CHAPTER 3

3. FOUNDATIONAL CONCEPTS AND KEY CROSSCUTTING ISSUES

3.1 SECTION CONTENT

This chapter discusses key overarching foundational concepts and crosscutting issues that will help the guide user understand the fundamental contextual issues related to flood management. The foundational concepts explain biophysical parameters and will help the reader understand how flood-related terms are defined and used. The crosscutting issues are key social and economic factors related to successful flood risk management. Key foundational issues include

- flood definitions and causes, benefits, hazards
- watershed systems and characteristics
- the water cycle and managing water
- climate, climate variability and weather
- resilience

Key crosscutting issues include

- institutions
- regulations
- cross-sector coordination and cooperation
- community engagement
- gender
- private sector
- finances and funding

3.2 FLOODS: DEFINITIONS, NATURAL PROCESS AND BENEFITS, HAZARDS

3.2.1 DEFINITIONS

Floods come in many shapes and forms and have the potential to cause tragic loss of life and enormous economic damage. In some situations, however, floods are also an important natural process, and serve a broad range of functions for people and **ecosystems**, as discussed in section 3.2.2.

Lake Flooding in East Dongting Lake, Yuyang City, Hunan Province, China.

There are as many different definitions of floods as there are types of floods. Most government and academic agencies define floods according to their own missions and/or responsibilities related to physical or social priorities. For example, the US Geological Survey (USGS) defines flood as "an overflow or inundation that comes from a river or other body of water and causes or threatens damage. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream."[1] The Asian Disaster Preparedness Center (ADPC), on the other hand, defines flood **disaster** as a damaging flood hazard that adversely affects human populations and the **environment**.[2]

Floods can be grouped into several different types and sub-types. For the purpose of the Flood Green Guide we have developed a flood hazard typology as described in appendix A. The typology provides a list of flood hazard types, definitions, and associated causes and processes (The Flood Green Guide does not include glacial lake outburst floods [GLOFs]).

Flood types:

- **Riverine (fluvial) flooding** is the most familiar type of flooding. It results from water in a river or drainage channel that cannot be constrained within its stream channel or by constructed structures (e.g., levees) and inundates the floodplain. Riverine flooding can develop from heavy or extended periods of rainfall and rapid snowmelt, and it is often seasonal (i.e., occurs in the rainy season). Overtopping/

1 US Geological Survey (USGS), "Flood Definitions," Kansas Water Science Center, accessed January 6, 2016, http://ks.water.usgs.gov/flood-definitions.

2 Asian Disaster Preparedness Center (ADPC) and United Nations Development Programme (UNDP), *A Primer Integrated Flood Risk Management in Asia* (Bangkok, Thailand: ADPC, 2005), http://www.preventionweb.net/files/2776_adpcprimerapr05.pdf.

bank flooding is caused by an increase in water volume within a river channel, which overflows natural or constructed banks, flooding adjacent areas. This type of flood is often associated with riverine flooding.

- **Flash flooding** normally results from heavy or intense rainfall over a period ranging from minutes to hours, inundating creeks, streams and otherwise dry valleys.[3] Because they are not always caused by meteorological phenomena, flash floods present different forecast and detection challenges. Flash floods result when favorable meteorological and hydrological conditions exist together; while heavy rainfall is always present, the hydrologic characteristics of the watershed where it is raining can affect whether the amount and duration of rainfall result in a flash flood.[4]

- **Lake level flooding** can be caused by excessive inflow from the lake's tributaries; although extremely uncommon, lake tsunamis can be triggered by landslides and changes in regional groundwater conditions, particularly in constructed reservoirs.

- **Coastal flooding** can be caused by hurricanes, cyclones and other large storm systems, tsunamis and rising sea levels. It often results from a combination of rising coastal waters and riverine flooding. During periods of high tides or strong winds onshore, coastal water can act as a dam that blocks surface runoff from dissipating, with the buildup of standing water resulting in flooding. Where areas inland from the sea are very flat, this type of flooding can develop some distance from the coast as natural and constructed drainage systems back up.[5]

- **Storm surge** is a type of coastal flooding, an abnormal rise of water generated by a storm, over and above predicted astronomical tides. The water level rise from the combination of storm surge and an astronomical tide is called a storm tide and can result in extreme flooding in coastal areas – reaching up to 6 m or more in some cases – particularly when storm surge coincides with normal high tide.[6]

- **Tsunami flooding** is often coastal, and while similar to a storm surge, has different causes (e.g., an earthquake or subsea landslide) and can occur with very short warning compared to surges.

- **Urban flooding** is often due to a combination of factors that accompany urbanization. These factors include an increase in impervious surfaces, such as rooftops, roads and parking lots, that prevent water from being absorbed; inadequate stormwater storage or drainage capacity; and poorly planned infrastructure – particularly in rapidly urbanizing areas.[7]

- **Areal flooding** develops gradually, usually from prolonged and persistent moderate to heavy rainfall. Gradual ponding or buildup of water in low-lying, flood-prone areas, as well as in small creeks and streams, can occur more than six hours after rainfall begins, and may cover a large area.[8]

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3 NOAA National Weather Service (NWS) Weather Forecast Office, "NWS Flood Products: What Do They Mean? Flash Flood Warning, Areal Flood Warning, River Flood Warning or Urban and Small Stream Flood Advisory," accessed January 6, 2016, http://www.srh.noaa.gov/bmx/?n=outreach_flw.

4 NOAA National Severe Storms Laboratory, "Flood Forecasting," accessed January 6, 2016, http://www.nssl.noaa.gov/education/svrwx101/floods/forecasting/.

5 Sam Ricketts and Jennifer L. Jurado, "How Can the Federal Government Help Prepare Local Communities for Natural Disasters?" (briefing, Environmental and Energy Study Institute (EESI), Washington, DC, April 1, 2015) http://www.eesi.org/briefings/view/040115resilience.

6 National Oceanographic and Atmospheric Administration (NOAA) National Hurricane Center, "Storm Surge Overview," accessed January 6, 2016, http://www.nhc.noaa.gov/surge/.

7 James Wright, "Chapter 2 Types of Floods and Floodplains," FEMA Emergency Management Institute, 2008, https://www.training.fema.gov/hiedu/aemrc/courses/coursetreat/fm.aspx.

8 NWS, "NWS Flood Products."

Typhoon Haiyan in the Philippines caused storm surge that devastated local communities.

- **High groundwater** can affect buildings or other infrastructure and sources of livelihoods (e.g., fields that become very muddy). High groundwater is not universally considered flooding, but it is included here because managing the impact is often related to managing other types of flooding.
- **Mudflood** occurs when floodwater carries a heavy sediment load (such as mud, rocks, trees), and it is often triggered by flash flooding or heavy rainfall flowing over nonporous geology with a soluble surface layer. Examples of these conditions include barren soil or land after a wildfire. Mudfloods are also known as mudflows, debris flows, or landslides triggered by rain.
- **Rain on ice flooding** is a type of sheet flooding, where rainfall on ice leads to flows across the ice, flooding low areas.

3.2.2 NATURAL PROCESS AND BENEFITS

While floods result in incalculable loss of life each year and cost the global economy billions in damages, flooding is also a natural process that supports important biogeochemical and ecological processes such as supplying water and recharging aquifers for humans, animals and crops. Floods provide sediment and nutrients required for fertile soil, which support human well-being. For example, many fish species require an inundated floodplain to reproduce, thereby supporting both **livelihoods** and **biodiversity**. In Niger, farmers grow onions in riverbeds where wet season floodwaters soak in to create high groundwater levels and optimal growing conditions. The produce, exported to other parts of West Africa, is an important agricultural livelihood system that would not be possible without the seasonal flooding.

Freshwater floods can also help to flush out **floodplains**, helping to prevent silt buildup, encouraging greater biodiversity and productivity by encouraging floodplain habitat. While floods can cause damage, in some cases, they provide ecological and/or social co-benefits. An **integrated water resource management** (IWRM) approach, which **integrated flood management** (IFM) supports, is designed to acknowledge these co-benefits, environmental flows and/or ecosystem services while minimizing the damage caused by floods.

Environmental flows are defined as the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems, as well as the human livelihoods that depend on them.[9]

Ecosystem services are defined as the benefits that people and communities obtain from ecosystems. These benefits include regulating services such as regulation of floods, drought, land degradation, and disease; provisioning services such as food and water; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits.[10]

Examples of ecosystem services supported by floods include the following:

9 Rafik Hirji and Richard Davis, *Environmental Flows in Water Resources Policies, Plans, and Projects: Findings and Recommendations* (Washington, DC: World Bank, 2009), http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-7940-0.

10 UN International Strategy for Disaster Reduction (UNISDR), "Terminology on DRR," August 30, 2007, http://www.unisdr.org/we/inform/terminology#letter-e.

Regulating:

- sediment, nutrient and water delivery (e.g., rice farms in Madagascar, floodplain agriculture in Bangladesh)
- episodic inundation of dry valleys and recharge of **groundwater** (e.g., seasonal rivers in Central Niger)
- flushing of sediment to maintain (natural and engineered) flow channels (e.g., Mississippi)
- flushing of nutrients and organic materials to prevent eutrophication (e.g., Amur wetlands)

Provisioning:

- large-scale nutrient and sediment cycling to support mangroves and marine fisheries (e.g., coastal wetlands of Marismas Nacionales in Mexico, fisheries reproduction in the Sea of Japan)
- inundation of floodplain lakes and wetlands to trigger fish spawning (e.g., subsistence fisheries in the Amazon and Mekong [Tonle Sap])
- transportation mechanism for inland and coastal water systems

Cultural:

- transportation of human remains in religious rituals (e.g., Ganges, India)

Recreational:

- kayaking and rafting during high flow events (e.g., Western United States, tourism related to rafting and recreation in Sri Lanka)

In other words, ecosystem services can directly and indirectly support community survival and quality of life.

Efforts to mitigate flood damage should consider the benefits of flooding. For example, in Bangladesh, dikes were constructed to prevent flooding of fields. When communities learned that floods actually provide nutrients, water and sediment for rice production, they shifted flood management strategies to focus on limiting damage of detrimental flooding rather than trying to prevent all floods.

EXAMPLE: No other aspect of Bangladeshi life is more sensitive to the flood problem of the country than its time-honored agricultural practices. This is because the cropping patterns in the floodplains have been so intricately adjusted to the annual flood regime that any major deviations from the normal regime, with regard to timing, duration, or magnitude, may cause a serious setback in crop production. In normal years, flooding is considered an asset because it supplies the moisture and fertility (silt) to the soil that are vital to crop production. It is the abnormal flood, the extreme event, that is considered a hazard, as it can cause widespread damage to standing crops and property and sometimes to livestock and human lives. The agriculture in Bangladesh is, thus, both flood dependent and flood vulnerable.[11, 12]

11 Text adapted from Bimal Kanti Paul, "Perception of and Agricultural Adjustment to Floods in Jamuna Floodplain, Bangladesh," *Human Ecology* 12, no. 1 (1984), http://www.jstor.org/stable/4602721

12 Example from Harun Rasid and Bimal Kanti Paul. "Flood Problems in Bangladesh: Is There an Indigenous Solution?" *Environmental Management* 11, no. 2 (1987): 155-173.

3.2.3 HAZARDS

Although there are many types of floods, not all floods are hazards. A **hazard** is defined as a "potentially damaging physical event, phenomenon or human activity that may cause the loss of life, or injury, property damage, social and economic disruption, or environmental degradation."[13]

Factors in understanding the threat posed by a flood hazard include the following:

- **Magnitude:** For flood-related hazards, the magnitude is often expressed as the volume of water per time period (e.g., cubic meters per second) or as total volume (e.g., cubic meters of water flooding an area).[14]
- **Frequency:** How often a hazard of a certain magnitude occurs, often expressed in the number of times an event occurs during a specific period of years.
- **Exposure:** What might be affected or damaged by a hazard of a specific magnitude recurring within a specific frequency. Exposure is often assessed by identifying the extent to which lives and physical assets would be affected by a flood of a specific magnitude.

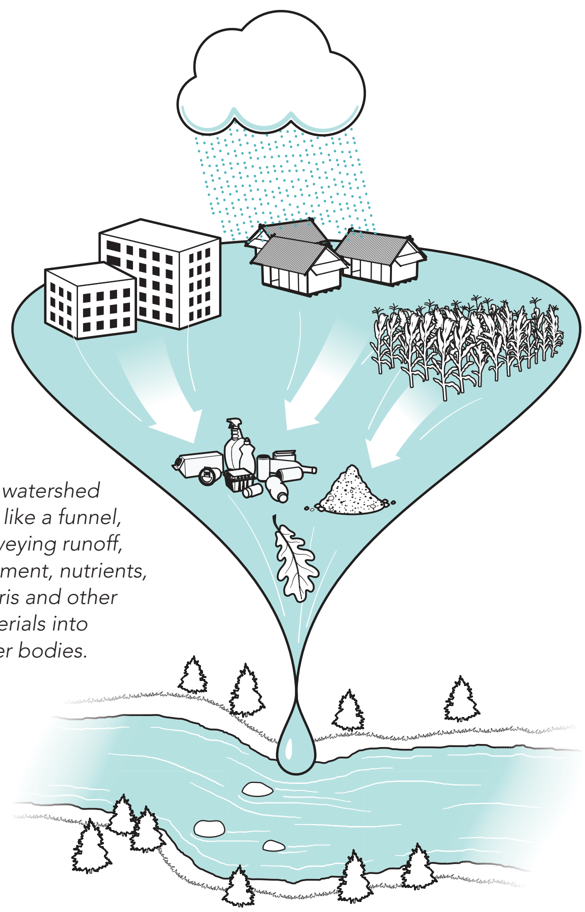
The nature of hazards and risks is further described in chapter 4.

3.3 THE WATERSHED SYSTEM

To better assess a region's flood-related risk and options available to manage that risk, it is important to know the area of interest's location within the watershed. Multiple and varied factors within a watershed affect the potential for **flood risk** and the options for putting together a flood management strategy.

A **watershed** is commonly defined as the area of land that drains downslope to the lowest point and conveys water to a common outlet.[15] For the purposes of the Flood Green Guide, we are using the term watershed interchangeably with the terms **river basin**, sub-basin, **catchment**, catchment area, drainage basin and drainage area.

Watersheds have been shaped by thousands, if not millions, of years of interaction between climate, vegetation and geology. Large watersheds contain thousands of smaller watersheds, "sub-watersheds" or "sub-catchments." Similar to the rim of a funnel, the boundary of a watershed is often defined by the highest points in an area – hills, mountains and ridges – that capture the precipitation (rain, hail, snow) that falls within the watershed.



The watershed acts like a funnel, conveying runoff, sediment, nutrients, debris and other materials into water bodies.

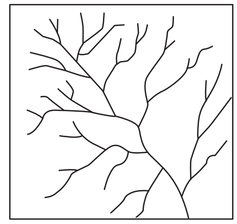
13 World Meteorological Organization (WMO), "DRR Definitions," Disaster Risk Reduction (DRR) Programme, accessed January 6, 2016, https://www.wmo.int/pages/prog/drr/resourceDrrDefinitions_en.html.

14 High groundwater is measured in water depth below the level of the ground.

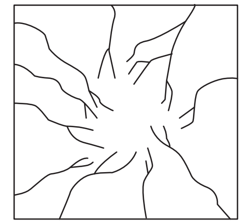
15 USGS, "What is a watershed?," accessed February 10, 2017, https://water.usgs.gov/edu/watershed.html.

3.3.1 DRAINAGE SYSTEM

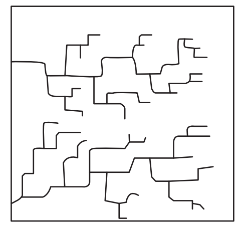
Moving downslope, away from the watershed divide, stream channels develop and then merge with other, smaller tributaries, gradually combining flows into larger and larger streams. The linked channels become what is known as a drainage network.[16] Drainage networks can evolve over time by natural processes such as erosion, changing the shape of streams, for example.



Dendritic Drainage



Radial Drainage



Rectangular Drainage

© Stephen Nelson

Common drainage patterns.

3.3.2 DRAINAGE PATTERN

Drainage channels tend to develop along areas where rock types and structures are most easily eroded.[17] The types of drainage patterns that develop in a region thus often reflect the structure of the rock and the faulting or fracturing. Here are some common **drainage patterns**, as defined by Stephen A. Nelson, of Tulane University:[18]

- **Dendritic drainage patterns** are the most common. They develop on a land surface where the underlying rock uniformly resists erosion.
- **Radial drainage patterns** develop surrounding elevated land areas where elevation drops from a central high area to surrounding low areas.
- **Rectangular drainage patterns** develop where linear zones of weakness, such as joints or faults, cause the streams to cut down along the weak areas in the rock.

ADDITIONAL INFORMATION:

A watershed is the most logical unit to use for flood risk management planning, as it defines a more or less "closed" system for measuring and predicting **water balance** (broadly defined as the input, output and storage of water).

3.3.3 SIZE OF THE WATERSHED

The size of a watershed determines how much water can be expected to accumulate in streams and rivers following precipitation (rainfall or snowmelt). Within larger watersheds, smaller sub-watersheds may respond differently to the same volumes and intensities of precipitation. Therefore, it is important to assess flood risk at the appropriate scale for each watershed.

3.3.4 SLOPE OF THE WATERSHED

In general, the slope of a watershed can have a bearing on floods. Steeper slopes are generally more prone to flash floods, while flatter areas are more likely to experience areal or riverine flooding due to poor drainage.

3.3.5 PRECIPITATION REGIME

Precipitation (e.g., rain, snow, hail) in a watershed can be a major factor in eventual flooding. Defining a precipitation regime for the watershed helps users understand how and when flooding can be expected.

16 Stephen A. Nelson, "Streams and Drainage Systems," Tulane University, EENS 111 Physical Geology, accessed January 6, 2016, http://www.tulane.edu/~sanelson/eens1110/streams.htm.

17 Ibid.

18 Four drainage pattern definitions from Nelson, "Streams and Drainage Systems."

The following are five generalized precipitation regimes:[19]

1. **Infrequent precipitation** is confined to specific months and on average comes in very small amounts. This regime can experience infrequent (sometimes once a decade) rainfall, which can be heavy and result in widespread flooding.[20] Examples are the deserts of northern Chile and southern coastal Peru, where precipitation is rare but, when it does occur, can lead to extensive flooding.

2. **Frequent precipitation** occurs throughout the year but with months of higher totals. Flooding in this regime occurs when rainfall exceeds averages, either in single events (a cyclone) or in a combination of events (several cyclones in a short period). The Solomon Islands, which experienced severe flooding due to a cyclone in 2014, is an example of this regime.

3. **Variable precipitation through the year**, with some of the precipitation as snow, can lead to flooding from single severe storms, from melting snow, and from periods of extended intense precipitation, such as cyclones or stalled weather systems. Much of continental Europe fits this regime.

4. **Variable precipitation concentrated in specific periods of the year**, such as rain in the fall, snow in the winter, and rain and snow in the spring, can lead to floods from intense storms in the fall or spring and the combined effects of rainfall and snowmelt in the spring. Central Asia fits this regime.

5. **Distinct dry and wet periods** can lead to precipitation from low pressure systems bringing in moisture from the oceans, even from a significant distance.[21] Flooding can be associated with the violent storms at the beginning of the rainy season or as the result of weather systems that stall over an area and lead to unusually heavy precipitation. The coastal and interior zones of West Africa and South Asia fit this regime.

These regimes are generalized, and variations can occur over relatively small distances (e.g., from the windward to the leeward side of a mountain) and with elevation. Near sea level the precipitation regime may have distinct wet and dry periods, whereas nearby mountains may experience relatively low levels of average precipitation.

Extreme precipitation can occur at almost any time under each of these regimes. For instance, the Himalayas normally experience most precipitation – and flooding – during the summer monsoon. Occasionally, however, low pressure systems can bring heavy snowfall and rains during the normally dry fall and winter seasons. To predict future flooding events, it is important to know when these extreme precipitation events have occurred in the past, based on local histories and weather data, and whether these events led to flooding.

3.3.6 VEGETATION AND SOIL

Under some conditions, the abundance and type of vegetation in a watershed can affect the likelihood of flooding. Vegetation can influence flood hazard by

- reducing the intensity of precipitation, as when rainfall hits multiple layers of leaves and results in smaller drops hitting the ground, thereby protecting the soil;

- creating a layer of organic material above and in the soil, which can protect the soil from the direct impact of rain;

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19 Drawn from Michael Pidwirny and Scott Jones, "Introduction to the Atmosphere," in *Fundamentals of Physical Geography*, 2nd ed. (E-book, 2010), http://www.physicalgeography.net/fundamentals/7v.html.

20 This regime can be applied to polar areas where there are relatively low levels of precipitation. In these areas, flooding can occur when rapidly increasing temperatures melt snow but not the underlying frozen ground.

21 "Dry" is used here as the absence of regular precipitation. These areas may remain humid in the absence of rainfall.

- holding soil together with roots; and
- absorbing water from the soil, thus increasing soil water storage capacity.

However, human-modified areas, such as agricultural fields, orchards, pastures, mining areas, roads and developed areas, often have degraded soils and/or less vegetation coverage than unmodified areas. This can affect infiltration capacity and contribute to higher levels of runoff and increased localized flooding.

It is often assumed that the presence of more natural vegetation in a watershed lowers the risk of flooding. The critical factor in flood reduction, however, is the condition of the soil. Intact natural vegetation is usually an indication of stable soil conditions. Altered landscapes (from logging or agriculture, for example) often result in soil compaction and, therefore, reduction in infiltration capacity. **Deforestation** is often accompanied by logging roads and skid tracks, which create pathways for floodwaters to accumulate and shortcuts to streams and rivers.[22]

Managing vegetation at a watershed scale to address flood risk can be complicated and is not always possible (e.g., on very steep slopes with thin soils or where not politically or economically possible). Conserving natural landscapes and their infiltration capacity can be far more cost effective than restoration after the fact. Assessing the type of vegetation and the conditions of the soil in a watershed can help predict whether and what kind of vegetation and soil management might contribute to managing flood risk.

When a manager plans restoration as an element of flood management, a few general guidelines should be considered:

- Native plant species are usually better adapted to the climate conditions present.
- Non-native or invasive species have the potential to alter hydrological processes. For example, fast-growing trees such as Eucalyptus (*Eucalyptus* species) or Poplar (*Populus* species) transpire water much faster and in greater volumes. These qualities might make them a useful choice for certain drainage solutions, but they tend to shade out lower layers of vegetation, resulting in soil erosion under tree plantations and soil compaction.
- Layered vegetation – typical in a natural forest, with layers close to the ground, at midlevel and taller – is more effective than a single layer. The understory (vegetation close to the ground and at midlevel) can reduce the impact of rainfall, slow the melting of snow, and promote the development of the organic materials at ground level.[24]

GUIDANCE: While some of the natural functionality of the soils in the landscape can be restored, doing so is typically very complex, taking decades to centuries and is usually prohibitively expensive.[23] Therefore, it is better to avoid altering the landscape whenever possible.

3.3.7 SOIL AND GEOLOGY

A watershed's soils and underlying geologic conditions determine its basic hydrologic nature and how water flows through it. This information helps to explain the watershed's risk for flooding. More porous geologic features,

22 L. A. Bruijnzeel, "Hydrology of Moist Tropical Forests and Effects of Conversion: A State of Knowledge Review," (UNESCO/Vrije Universiteit, 1990), http://www.hydrology-amsterdam.nl/personalpages/Sampurno/Bruijnzeel_1990_UNESCO.pdf; Chandra Prasad Ghimire et al., "Reforesting Severely Degraded Grassland in the Lesser Himalaya of Nepal: Effects on Soil Hydraulic Conductivity and Overland Flow Production," *Journal of Geophysical Research: Earth Surface* 118, no. 4 (December 2013): 2528–45, doi: 10.1002/2013JF002888; M. Bonell and L. A. Bruijnzeel, eds., *Forests, Water, and People in the Humid Tropics: Past, Present, and Future Hydrological Research for Integrated Land and Water Management* (Cambridge, UK; Cambridge University Press, 2004), http://public.eblib.com/choice/publicfullrecord.aspx?p=228293; L. A. Bruijnzeel, "Hydrological Functions of Tropical Forests: Not Seeing the Soil for the Trees?" *Agriculture, Ecosystems & Environment* 104, no. 1 (September 2004): 185–228, doi:10.1016/j.agee.2004.01.015.

23 For more information, visit FAO at http://www.fao.org/docrep/008/ae929e/ae929e04.htm.

24 Ibid.

such as certain types of limestone or volcanic rocks, will absorb water better than less porous features, such as granite. Porous soils – generally those with more sand or organic content – absorb water better than less porous soils, such as those with higher clay content. Soil characteristics such as thickness, permeability, infiltration rate and degree of moisture have an effect on how, when and where water moves through an area.[25] More permeable soils and geologic features (e.g., karst, certain volcanic formations) can reduce the volume and/or speed of water moving downslope, so collection routes like streams, creeks and rivers are less likely to be overloaded.

Further, when precipitation saturates the soil, the likelihood of flash flooding – and other downslope movement of soil, mud and rock – increases. Once the soil has become saturated, any additional water will flow across the surface, and if the volume of precipitation or snowmelt is high, this can lead to flooding – often rapidly. Consequently, monitoring soil water levels and precipitation is important for flood risk management.

3.3.8 WETLANDS, LAKES AND MARSHES

Wetlands, lakes and marshes can collect floodwater and release it more slowly, limiting or preventing downstream flooding. In general, a watershed with more wetlands, lakes and marshes is better able to absorb floodwater, although extreme weather events have the potential to overload any system. From an ecosystem perspective, such watershed features should be managed and restored as natural ways to manage flooding; in many cases, wetland restoration is a low-cost method for managing potential flooding.

© Mauri Rautkari/WWF

Wetlands in Amboseli National Park, Kenya.

3.3.9 GEOMORPHOLOGY AND CHANNELS

Stream and river channels often affect the impact of flooding. Generally, if the watershed is steep and water runs over or close to the bedrock, channels are relatively straight, and water flows rapidly. These conditions are often found in the upper part of large watersheds.

25 Liu Zhiyu et al., *Guidelines on Urban Flood Risk Management (UFRM)*, Technical Report of TC Cross-Cutting Project on Urban Flood Risk Management in the Typhoon Committee Area (Macao, China: ESCAP/WMO Typhoon Committee (TC), 2013), http://www.typhooncommittee.org/46th/Docs/item%2010%20Publications/UFRM_FINAL.pdf.

Lower in a watershed, a river or stream has a natural tendency to meander, moving in an "S-" shaped pattern, particularly if erodible geology and soils exist. Over time the "S" can change, with downstream curves eroding banks and leading to local flooding as banks wash away.

Since downstream channels carry more flow than channels higher in a watershed, and flow may vary over the course of the year, these channels may naturally accommodate significant volumes of water. However, large volumes of water can increase erosion, with riverbank loss and associated flooding creating significant problems.

In particularly large channels, the meander process can create large river loops that are cut off from the main channel through bank erosion. The resulting lakes and wetlands can become natural retention areas for floodwaters.[26]

3.3.10 LAND COVER, LAND USE AND INFRASTRUCTURE

Infrastructure in a watershed can influence both the likelihood of flooding and the severity of potential flood damage. Infrastructure – such as dams, dikes, embankments and diversions – can reduce the impact of small and frequent floods if they are appropriately designed, constructed and maintained. At the same time, poorly designed bridges that prevent sufficient water from passing during floods, or structures built in places that experience frequent flooding, can heighten damage from floods – not only to the structures themselves but also to neighboring areas.

Because floodplains are flat, easy to build on, and accessible, they are often the sites of towns and industry. When not adequately protected, these areas can suffer considerable losses from flooding. While it is sometimes impossible to avoid building on a floodplain, planners should consider potential flooding and build in a way that protects the area without shifting flood problems elsewhere (e.g., upstream, downstream or to neighboring low-lying areas).

Changes in land use upstream (especially increased urbanization) will have serious implications for floodplains located **downstream**.

> "Of all the land-use changes that can impact a watershed and its **hydrology**, urbanization is by far the most significant. Such development increases impervious surfaces, such as asphalt and cement, producing greater volumes of runoff from storms, which 'run off' the land quicker than if a natural watershed was absorbing rainfall. Urbanization tends to increase the volume and peak of stream flows. The delivery of runoff to streams after the beginning of rainfall becomes flashier, reducing the lag time between the rainfall and the peak of a stream's flood stage… While urbanized watersheds can be expected to create long-term increases in runoff and stream flows, they cause more complex cycles in contributing sediment to their streams and valleys."[27]

In other words, because **urban** areas typically have a lot of pavement that prevents water from infiltrating, cities and towns are at particular risk for experiencing rapid onset (flash) floods. Urban areas can also change the type and amount of sediment that ends up in local waterways, reducing water quality and increasing water and physical pollution in local waterways.[28]

Upstream land use, such as farming, commercial agriculture and roads, can affect flood risk in the downstream community, mainly due to changes in how water infiltrates soils. Land use planning, management and enforcement are thus key elements of flood risk management.[29]

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26 Text in Geomorphology and Channels adapted from Stephen A. Nelson, "River Systems and Causes of Flooding," Tulane University, EENS 3050 *Natural Disasters*, July 13, 2012, http://www.tulane.edu/~sanelson/Natural_Disasters/riversystems.htm.

27 Ann L. Riley, Restoring Streams in Cities: A Guide for Planners, Policy Makers and Citizens (Washington, DC: Island Press, 1998), 132.

28 For more discussion on the unique features of urban areas, see chapter 6.

29 UNISDR, Progress and Challenges in Disaster Risk Reduction: A Contribution towards the Development of Policy Indicators for the Post-2015 Framework on Disaster Risk Reduction (Geneva: UNISDR, 2014), https://files.zotero.net/818470294/40967_40967progressandchallengesindisaste.pdf.

3.4 THE WATER CYCLE AND MANAGING WATER

The way water naturally changes and moves around the Earth is known as the hydrologic cycle. The hydrologic cycle begins when water evaporates from oceans. After temporary storage in the atmosphere, moisture precipitates in the form of rain, hail or snow (**precipitation**). Some of the water reenters the atmosphere after direct evaporation from the surface or from inland water bodies (lakes, rivers), while some is transpired by vegetation (**evaporation/transpiration**). The remainder infiltrates to the groundwater or "runs off" through rivers and streams, until it eventually returns to the ocean (**streamflow and groundwater recharge/discharge**).

After precipitation falls, water undergoes a complex interaction with vegetation and soil. If the soil surface has sufficient capacity, the water will infiltrate the soil and penetrate downward through the soil profile. If soils are compacted, possibly due to agricultural intensification or the application of an impervious (impermeable) layer, such as concrete or asphalt, water will run over the surface in the form of **overland flow** or **surface runoff**. The water flows across the surface as either confined or unconfined flow.[30] Unconfined flow moves in broad sheets or as a temporary layer of water, often causing sheet erosion, removing thin layers of soil uniformly.[31] This often occurs on recently plowed fields or where soil is loose and there is little vegetation. On the other hand, confined flow occurs in gullies, ditches and other natural or artificial flow channels, rapidly increasing in volume as water accumulates downslope.

Surface runoff may become trapped in, and slowed by, depressions. Here water may either evaporate back into the air, infiltrate the ground, or spill out as the depression fills.[32] If local drainage conditions cannot accommodate rainfall through a combination of evaporation, infiltration of the ground, and surface runoff, accumulation of water may cause localized flooding problems.[33] Water that infiltrates the ground can take hours to months to arrive in a stream, while water flowing freely usually takes minutes to hours to end up in streams.

ADDITIONAL INFORMATION:

Professional hydrologists can measure and model the water that moves through a catchment, and that understanding can help with planning for flood risk management. A professional hydrologist can help the manager understand local water balance and how that information can affect the selection of flood management methods.

Understanding short and long-term water balances can help to determine where and how much water to expect during flood conditions. While it is often hard to exactly predict a flood event, it is possible to identify and map the parts of the landscape prone to flooding, and what the prevailing pathways of flow might be. Where, when, how and how much water flows in a watershed depends on a series of complex interactions between weather, land cover, river channel **geomorphology** (the physical features and shape of the river and land surface) and geology (the physical properties of the rocks underlying the land surface). It is important to recognize the limits to our knowledge and our ability to predict extreme events such as floods.

30 James Wright, "Chapter 2: Types of Floods and Floodplains," FEMA Emergency Management Institute, 2008, https://www.training.fema.gov/hiedu/aemrc/courses/coursetreat/fm.aspx.

31 Ibid.

32 Ibid.

33 Wright, "Chapter 2: Types of Floods."

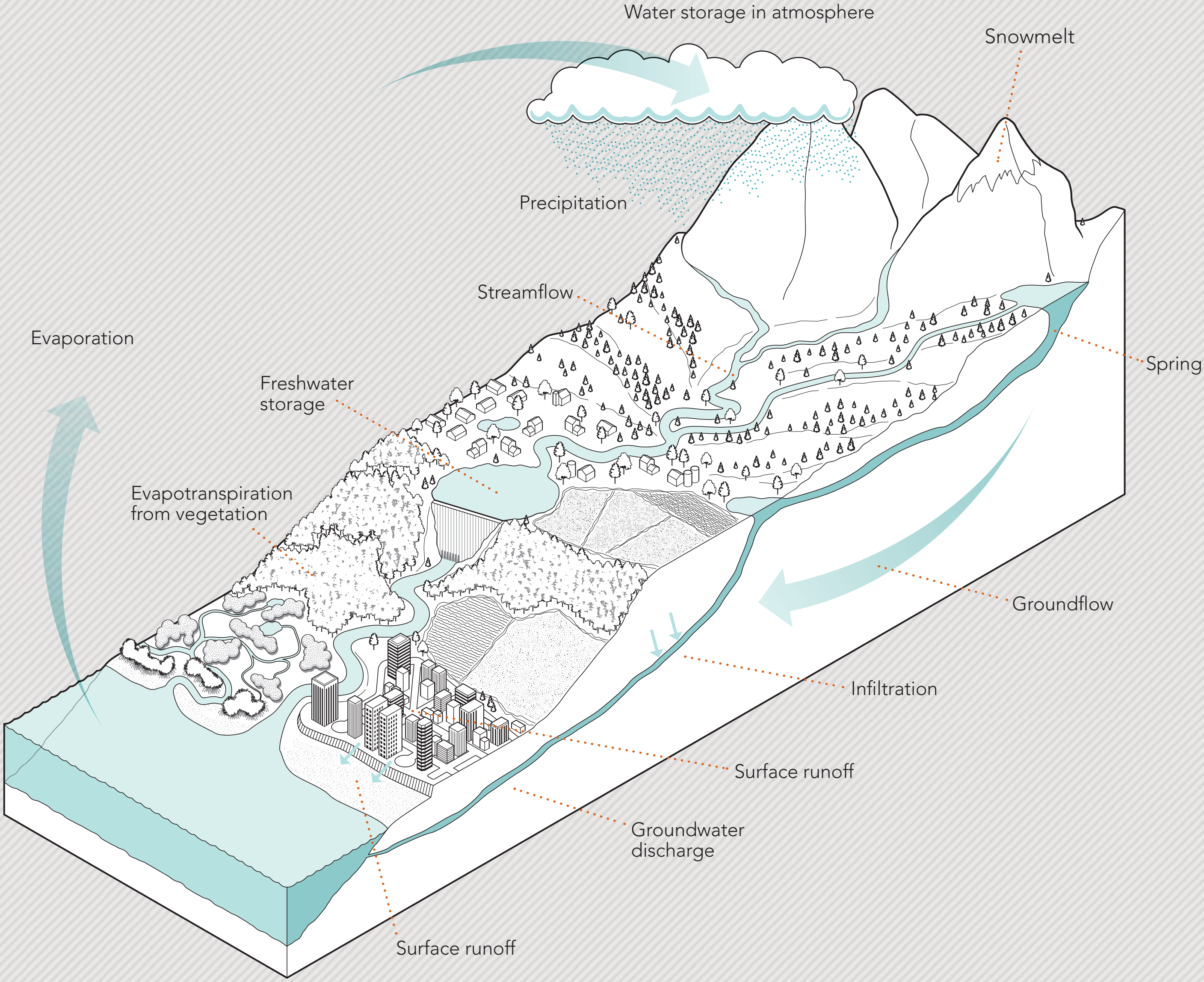

FIGURE 3.1 THE WATERSHED AND WATER CYCLE

3.5 CLIMATE AND WEATHER

3.5.1 WHAT IS CLIMATE?

The World Meteorological Organization (WMO) defines **climate** as the average **weather** (e.g., temperature, precipitation and wind) over a 30-year period.[34]

The climate variables of a watershed – precipitation, temperature and wind – can change with the following:

- **Elevation:** Precipitation can increase, while temperature can decrease, with elevation.
- **Peaks:** Peaks, high hills or mountains can contribute to severe local weather like thunderstorms, which can trigger flooding or flash flooding, and heavy snowfall, which can lead to localized flooding during melting.
- **Passes:** Low areas (known as passes or saddles) in the hills or mountains around a watershed can channel winds into and through it, at times causing more severe damage to some parts of the watershed. Watersheds themselves can channel wind and contribute to local damage during storms.
- **Orientation:** Watersheds facing away from prevailing weather systems may receive less precipitation than watersheds facing prevailing weather systems. This is often referred to as a rain shadow effect. For example, moist air pushed by winds to the base of a mountain will create rain on one side of the mountain as the air rises and cools. The air is dry as it flows over the top of the mountain, contributing to dry conditions on the other side of the mountain range.

Climate conditions in one part of a watershed can impact other parts of the watershed, thereby influencing flood risk. For instance, the bottom of a watershed may be an arid zone with almost no rainfall. The upper areas of the watershed, however, may experience high levels of snow and/or rainfall throughout the seasons. Melting snow and rain, therefore, could be essential for irrigation in the arid lower sections of the watershed.

Snow and rain can also contribute to flooding. Knowing whether the upper sections of a watershed will accumulate precipitation, how much may accumulate, the intensity of precipitation, and how fast snow may melt as a result of temperature change is critical for flood risk management.

Although climate is defined by wind, temperature and precipitation averages over a 30-year period, these averages are not the only information needed for flood risk management. For instance, average precipitation data for two different years can obscure the fact that in one year most of the precipitation fell in a short period and contributed to flooding, while in another year, precipitation was spread out over many months, and no flooding occurred. Historical analysis of precipitation can identify baseline conditions, as monthly, seasonal or average means. Further analysis can be carried out, based on the availability of daily weather station data, to identify precipitation extremes, precipitation intensity, the number of wet days per month or season, and the trends in this data. In the absence of weather station data, gridded data sets and satellite data can be used for analysis. Projections of precipitation based on climate model outputs can be analyzed and compared to historical climate data to identify how precipitation is expected to change in the area of interest.

Local climate monitoring within a watershed should identify minimum and maximum levels of precipitation and temperature. The data can be used to predict the likelihood of extremely high precipitation or temperature levels that can lead to either flooding or very dry conditions. The use of climate data to better understand flood risk is

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34 Intergovernmental Panel on Climate Change, *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* (New York: Cambridge University Press, 2012), 557.

most reliable when managers also consider past flood events' precipitation and temperature data and look at other local and regional factors (such as vegetation cover, **permeability** of soils, development), which can also contribute to flood risk.

3.5.2 CLIMATE VARIABILITY AND CLIMATE CHANGE

The Flood Green Guide definitions of climate change and variability are based on the Intergovernmental Panel on Climate Change (IPCC) definitions, as follows:

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.[35]

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events.[36]

For flood risk management, it is important to consider both climate variability and climate change. Past records of weather data (from as far back as possible) can help illustrate how precipitation patterns (and extremes) have changed over time. A climate-informed approach to flood risk management calls for considering historical climate trends in the region in conjunction with existing knowledge based on projections and scenarios of extreme weather events and any information available on predicted future climate change.

For example, an analysis of daily precipitation and flood records may indicate that when a certain level of precipitation falls in an hour, flash flooding can be expected. As a result, weather conditions can be monitored to identify when storms may lead to precipitation that can cause flash flooding, prompting warning systems and evacuation. Analysis of historical climate and **climate projections** could identify future possibilities in terms of increased precipitation (at the monthly or seasonal scale) and changes in intensity.

Considering future changes to climate provides a perspective on what adaptations may be required to withstand climate extremes and minimize harm.

Global climate models are widely used to project future climate conditions – for instance, the climate in 30 or 100 years. The models show changes in the *average* precipitation and temperature and, in some cases, can identify extreme events. In addition to the range of climate outcomes in the future, non-climate factors can be expected to change as well.

The goal is to take a holistic approach, as many factors will influence future climate and future flood risk, as well as options for flood risk management.

ADDITIONAL INFORMATION:

In the United States, federal government policy requires agencies to systematically consider climate resilience in the US government's international development work and to promote a similar approach with multilateral entities.[37]

35 International Panel on Climate Change (IPCC). "Annex III: Glossary." In *Climate Change 2013: The Physical Science Basics*. (New York: Cambridge University Press, 2013).

36 Ibid.

37 Executive Order No. 13677, 79 FR 58229 (September 23, 2014), https://www.federalregister.gov/articles/2014/09/26/2014-23228/climate-resilient-international-development.

3.5.3 WEATHER OBSERVATION AND MONITORING

Precipitation, temperature and wind data is necessary to understand the local and regional climate. The data can be collected from national meteorological and hydrological services (NMHSs), agricultural stations or river basin authorities, among other sources. Flood risk management depends on, first and foremost, reliable weather observations – ideally taken throughout a **catchment** area, especially at higher elevations since precipitation is often driven by changes in elevation. Managers should determine whether national weather service information is available and historical climate data for the area can be obtained. Where local weather station data is not available, other climate products and satellite information can be used. In order to use this information effectively, however, guidance from meteorologists and climate scientists is recommended.

Ideally, managers should collect data about weather and water levels from several locations within the area of interest and, if possible, upstream from the area. If a nearby weather station is not available, a simple station to collect precipitation, temperature and wind data can be constructed at minimal cost and operated with basic knowledge. Community-based monitoring of weather and water-level conditions can encourage community participation in, and ownership of, flood risk management actions. At least 30 years of good-quality data are required in order to conduct a historical analysis of the climate. Data from historical records and more recently established weather station data can be useful to identify recent extreme events and flooding. Setting up new weather stations is useful, especially in areas where observed climate measurements are sparse or absent. For more information on weather and water-level gauge construction, see chapter 4.

© Filmaciones y Contenidos/WWF

This weather station monitors precipitation, temperature and wind to relay weather information to farmers.

3.6 RESILIENCE

USAID defines resilience as the ability of people, households, communities, countries and systems to mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth. As this suggests, the concept of resilience and its measurement are complex.[38]

38 United States Agency for International Development (USAID). "Resilience at USAID." (Washington, DC: USAID, June, 2015).

WWF defines **resilience** as the ability of a social-ecological system to absorb and recover from shocks and disturbances, maintain functionality and services by adapting to chronic stressors, and transform when necessary.

The Zurich Flood Resilience Alliance[39] includes Four Rs in its characterization of community flood resilience:

- robustness (ability to withstand a shock)
- redundancy (functional diversity)
- resourcefulness (ability to mobilize when threatened)
- rapidity (ability to contain losses and recover in a timely manner)

There are therefore multiple ways to define and employ the concept of resilience in both natural and social systems. Thus in relation to flood risk management, the term "flood resilience" is also associated with multiple uses; for example, reference may be made to flood-resilient buildings, construction, or communities.

The Flood Green Guide recommends using four guiding questions for flood management issues (adapted from Carpenter et al., 2001[40]) in order to operationalize the concept of resilience:

1. **Resilience *of* what?** Which community, livelihood, institution, infrastructure, ecosystem, protected area?
2. **Resilience *to* what?** Are you addressing a shock, disturbance or stressor?
    - **Shocks and disturbances:** floods, cyclones?
    - **Stressors:** increased frequency and intensity of tropical storms, sea level rise, glacial melt, unpredictable rainfall?
    - **Impacts:** loss of life, damage to infrastructure, failing infrastructure?
3. **Resilience *for* what? (Why? Who benefits?)** An objective related to community, household, institution, infrastructure, ecosystem, protected area?
4. **Resilience *through* what? (How?)** Activities in flood management methods, land use planning, conservation, sustainable development, **disaster risk reduction**? These may be potentially new pathways to resilience through new and different sets of activities.

3.7 CROSSCUTTING ISSUES

3.7.1 INSTITUTIONS

Integrated flood management (IFM) takes place at various scales, including community, local/municipal, watershed, national and sometimes the region as a whole (for example, the Himalayas, the Greater Mekong region).[41] Because the source and/or causes of flooding may be some distance from the primary area of interest, managers must consider issues of scale.

Often, the best option may be to address flooding before it reaches the area of interest, and it is critical to ensure flood management methods in one area do not shift flood risk to other communities.

Managers should understand the institutions that are, or could be, involved with flood management, as well as those relevant to the use of natural and nature-based management methods. Relevant

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39 A collaboration between the International Federation of Red Cross and Red Crescent Societies (IFRC), Practical Action, International Institute for Applied Systems Analysis (IIASA), and the Wharton Risk Management and Decision Processes Center.

40 Steve Carpenter et.al., "From Metaphor to Measurement: Resilience of What to What?" *Ecosystems* no. 4 (2001): 765-781, doi: 10.1007/s10021-001-0045-9.

41 Zhiyu et al., "Guidelines on Urban Flood Risk Management (UFRM)."

institutions may include those involved with water management, land management, planning, infrastructure, agriculture, the environment and meteorological services, to name a few.

Institutional mapping can be used to identify the level of awareness and perceptions of key institutions, both formal and informal, as well as of key individuals, inside and outside a community, city, province or country.[42] Institutional mapping also will help the manager identify how the different actors relate to one another.[43]

See chapter 4 for additional information on assessing institutional capacity.

3.7.2 REGULATION

Regulations play a vital role in implementing and enforcing flood risk management strategies. In most cases, three types of regulations can be put into place:

1. **Command and control:** Restrictive regulations prohibit specific types of development (such as residential structures in a floodway); limit density (the number of structures built); and exclude hazardous or critical facilities (such as medical or industrial complexes). Prescriptive regulations can mandate such norms as building safety standards and minimum ratios of unpaved areas. Command and control regulations are generally introduced as laws, municipal bylaws, statutory norms or mandatory agency procedures. Command and control regulations are effective but often require significant financial and human resources for monitoring and enforcement.

2. **Self-regulation:** Self-regulation means that certain policies and practices are adopted by industries, communities or businesses. The regulations are encouraged by the government but are without means of enforcement. Self-regulation can be cost-effective, but it requires genuine commitment from businesses and communities.

3. **Incentive-based regulations:** As an alternative to costly command and control regulations, governments can provide economic incentives to induce businesses and communities to follow desirable practices. Economic incentives include taxing offending development while subsidizing preferred types of development. Incentives are formally instituted by governments through regulatory agencies and require a certain degree of monitoring and legal enforcement.

The use of natural and nature-based methods may require adoption of new, or modification of existing, regulations. When selecting methods, managers should consider the role regulation plays in the success of those methods.

3.7.3 CROSS-SECTOR COORDINATION AND COOPERATION

Integrated flood management (IFM) includes coordination between national and city governments and public-sector companies, including utilities, along with civil society, nongovernmental organizations (NGOs), educational institutions and the private sector.[44] Cooperation and coordination among various sectors in both planning and implementing flood risk management methods are important in the IFM approach because the contributing factors of flood risk may reach across organizational and governmental boundaries.[45] Coordination and collaboration among various agencies will help bring about improved flood risk management. For example, municipalities, which often handle community-level development and building approvals, should coordinate with the urban development agencies that handle city-level planning.

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42 Ibid.

43 Ibid.

44 Ibid.

45 Gasparini et al., *Resilience and Sustainability in Relation to Natural Disasters*, highlights cross-sector coordination as essential for building resilience and sustainability in relation to natural/manmade disasters in cities.

Managers can approach cross-sector coordination in a number of ways. One is to create a platform, such as a flood task force, to facilitate discussion and decision-making among various agencies and actors. For example, some governments will create a task force consisting of elected or appointed officials and business representatives to review past flooding events and develop recommendations to minimize or eliminate future flooding in the region. Another approach is to delegate one agency as a coordinating body. National or state-level disaster management agencies can often take on this role. The Flood Green Guide recommends, however, that when multiple institutions and actors are involved, care and consideration are given to understanding and managing institutional boundaries, so staff in agencies are motivated and willing to cooperate. In addition, organizational policies and procedures can be set up to compel agencies to communicate with each other when making decisions that have an impact on flood risk.

3.7.4 COMMUNITY ENGAGEMENT

Engaging the community at all stages of flood management – from assessment to selection and implementation of management methods – will help ensure that the methods enacted are fair, equitable and effective, and meet the needs and priorities of the entire affected population.[46] Community engagement also helps generate extra knowledge and resources; however, it can easily be absent due to lack of training, cohesion and community organization.[47] According to the National Research Council (USA), "communities most likely to survive disaster are those committed to building a sense of community, those that are actively committed to social equity and inclusion, those that are economically and environmentally sustainable, and those that create a vision to which its residents and institutions can relate."[48] Flood risk management interventions planned or implemented without proper community engagement have a high risk of failure.

Engaging the community can occur at many levels: through community consultation, participatory planning, community involvement in implementation and construction, and community-based monitoring and evaluation. Community engagement leads to community empowerment and a greater chance of success in flood management. Generating the necessary changes in attitude and behavior, however, calls for time and investment in widespread communication and participatory consultation with multiple stakeholders.[49] Flood management project design and implementation can be substantially strengthened when the community works with the experts on assessment, planning and decision-making.

The issue of time constraints must be considered by decision-makers in relation to the involvement of communities and other stakeholders. The time that most people have to participate in flood risk management measures, including public consultations and other activities, is often limited. Mobilizing the community to participate in voluntary service is also a challenge.[50] Managers and decision-makers should also note that various marginalized groups – including the poor, indigenous people, ethnic and religious minorities, marginalized castes, migrants, and people with special needs – are often underrepresented in community planning. Gender issues should also be considered in participatory activities (see gender section).

Young people can contribute much to flood management approaches. Examples from around the world confirm the opportunities and benefits of engaging a community's young people.

To the extent possible and appropriate, flood risk management activities should aim to empower communities through building awareness of, and resilience to, floods, while building technical skills and generating **co-benefits** such as local employment.

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46 Zhiyu et al., *Guidelines on Urban Flood Risk Management* (UFRM).

47 See Jha et al., *Cities and Flooding*, Section 6.3.

48 See National Research Council (US), *Private-Public Sector Collaboration to Enhance Community Disaster Resilience*, 3.

49 Zhiyu et al., *Guidelines on Urban Flood Risk Management* (UFRM).

50 Ibid.

3.7.5 GAMES

Games can be tools to foster community engagement and cooperation, and help with complex decisions related to flood risk management. Games and visuals can help participants understand the existing and future risks while assisting with decisions about management approaches.

Dr. Bruce Lankford, a professor at the University of East Anglia, UK, developed a water resource management game as a teaching tool for facilitating cooperation over water resources. His research shows simple activities like games can facilitate discussion and expand people's perspectives on water issues.[51]

People's ideas relating to water, for example, are often biased toward their own experiences. Whether the water user is a farmer, engineer or policy-maker, solutions for water-related problems are influenced by how they use and benefit from the water. Their solutions are usually based on their experiences and needs. When games are employed, participants are more likely to work together to generate interdisciplinary proposals that will benefit all involved.[52]

Lankford's games approach was adapted by LIMCOM (Limpopo Watercourse Commission) in September 2011. LIMCOM conducted water allocation training for officials and commissioners and included the River Basin Water Allocation game. "The River Basin game was found to be very important in the sense that participants could understand aspects of water resources management, taking into account the basin as a unit."[53]

Although games can be a useful approach, underlying the use of such tools must be a fundamental understanding – so often lacking – of the physical impact of flooding and the expected outcomes of the flood management techniques in place.

3.7.6 GENDER

With increased research and analysis, our understanding of how gender plays a role in disaster management, including flood risk management, is growing. For the purpose of the guide, we use the following definition of gender:

> **Gender** is a social construct that refers to relations between and among the sexes based on their relative roles. It encompasses the economic, political, and sociocultural attributes, constraints, and opportunities associated with being male or female. As a social construct, gender varies across cultures, is dynamic, and is open to change over time. Because of the variation in gender across cultures and over time, gender roles should not be assumed but investigated. Note that "gender" is not interchangeable with "women" or "sex."[54]

3.7.6.1 Why Is Gender Important?

It has been well established that climate change and disasters, as well as disaster risk reduction activities, have gender components in terms of impacts and interventions. For example, women are affected by disasters differently – and often more severely – than men; this is largely because men and women are bound by distinct social and economic roles and responsibilities.[55]

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51 Dr. Bruce Lankford, a professor at the University of East Anglia, UK, developed a water resource management game as a teaching tool for facilitating cooperation over water resources.

52 Bruce Lankford, *Resource Efficiency Complexity and the Commons: The Paracommons and Paradoxes of Natural Resource Losses, Wastes and Wastages* (Abingdon, UK: Earthscan Publications, 2013), 190.

53 Email from Sérgio Bento Sitoe, Limpopo Watercourse Commission (LIMCOM) secretariat, to Dr. Bruce Lankford, of University of East Anglia, UK, sent February 19, 2016.

54 USAID, *Guide to Gender Integration and Analysis: Additional Help for ADS Chapters 201 and 203*, March 31, 2010, https://www.usaid.gov/sites/default/files/documents/1865/201sab.pdf.

55 UNDP, *Gender and Climate Change: Impact and Adaptation Workshop Highlights*, UNDP Asia-Pacific Gender Community of Practice Annual Learning Workshop (Negombo, Sri Lanka, 2009), http://www.snap-undp.org/elibrary/Publications/GenderAndClimateChange.pdf.

Following its adoption at the Third UN World Conference on Disaster Risk Reduction, the UN General Assembly endorsed the Sendai Framework for Disaster Risk Reduction (DRR), which recognizes the importance of gender dimensions in DRR and calls for inclusiveness and engagement of all of society. The Sendai Framework calls for

> "a gender, age, disability and cultural perspective in all policies and practices; and the promotion of women and youth leadership; in this context, special attention should be paid to the improvement of organized voluntary work of citizens."[56]

Furthermore, the Sendai Framework emphasizes that

> "women and their participation are critical to effectively managing disaster risk and designing, resourcing and implementing gender-sensitive disaster risk reduction policies, plans and programmes; and adequate capacity building measures need to be taken to empower women for preparedness as well as build their capacity for alternate livelihood means in post-disaster situations."[57]

The Flood Green Guide promotes gender integration in all aspects of flood risk assessment and management, including planning, design, implementation, monitoring and evaluation. A number of resources and tools can assist the user with gender integration (see the additional resource section in this chapter).

3.7.6.2 Gender Analysis

As a key component of contextual analysis (see chapter 2), guide users should conduct or commission a gender analysis. A **gender analysis** will provide guide users with greater understanding and appreciation for the existing and future role that gender can play in local flood risk management. Gender analysis should always be a part of assessments, project planning, design and implementation.

Six domains of gender are typically included in gender analysis:[58]

- access
- knowledge, beliefs and perceptions
- practices and participation
- time and space
- legal rights and status
- power and decision-making

Appendix B provides details related to the six domains and suggests questions that might be included in gender analysis as part of designing a flood risk management project.

3.7.6.3 How to Integrate Gender and Flood Risk Management

Based on work conducted by the International Centre for Integrated Mountain Development (ICIMOD) in 2014, the United Nations Development Programme (UNDP) in 2010, and others, we suggest the following guidance be applied to flood risk management methods to better integrate gender:

- Analyze how flood risk affects both males and females.
- Develop and apply gender-sensitive monitoring criteria and indicators.

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56 UNISDR, "Gender," last accessed February 2016, http://www.unisdr.org/we/advocate/gender.

57 Ibid.

58 USAID, "Tips for Conducting a Gender Analysis at the Activity or Project Level," March 2011, https://www.usaid.gov/sites/default/files/documents/1865/201sae.pdf.

- Include statistics on women as well as on men when collecting and presenting data.
- Capitalize on the talents and contributions of both women and men.
- Develop local infrastructure with the active involvement of local men and women.
- View flood risk management as a social and development activity rather than an exclusive domain of engineers and technicians.
- Consider gender from the very beginning of the project cycle, to avoid interventions that can have unintended gender implications.
- Ensure that facilitators are sensitive to equitable community participation in discussions and decision-making.
- Utilize new techniques and technologies as entry points for overcoming traditional gender barriers.
- Work to establish gender-balanced participation in all aspects of project planning and implementation.
- Undertake a gender analysis of all budget lines and financial instruments.

3.7.6.4 Gender-Responsive Budgeting

Applying a gender integration approach to flood risk management also includes gender-responsive budgeting (GRB). GRB is a tool that can be used to ensure that budgets recognize that while the needs of women and men are sometimes the same, they can also be different, and allocations should reflect these differences.[59] GRB is one way of ensuring that observed gender differences are reflected in project budgeting, making it more likely that the project will equally assist men and women.[60]

3.7.7 PRIVATE SECTOR PARTICIPATION

According to the Asian Disaster Preparedness Center (ADPC) and the UN Office for Disaster Risk Reduction (UNISDR), private sector involvement is a key part of building disaster-resilient cities.[61] Big businesses as well as small and medium enterprises (SMEs) suffer substantial losses in disasters. SMEs can be hit the hardest, as their losses are often not fully covered by insurance.

Private sector involvement in flood risk management is advantageous in two ways. First, it can reduce the market-based barriers to plans for flood risk management activities, including natural and nature-based methods. Second, it can channel private sector resources to flood risk management.[62]

The private sector can participate in flood risk management in a number of ways. Managers should include representatives from the business community in discussions and meetings. Start by consulting local business associations like the chamber of commerce. A more advanced step is to launch flood risk management or recovery initiatives as public-private partnerships by enlisting select private sector companies as partners in the project.

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59 UNDP, *Gender, Climate Change and Community-Based Adaptation* (New York: UNDP, 2010), http://www.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/climate-change/gender-climate-change-and-community-based-adaptation-guidebook-/Gender%20Climate%20Change%20and%20Community%20Based%20Adaptation%20%282%29.pdf.

60 Ibid. For more information from UNIFEM, visit www.gender-budgets.org.

61 See *ADPC 2020 Strategy*; also see UNISDR, "Private Sector."

62 See UNISDR and Roeth, *The Development of a Public Partnership Framework and Action Plan for Disaster Risk Reduction (DRR) in Asia*.

Private sector partners may contribute funds for flood risk management activities when they are equal partners. These may come through contracts or memoranda of understanding (MOUs) that honor private sector interests. Private sector resources also might be obtained as in-kind support, such as donations of equipment, material, labor or expertise, especially in cases where the private sector will benefit from flood risk management.

A number of corporations promote and/or benefit from what is sometimes called "natural infrastructure." For example, the Caterpillar Corporation held a summit on restoring natural infrastructure in 2015 that promoted plans to expand education, outreach and partnerships related to natural infrastructure. Private corporations may be potential partners and/or stakeholders in developing and using natural and nature-based methods.

3.7.8 FINANCE

Funding sources for flood risk management can be as varied as the stakeholders and issues involved. Financial support for community development, infrastructure, disaster risk reduction, disaster **response**, climate change adaptation, sustainable development, education, and environmental management can come from any number of government agency budgets, donors, NGOs, and the private sector. In the Philippines, for example, the Palo municipality conducted a review of its local planning and development tools to incorporate DRR in order to reduce the impacts of flooding. Once the assessment identified the most appropriate measures, responsibilities were allocated among relevant administrative bodies and incorporated into the municipality's Annual Investment Plan.[65]

When planning how to use natural and nature-based flood risk management methods, finances from multiple sectors should always be considered. In addition, communities may consider establishing links to microfinance sources and setting up a community-owned disaster fund to support development and management of certain flood management methods.

EXAMPLE:
The Philippines provides an example of a national-level framework for private sector participation in disaster risk reduction. In that country, a number of private sector associations, such as the Private Sector Network for Disaster Management (PSNDM) and the Corporate Disaster Response Network (CDRN), have been formed to expedite mobilization of resources through partnerships between nongovernmental organizations, private volunteer organizations, government offices and communities.[63] In 2007 and 2008 the PSNDM and CDRN participated in the "National Multi-stakeholder Dialogue on DRR" to help assess progress made on national DRR goals.[64]

63 UNISDR and Helen Roeth, *The Development of a Public Partnership Framework and Action Plan for Disaster Risk Reduction (DRR) in Asia* (Bangkok, Thailand: UNISDR, 2009), http://www.unisdr.org/files/12080_TheDevelopmentofPublicPartnershipFr.pdf.

64 Ibid.

65 Zhiyu et al., *Urban Flood Risk Management.*

3.8 ADDITIONAL RESOURCES

1. Associated Programme on Flood Management (APFM), http://www.apfm.info/.
2. APFM, *Flood Management in a Changing Climate*, 2009, http://www.apfm.info/publications/tools/Tool_09_FM_in_a_changing_climate.pdf.
3. APFM, *Formulating a Basin Flood Management Plan*, 2007, http://www.preventionweb.net/files/2626_ToolsBasinFloodManagementPlan.pdf.
4. FAO, *Forests and Floods: Drowning in fiction or thriving on facts?* 2005, ftp://ftp.fao.org/docrep/fao/008/ae929e/ae929e00.pdf.
5. USAID, *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change*, 2014, http://pdf.usaid.gov/pdf_docs/PBAAA245.pdf.
6. USAID, *Tips for Conducting a Gender Analysis at the Activity or Project Level*, 2011, https://www.usaid.gov/sites/default/files/documents/1865/201sae.pdf.
7. UNDP, *Gender, Climate Change and Community-Based Adaptation*, 2010, http://www.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/climate-change/gender-climate-change-and-community-based-adaptation-guidebook-/Gender%20Climate%20Change%20and%20Community%20Based%20Adaptation%20(2).pdf.
8. UNISDR, *Making Disaster Risk Reduction Gender-Sensitive Policy and Practical Guidelines*, 2009, http://www.preventionweb.net/files/9922_MakingDisasterRiskReductionGenderSe.pdf.
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