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Implementation Guides November 2021

How to reduce flood risk in your city

Adapting to Climate Change | Spotlight On: Nature-based Solutions

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Floods are the most common natural hazard, accounting for 43% of hazard events from 1995 to 2015 and affecting 2.3 billion people.[1] Already, urban flooding poses significant social and economic risks to cities around the world. They have caused more than USD 1 trillion in economic damage since 1980,[2] and most cities (91% of C40 member cities) are impacted by them. Climate change is making this situation worse: by 2030, the number of people affected will have doubled compared to 2010.[3]

> This focuses on river flooding, and flash flooding from heavy rainfall or 'cloudburst' events; for coastal flooding, read *How to adapt your city to sea level rise and coastal flooding*.

Cities are vulnerable to flooding not only because of their proximity to rivers, lakes and seas. Urban development has failed to safely and sustainably integrate water systems into urban space. This article explains how cities can address this to better manage urban flood risk.

Begin by assessing your city's flood risk

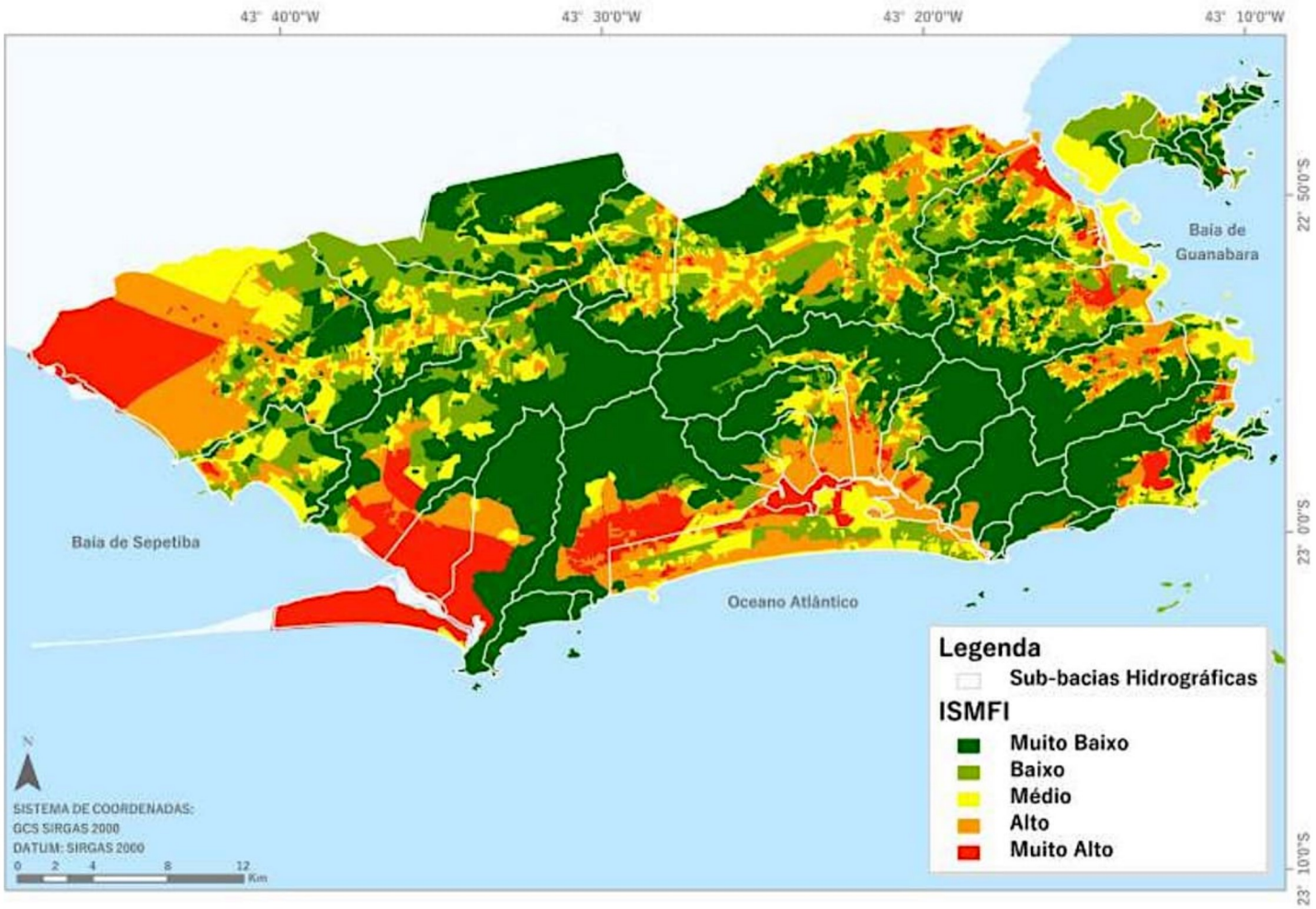
A flood risk assessment enables the city to identify and understand current and future flood impacts. This should ideally form part of a wider climate risk assessment. Read *How to conduct a climate change risk assessment* for advice on delivering this as part of the climate action planning process.

At a minimum, cities need to develop a flood map. Ideally, they should develop a full flood risk assessment to plan for and adapt to future climate change scenarios. Work with expert partners, such as national or regional meteorological departments, universities and other research institutions, as well as relevant non-governmental organisations, to develop it.

Here are the main approaches that cities can take to assess flood risk, from lesser to greater value and complexity:

- **Mapping the location of past floods in the city.** This is a technically simple and low-budget option, which can be based on records of flood damage, flood emergency calls and newspaper records. For example, San Francisco produced a flood map by geolocating emergency calls during flood events. This 'public perception' map was one component of the city's Assessment of Vulnerability to Flooding and Extreme Storms, which also included socioeconomic, demographic and other vulnerability data. Cities assessing flood-exposed areas for the first time, however, can use this standalone approach as a starting point.

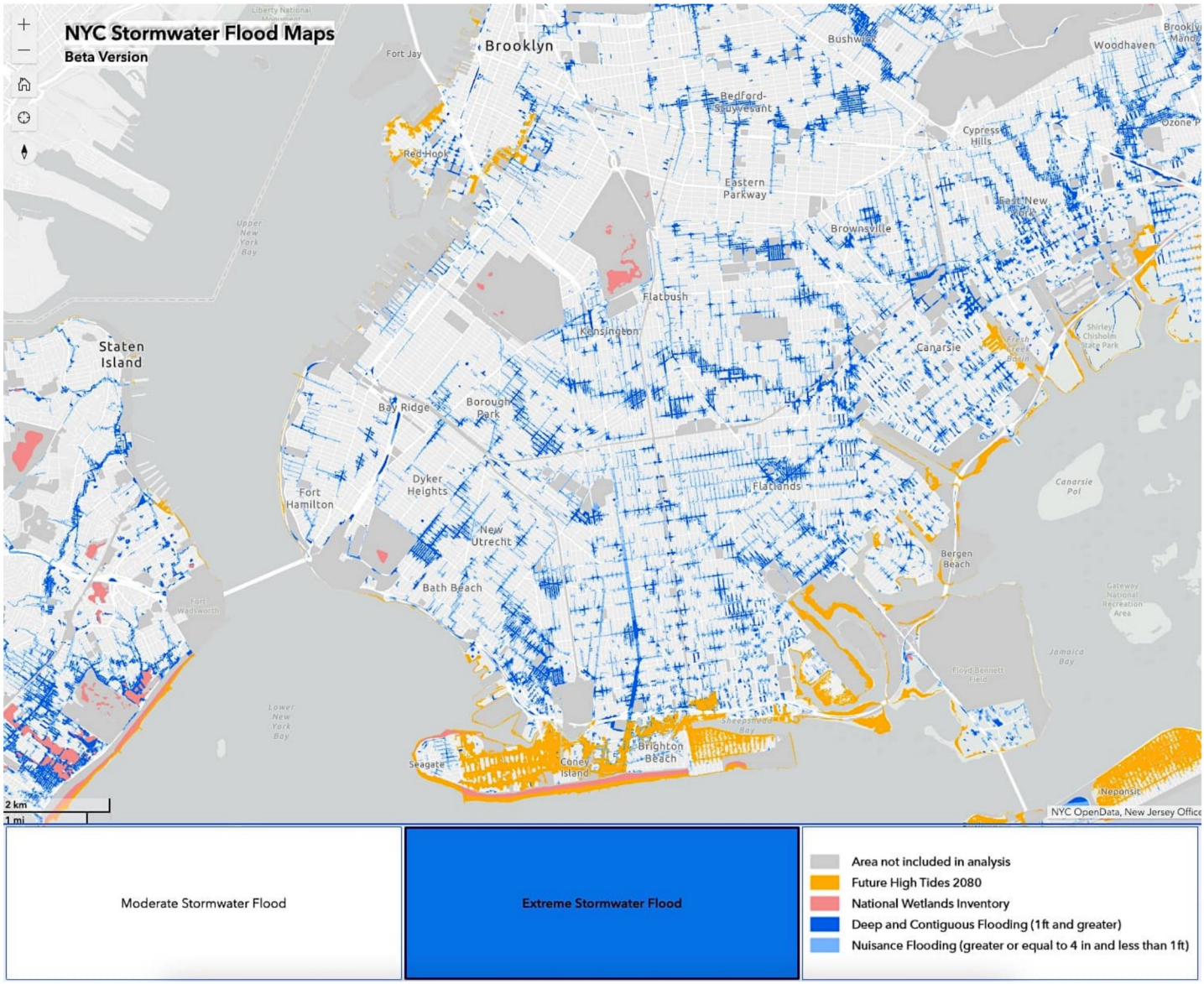
- **Mapping areas that are susceptible to flooding based on their geography.** These maps are produced using land elevation and use data to estimate water runoff and areas that are likely to flood. For example, Rio de Janeiro analysed geography, proximity to water bodies and permeability to produce the Índice de Suscetibilidade do Meio Físico a Inundações (Index of Susceptibility to Floods of the Physical Environment); shown in the map below, the red areas are those at highest risk of flooding.[4] This can be overlaid with information about vulnerable population groups and assets as part of a comprehensive flood risk assessment.



- **Comprehensive flood risk assessment.** This combines data on flood-prone areas with information

on vulnerable people and built assets to identify the most at-risk areas and priority actions. It should, for example, include factors such as land use and the locations of low-income communities, critical assets and infrastructure. Cities can follow the IPCC methodology to develop this comprehensive assessment, to spatially measure hazard exposure, vulnerability and the likelihood of an event. Curitiba's climate risk assessment and Durban's online, interactive assessment include flood risk maps overlaid with vulnerability data, such as critical roads and highly vulnerable informal settlements.[5, 6]

- **Sophisticated flood modelling.** This uses hydrodynamics analysis that considers data on rainfall, waterways, drainage systems, land use and, sometimes, geohydrological data. New York City has undertaken comprehensive flood modelling to develop maps like that below, which shows vulnerable areas in an 'extreme stormwater flood' scenario.[7,8]



Design responses to address local injustices

Mapping flood risk often highlights inequities and the need embed social justice in adaptation responses. In many cities in the United States, for example, flood risk is higher in areas that were 'redlined' by a racist housing policy in the 1930s – largely non-white neighbourhoods that were deemed undesirable for loans.[9] Flood protection investment based on cost-benefit analyses has also tended to favour areas with higher property values – further disadvantaging lower-income neighbourhoods.[10]

It is critical that flood risk reduction efforts are designed to address social justice issues. Houston, Texas is among the first cities in the United States to do so and is seen as a test case in the design of 'fair and equitable' flood risk policy.[11] Multiple flooding events, most significantly that caused by Hurricane Harvey's heavy rains in 2017, have disproportionately affected lower-income communities of colour. Flood investments associated with the city's 2020 climate action plan the resilience plan prioritise projects partly on neighbourhoods' 'social vulnerability', using an index that reflects recovery challenges.[12]

Develop flood emergency protocols and early warning systems

Informed by the flood risk assessment, develop and implement a plan to protect lives and assets in the event of a flood. Work with national and/or subnational governments, meteorological and emergency response departments, and other departments with relevant assets and responsibilities (such as education public health) to deliver this. The early warning system should use the best available weather forecasting and river-flow monitoring data available. If weather forecasting capacity in your country is low, consider working with a regional expert partner.

To develop and implement the plan, cities should:

- **Build cooperation mechanisms** between the city government, meteorological agencies, emergency departments, media and other partners to develop and implement the plan. Establish a flood emergency management governance structure and be clear on the roles of each agency in flood risk management and during a flood emergency. Consider appointing a steering group or lead officer to coordinate these stakeholders. Most cities do this as part of wider emergency management planning, as in Toronto and Durban (see box).

- **Determine the flood response actions to be triggered by an alert.** Priority actions for the city should include clearing debris from drainage systems immediately before a rain event, opening and raising awareness of shelters where the population can stay safe, distributing sandbags, deploying emergency services and using trucks with pumps to support drainage systems.

Rio de Janeiro's flood alert system

Rio de Janeiro has an emergency protocol to minimise the impact of flood events in low-income

communities. When a critical rain event is forecast, communities receive a flood alert to their phones by SMS, and sirens sound. Citizens are strongly encouraged to go pre-built shelters, and community leaders are trained to support people on route to the shelter.

Roles and responsibilities in Durban's disaster management planning[13]

Durban's Municipal Disaster Management Plan sets out a terms of reference for the city's Disaster Management Advisory Forum, which includes a city-wide risk assessment technical team, a municipal adaptation planning technical team and a South Durban Basin 'off-site' planning technical team. It also establishes procedures to activate the Disaster Operations Centre and Strategic Coordination Group, the roles and responsibilities of different agencies in pre-disaster planning and during disaster events, and more.

- **Determine how the alert will be communicated to the public.** Cities can use a combination of sirens, SMS alerts to mobile phones, volunteer groups, radio and other media alerts to get the message out quickly. It is critical that the alert reach vulnerable groups, such as elderly and isolated people, or people living in informal settlements.
- **Communicate with the public and businesses located in high-risk areas** to ensure that they know what to do in times of flooding, to minimise impact. For example, citizens located in high-risk areas should have pre-identified escape routes from their properties. If your city has established shelters, make sure residents know where they are.

Auckland's emergency management website[14]

Flooding is Auckland's most common natural hazard. The city's emergency management website includes guidance for local households, communities and businesses and explains what to do in a flood event, as well as other emergencies, such as earthquakes, tsunamis and severe winds. It provides guidance on what to do before, during and after a flood event, alongside dedicated personal planning resources, news and updates. Citizens can view a flood map to find out if their home or place of work is located in a flood risk zone, sign up for alerts and more.

Adapt your city to flooding: develop a long-term flood resilience plan

Urban surfaces, such as concrete and paving, are not permeable. Water quickly flows over them to collect in – and flood – lower-elevation areas, both within and downstream of cities. Many cities have also hidden

their natural waterways and drainage underground to create more urban space and to funnel away water as fast as possible, but these drainage systems are often unable to cope with high water volumes, leading to flooding when they are overwhelmed.

Cities can reduce the likelihood and impact of urban flooding by implementing strategies to better manage water on the surface, store excess water, and adapt buildings and infrastructure to better cope with floodwater.

Your city's plan for reducing the likelihood and impact of flooding should be informed by your flood risk assessment. Key partners in developing flood resilience plans include the city's urban planning and transport departments, water utilities, large building and land managers (such as education and health sectors, large retailers and housing providers), architectural and engineering experts, neighbouring local governments and relevant national government departments.

Adaptive measures at ground level are both easier and cheaper to implement than major upgrades to drainage infrastructure. These measures, particularly 'blue and green' (or nature-based) options, also help to reduce urban heat, manage water scarcity, improve water and air quality and create recreational space and leisure facilities. To minimise costs and disruption, cities can incentivise or require the installation of these measures during new developments, major roof repairs, building refurbishments or extensions, landscaping enhancements, road maintenance and other scheduled works.

The four-minute video below explains this concept of 'water sensitive cities' as part of an integrated approach to water management:

The main measures that cities can implement to reduce flood risk are:

- **Avoid new development on wetlands and floodplains as much as possible, ensuring that any new development in these zones is adapted to reduce flood risk** through the following measures. Use zoning and your building permit applications process to do this, making it compulsory to follow flood-resilient standards when building in floodplain areas. Philadelphia is one example of a city regulating development in flood-plain areas, including a mandatory flood-protection scoping meeting before submitting a permit application.

- **Increase the natural space along riverbanks and in flood plains to enable safer riverine flooding.** Returning vegetation to this land helps to increase water infiltration, decrease the likelihood of flooding and reduce damage when the river does flood. For example, Portland, Oregon has restored the Crystal Springs Creek and its watershed to reduce flood risk and improve the local environment for residents and wildlife. Seoul dismantled a 10-lane motorway and elevated highway to restore the Cheonggyecheon Stream that ran beneath it, providing enhanced flood protection and creating a new urban park that attracts more than 50,000 visitors daily, boosting the local economy, air quality and public-transit ridership.

- **Replace impermeable surfaces across the city with permeable, ideally green, options.** This will reduce and slow water runoff by increasing water infiltration (drainage into the surface) and retention (storage on or under the surface) across the watershed, mimicking the natural environment. The expansion of permeable surfaces, sometimes called low impact development (LID) or sustainable

draining systems (SuDS), is now widely accepted as an effective, low-cost way to reduce flash flooding during heavy rainfall or 'cloudburst' events. Options include permeable road and paving materials, which are porous to allow water to run through, and rain gardens and 'bioswales', which are planted depressions that collect and treat rainwater from roofs and streets.[15] *How to increase your city's permeability* explains more about how cities can roll-out these measures on streets, and on public and private property.

Take a whole-watershed approach

To be most effective, improve how water moves through the whole watershed by implementing measures in areas water flows *from* as well as the flood-prone areas it flows *to*. In higher-elevation areas, the focus should be on measures to increase water infiltration, while lower-elevation areas are better suited to water retention.

- **Create basins or small reservoirs to retain rainwater in the city.** These are public spaces that are designed to flood safely, through the controlled collection and retention of rainwater. In dry conditions, they can be used for sports and leisure. For example, Rotterdam has built 'water squares' to hold excess rainwater until it can drain into the nearby canal. In 2018, Bangkok opened a new 'amphibious' public park designed to collect and store a million gallons of city's floodwater. Chennai is restoring hundreds of water bodies, almost of a third of which were previously used as informal dumpsites, to better manage water stress and heavy rainfall. Copenhagen's Enghaveparken also received a makeover in 2019 to enable the space to hold excess water – watch Copenhagen: How to flood proof a city to see how it works.

- **Construct large-scale, underground rainwater retention tanks.** These tanks are expensive to install compared with other measures, but can hold vast amounts of water. They can be a good option in densely built-up areas where surface space is at a premium. For example, Rio de Janeiro's Praça Niterói reservoir consists of three large underground wells with a total floodwater storage capacity of 58 million litres. Tokyo has the largest underground floodwater tank in the world, which channels overflowing flood waters from rivers through tunnels into five huge silos underground.[16]

- **Reduce debris and waste in the drainage system to reduce blockages.** Ensure your city has universal waste collection and disposal systems – including for informal settlements – to reduce the dumping of waste. Uncollected waste is a common cause of blockages, contributing to localised flooding. All cities can also raise awareness of what can and cannot be flushed down drains. For example, New York City launched the Trash it, don't flush it campaign, while London made headlines by working with the Museum of London to install a 'fatberg' in an exhibition dedicated to the waste in the city's sewers.

- **Construct building-scale rainwater tanks, green walls and other building-scale green infrastructure, such as green roofs.** Building-scale rainwater retention tanks collect rainwater runoff from roofs to reduce the amount of water that flows into the city's streets and waterways. The water they collect can be used to flush toilets, water gardens, wash cars and more, reducing demand for drinking-quality water. Install green roofs and small rain gardens to increase rainwater infiltration. Rotterdam is transforming flat roofspace into green roofs, as well as 'blue roofs' designed to hold water, starting with municipally-owned buildings, and incentives and support for private buildings. In Toronto, a city bylaw requires large new building developments or additions to build green roofs, with a rising scale of roof coverage requirements depending on scale, from 20% for buildings over 2,000m^2 to 60% for those over 20,000m^2.[17] Read the *Growing Green Guide to green roofs, walls and facades* produced by the City of Melbourne, and our guide to using nature-based solutions, for more.

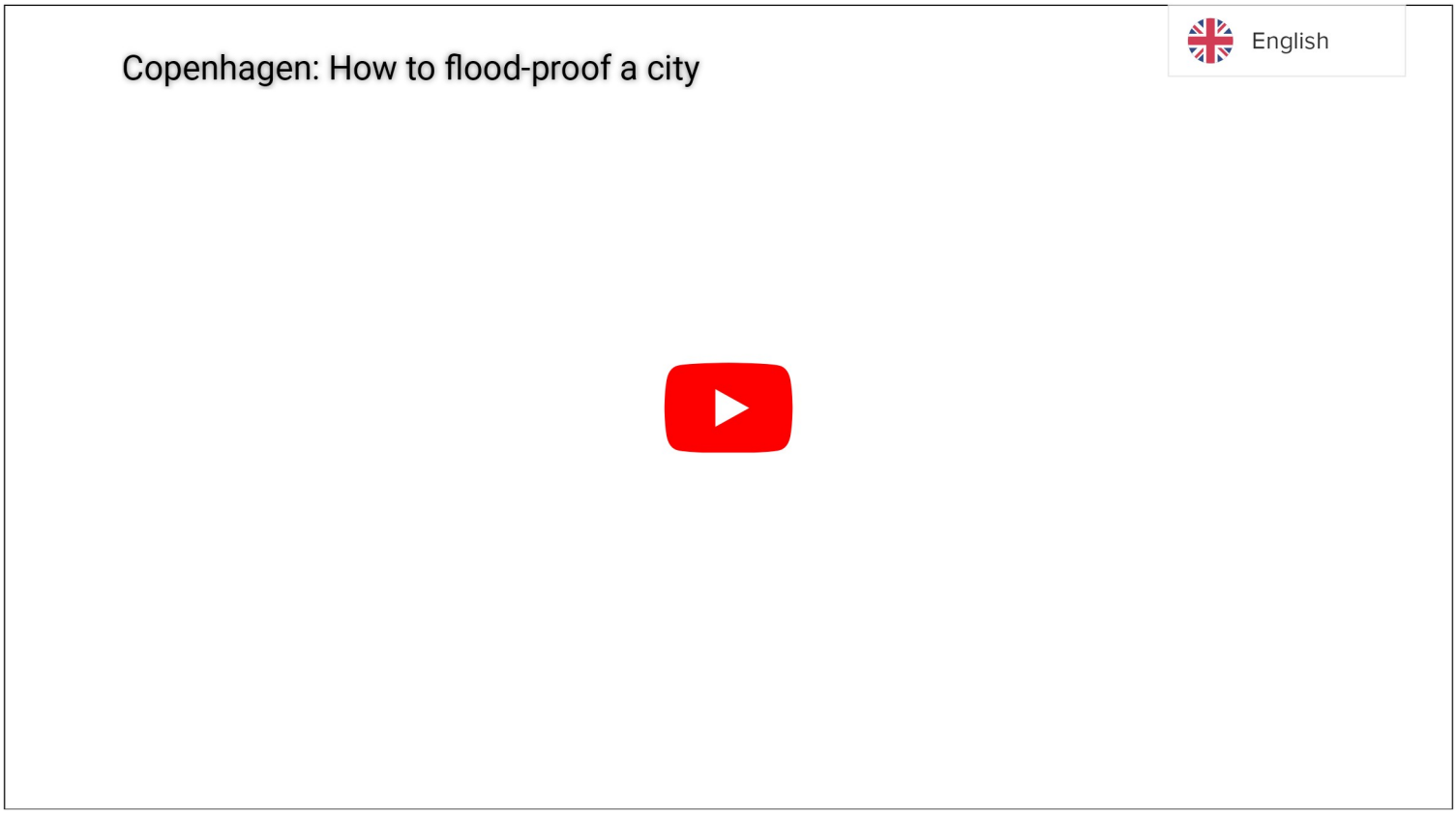
- **Protect public and private property in flood-prone areas.** Cities can support and/or require building owners and developers to elevate their whole property, raise the floor level, (re)locate critical building systems and appliances above flood levels, transition a property's lowest floor to be used solely for parking, access and storage, implement wet or dry floodproofing, install backwater valves and sump pumps to reduce basement flooding, and avoid building new basements. For example, Toronto has a Basement Flooding Protection Subsidy Program offering homeowners a subsidy of up to $3,400 to install flood protection devices. Cities should also **apply these measures to government buildings in flood-prone areas**, particularly schools, hospitals, shelters and emergency service buildings which are critical disaster response buildings.

- **Work with neighbouring municipalities and regional/national authorities to reduce and slow the flow of flood water from beyond city boundaries,** especially if your city is at risk from river or coastal flooding. This might mean supporting wetland or mangrove restoration, or the re-meandering of rivers upstream that have been artificially straightened, for instance.

Copenhagen's Cloudburst Management Plan

The 2012 Copenhagen Cloudburst Management Plan sets out a series of measures to help the city cope with extreme rainfall events. The plan was developed in partnership with the neighbouring City of Frederiksberg and utility companies, and began by prioritising measures in flood-risk hotspots. Its full implementation, which will take around 20 years, will cost DKK 3.8 billion (USD 600 million) – cheaper than the DKK 5 billion (more than USD 790 million) cost of flooding that affected the city in 2011 alone.

Watch the DW Planet A video below to learn more about how the plan works and hear from Jan Rasmussen, Director of the Cloudburst Management Plan.



New York City and Hoboken's upgraded requirements for flood-resilient buildings[18]

In New York City, after Hurricane Sandy inflicted almost USD 19 billion in damages and lost economic activity, the city government published a plan for A Stronger, More Resilient New York, followed by a Flood Resilience Zoning Text Amendment and a Retrofitting Buildings for Flood Risk guide for waterfront communities and building owners. The neighbouring City of Hoboken, New Jersey's Resilient Building Design Guidelines sets out laws and regulations governing construction within flood-prone areas, flood-resilience strategies for residents, property owners, developers and businesses, and the approval process and requirements for repairs, improvements and new construction.

London's 20-year, low-cost plan to improve surface drainage

London is outgrowing its drainage and sewerage system, which was designed for a smaller, greener, more permeable city. The London Sustainable Drainage Action Plan (2016–2021) is a 20-year plan to transition from managing rainwater as a waste product to a valuable resource, by replacing impermeable surfaces on existing land, buildings and infrastructure with permeable, sustainable drainage. Focusing on opportunities to retrofit sustainable drainage as part of other scheduled maintenance, repair or improvement works – minimising costs and disruption – it will ease pressure on drains and sewers, reduce the pollution of rivers and streams, save water and create a greener, more pleasant environment.

English

Integrate flood management strategies into wider climate action planning

This flood resilience plan should be connected to your city's Climate Action Plan. Read our Climate Action Planning Guide for steps on developing a city-wide plan that is consistent with the objectives of the Paris Agreement and addresses the city's wider socio-economic needs.

Strategies to reduce flood risk should also be incorporated into relevant sectoral legislation. Follow the links for advice on actions that reduce flood risk through urban planning and in new buildings, existing municipal and private buildings, clean energy, mass transit, waste systems, and walking and cycling.

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