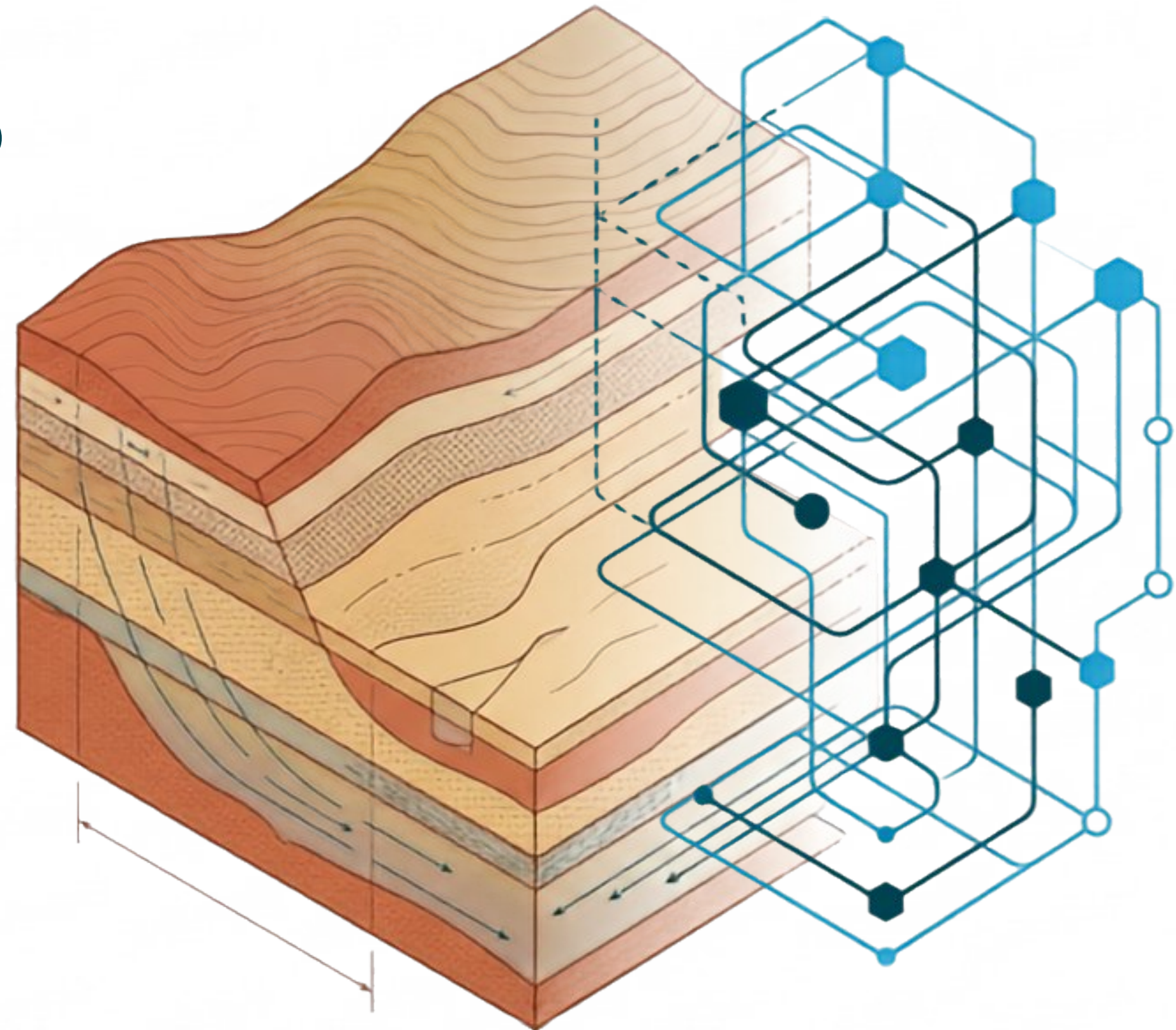


From Aquifer Knowledge to Groundwater Security:

An Operational Framework for Equitable Groundwater Management in India

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Topics for Discussion

01

Equity in Groundwater Management

02

Hydrogeological Reality and Current System Gaps

03

Diagnostic Framework and Design Requirements

04

Six-Stage Groundwater Security Framework

05

Rural Drinking Water Security and SSIA

06

Pilot Testing, Monitoring and Scale-up



What is EQUITY & Why it is important in India's Groundwater Management?

EQUITY

Different support based on need so that everyone can achieve fair access and comparable opportunity.

Equal treatment

SAME SUPPORT. DIFFERENT OUTCOMES.



Same support does not ensure equal access.



FROM
EQUALITY
TO
EQUITY
FOR A
STRONGER
TOMORROW

Equity-focused support

DIFFERENT SUPPORT. A SHARED TOMORROW.



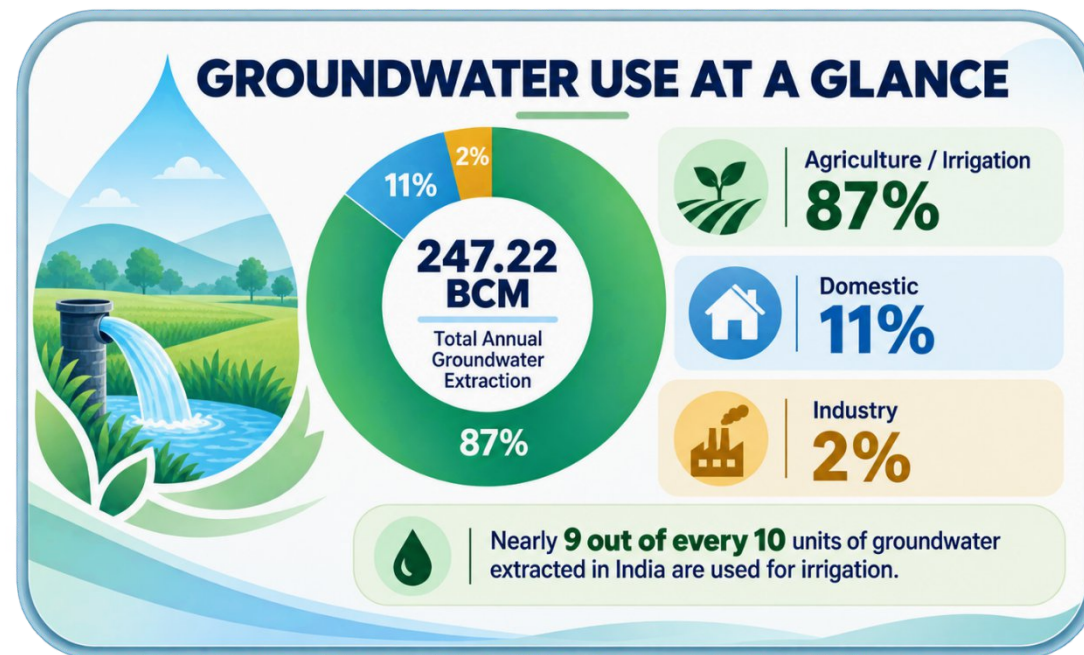
Support tailored to need enables fair access for all.

Equity is fair access, protection and allocation of groundwater resources across people, livelihoods, economic users, and ecosystems, especially under scarcity.

What is EQUITY & Why it is important in India's Groundwater Management?

WHY EQUITY MATTERS ACROSS USERS & SYSTEMS

HOW GW DECLINE BECOMES AN EQUITY ISSUE



AGRICULTURE & LIVELIHOODS
62.8% GW-irrigated NIA
86% Small & Marginal Farmers
Equity concern: limited capacity to deepen wells or absorb costs.

DRINKING-WATER SECURITY
~85%
JJM drinking-water schemes are GW-source based
Equity concern: source failure/quality decline affects vulnerable communities first.

INDUSTRY & LOCAL ECONOMY
Cost-effective source
supports production, enterprises and employment
Equity concern: concentrated abstraction can intensify aquifer competition.

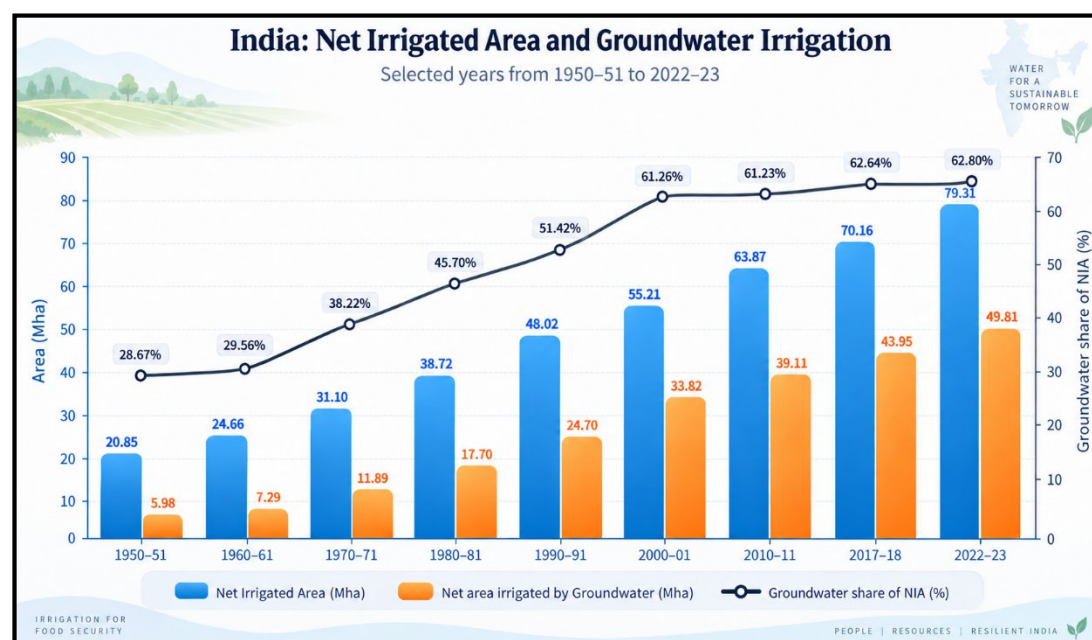
ECOSYSTEMS & COMMUNITIES
~200M people
Are dependent on springs. Wetlands and lean-season river flows
Equity concern: aquifer decline transfers impacts to dependent systems.

1 **Availability declines**
Falling water levels • reduced baseflow • source stress

2 **Access becomes harder**
Deeper wells • more energy • higher supply/mitigation costs

3 **₹ Coping needs resources**
Capital • technology • alternatives • institutional support

4 **! Impacts become unequal**
Least adaptive capacity — and dependent ecosystems — face greatest risk.



Equity Lens

Who has access?

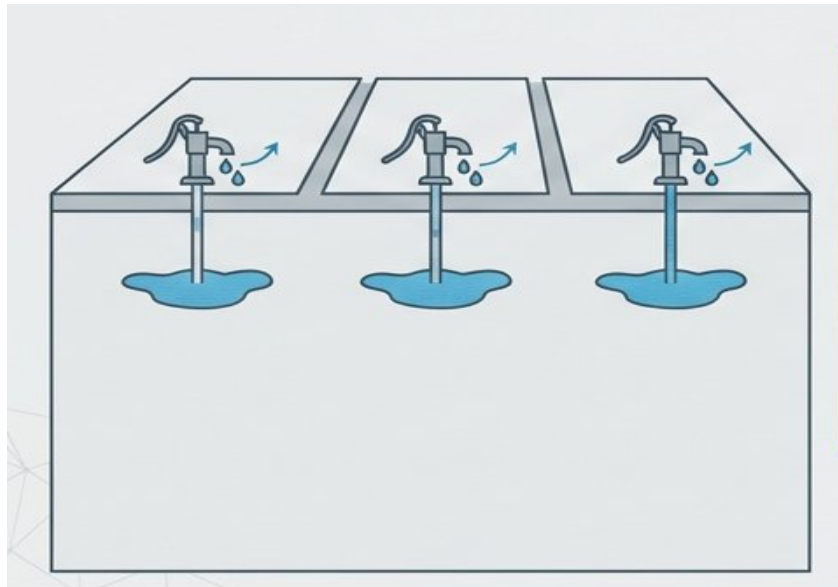
Who can adapt?

Who bears cost?

Equity in groundwater management is about balancing water for people, production and ecosystems under scarcity.

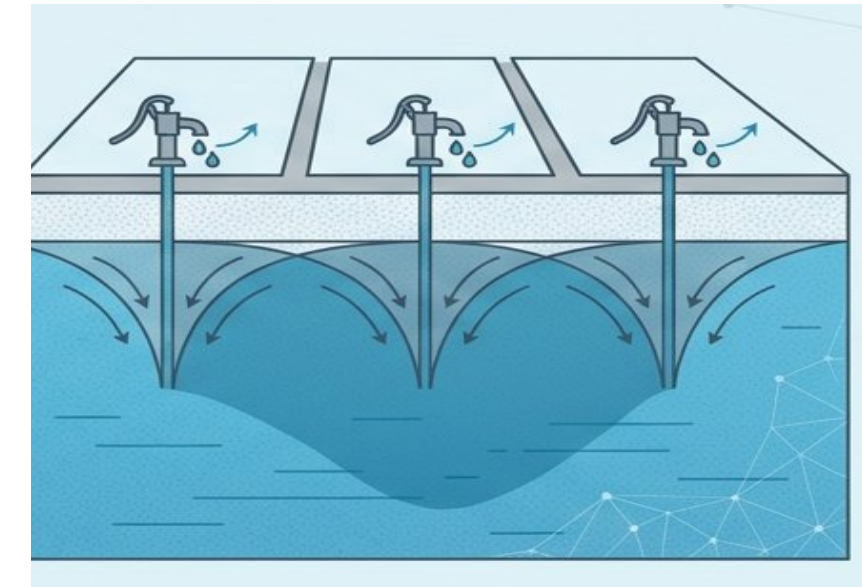
Hydrogeological Reality

1. Decentralized Access (Individual Choice)



- Millions of individual, independent wells.
- Pumping decisions are made locally based on individual water needs.

2. Shared Aquifer Response (Hydraulic Continuum)



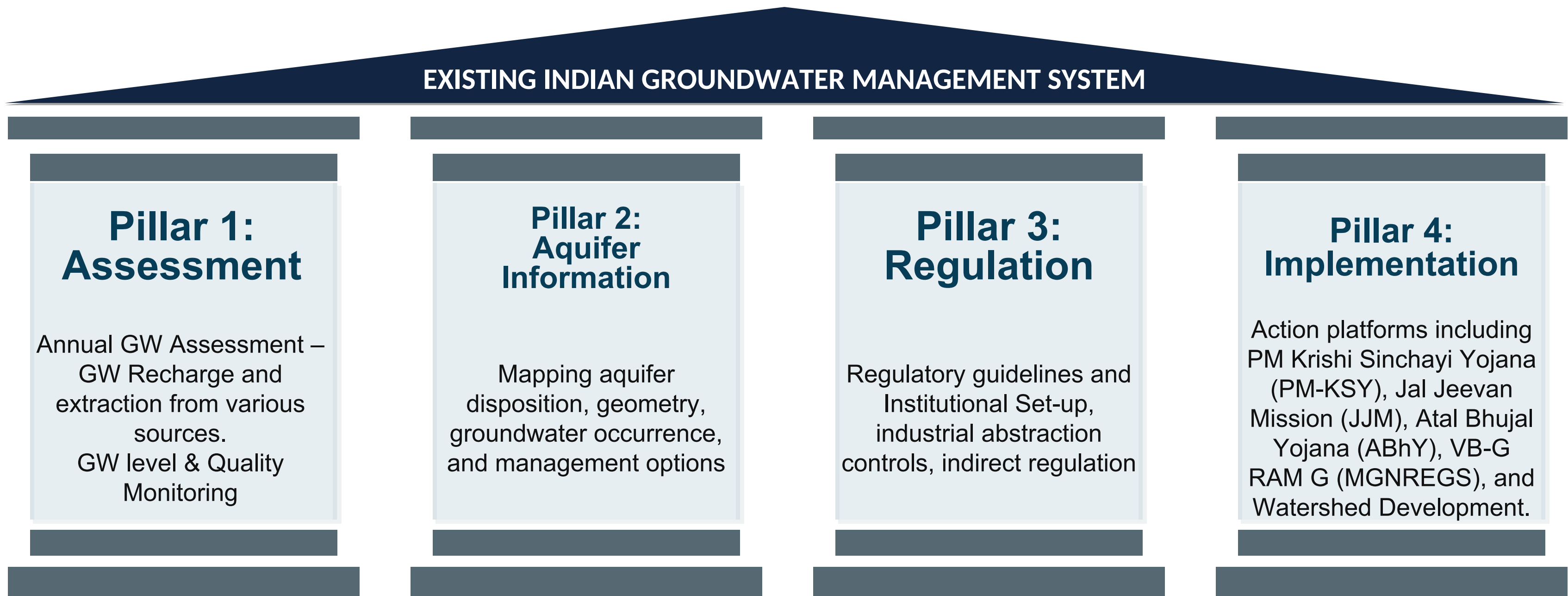
- Pumping at one well alters water levels & hydraulic gradients for neighbors.
- Intercepts groundwater discharge to connected streams & springs.

Decentralized Access ➡ Shared Aquifer Response ➡ Unequal Impacts

Cumulative Aquifer Response

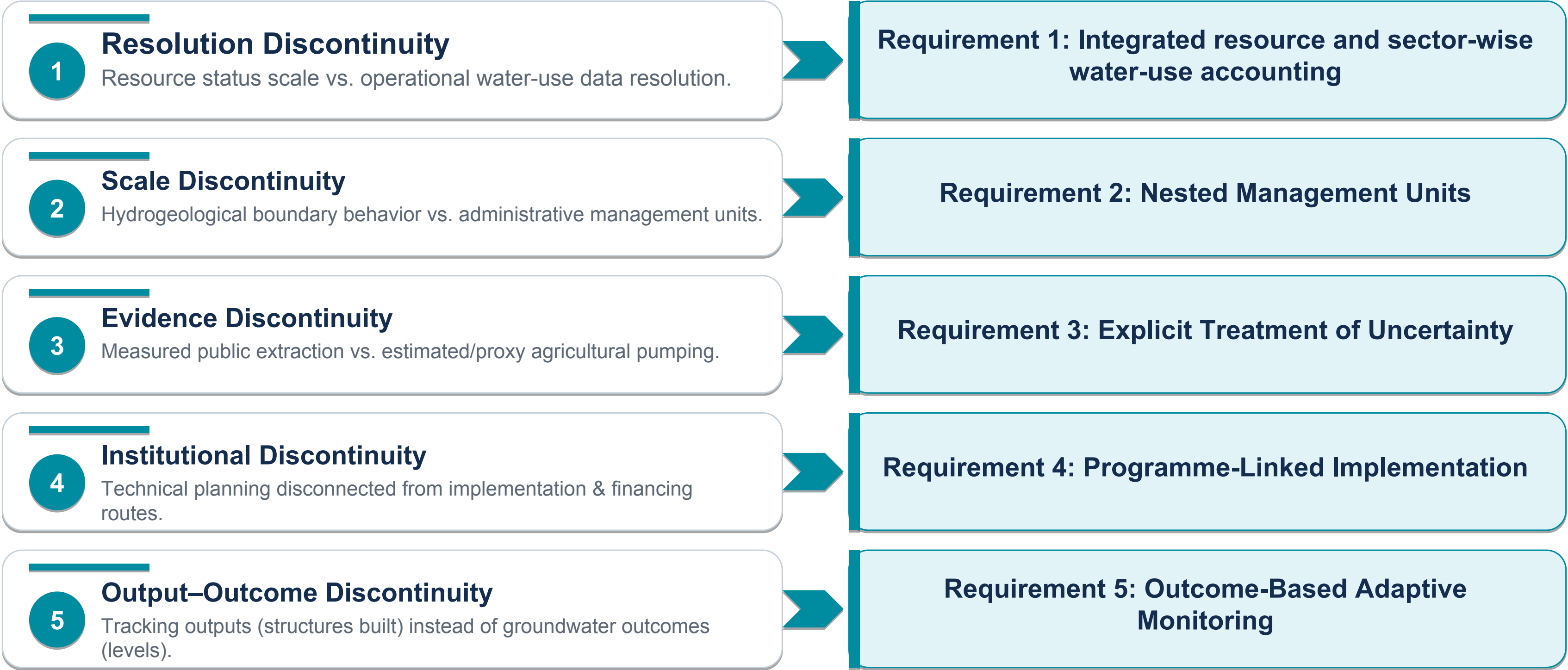
One user's pumping can affect another user's access. Groundwater management must therefore consider cumulative impacts and distributional consequences.

Existing System and Operational Weakness



THE CENTRAL OPERATIONAL WEAKNESS: Unconnected Functional Interfaces
As a result, who is using groundwater, who depends on it most, who has alternatives and who bears the impact of stress may not be brought together in the same decision process.

Diagnostic Framework: Five Discontinuities & Design Requirements



Each discontinuity identifies a specific operational gap; each requirement provides the design response.

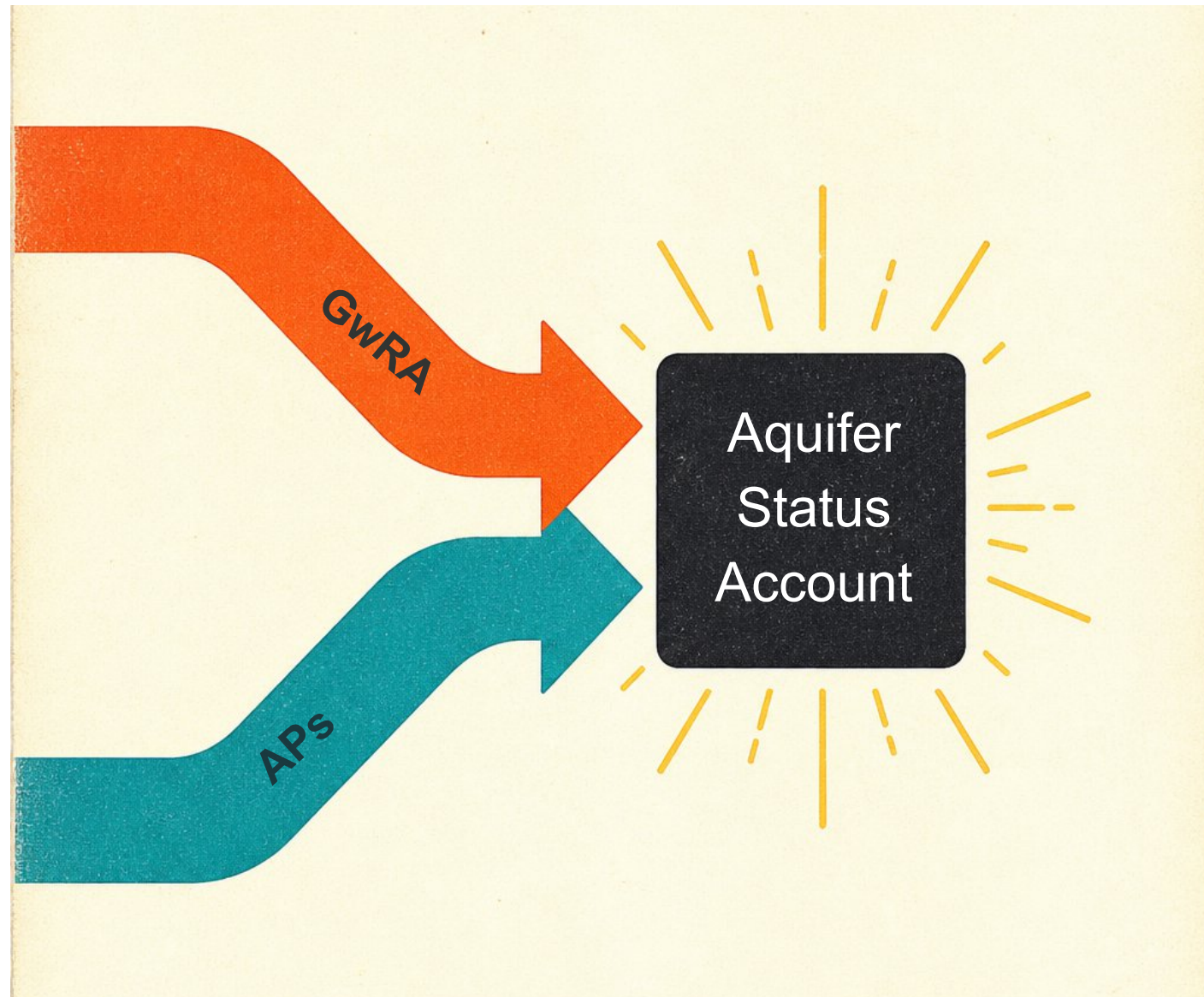
The Six-Stage Operational Cycle: Continuous Adaptive Management



CONTINUOUS ADAPTIVE FEEDBACK: Stage VI (Monitoring) continuously feeds back into Stage I (Assessment), Stage II (Water Account), and Stage III (Groundwater Budget) to revise management actions as aquifer conditions change.

Stage I — Aquifer Status Account

Establishing the common evidence base for allocation and intervention



- **Groundwater Resource Assessment (GwRA)**
Annual recharge, extractable resources, existing extraction, and assessment unit categories serving as the quantitative reference.
- **Aquifer Parameters (APs)**
Detailed hydrogeological interpretation including geometry, connectivity, levels, trends, and quality risks.
- **Aquifer Status Account**
The central pivot point evaluating resource condition, response, quality constraints, pressure, and uncertainty.

Equitable management begins with a shared account of aquifer condition. It creates a common, transparent baseline for evaluating sectoral demand, source vulnerability, and future management choices.

Stage II — Sector-wise Water-Use Accounting

ACTUAL ABSTRACTION

Question: “What are we withdrawing now?”

RWR (Reference Water Requirement)

Question: “What water is reasonably required for the stated service or productive purpose?” Justified water requirement

GDR (Groundwater Dependent Requirement)

Question: “After feasible alternatives are considered, how much of that requirement still depends on groundwater?”

Observed use $\neq$ justified requirement $\neq$ groundwater dependence

Sectoral Analysis

- Drinking & Domestic: Essential service, source reliability, efficiency, feasible conjunctive supply
- Agriculture & Livelihoods: Crop and irrigation requirement, efficiency scenario, groundwater dependence, livelihood implications
- Industry & Commercial: Measured abstraction, process-water requirement, reuse and recycling, source substitution
- Ecological Functions: Hydrogeologically demonstrated dependence, baseflow, spring and wetland constraints



What does each sector genuinely require, how dependent is it on groundwater, what alternatives exist, and what constraints must the aquifer impose?

Stage III — The Groundwater Budgeting & Security Envelope

EVIDENCE TO RECONCILE

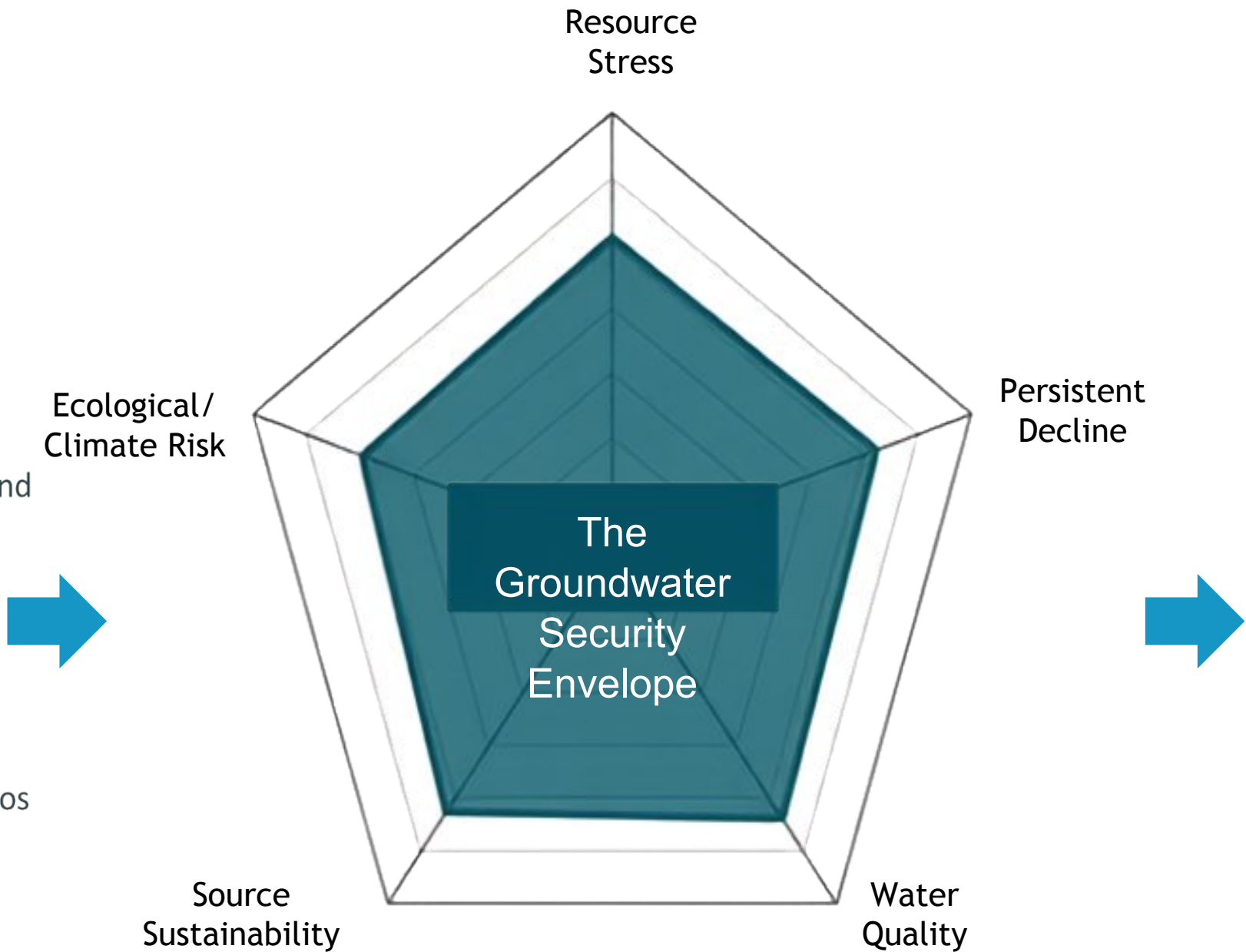
- 1

RESOURCE STATUS
Official assessment: recharge, extractable resource, stage and category
- 2

ACTUAL ABSTRACTION
Measured or estimated sectoral withdrawals and current groundwater pressure
- 3

SCENARIO-BASED GDR
Reference water requirement after feasible alternatives and demand-management scenarios
- 4

AQUIFER RESPONSE
Water levels, drawdown, quality, source reliability and ecological response



ADAPTIVE OPERATING STRATEGY

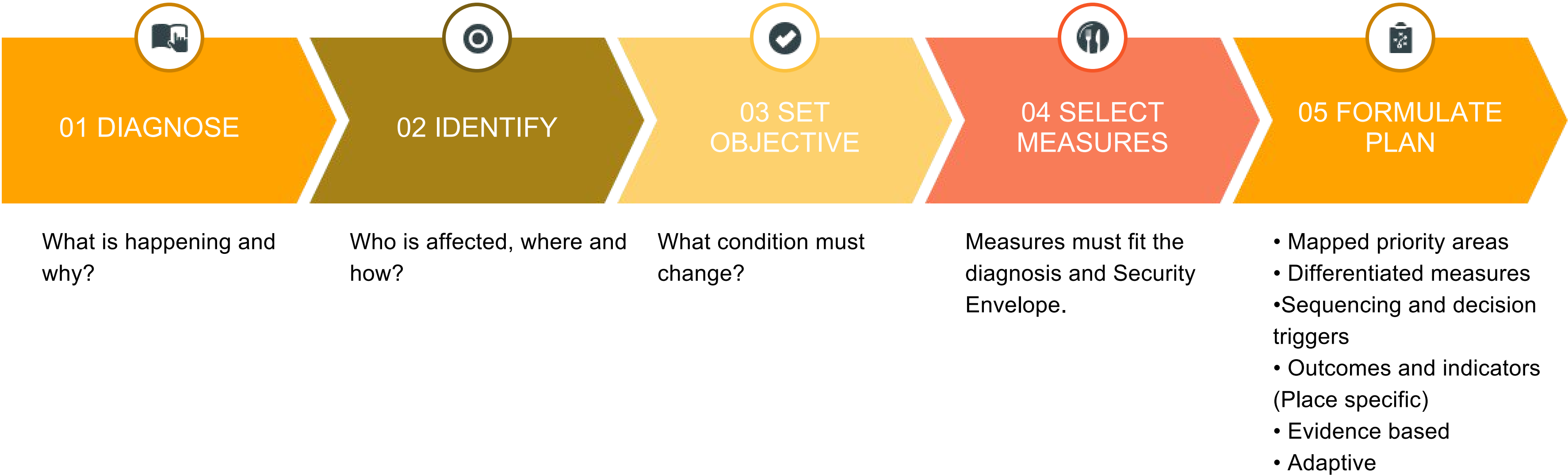
Indicators: groundwater level, drawdown, recovery, yield, quality and service reliability

NORMAL	Routine demand management; planned recharge or substitution where justified
ALERT	Reduce avoidable demand; strengthen monitoring and advance feasible substitution
CRITICAL	Protect essential services; activate alternatives and defer discretionary expansion
EMERGENCY	Direct regulation of GW extraction in all sectors, through enforceable means
RECOVERY	Relax temporary measures cautiously while retaining actions with durable benefit

It is a condition-specific management decision construct.

Stage IV — Groundwater Security Planning

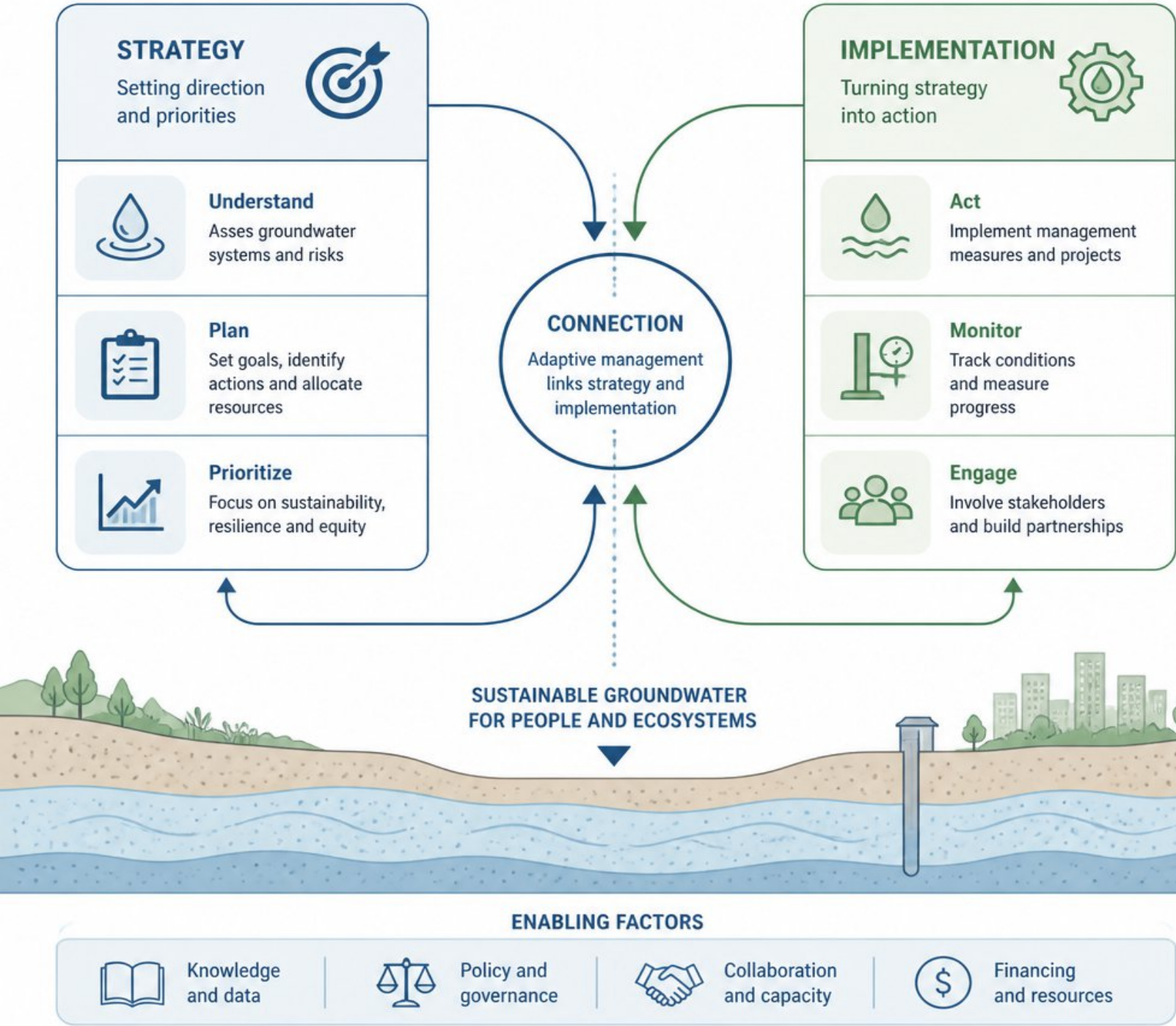
Translating diagnosed aquifer risks into place-specific and equitable management measures



Stage V — Institutional and Programme Alignment

INPUT FROM STAGE IV: Groundwater Security Plan (priority areas, differentiated measures, sequencing, decision triggers)

Priority	Management Response	Accountable Agency	Programme / Institutional Convergence	Measurable Outcome
 Drinking-Water Security Public source at risk	• Source protection • Pumping management • Alternative supply	Drinking water agency	• Groundwater agency • Relevant programmes • Central/State/ local funds	• Reliable source • Safe water • Service continuity
 Agriculture & Livelihoods Declining irrigation	• Demand moderation • Efficient irrigation • Recharge	Agriculture / Irrigation Dept.	• Agriculture & Irrigation schemes • Rural-employment & State agriculture programmes	• Reduced abstraction • Improved WL • Irrigation access
 Industry / Commercial Use High abstraction	• Metering • Efficiency • Reuse • Substitution	User establishment, regulatory agencies	• GW / pollution-control authorities • Regulatory incentives	• Lower freshwater abstraction • Higher reuse • Compliance
 Ecological Dependence Springs / wetlands under stress	• Protection zones • Pumping controls • Recharge	Water-resources, Environment authority	• Local government • Watershed / wetland & State environmental funds	• Spring discharge • Baseflow • Ecosystem-condition trend



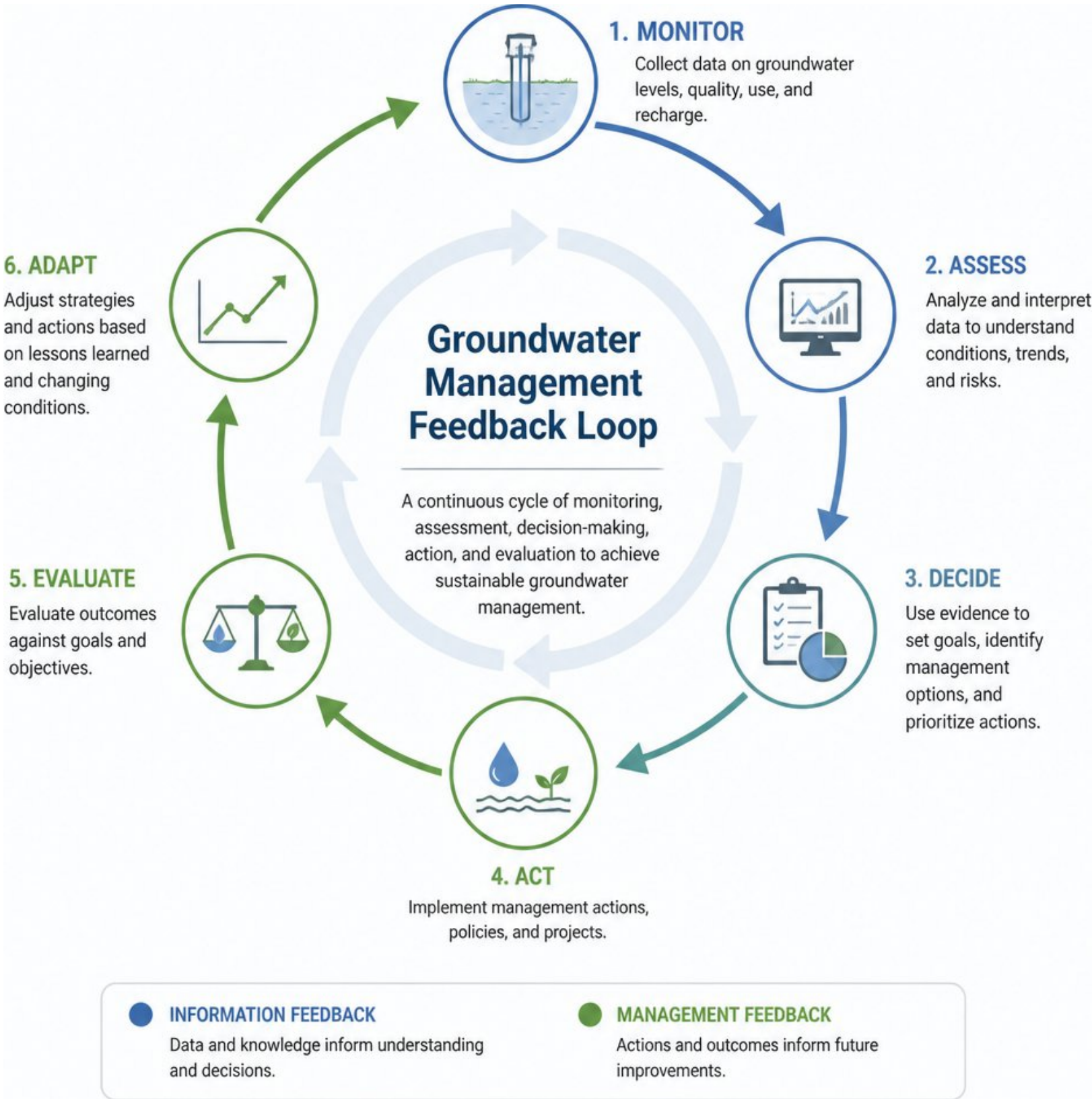
No action enters the plan without an accountable owner, a financing route and a measurable outcome.
Using existing mandates and programmes to deliver the plan.

STAGE VI — MONITORING, EVALUATION & ADAPTIVE REVISION

Output ≠ Outcome

The transition from implementation to sustainable results requires a continuous feedback loop:

- Implementation Performance: Tracking activities against planned milestones.
- Groundwater/Service Response: Evaluating actual system impacts.
- Adaptive Revision: Using performance data to inform and update Stages I, II, and III.



Interpret groundwater response with rainfall, antecedent groundwater conditions and longer-term trends.

Rural Drinking Water Security Framework

Connect source operation and service reliability with aquifer conditions, surrounding abstraction and water-quality risks

1 SOURCE + SERVICE ACCOUNTABILITY

LOCAL SERVICE ARRANGEMENT

GP / VWSC / Paani Samiti or other accountable service arrangement

- SOURCE** Abstraction and water quality
- SERVICE** Reliability, distribution losses and O&M
- CONTINGENCY** Alternate supply and emergency arrangements

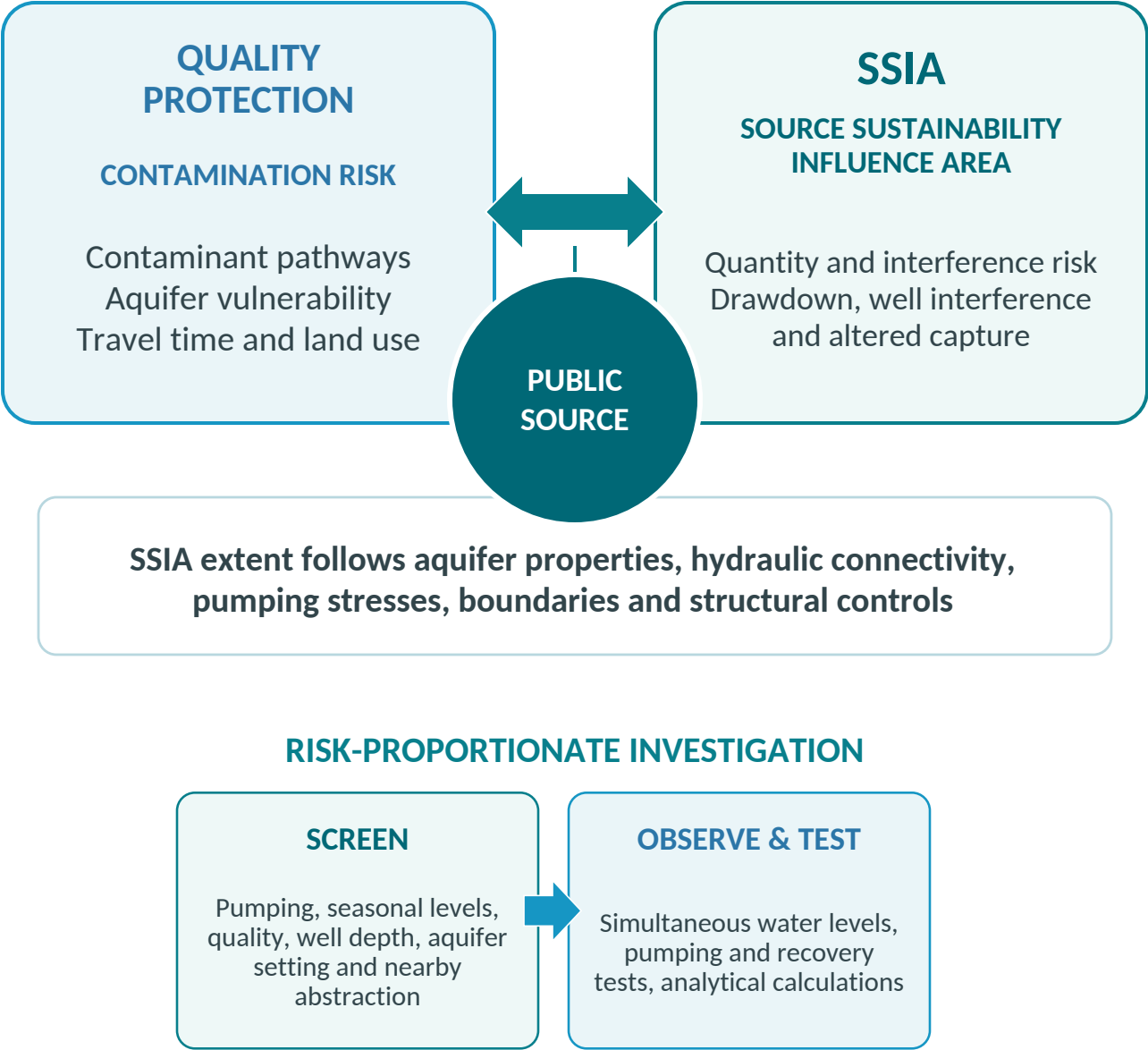
SSOR

Source Sustainability and Operating Record

- Aquifer tapped and well construction
- Pumping regime and seasonal groundwater levels
- Yield, recovery and water quality
- Nearby significant abstraction
- Operating limits and alternate source arrangements

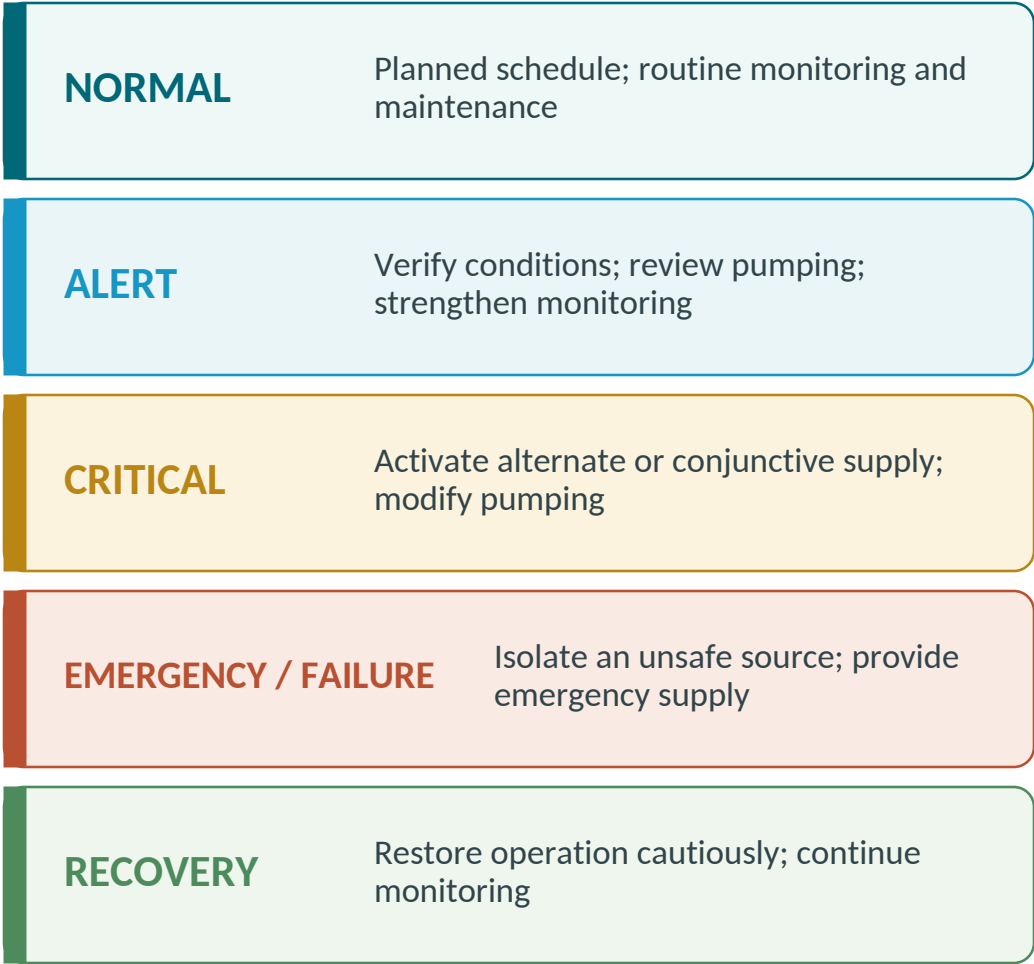
Review the SSOR periodically and link it to the wider hydrogeological management unit

2 DUAL PROTECTION



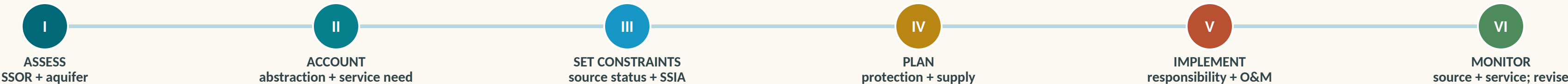
3 ADAPTIVE SOURCE OPERATION

Indicators: groundwater level, drawdown, recovery, yield, quality and service reliability



Triggers depend on local source performance.

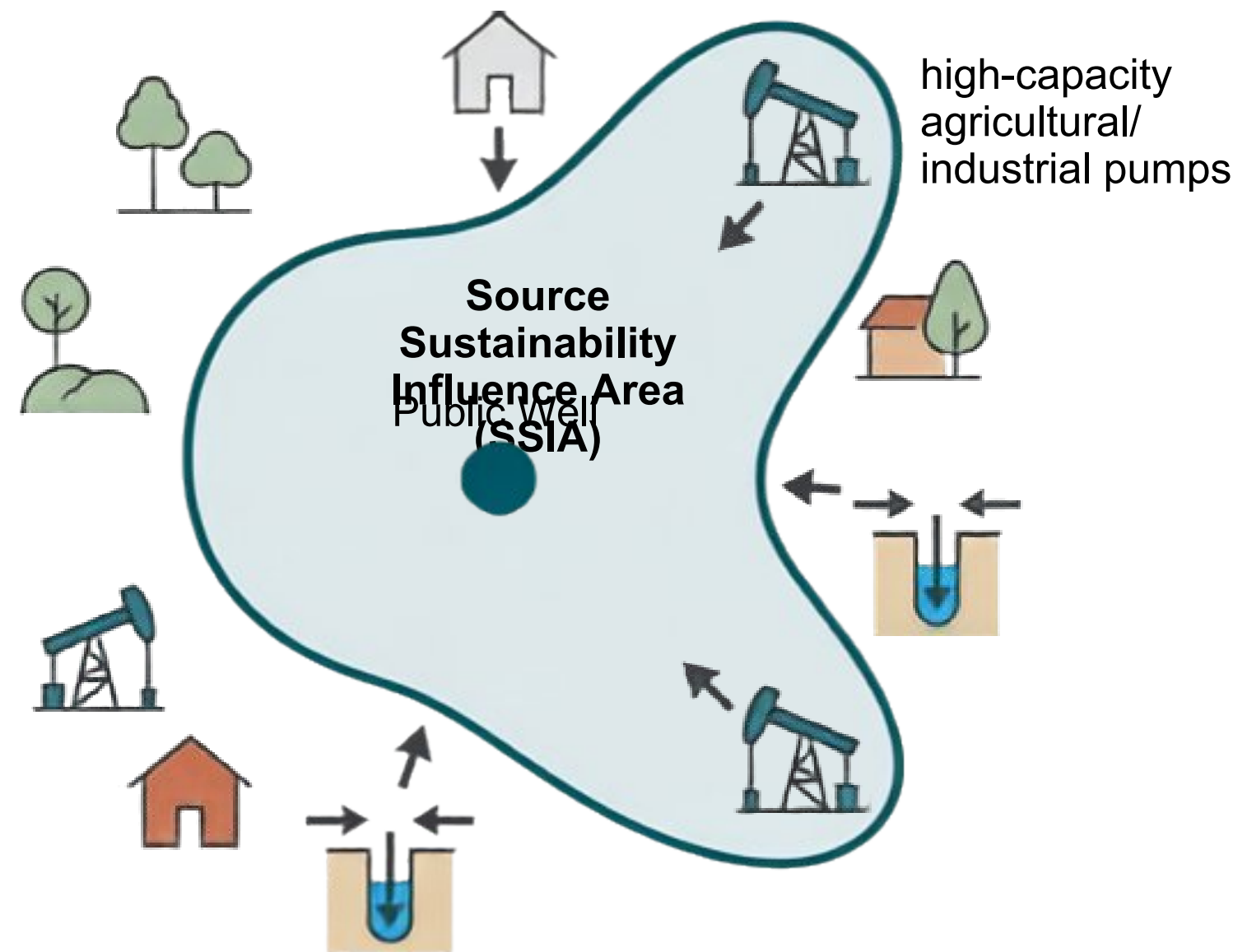
SOURCE-SCALE APPLICATION OF THE SIX-STAGE FRAMEWORK



Rural Drinking Water Application: SSIA

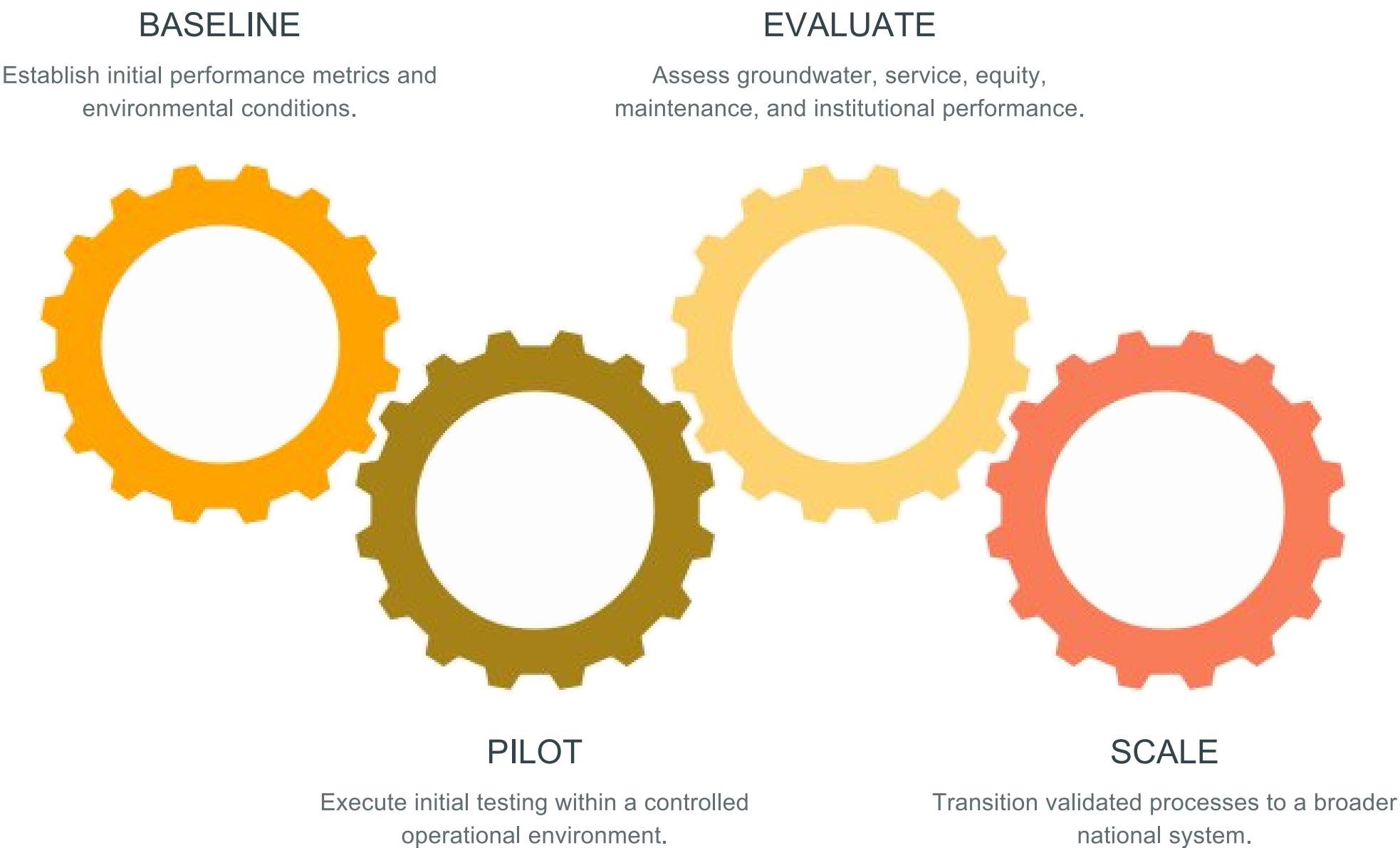
Propose

8 screens for surrounding abstraction that may impair public source reliability through drawdown, interference, or altered capture.



FROM PILOT TESTING TO SCALE-UP

Operational sequence for system integration



THE KNOWLEDGE EXISTS; THE TASK IS OPERATIONAL INTEGRATION. Note:
This design requires pilot validation—not yet a validated national system.

FROM AQUIFER KNOWLEDGE TO
GROUNDWATER SECURITY

THANK YOU

Questions and Discussion

An Operational Framework for Equitable
Groundwater Management in India

