Lecture 9
Floods in the Humid Tropics (III): Fluvial Flood Management Strategies

KEY QUESTIONS:

- ✓ *Can fluvial floods be effectively managed?*

With the completion of this lecture, attached readings and tutorial, you should be able to understand the:

- Strengths and limitations of strategies to manage fluvial floods
- Varying success of strategies to manage fluvial floods
- Extent to which humans can control natural phenomenon such as fluvial floods

Lecture Outline

9.1 Introduction: Categorising Flood Management Strategies

- The impacts of floods can be managed through broadly three categories of strategies, and each of these categories serve different purposes. Ideally they should be adopted together to provide a more comprehensive approach to help prepare for the adverse impacts of floods.
  - **Prediction**: These involve the use of scientific methods, historical data, and meteorological information to forecast the occurrence, extent, and severity of flooding events. The primary goal of flood prediction is to offer early warnings, allowing people to take precautionary measures, evacuate if necessary, and prepare for the flood event ***before*** it happens. (See **Section 9.2**)
  - **Mitigation**: These focuses on reducing the impact of flooding events by implementing strategies and measures that minimise the extent of damage and disruption caused by floods. Unlike flood prediction, flood mitigation addresses ***the long-term aspect of flood risk reduction***. (See **Section 9.3**)
  - **Responses:** These are often the implemention of **pre-planned activities**, usually ***during*** and ***after*** flooding to reduce the adverse impacts of flooding on the population and property at risk. (See **Section 9.4**)

9.2 Prediction

9.2.1 Recurrence Intervals

- The magnitude of a flood and how frequent it can occur is of interest to us.
- We can calculate the **likelihood or statistical probability of flooding** from flood frequency graphs, or flood recurrence interval graphs (see **Fig. 1**). Usually, the relationship between magnitude and frequency of flood is inverse. High magnitude floods are less frequent and vice versa.
- Using these graphs, we can make statements about the statistical probability of flood events. The longer and fuller the flood records, the more confidence we can place in this extrapolation. Thus, in **Fig. 1**, a low magnitude flood with 100 m^3/s discharge will occur more frequently i.e. after every 10 years, whereas a high magnitude flood with 200 m^3/s discharge occurs less frequently i.e. after every 50 years.

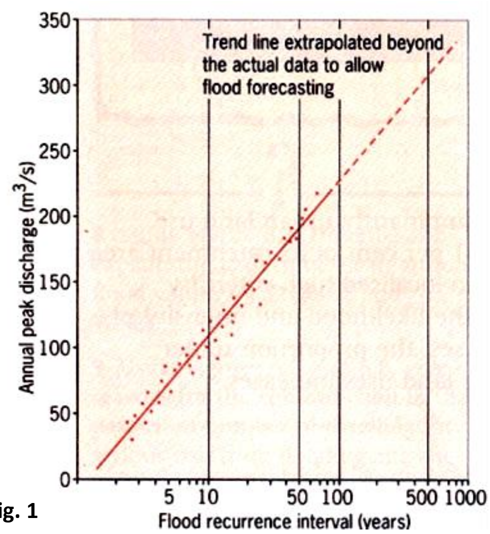


Fig. 1

- However, the statistical prediction of flood recurrence intervals is only an indication of probability based upon <u>past</u> records.
  - Drainage basins do not adhere to probability theory. A so-called 50-year flood may not necessarily occur only once in 50 years afterall.
  - Past records may not stretch over a period long enough. A 50-year record is more precise than a 10-year record, especially if we want to predict a 10-year flood. Furthermore, a 50-year record may not be sufficient to predict a 100-year flood.
  - As events happen, the statistical prediction will chance. For example, changes in landuse may alter the probability of floods of a particular magnitude.

9.2.2 Forecasting and Warning

- Flood forecasting and warning schemes exist widely and are most effective for large rivers, such as the Mekong.
- Increasingly, technology has allowed meteorological and discharge data to be collected more effectively. Computer modeling enables scientists to predict how individual river systems will react to precipitation inputs, for instance.
- Improved communications technology has also enabled more efficient dissemination of warnings to the public (see **Fig. 2**).

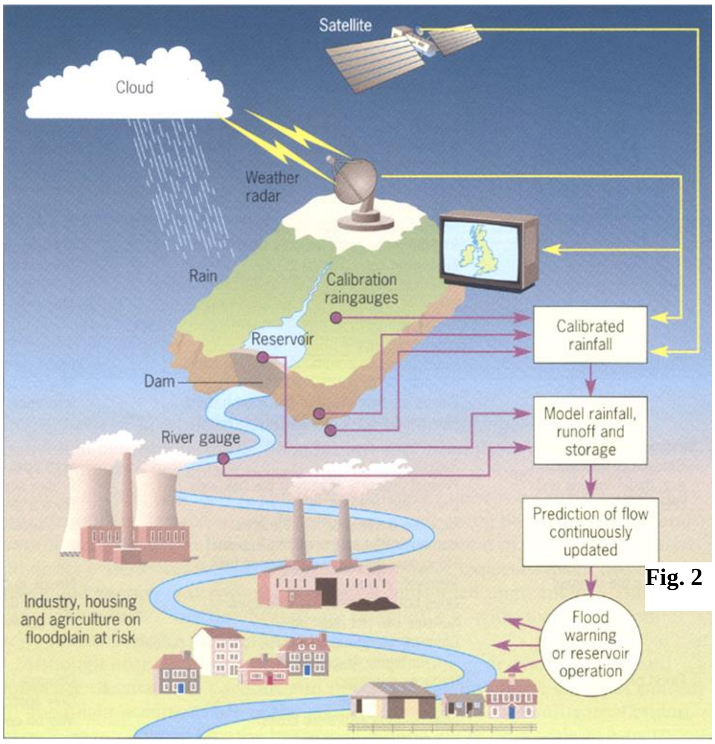


Fig. 2

Box 1: Flood forecasting in India

- Flood forecasting has been recognised as one of the most important, reliable and cost-effective non-structural measures for flood management.
- The Central Water Commission (CWC) under the Ministry of Water Resources has established a network of forecasting stations along flood-prone interstate rivers. These forecasts aid local administrations in evacuating flood-affected areas and reservoir operators in managing water levels.
- In 2016, 6239 flood forecasts were issued, with 95.34% accuracy. CWC operates flood forecasting at 199 stations in India, using rainfall-runoff modeling and IMD rainfall forecasts to provide three-day advisories, contributing to timely disaster management and property protection.

9.3 Mitigation

- These steps involve trying to lengthen the amount of time it takes for water to reach the river channel (thereby increasing the lag time), confine floodwater to river channels, divert water to temporary storages, or facilitate quicker flow away from places to be protected. Flood management techniques can be divided into hard- and soft-engineering options.

9.3.1 Hard-engineering Strategies

- **Hard-engineering** strategies act as a barrier between the river and the surrounding land. Artificial structures are used to change or disrupt natural processes. Hard options tend to be more expensive and have a greater impact on the river and the surrounding landscape. Examples of hard engineering strategies include artificial embankments or levees, dams and channelisation.

(a) Levees (or Dykes)

- A levee is *an embankment constructed by humans, along a river (on its banks) to prevent the flooding of lands adjacent to the river*. These are common form of flood control (see **Fig. 3**).

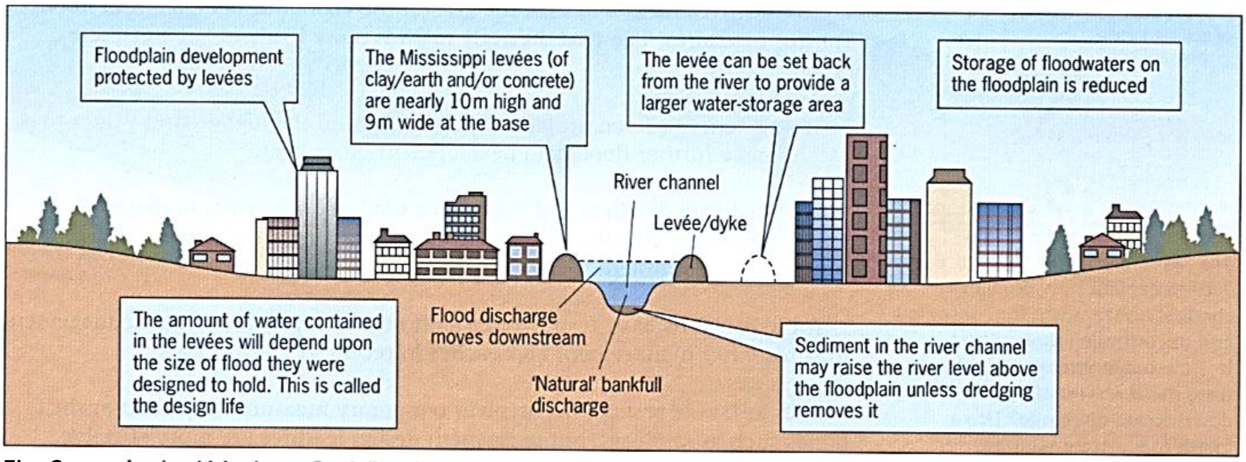


Fig. 3 **Levées (dykes) as a flood-diversion measure**

- Under natural conditions, water floods out of the channel and is stored in the floodplain, and the discharge is reduced downstream. The flood waters contained within the levees continue to flow rapidly downstream.
- Well-maintained levees are an effective management approach within the flood size that they are designed to contain. **However**, if levees fail, the area inundated will be more severely affected as water pours through the breach. The results can be disastrous and the flood event made worse.
- Levees thus must be maintained as they decay and deteriorate over time, and so require comprehensive maintenance programmes, which become a challenge as the systems age. Maintenance is also a costly affair.

(b) Dams

- Dams are *structures that are built across the channel in order to store water and regulate the discharge of the river*. They offer the temporary storage of water so that the flood peaks downstream can be reduced (see **Fig. 4**).

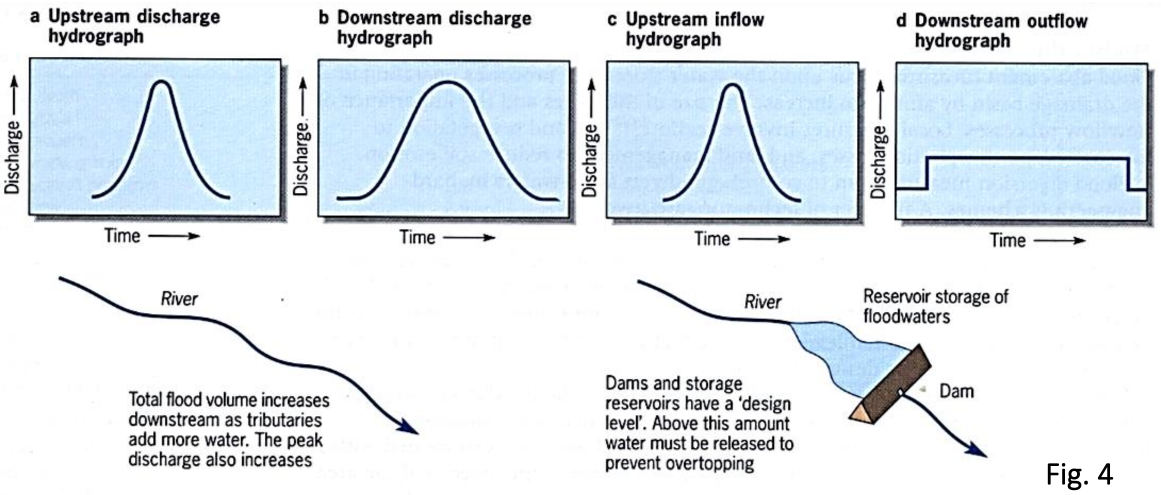


Fig. 4

- Dams can provide multipurpose benefits of irrigation, water supply, improved navigation, recreation and leisure, and very importantly, hydroelectric power (see **Cluster 1 Lect 7**).
- Dams have been used for well over 2,000 years, but their construction of dams has been **highly controversial**. These are due to a range of economic, ecological and social concerns. (Again, see **Cluster 1 Lect 7**).
- Just like levees or dyke can fail, **dams can fail** too, and will lead to disastrous effects.
  - In July 2018, a dam in Attapeu province in Laos collapsed, sending flash floods through six villages over an area as far as 5 km away, killing more than 70 people, with more than 6,600 people made homeless.
  - Poor construction quality of the dam was believed to have contributed to it not being able to hold back the waters due to continuous monsoon rains.
  - This incident is believed to be the deadliest dam accident in Laos history.

(c) Channelisation

- Channelisation is *a deliberate attempt to alter the natural geometry of the river*. Although often also used to protect channel bed and banks from erosion, for our purpose we focus only using channelisation to reduce flooding by increasing the **capacity** of the channel and/or its **efficiency** as a conveyor of water.
- This objective is achieved by **increasing the hydraulic radius**.
  - The hydraulic radius is *a measure of the efficiency of a channel to transport water and its sediment load*. This is measured through dividing the channel's **cross-sectional area** (A) (index for water volume) by its **wetted perimeter** (WP) (index for friction) – the *higher* the value, and the *more efficient* it will be (i.e. **HR =** $\frac{\mathbf{A}}{\mathbf{WP}}$).
  - If there is less energy loss through friction of water with the bed and banks, velocity will increase and more water will move quickly through the channel. The likelihood of flooding will therefore be reduced.

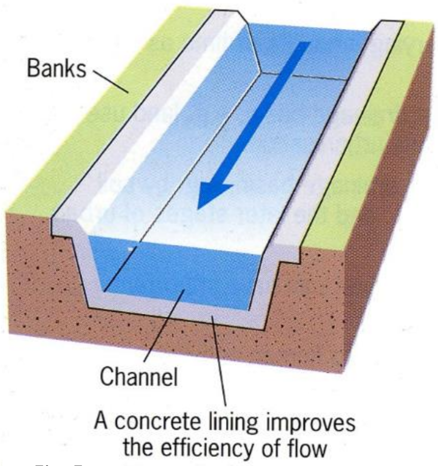


Fig. 5 **Resectioning the channel**
(*Source*: Knapp et al, 1989)

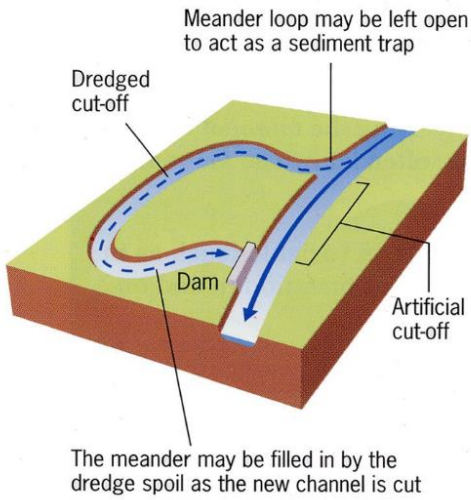


Fig. 6 **Realigning the channel**
(*Source*: Knapp et al, 1989)

(i) Channel Resectioning

- The channel capacity is increased by resectioning or **enlarging the cross-sectional area**. The channel is deepened and/or widened to increase its hydraulic efficiency, and to allow a larger discharge to be contained within the channel (See **Fig. 5**).
- Often, this method would also involve **lining** the channel with concrete to improve efficiency. Lining makes the surface smooth and thus reduces friction and increases velocity of river flow. Lining the channel also helps to reduce bed and bank erosion.

(ii) Channel Realignment

- A meandering river can be **straightened** by means of artificial cut-offs. This helps to increase velocity of flood waters, allowing quicker removal of discharge (See **Fig. 6**).
- **However**, while channelisation for flood control may reduce the incidence of flooding in the channelised area, it often results in more severe flooding further downstream.
- Vegetation from banks and beds of a channel may be removed as they contribute to channel roughness. This measure interferes with the natural habitat of the river system and decrease the aesthetic value of the river.

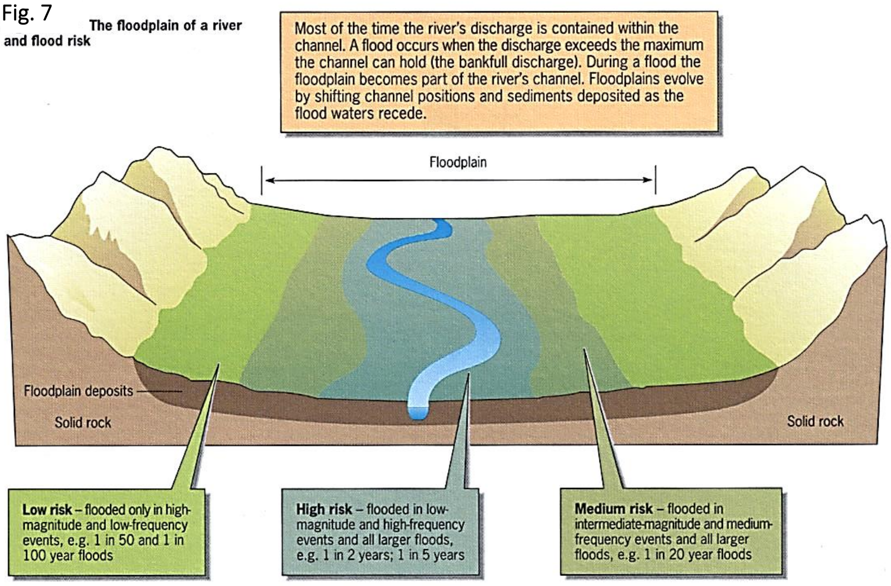
9.3.2 Soft-engineering Strategies

- **Soft-engineering** strategies aim to enhance a river's natural features and its banks. Soft options are increasingly favoured, as they tend to be more ecologically sensitive and therefore more sustainable. Examples of soft engineering strategies include planting vegetation and river restoration.

(a) Land Use Planning and Zoning

- Floodplain zoning involves dividing the floodplain into area which experience different degrees of flood risk (**Fig. 7**). High risk zones are near the river and as ones moves away from the river risk reduces.
- It also involves regulating land use to take account of the nature of the flood hazard (**Fig. 8**).

Fig. 7 The floodplain of a river and flood risk



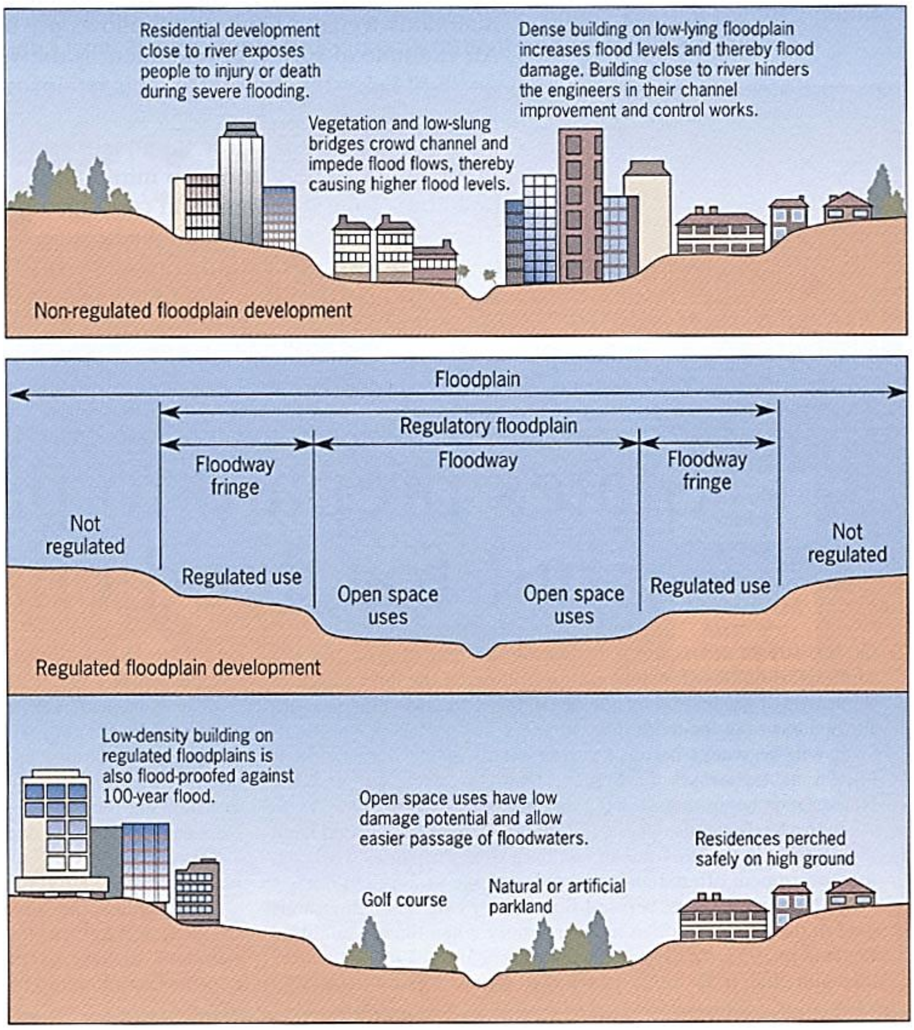


Fig. 8 Floodplain zoning

- **In the highest-risk areas, development is excluded, except for land uses which have a low damage potential.** Land uses which retain the floodplain as a natural floodwater storage area and wetland also help to reduce the flood risk downstream.
- In urban areas, recreational uses allow the valuable provision of open space which maintains wetland habitats but allows use by residents for most of the time.
- Floodplain zoning is a successful mitigation technique because it is cheap and effective.
  - The state of Manipur in India has enacted the floodplain zoning legislation in 1978 and made concerted efforts to implement it fully. By 1988, the flood zoning area had been published, and the most recent activity has been an eviction campaign to free the banks of the Imphal river.
- **However,** it is not realistic for *existing* urban areas and may be more suitable for new urban areas.
  - Relocation of people, property and businesses would be effective but might be resisted by owners who lose the advantages of a floodplain location.
  - Also, the cost is prohibitive because people will need compensation payments as well as the expense of re-building. Successful cases certainly exist such as in Australia where acquisition areas are typically of low property values hence relocation actually offers families to better themselves.

  - Only three states in India have enacted floodplain zoning laws, while other flood-prone states such as Assam and Bihar have conveyed that implementing a floodplain zoning law is neither practical nor implementable. The constraints arise from evacuating people who occupy the densely populated floodplains and finding suitable land to rehabilitate the displaced communities.

(b) Dredging

Fig. 9

- Dredging the river is the process by *which bedload is removed from the channel of the river*, through the use of heavy industrial pumps or diggers (see **Fig. 9**).
- The purpose is to increase depth of the channel, hence increasing the cross-sectional area of the channel (and thus its water holding capacity) and its hydraulic efficiency.
- The benefit of using dredging is that it maintains the natural aesthetics of the river channel, which is in contrast to methods such as channelisation.
- **However**, dredging is a costly and time consuming process that is only suitable for small section of the river, for example close to or within urban environments. In addition, the process may bring high ecological impact on natural ecology such as through disturbance to aquatic ecosystems.
- Dredging also has to be carried out frequently, as sediment is continually deposited on the river bed.

(c) Reforestation of Channel Banks

- By allowing vegetation to develop, or the deliberate planting trees and other vegetation close to the banks of the river, can help to intercept rainwater and raise evapotranspiration. Vegetation also promote infiltration, which together with subsequent percolation, increases the amount of water stored in soil water and groundwater storages. These reduce runoff and lengthens the lag time. River discharge is lower, making the river less likely to flood.
  - In the lower Mississippi river basin, there have been ongoing efforts to conduct reforestation on marginal agricultural lands. More than 75,000 hectares of forests have been planted to reduce flooding.
  - After the devastating flash flood in Pakistan in 2016, the northwestern Khyber Pakhtunkhwa (KPK) province began a large scale reforestation project called "The Billion Tree Tsunami". This added 350,000 hectares of trees both by planting and natural regeneration, with the billion tree goal met in August 2017.
- Plant and tree roots bind the soil together in addition to reducing surface runoff, so less sediment enters the river. A reduced sediment load helps to improve channel capacity, which in turn lowers the risk of flooding.
- **However**, while reforestation will reduce flood risk, it will not eliminate it entirely. Also, if vegetation is allowed to grow in an unregulated way, it may in fact encourage greater channel

roughness, and reduce the hydraulic efficiency of the channel, increasing the possibility of flooding.

- Landowners may also oppose the loss of land of economic value (e.g. agricultural land) to reforestation measures. Most of the land available for restoration in the lower Mississippi river basin is privately owned, making landowners decision makers. Most landowners want some financial return from their land, and thus a major challenge is to make conservation and restoration profitable for private landowners.

9.4 Responses

9.4.1 Disaster Aid

- Calls for government relief following flood disasters are common, but there is recognition in the developed countries that the taxpayer cannot be expected to fund all the loss. This attitude is sometimes enforced by legislation limiting any disaster relief to un-insurable losses.
- For many of the developing countries, international aid very important. Recall from **Lect 7**, we learnt about the **2022 Pakistan floods**:

Initial impact	**Short term response**
More than 1,265 people have been killed	The WHO has said that more than 6.4 million people are in dire need of humanitarian aid
A million homes have been destroyed or badly damaged	The UN has appealed for $160 million (£139 million) to help with what it has called an "unprecedented climate catastrophe"
33 million people have been directly affected	Aid agencies have asked the government to allow food imports from neighbouring India (the border is normally closed)
Total flood damage estimates exceed £8.7 billion	The UK government has announced humanitarian support of up to £15 million to help Pakistan's flood response
Sindh, with a population of 50 million, has been hardest hit, receiving 466% more rain than the 30-year average	A French aircraft carrying relief goods landed in Islamabad on Saturday and was received by the national health services minister Abdul Qadir Patel

Table 1 a brief summary of the 2022 Pakistan floods

9.4.2 Community Preparedness

- Some countries rely on the routine civil emergency arrangements, including voluntary organisation and the armed forces, to combat flood losses. However, specialised flood preparedness programmes have increased with the spread of forecasting and warning systems.
- The greatest need for advice exists in flash flood events with short warning times where lives can be saved provided people run immediately to higher ground.
- Preparedness has become a key flood mitigation factor in the developing countries.
    - There are 30,000 Red Cross-trained volunteers in Bangladesh charged with a wide range of tasks from raising hazard awareness, health and hygiene education and first aid techniques through to emergency response skills that include warning villages through loud hailers and the evacuation of people to refuges and higher ground.