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Flooding: How to increase your city's permeability

Adapting to Climate Change | Spotlight On: Nature-based Solutions | Urban Planning and Design

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The dominance of impermeable surfaces in cities – the asphalt and paving used for roads, sidewalks and parking, and the roofs of buildings – causes rainwater to flow rapidly over the surface and into urban drainage systems. This can cause localised flash flooding during heavy rainfall or 'cloudburst' events if those systems become overwhelmed. The incremental expansion of natural and man-made permeable surfaces, sometimes called low-impact development or sustainable drainage systems (SuDS), is now widely accepted as an effective, low-cost way to slow and manage stormwater. It should be a core pillar of every flash flood-prone city's adaptation strategy. This article looks at how to implement it, building on the broader recommendations of *How to reduce flood risk in your city*.

Prioritise 'nature-based' or 'blue-green' infrastructure to deliver the greatest benefits

As well as being cheaper than man-made options, these approaches help to mitigate risk from heat and drought and improve local air and water quality, biodiversity, wellbeing, public realm and more. Read *How cities can use nature-based solutions to manage climate risks* for advice on increasing permeability as part of a wider strategy.

Permeable surfaces reduce the urban heat-island effect as they capture less heat than materials such as concrete and provide cooling through evapotranspiration.[1] The shade and cooling provided by trees, however, will usually have a greater impact on heat risk. *Heat: How to expand your city's tree canopy cover* explains more.

Permeable surface infrastructure is likely to be the cheapest way to reduce flood risk

New York City, for example, estimated that blending green infrastructure with grey would reduce the cost of upgrading the city's stormwater system and controlling combined sewer overflows from US$ 6.8 billion to US$ 5.3 billion over 20 years.[2] Copenhagen's review of the economics of cloudburst and stormwater management found that using surface solutions that retain and drain water, in conjunction with the traditional solution of expanding the underground sewer network, would deliver a net *benefit* of DKK 5 billion (over US$ 650 million) – compared with a net *cost* of DKK 4 billion for sewer expansion alone.

Foster collaboration between key departments and sectors to develop integrated strategies

As well as accelerating the expansion of permeable surfaces, integration will help to keep costs down. Planned road maintenance, street upgrades like those aimed at shifting car trips to walking and cycling, regeneration projects and other planned construction offer cost-effective opportunities to replace surfaces with permeable options. Cities should capitalise fully on these opportunities, as well as plan discrete projects to retrofit streets with permeable surfaces.

The most critical departments and agencies are those responsible for the city's roads, public works, water/sewerage, urban planning, environment and parks. Ideally, integrate targets and policies to increase permeability on the streets into the city's transport plan, as well as other strategies pertaining to streets and construction, including for new buildings and retrofits.

Good examples of integrated planning include:

- The London Sustainable Drainage Action Plan intersects with the overall London Plan and sectoral plans as described here. For instance, London's transport strategy includes an annual target of adapting 50,000 m^2 of impermeable surface to drain into SuDS.[3, 4] According to Transport for London's Principal City Planner, having a quantified target is important for raising awareness and driving implementation; the specific figure used is less significant.[5]

- Blue-green stormwater retrofits were integrated into a major neighbourhood-scale regeneration programme in the Augustenborg neighbourhood of Malmö, Sweden. The programme was implemented between 1998 and 2002 with a view to meeting socioeconomic, flood risk, waste management and biodiversity goals, and delivered through a collaboration between the city council and a social housing company, with broad participation by residents.[6] The extensive network of nature-based urban drainage infrastructure it created has been effective at controlling local surface flooding – total flooded surfaces have declined 70% and peak flows in the piped drainage system

have been reduced by around 80%.[7]

Improve waste collection and disposal to improve drainage. If your city lacks adequate waste collection and disposal systems, the dumping of waste is likely to be clogging drainage systems and contributing to local flooding. *Why every city needs universal waste collection and safe disposal* explains more, linking to further advice on how to implement these systems.

Cities prone to river and coastal flooding should also consider working with neighbouring municipalities and regional/national authorities to increase permeability and slow the flow of stormwater from beyond city boundaries. This might mean supporting wetland or mangrove restoration, or re-meandering upstream rivers that have been artificially straightened, for instance.

Involve the local community in designing the scheme and maintaining planting

Community organisations, particularly those focused on environment, air quality, wildlife and community-building, can help generate backing for such initiatives, to design solutions that deliver the greatest benefits for local people, and support maintenance. Involve people as early as possible. Set out the benefits on the most local scale and explain how improvements contribute to the city's wider plans for managing water.

Consulting on a set of pre-developed feasible options at site, street or neighbourhood level tends to deliver more constructive engagement than open-ended questions or inviting views on whether to implement such measures at all.

However, **manage expectations carefully**. Green infrastructure and permeable surfaces will reduce the likelihood and impact of flash floods, but cannot guarantee a flood-free future.

A bioswale in Greendale, Wisconsin[8]

Work with landscape architects, engineers, utilities and communities to plan measures on the city's streets

Measures to increase permeability should be implemented in higher-elevation areas where water flows *from*, where they are most effective, as well as in the flood-prone areas which it flows *to*. Informed by mapping and the characterisation of flood risk, identify priority sub-catchment areas and the types of intervention best suited to different neighbourhoods. Potential solutions at specific sites will be shaped by the soil and utility service lines present, for example.

The main ways to increase street permeability are to:

- **Replace concreted and paved surfaces with blue-green infrastructure, such as rain gardens, bioswales and natural retention ponds.** These are planted or mulched depressions that collect rainwater from roofs and streets, slow and filter it, and allow it to infiltrate the soil. Deployed on the kerbside and beside roads, they offer an effective and low-cost approach to improving permeability. The captured runoff can allow trees and vegetation to self-sustain; use native, water-wise plants to

reduce watering costs.[9] Such initiatives have been deployed in many cities, including Seattle, São Paulo, Copenhagen, Sheffield and New York. The US National Association of City Transportation Officials' (NACTO) *Urban Street Stormwater Guide* provides a comprehensive guide to planning and implementing measures to improve infiltration on city streets, focusing on green stormwater infrastructure options. See also the US Environmental Protection Agency's (EPA) Green Streets Handbook, London's guide to SuDS and Urban Design London's guide to designing rain gardens.

- **Replace concreted and paved surfaces with permeable street-surface materials.** Permeable paving and permeable asphalt are porous to allow water to run through them and are best suited to sidewalks and low-traffic areas, as well as parking lots and driveways. As well as reducing flood risk, they support the watering of adjacent trees. Sixteen Chinese cities, including Zhenjiang, have been exploring a 'sponge city' strategy of permeable paving street upgrades since 2015, which has been found to be highly effective at managing heavy rainfall.[10] Consider sourcing permeable paving surfaces made from recycled materials, such as plastics or slag cement, to help reduce landfill waste. Cities experiencing extreme heat can also consider using evaporation-enhancing permeable pavements, which can significantly reduce surface temperatures relative to conventional permeable pavements.[11]

If plans to improve permeability meet resistance, consider inviting communities and neighbourhoods to put themselves forward as willing first-movers

The Pontilly Neighborhood Stormwater Network in New Orleans began when residents approached the New Orleans Redevelopment Authority of their own volition with a proposal to use green infrastructure to reduce local flooding. For decades, this low-income, minority neighbourhood had experienced recurrent losses due to flooding during heavy rainfall events. The US$ 15 million project was paid for with a federal grant and took two years to implement. Built largely on streets and public land, the stormwater network can hold more than 8 million gallons of water.

By the time the project was completed in April 2021, it was already having an impact. The neighbourhood association president had this to say about it:[12]

> "We've watched it work. Over the past couple of months, with the rain events that we've had, we actually saw how the process worked — how it fills up, how it slowly goes out. It's been actually saving us from flooding."

Incentivise or require increased permeability on public and private property

The rain gardens, bioswales and permeable asphalt used on city streets can also be installed in parking lots and beside buildings. In addition, public and private landowners can increase water infiltration on their property with permeable driveway and patio materials (for example, by switching concrete for gravel) and green rooftops.

To mandate or encourage the roll-out of these measures, cities can introduce a combination of:

- **Charging property owners for impervious surfaces on their land.** These charges, often known as stormwater fees or drainage charges, provide funding to support water management and flood risk reduction projects on public land and should be ringfenced for this purpose.[13] Ideally, they should be structured to encourage the removal of impervious surfaces and incentivise green stormwater infrastructure: charge lower fees for less impervious surface coverage of gardens, rooftops, driveways and parking lots, for instance.[14] This will require granular land-surface data. If existing flood risk mapping doesn't deliver them, use aerial photographs to develop estimates. Cities with limited capacity to assess actual permeability can begin by establishing a fixed fee based on local, regional or national averages for different property types.[15] The fixed charges for stormwater management rates in Palo Alto are based on a sampling of different property types in the city, for example.[16] Build regular rate reassessments into the programme design, with an easy-to-use review mechanism to enable property owners to challenge the measurement. These fees usually face some pushback; it may help to start small by creating a fee to fund a single, priority project.[17] Stormwater fees are in place in cities including Asheville, Nashville and Austin.[18]

- **Offering grants for the installation of permeable surfaces and rebates or other credits to properties with greater permeability.** These often combine permeability incentives with those for other building-scale water-retention infrastructure, such as rain harvesting systems. Fixed stormwater fees should be partnered with rebates to incentivise improvements – Palo Alto offers rebates per square foot of permeable pavement, and for rain gardens, cisterns and rain barrels, for instance. The IPTU Verde programme in Salvador offers land tax cuts to developers for the inclusion of green roofs or rainwater collection and reuse technologies linked to renewable energy and energy efficiency measures. Toronto's Eco-Roof Incentive Program and Green Roof Bylaw, both introduced in 2009, established grants for the installation of green roofs and put in place green roof requirements for target building types, respectively.

Incentives can be made tradeable and grow the local market for investment

Washington, DC allows property owners in the area covered by the municipal separate stormwater system to sell Stormwater Retention Credits, earned for the installation of green infrastructure, to the District's Department of Energy and Environment (DDOE) as well as to developers. Developers can purchase them as a way of meeting their stormwater reduction obligations, securing private investment in these measures. The DDOE intends to eventually remove itself as a buyer in this market and to retrofit the entire area with privately-funded green infrastructure.[19]

The International Institute for Sustainable Development's *Stormwater Markets: Concepts and applications* explains more about Washington DC's model, as well as those in place in four other cities and states in North America. Stormwater Currency's guide to establishing a stormwater volume credit trading programme provides further advice, again focusing on the United States.

- **Encouraging or requiring green roofs through incentives and building codes.** Rotterdam, which is working to transform flat roof space on large buildings into green and blue roofs, suggests starting with municipally owned buildings and incentives for private buildings. Barcelona's *Guide to Living Terraces and Green Roofs*, Durban's *Guidelines for Designing Green Roof Habitats* and the *Guide to Green Roofs, Walls and Facades in Melbourne and Victoria, Australia* are useful resources setting out the benefits, social and technical considerations, and advice on choosing green roof types. As green roofs help to reduce building energy consumption for heating and cooling, requirements for green roofs can also be incorporated into building energy efficiency standards for new and existing buildings.

Ordinance types and examples from the United States

The US EPA provides guidance for local governments on the types of ordinance cities can enact to improve infiltration, evapotranspiration or the use of stormwater. The site also provides examples of each ordinance type in use. It will be most relevant for cities in the United States, but may also be useful in other countries.

- **Incorporating permeability requirements into codes and ordinances for new developments and existing property.** Align permeability requirements with established ordinances. For example, adopt established categories and definitions of what is considered impervious. Begin by removing any regulations that prevent developers and property owners from using pervious surfaces. Minneapolis enacted an ordinance to revise its zoning code to allow pervious pavements for driveways, for instance, subject to weight-bearing requirements and with continued prohibition in areas where hazardous liquids, such as gasoline, could be spilled.[20] To further expand permeable surfacing in new developments, cities can provide permitting credits and discounts, require permeability assessments

or incorporate minimum standards into building codes for new developments and major retrofits. Private development projects in the city of Elgin are required to submit a stormwater management report and pay a stormwater management review fee. Other good examples include those adopted by Buenos Aires (see page 1265), Durban and São Paulo.

SuDS in Sheffield's award winning Grey to Green scheme[21]

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