed to such risks, due to the prevalence of monsoon type flooding. Whilst there is general agreement about the desirability of EWS, the implementation of such a system is necessarily subject to local factors.

4.9.1. Essentials for an effective EWS

The four main essentials for any flood warning system are:

- Detection of the conditions likely to lead to potential flooding, such as intense rainfall, prolonged rainfall, storms or snowmelt
- Forecasting how those conditions will translate into flood hazards using modeling systems, pre-prepared scenarios or historical comparisons
- Warning via messages developed to be both locality- and recipient-

relevant and broadcasting these warnings as appropriate

- Response to the actions of those who receive the warnings based on specific instructions or pre-prepared emergency plans

Photo 4.2: Detection and measurement equipment Samoa and India.
Source: Alan Bird

Failure in any one of the four key elements of an EWS will lead to a lack of effectiveness. Inaccurate forecasts may lead to populations ignoring warnings issued subsequently.

The lack of clear warning and instruction may have resulted, for example, in the deaths of people escaping the Big Thompson Canyon flood in the US in the 1970s. Without clear instructions many people were killed trying to drive out of the canyon rather than taking the safer option of abandoning cars and climbing to higher ground.

Finally, the case of Hurricane Katrina demonstrated the scenario where clear advanced warnings failed to protect the population because the evacuation planning was inadequate. .

4.9.1.1. Possible responders to warnings

May stakeholders can influence the way a flood event is handled and the resultant impact. The list of stakeholders usually includes:

- Government (local, regional, national or international depending on the scale of the incident and the catchment). Governments will usually be the first to receive warnings and will put into action their carefully prepared procedures. Often this may involve categorizing the forthcoming emergency and authorizing emergency powers and resources. For example, the decision regarding whether to begin evacuation of an area often rests with local authorities.

- Emergency services and responders. Emergency services and responders will begin to mobilize and relocate their resources and staff.
- Public affected. Where the public is prepared, for example with temporary protection measures or evacuation plans, they will need adequate warning to put these into action.
- Local industry. Businesses can begin to put in place their business continuity plans and warn their staff.
- Voluntary organizations. Such organizations play a very large role in supporting emergency services and will also need to deploy their personnel and resources in the most appropriate and efficient manner.
- Water and drainage authorities. With sufficient notice water authorities may have a role to play in mitigating the speed, severity and duration of inundation. However, they may also need to protect or rearrange their facilities, to ensure the continued supply of essential clean water.
- Utility providers. Where the utility sector has emergency plans to protect and divert services, adequate warning enables such plans to be carried out.

As these and other potential responders will have different information requirements, these needs should be integral to the design of EWS. The most basic and optimal requirements should be understood and the capacity of the detection and forecasting systems be adequate to supply the information assessed.

4.9.2. Needs of responders

It is not possible to generalize regarding the needs of responders or warning messages as the information requirements will be entirely dependent on the specific plans and actions which the warnings will trigger. However, some illustrative examples will show typical lead times and the information that is required.

Local flood warning systems in Fiji are in the process of being upgraded. The Navua system was installed in 2007, initially to provide up to three hours warning of flash floods. It is hoped that this can be extended to six hours in the future. The benefits of the Navua system are predicted to be almost quadruple the costs of installation and maintenance (Woodruff and Holland 2008).

The time taken to evacuate will naturally depend on the number of evacuees and the distance they must travel. Evacuation time is divided between preparation, (which may involve installing protection or moving items upstairs, locating family members and pets) and implementation time (travelling from the area at risk area to a place of safety). Places of safety may be a local shelter or a distant evacuation center; for example, in Hurricane Floyd, which struck the US in 1999, departure times varied, as some people left before official warnings while others stayed until the last moment. Once in transit, average time to the safe destination was nine hours.

Installation of flood protection can take less than half an hour but some systems take longer. The time required to move different items was estimated within the Philippine manual (Neussner 2009) and is shown in Table 4.9.

Table 4.9: Time estimations for moving different types of items

<30 minutes	<2 hours	<4 hours	>4 hours
Television	Karaoke	Large appliances such as a refrigerator	Big oven, freezer
Stereo equipment	Microwave, small stove, toaster	Bookcases, dining furniture	Kitchen utensils
Small electrical appliances	Items in cupboards	Carpets	Beds
Personal effects	Expensive clothing	Additional clothing and personal effects	
	Vehicles	Chickens, pigs	

Source: Neussner 2009

4.9.3. Organizational aspects of flood warning dissemination

It has been noted that there are often multiple sources of flood warnings (ADPC 2006) and that this can be confusing or misleading. For example, separate weather reports and flood alerts may generate confusion. The most desirable situation is that all official warnings, however disseminated, should come from the same source and therefore be consistent. For this to occur there needs to be a clear chain of authority for warnings whereby the necessary information is collated at the appropriate spatial scale and a clear decision process authorizes the release of warnings to potential responders.

There are multiple communication channels by which a flood warning may be broadcast and the choice of media will vary depending on the intended recipients. It is also essential to consider the use of media that will be robust to the impacts of a flood. Formal protocols may exist, via secure dedicated servers or emergency radio frequencies, to allow for exchange of warnings between professional responders.

For the public the number and variety of possible outlets are vast. For example:

- Telephone; text; fax ;pager; email warning service
- Local and national television, press and radio
- Sirens
- Loudhailers
- Drums
- Flags
- Flood warden service
- Internet
- Telephone information service
- Road signs
- Posters
- Word of mouth

The most successful warning services use a combination of media, ideally with consistent messages and timescales, as well as the response the message hopes to initiate. For example, an individuals whose home is likely to be flooded will probably react best to a personal message either via phone, fax or in person; people who should avoid travelling to or through an affected area may prefer a news bulletin backed up by an internet or press map of the affected area.

4.9.4. Appropriate message content

Message content must be appropriate to the context and understanding of the responder. In general, the general public has difficulty in interpreting flood warning messages which are technical in nature.

For a public message the essentials should include

- Clear initial opening line
- Specific local context of where it is going to flood
- Severity of the impact of flood
- Actions people should take
- Timing of the expected flood; how long people have to act
- Language that conveys the appropriate urgency
- Where to get further information
- Repetition of the most important points (if orally delivered).

The clear opening line is essential to catch the attention and alert the listener to the importance of the following information. Repetition is always helpful as this allows for maximum comprehension.

Local context must be comprehensible to the population affected. Recent research in the UK showed that the language used by technical staff about river catchments is not meaningful to local populations (Pitt 2008).

Severity may be indicated by depth, velocity or by reference to a past flood of known or recognized severity. Alternatively, a system of codes may be appropriate: for cyclones in the Bay of Bengal, for example, there is a standardized warning system using numbers and flags.

The most important aspect of the warning is that the message should detail specific actions to take or trigger action in some other way. For example, specify the precise time available to implement a personal flood action plan, if they are common in the population, or refer the individual to the agency which can give emergency instructions. The instructions should be clear and not contradictory. For example, an instruction to: “Listen to your radio or look on the Internet for more information” included in the same message as “Turn off your electricity” can lead to confusion.

Timing aspects are crucial and the message should change in the run up to the event to recognize that actions appropriate well in advance should be abandoned as the water arrives.

Urgency should be conveyed in language that is precise and clearly understood. For example, early in an alert less certain warnings should use words such as “Flooding is possible” and “You should keep an eye on the situation”. Later on it will be necessary to use more certain or hazardous flood warnings and should use words such as “Flooding is expected” or “You must prepare to evacuate”. Another example of different warning levels is shown in Figure 4.14 (Neussner 2009).

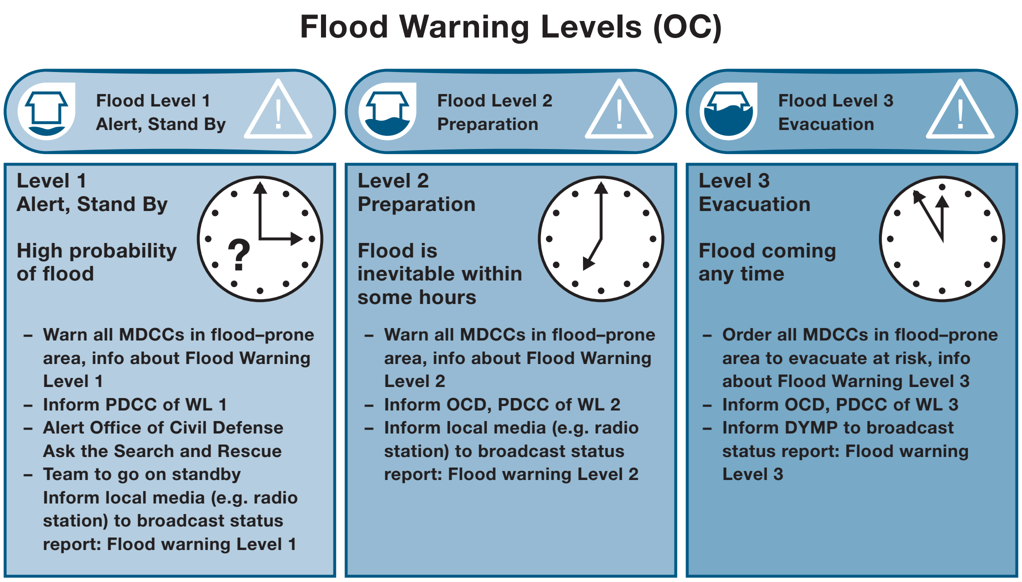

Figure 4.14: Flood warning levels, Source: Adapted from Neussner 2009

4.9.4.1. How to develop an EWS

Early warning systems should be designed in consultation with responders and forecasters to allow assessment of responders’ information needs and the capability of the detection and forecasting models to meet those needs. Where the warning system would not be capable of supplying sufficient warning (which may well be the case, for example, in flash flood situations) it will be necessary to reconsider whether a different measure would be more cost effective.

Method

1. Needs and Applicability analysis

2. Definition of stakeholder group

3. Establishment of stakeholder needs

4. Define warning levels for responders

5. Establish warning center

6. Determine communication media

7. Purchase and distribute equipment (if necessary)

8. Set up warning service

9. Train staff in warning communication

10. Register users of warning services

11. Carry out drills

1. Needs and applicability analysis

Need is determined by the frequency and severity of flooding, the vulnerability of the population at risk and the adequacy of the current or indigenous practices. Applicability is dependent on the type of flood, particularly the predictability and speed of onset, lead times will differ for different causes. Are the indigenous or current practices sufficient or not and do they have specific features which would be useful to adopt in any new system. Capacity to provide warnings consistently over time and to respond to warnings is also a factor to take into account.

2. Define stakeholder group

Stakeholders may include Government, Forecasting groups, Responders, Community groups, Householders and businesses. Representatives of these groups need to be engaged from the start of the process to ensure that all views, needs and capabilities are accounted for.

3. Establish responders' needs

Different responders' needs are related to their mobilization and evacuation lead times as a warning that comes too late to be acted on is of no use. Some responders may be more tolerant of false alarms. Consultation either on a one to one oras part of participatory emergency planning exercise can establish responders needs. Thereby objectives and performance indicators can be developed and the feasibility of developing a suitable system be established in advance of major investment.

4. Define warning levels for responders

Pre-defined warning levels add to the clarity of communication. Clarity of message is necessary for responders to judge the appropriate action level. The definition of warning levels can be part of the consultation or planning exercises used to establish needs. Ideally there should be a single system which conveys likelihood, severity and urgency. Things to consider are: Appropriate language, will everyone understand the message, the use of graphical information or color coding, whether actions are voluntary or compulsory, are there other warning systems which could share the same warning levels or be confused.

5. Establish warning center

The scale and scope of the warning center could be national or at a local level. Available funding, forecasting capacity, spread of risk, vulnerability and cultural or historical factors will influence the choice of local or national warning systems. The center must be seen as a trusted source of information which may require it to be situated in an established ministry or other command structure. Importantly the physical location should not be in an area at risk from flooding and there should be good access and infrastructure with emergency back up facilities.

6. Determine communication media

Identifying responsible authorities with defined roles increases the capacity to disseminate warning information on a well organized manner. While the message should be consistent for all communities the media for communication will be different for different communities. There may be oral or visual methods of communication, for example flags of different colors, sirens, media broadcasts. Consultation will establish the preferred option for communities at risk and it is vital to include representatives of hard to reach and vulnerable groups. The use of mobile phones is likely to be an increasingly important communication option as their use is prevalent in many otherwise isolated areas. It is vital to have at least one communication route which is resilient to the impact of serious flooding on infrastructure such as power distribution and telephone cables.

7. Purchase and distribute equipment if necessary

Responders to warnings have a vested interest in obtaining the best equipment to receive and process warnings. Sometimes this may involve some investment in new equipment. Systems should be designed to use low cost easily sourced equipment wherever possible and the cost of equipment carefully balanced against the effectiveness. Other considerations in the choice of equipment are: the expertise of the operators; locally available resources and local knowledge; the ability of responders to provide a resource base in a collaborative manner.

8. Operationalize warning service

Operationalizing the service involves linking all the elements of forecasting and warning described in order to technically provide a warning service. A parallel programme of publicity for the presence, objectives and warning practice should result in responder and wider community engagement with the system. Awareness of the system and the need to respond to warnings must be generated.

9. Train staff in warning communication

Large numbers of trained staff are needed and regular reviews of trained numbers should be undertaken. Staff will need to be available around the clock and to work at short notice should an incident threaten. Involvement of local volunteers can be effective if these individuals are well trained. Alternatively staff with back office roles can be diverted to warning services in the event of a flood.

10. Register users of warning services

Responders to or users of the system need to be registered and their communication preferences recorded. Registration may be voluntary or compulsory, it may be appropriate to levy a charge for commercial users but the cost for domestic and vulnerable populations should be negligible. An opt out system can be useful in maximizing participation but will not guarantee action as engagement may be lacking.

11. Carry out drills

To test the system, that all the elements such as lead time and communication equipment are appropriate some drills or dummy exercises are needed. It is important to strike a balance between preparedness and not being accused of ‘crying wolf’. Training and drills keeps the system prepared for the actual event. Therefore it is of immense importance that regular drills are managed and monitored.

Costs and resources

Setting up a warning system may be a low cost option for countries and is often seen as the first line of defense for that reason. The cost will be lowest in nations with existing and adequate forecasting and monitoring services. In this case the setting up of a warning center can be a very low cost process and this can be quickly established during consultation and stakeholder identification.

Setting up adequate forecasting and monitoring serviced can require much larger investments in expertise, software and hardware for modeling and monitoring equipment. The lead time to establish forecasts of the required reliability and timeliness may be a deterrent.

Once established the service will require continuous investment in manpower, data and other resources in order to be functionally useful. Recruitment and retention of qualified personnel, continuity of funds and operations and maintenance of monitoring, modeling and dissemination equipment can be key challenges in the long term sustainability of systems. This can be particularly acute for low frequency events.

4.9.5. Further reading

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4.10. Evacuation planning

To minimize the loss of lives and reduce other flood impacts, an area should be evacuated when the depth of standing water due to flooding is already or is expected to become high. Such floods are defined as those which are expected to cause buildings, including residential houses, to be washed away or seriously damaged by the flooding.

4.10.1. Organizational aspects of evacuation planning

An interdisciplinary planning organization must be set up covering the key institutions that have remits relating to disaster and specifically flood management. This organization can be a Community Flood Management Committee (CFMC). In addition to the CFMC, evacuation centers should also be established in appropriate settlements.

The members of the CFMC should have knowledge of evacuation and rescue operation and emergency, including medical care (if this is not the case, then basic training should be provided to them). Evacuation plans should be prepared after discussion with the community. Participatory planning will increase people's awareness and ability to cope and manage flood risk. The evacuation plan should be available to all members of the community, including the most vulnerable.

Dissemination of information on flood risk and flood preparedness requires the organization of regular community meetings. Such meetings can take place before the onset of the rainy season, or monsoon. It is vital that evacuation drills will be held regularly to test the effectiveness of the evacuation plans.

The evacuation plan should delineate an escape route and also identify small-scale works that may be needed to make the route safer. Such works can be executed in cooperation with the community as well as with external support. The evacuation plan should also determine modes of transport and access routes for evacuation and rescue operations and relief projects. In addition, the evacuation plan should identify open spaces and buildings to be used as evacuation centers. These can function as described by Arnold, Chen, Deichmann et al. (2006: 149).

- Temporary shelters and refuges
- Hospitals, possibly in existing buildings with stored supplies and basic medical equipment
- Information centers, with uninterrupted linkages to

the central communications system

– Supply distribution points for basic survival supplies, such as water, food, and blankets

– Sanitary facilities, including toilets, showers, and waste disposal units.

To develop evacuation plans and carry out the tasks outlined above, maps showing the most exposed areas to flood risk should be available. Chapters 1 and 2 provide guidance on how to prepare a flood hazard map and a vulnerability map. EWS should also be in place to give advance notice of an impending flood allowing evacuation plans to be put into action (as discussed in Section 4.9). Even when a flood is not as severe as predicted, these preparations help test evacuation plans and inform the communities as to the nature of flood risk.

4.10.2. Provision of flood shelters and refuges

As stated in UNDP (2009:36):

"Shelter is likely to be one of the most important determinants of general living conditions and is often one of the largest items of non-recurring expenditure."

Shelters and refuges must, as a minimum:

– Provide protection from the climate conditions

– Provide space to live and store personal belongings

– Ensure dignity, privacy, safety and emotional security.

In most emergencies there is a common basic need for shelters or refuges. However, issues such as the type and the design of the shelter, the required materials, by whom it is constructed, and the duration it is expected to last, will vary significantly according to the situation. Vulnerability analysis can identify the basic needs and priorities of the affected population in relation to shelters. Safe areas for flood shelters or refuges may include:

– Schools

– Religious meeting places (such as temples, churches, mosques)

– Community centers

– Higher ground (such as roofs, upper floors, embankments)

– Military installations

– Barracks.

4.10.3. Location and size of shelters and refuges

The need for the location and size of shelters and refuges needs to be decided in consultation with the communities. Transportation between the shelters and social and work locations for the displaced population should be considered. Existing social practices, and the provision and maintenance of shared resources (such as water, sanitation facilities and cooking) should be taken into consideration in the design of shelters and also in the allocation of space within shelters and plots. The plot layout in the evacuation centers must preserve the privacy and dignity of individual households.

The use of materials and the type of shelter that are most commonly used among refugees or the local population is to be preferred for the construction of shelters. The design of the shelter must follow the simplest principles and structures. The provision of a solid and robust roof is the main requirement, and even when a complete shelter cannot be provided, adequate roofing should always be the priority.

Plastic tarpaulins can be easily found in most cases. Tents are not always the best type of shelter because it is not easy to live in them and also they cannot provide adequate protection against extreme climate conditions. Nevertheless, in certain cases, tents may be used as storage facilities, or to set up hospitals, schools and other facilities. The success of the evacuation centers highly depends on these facilities.

Table 4.10 outlines the specific requirements regarding flood shelters and refuges, as recommended in the Humanitarian Charter and Minimum Standards in Disaster Response (The Sphere Project 2004).

Table 4.10: Specific requirements for flood shelters and refuges

Surface area	45 square meters per person is indicated as the adequate surface area for a temporary evacuation center. This includes the shelter plots and areas necessary for roads, footpaths, educational facilities, sanitation, firebreaks, administration, water storage, distribution areas, markets and storage, plus limited kitchens for individual households.
Topography and ground conditions	The site gradient should not exceed six percent,, unless extensive drainage and erosion control measures are taken, or be less than one percent to provide for adequate drainage. Drainage channels may still be required to minimize flooding or ponding. The lowest point of the site should be not less than three meters above the estimated level of the water table in the rainy season.

Access to shelter locations	Existing or new access routes should avoid proximity to any hazards. Where possible, such routes should also avoid creating isolated or screened areas that could pose a threat to the personal safety of users. Erosion as a result of the regular use of access routes should be minimized where possible through considered planning.
Access and emergency escape	Steps or changes of level close to exits to collective shelters should be avoided. Where possible, occupants with walking difficulties or those unable to walk without assistance should be allocated space near to exits or along access routes free from changes of level. All occupants should be within a reasonable distance of a minimum of two exits, providing a choice in the direction of escape in case of fire, and these exits should be clearly visible.

Source: The Sphere Project 2004: 217-218.

4.10.4. Water supply and sanitation facilities for flood shelters and refuges

Access to water supply and sanitation facilities are two of the most important components in flood preparedness and relief; these are necessary to prevent the spread of diseases, create a safe environment and provide minimum personal hygiene. Health protection is always one of the major concerns when disaster occurs and creation of a healthy environment, therefore, becomes essential.

Excreta and other waste must be disposed of properly. In addition, general disinfestation measures must be taken. It is important that all sanitation measures are carried out in close coordination with those responsible for water supply and health services.

The identification of a water source is the most important task for the water supply system. Natural water can be sourced from groundwater, rainwater, and surface water. In most areas groundwater is the safest, followed by rainwater and then surface water. However in some areas, such as in India and Bangladesh, this is not suitable as groundwater may be naturally contaminated by arsenic, a poison.

Access to sanitary facilities, including toilets, showers, and waste disposal units, should be planned taking into consideration their adverse effects on any neighboring population. Evacuation planning should also reflect the gender roles, and the local social practices of the affected population, and particularly the needs of the most vulnerable (The Sphere Project 2004).

4.10.5. Stockpiles of required materials

The evacuation plan should include provision for the materials, equipment and tools that will be necessary during an evacuation. The CFMC should assess the need of such provisions in consultation with the community. Moreover, individual households should be asked to maintain some of the provisions, whilst the remainder should be maintained by the CFMC at easily accessible locations. Stockpiles of required materials may include:

- Ropes, harnesses or both
- Ladders
- Floating rescue devices
- Life jackets
- Inflatable boats
- Torches
- Loudspeakers
- Blankets
- Tents
- Food and clean water
- Dry food
- Tools (such as axes, metal cutters, crowbars, rescue knives)
- Radios or other reliable communications equipment.

4.10.6. Communications between shelters and refuges

The success of an evacuation plan is highly dependent on the efficacy of the communication systems. Established communication systems must ensure that the relevant authorities are promptly informed, for example by radio or telephone. Given that during the flood emergency situation the public telecommunications infrastructure may have been damaged and be out of order, the communications systems must be based on equipment that can operate independently. Standby electrical power sources may be required.

The sharing of information is essential to achieve a better understanding of the problems. Coordination among all those involved in an evacuation operation is necessary to assure that the evacuation plan is being implemented successfully. It is also important to establish communication mechanisms to allow the affected population to comment on the process of the evacuation operation. This can be done by organizing public meetings and through community-based organizations. Specific provision should be taken into consideration for individuals who are confined to their shelter, for example, the disabled.

Adequate access to information is a fundamental requirement for any communication system. A way to avoid anxiety and distress is to accurately inform the local population about all the aspects of a disaster. Information about the nature and scale of the flood, as well as the emergency operations undertaken by the local government and authorities, and other aid and relief organizations should be shared. Information should be uncomplicated and empathic with the difficult situation of the affected population.

Finally, national governments should designate certain radio frequencies (for in-country and for international communications) to facilitate disaster communications. These frequencies should be available to relief organizations and be known to the local communities prior to the disaster.

A case of an evacuation plan in Pakistan is now detailed in the case study below.

Case Study 4.11: The Lai Nullah Evacuation Plan, Pakistan

In order to mitigate the losses caused by floods, and particularly the loss of life, an evacuation plan was developed by the Japan International Cooperation Agency (JICA) in collaboration with the City District Government Rawalpindi (CDGR). The plan was accompanied by the implementation of a forecasting and warning system.

The Lai Nullah Basin has a large catchment area which extends to the twin cities of Islamabad and Rawalpindi. Floods in the region are caused by heavy rainfall during the monsoon season. In 2001, floods caused 74 deaths and damaged or completely destroyed a thousand houses.

The main purpose of this project was to establish an adequate evacuation system. As a result the project aimed to:

- Utilize the flood early warning system effectively
- Develop the capacity of local authorities and promote people's awareness and preparedness on floods.
- Strengthen the capacity of other related organizations to mitigate flood losses.

Before implementation, a field survey was conducted in the targeted area in order to build an understanding about the social and cultural context and better inform the evacuation plan. In particular, the survey aimed to investigate the ways in which individuals and local communities respond to flood events and how their behaviour might positively or negatively contribute to flood risk.

During the implementation of the program evacuation drills for residents will be taking place and hazard maps will be evaluated and improved. The case illustrates that evacuation planning along with flood forecasting and warning systems should be part of any emergency plan. Evacuation plans minimize the risks and impacts of flooding for the population of cities and towns.

Source: JICA Pakistan; JICA 2007.

4.10.7. Further Reading

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4.11. Flood recovery and reconstruction

Not all floods can be defended against: the planned recovery from a flood event is a valuable tool in flood risk management, and forms a part of a flood resilient mentality. As discussed above, emergency warning and evacuation together with the construction of the most resilient critical infrastructure and buildings is a planned way of ensuring in advance that the need for recovery and reconstruction is minimized. However, there will inevitably be some damage necessitating reconstruction. This section covers this process.

As full reconstruction can take many years, it is important to do two things: firstly, to ensure that normal life can be resumed despite the on-going reconstruction work; and secondly, to shorten the time taken for reconstruction as much as possible. Gaining access to flooded areas is the first stage, as discussed below. Next, a rapid assessment of the state of critical infrastructure will help to establish the extent and scale of damage and inform plans for getting the critical infrastructure up and running again at a national level. Coordination of recovery efforts throughout all sectors can then be most easily achieved.

4.11.1. Access and solid waste clearance

Recovery agencies and those affected will need access to the affected areas. After the floodwaters have receded, access difficulties are likely to continue because of the destruction of roads and other transport routes. Furthermore, there will be blockages formed by large amount of debris which has been carried out from its place of origin and deposited elsewhere, as well as from collapse of structures in situ. Clearance of the waste is, therefore, a high priority during recovery to enable access and for reconstruction work to commence.

4.11.1.1. Types of flood-generated waste

Solid waste generated by flooding will include:

- Eroded soils and rocks, depending on the local topography
- Building materials such as concrete and wood
- Uprooted and washed out vegetation
- Corpses, both human and animals

- Vehicles, and in the case of a tsunami, boats.

The type of material deposited is dependent on factors unrelated to the waste normally generated, including the following:

- The dynamics or destructive power of the flood
- The source of the flood, whether from the hinterland of a town, or from the sea for a tsunami or tidal surge
- The topography of the town and surrounding area, including if it is flat or mountainous and also the size of the urban area affected.

4.11.1.2. Types of flood-related wastes

- Mud and rocks. The upstream erosion of land will generate significant volumes of mud and rock debris which is likely to be deposited in the urban areas as a result of the slowing of the floodwater as it passes through urban areas.
- Household debris. Household goods will stay mostly within the surviving buildings but some possessions and furniture may be lifted and carried by fast flowing water. Vehicles will be easily washed way and may form a significant component of the debris in the larger urban areas.
- Construction materials. The majority of the debris from a high energy flood will reflect the predominant building material of the area, such as concrete and stone in the more affluent areas, wood in earthquake prone areas and sheeting (including corrugated iron) in the low income areas.
- Corpses (human and animal): The decomposition of corpses poses a significant health risk, especially in hot climates where biodegradation and disintegration will occur rapidly. Wherever possible human remains should be identified and recorded by listing in public places for relatives to consult. Where there are insufficient facilities to retain bodies, these should be buried in marked mass graves with the appropriate cultural and religious traditions. Animal carcasses should be buried in separate mass graves. It is unlikely that the size of existing burial sites will be sufficient, and new sites should be selected with regard to land ownership and distance from ground and surface water supplies.

4.11.1.3. Clearance of flood-generated waste

The purpose of flood waste management, in order of priority, is as follows:

- Clearance of waste to allow access to important locations within the impacted urban area

- Clearance of waste that is preventing drainage of flood water
- Clearance of domestic waste from the new centers of population
- Clearance of waste from hospitals
- Clearance of corpses
- Re-establishment of regular collections to surviving areas.

In the event that the pre-flood waste management system is no longer operational and the equipment has been destroyed, a completely new system will have to be established, preferably under a single temporary agency to maximize the use of scarce equipment and manpower. If the pre-flood waste management system is still operational it is unlikely that the existing equipment would be sufficient or that the personnel would be able to adjust to the significant change in operational practices required.

The clearance equipment required would include:

- Mechanical diggers, preferably wheeled, because unlike tracked vehicles they are able to access sites without the need for a low loader.
- Large capacity dumper trucks.
- Tractor trailers may also be used for local unspecialized collections.

Manpower may be recruited from amongst the internally displaced persons (IDPs); although waste collection is not the most attractive of operations, it provides employment as well as a sense of contributing to the restoration of their town and often confers status amongst the community.

The different types of material that may be segregated for reuse, their potential uses and the processing required are shown in Table 4.11.

Table 4.11: Types of material that may be segregated

Material	Potential use	Potential processing
Soil (contaminated)	Replacement of eroded soil. Flood defenses. Landscaping of subsequently abandoned areas to form public open spaces. Replacing soil eroded from agricultural areas	Segregation, mixing with uncontaminated organic material

Trees and vegetation	Sawing into building material. Chipping as fuel. Export for manufacture of building board.	Segregation, cutting and chipping
Wood (construction)	Construction of temporary shelters and fuel.	Segregation, cutting and chipping
Sheeting (metal)	Reuse for temporary shelters. Bailing and export for recycling	Segregation, sorting and bailing for export
Bricks, concrete, stones and sand	Size selection and crushing for use as hard core for infrastructure (e.g. replacing or raising roads, replacing wharfs, replacing or repairing railway embankments and flood defenses).	Segregation, sorting and crushing
Steel	Export for reuse.	Segregation and storage for future-use
Household goods	Repair and reuse depending on condition.	Segregation
Industrial equipment	Repair and reuse depending on condition	Segregation
Vessels and vehicles	Re-floating vessels, salvaging useable items, breaking for timber or steel	Segregation, disassembly and export

4.11.1.4. Management of the waste of Internally Displaced Persons (IDP)

Floods, like other emergency situations, result in a considerable displacement of people elsewhere in the country, to unoccupied buildings unaffected by the flood and open areas or to refugee camps. Many IDPs, by preference, are likely to move out of the area to stay with relatives where they will add to the quantity of household waste being produced. This may strain existing waste management facilities. Other IDPs will wish to stay near their properties and communities, occupying any available space, including buildings and open ground. These will be at best only equipped with rudimentary facilities.

– Those people who have no other opportunities will often be temporarily housed in refugee camps run by external organizations. The camp design should incorporate waste collection and sanitation facilities, and allow the collection and transportation of waste from the camps to the disposal site.

– After the flood emergency had passed, the closure of buildings and land previously occupied by camps and emergency facilities will generate large quantities of a wide range of waste material redundant household goods (blankets, cooking materials); shelter facilities (such as tents and plastic sheeting); infrastructure (fencing, lighting and latrines); and much of this will not be reusable and will, therefore, require collection and disposal. Departing Agencies should not be relied on to clear the sites and remove and dispose of their waste.

4.11.1.5. Management of non-flood waste after a flood

After a flood, waste will continue to be generated by the resident population but where the pre-flood waste collection system has not recommenced, this will be disposed of wherever possible, including those areas which have already been cleared. The type and quantity of waste is also likely to change significantly in the following ways:

- Municipal waste or household waste: there will be a reduced volume where it is normally collected, because of the reduction in the number of inhabitants. However, this will be replaced by that generated by the camps and emergency facilities.
- Commercial and industrial waste: following any occupation of commercial and industrial premises by IDPS, owners and occupiers will want to regain access to their buildings, clear waste (including silt, debris, damaged goods and equipment), refugees' household materials and sewage, where relevant.

4.11.2. Mitigating damage

There are steps that can be taken after a flood, by both governments and individuals, which may reduce the level of damage suffered. As discussed in Chapter 2, the damage suffered during flooding is made worse by factors such as the duration of the inundation. Where floods are prolonged, the potential for water-borne disease is greater, materials in contact with floodwater will degrade and the potential for scour, erosion and undermining increases. Draining floodwaters from the affected area can therefore be a crucial first step in recovery and lead to a faster restoration process. One of the disadvantages of hard engineered flood defenses is that, if overtopped, they stand in the way of water regaining its normal course and lead to more prolonged flooding. In these cases, either pumping out the water or, possibly, destruction of portions of defenses is warranted.

Within buildings and enclosed areas, underground spaces may allow water to accumulate and take time to disperse. In some instances this can increase structural damage, if the water outside has receded: careful pumping out of water from such areas is advisable.

Secondary damage is also possible, either from wet and damaged contents, or from ill-advised attempts to dry buildings and contents. It is advisable to remove wet and damaged contents from buildings as soon as possible, as this will enhance drying and reduce damage. In temperate conditions, the access of air to wet buildings and contents will enhance drying and speed up recovery.

4.11.2.1. Identify and prioritize key items of reconstruction

The most important component of continuity planning is to prioritize the repair of public infrastructure, especially roads, railways and embankments. A prioritization process should consider the provision of services at the regional, city and community levels, so as to ensure the continuation of minimum functions. For example, if suppliers of food, fuel, telecommunications, or transport services have not developed plans covering continued delivery of their services in the context of a flood disaster, then the economic, social, humanitarian and governance consequences of a disaster can be significantly intensified.

Critical infrastructure can be defined as those facilities, systems, sites and networks necessary for the functioning of the country. Typically this might include any or all of:

- Roads including bridges and tunnels
- Railways
- Canals and rivers
- Airports
- Ports
- Electricity generation and supply
- Water treatment and supply
- Wastewater removal and treatment
- Fuel supply domestic and industrial and to transport networks
- Telecommunications
- Computer networks
- Hospitals and health facilities

- Government buildings
- Food distribution network.

The order of priority of restoration of the infrastructure will be to some extent specific to the country and settlement size concerned and will also depend on the scale and severity of the flood event. Planning for resilience in the critical infrastructure makes the restoration more straightforward, for example, careful placement of infrastructure sites will cause them to suffer less damage. Increasingly the dependence of all other systems on power means that the restoration of power, or provision of emergency power supplies, may be the most important need. However, the provision of clean drinking water, either through emergency distribution or rapid restoration of clean water infrastructure, can also be seen as a major priority in large disasters, as this can significantly reduce the incidence of waterborne diseases such as cholera.

4.11.2.2. Planned redundancy

The failure of some infrastructure is an inevitable consequence of flooding and where the drive towards efficiency has led to a tightly integrated infrastructure, the failure of one element can lead to a domino effect of further indirect consequences. For example, the failure of electricity systems can leading to pumping station failures, which could worsen both the depth and impact of a flood event. Similarly, road failure leads to the inability of emergency responders to reach affected populations. The notion of planned redundancy is to increase the capacity of systems, such that a reasonable proportion of the infrastructure can be affected but the extra demand can still be absorbed elsewhere. In power generation grids this could be achieved by having reserve capacity in the system (operational capacity over and above that required to meet demand).

4.11.3. Assessment and prioritization of needs

There are many different types of assessment which may be carried out in the aftermath of a flood as shown in Table 4.12. These assessments have different purposes and can be carried out with varying degrees of accuracy depending upon the purpose of the evaluation. A rapid assessment is required at the outset of recovery, to assess the level of damage and the priority areas for direction of recovery effort. Such an assessment will be achievable more rapidly, with greater accuracy and, therefore, be more effective if it builds upon pre-event vulnerability and risk assessments. Ideally, a database of vulnerable assets and likely damage levels should be created in preparation for severe flooding.

Rapid assessments may be based on remote sensing equipment, satellite or airborne survey, eye witness reports or reports from emergency responders. Co-ordination of such evidence sources can also be planned in advance.

Table 4.12: Types of assessments

Type	Definition
Damage Assessment	An assessment of the total or partial destruction of physical assets, both physical units and replacements costs
Loss Assessment	An analysis of the changes in economic flows that occur after a flood and over time, valued at current prices
Needs Assessment	An assessment of the financial, technical and human resources needed to implement recovery, reconstruction and risk management. Usually 'nets out' resources available to respond to disaster.
Rights-based assessment	An assessment that evaluates whether people's basic rights are being met. Has its origins in the United Nations Universal Declaration of Human Rights
Rapid Assessment	An assessment conducted soon after a major flood event, usually within the first two weeks. May be preceded by an initial assessment. May be multi-sectoral or sector-specific. Provides immediate information on needs, possible intervention types and resource requirements
Detailed Assessment	An assessment undertaken after the first month to gather more reliable information for project planning. Often takes about a month to conduct and is usually sector-specific.
Housing Damage Assessment	A damage assessment that analyzes the impact of the flood on residential communities, living quarters and land used for housing.
Housing sector assessment	An assessment of the policy framework for housing, the post flood housing assistance strategy and the capability of the housing sectors to carry it out
Community-based assessment (CBA)	An assessment that analyses how the context will affect reconstruction and the way in which communication with the affected community can support the reconstruction effort. It includes government and political risk analysis, stakeholder analysis; media communication environment and local capacity analysis and social and participatory communication analysis

Source: Jha 2010

In any assessment and priority setting exercise it is important to consider the needs of the vulnerable. Good practice includes including members of vulnerable groups in assessments and collecting information on their needs. Vulnerable groups may be based on gender, age, and health, economic, racial, religious and marital status. Views on the needs and relevant groupings and even contact details can be collected in advance of flooding and this will make post-disaster consultation less onerous.

4.11.4. Post-disaster reconstruction and resettlement

4.11.4.1. Assessment of resettlement needs

In situations where flood damage has been extensive and the risk of further flooding of the area remains, then there may be little option but to relocate the affected population. People may have been temporarily relocated to evacuation facilities, but it is in everyone's interest that IDPs should be re-housed and that the temporary camps are closed as quickly as practicable after the ending of the emergency phase of the flood. The closing of evacuation facilities (often public buildings, such as schools) will need to be done as soon as possible to allow them to be returned to their normal role. The closing of the emergency shelters will not only contribute to the restoration of communities, by focusing on the way forward to rebuilding livelihoods, but will also provide a focus for agencies who may wish to withdraw their assistance at the end of the emergency phase, especially if resources are required to meet a disaster elsewhere in the world.

4.11.4.2. Resettlement planning

It is imperative that there should be an appropriate institution with the mandate and resources to address the need for resettlement after a serious flood event where people have been displaced. A fundamental and far reaching decision will need to be made, regarding the need to resettle IDPs in their original location or the extension of an existing urban area for the development of a new town. In formulating that decision the following factors should be considered:

- The susceptibility of the flooded area to further flooding and the cost of the engineering work to reduce that risk.
- The susceptibility of the proposed host area and the cost of the engineering works required.
- The willingness of IDPs to return to their home town, or the

willingness for the new host population to receive an influx of people whom they may regard with suspicion, if not open hostility.

- The extent of the restoration of the services in the flooded area, particularly potable water supply, wastewater collection and treatment, surface water drainage, electricity and other forms of energy. This needs to be compared to the cost and technical ease of supplying such services to a new area.
- The suitability of the proposed host area to provide the facilities for IDPs to continue their pre-flood livelihoods (for example, fishing households that need to live on the coast, as is often the case with tsunami and cyclone affected areas).
- Transport facilities to previous work and social areas, for those unable to find work locally, or with responsibilities for an extended family.
- The ownership of the host land and the arrangements for acquisition and financial compensation to the existing owners, whether private or public.
- The resolution of land ownership in the flooded area, when ownership documents may not exist or have been destroyed in the flood.
- Development plans for the abandoned urban area, that render it safe but which do not preclude further development. The silt cleared from the town may be stored and beneficially used to cover and seal the urban area for subsequent use for farming or a memorial park.
- Financial and institutional resources to implement a formulated detailed resettlement plan.

The planning and implementation of such a resettlement plan will need to be a highly participative process, including all of the affected people, both the flood displaced people and also those people living at the locations being considered as appropriate sites for relocation. In order to facilitate rapid implementation, resettlement plans should start to be developed during the emergency phase of the flood relief effort. Early decisions may then be incorporated in the clearance of debris in order not to preclude future development.

Case Study 4.12 illustrates good practice in this area.

Case Study 4.12: The case of the tsunami-damaged village of Xaafuun, Somalia

Disaster affected areas can be improved considerably by taking advantage of the opportunities that might arise after a disaster. In Xaafuun, a remote village located in the northeastern coast of Somalia, post-disaster reconstruction after the Indian Ocean Tsunami in December 2004 provided an opportunity to tackle multifaceted problems in the Somali coastal region.

Owing to a lack of formal institutional arrangements, and insufficient expertise in planning and coordination, the initial interventions that were implemented by numerous organizations were located within the sensitive and unstable dune ecosystem near the old village. In particular, houses were built at sea level near the coast, destabilizing the very fragile ecosystem of the area.

In response to this, UNICEF, in partnership with UN-HABITAT, investigated the ways in which the village could be relocated to a more appropriate site. A multi-disciplinary team, comprised of urban planners, a local economic development expert and an environmental expert were given the task of identifying a safe and environmentally sustainable site.

The final decision for the new location of the village was agreed upon with the district authorities, the village elders and the women's representatives. A new and more appropriate layout for the houses was agreed, after the preparatory sketch plan was discussed with all local actors. The village plan (shown in Figure 4.15) was based on the following principles:

- Compact settlement to mitigate the impact of strong winds on living spaces and housing units, which also ensures the cost-efficient development and operation of basic services
- A public zone comprising both public spaces and public buildings that faces the sea, is acting as a buffer between the residential area and the dunes
- The main road links the main public facilities and aligns with the access road to the village and previously built structures
- A small-scale fishing industry and spaces for spontaneous economic activities and social gatherings were created next to the formal market
- The plan considered the need for expansion of the village over time.

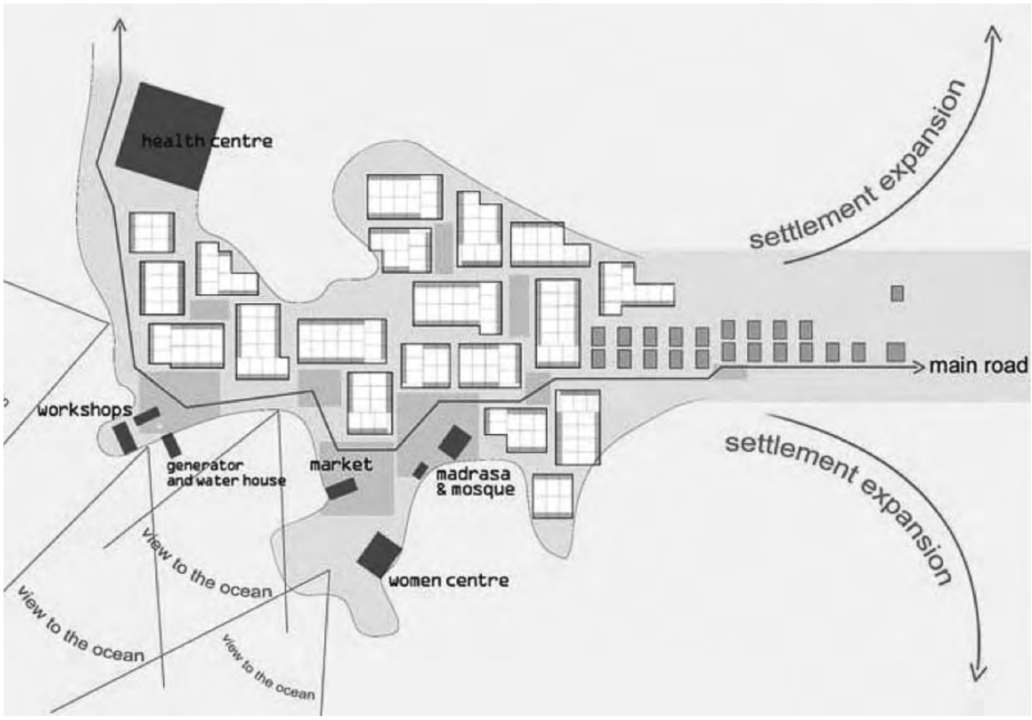

Figure 4.15: Village plan, Source: UN-HABITAT 2006

Relocation of the settlement allowed the dismantling of the original village and the environmental rehabilitation of the dunes. Local authorities demonstrated clear environmental awareness, for example, by forbidding cutting of live wood and re-using construction materials from the old village, while youth and women's groups showed interest in re-planting the dunes to facilitate the natural rehabilitation of the disrupted ecosystem. Since the completion of the project, Xaafuun attracted substantial investments that can further contribute to economic development objectives over the longer-term. Good practice in this case was demonstrated in the way in which long-term development perspectives were introduced in a post disaster situation.

Source: UN-HABITAT 2006.

Many former residents may not wish to return to a flooded location and may individually make the decision to move elsewhere in, or away from the urban area. This is often the case where there are family links to locations elsewhere: this has been a significant factor for large numbers of people who did not return to New Orleans after Hurricane Katrina. Significant migration away from the flooded urban area will reduce the number of people that have to be formally resettled. However, it is often the case that it is the least able people (typically the poor, the elderly and the economically challenged) who will have little choice but to remain in the flood affected area. It may be the case that these people are concentrated in a particular area (in a specific section of an urban area, as was the case in New Orleans) and this may place additional burdens on the land and services there, which may already be fragile. A significant challenge will be the establishment of an adequately resourced and technically capable authority with the remit and commitment to direct, oversee and co-ordinate the resettlement program.

4.11.4.3. Implementation of resettlement and reconstruction programs

It is unlikely that the resettlement plan will be implemented until sometime after the emergency. Some possible major barriers to its effective implementation include the following:

- Land availability
- Local hostility
- Availability of resources
- Political interference
- Corruption

The flood victims and the host community should be involved at every stage, but it should be recognized that the former may be so traumatized, and their lives so disrupted by the flood, that they are unable to make long term decisions. Failure to involve communities may result in violence motivated by land issues, jealousy that IDPs are receiving preferential treatment, significant corruption by individuals and the lack of clarity in the plans and the speed in carrying the plans forward.

4.11.4.4. Resettlement of flooded areas

Once cleared and drained the urban area may be resettled; many damaged buildings may be reinstated and repaired to a habitable condition, sometimes to a better standard than their pre-incident condition. Before any reinstatement works commence, it is very important to ensure that building components and materials are sufficiently dry. Failure to adequately dry buildings can lead to latent defects, mould growth and the need for further remedial works. A useful practical guide to drying water-damaged dwellings can be found in Lakin and Proverbs (2011) and is detailed in the How To section below. The drying of a flood damaged property is a complex process that is best undertaken by a competent and well trained technical person, such as a qualified damage management technician. The following outline provides a succinct guide:

- Stop the flow of water. No drying process can be successfully completed until the flow or ingress of water is stopped.
- Assess and address health and safety issues. Post warning and information notices.
- Survey the whole building inside and out, take pictures of pre-existing damage to the property. Take moisture readings and record on a drying plan. Take control 'dry' readings. Check outside relative humidity and temperature readings to facilitate flushing the building.
- Access and extract pooled and reservoired water.
- Install correct drying equipment and erect containment to create a balanced controlled drying system.
- Use the target drying method to efficiently achieve aims.
- Visit the property regularly to record moisture readings and adjust until completion.

Each stage of this process involves considerable care and attention requiring a detailed knowledge and understanding of the many technical issues involved.

In other cases, resettlement may be difficult to implement, because of the occupation of any remaining buildings, proving land ownership and inappropriate clearance that may prevent development. Improvement in urban planning and infrastructure may be difficult to achieve for similar reasons. There may also be an understandable fear of settlement in the area due its perceived continuing flood risk.

4.11.4.5.New development

Key elements in the design of the new habitation areas include the following considerations:

- The layout of the development and population density

- The facilities normally available to a typical family (for example the number of rooms in a house). A well proven strategy is to design a basic core house that can then be modified by individual households to meet their requirements
- The availability and suitability of appropriate materials (for example wood in earthquake prone areas)
- The availability of skilled workers for the reconstruction works.

There should be elements of improvement – or building back better, as the phrase goes – which include the following:

- Reduction in population density
- The widening of roads to accept modern vehicles
- Improved water supply, sewerage and surface water drainage. In places where it has not already been carried out it may be prudent to consider the separation of sewerage from the surface drainage network and to construct the drains to reduce the risk of flooding from blockages
- Improved foundations to improve building stability, especially in earthquake prone areas
- Wider distribution of electricity
- Provision of neighborhood waste disposal points to encourage proper disposal of waste.

4.11.5. How to restore flood damaged buildings

Buildings which are flooded but which remain structurally sound will nevertheless need to be cleaned, dried and restored before reoccupation. Facilitating this quickly has been shown to reduce stress for homeowners and disruption for business and public service providers. The process for responsive restoration has several phases, including drying.

Method

1. Assess damage

2. Clear and remove standing water and decontaminate

3. Determine appropriate treatment

4. Drying phase

5. Repair phase

1. Damage assessment

As discussed in Chapter 2, damage and loss assessments can be required for different purposes. The purpose of damage assessment here is to assess the level of damage, likely cost of repair and any structural or health and safety issues which will affect the integrity of the restored building and may render restoration impractical or dangerous. Before entering any building to make a detailed assessment, it is essential to ensure that the structure is made safe. In cases of doubt expert assistance should be sought.

The involvement of structural engineers may be necessary, particularly if the flood was of a depth and/or velocity likely to cause structural damage. In some recent events of large magnitude the use of "building triage" was used whereby a rapid assessment was undertaken by trained personnel to identify which buildings needed a more in-depth expert evaluation. Insured properties may well need to be formally assessed by an agent of the insurance company prior to commencement of any restoration (a full estimation of repair costs can be made at this stage).

At damage assessment stage it is important to consider older and historic buildings as a separate case as they will require specialist input and potentially should observe requirements relating to relevant conservation orders. Report of the assessment should ideally include details of all building elements damaged and an inventory of damaged contents. Details of the flood characteristics, including its depth, velocity and contaminants,are also very useful.

2. Clear and remove standing water

Once it is safe to do so, standing, pooled and trapped water can be extracted to facilitate drying. The use of pumps, bailing or absorbent materials are suitable. It is important to wait until the water has subsided before pumping out water, and also until groundwater has receded before pumping out basements. To avoid structural stress on the building after deep flooding it is advisable to phase pumping to ensure equalisation of levels throughout the internal space. It is advised to limit basement pumping to one meter of water in any one day and to place generators outside of closed spaces (Ciria 2005). Vacuum pumps can be fitted to a variety of delivery mechanisms. These include mats and wheeled devices which will extract moisture from floor coverings. Mud should be removed while still wet, with shovels and can involve the use of scrubbing and high pressure hoses, if appropriate to the building type and finishes. Cavities should be opened for drying and cleaning. Disposal of mud and silt must be in accordance with controlled waste regulations with particular attention to any hazardous substances.

3. Determine appropriate treatment and strip out

The choice of drying and repair method is usually dependant on a variety of factors such as the building type, tolerance to further building damage, resources available and building occupancy (Soetanto and Proverbs 2004). Usually the choice will be based on an assessment that involves a thorough building survey, assessment of the risk of future flooding and consultation with property owners and occupiers. This survey must cover all areas of the property, whether apparently affected or not, as moisture can pool and wick through materials and evaporation within closed spaces can result in damaged areas that were not in contact with the water. If areas are neglected, there is a real possibility that the drying process will be incomplete. This can lead to rot, mold, and degradation of the building fabric. Inadequate drying can lead to health issues in the longer term.

A drying standard can be set at this stage using the information collected on site. Drying standards use the normal equilibrium conditions in a building to set a benchmark. Targeted moisture levels for the affected areas are determined based on a combination of established principles and criteria for the particular material balanced with moisture readings taken in an unaffected area. Attempts to dry buildings to theoretical standards that do not take account of pre-existing conditions and ambient factors may never reach expected completion readings.

Natural drying of buildings can take months (Ciria 2005), and the desire to dry quickly usually means some form of assisted drying is preferred. Experience suggests that drying using traditional techniques can take place in three weeks under ideal conditions. Ideal conditions include a combination of reasonable ambient temperatures, low humidity and adequate air circulation. Therefore even in high temperature zones drying can be delayed if humidity levels are high or the air is still. Internal conditions can become saturated quite quickly and cause further damage if adequate ventilation is not ensured.

Assisted drying can simply involve the use of fans to increase circulation and keeping all windows open. However, it is also possible to dry multiple properties very quickly and simultaneously using "speed drying" techniques although there is still some doubt as to the possibility of damage to building contents and they may not be suitable for historic or heat-sensitive buildings or building components.

Building elements may be dried in situ, removed for drying, or stripped out and replaced. Stripping out of materials which cannot be dried should occur before drying is attempted. However guidance is divided as to whether it is preferable to remove and replace other elements rather than undertake time consuming and expensive restoration. Removal of wet materials can assist the drying out of the building fabric. A decision on which elements to strip out and which dry will form part of the drying and restoration plan.

The cost of drying methods will need to be balanced with the required speed of drying and other factors such as the balance of energy used during drying against embedded energy in building materials stripped out and replaced (Tagg et al.2009). Security concerns can weigh against the desire to keep buildings open; in this case dehumidifiers may be employed in closed conditions. Historic features may need to be conserved despite the high cost of drying and restoration. Drying methods may also be varied during the drying process as different phases are reached (Soetanto and Proverbs 2004)

4. Drying phase

Once the water is extracted and wet materials stripped out, the drying of the building and remaining in situ fixtures and fittings can begin. Drying is fundamentally a process which involves evaporation from the surface of wet materials into air which is at a lower relative humidity than the material itself. Differences in relative humidity determine the speed of evaporation. It is vital that on completion of the drying process, the structural materials are checked to ensure they will not enable or support mould or mildew growth. There are three basic methods available:

Naturally with ventilation and possibly fan-assisted. This is the slowest method of drying a building and can be severely affected by the prevailing ambient conditions. An ideal initial approach is to allow natural ventilation and evaporation to “flush” the wet air from the building. This is achieved by correct placement of air movers to draw out damp air, thus replacing it with drier air from outside. It is much better for the structure if climatic conditions allow and enables the process to be kick started to aid efficient drying. The specific humidity differential of the introduced air needs to be 5 to 10 percent lower between outside and inside, with a temperature of 20 centigrade as an ideal.

Convection drying using heat and ventilation. This method includes high temperature “speed drying” methods and traditional fan heaters but could also encompass use of the in situ heating system, if one exists, and open windows. Great care must be taken when using high heat forced-air or air conditioning systems. Rapid drying out of historic buildings using hot air power drying systems could cause irreparable harm to significant features of the building. Knowledgeable use of a psychrometric chart, thermometer and hygrometer will greatly aid this process and illustrate the effectiveness of the drying plan for future reference. Expert assistance is usually advisable.

Use of dehumidifiers. There are two main types of dehumidifier namely refrigerant and desiccant. Refrigerant dehumidifiers operates best between 15-28oC and at 60-98% relative humidity as they cool down the air and extract water through condensation. Desiccant dehumidifiers have a wider range of operating conditions as they use chemicals which can attract water (desiccants) to draw water from the air. Desiccant dehumidifiers can be used to push dry air into closed spaces. Dehumidifiers should be used in a closed environment as they rely on creating an unnaturally dry atmosphere; the speed of drying is largely dependent on the capacity of the equipment relative to the space to be dried.

It is important to ensure that all drying equipment is working well and to select the optimum number of dryers or humidifiers. The capacity of a dehumidifier relates to the figures for water removal over a twenty four hour period at a given temperature. To calculate the number of dehumidifiers that will be initially required to be deployed, the first step is to decide how many air changes per hour will be required to use the drying equipment efficiently.

Monitoring of the drying process is also crucial to ensure controlled drying. The initial survey shows the state of the building on the day of the incident and target moisture levels for completion. As drying proceeds, regular monitoring will provide the information needed to target the drying effort, adjust the containment areas and to place equipment accordingly.

5. Repair Process

Once drying targets are reached, the reinstatement of the building can commence. The drying target for commencing repair may take account of the fact that wet processes such as re-plastering may be tolerant to high levels of moisture. Reinstatement may involve further stripping out of elements which did not dry satisfactorily or were damaged during the drying process. Repair should follow existing construction regulations, and observe health and safety standards. Recommended repair processes can be found in Proverbs and Soetanto (2004).

The repair process should, if finances allow, be designed to minimize the risk of future flood damage and may include the replacement of water-sensitive materials with more resilient alternatives (Proverbs and Soetanto, 2004). Characteristics