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DEPARTMENT OF LAND RESOURCES
Government of India

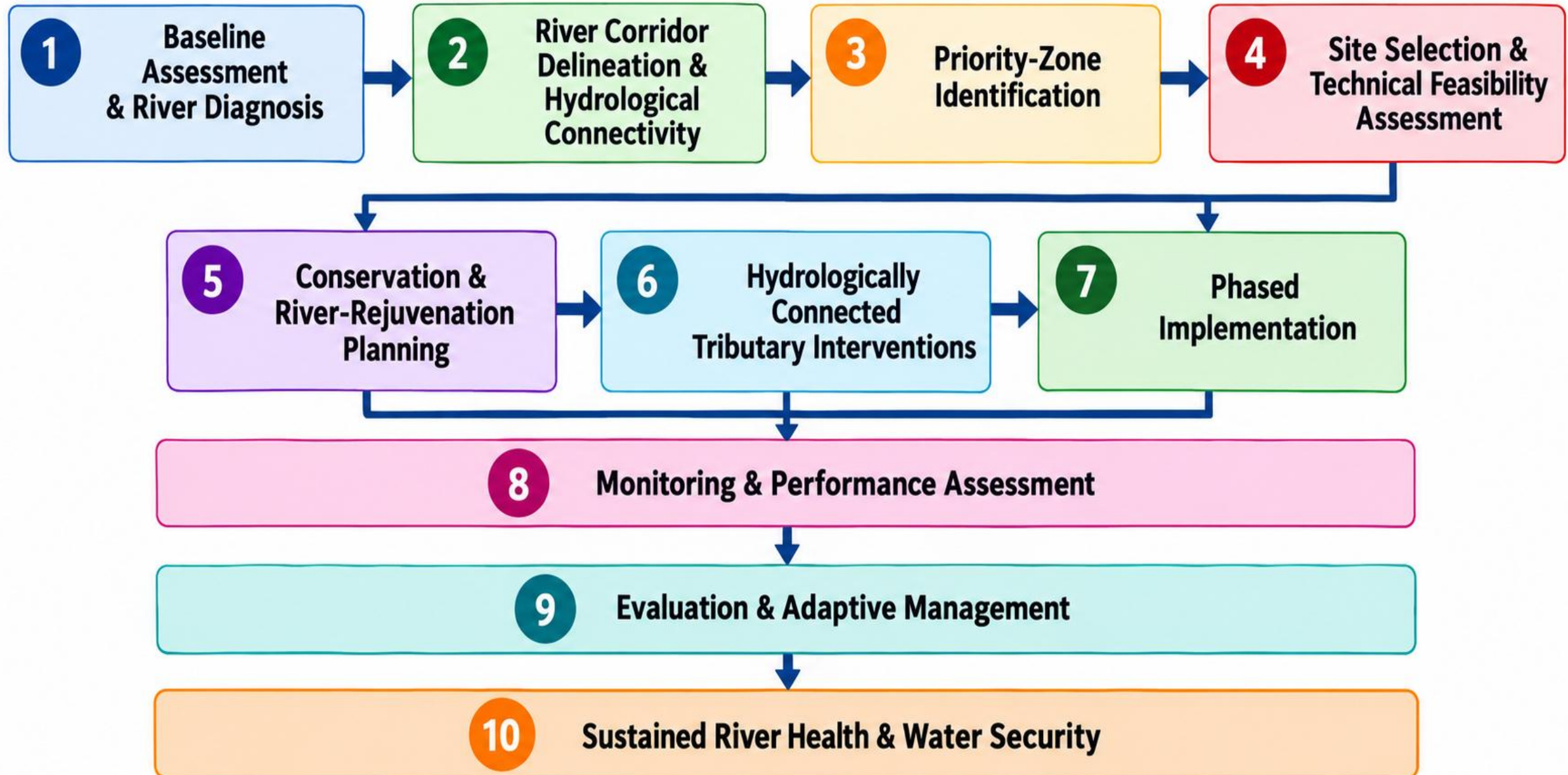
National Workshop on

“Rejuvenation of Rivers/Streams through Watershed Development Approach”

Framework for Execution of River Rejuvenation through a Watershed Approach

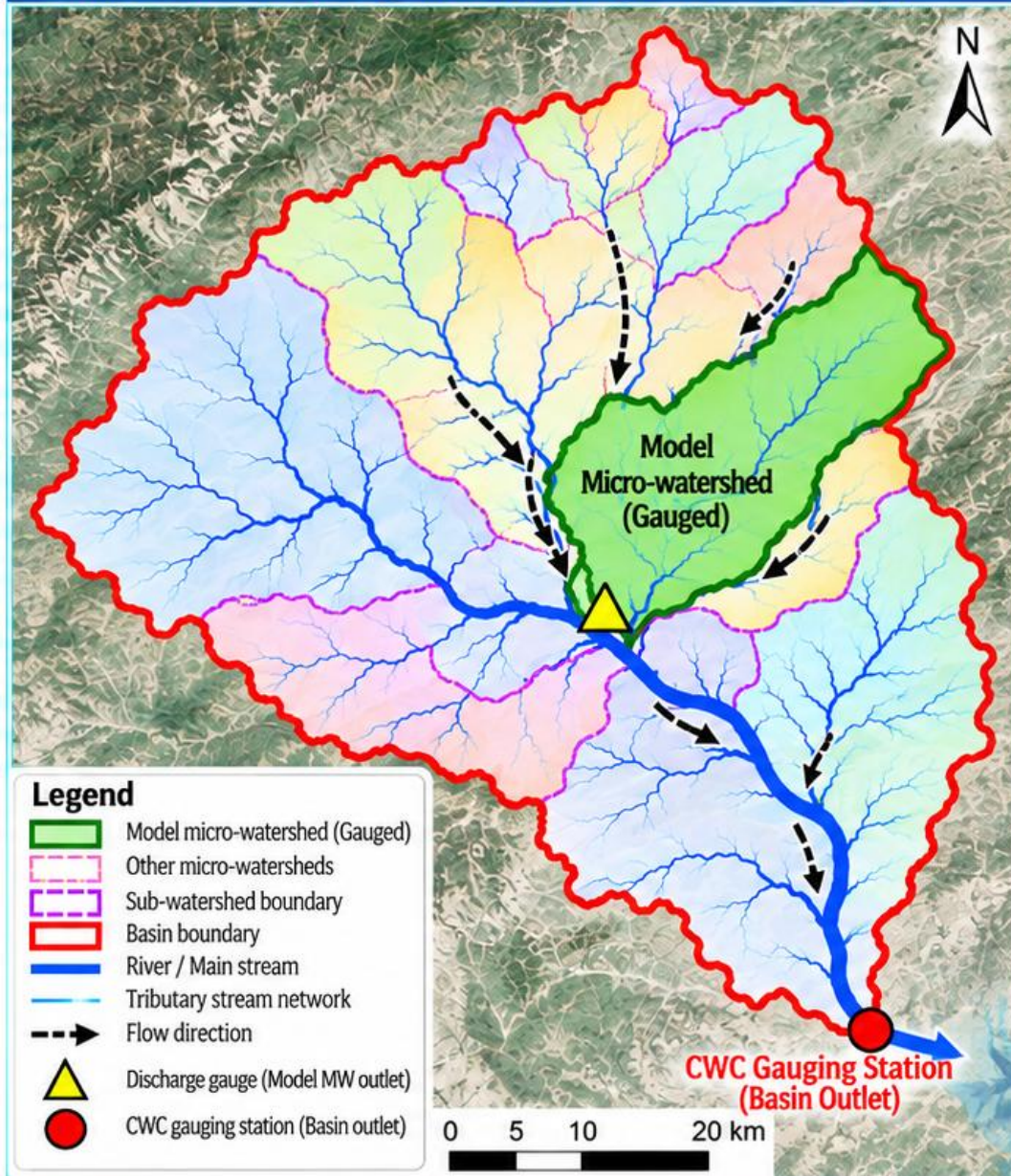
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Framework for Execution of River Rejuvenation through a Watershed Approach

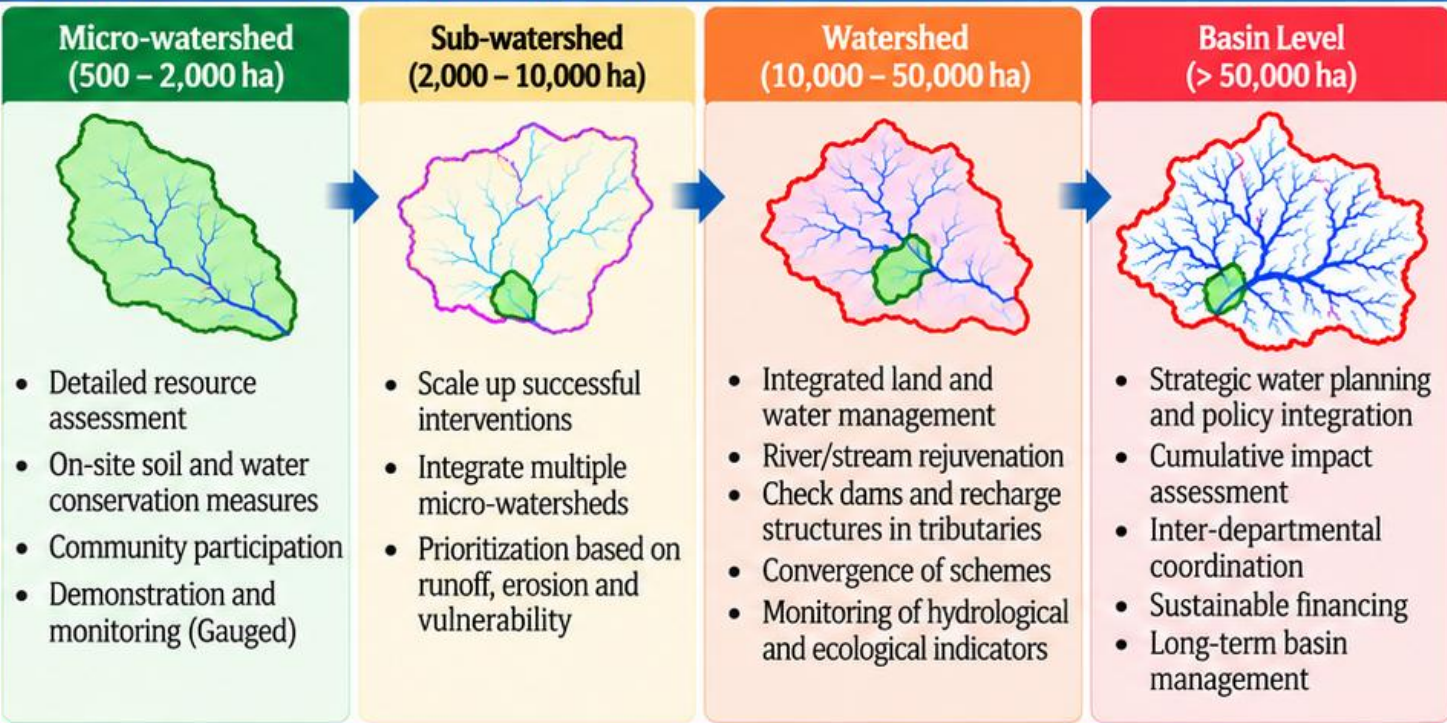


Micro Model Watershed to Basin Level Executive Framework for River Rejuvenation and Watershed Development

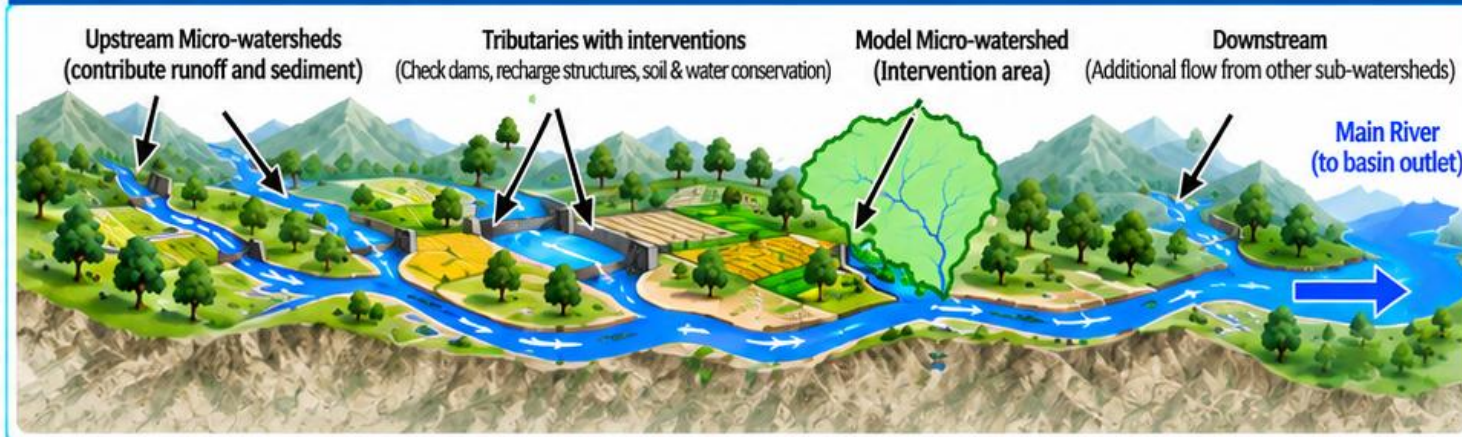
1. Watershed Hierarchy and Hydrological Connectivity



2. Hierarchical Planning from Micro-watershed to Basin Level

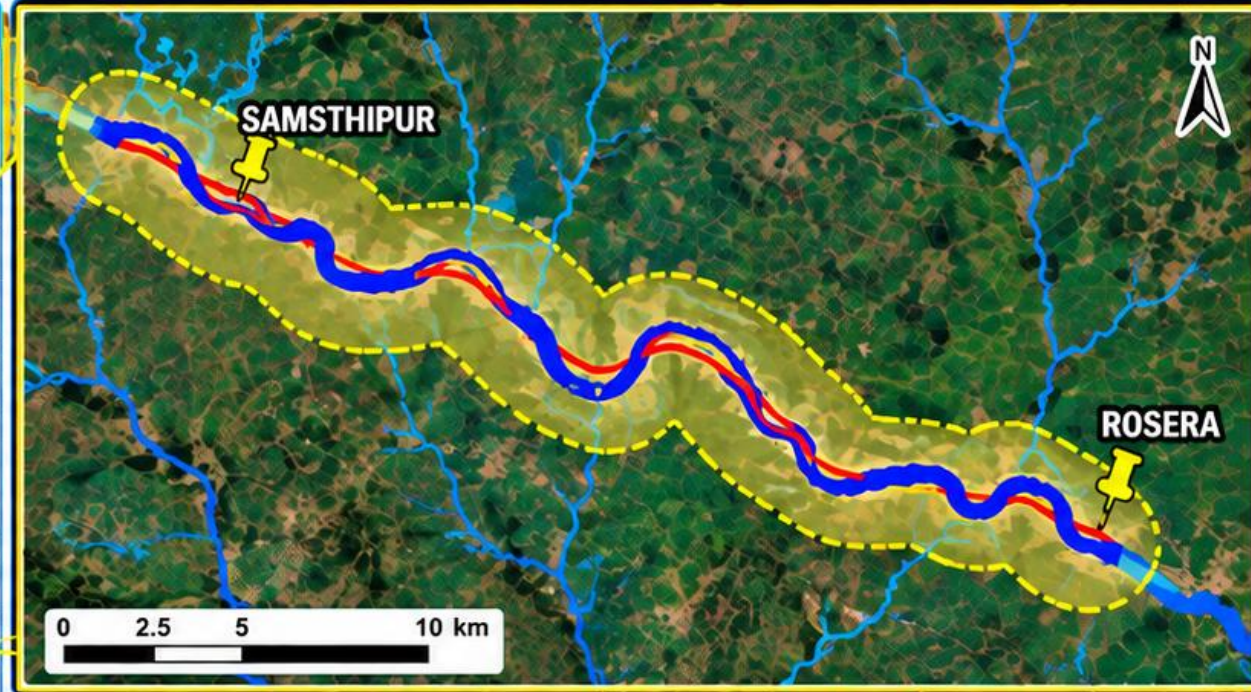
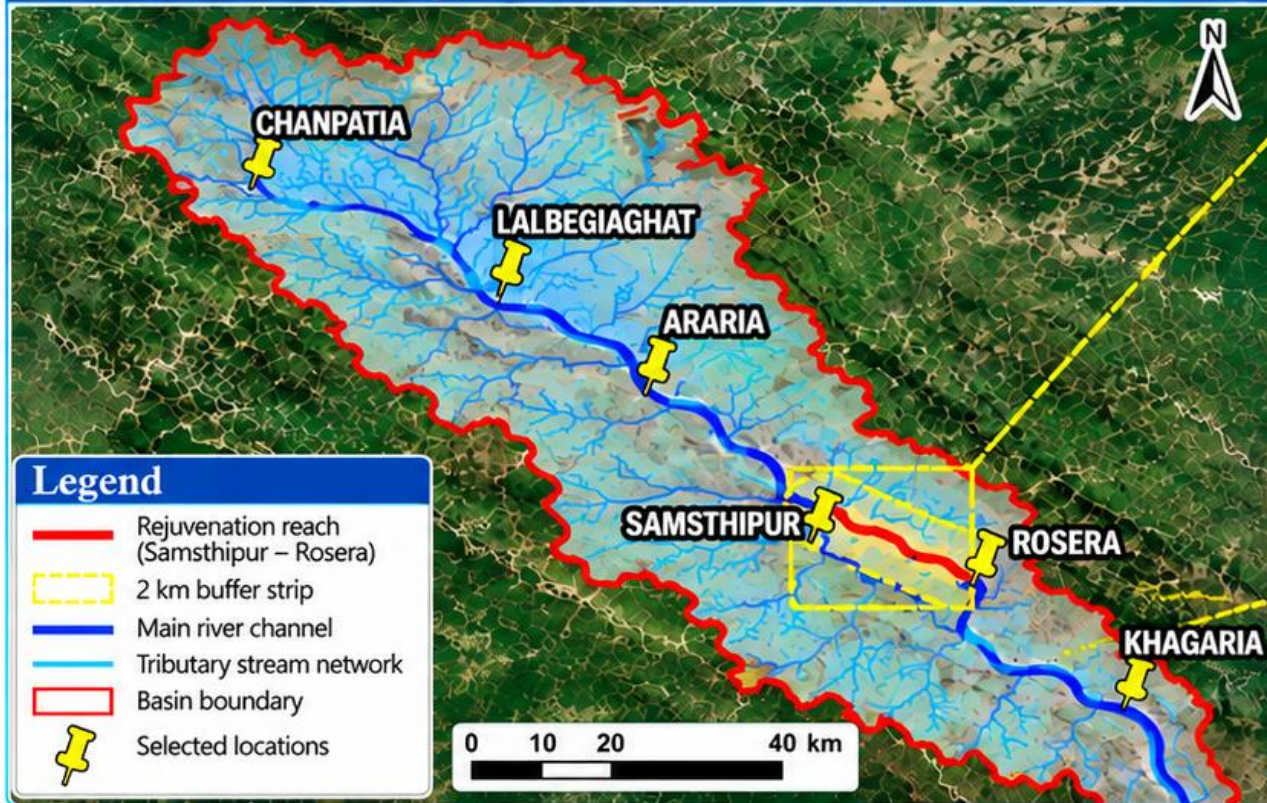


3. Hydrological Concept: Contribution from Micro-watersheds to Main River



River Rejuvenation Plan in 2 km Buffer Strip

1. Basin and Selected Rejuvenation Reach



2. Why this 2 km strip is chosen for River Rejuvenation?

-  **Strategic location:** This section connects upstream catchment flows to the downstream floodplain and is important for maintaining the hydrological continuity of the river.
-  **Significant sediment deposition:** The channel is highly silted, reducing depth and conveyance, which affects the flow regime.
-  **Degraded riparian condition:** Loss of riparian vegetation and bank instability are prominent in this stretch.
-  **Socio-economic importance:** The stretch passes through Samsthipur and Rosera, supporting agriculture, settlements and local livelihoods.
-  **High potential for multi-benefit interventions:** Suitable for combined measures such as desilting, bank stabilisation, floodplain management and catchment treatment within a manageable 2 km buffer.

3. Problems in this river section (Reasons for selecting for interventions)



Excessive sedimentation

- Reduced channel depth and conveyance
- Formation of sand bars and reduced flow capacity



Altered flow regime

- Seasonal low flow and disconnection of flow
- Increased flood risk during monsoon



Bank erosion and instability

- Lateral migration and loss of agricultural land
- Threat to settlements and infrastructure



Degraded riparian zone

- Loss of natural vegetation and habitat
- Reduced bank protection and increased erosion



Anthropogenic pressures

- Encroachment, sand mining and unplanned structures
- Increased pollution from settlements and agriculture



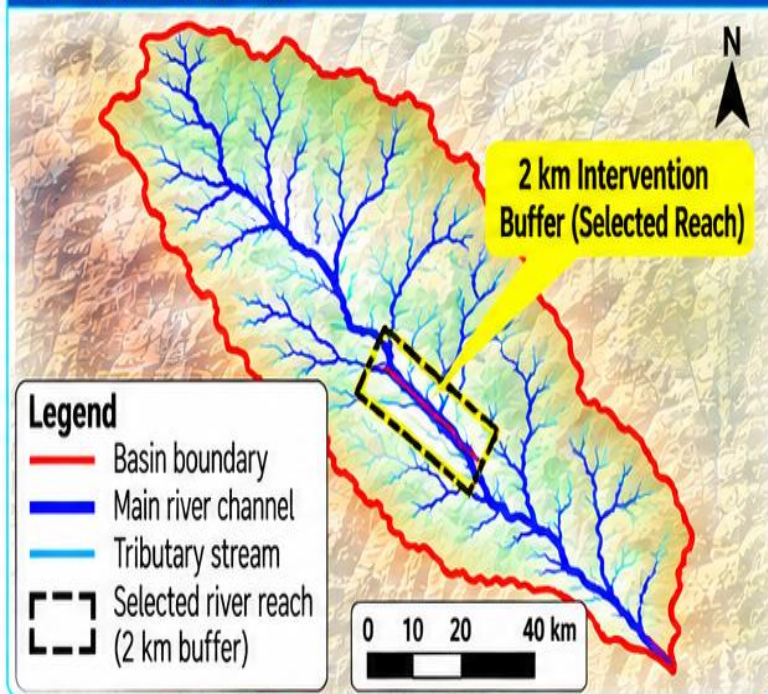
Reduced ecological health

- Degraded aquatic habitat and biodiversity
- Reduced base flow contribution in dry season

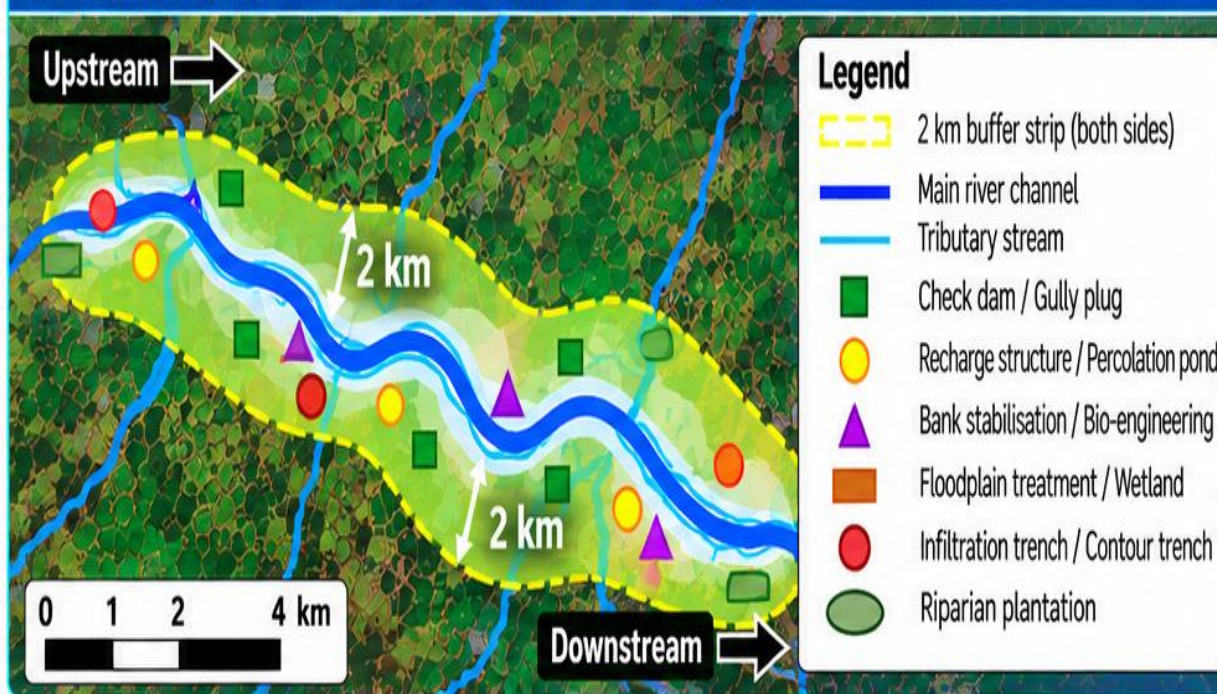
River-Rejuvenation Intervention Corridor

2-km River-Side Intervention Zone

1. Basin Overview



2. Zoomed View: 2-km River-Side Intervention Zone

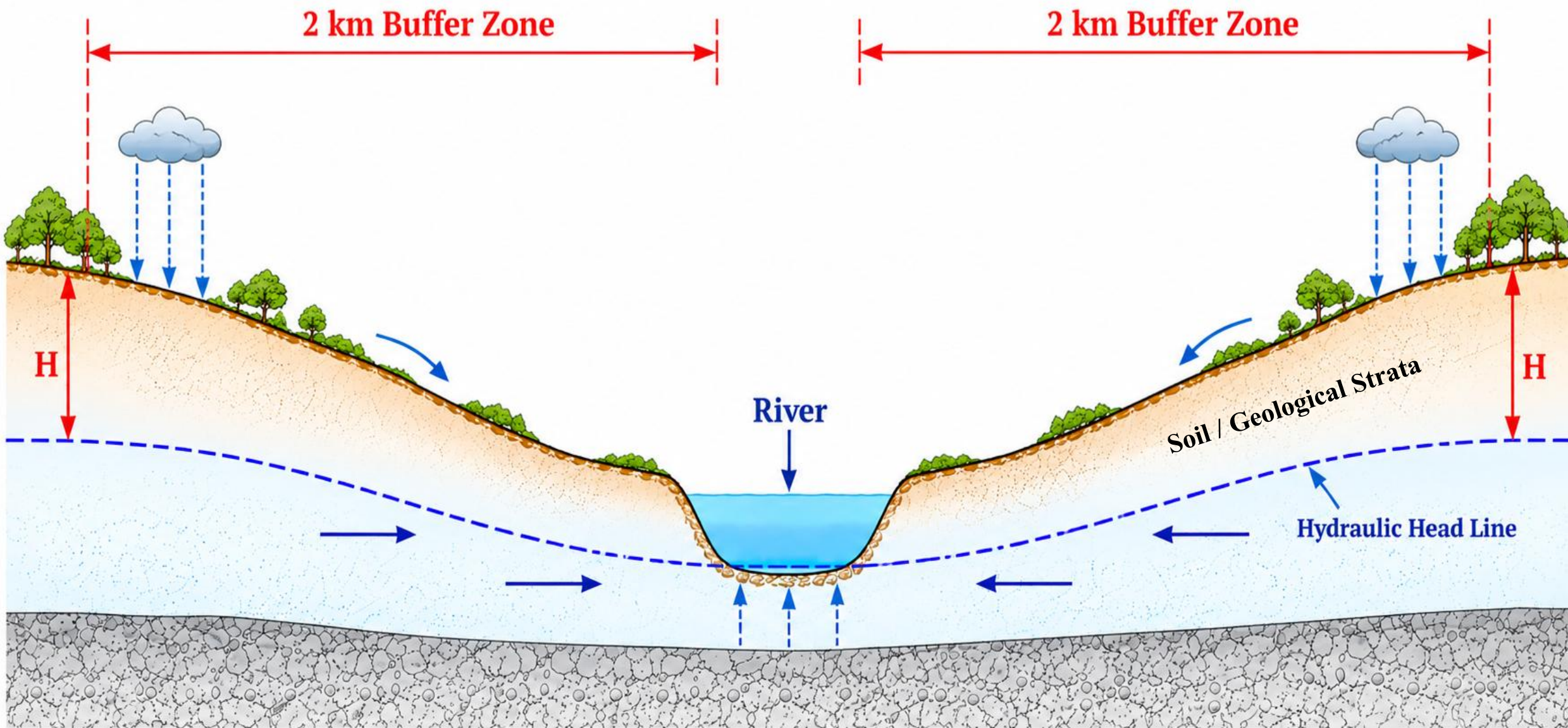


3. Planning Basis

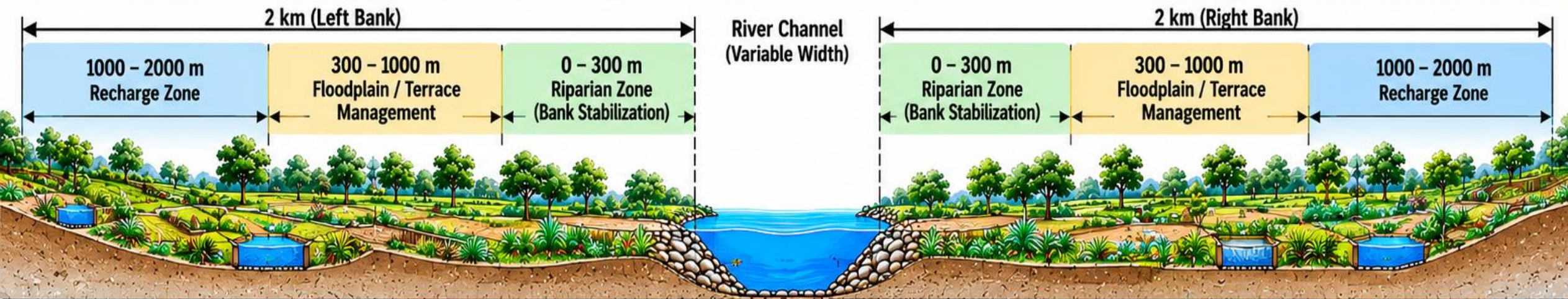
- A 2-km intervention buffer is proposed on both sides of the river channel.
- All proposed interventions are restricted to this 2-km corridor and integrated with the river channel, riparian zone, floodplain/terrace zones and adjacent slopes.
- The intervention zone is divided into functional management zones for systematic planning and treatment.
- Site selection is based on:**
 - river cross-section and bank condition
 - slope and terrain
 - drainage convergence
 - soil permeability and groundwater level
 - lithology / geology
 - erosion and sediment hotspots
 - land use and existing structures

4. Functional Management Zones within the 2-km River-Side Corridor

Zone	Lateral Extent (from river bank)	Key Features	Major Interventions
River Channel	Channel (variable width)	- Flow conveyance - Sediment transport	- Desilting / sediment management - In-stream structures (where required)
Riparian Zone	0 – 300 m	- Ecological buffer - Bank stability	- Riparian protection - Bank stabilisation - Vegetation treatment - Habitat improvement
Floodplain / Terrace Zone	300 – 1000 m	- Runoff attenuation - Sediment deposition - Agricultural use	- Gully control measures - Vegetation treatment - Runoff retardation - Sediment control - Confluence management
Recharge Zone	1000 – 2000 m	- High infiltration potential - Groundwater recharge	- Recharge ponds / percolation tanks - Recharge trenches - Recharge shafts / pits - Contour trenches and infiltration measures



River-Rejuvenation Interventions within a 2-km River-Side Corridor



Riparian Zone (0 – 300 m)

Riparian Protection / Bank Stabilization



Key Interventions (Examples)

- Riparian plantation (native species)
- Bio-engineering for bank stabilization (brush layering, coir logs, vegetative barriers)
- Protection of vulnerable banks
- Habitat improvement and ecological buffer
- Control of encroachment and regulated land use

Floodplain / Terrace Management (300 – 1000 m)

Floodplain / Terrace Management

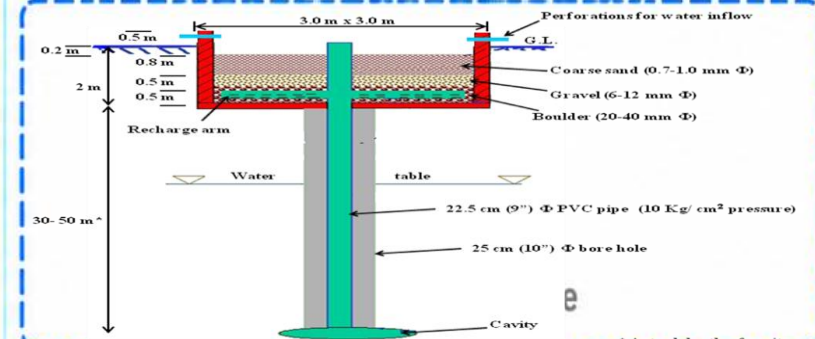


Key Interventions (Examples)

- Floodplain wetland restoration
- Sediment control and deposition management
- Agricultural best practices (e.g., agroforestry, contour farming)
- Gully control measures on adjacent slopes
- Confluence management (tributary junctions)
- Retention structures for runoff attenuation

Recharge Zone (1000 – 2000 m)

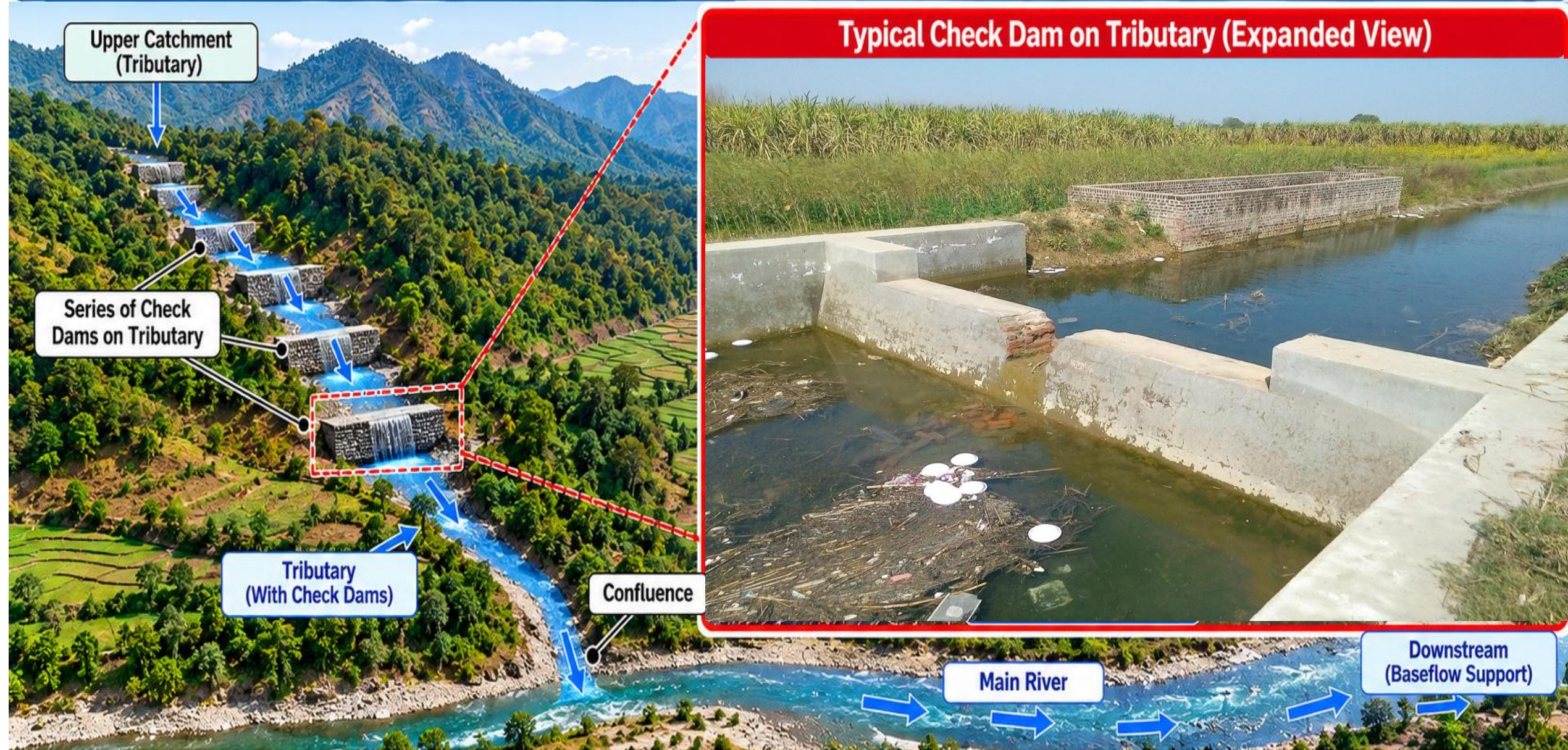
Groundwater Recharge Enhancement



Key Interventions (Examples)

- Recharge ponds / percolation tanks
- Recharge shafts / injection wells (where suitable)
- Contour trenches and staggered trenches
- Check dams (on tributaries / gullies)
- Infiltration measures and rainwater harvesting
- Afforestation / vegetation treatment for enhanced infiltration

Role of Check Dams on Tributaries for River Rejuvenation



The primary river-rejuvenation interventions are confined to the **2-km river corridor** however, hydrologically connected tributaries extending beyond this corridor may be selectively treated where they demonstrably contribute to the sustainability of the intervention reach.

Assessment Framework for Estimating Storable Water and Contribution to Base Flow for Watershed-Based River Rejuvenation

Phase 1: Foundational Analysis & Data Acquisition

1.1 Define Study Area

- Watershed boundary
- River section for rejuvenation

1.2 Data Collection

- DEM (Topography)
- LULC
- Soil texture and type
- Rainfall (long-term)
- Geological maps
- Socio-economic data
- Existing water infrastructure

1.3 Baseline Mapping

- Slope map
- Soil map
- LULC map
- Drainage map
- Sub-watershed delineation

Output:
Baseline geospatial database and thematic maps

Phase 2: Calculation of Core Assessment Parameters

2.1 Soil Erosion Potential (SEP)

Method: RUSLE

$$A = R \times K \times LS \times C \times P$$

- R: Rainfall erosivity
- K: Soil erodibility
- LS: Slope length & steepness (DEM)
- C: Cover management (LULC)
- P: Support practice

Output:
Soil erosion map (tonnes/ha/yr) & risk classification (Low/Moderate/High/Severe)

2.2 Harvestable Runoff Potential (HRP)

Method: SCS-CN

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)}$$

$$S = \frac{25400}{CN} - 254$$

$$I_a = 0.2S$$

- P: Design/average rainfall
- CN: From soil (HSG) & LULC
- S: Potential maximum retention
- I_a: Initial abstraction

Output:
Runoff potential map (mm) and total HRP (m³) for each sub-watershed

2.3 Existing Adaptive Capacity (EAC)

Method: Multi-Criteria Analysis (MCA)

- Physical/Infrastructure
- Social
- Economic
- Institutional

Output:
Adaptive capacity index (1–5) and map (Low/Medium/High)

2.4 Gap Analysis (Untapped Potential)

$$\text{Gap} = \text{HRP} - \text{EAC}$$

EAC converted to volumetric equivalent (total existing storage capacity in m³)

Output:
Untapped water potential map and table (m³ for each sub-watershed)

Phase 3: Synthesis & Final Assessment

3.1 Water Budgeting

$$\text{Total Rainfall} = \text{ET} + \text{Surface Runoff (HRP)} + \text{Groundwater Recharge} + \text{Soil Moisture}$$

3.2 Determining Storable Water

Storable Water = Gap (Untapped Potential) (target volume for new interventions)

3.3 Estimating Contribution to Base Flow

Increased Storage → Increased Recharge → Raised Water Table → Increased Base Flow to River

Method: Analytical / Water balance approach (recharge coefficient)

3.4 Final Output

- Total storable water volume (MCM or ML)
- Estimated increase in base flow (quantitative/qualitative)
- Prioritized sub-watersheds for intervention

Phase 4: Action Points

4.1 Identification of Intervention Sites

GIS overlay of SEP, HRP, Gap, slope, soil, LULC to identify suitable sites

4.2 Recommendation of Interventions

- Check dams
- Percolation tanks
- Contour trenches
- Farm ponds
- Gabion structures (Structure type based on site conditions)

4.3 Monitoring & Evaluation (M&E) Framework

- Change in groundwater level
- Increase in base flow
- Reduction in soil erosion
- Change in cropping pattern
- Socio-economic benefits

4.4 Stakeholder Engagement Plan

- Community participation
- Capacity building
- Participatory planning
- Convergence with government
- Long-term ownership and maintenance

Expected Outcomes (River Rejuvenation)

Increased groundwater recharge and improved water table

Enhanced dry-season base flow in river

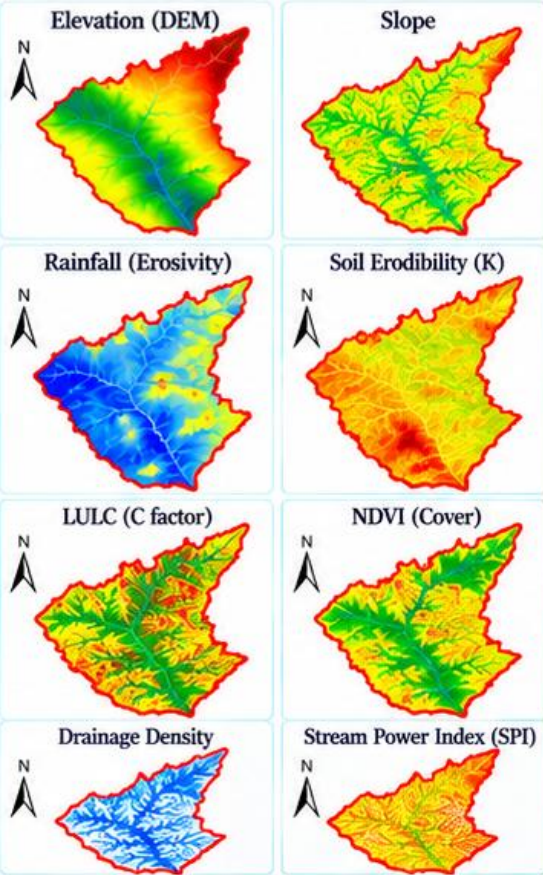
Reduced soil erosion and sediment load

Improved water availability for agriculture and domestic use

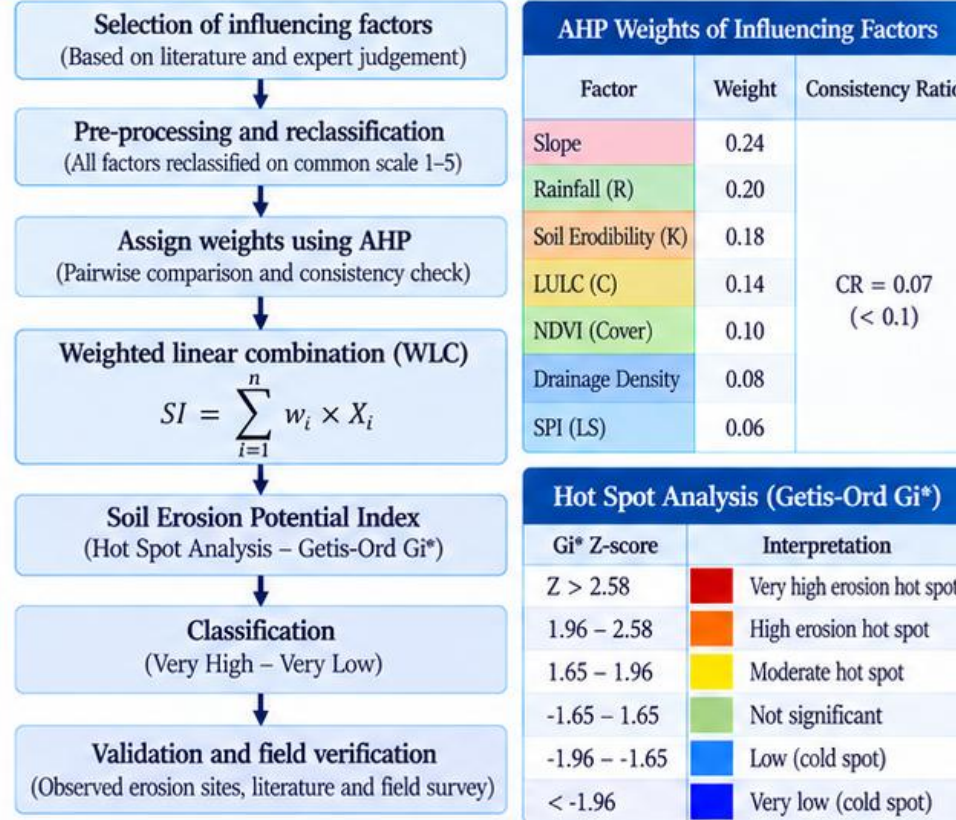
Enhanced river ecosystem health and resilience to climate variability

Soil Erosion Potential Mapping (Hot Spot Analysis) – Kamal Ganga Watershed

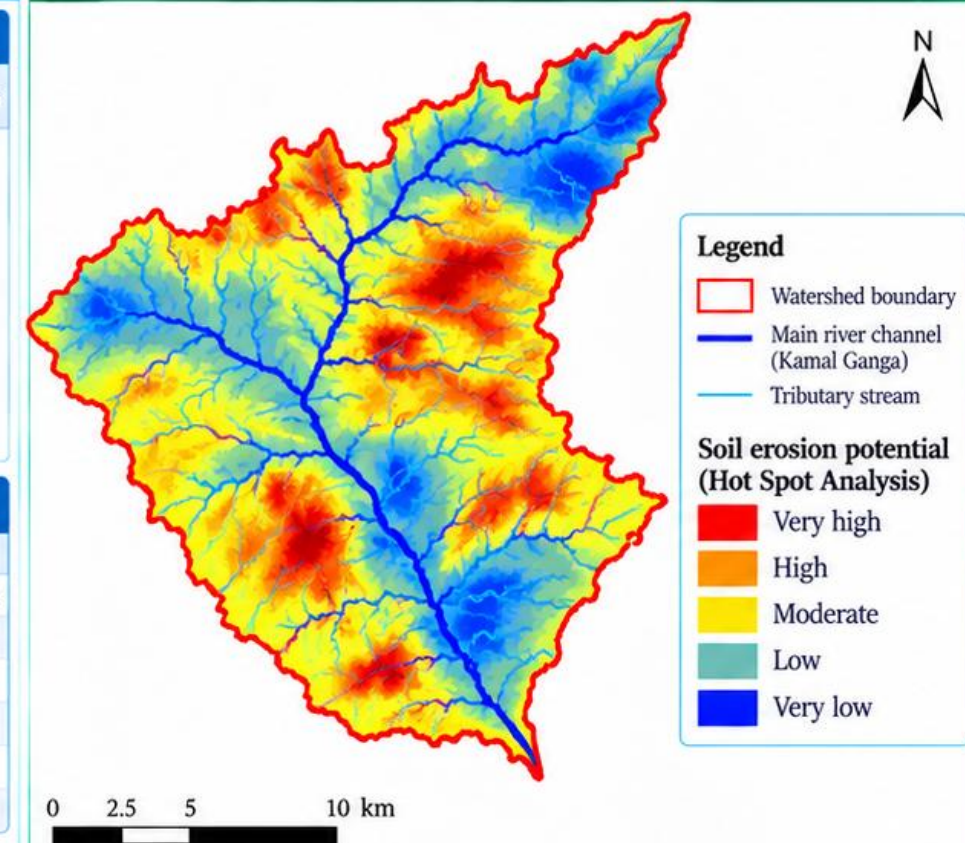
1. Input Thematic Layers



2. Methodology for Soil Erosion Potential Mapping



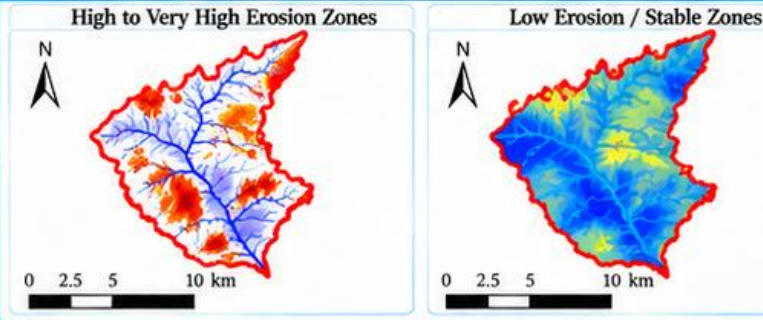
3. Soil Erosion Potential Map (Hot Spot Analysis)



4. Area Statistics of Soil Erosion Potential Zones

Erosion potential class	Area (km ²)	Area (%)
Very high	38.42	17.51
High	56.18	25.59
Moderate	72.36	32.98
Low	37.41	17.05
Very low	15.04	6.86
Total	219.35	100.00

5. Spatial Distribution and Hot Spot Zones

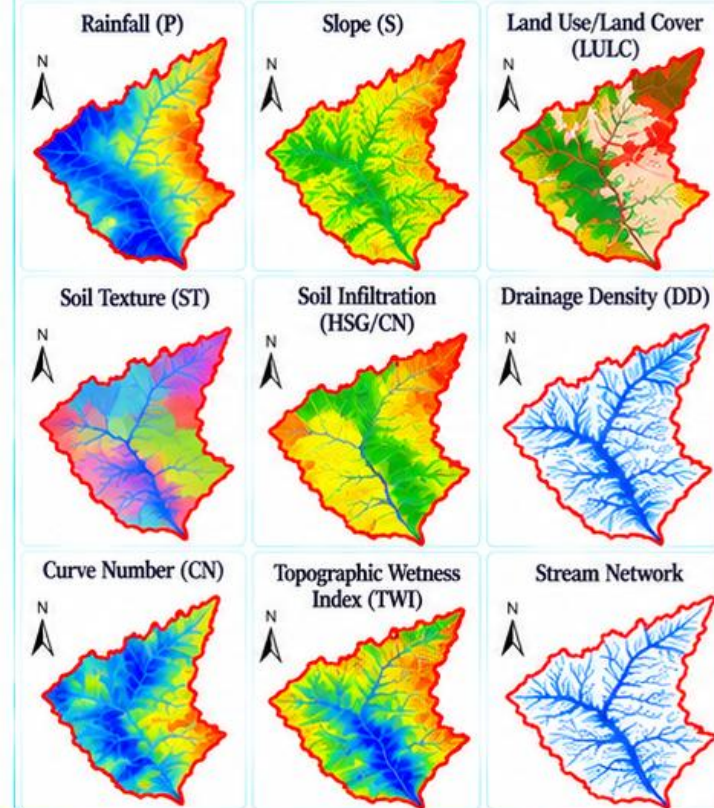


6. Key Observations and Implications

-  High to very high erosion potential zones are mainly observed in steep slopes, upper catchment areas and structurally disturbed zones.
-  Moderate erosion potential zones occur in mid-slope and transition areas.
-  Low to very low erosion potential zones are found in valley areas, near main river channel and areas with good vegetation cover.
-  Identified hot spot zones should be prioritised for soil and water conservation measures such as check dams, gully plugs, vegetative barriers and afforestation.

Harvestable Runoff Potential Mapping – Kamal Ganga Watershed

1. Input Thematic Layers



2. Methodology for Harvestable Runoff Potential

Selection of relevant factors
(Based on literature, hydrological relevance and expert judgement)

Pre-processing and reclassification
(All factors reclassified on common scale 1–5)

Assign weights using AHP
(Pairwise comparison and consistency check)

Weighted linear combination (WLC)

$$HRI = \sum_{i=1}^n w_i \times X_i$$

Harvestable Runoff Potential Index (HRI)
(Integrating runoff generation and feasibility)

Classification
(Very high – Very low)

Validation and field verification
(Comparison with observed runoff and existing structures)

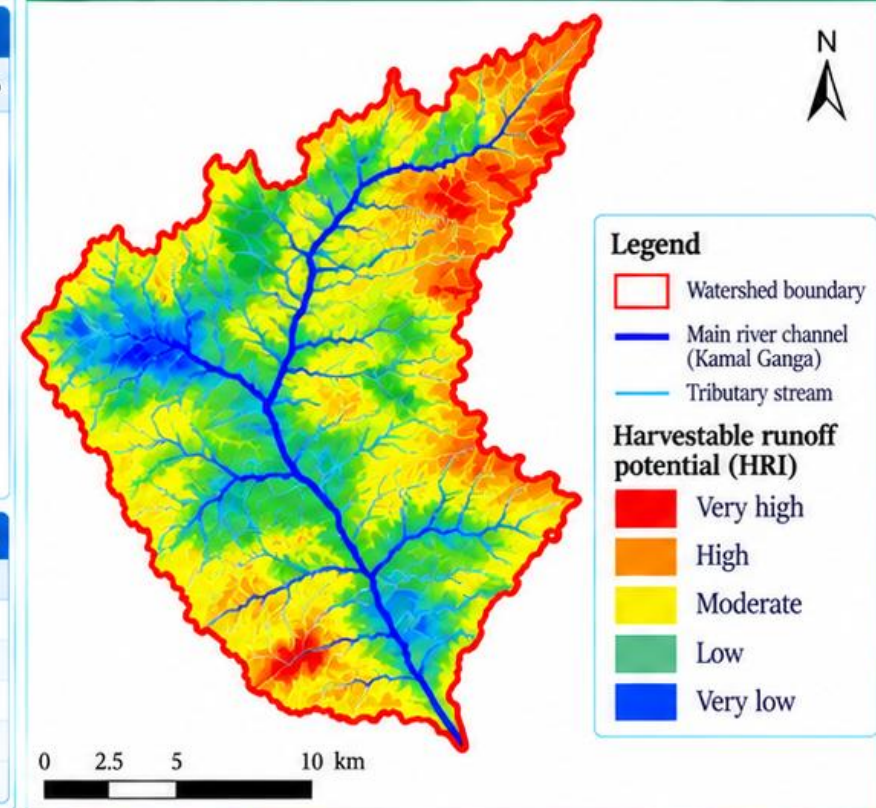
AHP Weights of Influencing Factors

Factor	Weight	Consistency Ratio
Rainfall (P)	0.22	CR = 0.06 (< 0.1)
Curve Number (CN)	0.18	
Slope (S)	0.12	
Soil Texture (ST)	0.10	
Land Use/Land Cover (LULC)	0.10	
Drainage Density (DD)	0.10	
TWI	0.08	
Stream Proximity	0.06	
Geology/Lithology	0.04	

Classification of Harvestable Runoff Potential (HRI)

HRI Range	Category
> 0.80	Very high
0.60 – 0.80	High
0.40 – 0.60	Moderate
0.20 – 0.40	Low
< 0.20	Very low

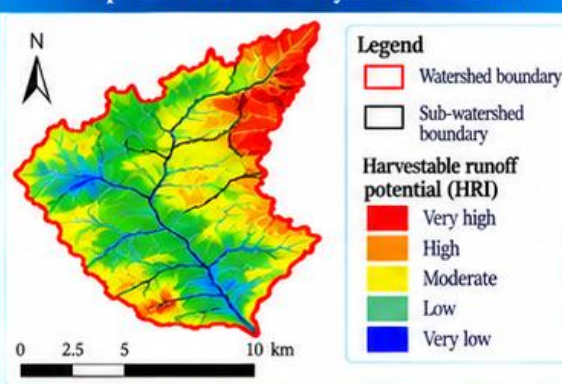
3. Harvestable Runoff Potential Map



4. Area Statistics of Harvestable Runoff Potential Zones

HRI class	Area (km ²)	Area (%)
Very high	42.18	19.22
High	58.67	26.72
Moderate	72.40	33.00
Low	31.86	14.52
Very low	14.24	6.54
Total	219.35	100.00

5. Spatial Distribution by Sub-watershed



6. Potential Harvestable Runoff by Sub-watershed

Sub-watershed ID	Area (km ²)	Mean HRI	Harvestable Runoff Potential (MCM yr ⁻¹)
SW-1	28.46	0.72	18.24
SW-2	31.15	0.58	14.62
SW-3	25.38	0.49	11.84
SW-4	37.72	0.36	9.18
SW-5	34.26	0.44	10.37
SW-6	29.38	0.63	15.21
SW-7	32.00	0.31	7.92
Total	219.35	–	87.38

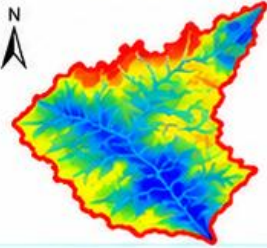
7. Key Observations and Implications

- High harvestable runoff potential zones are mainly observed in upper catchment, steep slopes and high-rainfall areas.
- Moderate potential zones occur in mid-slope agricultural and mixed land use areas.
- Low to very low potential zones are found in valley areas, flatter regions and areas with higher infiltration.
- Prioritise in-situ water-harvesting structures (check dams, percolation tanks, farm ponds) in high and very high potential zones.
- Useful for watershed planning, groundwater recharge, agricultural water security and downstream flood mitigation.

Gap between Harvestable Runoff Potential and Existing Adaptive Capacity – Kamal Ganga Watershed

1. Input Thematic Layers

Harvestable Runoff Potential (HRP)



Existing Adaptive Capacity (AC)



Elevation (DEM)



Slope



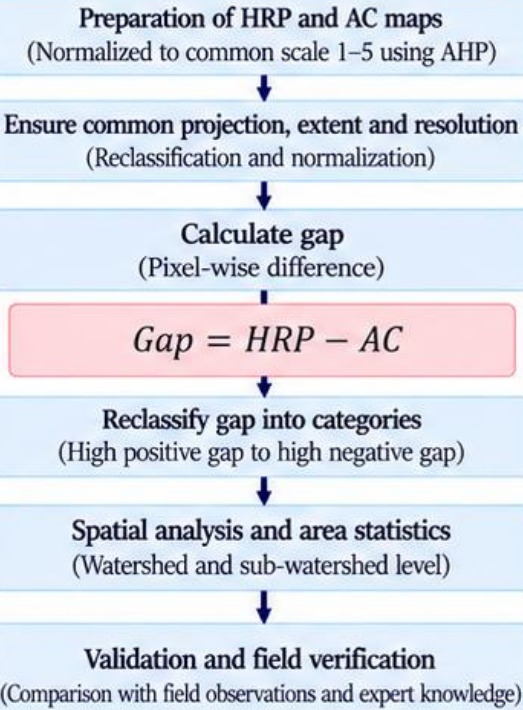
Land Use/Land Cover (LULC)



Drainage Density



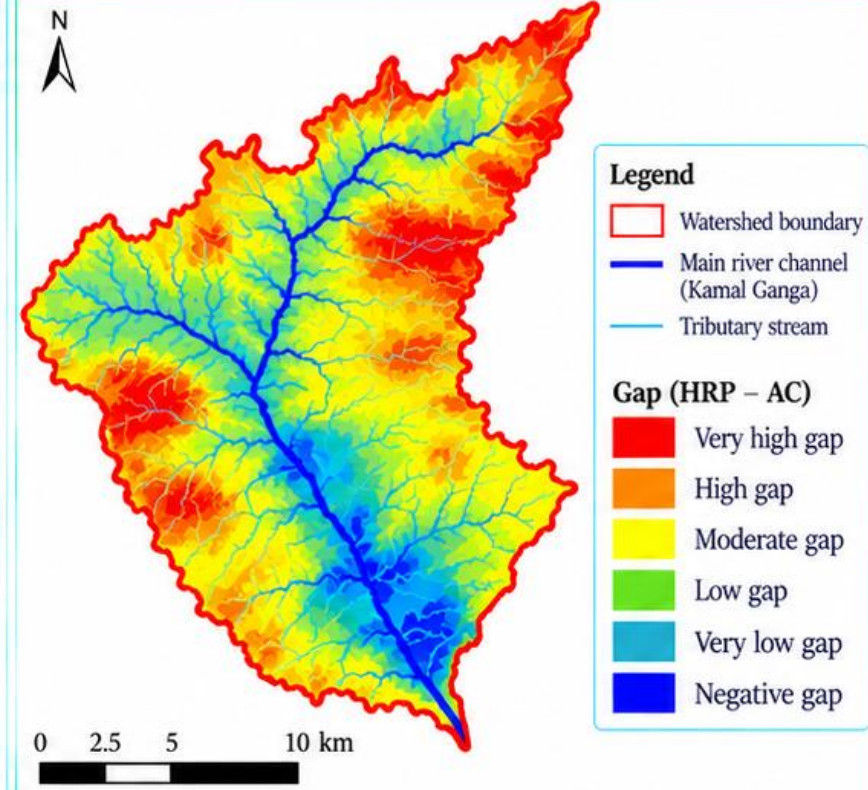
2. Methodology for Gap Analysis



AHP Weights of Influencing Factors		
Factor	Weight	Consistency Ratio
Rainfall (R)	0.22	CR = 0.06 (< 0.1)
Slope (S)	0.15	
LULC (C)	0.13	
Soil (ST)	0.12	
Drainage Density (DD)	0.10	
Curve Number (CN)	0.10	
Topographic Wetness Index (TWI)	0.08	
Stream Power Index (SPI)	0.05	
Geology/Lithology	0.05	

Gap Classification (HRP – AC)		
Gap Range	Category	Color
> 2	Very high gap	Red
1 to 2	High gap	Orange
0 to 1	Moderate gap	Yellow
-1 to 0	Low gap	Light Green
-2 to -1	Very low gap	Light Blue
< -2	Negative gap	Dark Blue

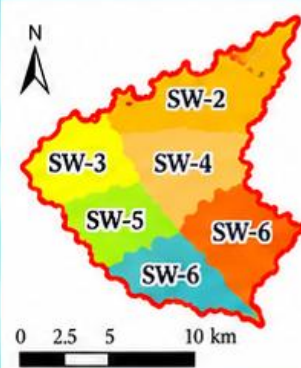
3. Gap Map (HRP – AC)



4. Area Statistics of Gap Zones

Gap class	Area (km ²)	Area (%)
Very high gap	41.28	18.81
High gap	68.95	31.44
Moderate gap	62.17	28.34
Low gap	32.36	14.76
Very low gap	14.59	6.65
Negative gap	–	–
Total	219.35	100.00

5. Sub-watershed Wise Gap Analysis



Sub-watershed ID	Area (km ²)	Mean HRP	Mean AC	Mean Gap	Gap class
SW-1	28.46	3.8	2.1	1.7	High
SW-2	31.15	4.2	1.9	2.3	Very high
SW-4	25.38	3.1	2.4	0.7	Moderate
SW-4	37.72	2.9	2.6	0.3	Moderate
SW-5	34.26	3.5	2.0	1.5	High
SW-6	29.38	4.0	1.8	2.2	Very high
Total	219.35	–	–	–	–

6. Key Observations and Implications



High gap zones indicate areas with high harvestable runoff potential but low existing adaptive capacity.



These areas should be prioritised for in-situ water harvesting structures, recharge interventions and watershed development.



Moderate gap zones can be strengthened through land and water management, improved infrastructure and policy support.



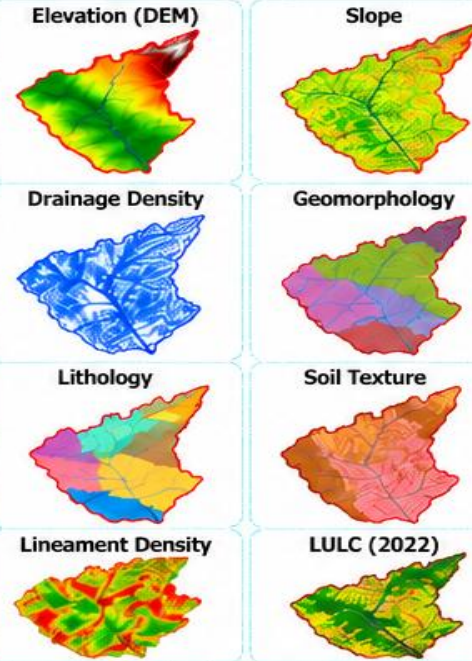
Low and very low gap zones indicate adequate adaptive capacity relative to runoff potential and require maintenance.



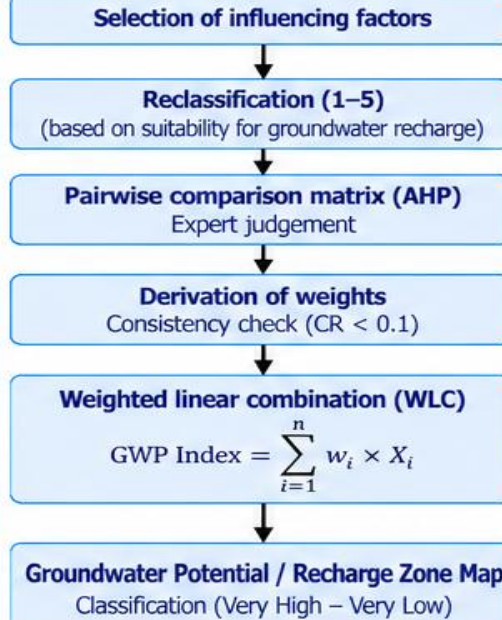
Negative gap zones have higher adaptive capacity than runoff potential and may be managed for ecological conservation and sustainable land use.

Groundwater Potential / Recharge Zone Identification and Validation Framework

1. Input Thematic Layers



2. AHP Based Weighting and Overlay



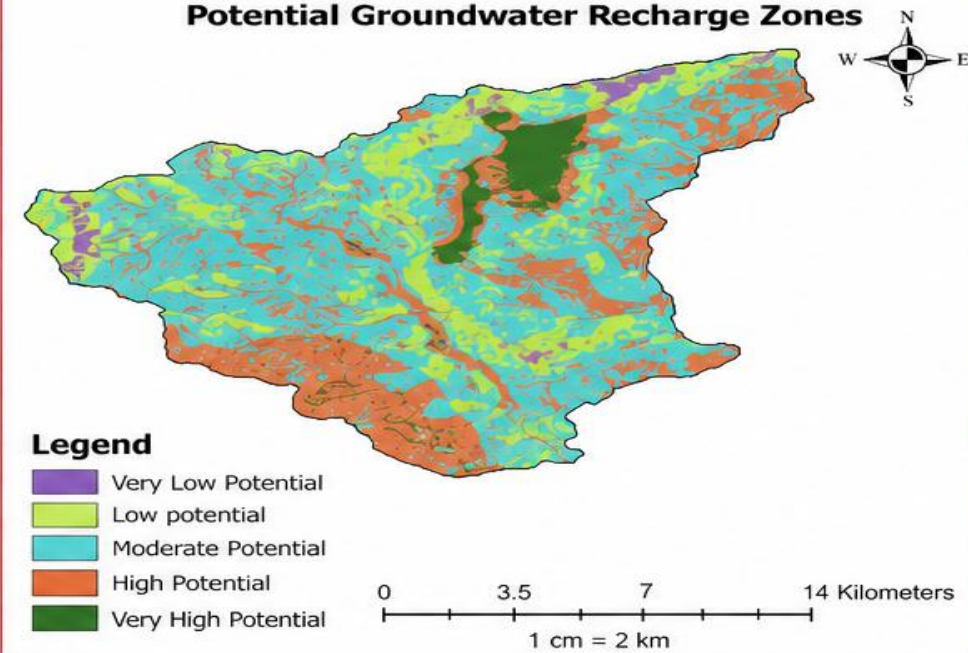
AHP Weights of Thematic Layers

Factor	Weight	Consistency Ratio
Geomorphology	0.24	CR = 0.06 (< 0.1)
Slope	0.18	
Drainage Density	0.15	
Lineament Density	0.13	
Lithology	0.12	
Soil Texture	0.10	
LULC (2022)	0.08	

Reclassification Criteria (Example)

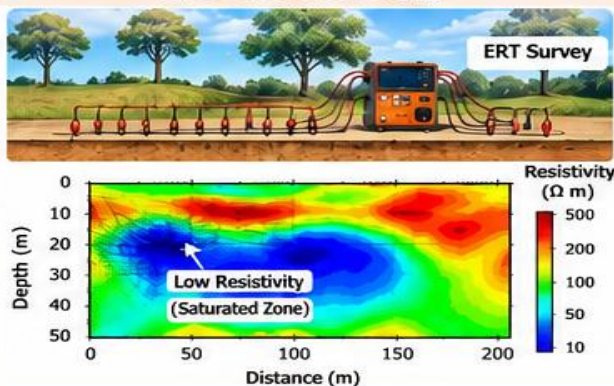
Factor	Most Suitable (5)	Least Suitable (1)
Slope	0 – 5%	> 30%
Drainage Density	High	Very low
Lineament Density	High	Very low
Geomorphology	Valley / Alluvial	Ridge / Structural
Lithology	Fractured / Porous	Massive / Impervious
Soil Texture	Coarse	Fine / Clayey
LULC	Forest / Agriculture	Built-up / Barren

3. Potential Groundwater Recharge Zones (AHP Overlay Result)



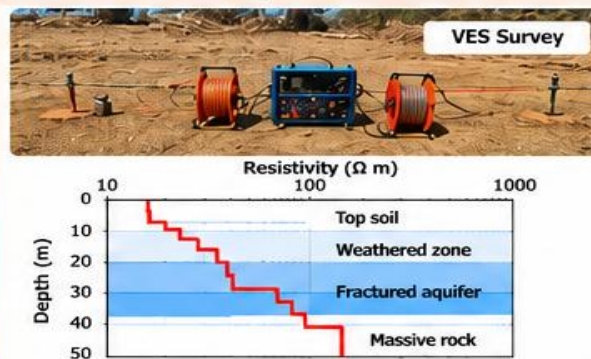
4. Field Geophysical Verification and Validation

4.1 Electrical Resistivity Tomography (ERT) 2D/3D Subsurface Imaging



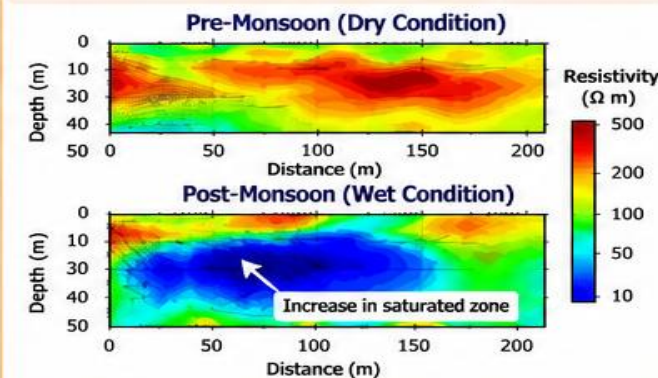
- Provides continuous 2D/3D subsurface resistivity profile.
- Identifies fractured zones, weathered zones and saturated aquifers.
- Validates high/very high potential zones identified from AHP.

4.2 Vertical Electrical Sounding (VES) Point-based Aquifer Characterization



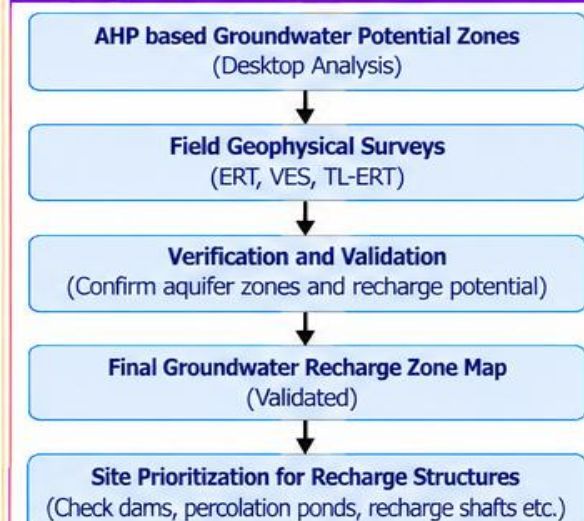
- Provides vertical variation of resistivity with depth.
- Determines thickness of weathered and fractured zones.
- Estimates depth to potential aquifer.
- Validates recharge potential at specific locations.

4.3 Time-Lapse Electrical Resistivity Tomography (TL-ERT) Pre- and Post-Monsoon Monitoring



- Monitors temporal changes in subsurface resistivity.
- Confirms increase in moisture/groundwater after recharge.
- Validates effectiveness of recharge structures and potential zones.

5. Integration and Application



Way Forward: Watershed-Driven & Expert-Led River Rejuvenation

- 1. Assessment & Site Selection** – Integrate GIS/RS, hydrology, hydrogeology, terrain, soil and field surveys to identify priority river reaches and intervention sites, with special consideration of harvestable runoff potential and specific yield of target hydrogeological strata.
- 2. River corridor rejuvenation** may be dovetailed with the holistic river catchment plan at the larger scale.
- 3. Erosion Hotspot and Recharge Zone Mapping** – Delineate groundwater recharge zones, erosion/sediment hotspots, drainage-convergence areas and vulnerable riverbanks for targeted treatments.
- 4. Site-Specific Conservation Planning** – Select appropriate water-harvesting, recharge, soil–water conservation, riparian restoration and erosion-control measures based on local site conditions.
- 5. Phased Implementation** – Execute prioritized interventions within the 2-km river-rejuvenation corridor, with selected Hydrologically Connected Tributary interventions where required.
- 6. Monitoring, Evaluation & Adaptive Management** – Monitor river flow, groundwater response, sediment, water quality and ecological indicators; evaluate intervention performance; and continuously refine the rejuvenation strategy.

“Thanks for your patience listening”