

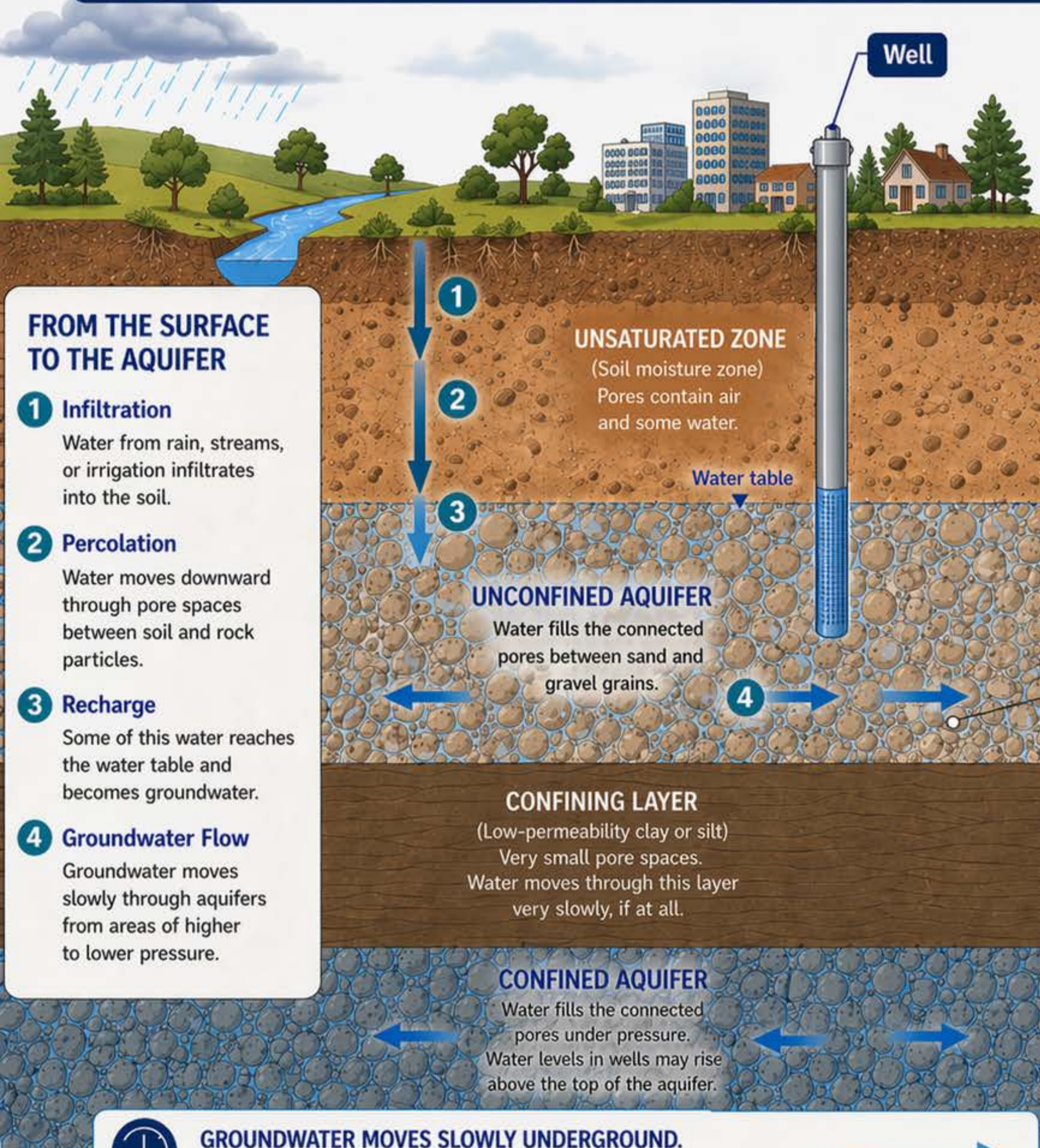
WHAT AN AQUIFER ACTUALLY IS

Aquifers are underground layers of sand, gravel, rock, or sediment that store and transmit groundwater.



An aquifer is **NOT** an underground lake.

Groundwater fills the tiny spaces (pores and cracks) between grains of rock and sediment.



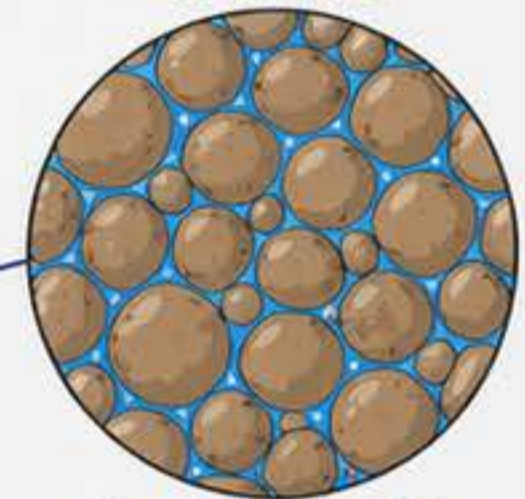
LAND SURFACE

- Rainfall, streams, lakes, and irrigation provide water that can recharge groundwater.
- Some water runs off, some evaporates, and some soaks into the ground.

UNCONFINED AQUIFER

- The upper surface is the water table.
- Water is under atmospheric pressure.
- Wells in this aquifer are often shallower.

WHAT IT LOOKS LIKE UP CLOSE



Groundwater fills pores and cracks
Tiny spaces store and move water.

CONFINED AQUIFER

- Water is under pressure from overlying layers.
- Wells may be deeper.
- Water can rise in the well when tapped.

FROM THE SURFACE TO THE AQUIFER

1 Infiltration

Water from rain, streams, or irrigation infiltrates into the soil.

2 Percolation

Water moves downward through pore spaces between soil and rock particles.

3 Recharge

Some of this water reaches the water table and becomes groundwater.

4 Groundwater Flow

Groundwater moves slowly through aquifers from areas of higher to lower pressure.

UNSATURATED ZONE

(Soil moisture zone)
Pores contain air and some water.

UNCONFINED AQUIFER

Water fills the connected pores between sand and gravel grains.

CONFINING LAYER

(Low-permeability clay or silt)
Very small pore spaces.
Water moves through this layer very slowly, if at all.

CONFINED AQUIFER

Water fills the connected pores under pressure.
Water levels in wells may rise above the top of the aquifer.



GROUNDWATER MOVES SLOWLY UNDERGROUND.

It can take days, months, or even years for water to travel short distances.

KEY TAKEAWAYS



Aquifers are geologic materials, not empty cavities or lakes.



Groundwater is stored in pores and cracks and moves very slowly.



Confining layers can protect water quality but also limit recharge and recovery.



Not every layer can store, transmit, or yield usable water. It depends on matters.

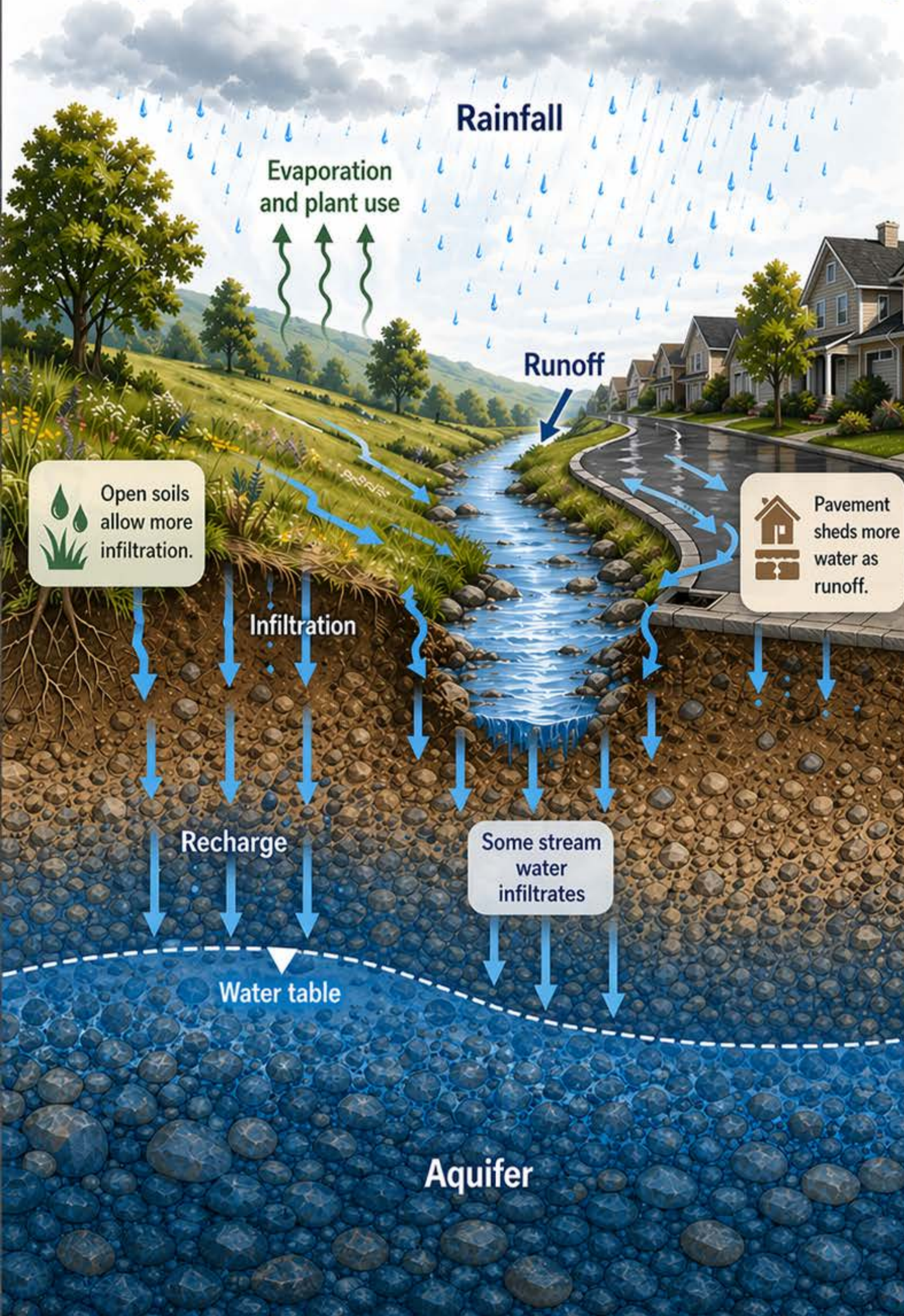


POLICY TAKEAWAY





Aquifer storage depends on geology.
Not every underground layer can store, transmit, or recover water effectively.

How Groundwater Recharge Works







Only some rain and surface water soak into the ground deeply enough to recharge an aquifer.



What happens to rainfall?

-  1 Some runs off to streams
-  2 Some evaporates or is used by plants
-  3 Some infiltrates into soil
-  4 Some stream water infiltrates and only some becomes groundwater recharge

Recharge conditions

More recharge	Less recharge
 Permeable soils	 Pavement
 Open land	 Compacted soils
 Connected floodplains	 Steep runoff pathways



Policy takeaway: Recharge is shaped by land use. Planning decisions at the surface affect groundwater storage below.

What Managed Aquifer Recharge Means

Managed aquifer recharge intentionally moves water underground so it can be stored and used later.

WATER SOURCES FOR MANAGED AQUIFER RECHARGE



Stormwater



River water during wet periods



Highly treated recycled water



Treated water only:

Recharge water must meet project-specific water-quality and monitoring requirements.

RECHARGE BASIN



A shallow basin that spreads water out so it can soak into the ground.

Recharge basin (spreading basin)

Surface infiltration

Stored groundwater

Injection well

Recovery well

DEEP INJECTION



Water is delivered below the surface into the aquifer through a well.

DRY PERIOD



Water recovered during dry periods

Confining layer

Limits downward movement and helps keep water stored.

HOW MANAGED AQUIFER RECHARGE WORKS



Capture water



Recharge aquifer



Store underground



Recover later



Policy takeaway:
MAR turns suitable aquifers into underground storage infrastructure.



Builds drought resilience



Protects water supplies

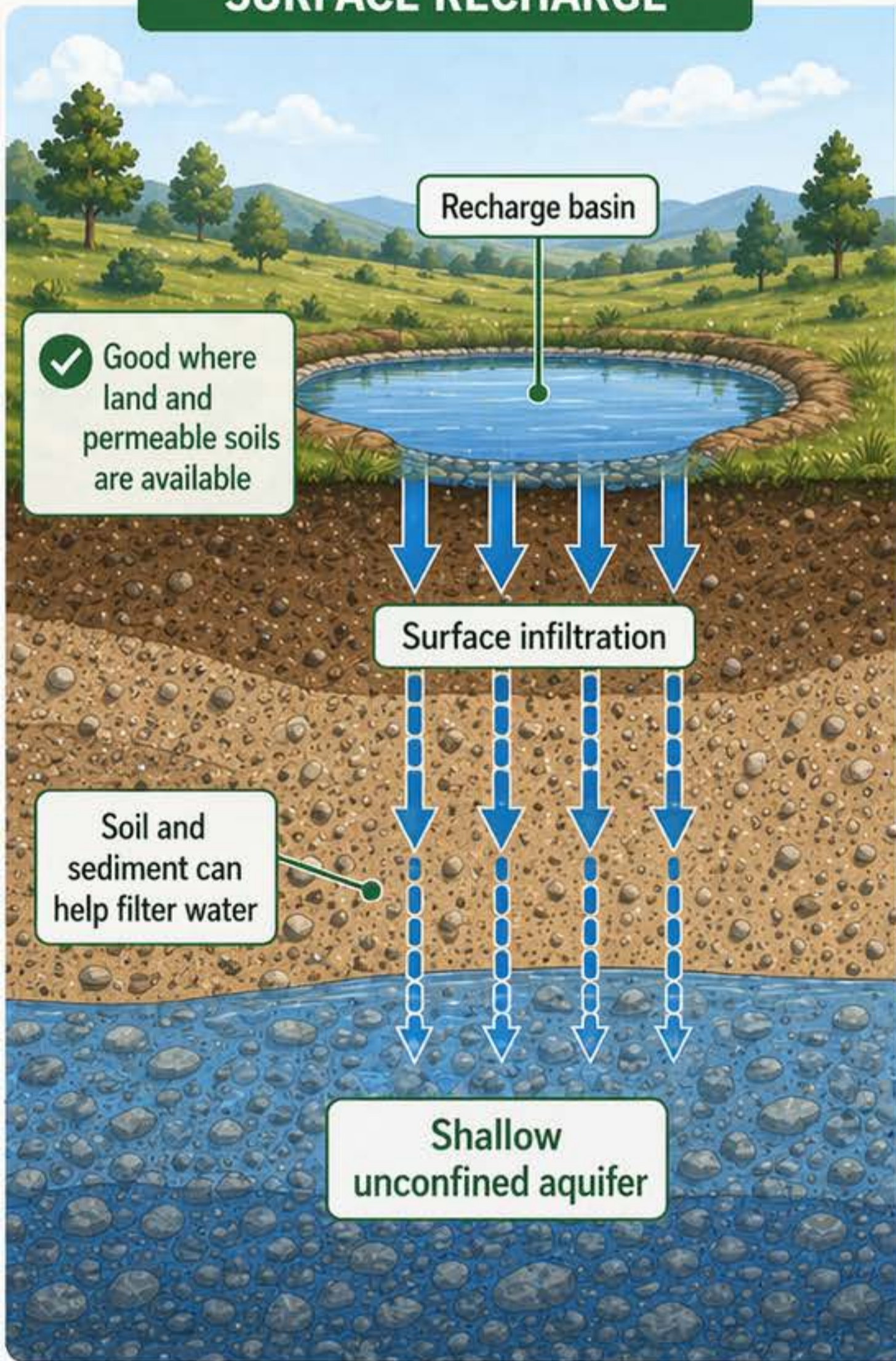


Supports sustainable water management

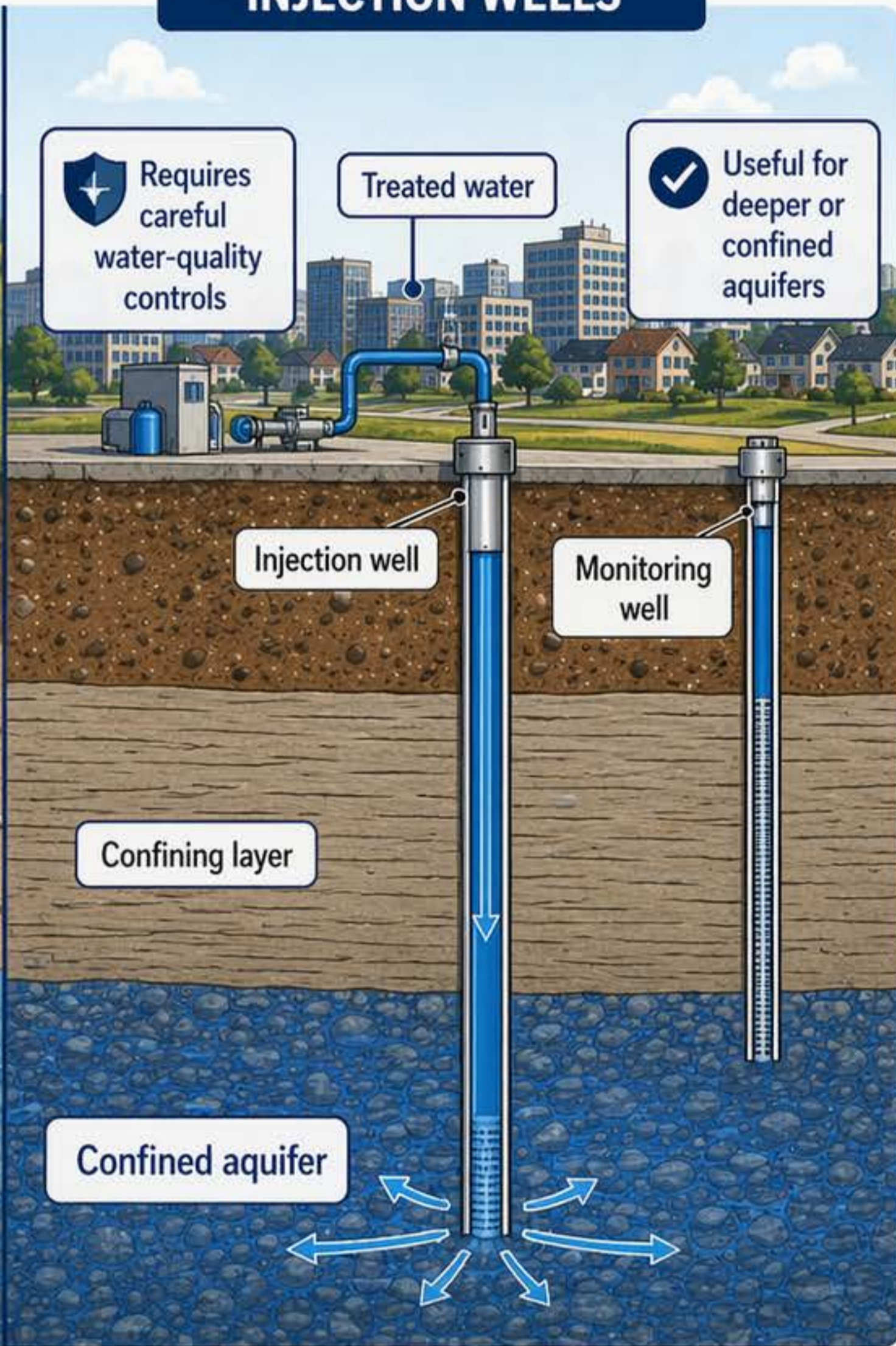
Surface Recharge vs. Injection Wells

Two common managed aquifer recharge methods fit different aquifers, water sources, and site conditions.

SURFACE RECHARGE



INJECTION WELLS



BEST FIT

Surface recharge

- ✓ Land available
- ✓ Shallow aquifer
- ✓ Permeable soils

Injection wells

- ✓ Limited land
- ✓ Confined aquifer
- ✓ Treated water needed



Policy takeaway: The right recharge method depends on geology, land availability, water quality, and project goals.

Why Aquifer Storage Can Help with Drought

STORE WATER UNDERGROUND WHEN IT'S AVAILABLE.
RELY ON IT WHEN IT'S NOT.



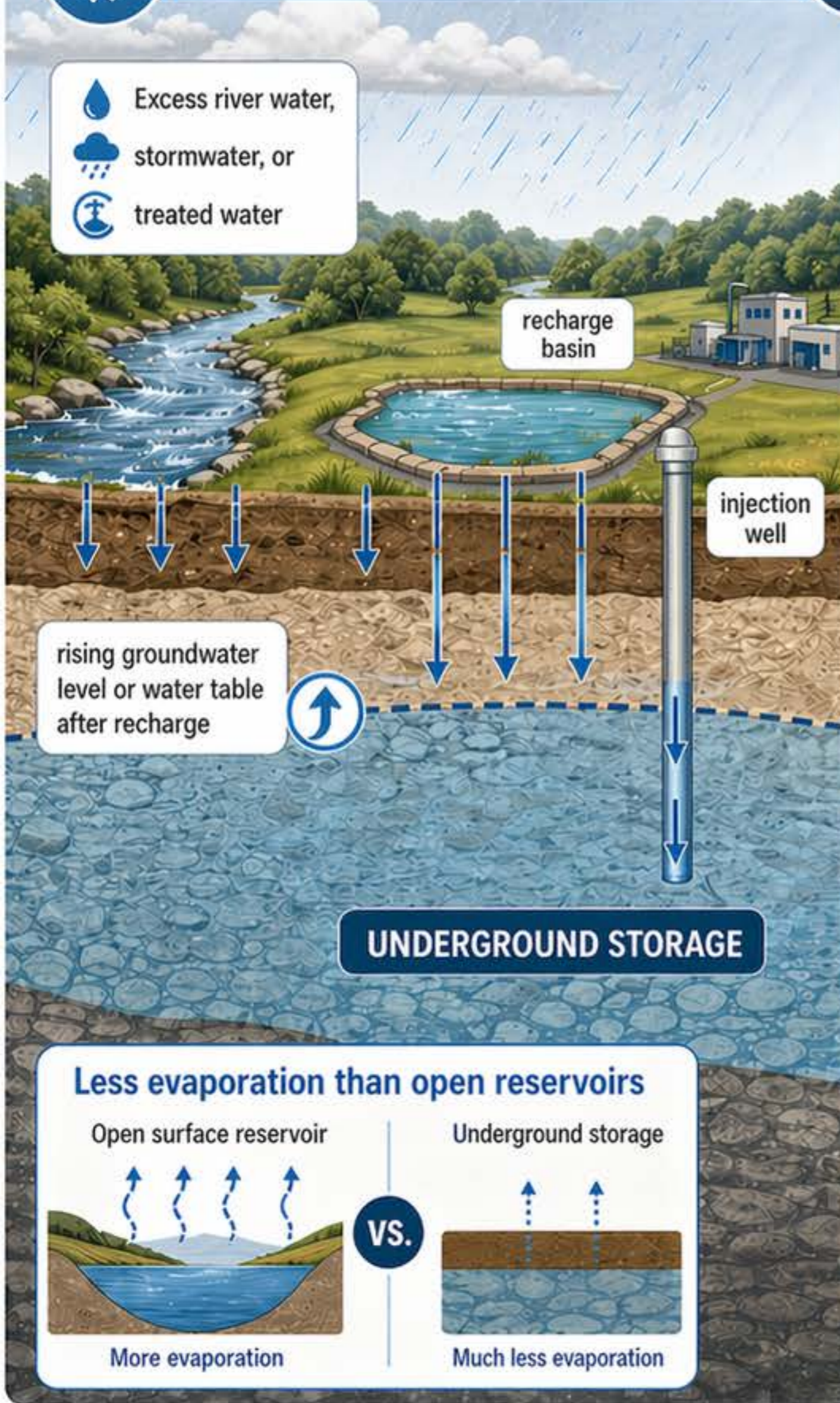
WET YEAR: STORE WATER



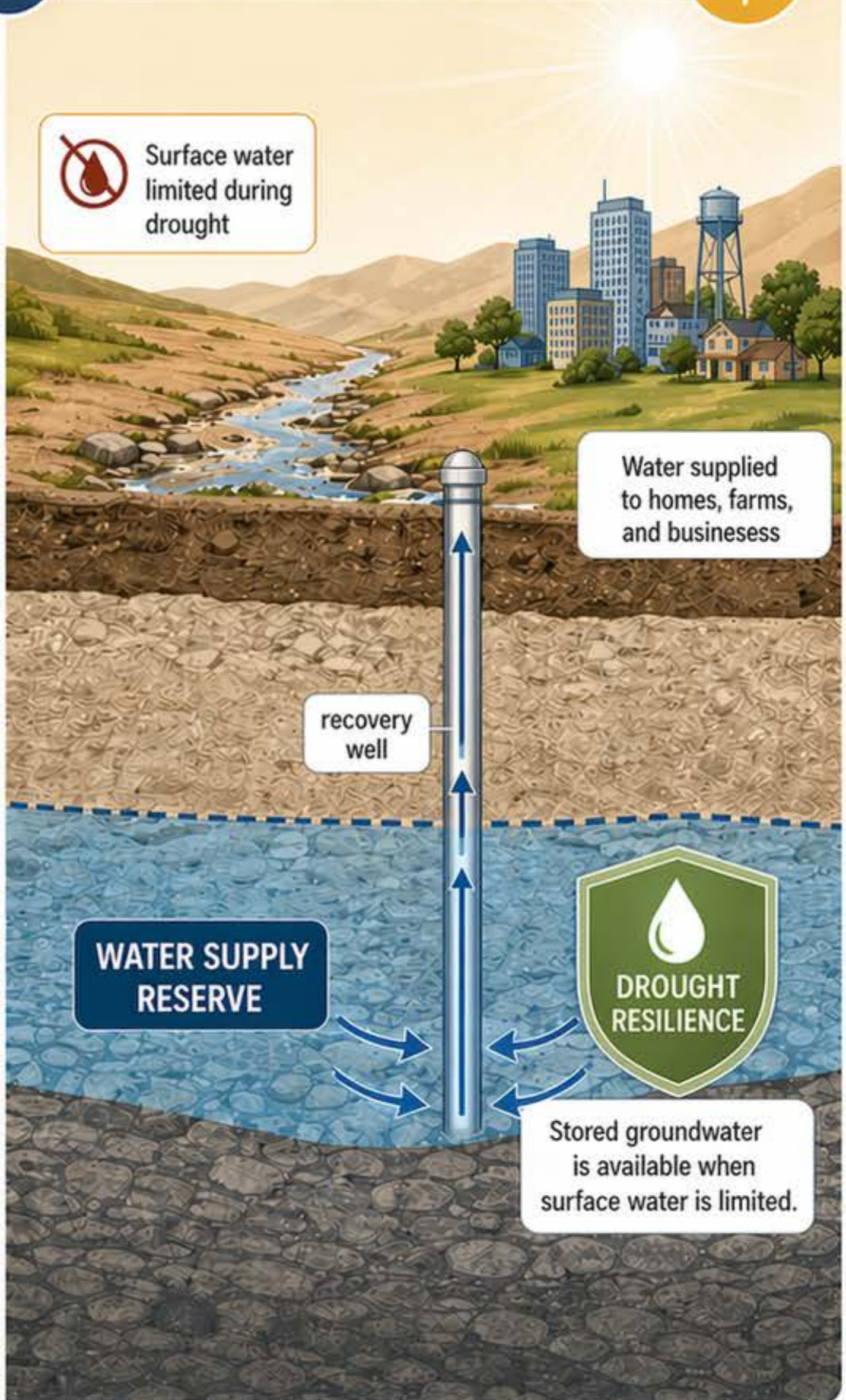
DRY YEAR: RECOVER WATER



- Excess river water,
- stormwater, or
- treated water



- Surface water limited during drought



ONE TOOL IN A BROADER WATER STRATEGY



Conserve water



Protect watersheds



Improve water efficiency



Plan and collaborate



Build and maintain storage (surface and groundwater)



Aquifer storage helps build resilience, but it has limits.

- Depends on local geology and water quality
- Storage size is finite
- Not a substitute for conservation and planning

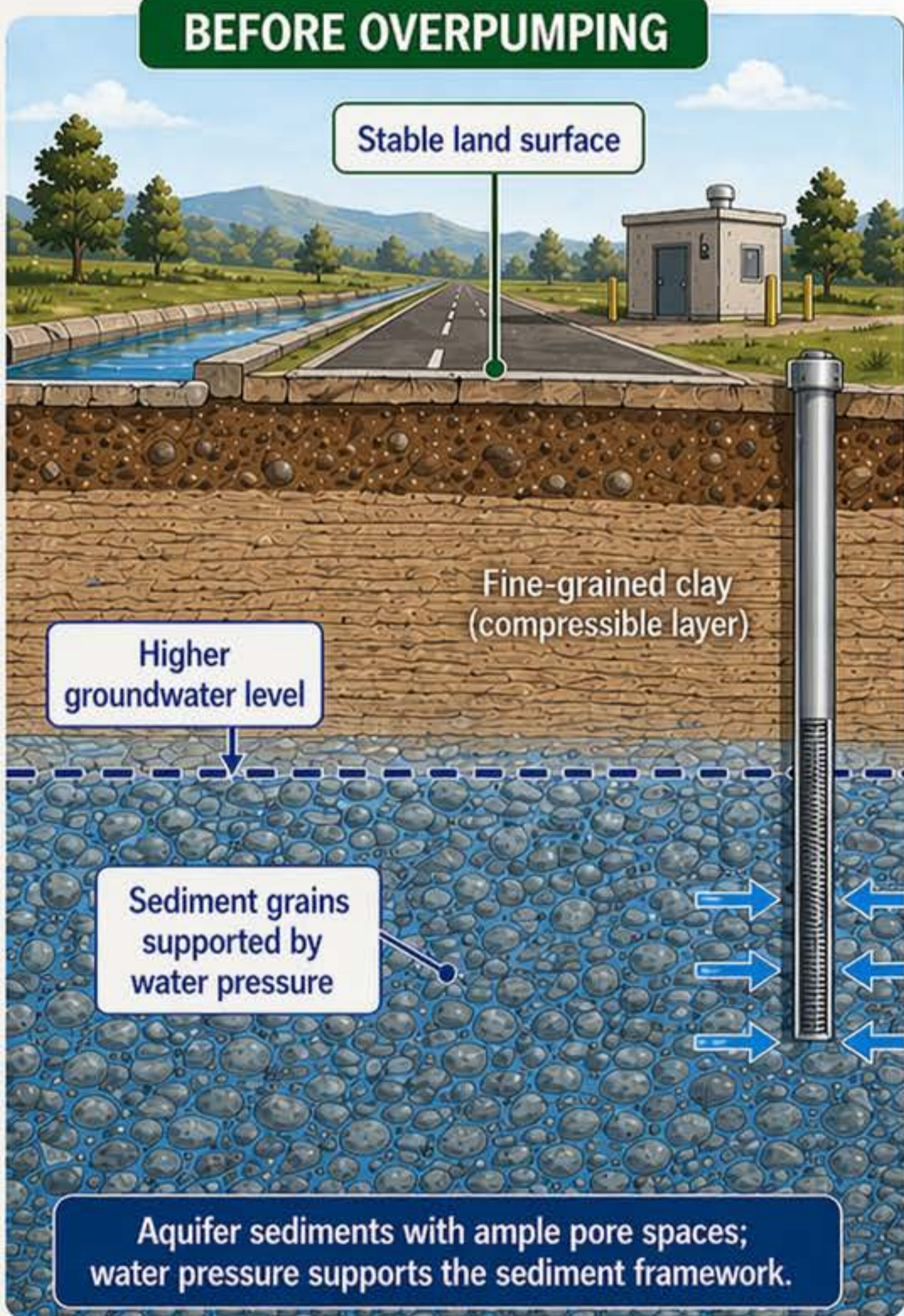


Policy takeaway: Managed Aquifer Recharge is most useful when planned **before drought**, not only during drought.

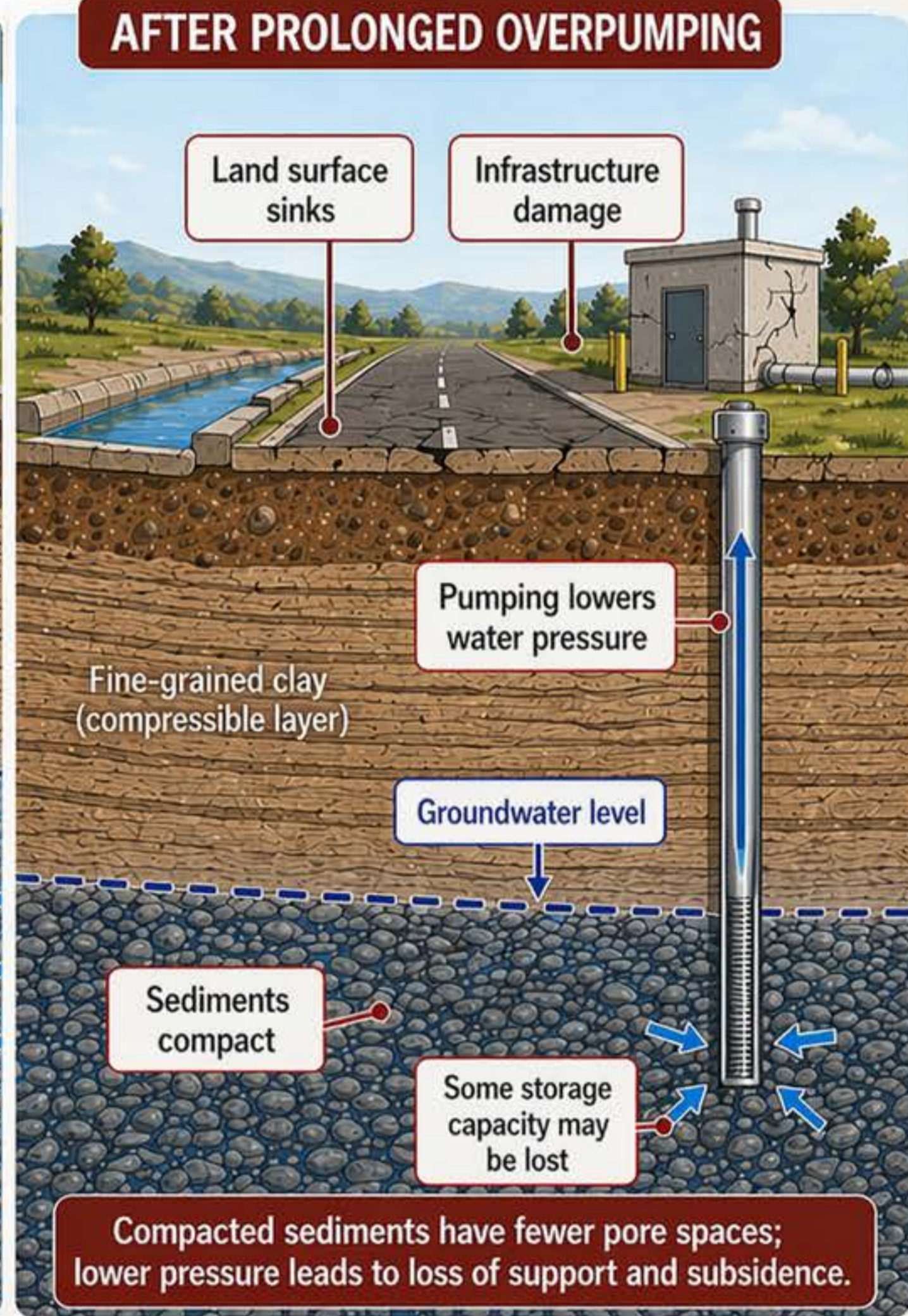
How Groundwater Depletion Can Cause Land Subsidence

Excessive groundwater pumping lowers water pressure, compacts aquifer sediments, and causes the land surface to sink.

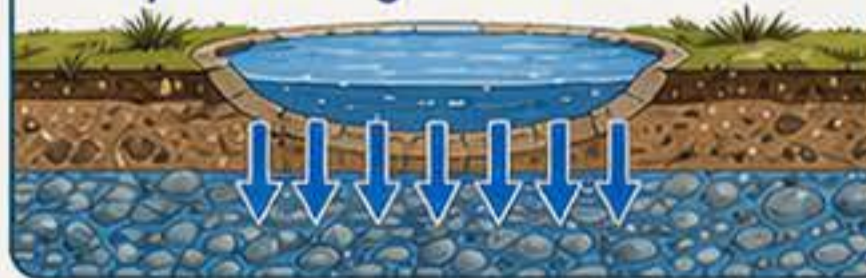
BEFORE OVERPUMPING



AFTER PROLONGED OVERPUMPING



Managed recharge can help restore groundwater levels.



! Some compaction may be permanent.



- Overpumping can lower groundwater pressure.



- When fine-grained sediments compact, the ground above can sink.



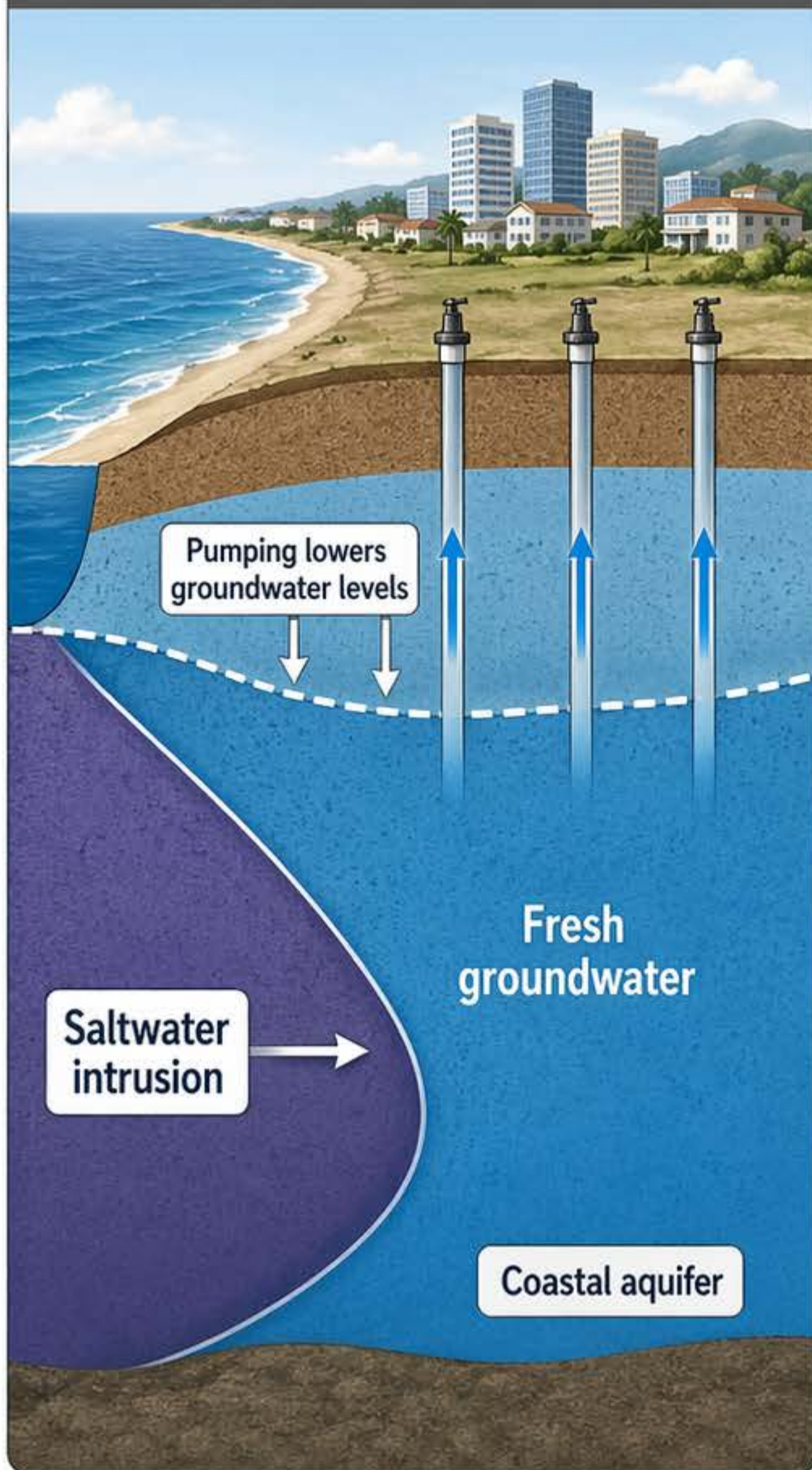
- Some lost storage capacity cannot be fully recovered.



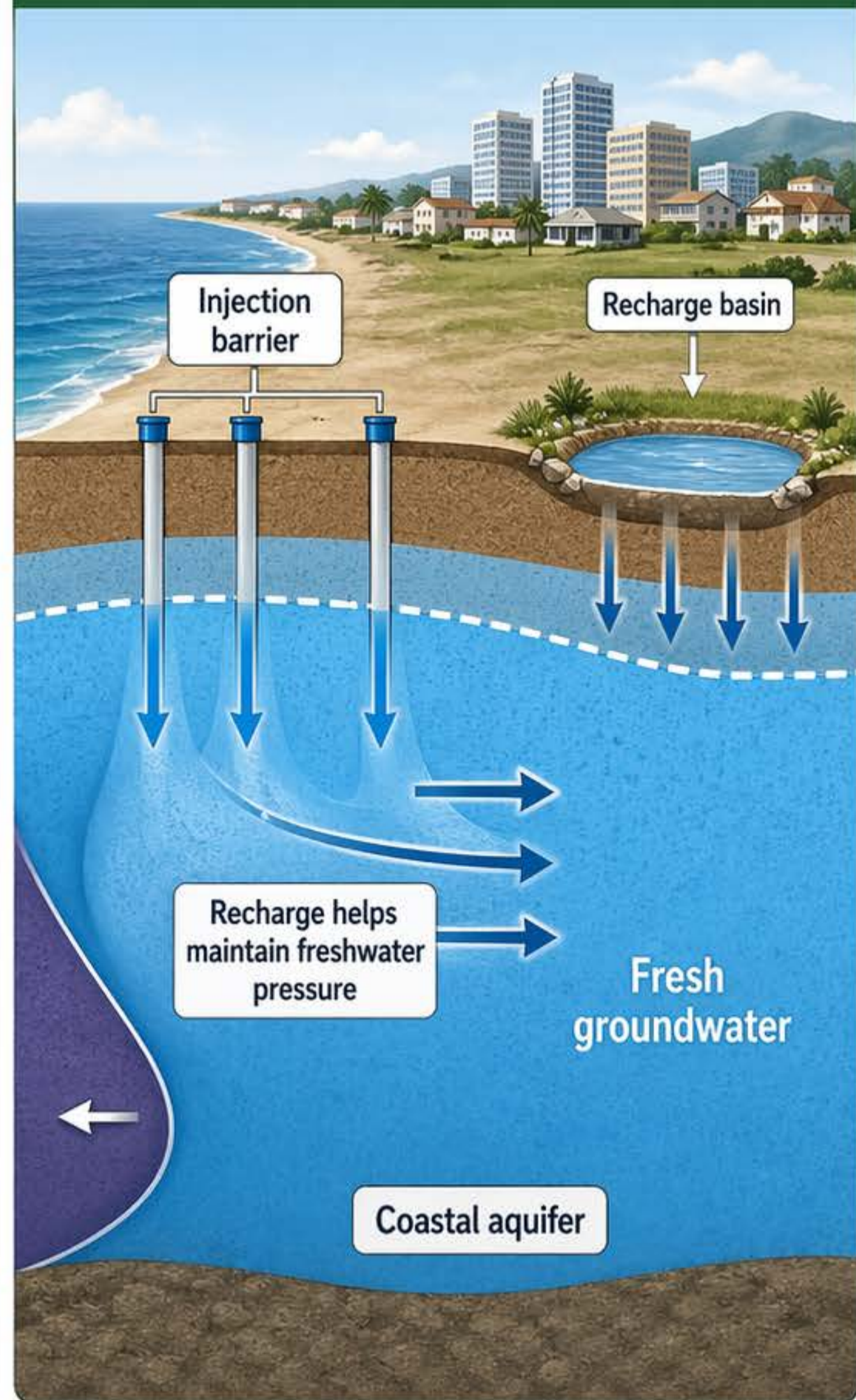
Policy takeaway: Groundwater management protects both water supply and infrastructure. Preventing subsidence is easier than reversing it.

How Recharge Can Help Protect Coastal Aquifers

1. WITHOUT ENOUGH RECHARGE



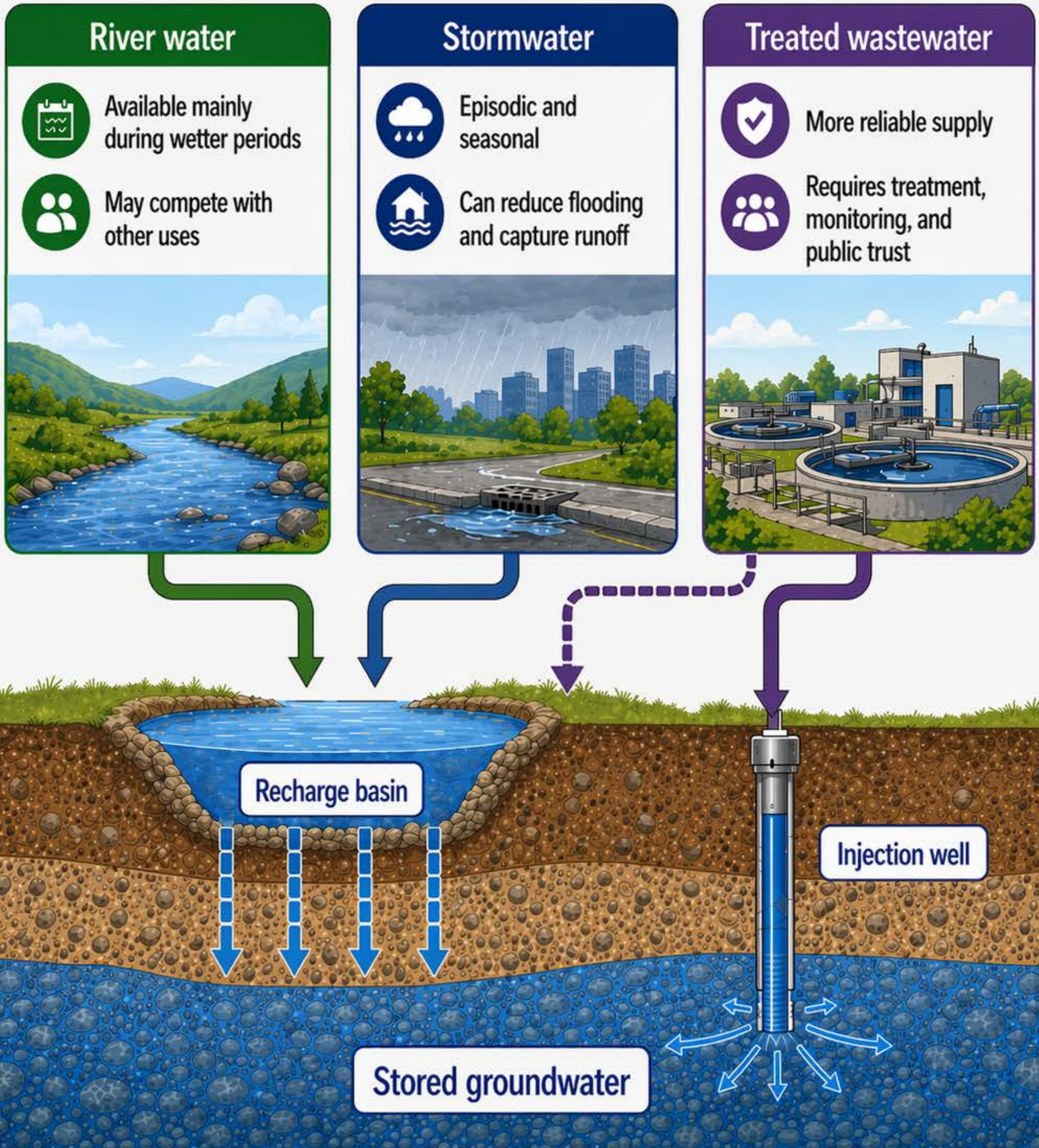
2. WITH RECHARGE AND INJECTION BARRIER



Policy takeaway: In coastal areas, recharge can protect water supply by helping keep saltwater out of freshwater aquifers.

Where Recharge Water Comes From

Managed aquifer recharge (MAR) projects can use different water sources, each with different availability, reliability, treatment needs, and policy tradeoffs.



Policy takeaway: Recharge projects depend as much on source-water planning as on aquifer geology.

How Geology Determines Whether MAR Will Work

Managed aquifer recharge (MAR) works best where geology allows water to enter, be stored underground, and be recovered later.



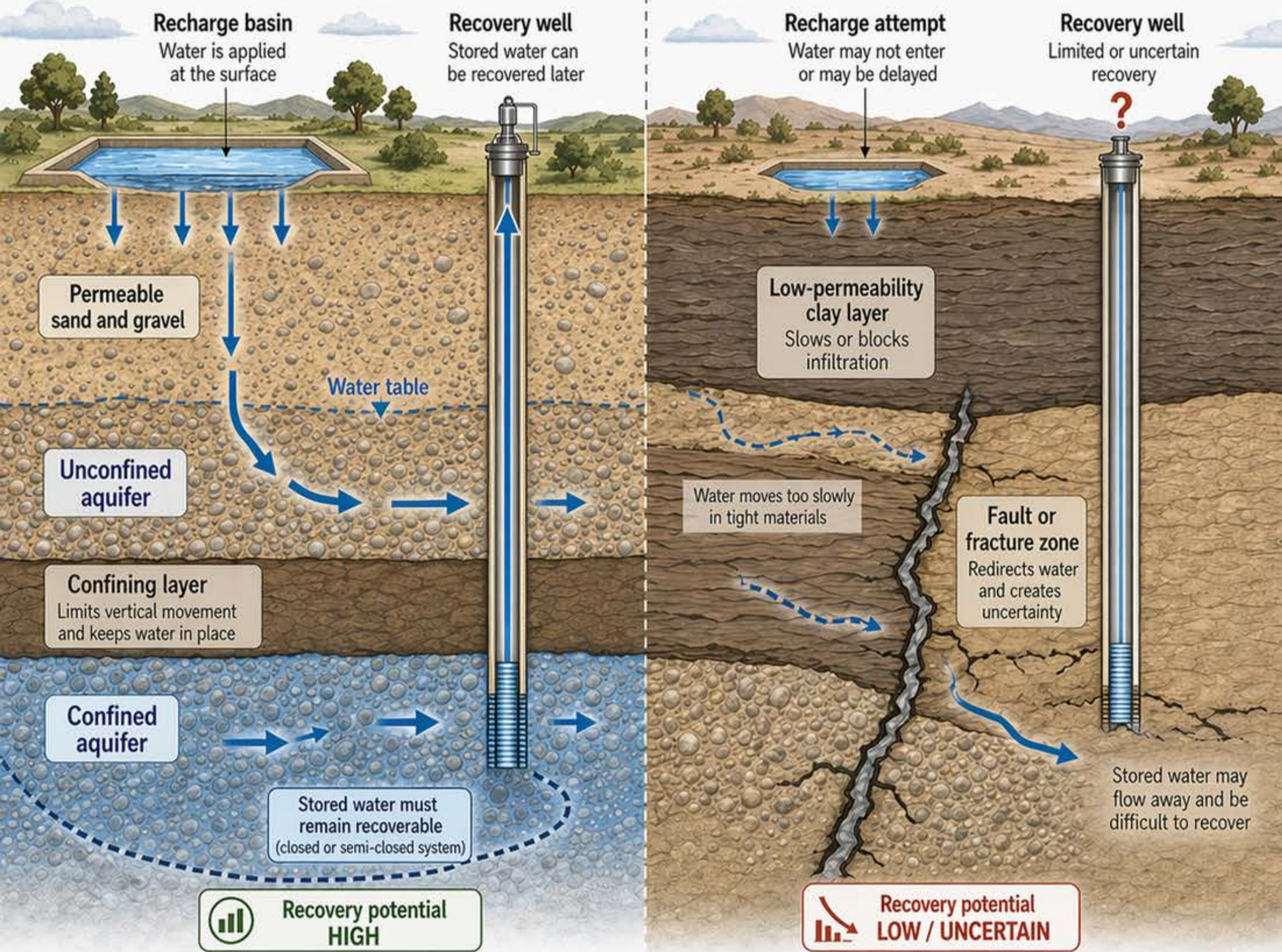
MORE SUITABLE FOR MAR

Geology supports recharge, storage, and recovery



LESS SUITABLE FOR MAR

Geology limits storage and makes recovery uncertain



More suitable for MAR

- Permeable materials
- Storage space in the aquifer
- Water can be recovered later
- Groundwater flow can be predicted and monitored

Less suitable for MAR

- Thick clay layers
- Water moves too slowly or too quickly
- Stored water may flow away
- Faults or barriers create uncertainty



Policy takeaway: MAR is a geology-dependent water strategy. A suitable aquifer must be able to accept, store, and release water.

Why Water Quality Monitoring Is Central to Recharge Projects

Recharge water quality must be understood before, during, and after water enters an aquifer.

Source-water quality



River water

Surface water from rivers and streams



Stormwater

Rainfall runoff from urban and natural areas



Highly treated recycled water

From advanced water treatment

Recharge basin

Upgradient monitoring

Measures water quality before recharge.

Natural filtration

Soil and sediment help remove some contaminants as water moves downward.

Injection well

Delivers highly treated water directly into the aquifer.



Treatment may be required

Downgradient monitoring

Measures water quality after recharge.



Not all contaminants are removed



Protect drinking-water aquifers

Clean aquifers support our communities and future.

Monitoring network



Source-water checks

Test incoming water quality.



Groundwater sampling

Monitor at multiple wells upgradient and downgradient.



Results over time

Track water quality over time to detect changes and inform decisions.



How monitoring needs differ

Surface recharge



- Soil and sediment can help filter water
- Still needs monitoring

Injection wells



- Water bypasses shallow natural filtration
- Usually needs stricter treatment and monitoring



Policy takeaway:

Recharge projects must be designed around water quality, monitoring, and public trust.



Understand water quality before, during, and after recharge



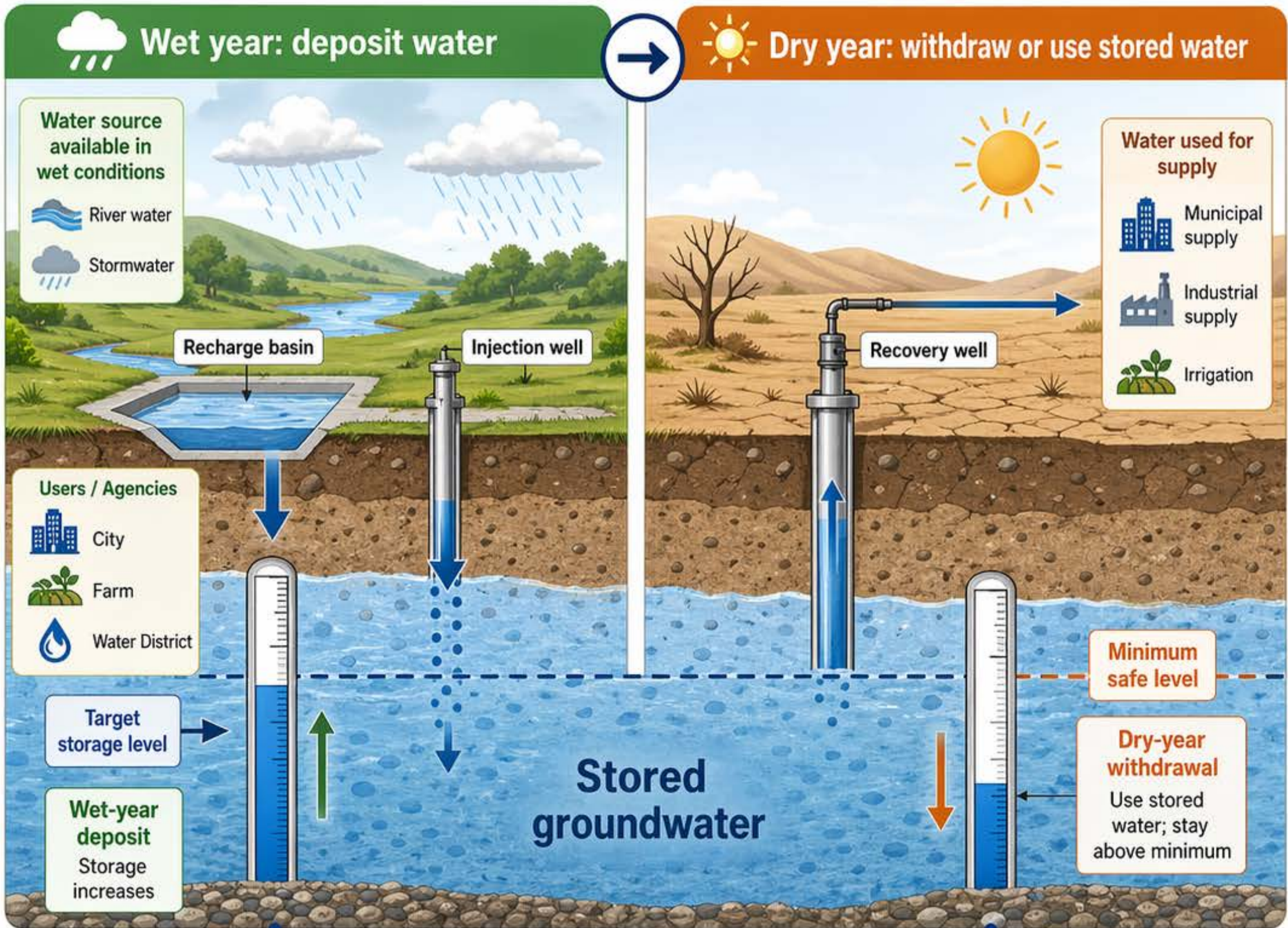
Monitor to protect groundwater and public health



Build confidence through transparency and accountability

What Water Banking Means

Water banking stores water underground in wet years and tracks how it can be recovered later in dry years.



Water accounting and operating rules

Ownership and rules
Define who can deposit, store, and recover water.

Recovery rights
Define who can recover, how much, and when.

Water accounting

↓ Deposits	+ 6,200 AF
Storage	12,400 AF (Acre-feet)
↑ Withdrawals	- 4,100 AF

Storage over time

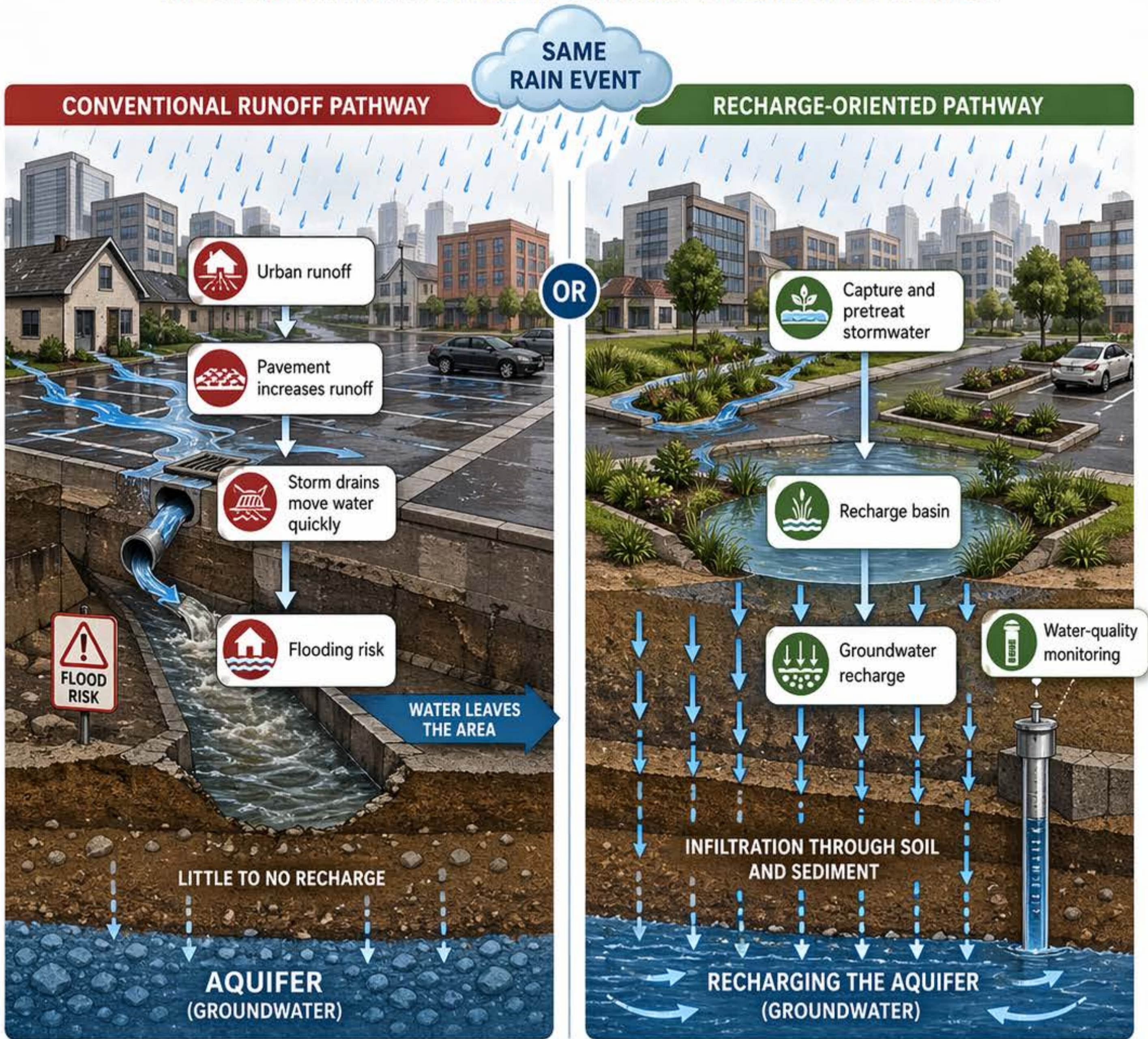
Operational thresholds
Stay within established levels to protect the resource.

- Target storage level
Plan for the future.
- Minimum safe level
Do not go below.

 **Policy takeaway: Water banking requires both underground storage and clear rules for accounting, ownership, recovery, and limits.**

Why Recharge Is Also Stormwater Policy

THE SAME RAINFALL. DIFFERENT CHOICES. DIFFERENT OUTCOMES.



Conventional runoff pathway

- Faster runoff
- More flood stress
- Water leaves the area



Recharge-oriented pathway

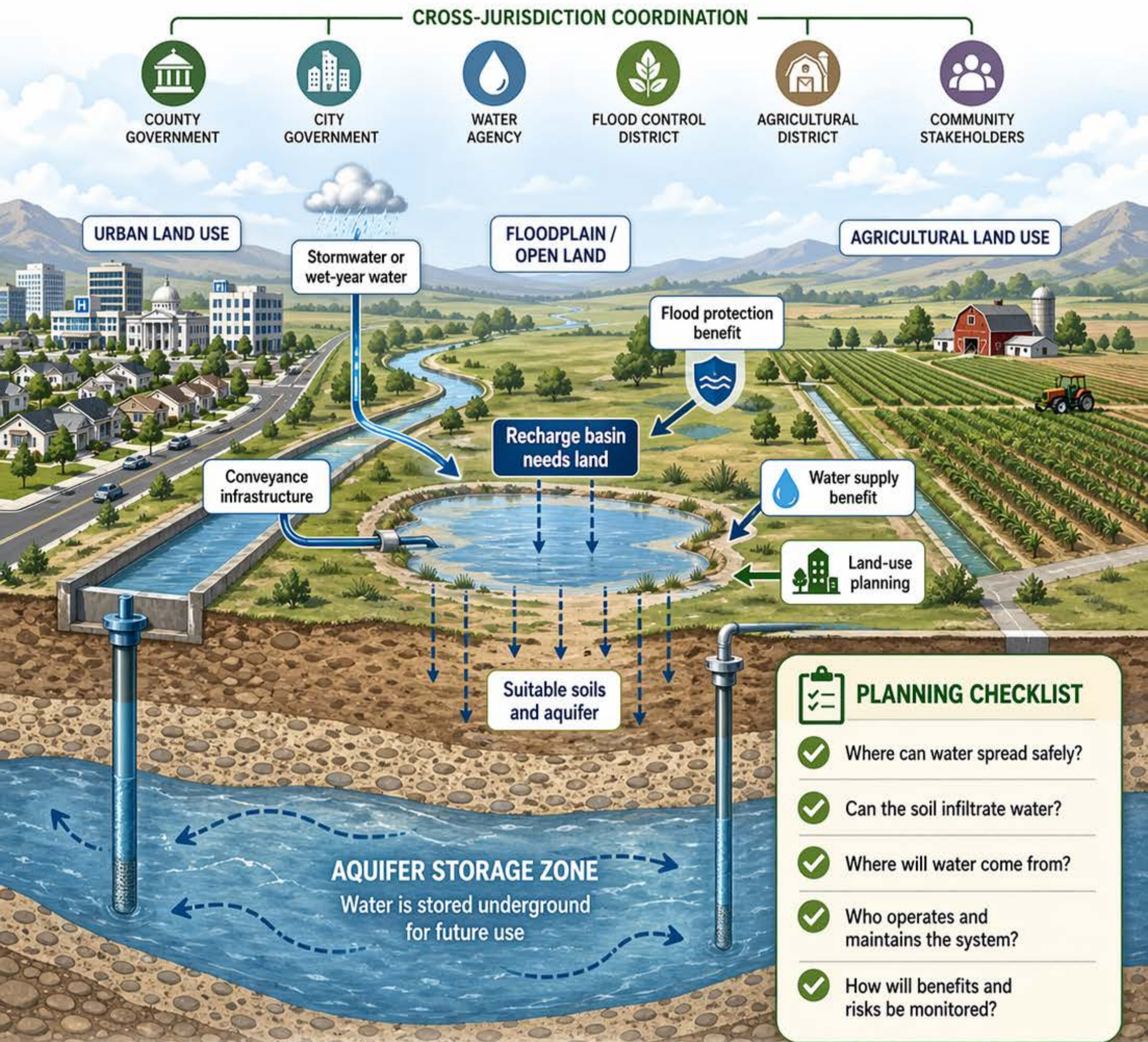
- Capture stormwater
- Reduce peak runoff
- Recharge groundwater where suitable



Policy takeaway: Stormwater policy can also be groundwater policy when runoff is captured, treated, and recharged safely.

How MAR Connects Water Supply, Flood Protection, and Land-Use Planning

Managed Aquifer Recharge (MAR) works best when water supply, flood management, and land-use planning are coordinated together.



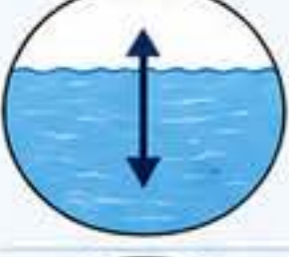




Policy takeaway: MAR projects work best when water supply, flood management, and land-use decisions are planned together.

Why Governance Matters as Much as Geology

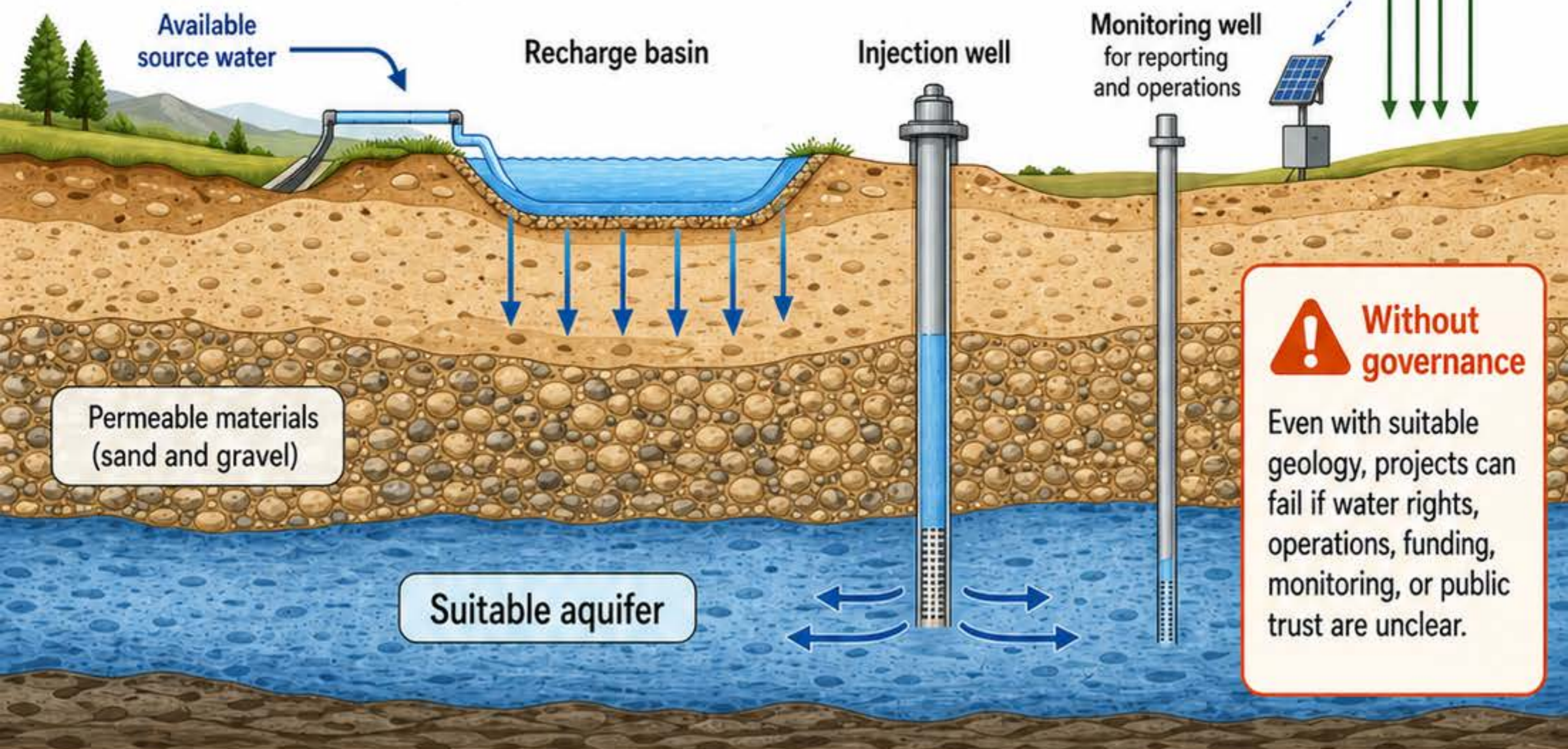
Managed aquifer recharge (MAR) depends on both subsurface conditions and human systems: rules, funding, water rights, monitoring, operations, accountability, and public trust.

Geology makes recharge possible

-  Suitable aquifer
-  Permeable materials
-  Storage capacity
-  Recoverable water
-  Available source water

Governance makes recharge workable

-  Water rights
-  Operating rules
-  Funding and maintenance
-  Monitoring and reporting
-  Public trust
-  Agency coordination



Policy takeaway: Geology determines whether recharge can work; governance determines whether it will work over time.