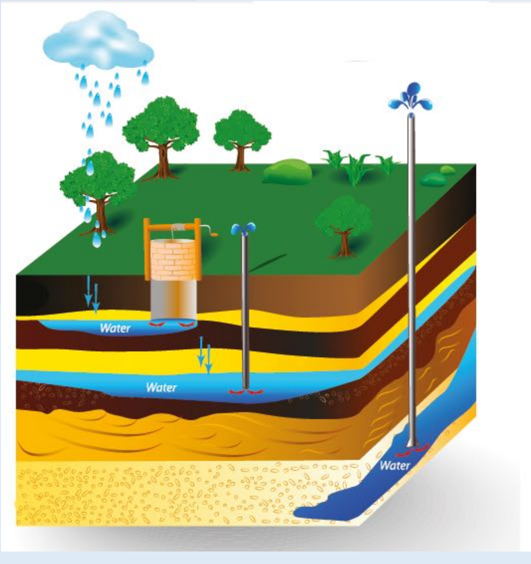
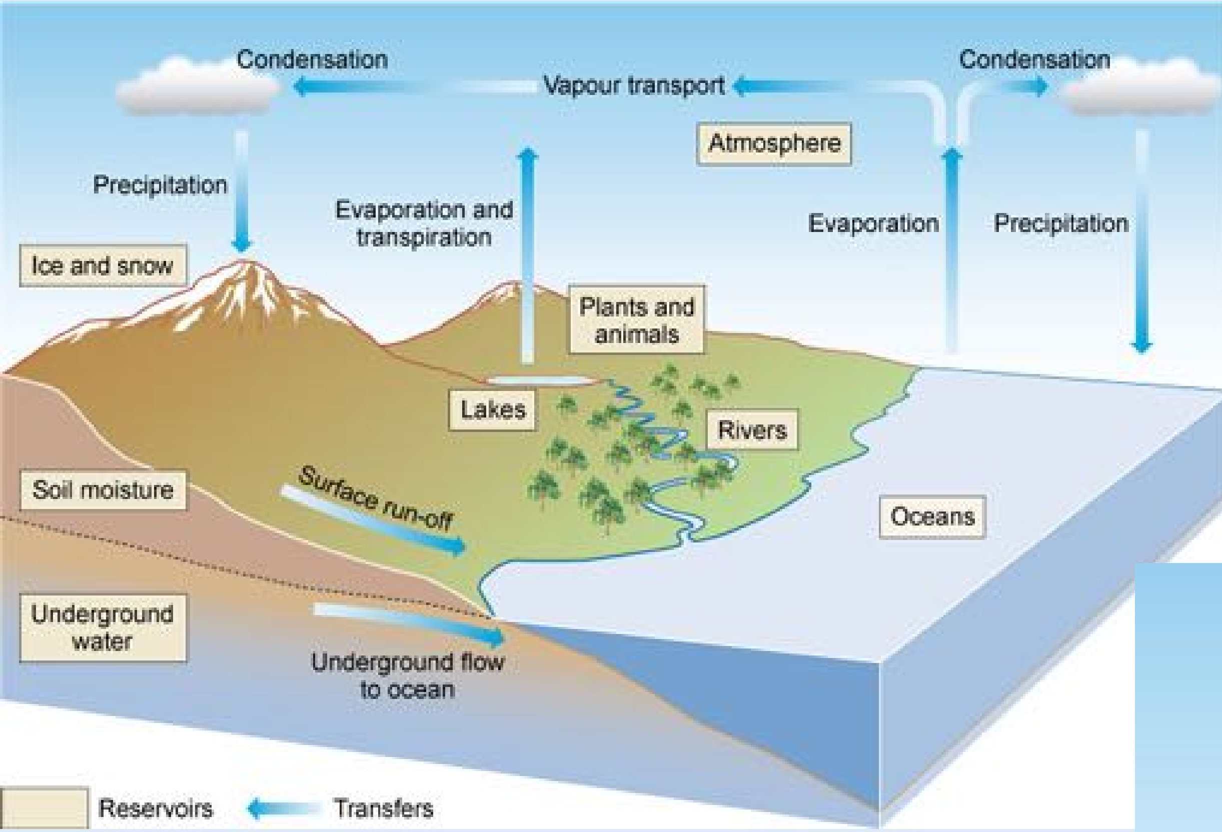
WSS 50 / Water Resources

Assessment, Development and Management aspects of Groundwater Resources

- Groundwater and the hydrologic cycle
- Why groundwater needs management
- Framework of groundwater utilization
- Timelines of knowledge and tools
- Observations
- Selling points of groundwater
- Framework for groundwater management
- Further reading

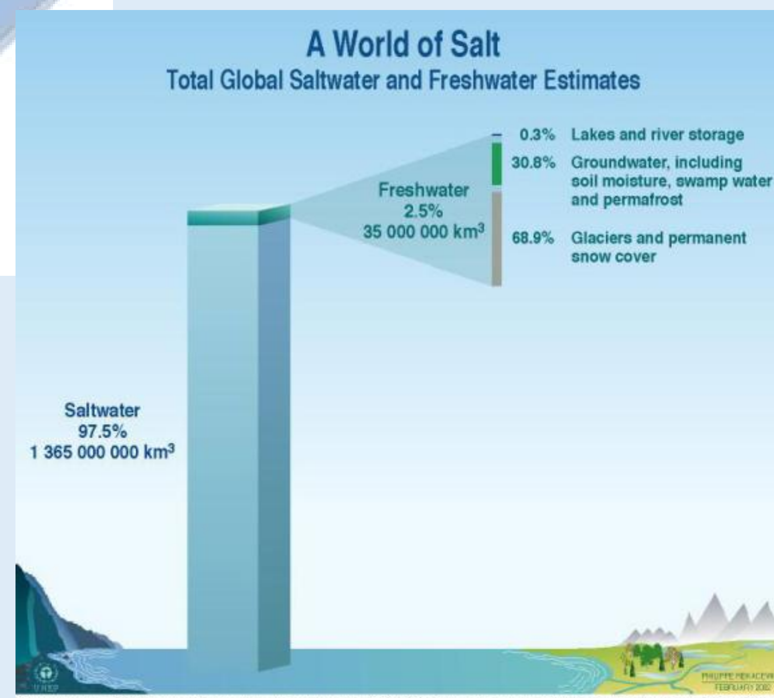


Groundwater and the hydrologic cycle



Hydrologic cycle: 39,000 km^3/year

groundwater and surface water are connected

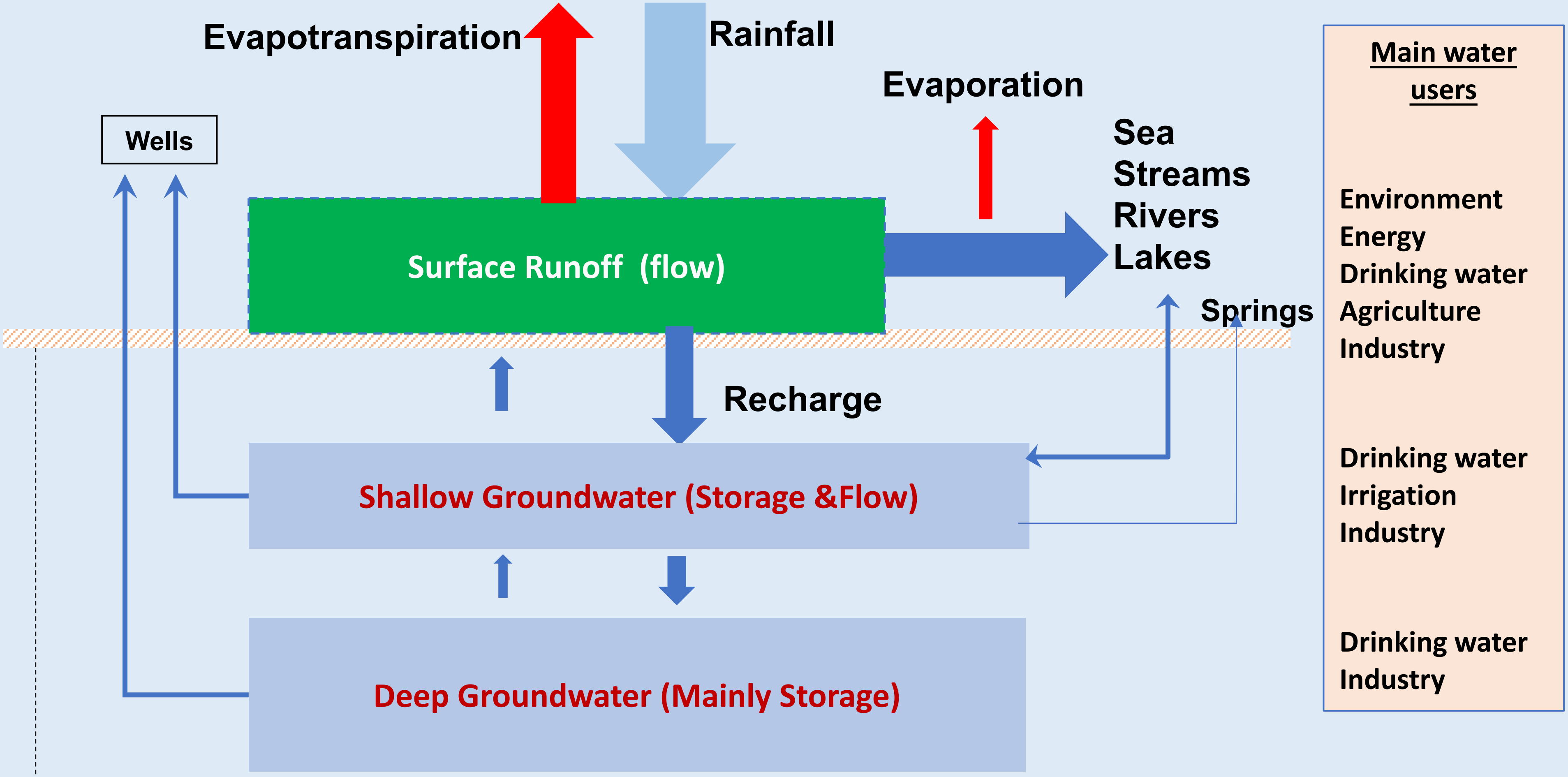


Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999.

groundwater stored >> surface water stored:

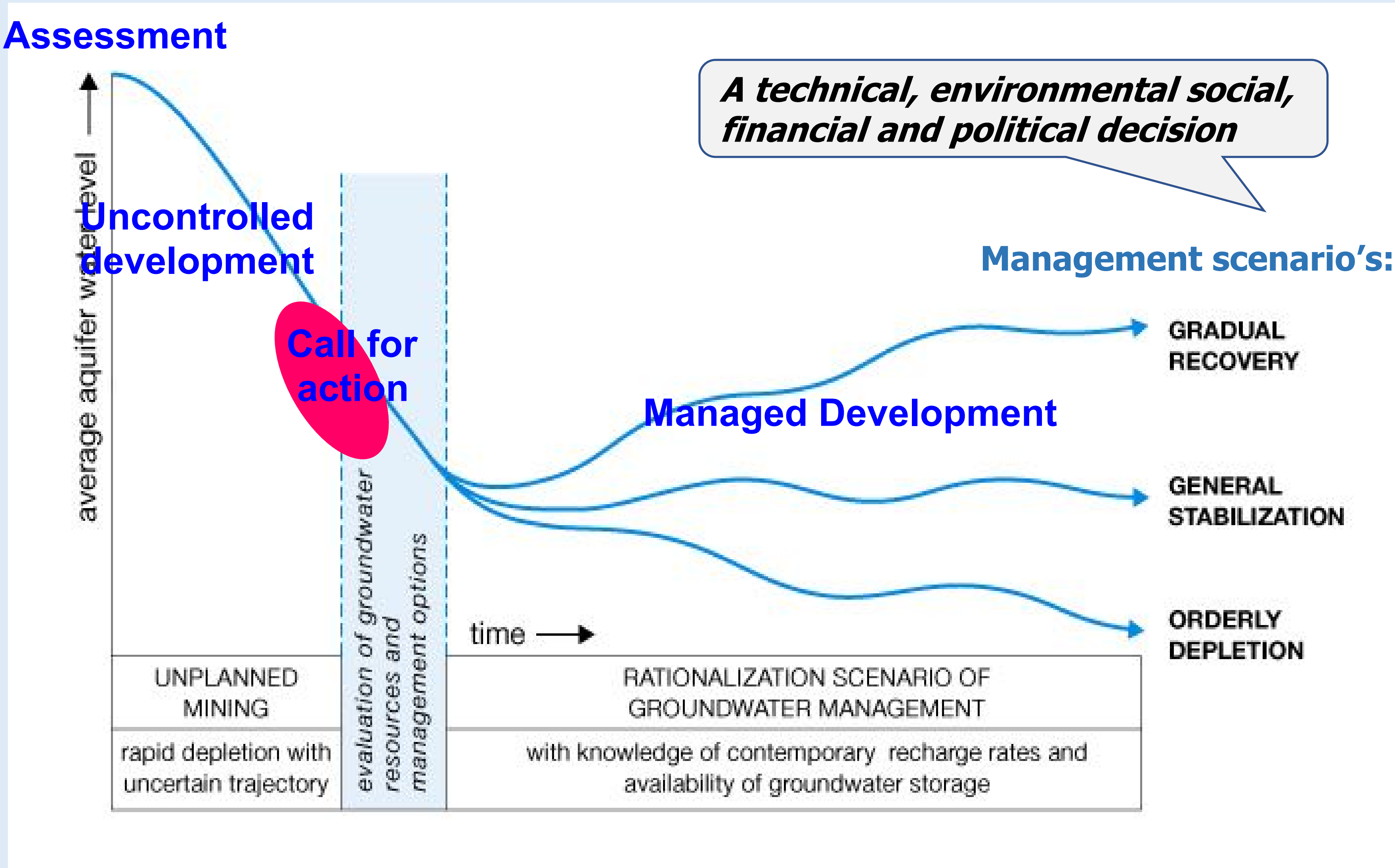
groundwater is our largest freshwater reservoir

Water cycle and uses



Groundwater is invisible: *out of (public) sight out of (political) mind*

Why groundwater needs management



Framework of groundwater utilization

use phases	Technical knowledge	Human Capacity and Knowledge Providers	Institutional, Regulation and Governance *1)	Finance sources
Assessment	Understanding the hydrogeology and recharge-flow-discharge patterns	Knowledge mainly with universities, consultants and drilling contractors	By government often inadequate. Mostly local level interest	Government Donors Private sector
Development	Wellfield design Well siting Drilling Completion	Private sector companies and (semi-)government companies	Often lack of planning and mandate for permitting	By users / end users and Government
Operations	Power supply and pumping + O&M	Well owner or outsourced to private sector	Often limited: no permits, no rules	By users / end users and other beneficiaries
Management and Monitoring	Monitoring flows, quality, levels based on mgt. scenarios	Big need in public water supply schemes. Often underestimated	Legislation and regulation often inadequate	Cost recovery Public funds. Fees through permits / metering

**1): out of (public) sight means out of (political) mind*

Timelines of knowledge and tools

Use phase	1970s	1980s	1990s	2000s	2010s
Assessment	Geology Areal photos	Geophysics Data bases Chemistry Modelling	Isotopes GIS	Airborne geophysics CC impacts	Global RS data sets
Development	Shallow wells dug wells Springs	Deeper drilling Riverbank infiltration (RBI)	Conjunctive use	Deeper aquifers (>400 m)	MAR / water buffering Solar energy
Management	Local conflict resolution	Computer applications, models, level predictions	IWRM, RBA GPA's, GDE	IWRM, RBA, Climate resilience, Data sharing via internet	Climate resilience. Real time data and models
Monitoring	Data locally collected on paper Hand held tools	Automatic monitoring, Nat. databases. Computer applications	Automatic (Flow+ Qlty) monitoring, Computer applications	GPS, internet, Data sharing	Real time data and models Dashboards

RBA: River Basin Authorities , MAR: Management Aquifer Recharge; GPA: GW Protectiion Area; GDE: GW Dependent Ecosystems, CC: Climate Change

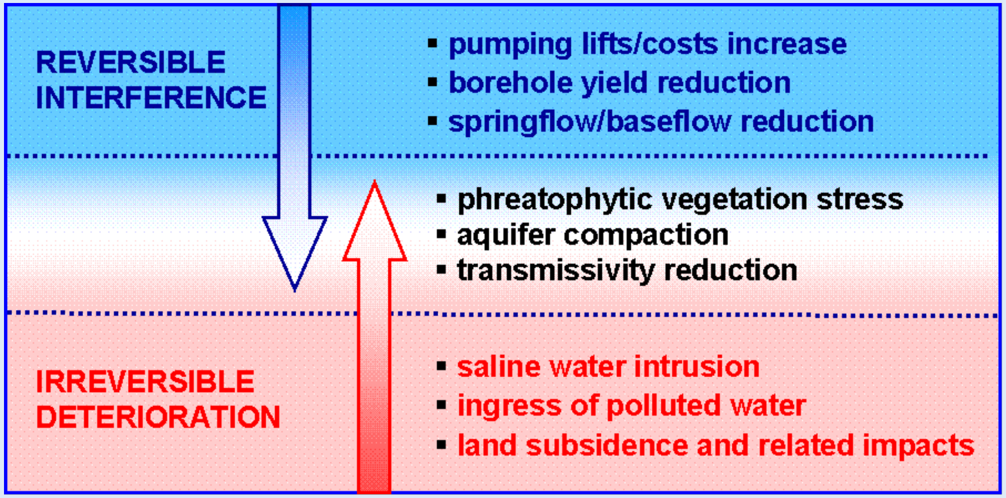
Observations : resource sustainability

Resource Sustainability (see slide 4)
Over time we see a shift from focus on simple access to water (MDG) to actions for sustainably managed resources (SDG)

Impacts of groundwater exploitation are becoming visible once they occur: land subsidence, water quality deterioration, salinization, well clogging and yield decline due to water level lowering.

Mitigation measures are in some cases not effective because negative impacts may be irreversible (diagram)

Message: prevention is much cheaper than cure



Observations : land subsidence

Example: Land Subsidence

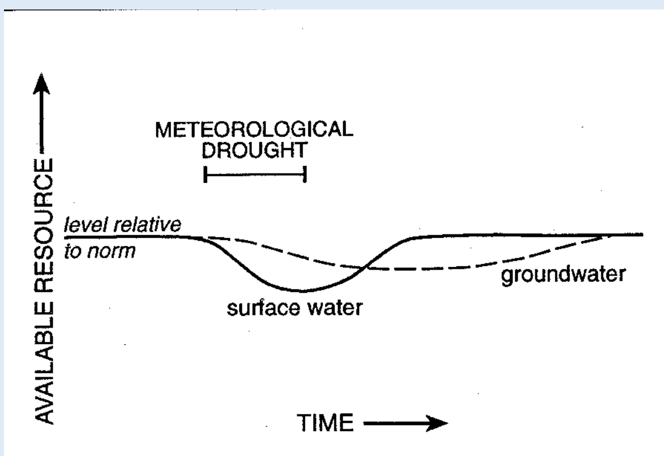
In many places uncontrolled groundwater exploitation is the main cause of land subsidence. It overrules the land subsidence due to impacts of climate change (Bangkok, Jakarta). Land subsidence is largely irreversible (slide 7) and solutions (e.g. reduce or stop the GW abstraction and move to alternative source) will not lead to full recovery and partial results are only visible after some time (e.g. Tokyo).

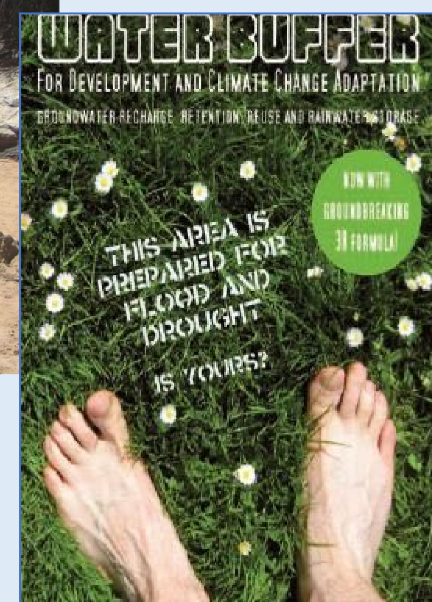
Approach to the problem follows the typical sequence of: unknown -> denial -> underestimation -> concern -> study -> action

Observations / Drought resilience

Climate change and groundwater buffering for drought resilience

Compared to surface water, groundwater is likely to be much more compatible with a variable and changing climate. Relative to surface water, aquifers have the capacity to store large volumes of water and naturally buffered against seasonal changes in temperature (evaporation) and rainfall. This can be further enhanced by MAR (managed aquifer recharge) interventions: building infrastructure and/or modifying the landscape to intentionally enhance groundwater recharge



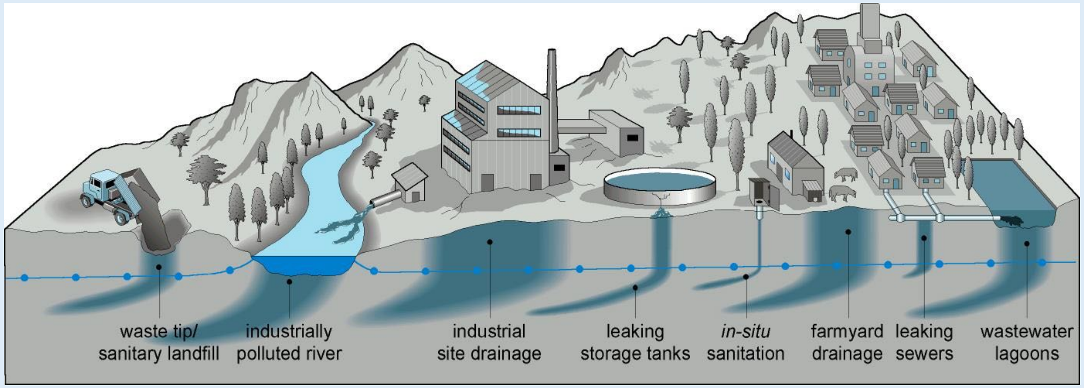


Observations: groundwater quality

Groundwater quality. Naturally, ground water contains mineral ions which slowly dissolve from soil particles, sediments, and rocks. The natural quality of groundwater is usually good but some ions (like arsenic, fluoride, chloride, iron) may cause health hazards when exceeding a certain level. Other ions (chloride, iron) may affect the taste.
Groundwater pollution. Human activities can cause an undesirable change in groundwater quality resulting from the disposal or dissemination of (industrial, domestic, agricultural) pollutants at the land surface and into soils, or through injection directly into ground water

Groundwater quality management is often underestimated, and preventive actions are often absent. Examples: Arsenic pollution in Bangladesh, Fluoride in the Rift valley in Kenya/Ethiopia; Agricultural & industrial pollution in Punjab, India; Industrial & domestic pollution in mega cites in Africa and Asia

Guidebook:
Groundwater Quality Protection: *Guide for water utilities, municipal authorities, and environment agencies*
World Bank/WHO a.o. (2007)



Observations: Non Technical

Resource management:

Groundwater management is often weak, partly because the resource is invisible. Need for management emerges with conflicting interests (slide4) . The structure of the WR sector and the stage of sector development differs from country to country, with GWR subsector usually being less well organized, managed and financed. Poor governance of the (G)WR sector is a major constraining issue in many countries in spite of its importance for livelihood

Knowledge / capacity building:

In many developing countries knowledge on GWR is scarce. In projects often capacity building gets insufficient attention. Also the braindrain to private sector causes scarcity of staff for government positions.

Lack of authority / mandate of counterpart:

Agencies set-up to manage groundwater resources often have insufficient mandate and authority to take the necessary management measures, like resource protection, cost recovery, exploitation permitting and prevention of land subsidence. Also here counts: out of sight is out of mind. Community based GW management for local water supply is generally more successful and sustainable than provincial or national managed systems

Observations / Non technical

Communication and information

As groundwater is relatively unknown, extensive and continuous communication and information on its use and the impacts thereof is required to both government parties and the public / private sector. Promoting MAR to increase drought resilience is a good example to make the role and benefits of groundwater visible to the public

Water supply driven groundwater studies:

Groundwater studies are often project driven to meet the water resources requirement for specific demands: irrigation, urban water supply, etc. There is insufficient incentive to share the collected information and data are often lost over time.

Data management: Over time there is a big increase of data accessibility, supported by the internet. Data availability grows from local to global level:

Level: local -> provincial -> national -> regional -> global

Selling points to promote groundwater management

Characteristic	**Explanation**
Available where needed	Decentralized resource which is widely available
Naturally protected	Often protected against pollution and not affected by evaporation
Our largest reservoir	Storage capacity is our largest reservoir and a powerful medium to bridge dry periods: tool for adaptation to climate change impacts
Untapped resource	• Large volumes of brackish groundwater become available with decreasing desalination cost • Deeper aquifers are discovered (>500 m)
Stable temperature	Source of renewable energy for heating (cold-heat transfer and geothermal energy)
Environmental function	Base flow to wetlands and rivers
Natural treatment	Aquifers are able to improve water quality by biological degradation (pollution remediation)

Framework for groundwater management

Where ? Why ?

HYDROGEOLOGIC CONDITIONS

- definition manageable GW bodies
- resource renewability and SW interaction
- susceptibility to irreversible degradation
- vulnerability and risk of aquifer pollution

SOCIO-ECONOMIC SITUATION

- GW user's profiles and demographic changes
- GW use and pollution drivers
- macro policy interactions
- financial and cost drivers/constraints

What ?

QUALITY MEASURES

- well head protection
- aquifer protection zoning
- pollution control (risk based)
- natural GW quality mgt.

DEMAND SIDE MEASURES

- irrigation use saving
- distribution/use efficiency
- water use charging
- awareness raising

SUPPLY SIDE ENGINEERING

- recharge enhancement
- conjunctive use
- alternative resources
- new technologies /re-use

How?

POLICY ADJUSTMENTS

- macro policy interventions
- macro planning intervention
- financing policy
- private sector participation

REGULATORY PROVISIONS

- GW access and use codes
- GW use rights / use charging
- operational legal framework
- drilling standards/monitoring

STAKEHOLDER PART.

- AMOR zones /link with BO's
- capacity /institution building
- policy and public awareness
- information/data sharing

PRIORITY MANAGEMENT ACTIONS (max 4 for realistic implementation)

Maximum four priority management actions accompanied by:

- *definition of plan and scheduling of the action*
- *financing plan for the management intervention*
- *mobilization plan of local government/stakeholders*
- *benchmarking and monitoring progress*

Further reading

- De Vries (2006); *History of groundwater hydrology*
- Rafael Bras, 1999; A *brief history of hydrology*
- World Bank (2010); *Water and Climate Change: impacts on groundwater resources and adaptation options ;* Water Working Notes
- Driscoll, 1986 : *Groundwater and wells*.
- Kruseman en de Ridder, 1970; *Analysis and Evaluation of Pumping Test Data*
- Jaques vd Gun a.o. (2013) Gr*oundwater in the World* : https://www.un-igrac.org
- World Bank , WHO (2007) Groundwater Quality Protection: Guide for water utilities, municipal authorities, and environment agencies 2007 : https://www.un-igrac.org

- *Groundwater the hidden resource (4 min)* https://youtu.be/tzkBvLXa8js
- *What is groundwater ? (5 min)* https://www.youtube.com/watch?v=oNWAerr_xEE
- *The Water Channel* thewaterchannel.tv

- GWMATE material https://www.un-igrac.org
  - Strategic Overviews (5) on key aspects of GW policy formulation
  - Briefing Notes (16) on thematic sub areas of GW management and protection
  - Case Profiles (20) to share knowledge acquired and lessons learned from experience around the world.