NOTE FOR THE READER OR PRESENTER:

- Talking points and additional resources are in the “notes” section of each slide
- **Bold text** highlights the main points and could be read aloud during a presentation, while non-bold text provides additional supporting information

WORLD RESOURCES INSTITUTE

WORLD BANK GROUP

GFDRR
Global Facility for Disaster Reduction and Recovery

NATURE-BASED SOLUTIONS FOR DISASTER RISK MANAGEMENT

Urban flooding and stormwater hazards

Photo credit: Flickr/ Cesar Garza

MANY TERMS FOR "NATURE-BASED SOLUTIONS"

Source: Cohen-Shacham et al. 2016; UNEP et al. 2014; EC 2015; Lo 2016; WWF 2017; USACE n.d.; EcoShape 2018; WBCSD 2017

PRESENTATION STRUCTURE

- Context
- The solutions:
    - Open spaces and waterbodies
    - Constructed wetlands
    - Bioretention areas
    - Green roofs
    - Permeable pavement
- Wrap-up

URBANIZATION

- More than **half of the world's population** now lives in urban centers. By 2050, **70%** will.
- **65% of cities** with populations above 2.5 million are located on coasts.

MANAGING URBAN FLOODING

- Urban flooding occurs when water flows into an urban area faster than it can be absorbed or transported away
- **Lack of drainage and insufficient water infrastructure** due to urbanization exacerbates flooding

Graphic: Oxfam International/flickr

URBAN FLOODING EXACERBATES WATER POLLUTION AND LANDSLIDE HAZARDS

Stormwater pollution

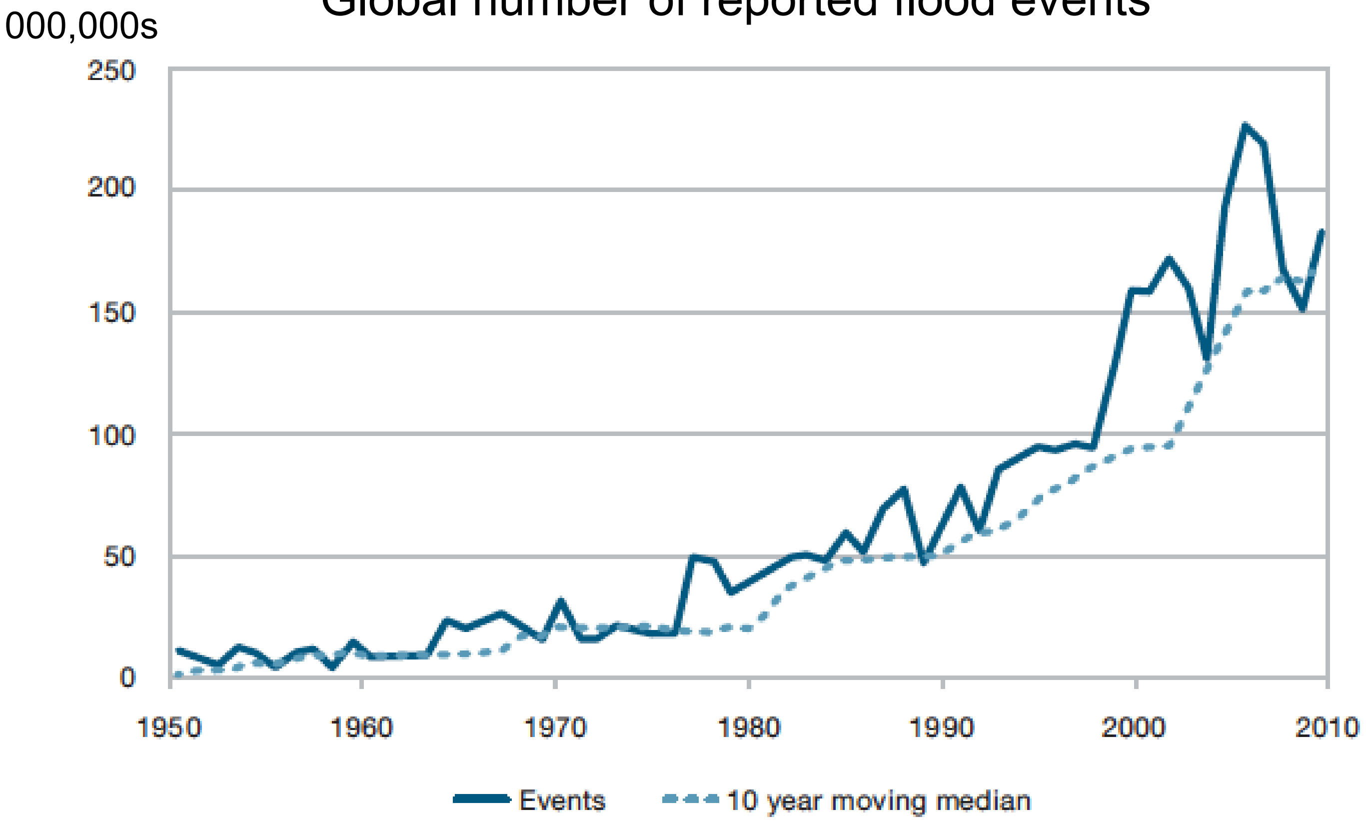
Landslides

Photo credit: Flickr/ fran001

INCREASING URBAN FLOOD RISK

- Urban flooding is **a serious and growing development challenge**.
- **Urbanization** and **climate change** pose significant threats for urban flooding and water quality.

Global number of reported flood events



Source: Jha, et al. 2012

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COSTLY CONSEQUENCES

- Urban flooding challenges **development, lives, and livelihoods**
- Poor populations suffer **disproportionately**

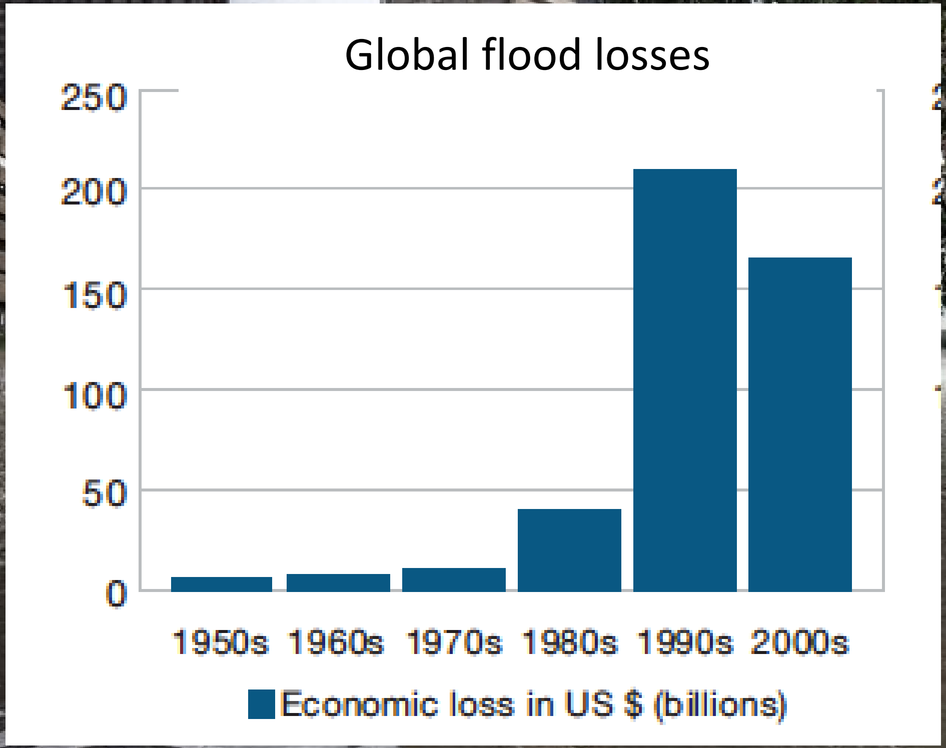


Photo credit: Wikipedia Commons; Graphic: Jha et al. 2012

WORLD BANK INVESTMENT PORTFOLIO DISASTER RISK MANAGEMENT (DRM)

Invested **~US$ 53 billion** in more than **680 DRM projects** globally

(FY2012-2018)

Invested **~US$ 540 million** in projects targeting urban flooding with **NBS**

(FY2012-2018)

STRUCTURAL STRATEGIES

	Nature-based Solutions (NBS)	
Built	**Hybrid**	**Natural**
Hard, gray, engineered structures built to address development objectives	Combination of ecosystem elements and hard engineering interventions for addressing development objectives	Creation, protection or restoration of only ecosystem elements for addressing development objectives

Source: World Bank 2017

CONVENTIONAL: ‘BUILT’ INFRASTRUCTURE

Examples: Pipes, combined sewers, treatment plants, curbs, gutters, channeled rivers, etc.

- Designed to **quickly move stormwater away** from urban centers and **treat polluted water**
- Massive need for global investment in flood infrastructure - even more than in **energy and transport.**

Photo credit: Flickr/darkday

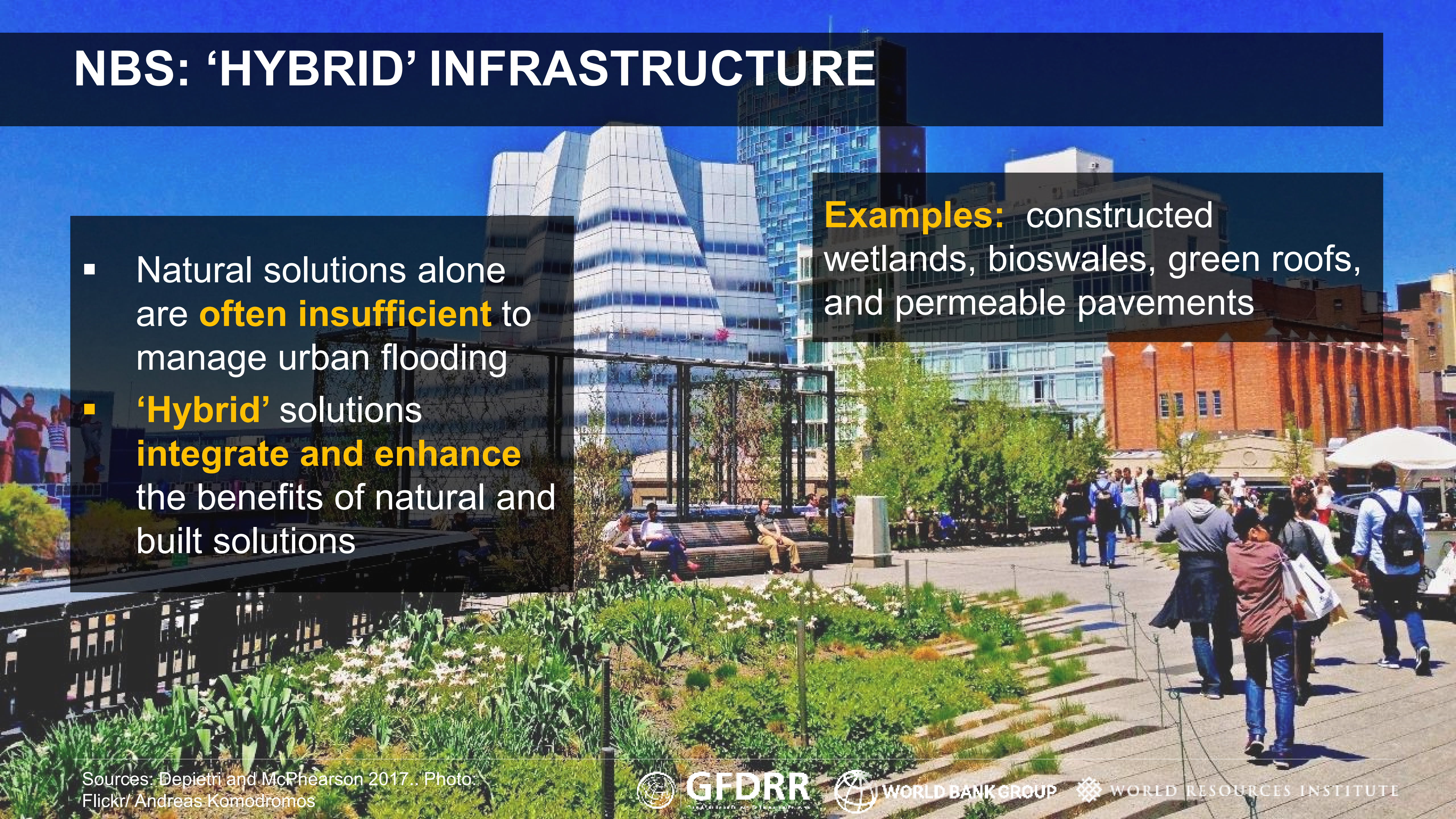
NATURE BASED SOLUTIONS (NBS)

- Established to **slow and attenuate runoff** and **filter pollutants**
- Includes both **natural and hybrid solutions**

Examples: Greenspaces, constructed wetlands, bioswales, green roofs, and permeable pavements

Photo credit: Flickr/Center for Neighborhood Technology

NBS: ‘HYBRID’ INFRASTRUCTURE



- Natural solutions alone are **often insufficient** to manage urban flooding
- **‘Hybrid’** solutions **integrate and enhance** the benefits of natural and built solutions

Examples: constructed wetlands, bioswales, green roofs, and permeable pavements

Sources: Depietri and McPhearson 2017.. Photo: Flickr/ Andreas Komodromos

ADVANTAGES OF NATURE-BASED SOLUTIONS

- Provide **wide range of additional co-benefits** to cities, beyond flood risk reduction
- Can be more **cost-effective**
- Can be designed as **resilient, flexible, climate adaptation measures**
- Have **capacity to adapt** and **regenerate**

Photo credit: Flickr/Payton Chung

WORDS OF CAUTION

- **Appropriate use of NBS is highly context specific**, requiring careful evaluation, planning and design of project components
- **There are limits to how NBS can perform** in urban settings

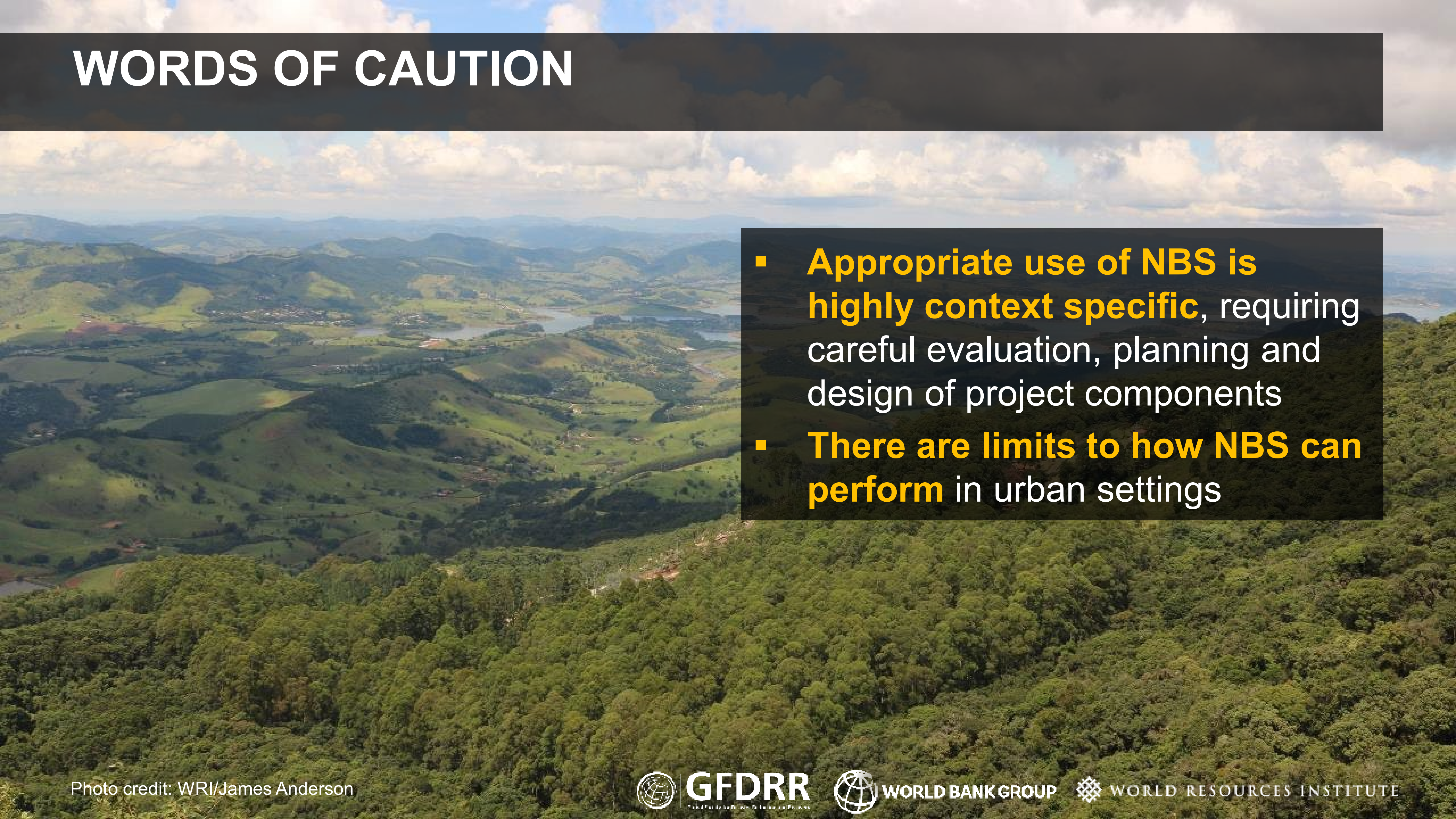
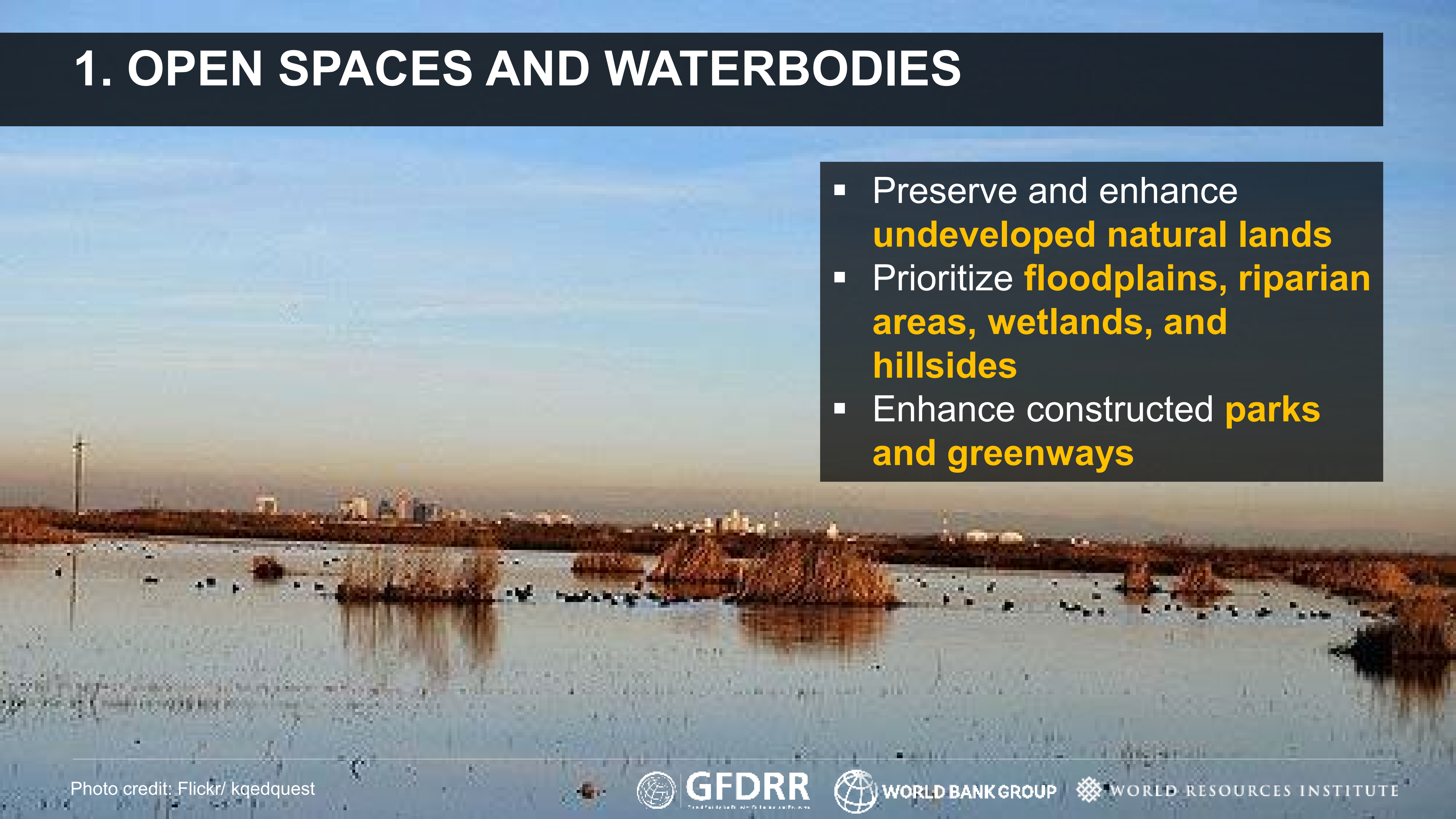


Photo credit: WRI/James Anderson

NBS FOR URBAN FLOODING

1. Open spaces and waterbodies
2. Constructed wetlands
3. Bioretention areas
4. Green roofs
5. Permeable pavement

Image source: Flickr / Joan

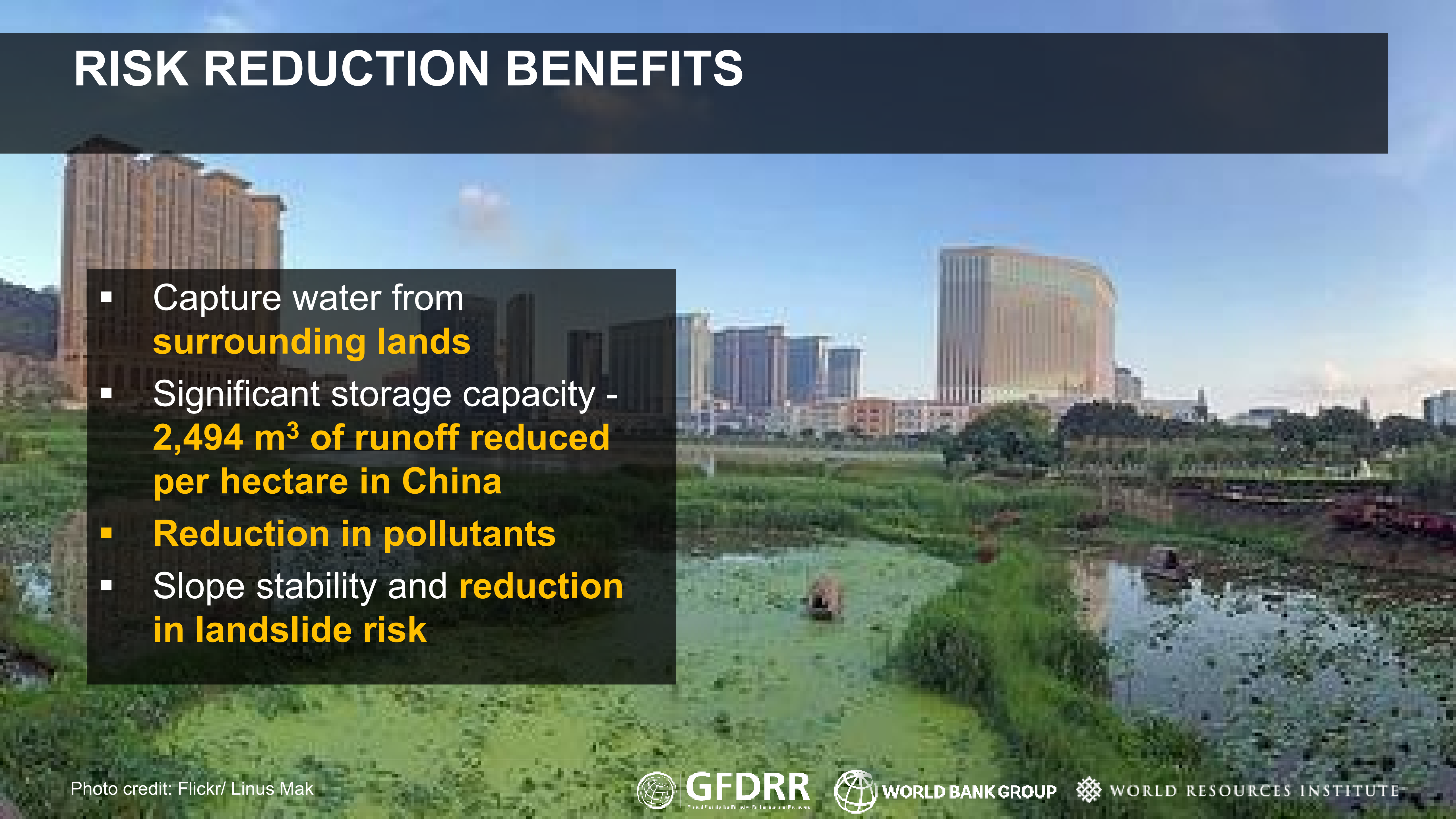


1. OPEN SPACES AND WATERBODIES

- Preserve and enhance **undeveloped natural lands**
- Prioritize **floodplains, riparian areas, wetlands, and hillsides**
- Enhance constructed **parks and greenways**

Photo credit: Flickr/ kqedquest

RISK REDUCTION BENEFITS



- Capture water from **surrounding lands**
- Significant storage capacity - **2,494 m^3 of runoff reduced per hectare in China**
- **Reduction in pollutants**
- Slope stability and **reduction in landslide risk**

Photo credit: Flickr/ Linus Mak

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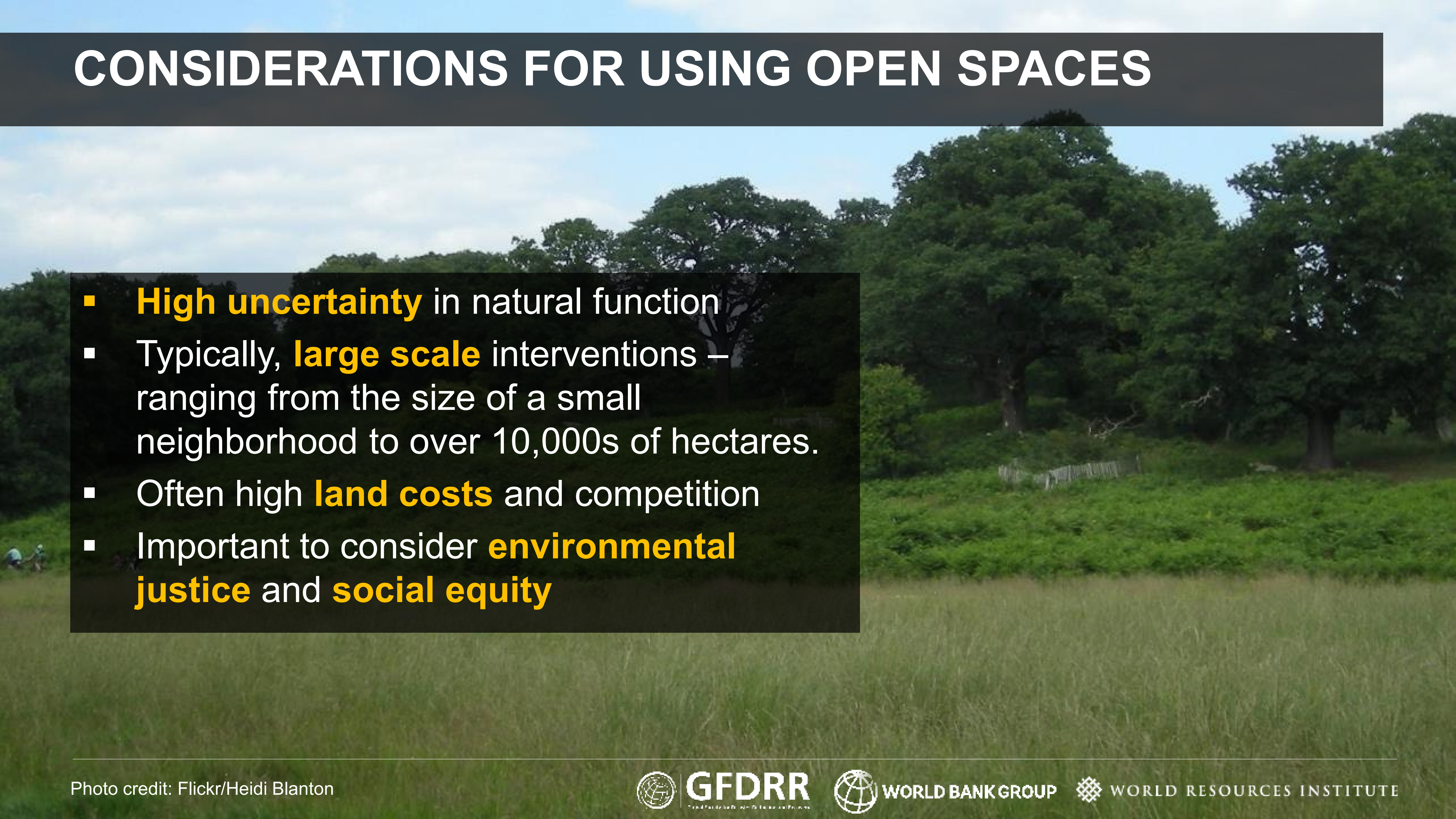
ADDITIONAL BENEFITS

- Provide **urban habitat and biodiversity** benefits
- Provide a **cool refuge**
- Control **air and noise pollution**
- Increase **property values 5-15%**
- Provide **social and psychological benefits**

Photo credit: Flickr/Gigi NYC

CONSIDERATIONS FOR USING OPEN SPACES



- **High uncertainty** in natural function
- Typically, **large scale** interventions – ranging from the size of a small neighborhood to over 10,000s of hectares.
- Often high **land costs** and competition
- Important to consider **environmental justice** and **social equity**

Photo credit: Flickr/Heidi Blanton

WHAT DO OPEN SPACES COST?

- **Variable cost** depending on **land prices**
- Consider **opportunity cost** of alternative uses, and **nonmonetary benefits**
- **Price of land** or property rights is often the largest cost
- Operations and maintenance **costs are typically low**

Photo credit: Flickr/ Vincent Parsons

CURITIBA, BRAZIL
RECLAIMING THE IGUAZU FLOODPLAIN

- Urbanization and poor infrastructure led to a **six-fold increase in flooding**
- Integrated multiple **NBS,** along with **built and non-structural measures**
- **Flooding, water quality and public recreation benefits**
- Led to **strategic system** of urban parks

Photo credit: Wikimedia Commons

2. CONSTRUCTED WETLANDS

- Designed for **water treatment and pollution abatement**
- **Complex, integrated systems** of water, plants, animals, and microorganisms
- Require **specific environmental conditions**.

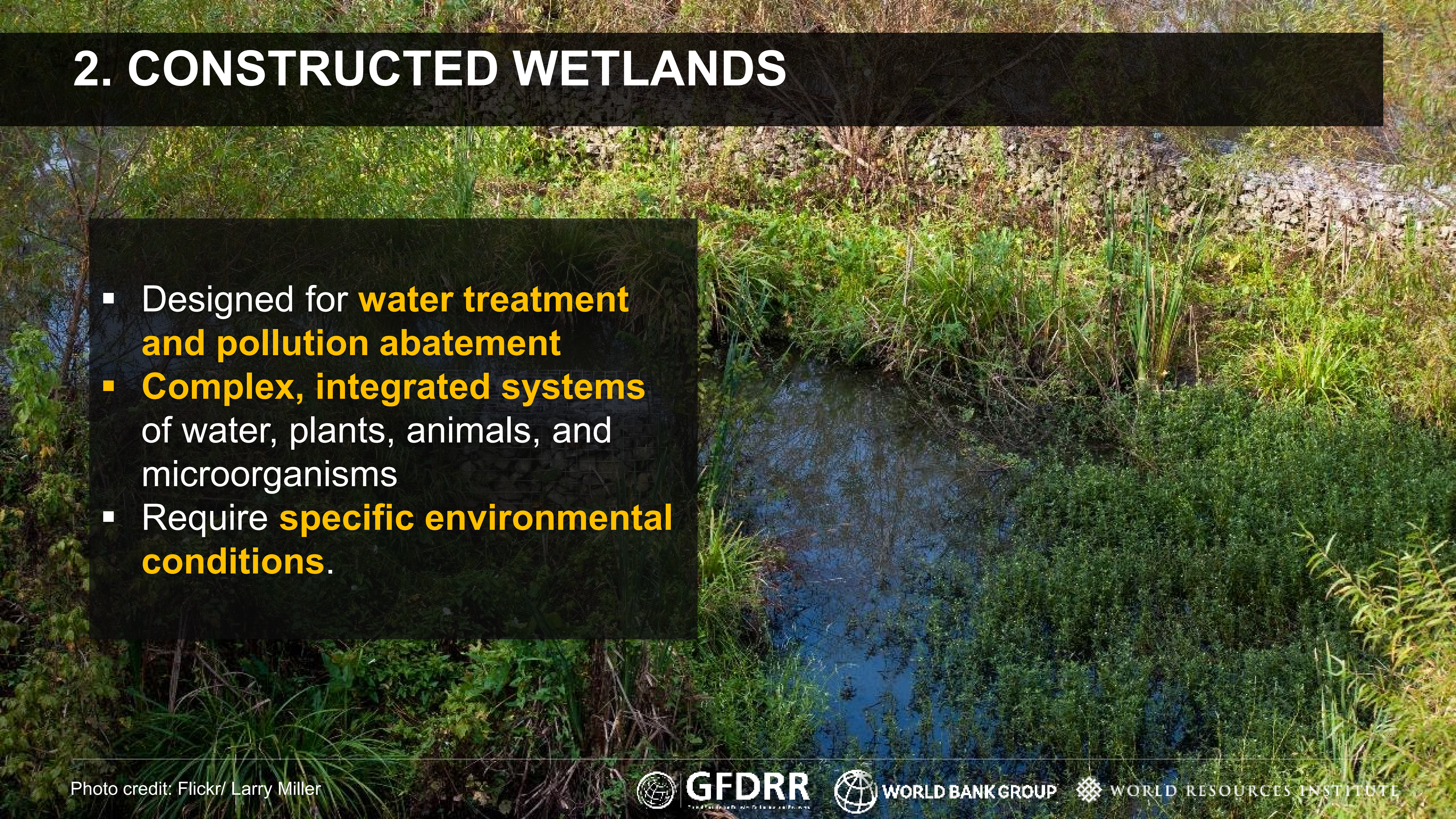


Photo credit: Flickr/ Larry Miller

RISK REDUCTION BENEFITS

- Very effective at reducing **pollutants** and **water treatment requirements**
- An acre of wetland **can store 1-1.5 million gallons of floodwater**
- Reduction in **runoff load** on stormwater and wastewater systems
- Reduction in **sediment loading** that can clog and damage built infrastructure

ADDITIONAL BENEFITS

- **Wildlife** and **biodiversity**
- **Recreation, tourism and education opportunities**
- Hydrologic connectivity and **water security**
- Non-potable **water supply**
- Ecosystem services averaged **$26,000 /ha/yr** in 2011

Photo credit: Flickr/ jandhands

CONSIDERATIONS FOR USING CONSTRUCTED WETLANDS

- Environmental condition **requirements**
- **Site-specific** design requires **management**
- **Variable levels of performance**
- Limits on **wetland function**

Photo credit: Flickr/USFWS

WHAT DO CONSTRUCTED WETLANDS COST?

- Usually **less expensive** than other treatment options.
- **$25,000 – $169,000** per hectare
- **Low operation and maintenance expenses**

Photo credit: Flickr/LBMO

KATHMANDU VALLEY, NEPAL: CONSTRUCTED WETLANDS (LATE 1990S - PRESENT)

- Poor **wastewater management**
- Small-scale, decentralized, **wetland system**
- **Community support** essential
- Highly effective, **low cost** pollutant removal: **US$290/yr** to treat wastewater from **80 households**

Photo credit left to right: Wikipedia Commons, Flickr/Giorgio Basile

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3. BIORETENTION AREAS

- Treat **on-site stormwater** runoff from **specific area** (parking lot, street, sidewalk)
- Integrated with **built infrastructure**
- Include:

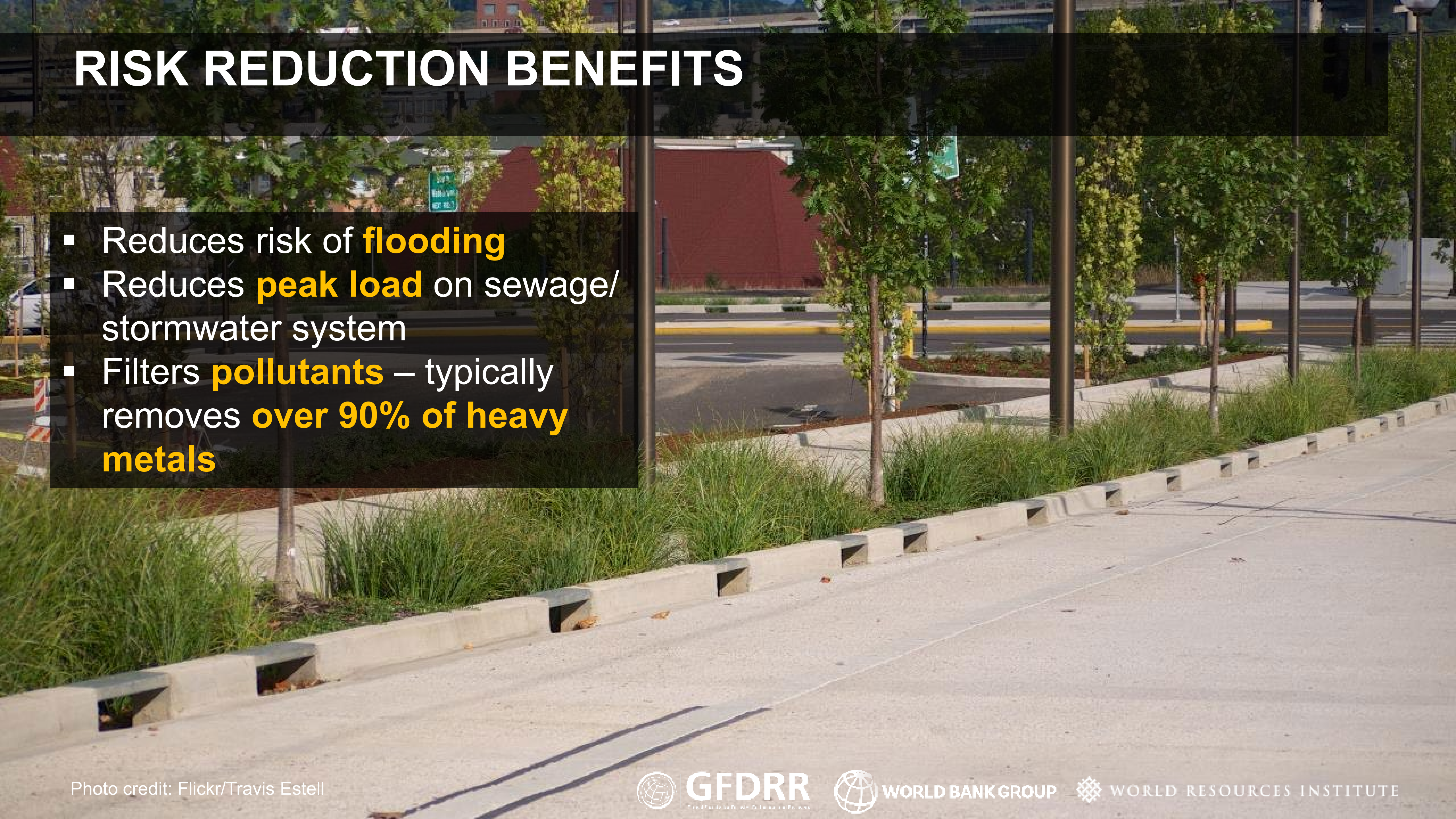
Rain gardens

Planter boxes

Bioswales

Photo credit: Wikimedia commons, Flickr / Andreas Komodromos, soils.org

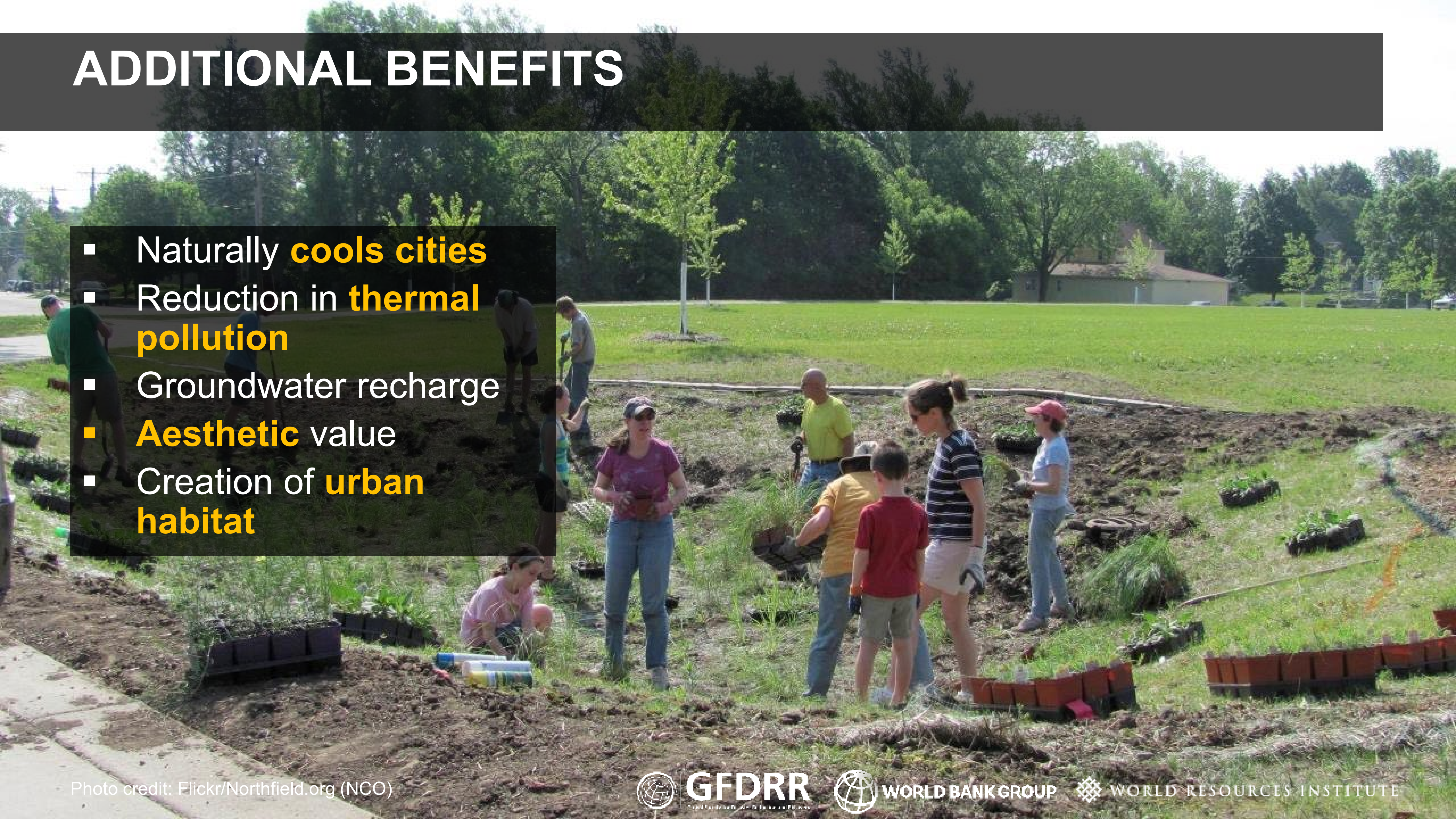
RISK REDUCTION BENEFITS



- Reduces risk of **flooding**
- Reduces **peak load** on sewage/ stormwater system
- Filters **pollutants** – typically removes **over 90% of heavy metals**

Photo credit: Flickr/Travis Estell

ADDITIONAL BENEFITS



- Naturally **cools cities**
- Reduction in **thermal pollution**
- Groundwater recharge
- **Aesthetic** value
- Creation of **urban habitat**

Photo credit: Flickr/Northfield.org (NCO)

CONSIDERATIONS FOR USING BIORETENTION AREAS

- Sizing **depends on desired runoff volume** controlled
- Important to consider location for **groundwater recharge** and possible **pollution**

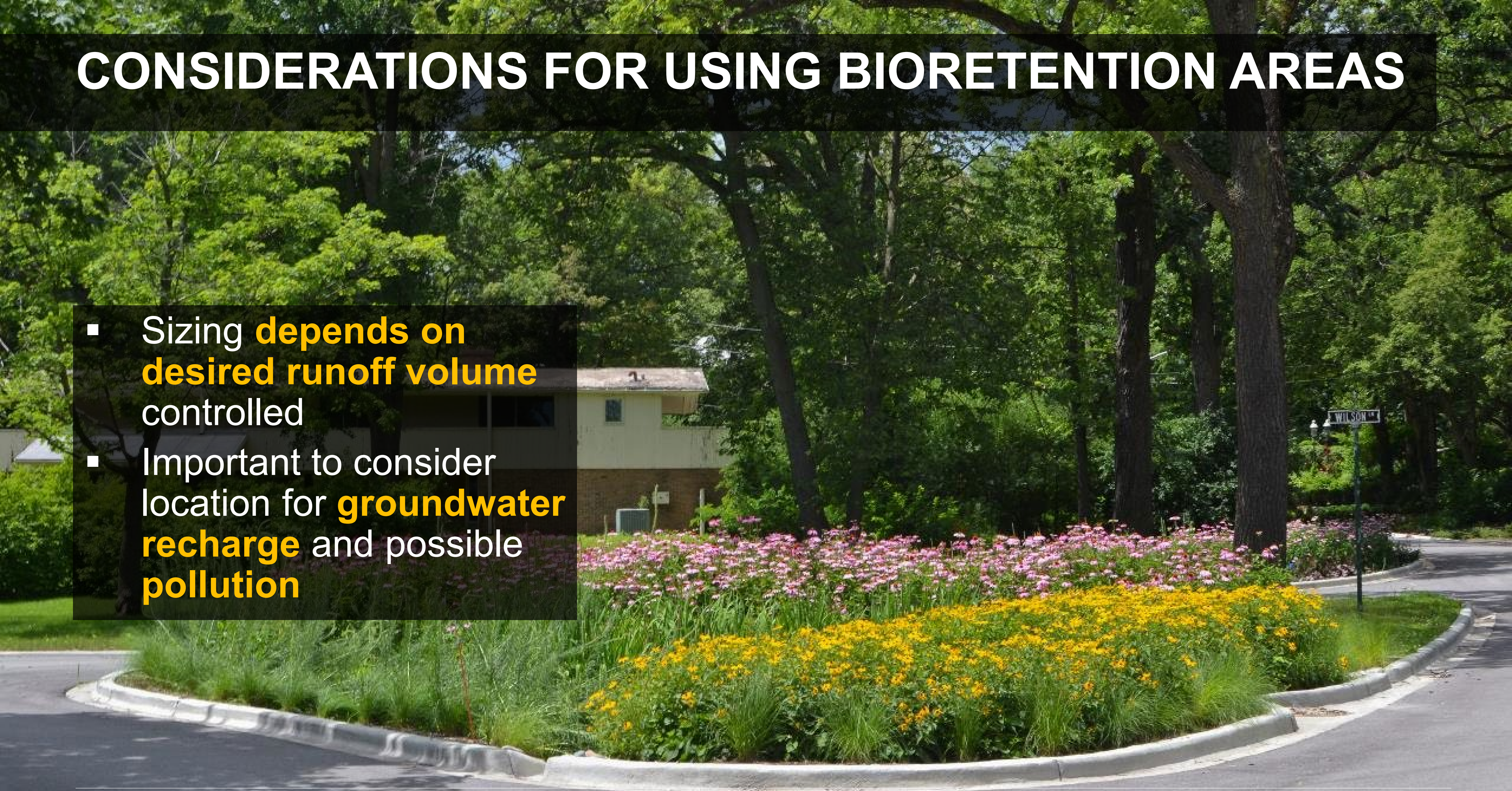


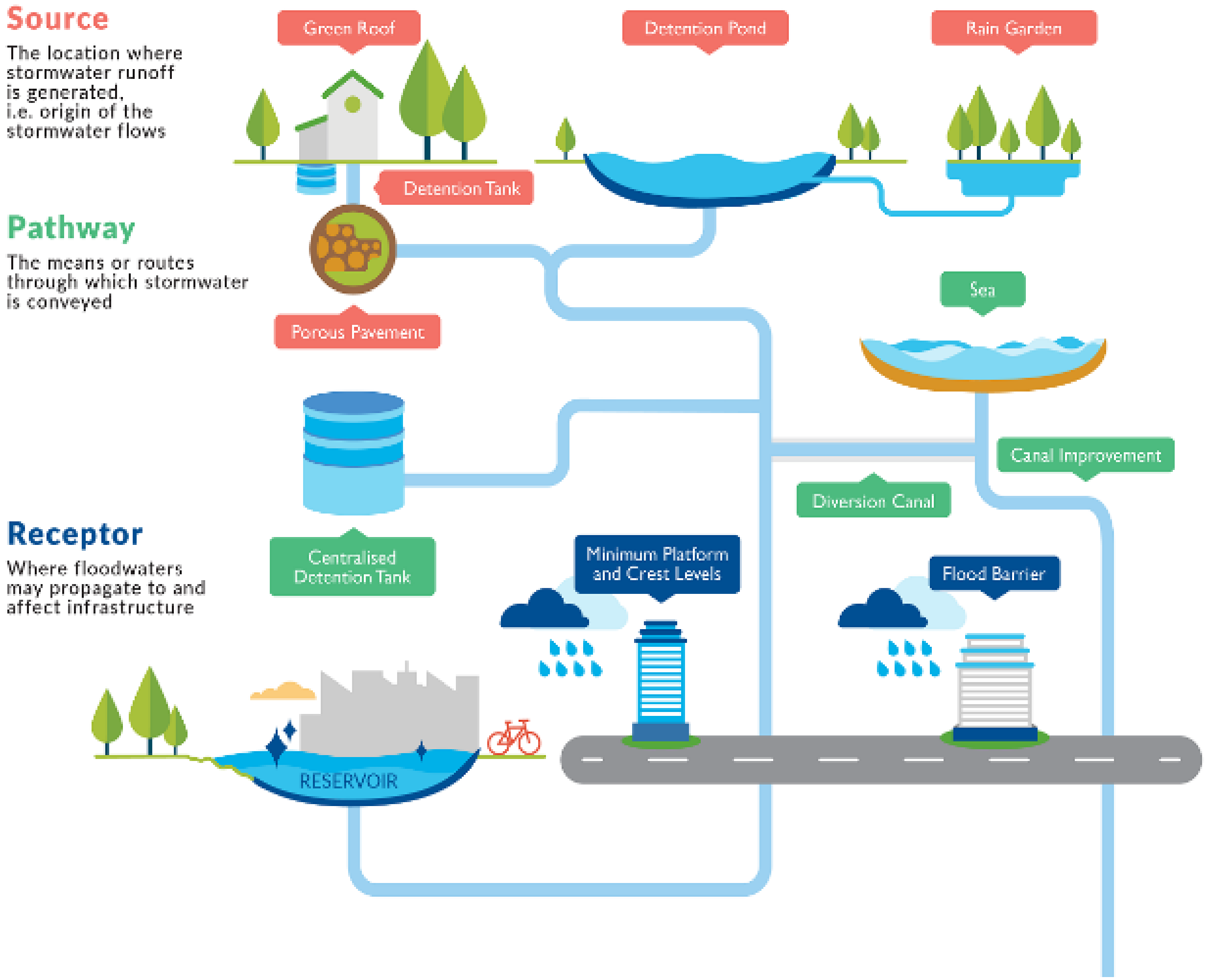
Photo credit: Flickr/Center for Neighborhood Technology

WHAT DO BIORETENTION AREAS COST?

- Residential rain gardens are estimated to cost **about \$32 to \$54 per m^2**
- Industrial bioretention sites may cost between **\$110 and \$430 per m^2**
- Generally, bioretention areas cost only a fraction of what stormwater infrastructure installations might cost

SINGAPORE - CITY OF GARDENS AND WATER
BALAM ESTATE RAIN GARDEN

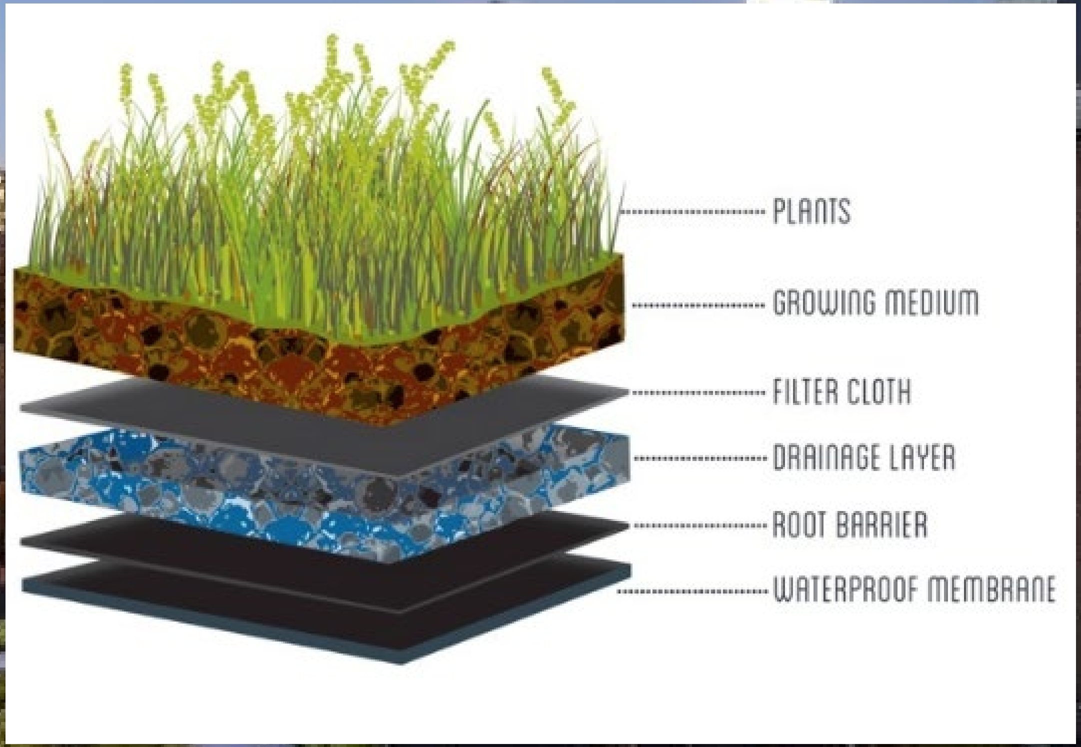
- Active, Beautiful, Clean (ABS) Waters Program
- **1st rain garden -** Balam Estate
- Variable nutrient removal, with **average removal rates** of:
  - **N: 46%**
  - **P: 21%**
  - **TSS: 57%**
- Now, stormwater codes **require developments to slow stormwater runoff**



Graphic: PUB 2018

4. GREEN ROOFS

- Roofs partially or completely **covered in vegetation**
- Planted in **growing medium placed on top of drainage and protective layers**
- **Recover the vegetated footprint** that was destroyed by the building



Graphic: Restoration Gardens; Photo credit: Flickr/Graham Hill

RISK REDUCTION BENEFITS

- Captures and slows **50-100% of local precipitation.**
- Enables evapotranspiration, **decreasing the volume of water entering built systems**
- Can **reduce the amount of pollution** delivered to the drainage system

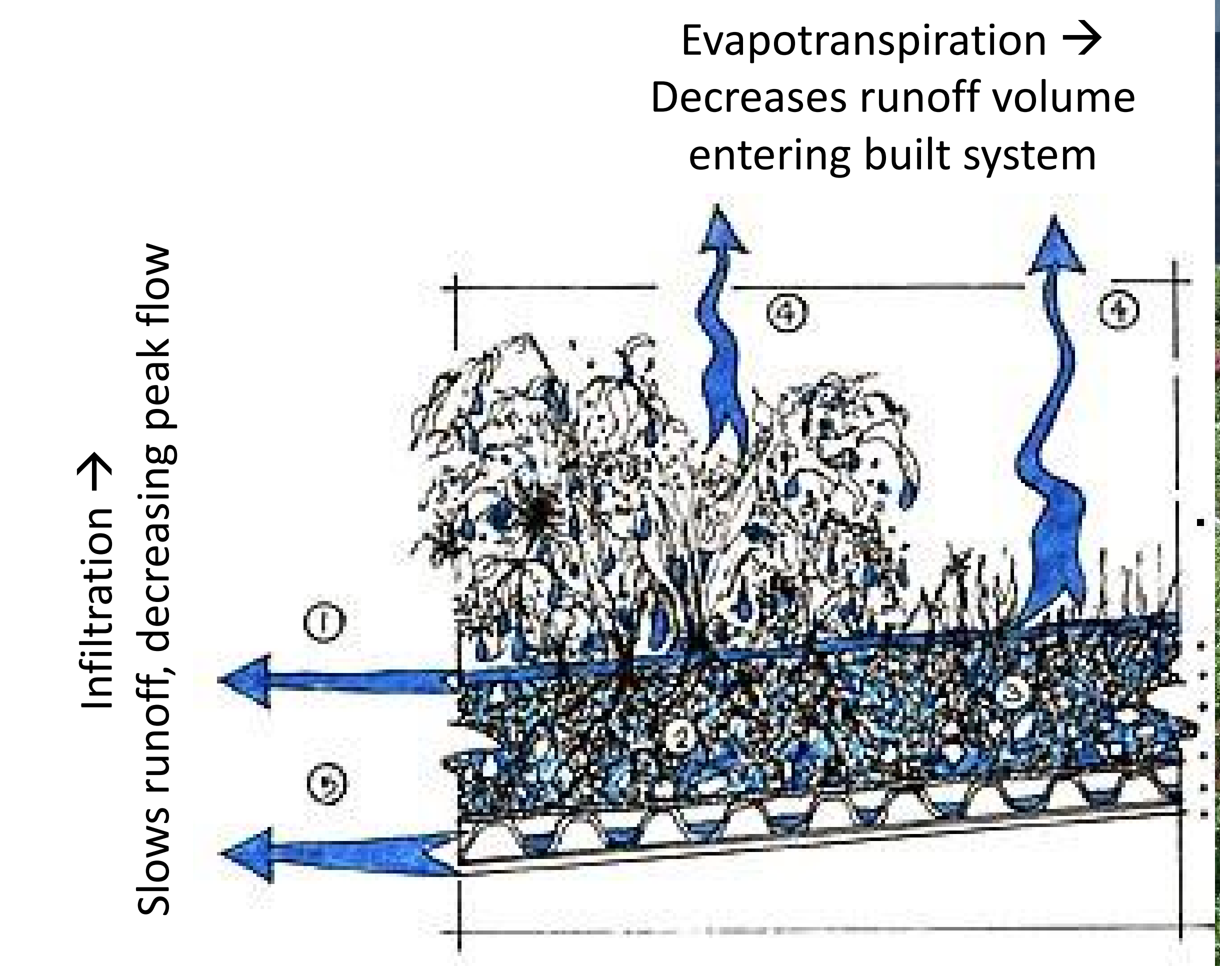


Photo credit: Flickr/USA EPA. Graphic: Low Impact Development Center

ADDITIONAL BENEFITS

- Regulate building temperatures, **reduce energy costs** and **carbon emissions**
- Reduce urban heat island effect
- Provide space for **urban agriculture**
- **Life spans twice as long** as traditional roofs reduced costs
- Provide urban wildlife habitat

Photo credit: Flickr/ National Energy Technology Laboratory

CONSIDERATIONS FOR USING GREEN ROOFS

- Roof must be **capable of supporting additional weight**
- **Not all plants are suitable** for green roofs
- Leaks, plant loss, inadequate drainage, soil erosion can result in **underperformance.**
- Green roofs **require regular maintenance.**

Photo credit: Flickr/ Eclipse Awards

WHAT DO GREEN ROOFS COST?

- Installation and maintenance **costs are higher** than conventional roofs
- US: **$110-270 per m^2**, which is 2-5 times more expensive than a traditional roof.
- Added longevity largely **makes up for added installation costs**
- Long-term **energy savings** and **stormwater benefits**
- Benefits increase with time

Photo credit: Flickr/Dolanh

CHINA’S SPONGE CITIES – SHANGHAI GREEN ROOFS

- Utilizes many NBS, **including green roofs**
- By 2030, **80% of built area** in pilot cities will serve as a “sponge“
- **70% of stormwater runoff**
- Cost effective with **significant energy saving**
- Incentives and education

Photo credit: Flickr/kafka4prez

5. PERMEABLE PAVEMENT

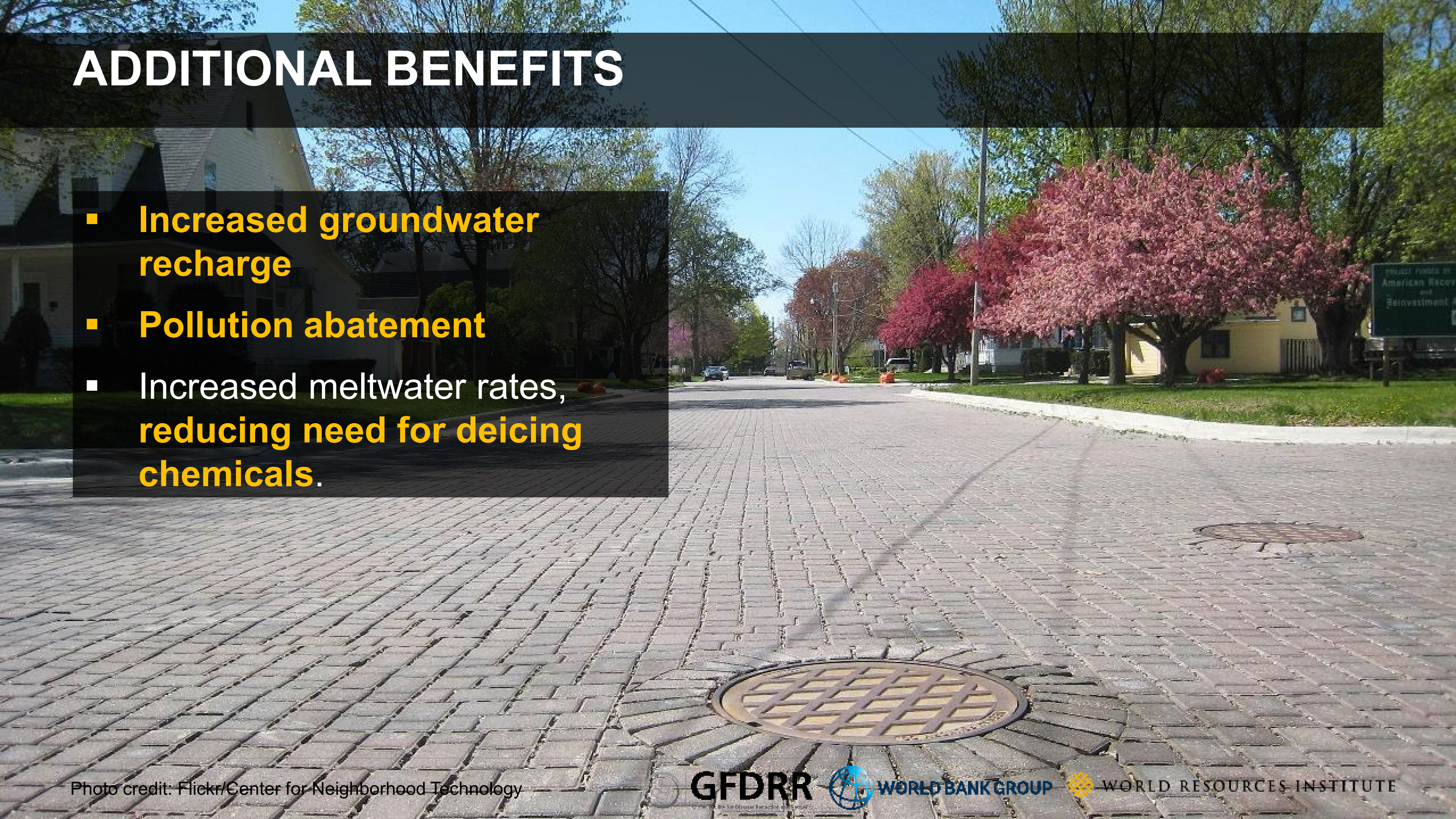
- **Alternatives** to traditional pavement
- Includes: **pervious asphalt, pervious concrete, and interlocking pavers**
- Allows **local rainfall to seep down through** underlying layers

RISK REDUCTION BENEFITS

- Infiltrates and **slows stormwater runoff by up to 90%**
- **Reduces peak load,** particularly during small storms.
- **Can reduce the amount of pollution,** including heat, delivered to the drainage system

Photo credit: Pixabay

ADDITIONAL BENEFITS



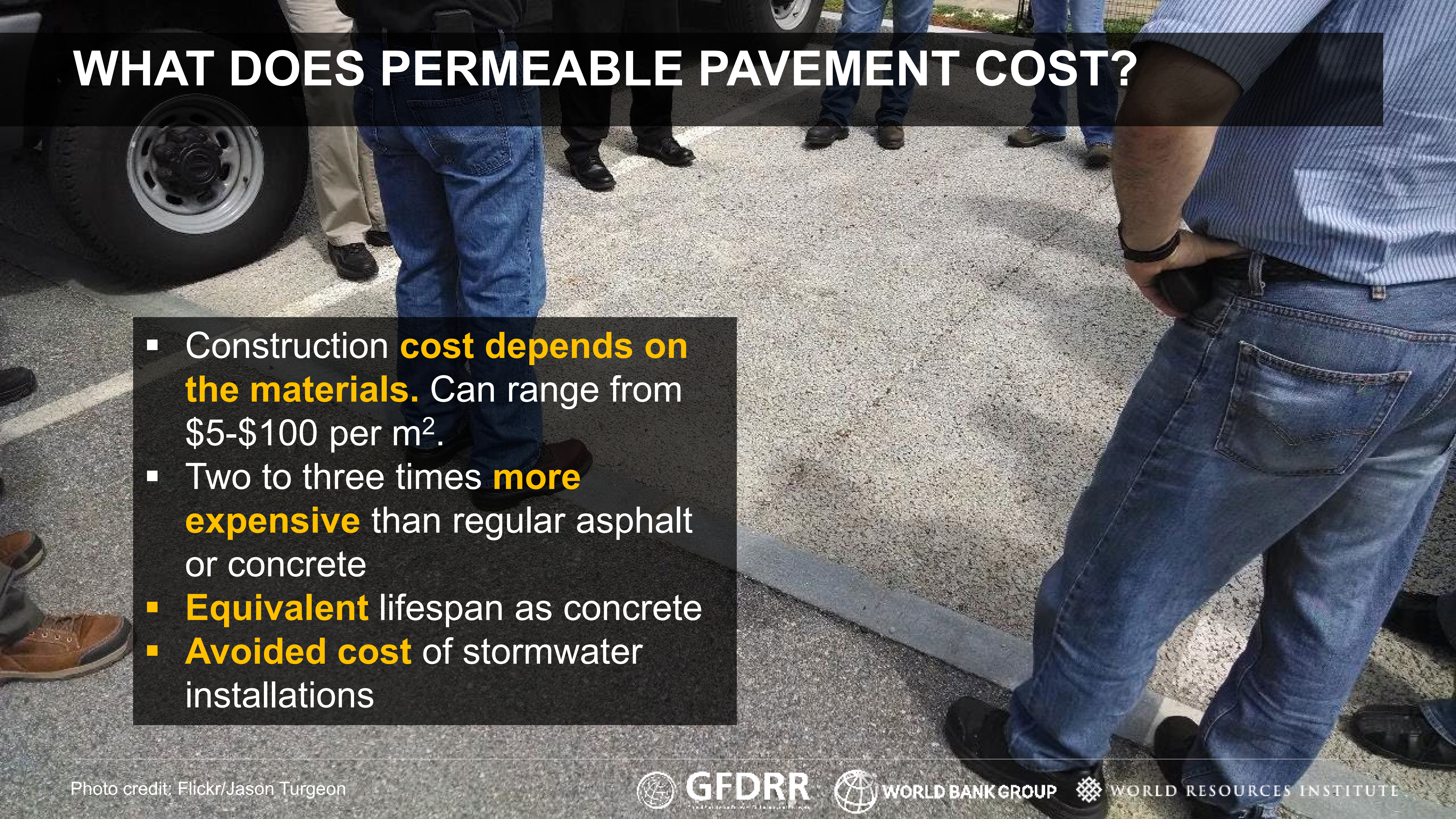
- **Increased groundwater recharge**
- **Pollution abatement**
- Increased meltwater rates, **reducing need for deicing chemicals**.

Photo credit: Flickr/Center for Neighborhood Technology

CONSIDERATIONS FOR USING PERMEABLE PAVEMENT

- Applicable to **low-volume uses**
- **Traffic and site considerations** guide structural design and construction materials
- **Steep slopes can reduce performance**
- **Requires maintenance** to maintain porosity
- **Cold climates affect performance**

Photo credit: Flickr/JR P



WHAT DOES PERMEABLE PAVEMENT COST?

- Construction **cost depends on the materials.** Can range from \$5-\$100 per m^2.
- Two to three times **more expensive** than regular asphalt or concrete
- **Equivalent** lifespan as concrete
- **Avoided cost** of stormwater installations

Photo credit: Flickr/Jason Turgeon

PORTLAND, OREGON, USA
GREEN STREETS AND PERMEABLE PAVEMENT

Tabor to the River Project

- Combining NBS with built infrastructure **saved US$63 million**

Westmoreland Project

- Construction cost: **US$ 412,000**
- Permeable blocks on public streets
- Opportunity arose during built system upgrade
- Benefits include: **reduction in total volume of wastewater in the sewer system, reducing long-term O&M costs**

Photo credit: Flickr/Phil's 1st pix

SELECTING AMONG NBS OPTIONS

Key considerations:

- Spatial footprint
- Integration with built infrastructure
- Runoff collection capability
- Pollution abatement capability
- Additional benefits

Photo credit: Widimedia Commons

THANK YOU

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Photo credit: Flickr/ NNECAPA Photo Library

WASHINGTON, D.C. 2017-2019, PAYING FOR SUCCESS: FINANCING URBAN GREEN INFRASTRUCTURE

One-third of DC's wastewater collection system is a single-piping combined sewer system built over 100 years ago.

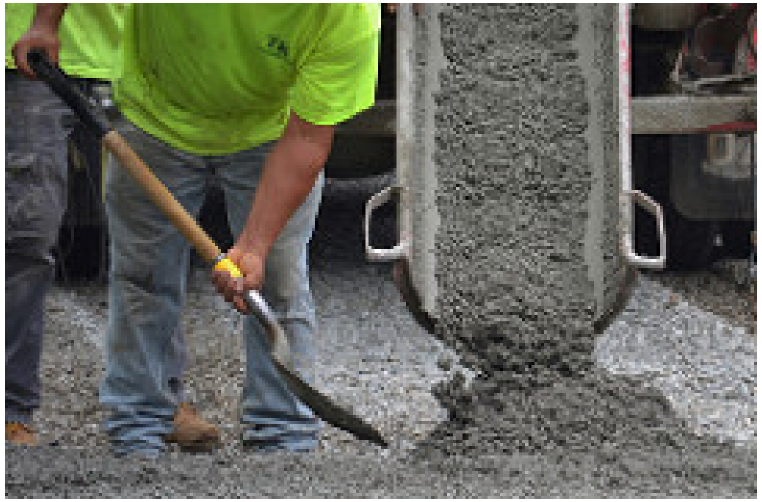
~$100 million total investments in green infrastructure

Approximately 2 billion gallons of CSO is discharged into local streams and rivers annually

Photo credit: Flickr/Florida Sea Grant

SHOREVILLE, MINNESOTA 2007-2009 ESCHEWING STORM DRAINS FOR PERMEABLE PAVEMENT

A residential street project in a suburb of St. Paul received national attention for the largest public street project in the country to use permeable pavement in lieu of storm sewers.



The city installed about 1 mile of permeable pavement in what is considered an environmentally sensitive area for being adjacent to Lake Owasso.

Photo credit: Flickr/Center for Neighborhood Technology