WES-BCA
Regional Training and Study Tour

Adaptation Measures for flood and storm water management

Activity Number: C1_REG/ST-6

Nature-Based interventions in river eco-systems

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

21 April 2026 at 11:00

Sheraton Hotel Nice

Presented by:
Dr Ioanna ZALACHORI, Senior Flood Expert,
Mr Stelios VAVOULOGIANNIS, Junior NBS / Research Expert

LDK CONSULTANTS S.A.

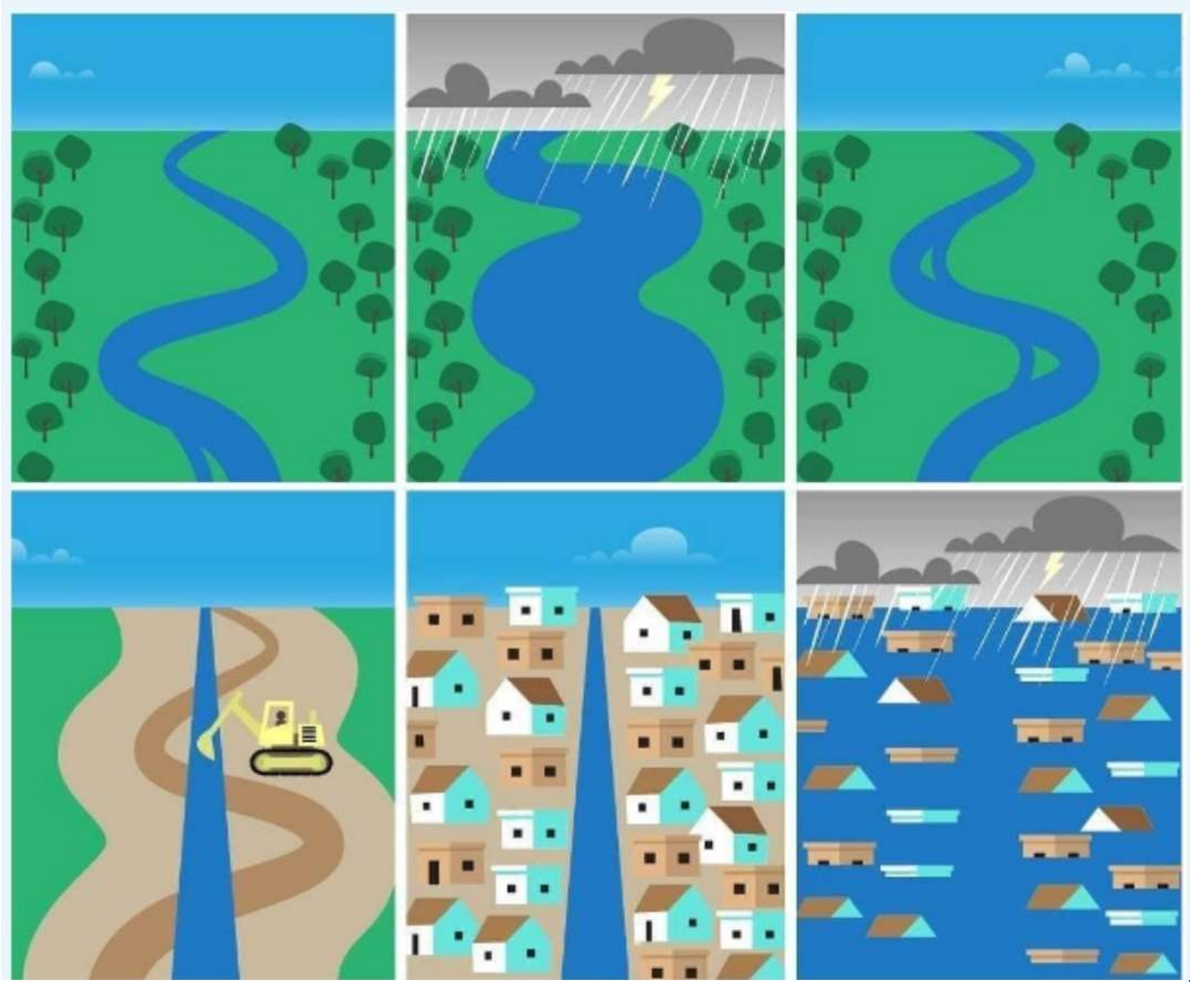
Funded by the European Union

Recent years: facts

Rising urbanisation

Flood plains invasion

Increased flooding risk



LDK CONSULTANTS S.A.

Funded by the European Union

Paradigm Shift

Shift from **"flood control"** towards **"flood management"** in the last decades.

"*Flood management consists in accepting that floods as part of river's natural life*":

- ❑ shifting from a *re-active* to a ***pro-active*** flood management strategy,
- ❑ balancing *flood risk* to ***sustainable development*** and
- ❑ from *ad-hoc flood control* to ***integrated flood management***.

Integrated Flood Management (IFM)

Natural Based Solutions (NbS)

WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

Nature-based solutions (NbS) emerged mid-2000s by the International Union for Conservation of Nature (IUCN) and the European Commission (EC) as:

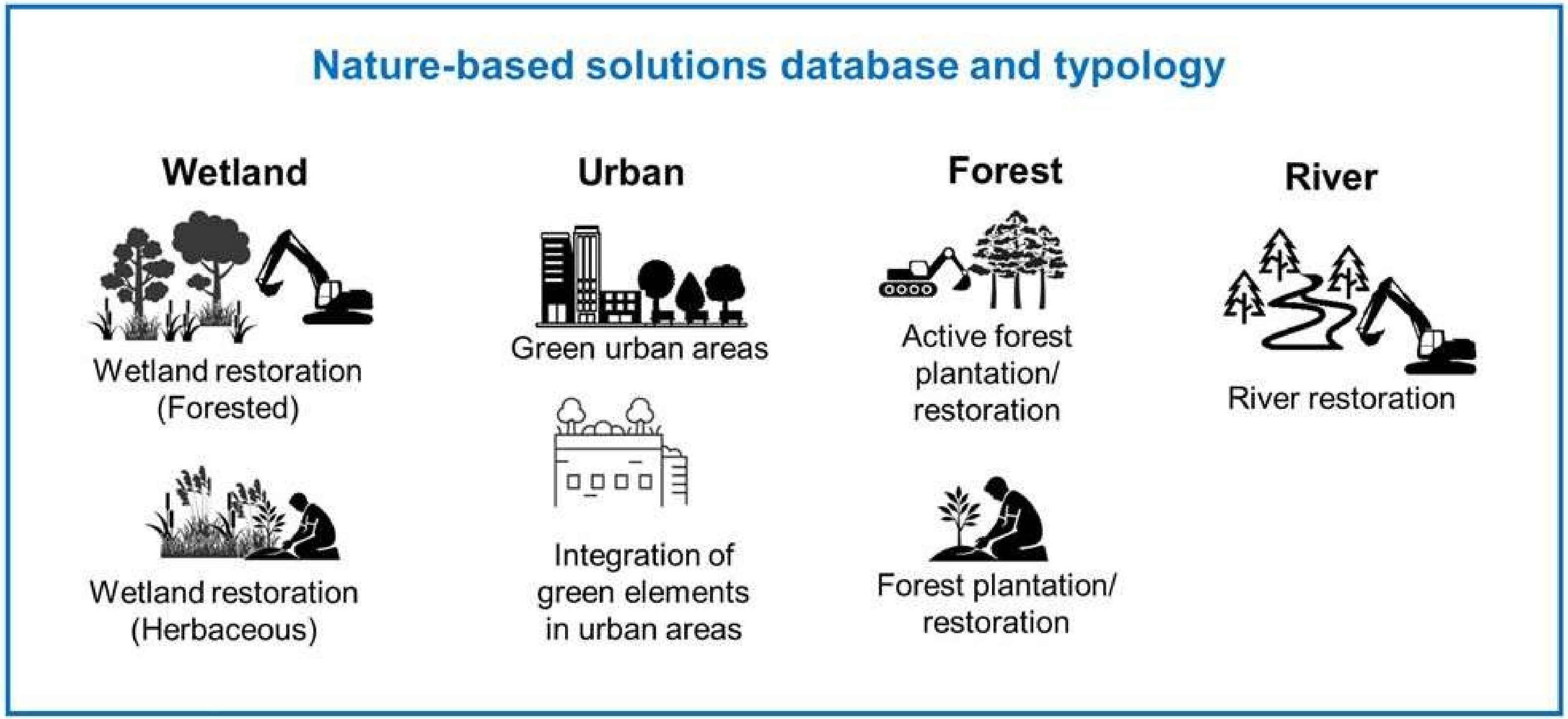
an effective combination of measures to addressing climate and disaster risks.

NbS is an umbrella term covering a range of ecosystem-based sustainable development approaches:

"… to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". (IUCN, 2020).

Natural Based Solutions (NbS)

WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

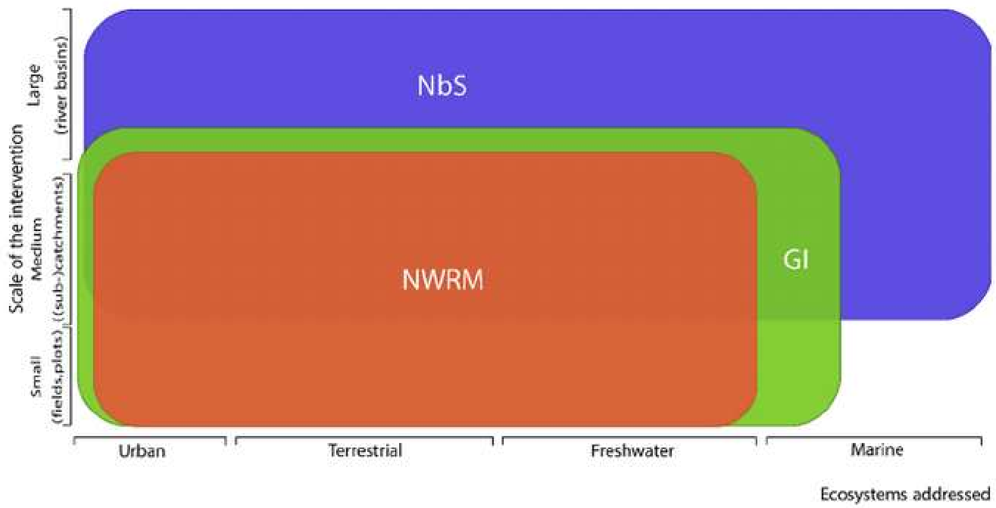


Source: EU GUIDE ON NWRMs, 2014

Natural Water Retention Measures (NWRM)

NWRM are multi-functional interventions, part of the **NbS** umbrella, aiming at:

- ✓ increasing **water storage**
- ✓ reducing **flood peaks**
- ✓ mitigating **drought impacts**
- ✓ restoring **natural river**
- ✓ supporting **climate adaptation**
- ✓ improving **water quality**
- ✓ restoring **ecosystems**
- ✓ stabilizing **landscapes**
- ✓ improving **potential**

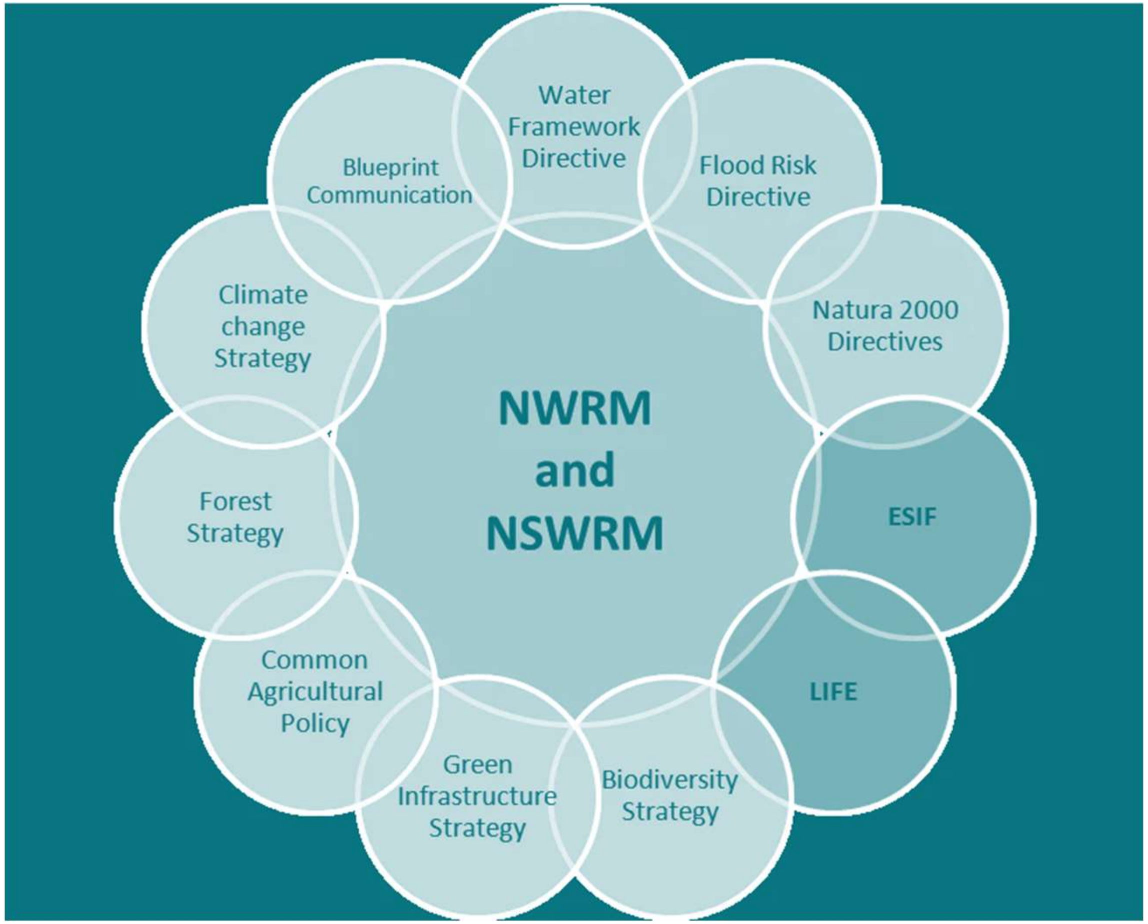


Source: Magnier et al. 2024

LDK CONSULTANTS S.A.

Funded by the European Union

Natural Water Retention Measures (NWRM)

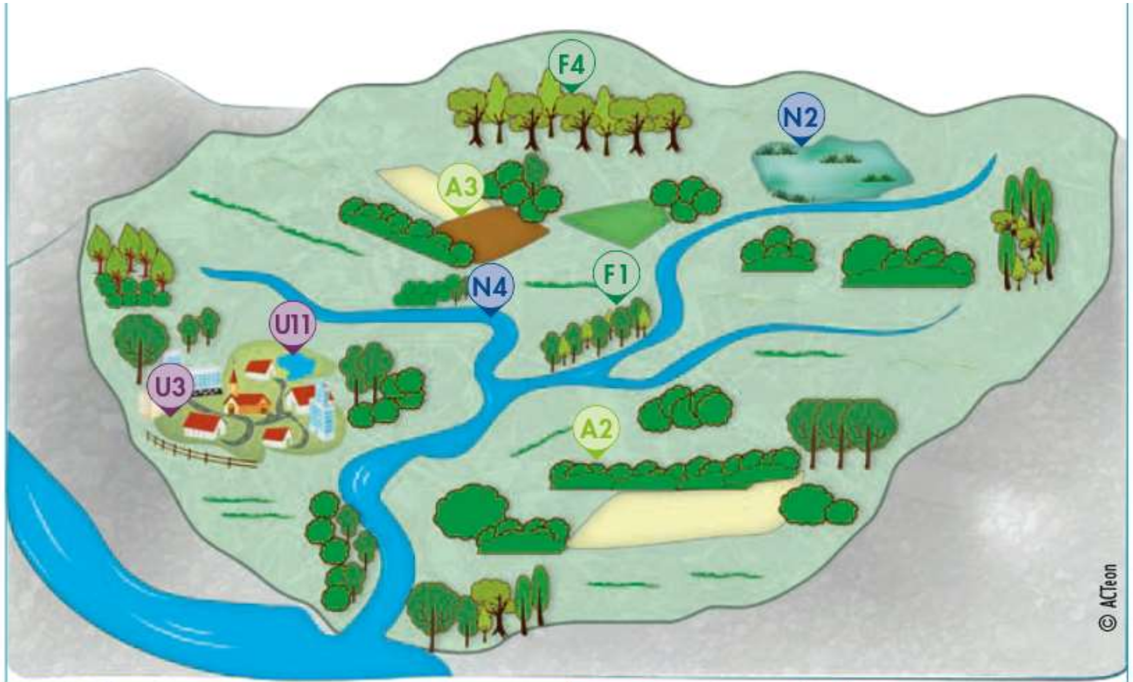


Source: Borchers T., 2014

Natural Water Retention Measures (NWRM)

WES-BCA
Water and Environment Support - Biodiversity and Climate Action

Natural Water Retention Measures (NWRM)



A2	Buffer strips and hedges	F1	Forest riparian buffers
A3	Crop rotation	F4	Targeted planting for catching precipitation
U3	Permeable surfaces	N2	Wetland restoration and management
U11	Retention ponds	N4	Re-meandering

Source: Gonzalez-Garcia et al., 2025

Natural Water Retention Measures (NWRM)

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

Category	Examples	Purpose
Hydro- morphological	Meander reconnection, floodplain restoration	Reduce peak flood, increase storage capacity
Wetland measures	Wetland creation/restoration, peatland rewetting	Store water, improve water quality
Agricultural	Cover crops, buffer strips, contour farming	Increase infiltration, reduce runoff and erosion
Forestry	Reforestation, afforestation, deadwood retention	Enhance soil moisture, stabilize slopes
Urban measures	Green roofs, permeable pavements, rain gardens	Reduce stormwater runoff, enhance infiltration

Hydromorphological NWRMs

Floodplain restoration

European Environment Agency (EEA, 2018), estimates that: **70-90%** of floodplain areas in Europe are ecologically degraded.

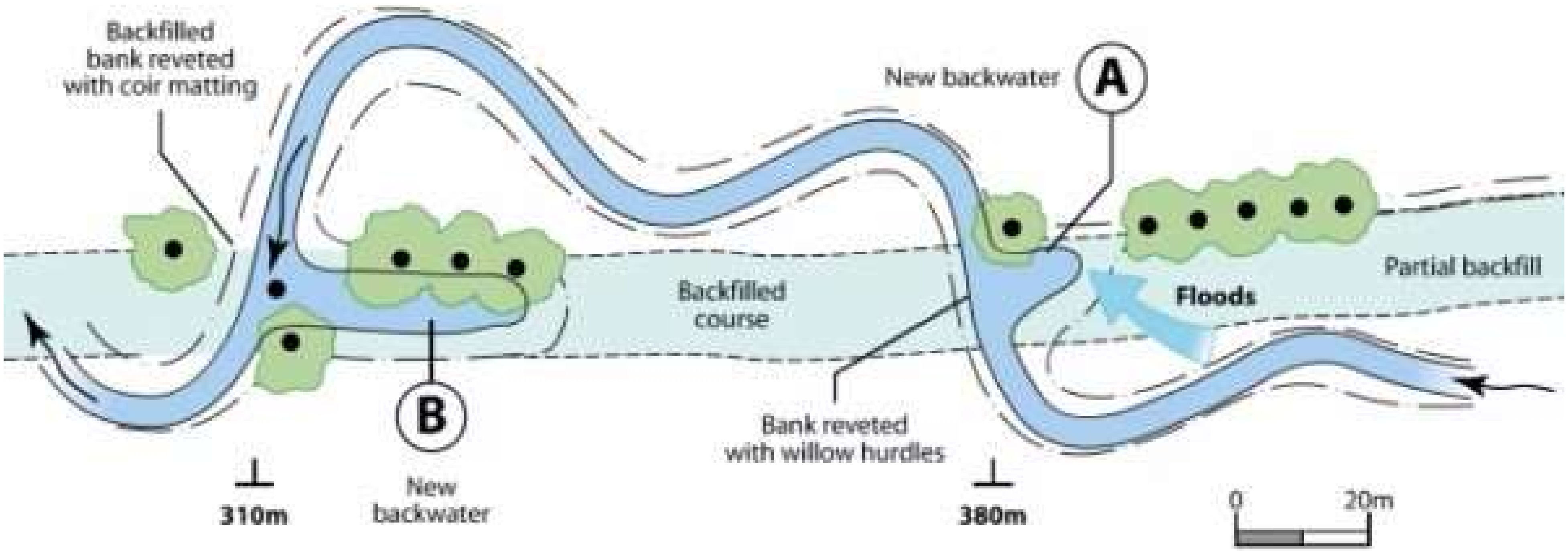
"room for the river"

source: King County, 2023

Hydromorphological NWRMs

River re-meandering

“room for the river”



Source: Manual of River Restoration Techniques

Hydromorphological NWRMs

Embankment removal through:

- ✓ **full removal** to restore the original ground level
- ✓ **breaching** to allow water to flow through
- ✓ **lowing embankments** allowing for part of floodwaters to pass
- ✓ **set-back** of embankments and constructing new ones further away


Source: Meredith Revill

Pre-work assessments are required to avoid increasing flood risks elsewhere with 5-20 year restoration timelines for ecological equilibrium.

Hydromorphological NWRMs

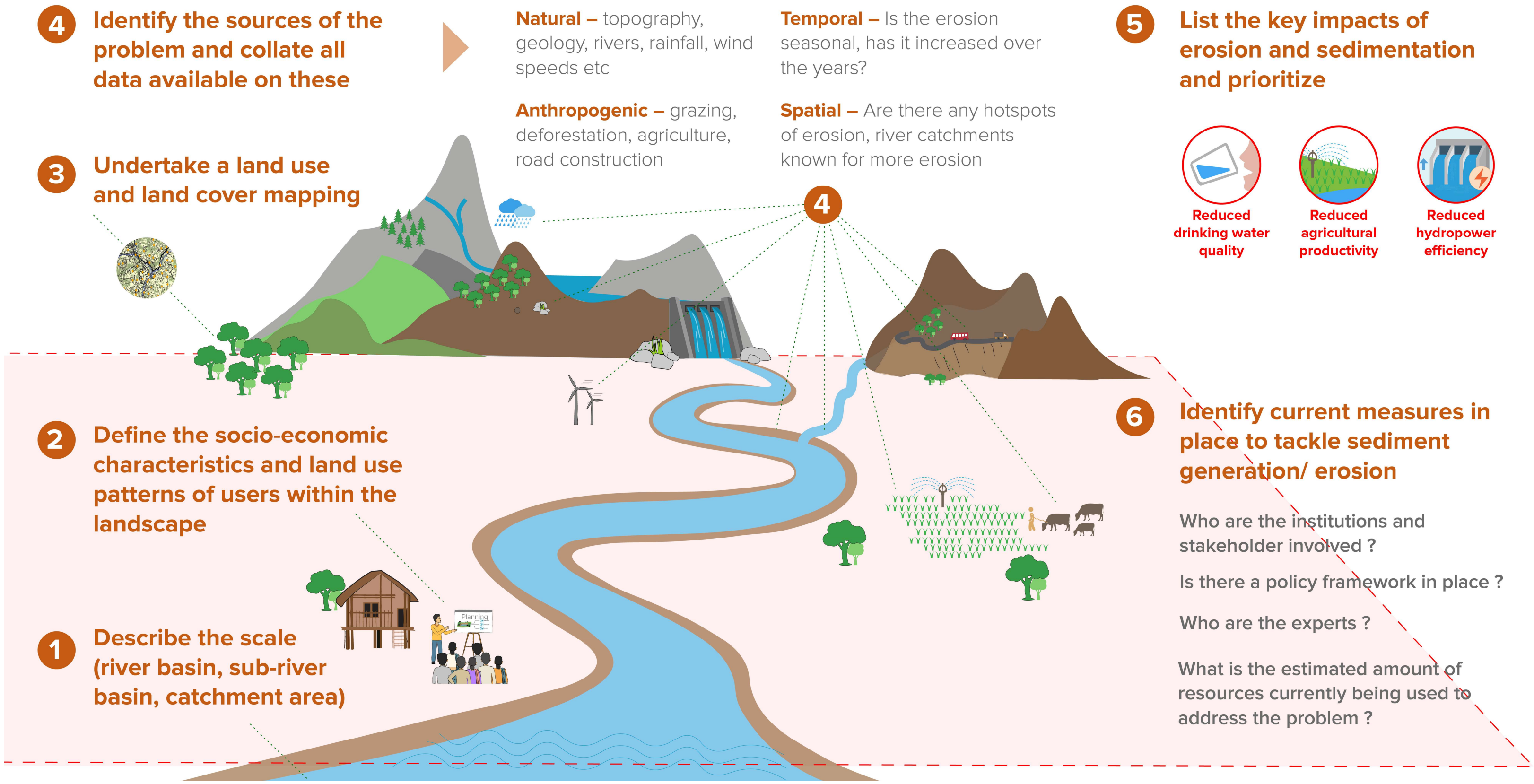
Side-channel reconnection through:

- ✓ **re-opening** historic channels,
- ✓ **breaching or setting** back levees,
- ✓ **installing or upgrading** culverts,
- ✓ **creating** new side channels.

Side channel reconnection is suitable for low slopes, where space is available between river and infrastructure.

Hydromorphological NWRMs

Sediment management



Source: spatialagent.org

Wetland & Aquatic Ecosystem Measures

source: wetlands international, 2021

Wetland & Peatland restoration through:

- ✓ **rehabilitating degraded** natural wetlands
- ✓ **building new wetlands** in strategic areas
- ✓ **rehydrating drained peatlands** by blocking ditches
- ✓ **coastal wetland restoration** that are threatened by sea level rises.

Drained peatlands represent 3 % of the EU's agricultural land, while rewetting them would avoid up to 25 % of the total greenhouse gas emissions in EU agriculture.

LDK CONSULTANTS S.A.

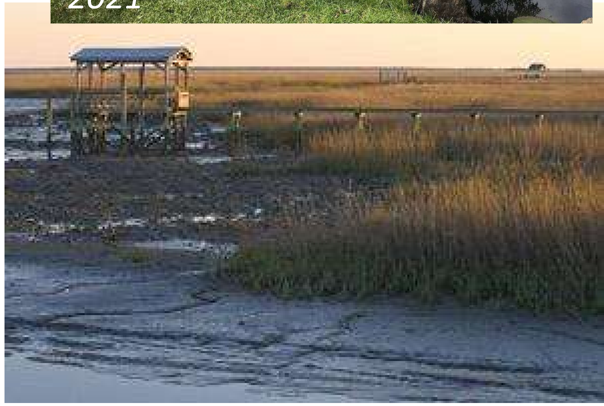
Funded by the European Union

Wetland & Aquatic Ecosystem Measures

Wetland & Peatland restoration are most effective in:

- ✓ **floodplains** where large areas of land are available,
- ✓ **coastal lagoons** and deltas,
- ✓ **upstream reservoir catchments,**
- ✓ **agricultural plains** with significant nutrient runoff,
- ✓ **urban areas** needing stormwater buffering.

source: wetlands international, 2021

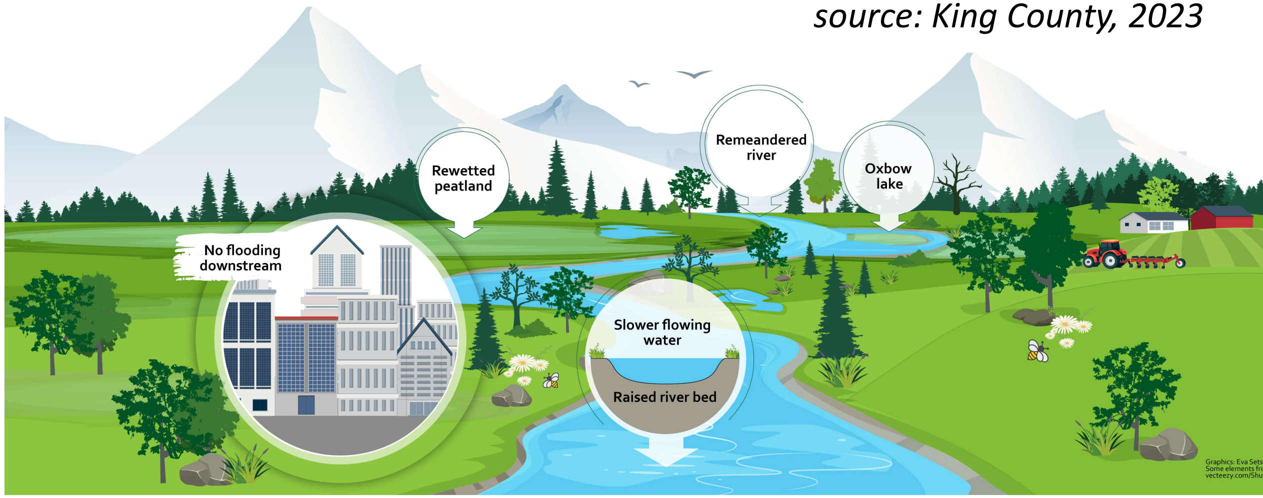


Wetland and aquatic ecosystem measures are not suitable for very steep slopes and highly urbanized areas.

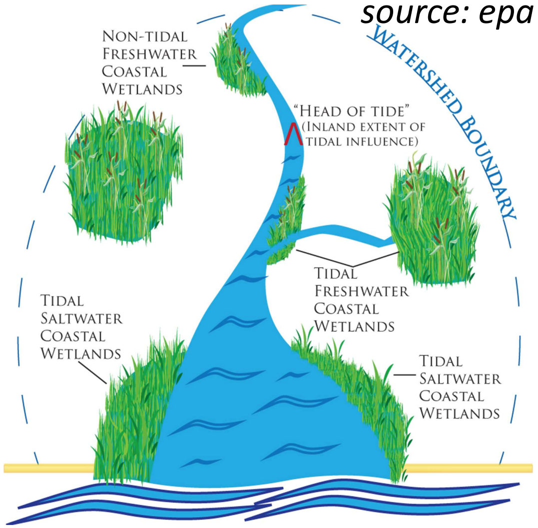
Nature-Based interventions in river eco-systems

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

source: King County, 2023



source: epa



The **main benefits** include:

- ✓ **flood peak reduction,**
- ✓ **water storage and retention,**
- ✓ **flood waves attenuation,**
- ✓ **biodiversity restoration,**
- ✓ **water quality improvement** by reducing nutrient loads,
- ✓ **extend downstream projects' lifecycle** through sediment trapping,
- ✓ **carbon sequestration** enhancement.

Institutional Preconditions

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

NWRM are **multi-benefit measures**, but without strategic alignment, they could remain isolated pilot projects.

Institutions must have the capacity to:

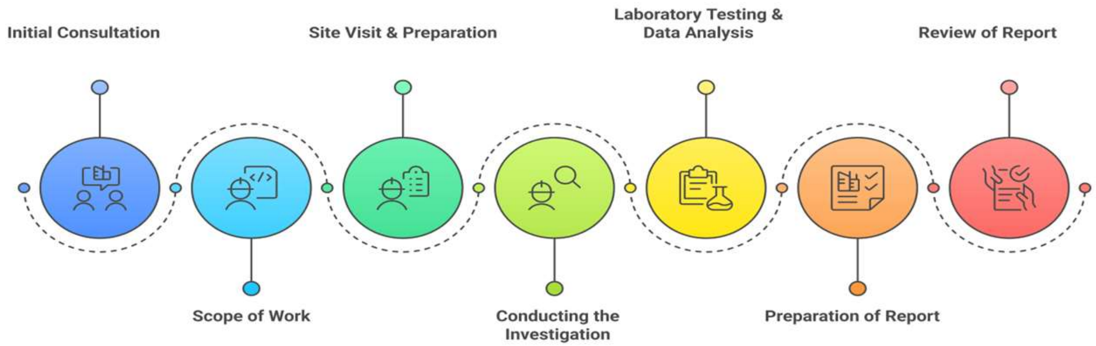
- integrate NWRM **into broader planning** frameworks (e.g. RBMPs, FRMPs)
- translate high-level objectives (flood mitigation, etc) **into operational targets**.
- ensure **coherence with regional** and **municipal constraints** (urban planning, etc),
- promote **acceptance among shareholders** and resolve potential conflicts.

NWRM require **interdisciplinary expertise, adaptive administration** and **institutional coordination** (multi-level- *vertical* and cross-sector - *horizontal*)

Technical Preconditions

NWRM implementation is **site & project specific**, so identification of in-situ conditions investigation is critical, like:

- **geomorphological** conditions (terrain, storage potential, floodplain width, etc),
- **geological/ geotechnical** characteristics (soil permeability, erosion risk, etc),
- **hydrological** conditions (flow regime, water availability, groundwater levels),
- **land use & availability** (stakeholder acceptance, compatibility of practices, etc),
- **ecological conditions** (biodiversity, vegetation, water quality, etc),
- **socio-economic conditions** (funding availability, community familiarity)



Data requirements

WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

Geospatial & Morphological Data

Hydrological and Hydraulic Data

Environmental & Ecosystem Data

Climate & Risk Data

Socio-Economic & Land-Use Data

Cost estimation

Project Cost = *Capital Expenditure (CAPEX)* + *Operational Expenditure (OPEX)* + *Indirect Costs*

Preliminary Cost Estimation

↓

Detailed Cost Estimation

↓

Life-Cycle Cost Assessment

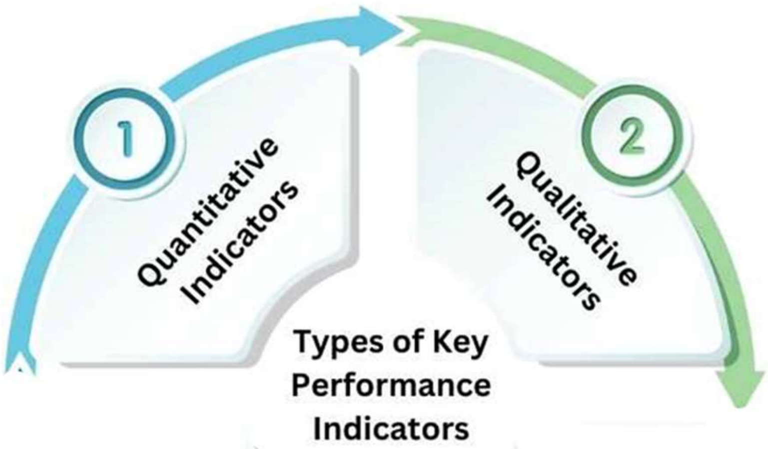
NWRMs cost estimation is inherently site-specific. Thus, comparison btw alternatives is done in terms of unit cost per m³ of runoff reduction or unit cost per area (hectare) of restored area is often used.

Performance Indicators

NWRM performance is **site-specific** and often the direct assessment of multiple benefits is difficult.

The use of **qualitative and quantitative indicators** (core and optional) is essential.

- **hydrological indicators** (runoff, groundwater recharge, erosion control, climate resilience)
- **climate-resilience Indicators** (recharge, low-flow & erosion sensitivity, extreme event sediment yield)
- **land use indicators** (land availability, practices compatibility)
- **ecological indicators** (biodiversity enhancement, area restored, water quality improvement),
- **socio-economic indicators** (local employment, avoided damages, insurance reduction).



Performance Indicators

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

A useful tool to judge NWRM performance is **Cost-Benefit Ratio**

(~*ratio of construction and operational costs with benefits from water retained*)

Costs		Benefits
Construction cost (material, personnel, machinery)	vs	**Flood risk reduction** (Insurance reduction costs, damages avoided, etc)
Design & Permitting costs (engineering fees, etc)		**Erosion Control** (projects increased lifespan through reduced sedimentation)
Land Acquisition Cost		**Carbon Sequestration valuation**
Maintenance Costs (instruments, personnel, repairs, etc)		**Ecological Gains valuation** (biodiversity, tourism, etc)

Performance Indicators

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

In the case of NWRMs it is critical for **all these benefits** to be accounted for.

Typical range based on EU studies:

- **CBR > 1** for most NWRMs when co-benefits are included.
- **CBR between 2 and 5** for measures with strong flood-mitigation effects (e.g., floodplain restoration).
- **CBR < 1** only when:
  - land acquisition costs are very high,
  - benefits are narrowly defined (e.g. only water retention),
  - or maintenance is not secured.

WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

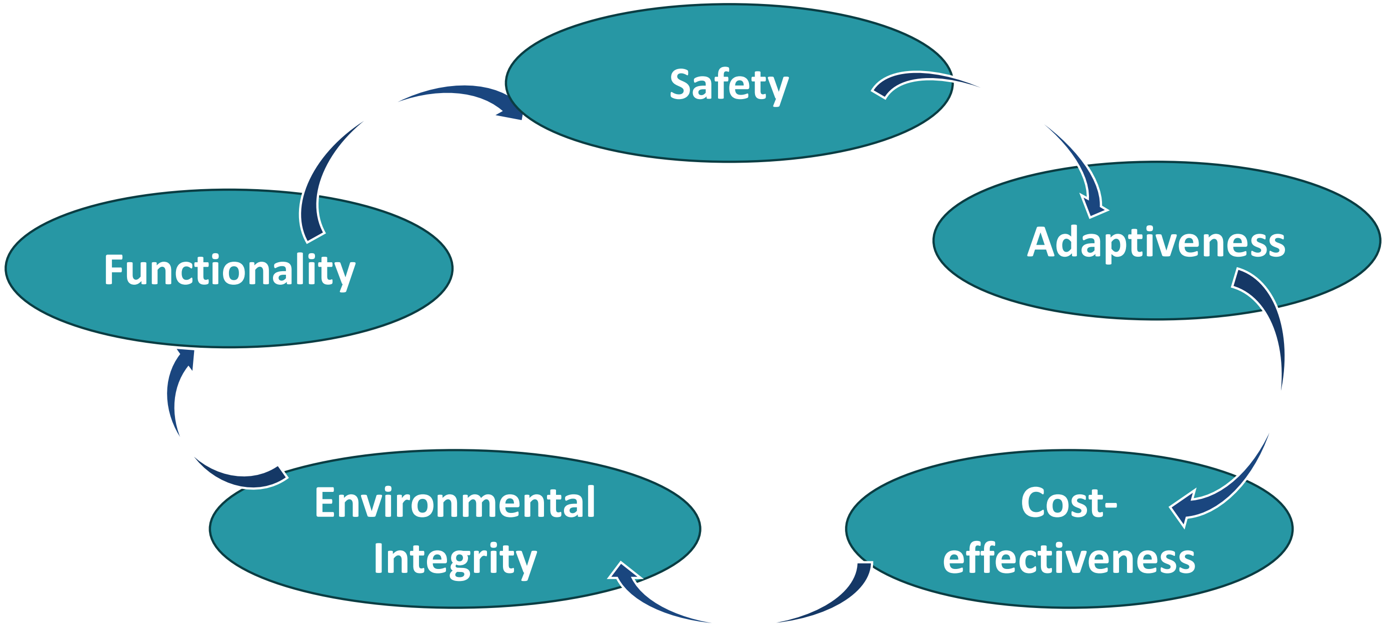
Performance Indicators

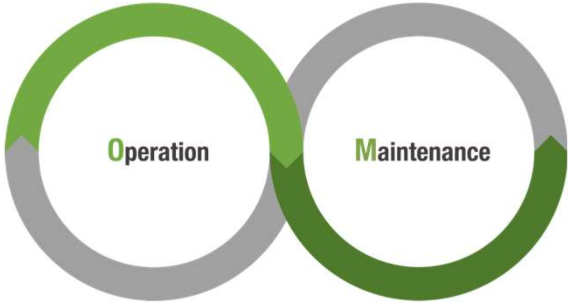
NWRM Category	CBR Range	Why This Range?	Key Drivers
Urban NWRMs	0.8 – 2.0	Benefits often localized, High maintenance costs	Urban land prices, avoided stormwater costs, heat-island reduction, maintenance intensity.
Agricultural NWRMs	1.5 – 4.0	Low implementation water quality, productivity benefits.	Soil fertility gains, erosion reduction, CAP incentives, low capital cost.
Hydromorphological & Wetland NWRMs	2.0 – 5.0+	Highest avoided-damage benefits in flood-prone basins; strong biodiversity and groundwater recharge co-benefits.	Flood-risk reduction, land acquisition cost, ecosystem service valuation.
Forest NWRMs	1.2 – 3.5	Moderate costs; strong performance in erosion-prone basins.	Carbon sequestration valuation, erosion control, wildfire risk reduction.

CONSULTANTS

Operation and maintenance (O&M)

Operational and maintenance (O&M) ensures that NWRMs remain functional, safe and effective throughout their life cycle.





A baseline monitoring plan should be developed in the beginning of NWRM's operation. The use of hydrological, ecological, socio-economic etc performance indicators is essential.

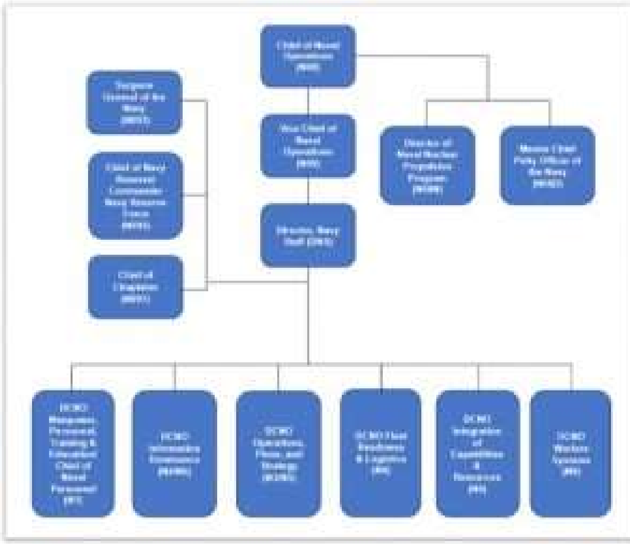
Operation

NWRMs require Operational Frameworks, with clear definition of tasks and responsibilities among personnel (organograms).

Operation

Management

Inspections



A baseline monitoring plan should be developed in the beginning of NWRM's operation.

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

LDK CONSULTANTS

Maintenance

Maintenance is integral to a NWRM's performance, as they tend to degrade faster than conventional measures.

Maintenance protocols

- **Regular**
- **Periodic**
- **Urgent/ post-event**

A baseline monitoring plan should be developed in the beginning of NWRM's operation.

Maintenance

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

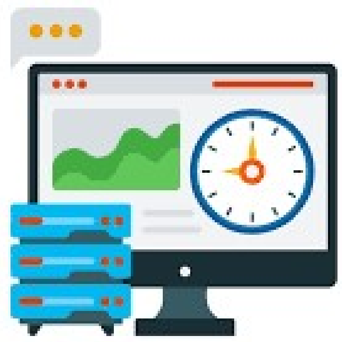
NWRM Category	Regular Maintenance (monthly–seasonal)	Periodic Maintenance (annual–multi-annual)	Post-Event Maintenance (after heavy rainfall, floods, storms)
Hydromorphological	Remove debris/ sediment Inspect bank stability Vegetation trimming Monitor flow paths	Repack stones / repair check dams Re-anchor bioengineering materials Sediment redistribution Bank reinforcement	Remove storm-deposited sediment Repair erosion and bank failures Restore damaged check dams or log barriers Clear large obstructing debris
Wetlands	Remove litter and floating debris Inspect water levels Monitor vegetation Control mosquito breeding	Sediment removal (3–5 years) Dredging of forebays Bank stabilization and reshaping	Inspect embankments Remove flood-deposited debris Repair erosion around inlets/outlets

Monitoring

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

Maintenance ⇔ Monitoring

Monitoring:
- Visual Inspection
- Equipment
  - Recorded
  - Collected
  - Statistical Analysis



Real Time Data

Baseline indicators should be set in beginning of operation.
Clear Monitoring Protocol required!

LDK CONSULTANTS
LDK CONSULTANTS S.A.

Funded by the European Union

Mediterranean: Implementation Challenges

Mediterranean Challenges	Impact on NWRMs
Flash floods, drought–flood cycles, sediment loads	Overloading of NWRMs, high maintenance
Fragmented governance, rigid public works law	Slow permitting
Hard-to-quantify co-benefits, short funding cycles	Underinvestment, preference for grey
Sparse data, limited modelling tools	Uncertainty in design/performance
Land-use conflicts, perception issues	Low acceptance, limited space

Summary River NWRMs Benefits & Limitations

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

Criteria	Benefits	Limitations
Hydrology	Increased retention, peak-flow attenuation, groundwater recharge, drought resilience	Slow response time, performance sensitive to catchment modification
Geomorphology	Sediment deposition, bank stabilization, floodplain reconnection	Sediment removal required
Ecology	Habitat creation, biodiversity gains, nutrient retention, carbon sequestration	Risk of eutrophication, long maturation time
Cost	Low OPEX, multi-sector co-benefits	High initial CAPEX, diffuse long-term benefits
Technical Feasibility	Adaptable multifunctional landscapes	Land acquisition, competing uses, stakeholder resistance
Governance	Aligns with EU NWRM	Lengthy permitting, long-term monitoring

CONSULTANTS

Nature-Based interventions in river eco-systems

WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

EXAMPLES

LDK CONSULTANTS
LDK CONSULTANTS S.A.

Funded by the European Union

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

Natural Water Retention Measures in the Mediterranean Flagship Case Studies from Greece, Morocco, Jordan and Cyprus)

- Lake Karla: large hybrid wetland restoration
- Morocco: distributed check dam networks
- Jordan: infiltration and recharge basins
- Cyprus: programme-level mix of NWRMs
- Lake Kerkini: reservoir transformed into ecological asset

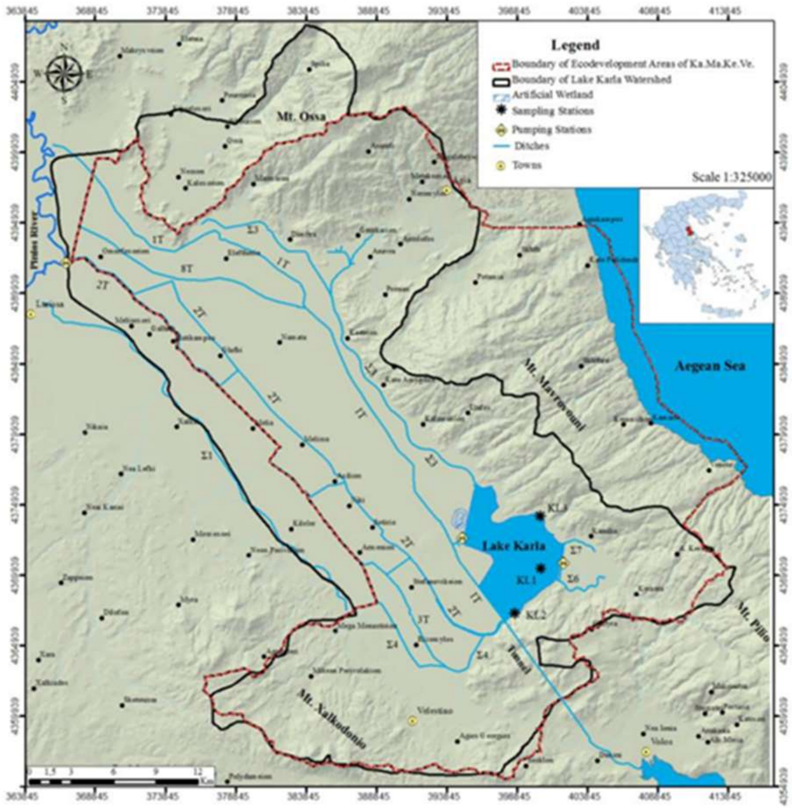
Greece	Morocco	Jordan	Cyprus

Core message: Mediterranean water management works best when natural processes are restored and conventional infrastructure is used only where necessary.

The Lake Karla Rehabilitation Project (Greece)

WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

- Originally a 180 km² lake in the Thessaly plain.
- Completely drained in 1962 to create agricultural land.
- Drainage removed a wetland ecosystem and fishing culture, but the reclaimed land became saline and unproductive.
- The region then faced water scarcity, aquifer over-extraction, and ecological degradation.



- Recreate about 50 km² of the former lake
- One of Europe's largest wetland restoration efforts

The Lake Karla Rehabilitation Project (Greece)

Main project components

- A new reservoir to re-establish a permanent lake.
- Diversion of Pinios River flows.
- Wetlands, reedbeds, and shallow biodiversity zones.
- Water supply and monitoring infrastructure.

Major benefits

- Flood protection for lowland areas and the city of Volos
- Groundwater recharge through reduced abstraction and lake-based irrigation
- Ecosystem restoration and landscape improvement
- Better water and soil quality
- New economic opportunities such as fisheries and ecotourism

Key message: A hybrid NWRM combining green restoration with grey infrastructure

Check dam systems, Morocco

Why check dams matter in Morocco

- Steep slopes, erodible soils and intense rainfall increase flash flood risk
- Rural areas also face chronic water shortages and groundwater stress
- Morocco's strategy includes many small retention structures and hillside dams

What check dams do

- Slow down flood flows
- Trap sediment and reduce downstream siltation
- Enhance infiltration and groundwater recharge
- Protect villages and agricultural terraces
- Store water locally in small upstream pools

Series Of Check Dams (Source: Hassanli & Beecham, 2013)

Gambion Check Dam (Source: Shrestha Et Al., 2012).

Cyprus: a national NWRM programme

Why Cyprus stands out

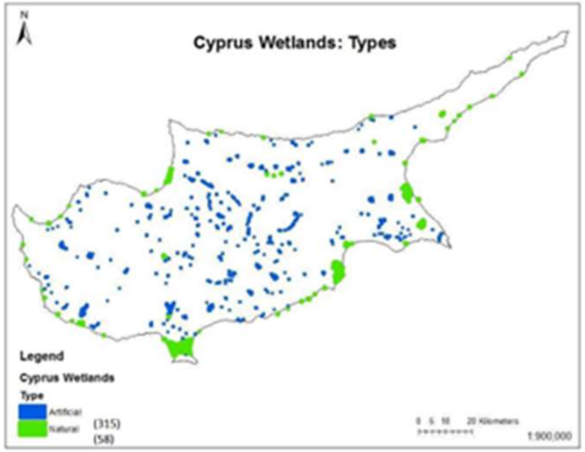
- One of the best documented NWRM programmes in the Mediterranean
- Measures explicitly included in River Basin Management Plans

Examples of measures

- Terracing in mountainous agricultural areas
- Retention reservoirs on temporary rivers
- Detention trenches in alluvial riverbeds
- Wetland and lake restoration
- Check dams and gabion weirs
- Sustainable Urban Drainage Systems in cities
- Afforestation on artificial terraces

PITSILIA TERRACING (SOURCE:POLYGNOSI)

LAKE MAGLI RETENTION RESERVOIR



MAP OF WETLANDS (SOURCE: “INVENTORY OF CYPRUS WETLANDS”)

OROUNDA CHECK DAM (SOURCE: DJUMA ET AL., 2017)

Lake Kerkini, Greece

An engineered reservoir that became a major wetland

- Created in 1932 through embankments and dam construction on the Strymon River
- Redeveloped in 1980–1982 due to sedimentation and reduced storage capacity
- Today functions as a regulated reservoir and an internationally important wetland

Current value

- Flood protection and irrigation support
- Habitat for 227 bird species and diverse ecosystems
- Ecotourism and local economic development
- Example of adaptive management of ageing grey infrastructure

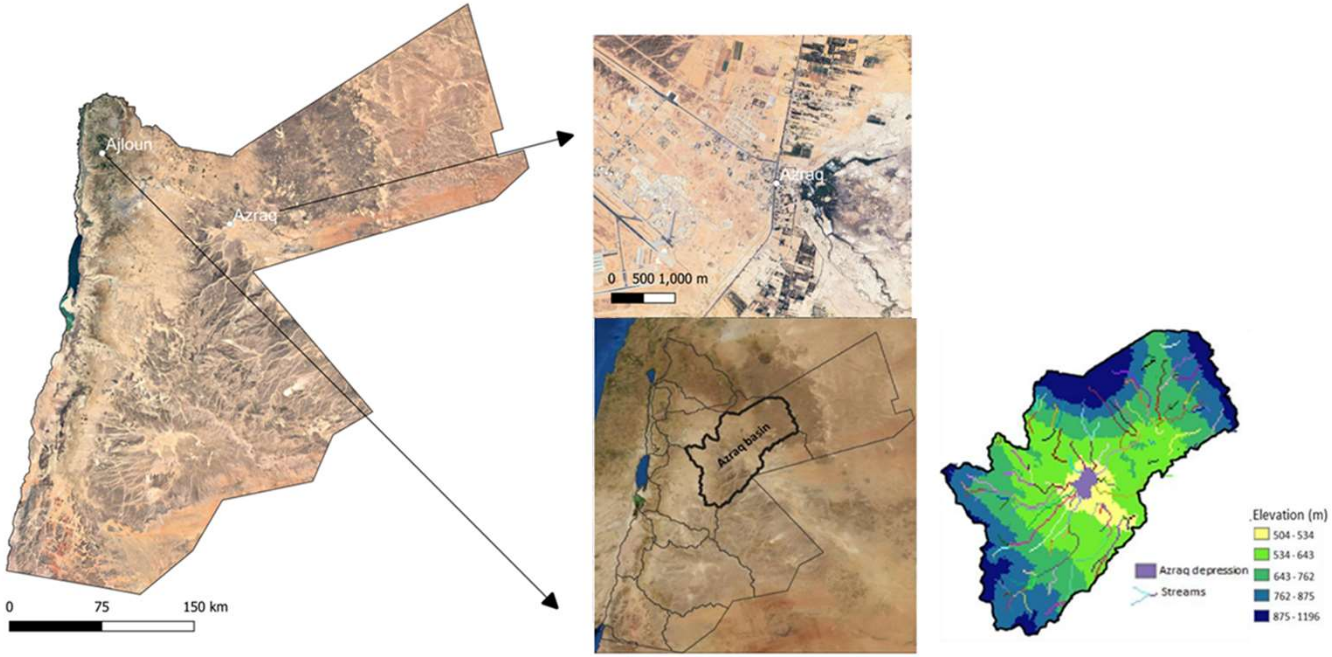
LAKE KERKINI ECOSYSTEM (SOURCE: © GEO PICTORIAL / GEORGE S BLONSKY).

Runoff retention and infiltration in Azraq, Jordan

WES-BCA
Water and Environment Support - Biodiversity and Climate Action in the Neighbourhood South region

Supporting a drying oasis

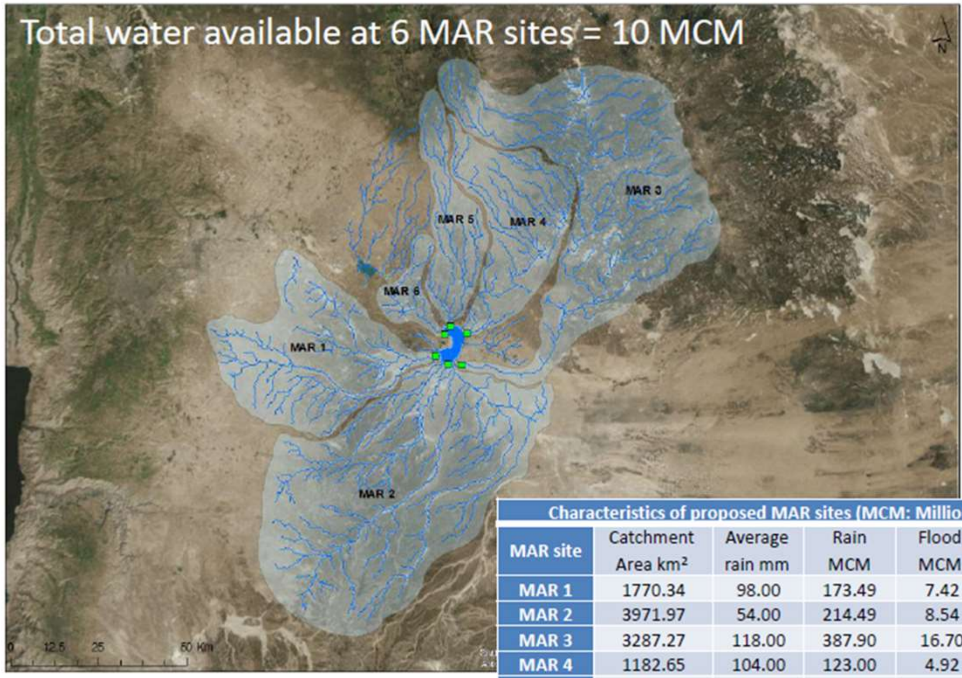
- Azraq is the pilot area of the **WES activity** on stormwater management and Natural Water Retention Measures.
- The basin contains a **vital aquifer** and serves part of Jordan's water supply, including water for **Amman, Zarqa and refugee camps**.
- At the same time, Azraq is associated with a **drying wetland/oasis**, making it one of Jordan's most sensitive water-stress areas drawing widespread international concern.



Runoff retention and infiltration in Azraq, Jordan

WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

INWRDAM
Water diplomacy



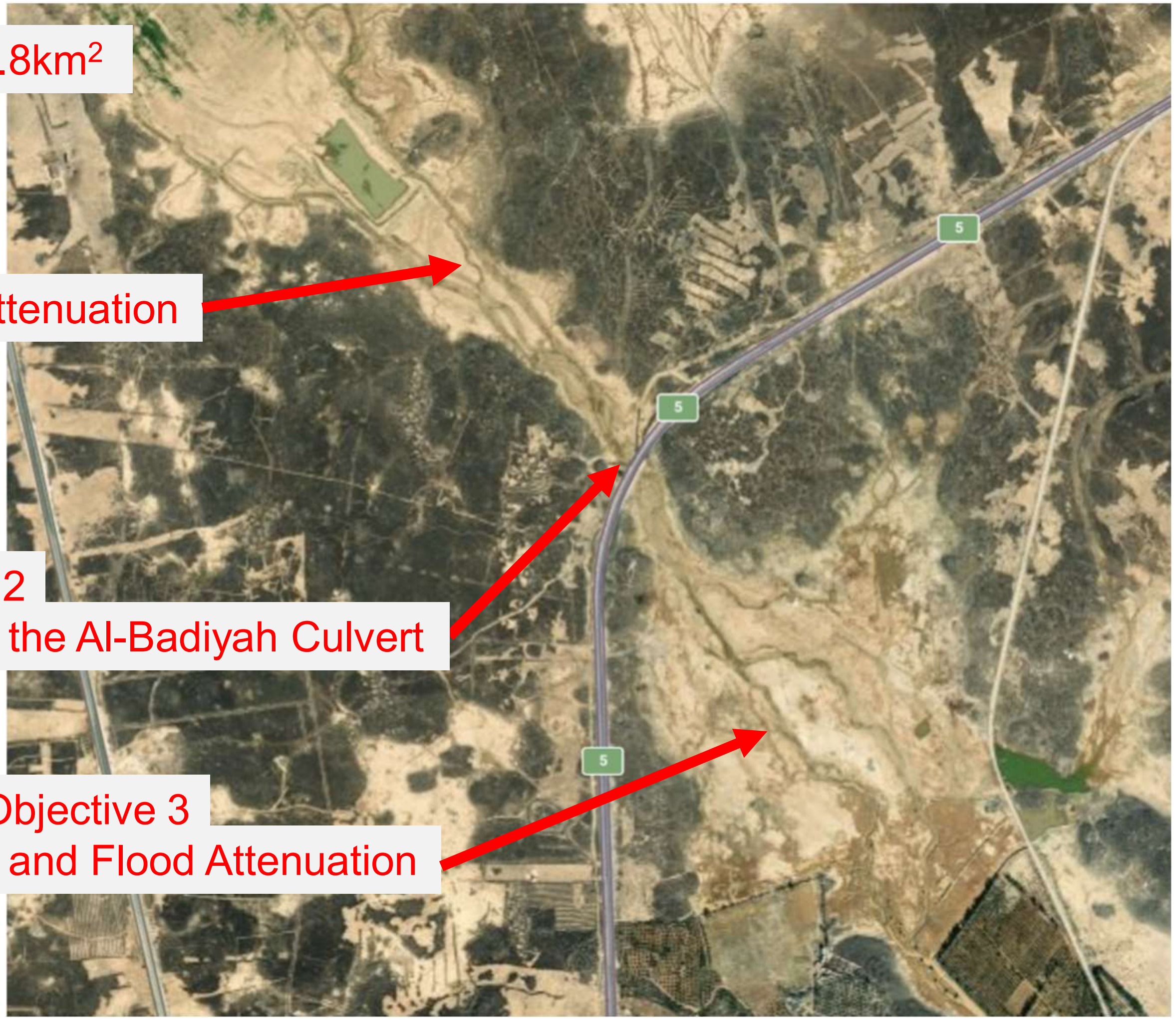
Characteristics of proposed MAR sites (MCM: Million Cubic Meters)

MAR site	Catchment Area km²	Average rain mm	Rain MCM	Flood MCM	Flood reachi MAR site MC
MAR 1	1770.34	98.00	173.49	7.42	3.37
MAR 2	3971.97	54.00	214.49	8.54	1.10
MAR 3	3287.27	118.00	387.90	16.70	3.50
MAR 4	1182.65	104.00	123.00	4.92	1.62
MAR 5	681.58	118.00	80.43	3.22	2.54

A new water harvesting structure has been built in MAR 5 that can harvest up to 65000 cubic meters of water

Runoff retention and infiltration in Azraq, Jordan

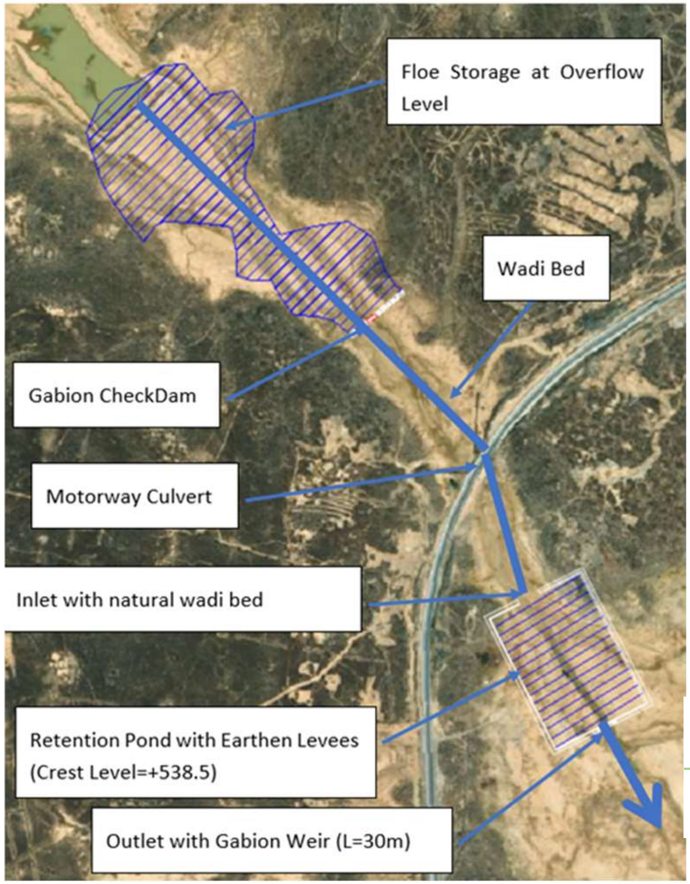
WES-BCA
Water and Environment Support - Biodiversity and Climate Action
in the Neighbourhood South region

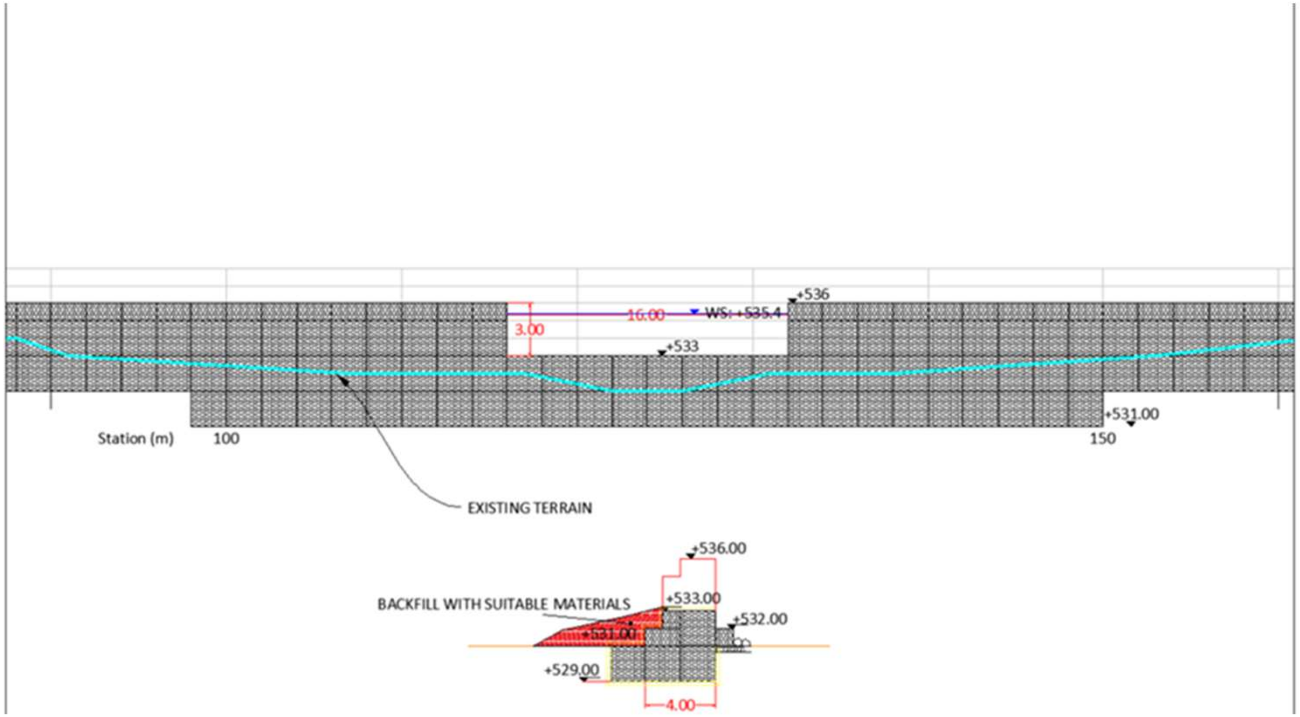


LDK CONSULTANTS
LDK CONSULTANTS S.A.

Funded by the European Union

Runoff retention and infiltration in Azraq, Jordan





NWRM	*Spillway elevation (m)*	Spillway length (m)	Peak Water Level Elevation (m)	Freeboard (m)	Total Volume (1000m^3)
Dam	+533	16	535.4	0.6	200
Pond	+536	30	537.5	1.0	125.75

LDK CONSULTANTS S.A.

Funded by the European Union

LDK CONSULTANTS
LDK CONSULTANTS S.A.

Funded by
the European Union