Groundwater recharge techniques & practices - a broader context
地下水回补技术与实践——更广阔的视角

China-Europe Water Platform
中欧水资源平台（CEWP）
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布鲁塞尔，2026年2月3日

Used terms:

术语定义：

Groundwater recharge ~ Artificial infiltration of groundwater ~ Managed Aquifer Recharge (MAR)

地下水回补 ~ 人工地下水补给 ~ 含水层管理性回补（MAR）

They all refer to intentional infiltration of available surface water into the aquifer

均指将可利用的地表水有意识地补给至含水层

What is needed for groundwater recharge:
地下水回补的必要条件：

1) Source of raw water for infiltration
   用于补给的原水水源
2) Suitable target aquifer
   适宜的目标含水层
3) Application of suitable techniques for infiltration and recovery of water
   适用的补给与取水技术应用

Groundwater recharge
地下水回补

- In most European cases (Northern and Central Europe): artificially infiltrated groundwater for drinking water production.
  在大多数欧洲案例中（北欧和中欧）：人工补给地下水被用于饮用水生产。
- A safe, sustainable and cost-efficient method.
  这是一种安全、可持续且经济高效的方法。
- Successful implementation requires a lot of expertise and data of the raw water conditions and hydrogeological and geochemical conditions of the target aquifer. Knowledge of the aquifer properties is essential in the designing of the infiltration and recovery techniques.
  要成功实施这一方法，需要大量专业知识，并充分掌握原水条件以及目标含水层的水文地质与地球化学数据。了解含水层特性对于设计渗透与回收技术至关重要。
- Groundwater recharge can be utilized in different geological environments and climatic conditions. Globally applicable method.
  地下水补给可适用于不同的地质环境和气候条件，是一种具有全球适用性的技术。
- This process harnesses the physical, chemical, and biological interactions that occur during the extended residence time of infiltrated water within the aquifer, including filtration, adsorption, redox reactions, ion exchange, and biodegradation.
  该过程充分利用了渗透水在含水层中长期停留期间发生的物理、化学和生物作用，包括过滤、吸附、氧化还原反应、离子交换和生物降解等。

Infiltration basin during the Finnish winter
芬兰的冬季渗透池

Photo: Turku Region Water Ltd.

Goals for groundwater recharge
地下水补给目标

Possible outcomes and problems
可能的结果与问题

Target
目标

Lack of raw water or
wrong infiltration technique
缺乏原水或错误的渗透技术

Inadequate application of
infiltration/recovery techniques
渗透/回收技术应用不当

Poor geochemical conditions of
the aquifer or too short residence
time of water
含水层地球化学条件差或水的
停留时间过短

WATER
QUALITY
水质

WATER QUANTITY
水量

Infiltration basin during the Finnish winter
芬兰的冬季渗透池

Photo: Turku Region Water Ltd.

Aquifers and infiltration methods
含水层与补给方法

Basic aquifer classifications
含水层基本分类:

1) Confined aquifer (an aquifer that occurs beneath an aquitard *or poorly permeable layer* which is often referred to as a *confining bed*)
承压含水层（位于弱透水层或渗透性较差地层之下的含水层，该地层常被称为隔水层）

2) Unconfined aquifer (an aquifer where the uppermost water table is at atmospheric pressure)
潜水含水层（最上部地下水面处于大气压力下的含水层）

3) Semi-confined aquifer (mixture of 1 and 2)
半承压含水层（类型1与类型2的混合）

The type of an aquifer has a major effect on the selection of the possible infiltration methods. However, also other aquifer properties need to be taken into consideration.
含水层类型对可选渗透方法的选择具有重要影响。然而，还需考虑其他含水层属性。

These are for example: Hydraulic conductivity values (K-values) of the aquifer material, oxygen concentration of the infiltration water and of the natural groundwater and geochemical properties of the aquifer.
这些属性包括：含水层介质的渗透系数（K值）、渗透水与天然地下水的氧浓度，以及含水层的地球化学性质。

Infiltration methods
渗透方法

1) Infiltration basins
渗透池

2) Sprinkling
喷洒法

3) Well infiltration
井渗法

4) (River) Bank filtration
（河流）岸滤

5) Drain / trench infiltration
排水沟/渠渗法

Indirect methods which aim to increase the aquifer volumes / natural yield
间接方法旨在增加含水层储量 / 天然补给量

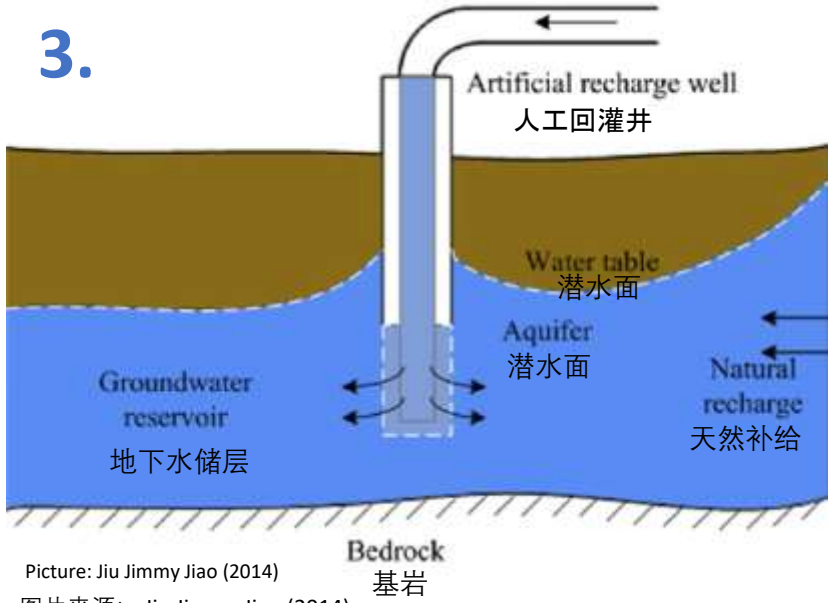
6) Subsurface dams
地下坝

7) Land surface modifications
地表改造

8) Reforestation
再造林

9) Check dams
拦沙坝

3.



Picture: Jiu Jimmy Jiao (2014)
图片来源： Jiu Jimmy Jiao (2014)

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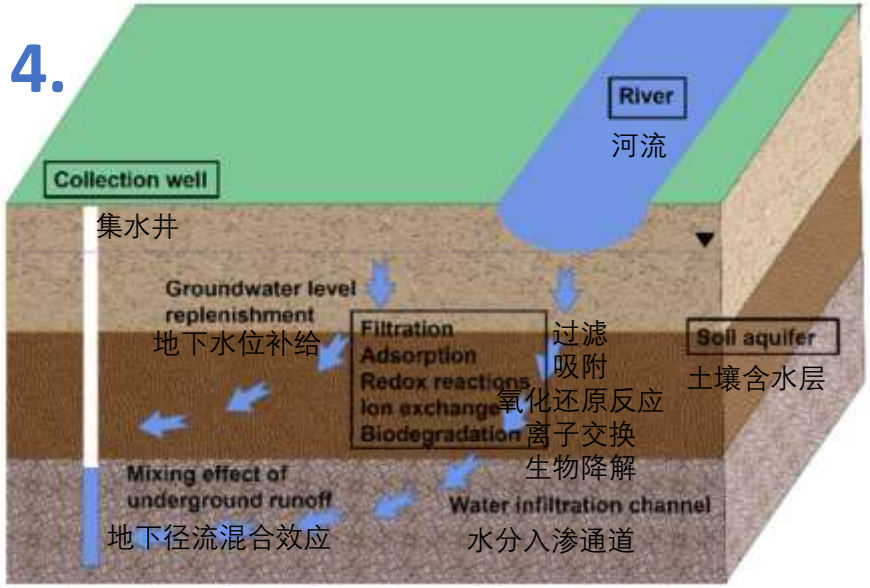

Picture: Gao et al. (2025)
图片来源： Gao 等人 (2025)

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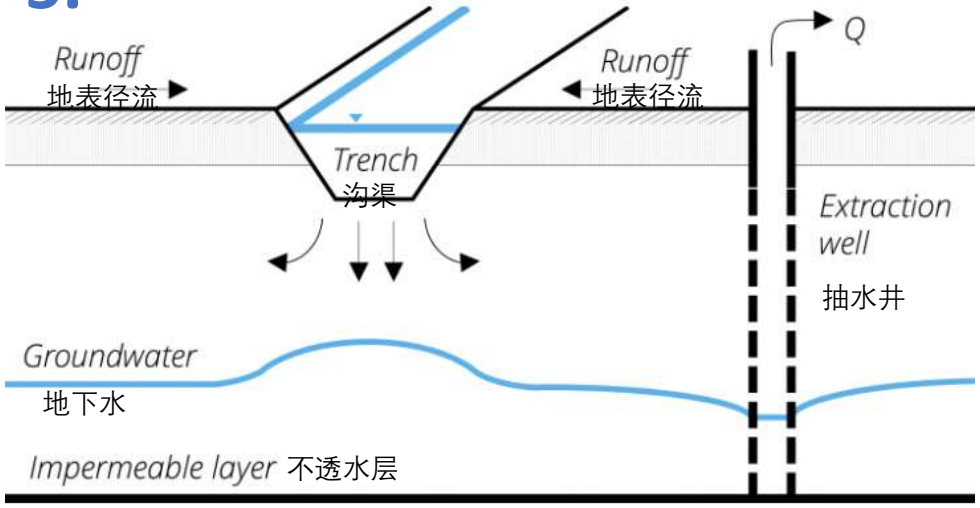


Picture: INOWAS (2018)
图片来源： INOWAS (2018)

Artificial infiltration of groundwater
人工地下水补给

Application and used infiltration techniques ALWAYS depend on:
应用与所选技术始终取决于:

- Local conditions (raw water, aquifer type)
  当地条件（原水、含水层类型）

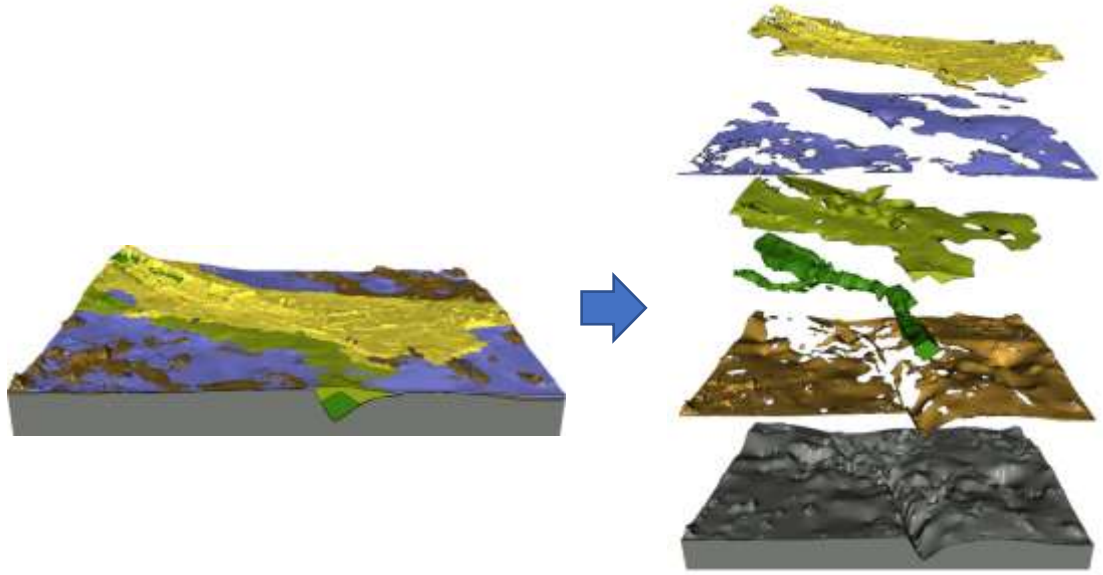
- Aim of the project concerning the needed quality and quantity of water (drinking water / gw for agricultural use / aquifer restoration etc.)
  项目目标涉及所需水质与水量（饮用水/农业用水地下水/含水层修复等）

- Investment budget (also inexpensive alternatives are available)
  投资预算（也可选择经济性替代方案）

- Production capacity aims with possible variation of production rates / seasonal changes in production
  产能目标应考虑产水率可能变化/季节性生产调整

- **Mixed aims and techniques are possible!**
  可结合多种目标与技术!

Problems and possibilities in artificial infiltration of GW
人工地下水补给的问题与潜力



Problems will arise when there is insufficient information of the subsurface conditions (lack of aquifer mapping / modelling)
若缺乏地下条件信息（如含水层测绘或建模不足），**将引发一系列问题**。

→ Failures in water infiltration and/or recovery
地下水入渗与回采效率低下

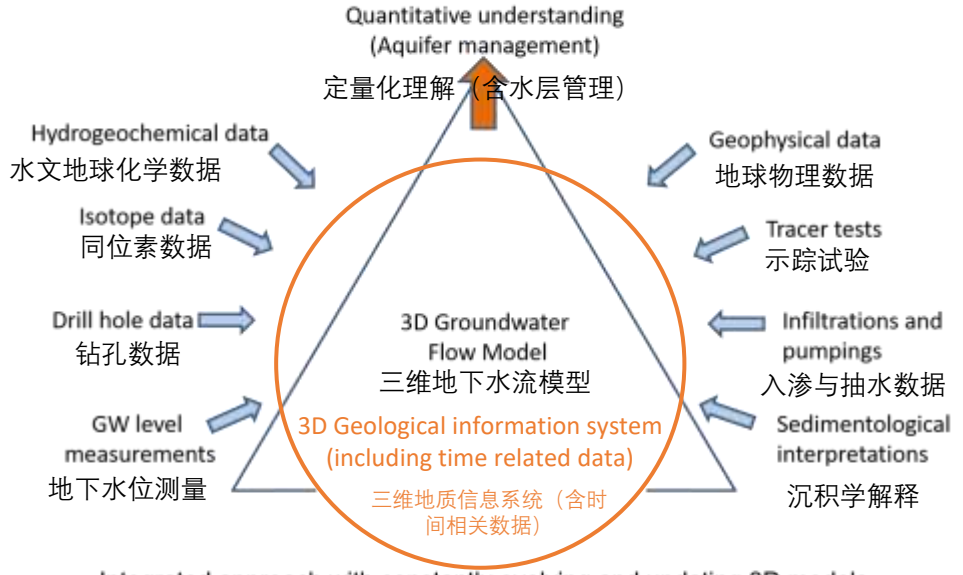
→ Insufficient control of the flow paths of the infiltrated water
对补给水流路径控制不足

→ Problems of the lost water, too short residence times, instable water quality
出现水资源流失、停留时间过短、水质不稳定等现象

Possibilities when high quality aquifer mapping data and correct infiltration techniques are available and used:
在具备高质量含水层测绘数据并正确应用渗透技术的条件下：

- MAR method can provide with more than ***10 times bigger production rates*** as compared with naturally formed groundwater without any unwanted changes in groundwater quality. (Finnish example)
与天然地下水相比，人工回灌（MAR）可实现**产水量提升十倍以上**，且不会引起地下水水质的不利变化（基于芬兰案例）；
- The natural groundwater conditions (hydraulic heads, spring discharge rates) can be restored.
能够恢复天然地下水环境（包括水力水头与泉水流量）；
- The aquifer's natural capability to purify water can be harnessed to be the primary purification method for good quality drinking water.
可充分利用含水层的天然净化能力，将其作为优质饮用水的主要净化手段。

项目执行工具
TOOLS FOR THE PROJECT EXECUTION



Integrated approach with constantly evolving and updating 3D models provides versatile tools for managed aquifer recharge.
通过持续演化和更新的三维模型开展综合研究，为含水层人工补给提供了多样化的工具。

Managed Aquifer Recharge: Conclusions
含水层管理性回补：结论

The method is:
该方法具有以下特点：

Cost-efficient technology even for large scale water supply
即使大规模供水，成本也非常**低廉**

- Natural method with minor chemical use
  化学药剂使用少的天然方法
- Easily automated and remotely controlled process
  易于自动化和远程控制
- Large sub-surface storage capacity
  巨大的地下储水容量

Sustainable way of managing water resources
是一种可持续的水资源管理方式

- Adapting to climate change
  适应气候变化
- Preparing for population growth
  为人口增长做准备
- Restoring and expanding the existing aquifer capacity
  恢复和扩大现有含水层容量

Safe solution for several common challenges
是一种能应对多种常见挑战的**安全解决方案**

- Raising or stabilizing groundwater level
  提高或稳定地下水位
- Preventing saline intrusion or land subsidence
  防止盐水入侵或地面沉降
- Managing stormwater runoff and floods
  管理雨水径流和洪水

Turku Region Water's MAR system has gained excellent *Sustainability Index* ratings presented in the MAR publication by UNESCO in 2021.
图尔库地区水务公司的 MAR 系统在联合国教科文组织 2021 年发布的《MAR 专刊》中获得了出色的可持续发展指数评级。
https://unesdoc.unesco.org/ark:/48223/pf0000379962

Turku Region Water

Thank you!
谢谢您！

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