NOTE FOR THE READER OR PRESENTER:

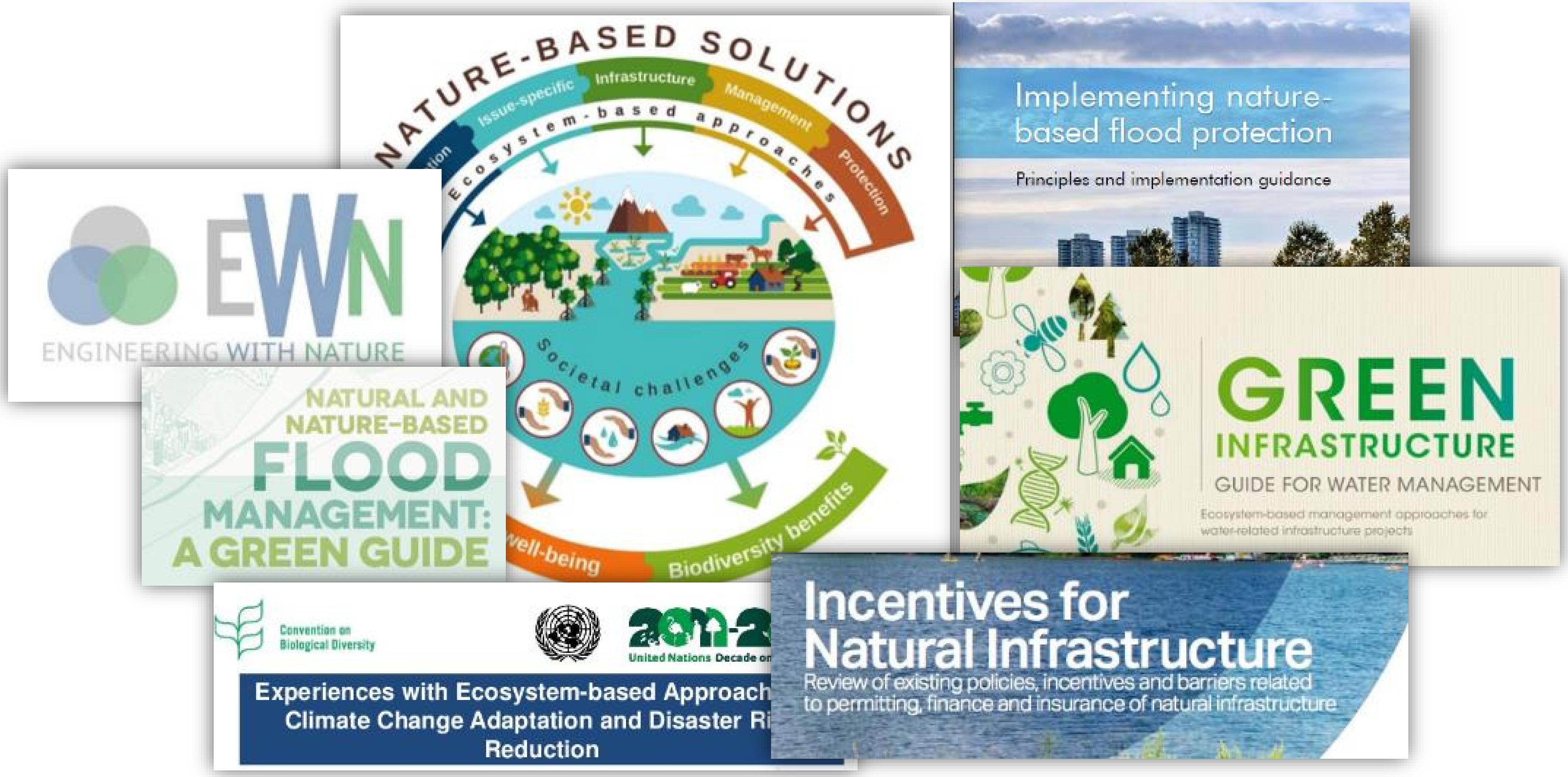
- Talking points and additional resources are in the “notes” section of each slide
- **Bold text** highlights the main points and could be read aloud during a presentation, while non-bold text provides additional supporting information

NATURE-BASED SOLUTIONS FOR DISASTER RISK MANAGEMENT

River flood hazards

Photo credit: Flickr/Sergio Tittarini

MANY TERMS FOR "NATURE-BASED SOLUTIONS"

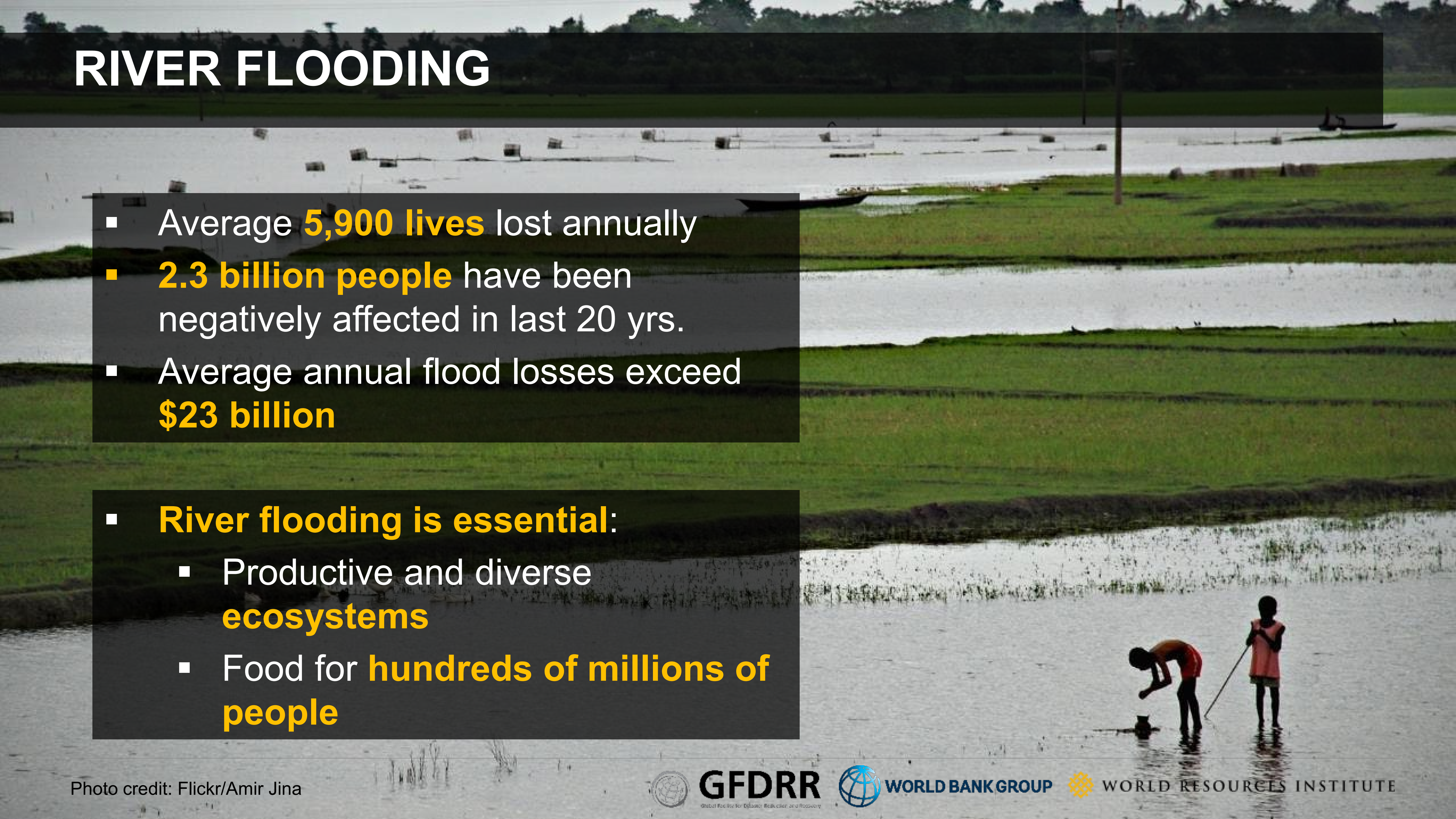


Source: Cohen-Shacham et al. 2016; UNEP et al. 2014; EC 2015; Lo 2016; WWF 2017; USACE n.d.; EcoShape 2018; WBCSD 2017

PRESENTATION STRUCTURE

- **Context**
- **The solutions:**
  - Floodplains and bypasses
  - Inland wetlands
  - Stream banks and beds
  - Upland forests
- **Wrap-up**

RIVER FLOODING



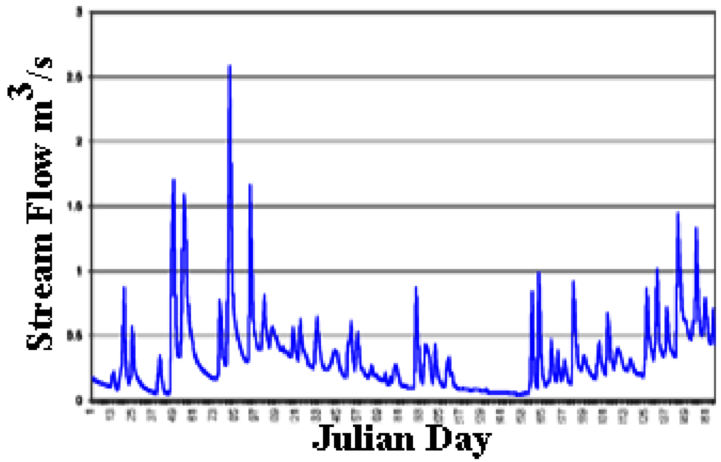
- Average **5,900 lives** lost annually
- **2.3 billion people** have been negatively affected in last 20 yrs.
- Average annual flood losses exceed **$23 billion**

- **River flooding is essential**:
  - Productive and diverse **ecosystems**
  - Food for **hundreds of millions of people**

Photo credit: Flickr/Amir Jina

FLOOD RISK

Hazard * Exposure * Vulnerability



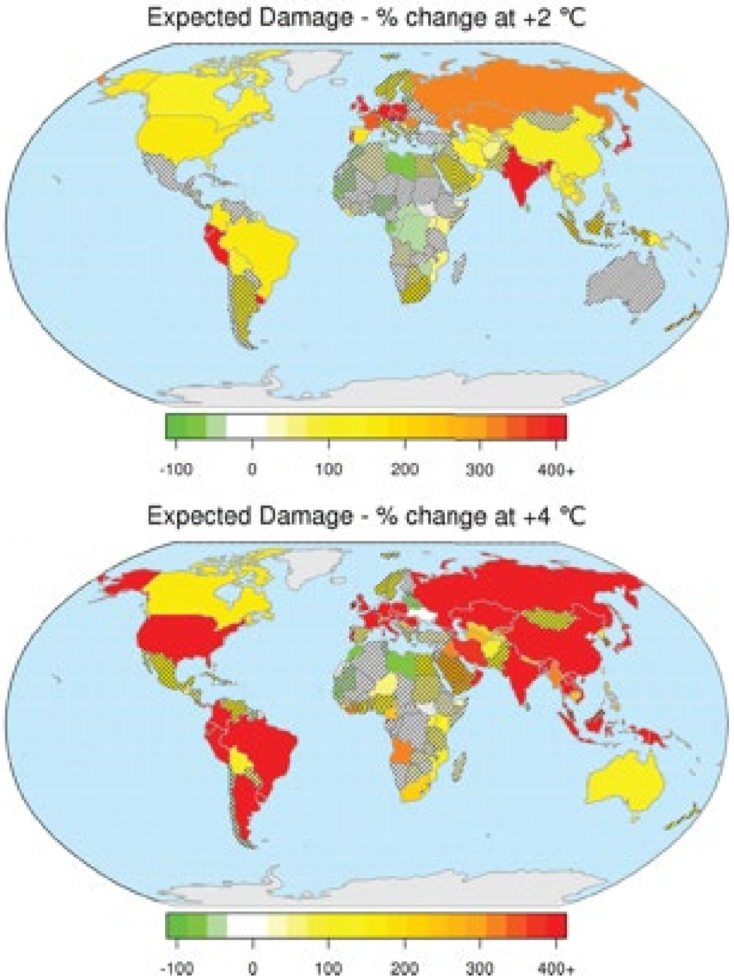
Photos/Figure (L-R): Wikipedia/NOAA; Wikipedia/KennyOMG; Wikipedia/Kumarrakajee

INCREASING FLOOD RISK

- **Development, climate change**, and **aging infrastructure**
- Population in floodplains **increased by 114%** (1970-2010)
- Economic losses increasing **6.3%/ yr**

Global Projections of River Flood Risk in a Warmer World

With **2°C increase, 170%** increase in damages and affected population



Source: Alfieri et al. 2016

STRUCTURAL STRATEGIES

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

Source: World Bank 2017

WORLD BANK INVESTMENT PORTFOLIO DISASTER RISK MANAGEMENT (DRM)

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

(FY2012-2018)

Invested **~US$ 1.2 billion** in 34 projects targeting river flooding with **NBS**

(FY2012-2018)

Source: World Bank 2018

CONVENTIONAL: 'BUILT' INFRASTRUCTURE

<u>EXAMPLES</u>: Dams, levees/dykes, flood walls, channel modifications

<u>ADVANTAGES</u>

- **Essential role** in preventing floodwaters from damaging assets and harming people
- Deep **industry knowledge**
- High **performance certainty** and control

<u>CHALLENGES</u>

- **20% of freshwater fish species** at risk
- Can **increase flood risk** over time
- **Massive investment gap** in flood infrastructure

Photo credit: Wikimedia/Ssbertuccelli

NATURE-BASED SOLUTIONS

- Allow watersheds to **function naturally,** with beneficial flooding
- **Slow and attenuate** floodwaters
- **'Hybrid'** solutions **integrate and enhance** the benefits of natural and built solutions

Examples: Floodplains, inland wetlands, stream beds and banks, and upland forests

Photo credit: Flickr/Keith Ewing

ADVANTAGES OF NATURE-BASED SOLUTIONS

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

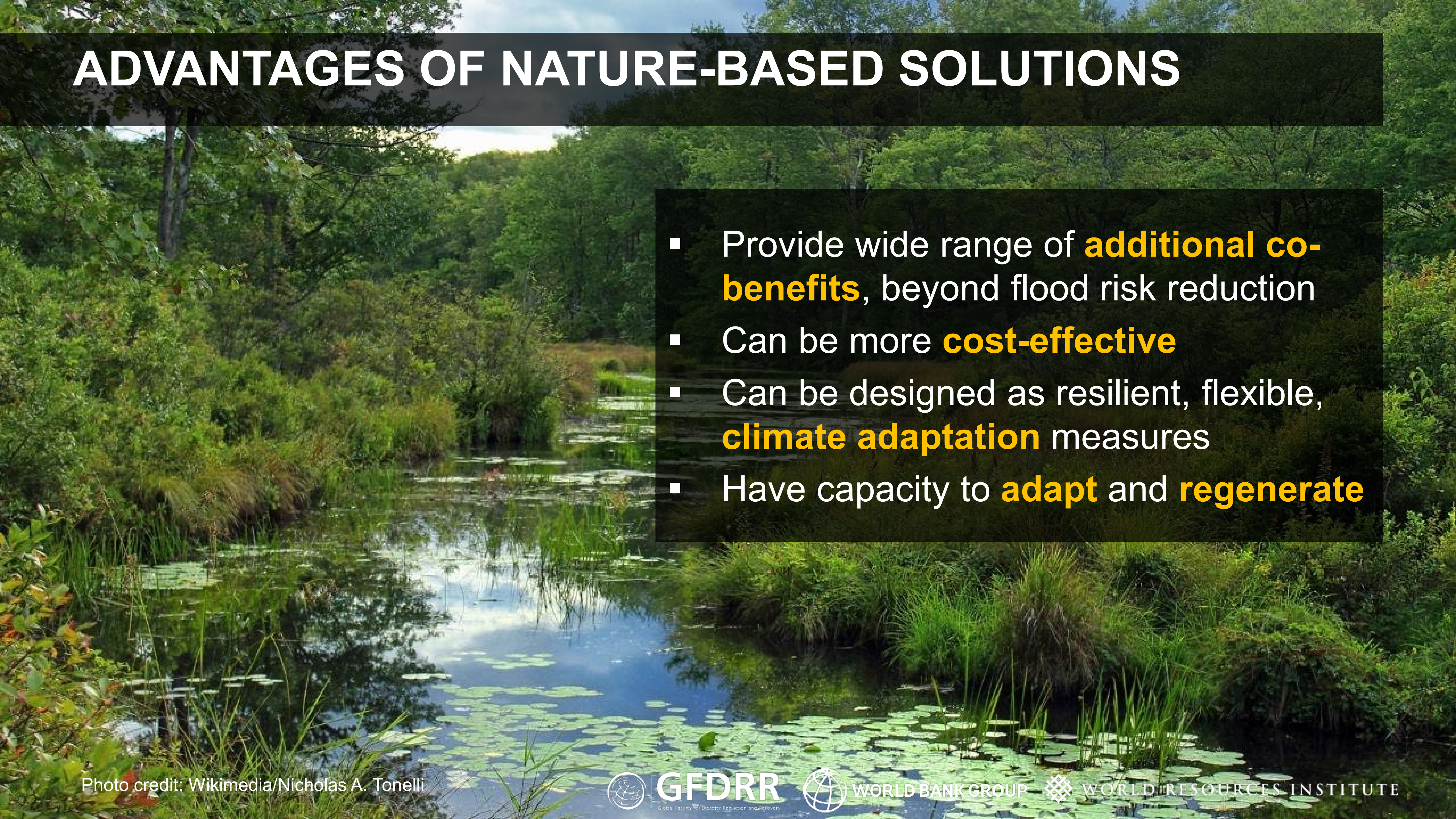


Photo credit: Wikimedia/Nicholas A. Tonelli

WORDS OF CAUTION

- Greater **variability and uncertainty**
- Disconnect between **upstream sources** of river flooding and downstream **communities at risk**
- **Data and capacity** limitations
- Challenging to make the **economic case**
- Land requirements and **social equity**

Photo credit: Pxhere

NBS FOR RIVER FLOODING

1. Floodplains and bypasses
2. Inland wetlands
3. Stream beds and banks
4. Upland forests

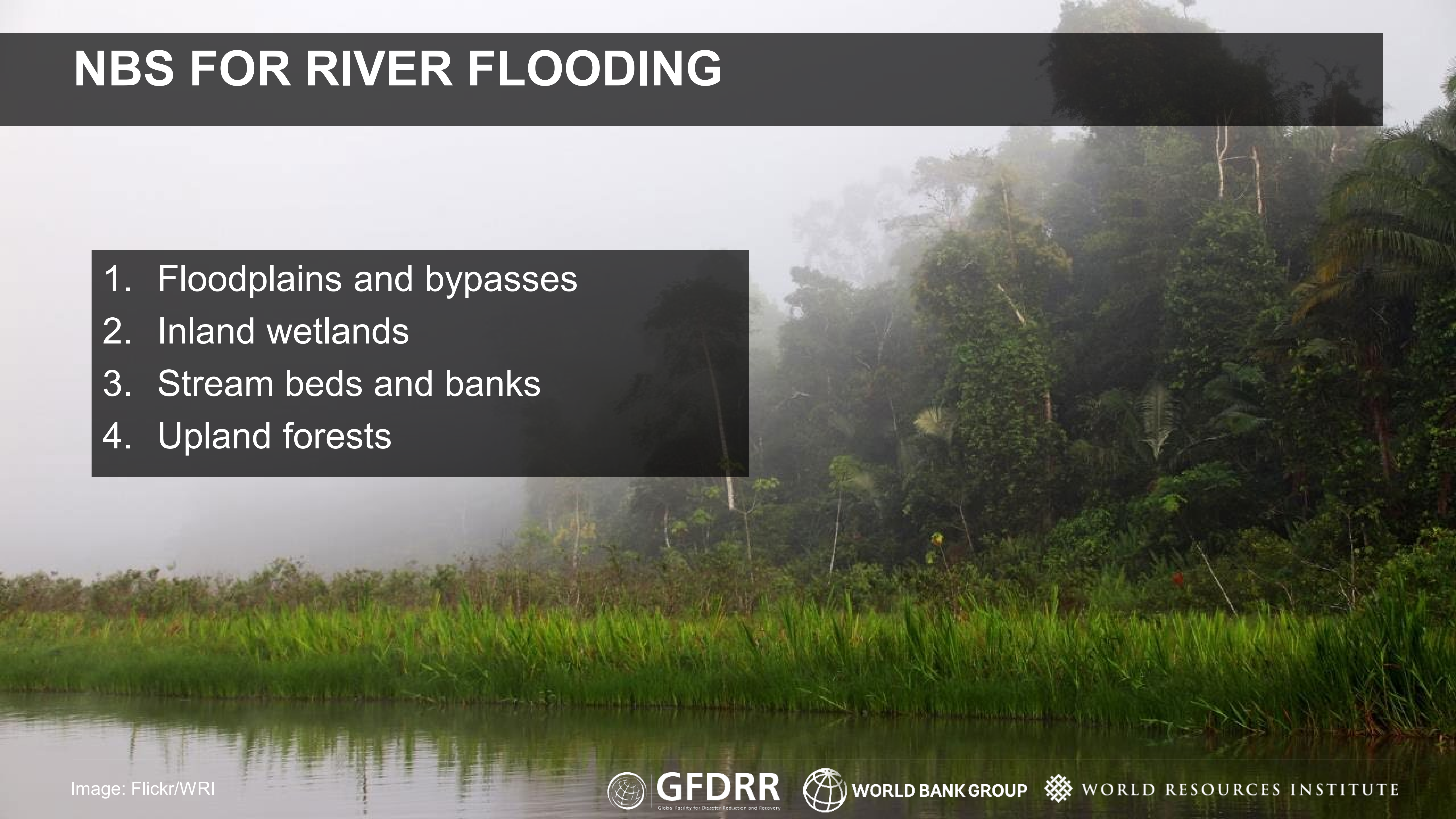
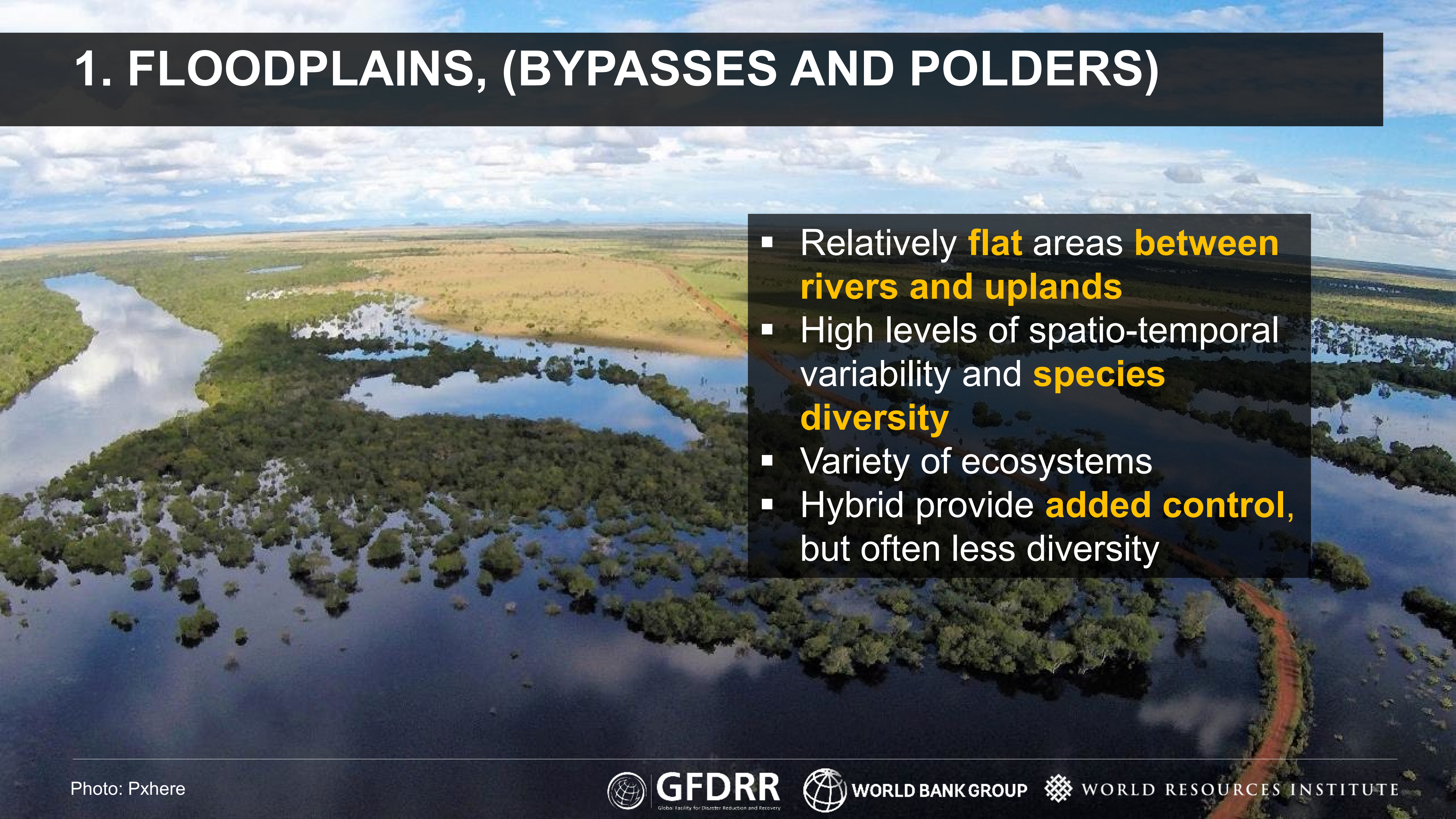


Image: Flickr/WRI

1. FLOODPLAINS, (BYPASSES AND POLDERS)



- Relatively **flat** areas **between rivers and uplands**
- High levels of spatio-temporal variability and **species diversity**
- Variety of ecosystems
- Hybrid provide **added control,** but often less diversity

Photo: Pxhere

RISK REDUCTION BENEFITS

- Integrated with rivers to **slowly, convey water and sediment**
- Capture **large proportion** of upstream water
- Successful applications **across the globe**

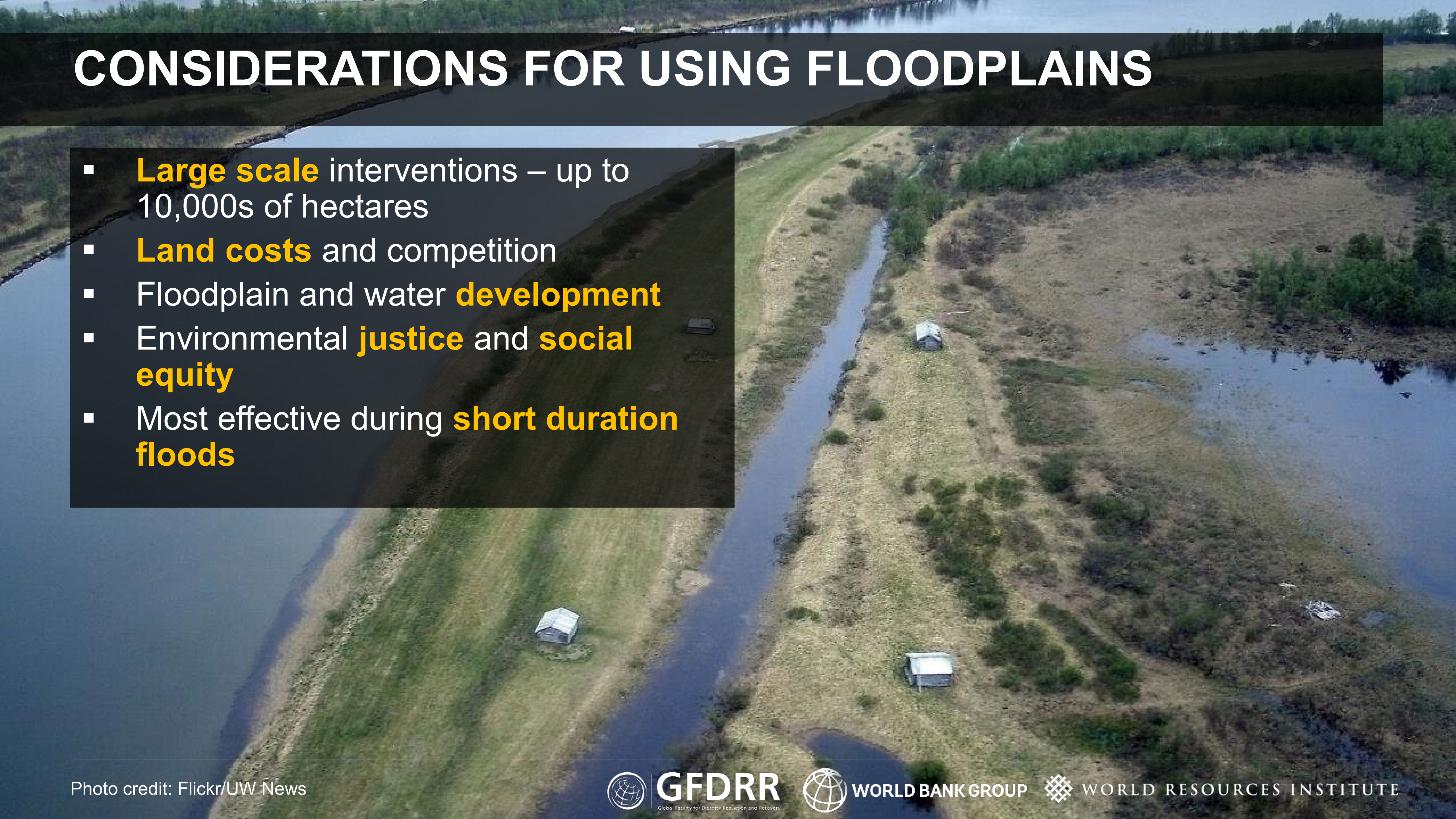
Photo: Flickr/Roger Price

ADDITIONAL BENEFITS

- Biodiverse habitat
- Improved water quality
- Groundwater recharge
- Productive agriculture and fisheries
- Carbon sequestration
- Recreation

- **Markets exist for some services**

Photo credit: Wikimedia/Basile Morin

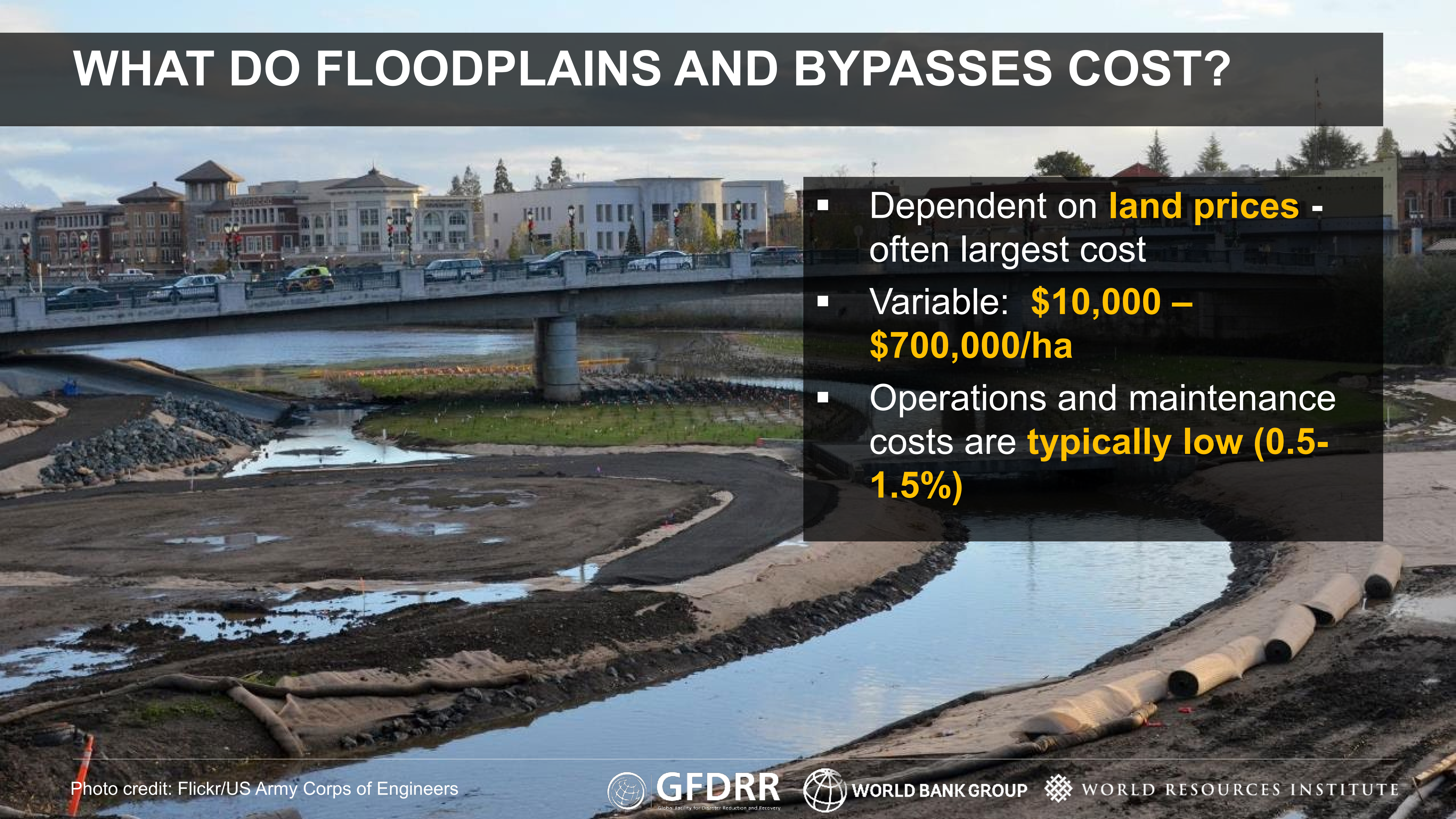


CONSIDERATIONS FOR USING FLOODPLAINS

- **Large scale** interventions – up to 10,000s of hectares
- **Land costs** and competition
- Floodplain and water **development**
- Environmental **justice** and **social equity**
- Most effective during **short duration floods**

Photo credit: Flickr/UW News

WHAT DO FLOODPLAINS AND BYPASSES COST?



- Dependent on **land prices** - often largest cost
- Variable: **$10,000 – $700,000/ha**
- Operations and maintenance costs are **typically low (0.5-1.5%)**

Photo credit: Flickr/US Army Corps of Engineers

CASE STUDY: DANUBE GREEN CORRIDOR

- 2006 floods: **US$ 464 million** in damages
- Dikes **cut off floodplains**
- **80% of wetlands** lost

Danube Green Corridor

- Restore **224,000 ha of natural floodplain**
- Cost: **US$ 214 million**
- Expected ecosystem services earnings: **US$ 100 million/ yr**

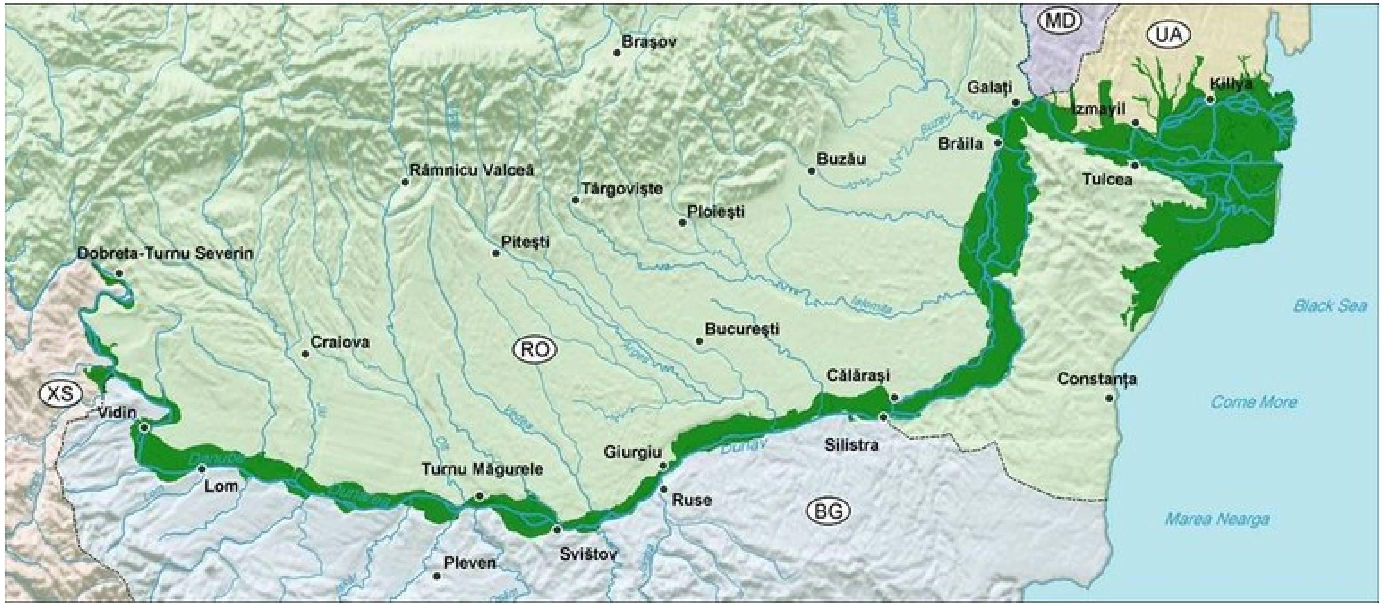


Photo credit: fFickr/chris lovelock and WWF 2010

2. INLAND WETLANDS

- **Complex, integrated systems** of water, plants, animals, and microorganisms
- Require **specific environmental conditions**
- **Wide variety of wetlands** and flood attenuation potential
- **64–71%** of the world's natural wetland area **have been lost**

Photo credit: Flickr/Ed Dunens

RISK REDUCTION BENEFITS

- "**Act like a sponge**"
- A hectare of wetland can **store up to 9,400 -14,000 m^3** of floodwater
- **Type and location** determine function
- **Floodplain river-fed wetlands** greater potential to reduce floods

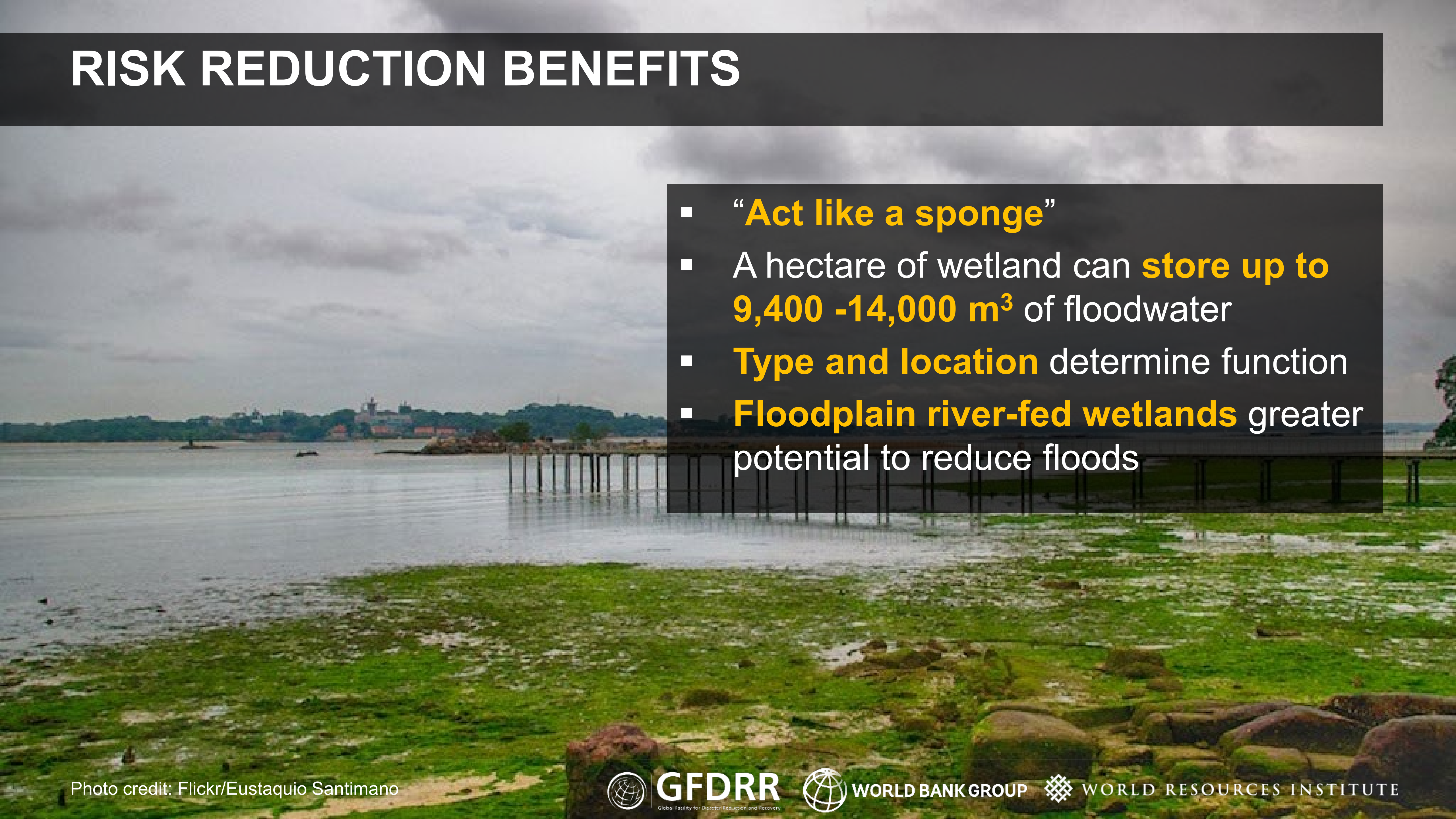
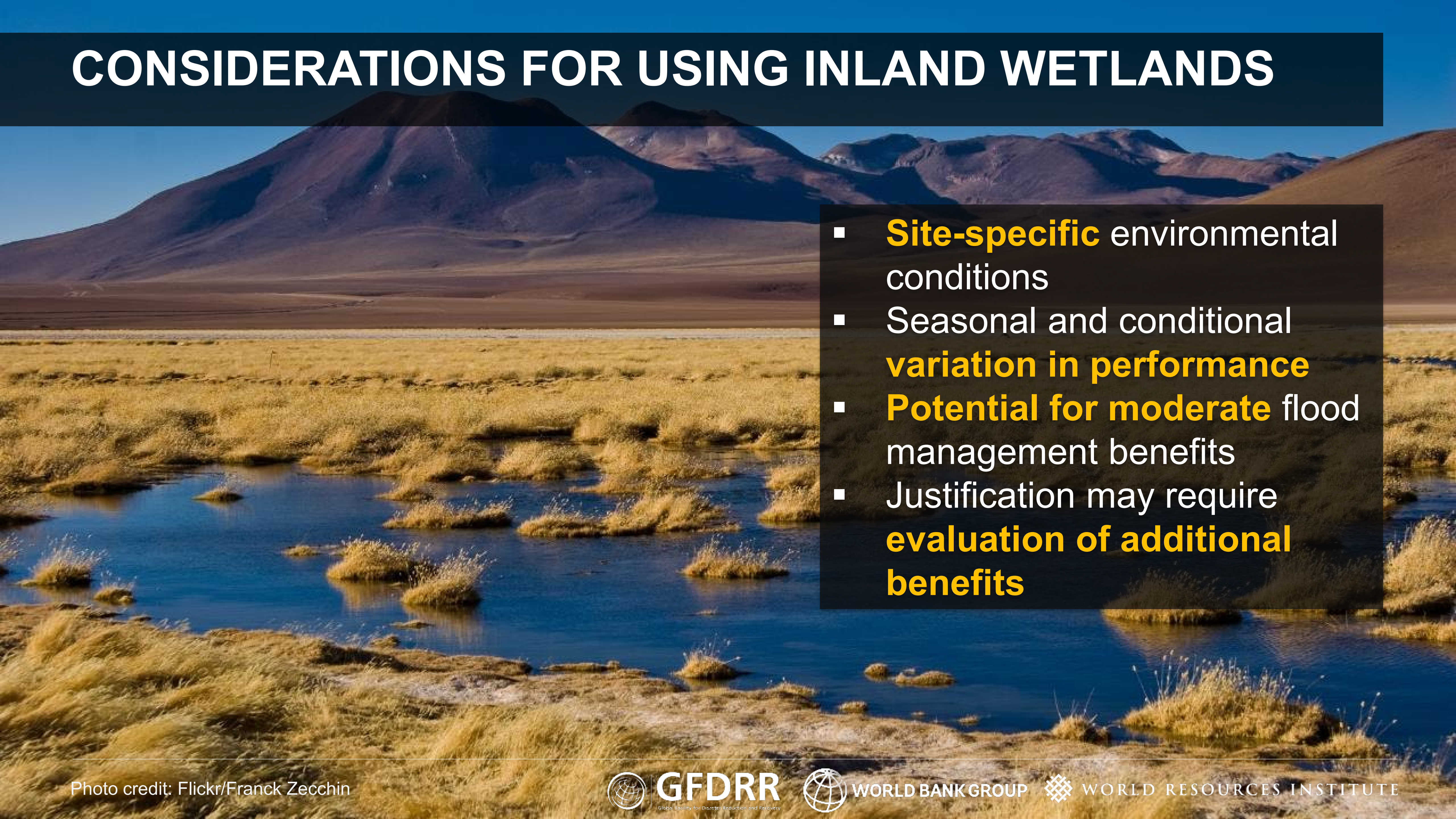


Photo credit: Flickr/Eustaquio Santimano

ADDITIONAL BENEFITS

- Effectively **filter sediments and pollutants**
- Hydrologic connectivity and **water security**
- **Wildlife** and **biodiversity**
- **Recreation, tourism and education** opportunities
- Ecosystem services averaged **$26,000 /ha/yr** in 2011

Photo credit: Flickr/NPS, Patrick Myers

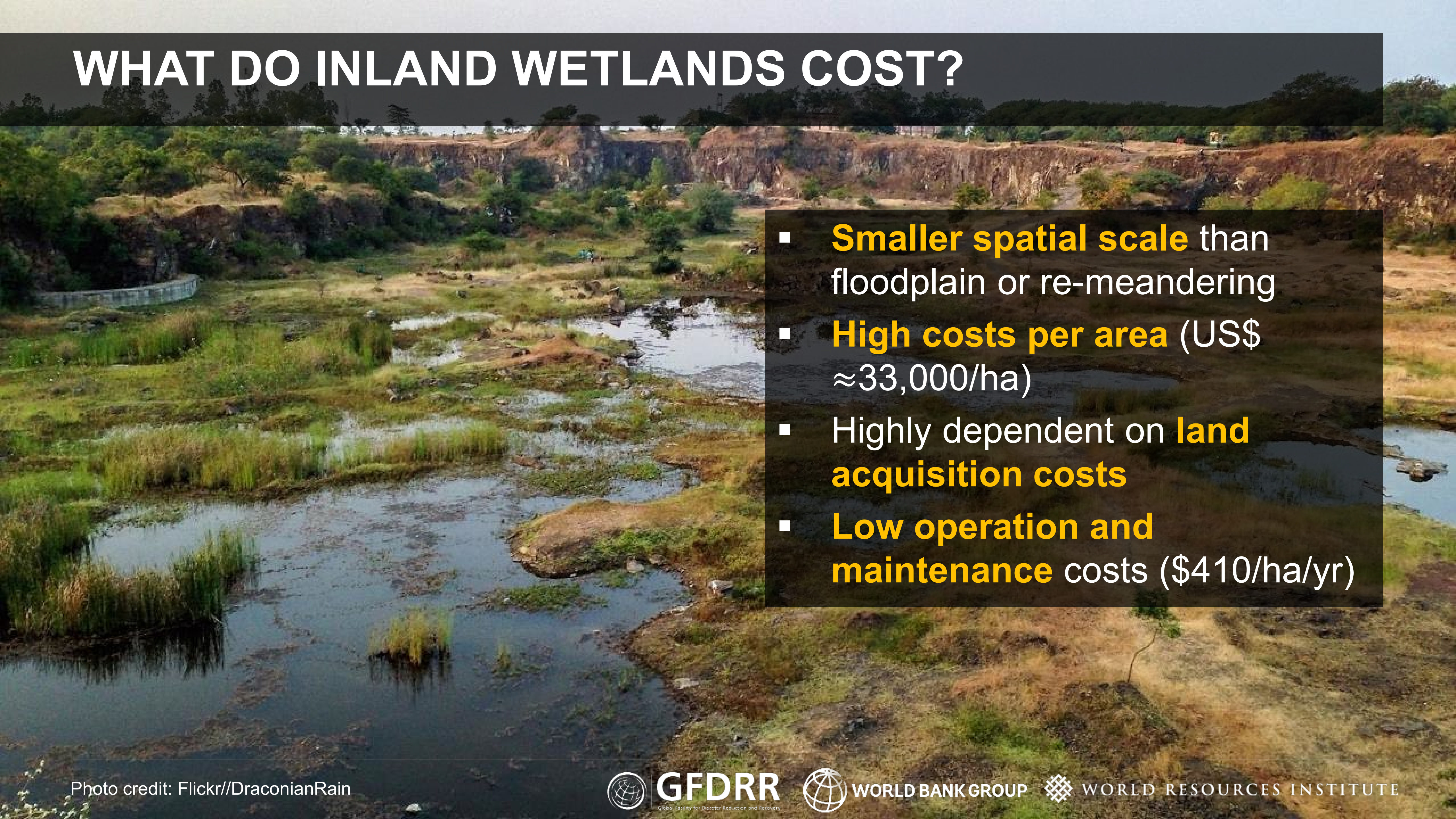


CONSIDERATIONS FOR USING INLAND WETLANDS

- **Site-specific** environmental conditions
- Seasonal and conditional **variation in performance**
- **Potential for moderate** flood management benefits
- Justification may require **evaluation of additional benefits**

Photo credit: Flickr/Franck Zecchin

WHAT DO INLAND WETLANDS COST?



- **Smaller spatial scale** than floodplain or re-meandering
- **High costs per area** (US$ ≈33,000/ha)
- Highly dependent on **land acquisition costs**
- **Low operation and maintenance** costs ($410/ha/yr)

Photo credit: Flickr//DraconianRain

CASE STUDY: BEDDAGANA WETLAND PARK, SRI LANKA

- 2010 Flood: **36,000 families homeless, US$ 50-100 million damages**
- Wetlands capture **39% of the flood waters** during storms
- Degraded at **1.2% (23 ha)/ yr**
- Without wetlands **1% lost of GDP/yr**

Wetland Management Strategy

- Restore and protect the **18 ha Beddagana Wetland Park**
- Cost: **US$ 1.2 million**
- Recreational income potential **US$ ≈ 13.6 million/ yr** (10x investment!)

Photo credit: World Bank/Andrina Fernando (top)
Sri Lanka Ministry of Defense and Urban Development (bottom)

GFDRR
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3. STREAM BEDS AND BANKS

- Vegetated banks along meandering streams **slow floodwaters**
- The majority of large rivers have been **modified**
- Modifications fight **against natural processes**

Interventions: Re-meandering, setting back levees, de-armoring and revegetating banks.

Photo credit: Wikipedia/US Bureau of Reclamation

RISK REDUCTION BENEFITS

- Re-meandering the River Skjern extended **stream length 36%**
- Mississippi River levee set backs could **reduce expected annual damages by 55%**
- Restoring streambed delayed flood wave by **two hours**

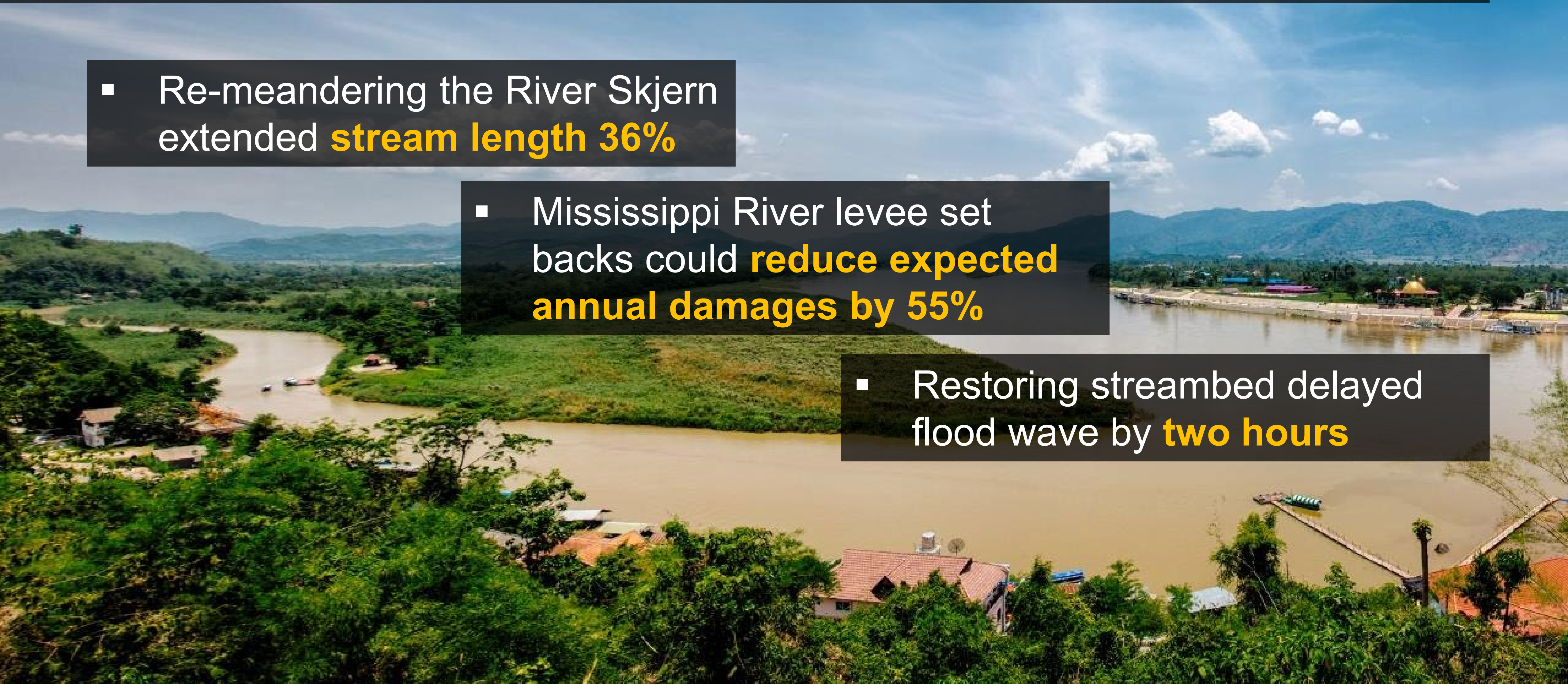


Photo credit: Flickr/Marcos Molina

ADDITIONAL BENEFITS

- Improved riparian biodiversity
- More diverse fish habitat
- Decreased water temperature
- Erosion control
- Recreation and aesthetic value

Natural river banks in Belgium evaluated at **US$ 27,000/km – 60,000/km** per year

Photo credit: Flickr/WRI

CONSIDERATIONS FOR RESTORING STREAM BEDS AND BANKS

- **Reference state** and objectives
- Requires solid understanding of **current and future hydrologic regimes**
- **Dynamic river systems** versus anthropogenic constraints

Photo credit: Flickr/ William Veerbeek

WHAT DOES IS COST TO RESTORE STREAM BEDS AND BANKS?

- **High construction costs**
- **Lower land acquisition** and **compensation** costs

- Bank stabilization: **$29,000 to $137,000/km**
- Channel rehabilitation: **$25,000 to $85,000/km**

Photo credit: Flickr/USFWS, Pacific region

CASE STUDY: ROOM FOR THE RIVER, THE NETHERLANDS

- **55% of housing** in flood-prone areas
- Higher dykes no longer sufficient due to **climate change**

Room for the River - Nijmegen

- **US$ 460 million** to push dyke 350 m inland
- **Local participation** and compensation
- New island and **river park**

Photo credit: Wikipedia/Roger Veringmeier

4. UPLAND FORESTS

- **Upstream watershed characteristics** influence downstream river floods
- Upstream forests **slow and retain runoff**
- **Land use changes** increase flood runoff

Photo credit: Flickr/Peter Steward

RISK REDUCTION BENEFITS

- **82% of studies** reported a decrease in peak flow after restoration
- Reforesting areas over 25-40% of a UK catchment could **decrease the flood maximum by 20%**

- Most risk reduction evidence from North American and European **temperate forests**
- Most effective during **moderate floods of short duration**

Photo credit: WRI/James Anderson

ADDITIONAL BENEFITS

- Water and air purification
- Carbon storage
- Soil production, reduced erosion and sedimentation
- Timber, food, and fuel
- Habitat creation
- Recreation

Photo credit: Flickr/Mathias Appel

CONSIDERATIONS FOR UPLAND FOREST RESTORATION

- **Not all forests are created equal**
- Some studies demonstrate **negligible flood impacts**
- Problems of **scale and cost**
- Importance of **data and monitoring**

Photo credit: Flickr/WRI

WHAT DOES FOREST RESTORATION COST?

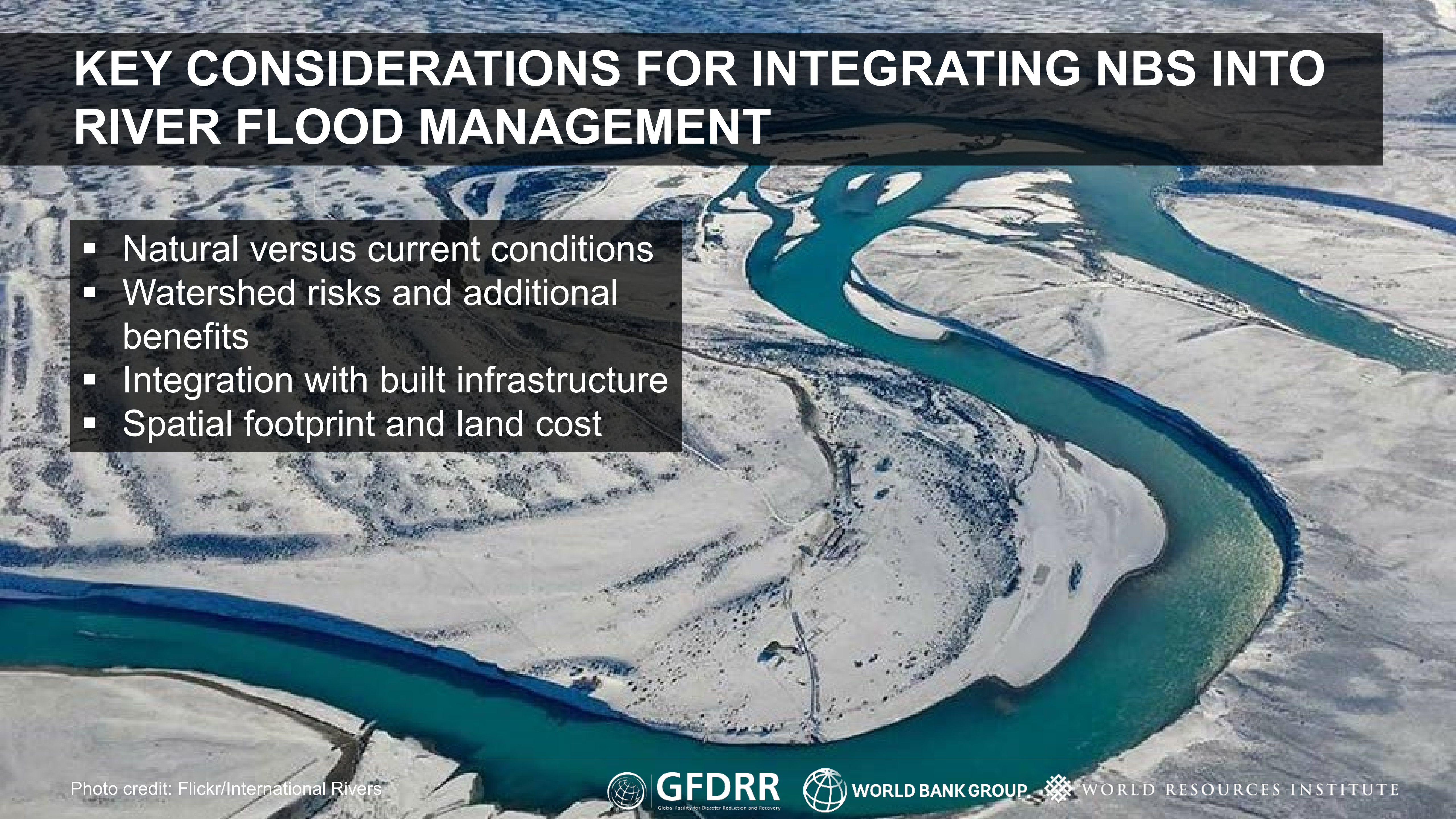
- **Lower per hectare cost** than other NBS: US$ 3,450/ha (tropical), 2,390/ha (other)
- Significant **compensation and transaction costs** in catchments with large private landownership
- **High aggregate costs**

Photo credit: Flickr/WRI

CASE STUDY: UPLAND FOREST RESTORATION AS PART OF INTEGRATED FLOOD MANAGEMENT FOR DAR ES SALAAM

- **7 disastrous floods** since 1995
- Avg of **14 people die annually**
- Main cause of **cholera outbreaks**
- Charcoal use severely **degraded upland forests**

- Suite of NBS, including forest restoration, **outperformed other strategies**
- **Pays for itself** in less than 10 years
- Net benefits of **US$80 million** over 20 years



KEY CONSIDERATIONS FOR INTEGRATING NBS INTO RIVER FLOOD MANAGEMENT

- Natural versus current conditions
- Watershed risks and additional benefits
- Integration with built infrastructure
- Spatial footprint and land cost

Photo credit: Flickr/International Rivers

THANK YOU

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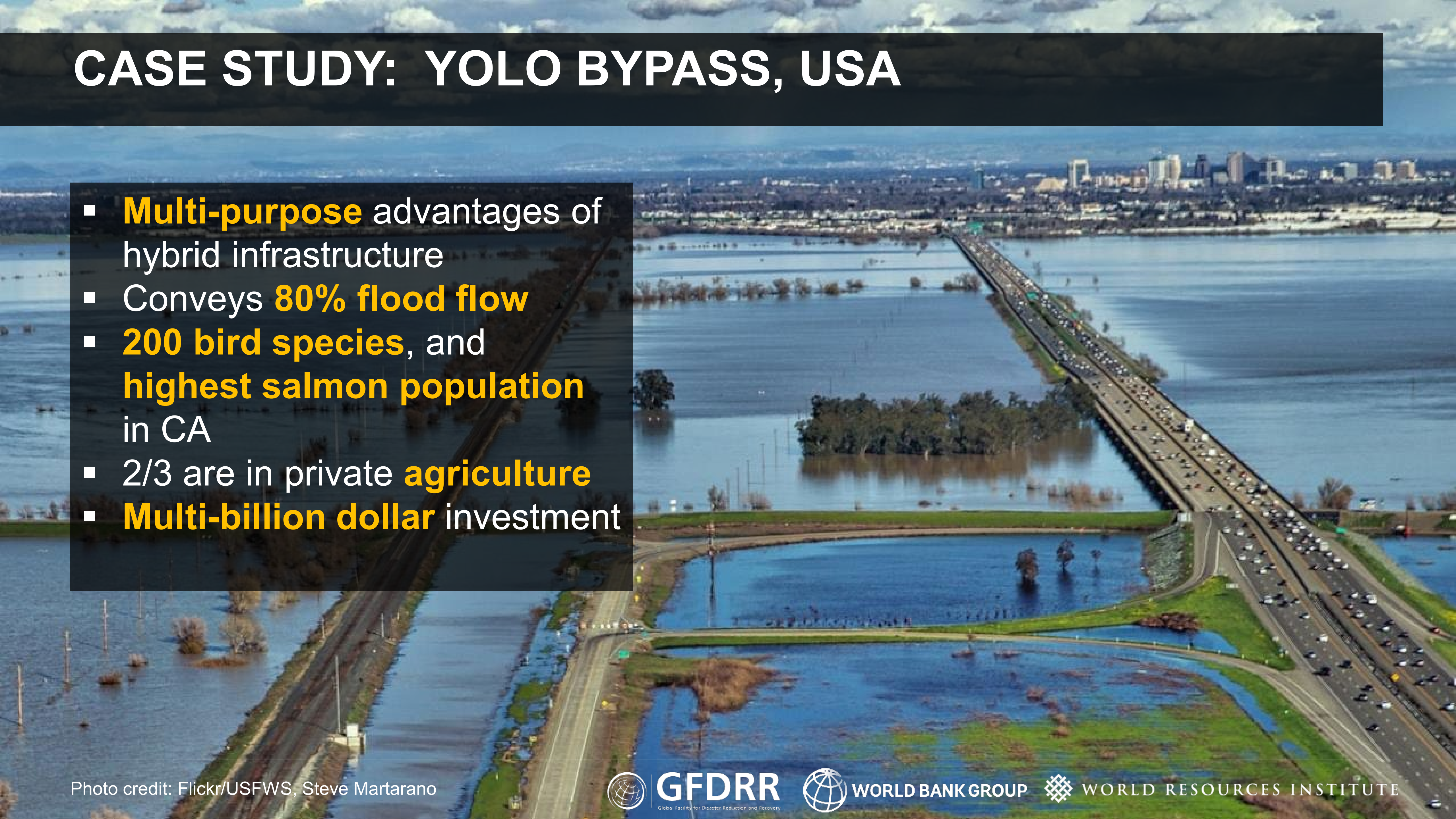
Photo credit: Flickr/bmalarky

CASE STUDY: NATURAL FOREST CONSERVATION PROGRAM (NFCP), CHINA - METRICS OF SUCCESS?

- **$26 billion in loses** (1998 floods) due to **deforestation and steep cultivation**
- NFCP meant to reduce flood risk, but **no flood metrics formulated**
- **3.3 times less** forest loss
- **0.84 million increase** in forest employment
- However, questionable net benefits

Photo credit: Flickr/CIFOR



CASE STUDY: YOLO BYPASS, USA

- **Multi-purpose** advantages of hybrid infrastructure
- Conveys **80% flood flow**
- **200 bird species**, and **highest salmon population** in CA
- 2/3 are in private **agriculture**
- **Multi-billion dollar** investment

Photo credit: Flickr/USFWS, Steve Martarano