

Centre for Ganga River Basin Management and Studies (cGanga)

Organized by



भूमि संसाधन विभाग
DEPARTMENT OF **LAND RESOURCES**
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National Workshop on Pilot Projects on River Rejuvenation by Watershed Development Approach (RRWDA)

Application of Hydrological Technologies for River/Stream Rejuvenation Restoring hydrological processes, not merely cleaning or beautifying channels



cGanga

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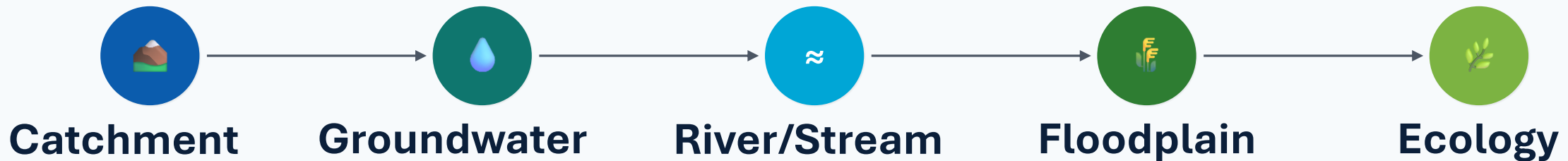
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Central premise

River/stream rejuvenation begins with hydrology, not cosmetics.

River rejuvenation is not about putting water into a channel.

It is about restoring the hydrological processes and catchment–groundwater–river–floodplain connections that enable the river or stream to function according to its natural character.



Pre-requisites for Selecting Watersheds / Small Rivers

Natural-flow restoration through baseflow enhancement and retardation of catchment runoff

**The first decision is not “what structure should be built?”
It is “what hydrological regime should this river naturally have?”**

**Natural
identity**

**Water
availability**

**Aquifer–river
connection**

**Retention
opportunity**

**Abstraction
pressure**

**Ecological
significance**



**DIAGNOSE
BEFORE INTERVENING**

Target: recover the natural flow regime and extend flow duration where hydrogeologically feasible — not indiscriminate perennialisation.

1. Establish the Natural Hydrological Identity

Perennial, seasonal/intermittent and ephemeral are different natural river types — not grades of degradation.

Perennial

Natural flow persists through the year, typically sustained by glacier/snowmelt, groundwater discharge or dependable upstream storage

Seasonal / Intermittent

Flow is naturally concentrated in wet periods; dry-season continuity depends on catchment storage and groundwater interaction

Ephemeral

Flow is event-driven and may occur only following rainfall. Dry channels can be part of the natural regime

Selection rule

Use historical hydrographs, old maps/images, local knowledge, channel/floodplain indicators and groundwater evidence to distinguish natural seasonality from anthropogenic loss of flow.

Do not set “perennial river” as the project objective until historical and hydrogeological evidence shows that perennial or longer-duration flow is a realistic reference condition

2. Reconstruct Historical vs Present Flow Regime

Restoration needs a reference: what changed, when, where and why?

Historical regime

- Flow duration
- Seasonal timing
- Dry-season pools
- Springs/baseflow

Present regime

- Hydrograph
- Zero-flow days
- Sewage/effluent contribution
- Regulated releases

Drivers of change

- Abstraction
- Land-use
- Drainage
- Channelisation
- Barriers
- Groundwater decline

Restoration target

Natural character +
feasible recovery of
flow duration and
variability

Key diagnostic: distinguish natural flow from “apparent perenniality” sustained by wastewater or imported water.

A continuously wet channel is not, by itself, evidence of a restored perennial river.

3. Establish the Catchment Water Balance

Baseflow enhancement cannot create water; it can only change where and when available water is stored and released.



Screening question: Is there a wet-season surplus that can realistically be retained and released later without simply increasing abstraction?

4. Hydrogeological Feasibility for Baseflow Enhancement

Recharge enhancement helps streamflow only if the aquifer stores water and is hydraulically connected to the river.

Aquifer storage

Is there adequate saturated thickness and storage?

Rechargeability

Are soils/geology suitable for infiltration?

Hydraulic gradient

Will groundwater move toward the stream?

Travel time

Will recharge emerge during the desired dry period?

River condition

Is the reach gaining, losing or seasonally switching?

Water quality

Is recharge compatible with aquifer and river quality?

Baseflow potential =
Recharge opportunity × Aquifer storage × Hydraulic connectivity × Time lag

5. Diagnose Gaining, Losing and Switching Reaches

The same intervention can have very different outcomes depending on river–aquifer exchange.

GAINING REACH

Groundwater head > river stage

Groundwater discharges to channel

Recharge in connected aquifer may support dry-season baseflow.

LOSING REACH

River stage > groundwater head

Water infiltrates from channel to aquifer

Additional catchment recharge may first replenish groundwater rather than create river flow.

SEASONALLY SWITCHING

Direction changes with monsoon, pumping and river stage

Requires seasonal monitoring and dynamic interpretation.

Minimum evidence:

paired river stage + piezometric levels + seasonal transects + discharge measurements + hydrochemistry/isotopes where needed.

6. Map Runoff-Retardation and Distributed Storage Opportunities

Prefer a catchment network of appropriate interventions over indiscriminate construction of recharge structures.

Upper slopes



Soil-water conservation • contour measures • vegetation

First-order drainage



Small retention • infiltration where suitable • erosion control

Ponds / tanks



Restore storage • desilt selectively • reconnect catchment

Wetlands



Temporary storage • attenuation • ecological functions

Palaeochannels



Reconnect where hydrologically justified • recharge/storage

Floodplain

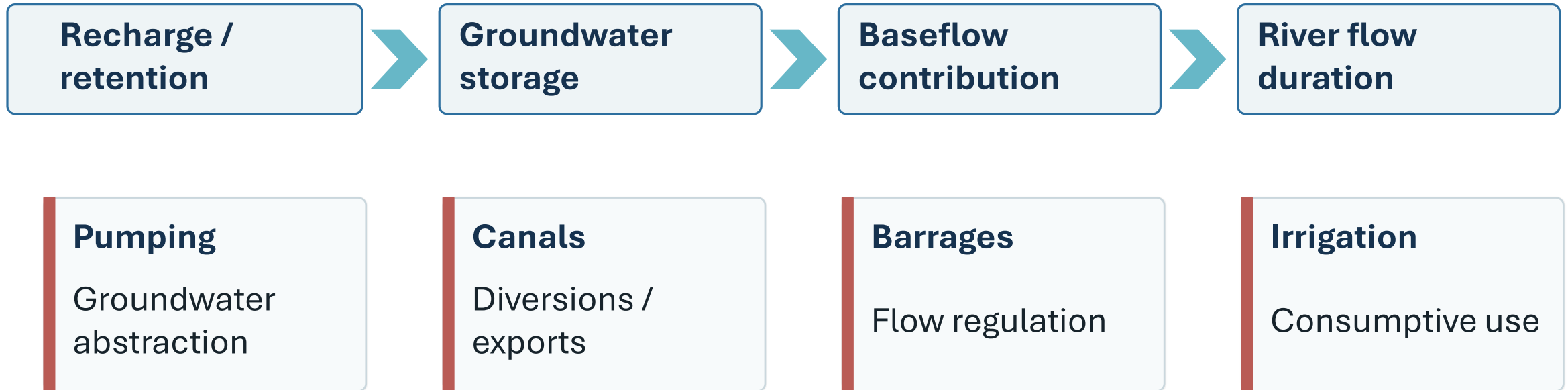


Lateral storage • recharge • peak attenuation

Selection must be controlled by slope, soil, geology, aquifer, drainage density, land use and downstream connectivity.

7. Account for Abstraction and Flow Regulation

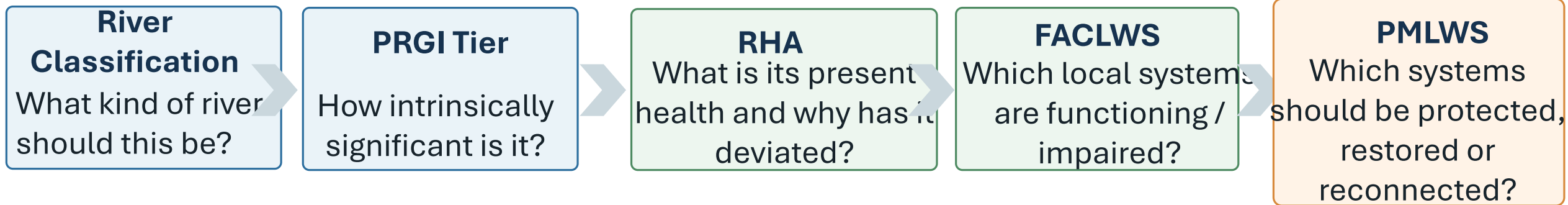
Recharge gains can disappear if withdrawals and diversions are not managed simultaneously.



**Project appraisal should include an abstraction-management scenario:
“What fraction of additional recharge will actually remain available to
support streamflow?”**

8. Integrate River Classification, PRGI, RHA and Local Water Systems

Selection should combine natural identity, ecological significance, present condition and restoration leverage.



Hydrological restoration potential

Water availability + hydrogeological connectivity + retention opportunity + manageable abstraction

Ecological / management priority

PRGI significance + RHA hydrological deviation + local-system leverage + feasibility of functional recovery

Select projects where hydrological feasibility and ecological value converge

9. Candidate Watershed / River Screening Categories

Use restoration objectives that match natural character and hydrogeological feasibility.

CATEGORY A High Potential

Historical evidence of perennial/longer flow

Adequate wet-season surplus

Rechargeable connected aquifer

Manageable abstraction

Objective: BASEFLOW
RECOVERY / LONGER FLOW
DURATION

CATEGORY B Seasonal Extension

Naturally seasonal/intermittent

Substantial monsoon runoff

Distributed storage/recharge opportunities

Objective: RETARD RUNOFF +
EXTEND SEASONAL FLOW

CATEGORY C Do Not Perennialise

Naturally ephemeral OR poor aquifer storage/connectivity

High losses / deep groundwater / excessive abstraction

Objective: RESTORE NATURAL
EPISODIC FUNCTION + SOIL
MOISTURE + ECOLOGICAL
CONNECTIVITY

Tier II / III status does not itself determine hydrological feasibility; it informs ecological significance and the care required in selecting interventions.

10. Minimum Baseline Before Sanctioning Interventions

A rejuvenation project should begin with a measurable hydrological baseline.

Flow

Stage/discharge • zero-flow days • flow-duration curve

Groundwater

Seasonal water levels • gradients • pumping

Rainfall

Event and seasonal rainfall • spatial variability

Catchment

DEM • LULC • soils • geology • drainage

Connectivity

Ponds • wetlands • palaeochannels • floodplain • drains

Quality

Surface water + groundwater + wastewater contribution

Ecology

Habitat • riparian condition • aquatic indicators

Use

Abstraction • irrigation • domestic/industrial demand

No baseline → no defensible attribution of post-project change.

11. Go / No-Go Decision Gate for Natural-Flow Restoration

A simple appraisal sequence for DoLR-supported watershed / small-river projects.

- | | |
|--|---|
| 1 Natural identity established? | 5 Retention/recharge opportunity suitable? |
| 2 Historical loss of flow demonstrated? | 6 Abstraction can be managed? |
| 3 Seasonal water surplus available? | 7 Water quality compatible? |
| 4 Aquifer–river connectivity favourable? | 8 Ecological benefit and monitoring plan clear? |

GO → Design function-based interventions

NO-GO / REFRAME → Restore natural seasonal function

12. Intervention Hierarchy — Hydrology Before Structures

The intervention should follow diagnosis; the structure should not define the project.

Protect



Intact recharge zones, wetlands, floodplain and natural drainage

Reduce losses / pressures



Manage abstraction, encroachment, rapid drainage and disconnection

Retard runoff



Soil-water conservation, landscape roughness, distributed retention

Enhance infiltration



Only where soil/geology/aquifer and water quality are suitable

Reconnect



Ponds, wetlands, palaeochannels, tributaries and floodplain

Optimise engineered systems



Stormwater detention, constructed wetlands, regulated releases

Monitor & adapt



Verify flow duration, groundwater response, connectivity and ecology

Rejuvenation should restore processes — not impose a predetermined physical form.

13. Performance Indicators: Did the River Actually Recover?

Success must be measured by hydrological and ecological response, not by counts of structures or expenditure.

Flow regime

- Flow duration
- Zero-flow days
- Dry-season discharge
- Variability

Groundwater

- Water-level recovery
- Recharge response
- Gradient to river

Catchment

- Runoff coefficient
- Lag time
- Soil moisture retained
- Storage

Connectivity

- Wetland/floodplains in reconnection
- Tributary continuity

Flood response

- Peak attenuation
- Inundation/storage behaviour

Water quality

- Pollutant
- Dilution is not treatment
- Ecological polishing

Ecology

- Habitat persistence
- Riparian/aquatic response

Sustainability

- O&M
- Abstraction compliance
- Community stewardship

Baseline → Intervention → Monitoring → Reassessment → Adaptive Management

14. Hindon Lesson: Annual Surplus Does Not Guarantee Dry-Season River Flow

The basin example demonstrates why project selection must be seasonal, hydrogeological and connectivity-based.

ANNUAL SCALE

Hindon basin analysis indicates a small annual surplus.

NON-MONSOON SCALE

The same analysis shows a substantial non-monsoon deficit.

HYDROGEOLOGY

Field transects reported influent/losing conditions in the Hindon and major tributaries.

Therefore: “retain more monsoon water” is only the beginning of the diagnosis. The decisive question is whether retained/recharged water can emerge as delayed streamflow after accounting for aquifer behaviour and abstraction.

Hindon is a useful demonstration of why seasonal water balance + river–aquifer interaction + source-of-flow diagnosis must precede rejuvenation design.

Hindon: a case for diagnosing hydrological identity before “rejuvenation”

The basin illustrates why visible water in a channel is not sufficient evidence of natural perenniality

Natural identity

Rain-fed / monsoon-dominated
Alluvial setting
Strong seasonal contrast

Present appearance

Continuous dry-season water can include
domestic and industrial discharges
Apparent perenniality $\neq$ natural perenniality

Rejuvenation question

What flow regime would exist without wastewater, canal transfers, abstractions
and regulation?

Restore the process regime — not a preconceived water level

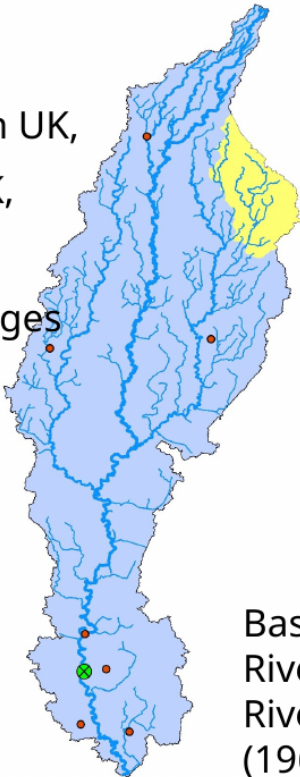
Hindon: a case for diagnosing hydrological identity before “rejuvenation”

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Hindon drainage network map

- 02 States
- 07 Districts in UP and 01 district in UK,
- 20 Tehsil in UP and 01 Tehsil in UK,
- 41 Blocks, 07 Class I Cities
- 1494 Gram Panchayats, 1829 Villages

River Length	No. Of Rivers
<1 km	57
1 to 5 km	87
5-10 km	42
10-15 km	15
>15 km	30
Total	231



- **CWC old sites:**
Galeta, Meerut (Hindon [GDSQ])
- **CWC new sites:**
Titawi, Muzzafarnagar (Hindon [GD]);
Baleni, Baghpat (Hindon [GD]);
Greater Noida, GB Nagar (Hindon [GDWQ]);
Barnawa, Baghpat (Krishni [G]);
Ratanpuri, Muzzafarnagar (Kali [GD])
- UGC at Daluhera
- Hindon Barrage at Mohanagar

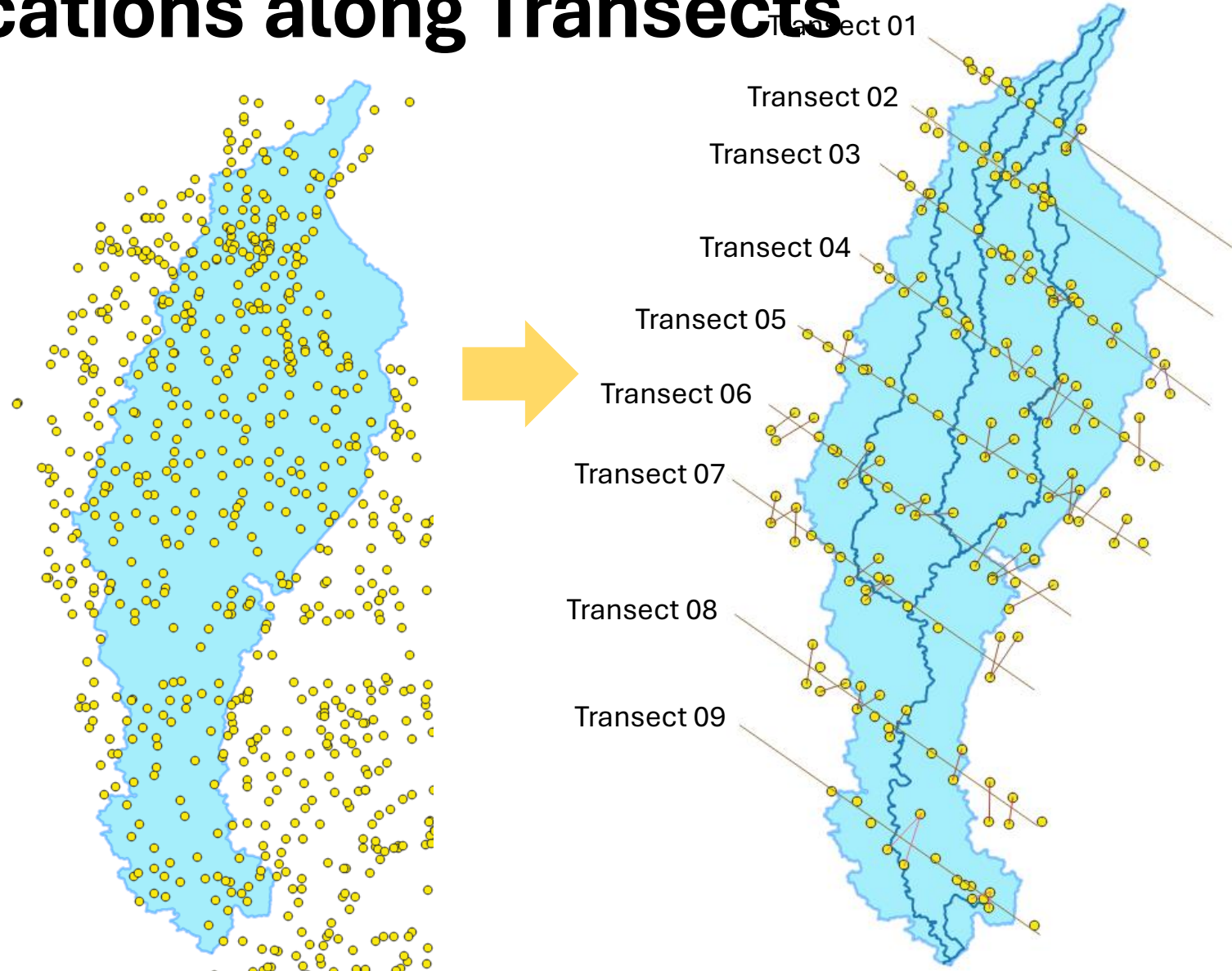
Basin area: 6950.04 km²,
Rivers: 231 (130 named, 101 unnamed),
River Network: 2150 km
(1960 km named, 190 km unnamed)
Barrage: 01, Canal network: 2664.61 km

Hindon
basin
context

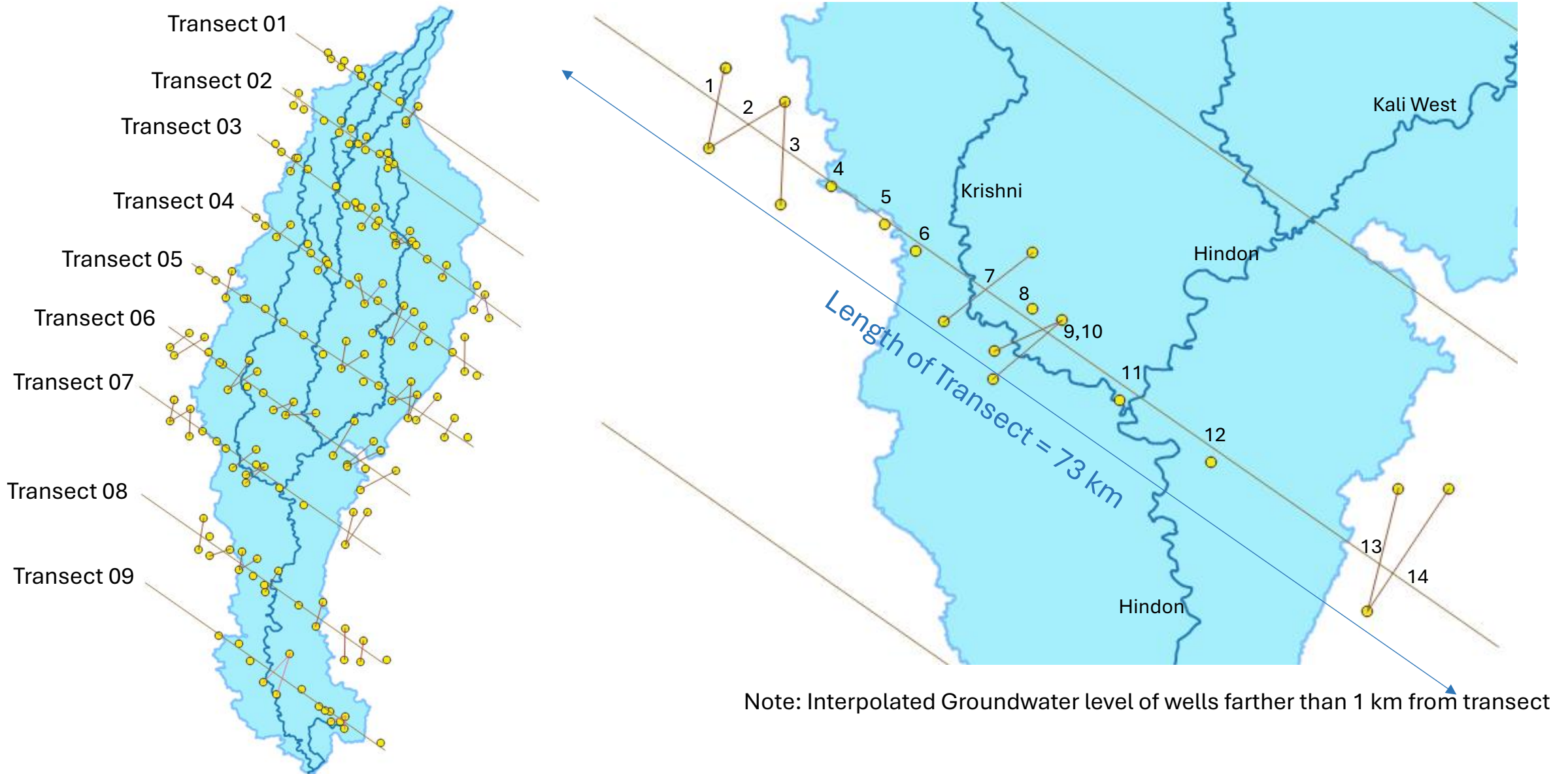
231 mapped rivers • ~2,150 km river network • major tributaries include Dhamola, Krishni and Kali West

Piezometer locations along Transects

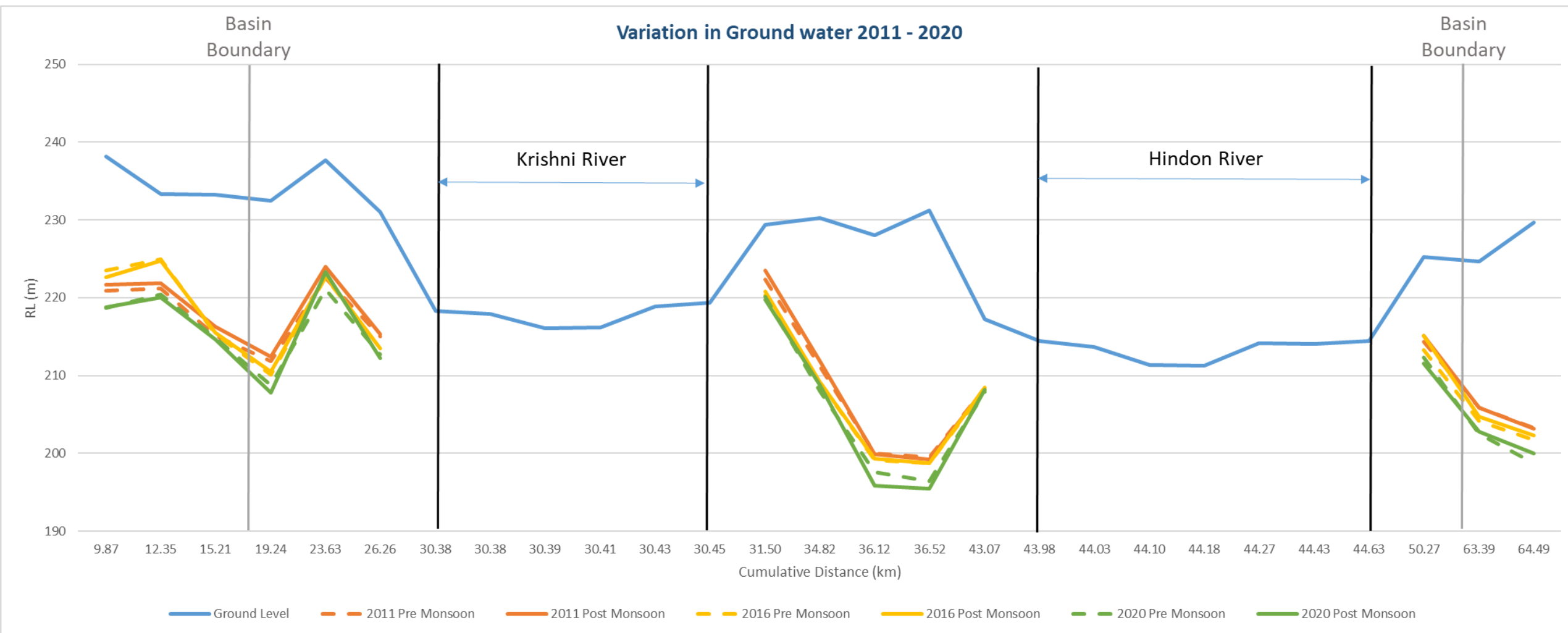
- Collected Groundwater data (Source: UP Groundwater Dept.)
- Plotted transects across the basin and studied piezometer wells along the transect.
- Analyzed trend of variation in groundwater from 2011-2020.
- Also prepared district-wise groundwater seasonal contour map for 2011, 2015 and 2020



Sample Transect Data: Transect 07



Variation in Groundwater along Transect 07



Note: Scale of x-axis is not uniform

Hindon water balance: annual sufficiency can coexist with seasonal stress

Hydrological rejuvenation must resolve timing, storage and connectivity — not only annual totals

Input	Non-Monsoon (Nov 01 – May 31) (MCM)	Monsoon (June 01 – October 31) (MCM)	Annual (MCM)
Rainfall	827.62	5287.79	6115.41
UGC Inflow	2247.31	1718.30	3965.31
Total Input	3074.93	7006.09	10081.02
Output			
UGC Outflow	1218.72	914.16	2132.88
HCC Outflow	643.30	391.57	1034.87
Stream Outflow	410.22	509.32	919.54
Evapotranspiration (MODIS)	2313.01	3613.14	5926.15
Total Output	4585.25	5428.19	10013.44
Surplus (+)/Deficit (-) [Input-Output]	-1510.32	1577.90	67.58
Surplus (+)/Deficit (-) (lpcd)*	-709.79	1032.36	18.48

*Population of Hindon Basin (Census 2011) = 99,89,871

The diagnostic message

Non-monsoon

Input – Output
≈ -1,510 MCM

Monsoon

Input – Output
≈ +1,578 MCM

Annual

Input – Output ≈ +68 MCM → near annual balance, but strong seasonal mismatch

Planning consequence

Rejuvenation should improve monsoon retention, recharge and seasonal redistribution before proposing new water-import or channel-storage structures.

Reach-based rejuvenation: one river, different diagnoses

IRAF separates intrinsic river identity from present health so that interventions can vary longitudinally

Diagnose each reach through RHA components

H1 Source–Dhamola

→ Protect headwater / piedmont processes

H2 Dhamola–Krishni

→ Manage tributary and local-system inputs

H3 Krishni–Muzaffarnagar

→ Diagnose flow–quality–sediment interactions

H4 Meerut corridor

→ Urban/industrial pressure + altered drainage

H5 Ghaziabad–Noida

→ High urban pressure; local drains dominate

H6 Yamuna confluence

→ Restore receiving-river and floodplain connectivity

H Hydrology

G Geomorphology

S Sediment

W Water quality

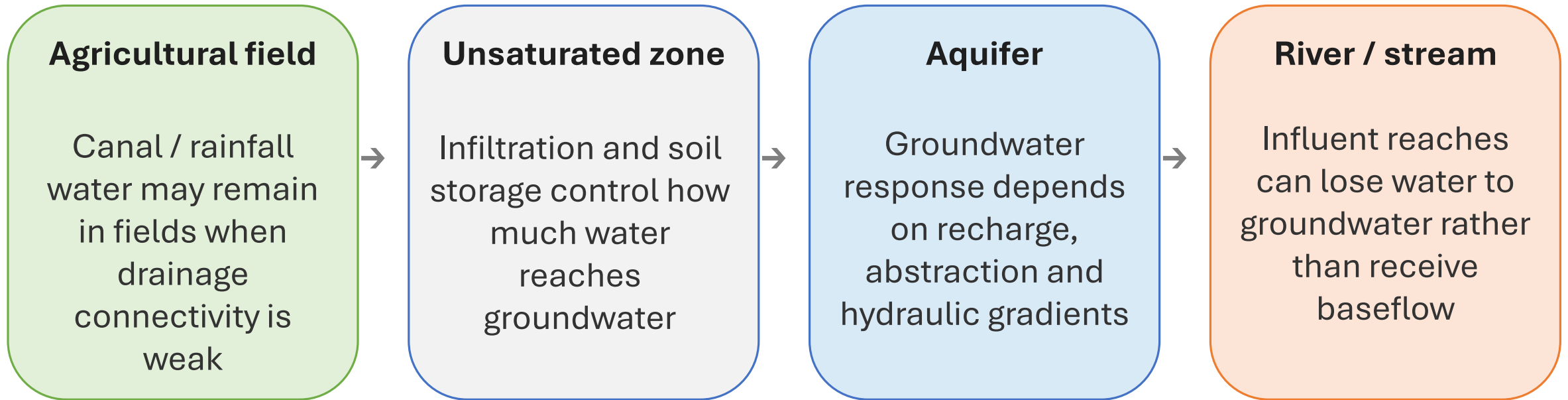
B Habitat & biodiversity

C Connectivity

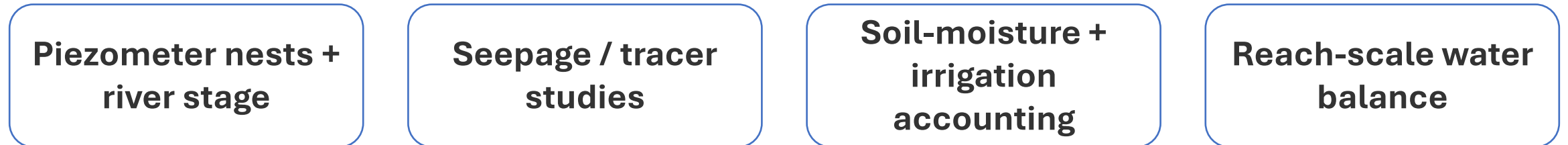
Tier = intrinsic significance • Class = present condition

Hydrological connectivity: water in the landscape does not automatically become river flow

Field evidence from Hindon points to infiltration, weak agricultural drainage connectivity and influent river conditions



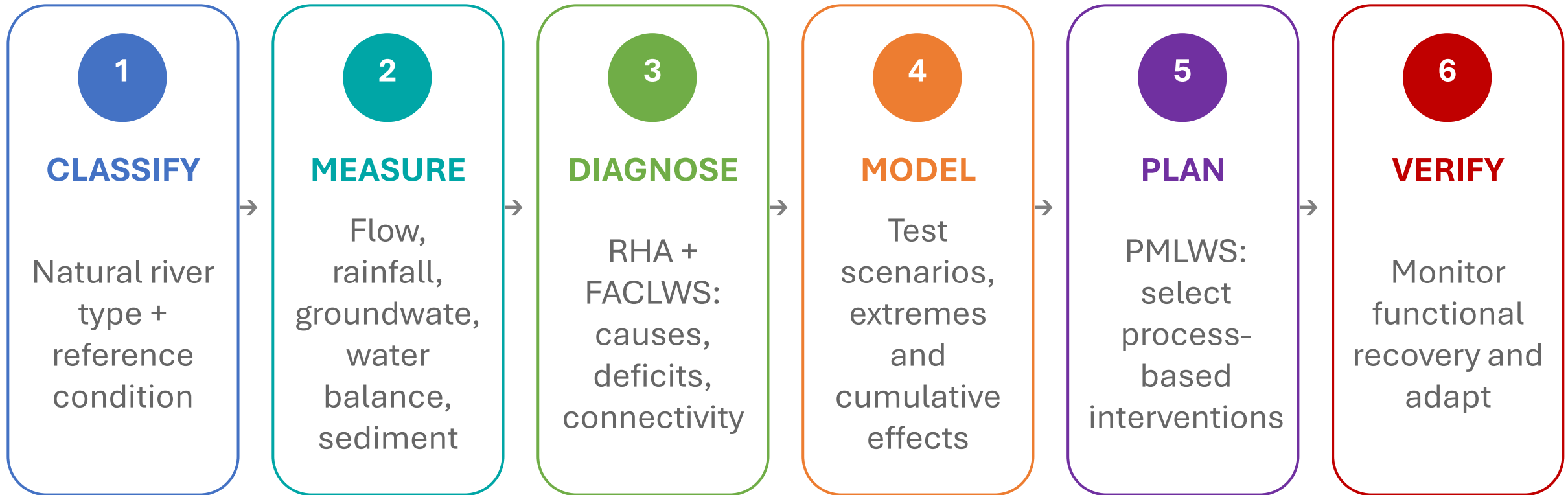
Technology implication



Do not assume that groundwater always sustains dry-season flow; first establish the direction and magnitude of exchange.

From hydrological diagnosis to intervention: a traceable decision chain

Every rejuvenation work should be able to answer “what process deficit does this intervention correct?”

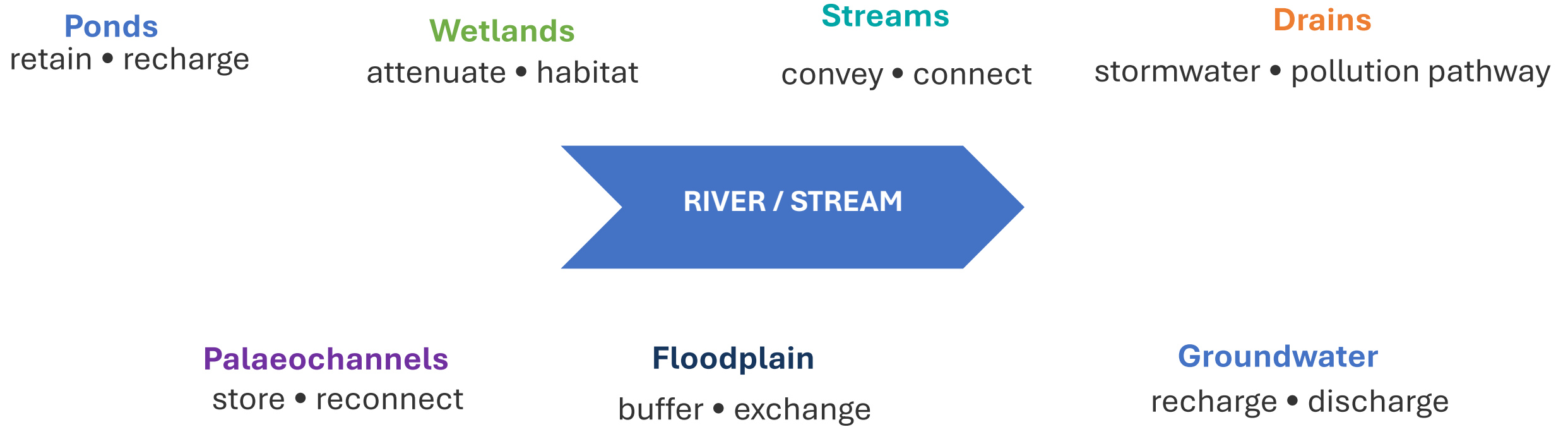


No structure should be the starting point.

The starting point is the process that is missing, altered or disconnected.

Local water systems are distributed ecological infrastructure

Rejuvenating the main channel alone misses the network that stores, transmits, transforms and reconnects water



PMLWS management logic Protect • Sustain • Restore • Rehabilitate • Reconnect • Optimise

→ **Water Security • River Health • Climate Resilience**

15. Recommended DoLR Selection Framework

A practical pre-project workflow for watershed / small-river natural-flow restoration.

1. Classify river / reach

**2. Define historical
reference**

**3. Quantify seasonal
water balance**

**4. Diagnose aquifer–river
exchange**

**5. Map retention / LWS
network**

**6. Assess abstraction +
quality**

**7. Assign restoration
category**

8. Design interventions

**9. Monitor functional
recovery**

Programme principle

Restore the hydrological processes that sustain the river's natural character; make flow longer-lasting only where the catchment–aquifer–river system can support it.

A DoLR-ready pre-intervention checklist

Before sanctioning a rejuvenation work, require evidence that the proposed action fits the river's hydrological character

IDENTITY Is the stream naturally perennial, seasonal or ephemeral?

**WATER
BALANCE** Where does water originate, go, get stored, abstracted or returned?

CONNECTIVITY What is the catchment–groundwater–stream–floodplain connection?

**PROCESS
DEFICIT** Is the problem flow, sediment, water quality, habitat, geomorphology or connectivity?

INTERVENTION FIT Does the proposed work restore the missing process without creating a new hydrological problem?

**PERFOR-
-MANCE** Which measurable functional outcome will prove rejuvenation succeeded?

Rejuvenation succeeds when the river/stream recovers its hydrological processes and connections — not when a structure is merely completed.

Thank You !



Questions, Comments & Suggestions may be sent to
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