The evolution of long-term groundwater storage in the north-western IGB aquifer

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British Geological Survey

Overview

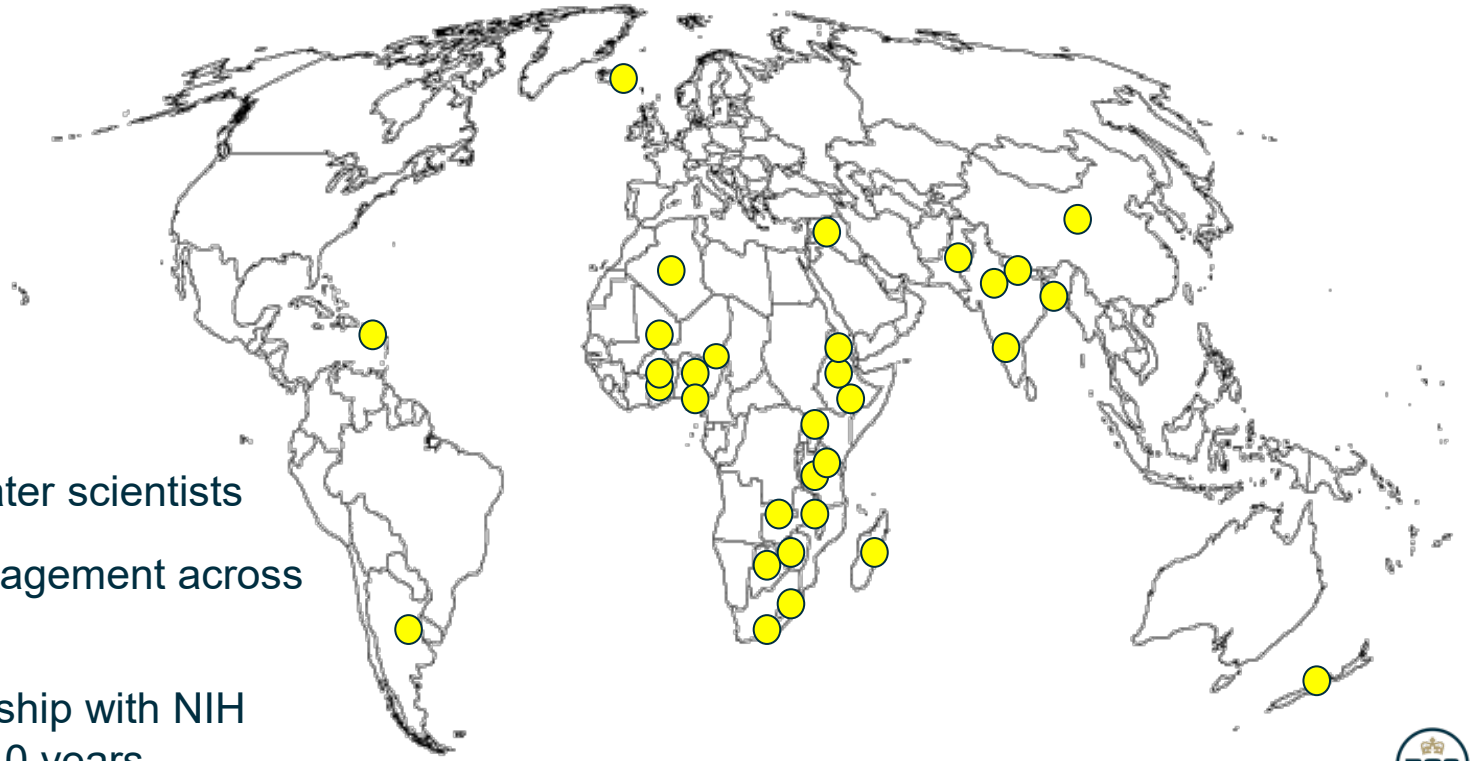
- Introduction to BGS and our groundwater work
- BGS work in India
- Groundwater in the IGB
- Long-term changes in groundwater in the north-western IGB aquifer
- Quantifying the relative influence of recharge sources in the north-western IGB aquifer

British Geological Survey

- A world-leading independent research organisation providing objective, expert geoscientific data, information and knowledge.

- www.bgs.ac.uk

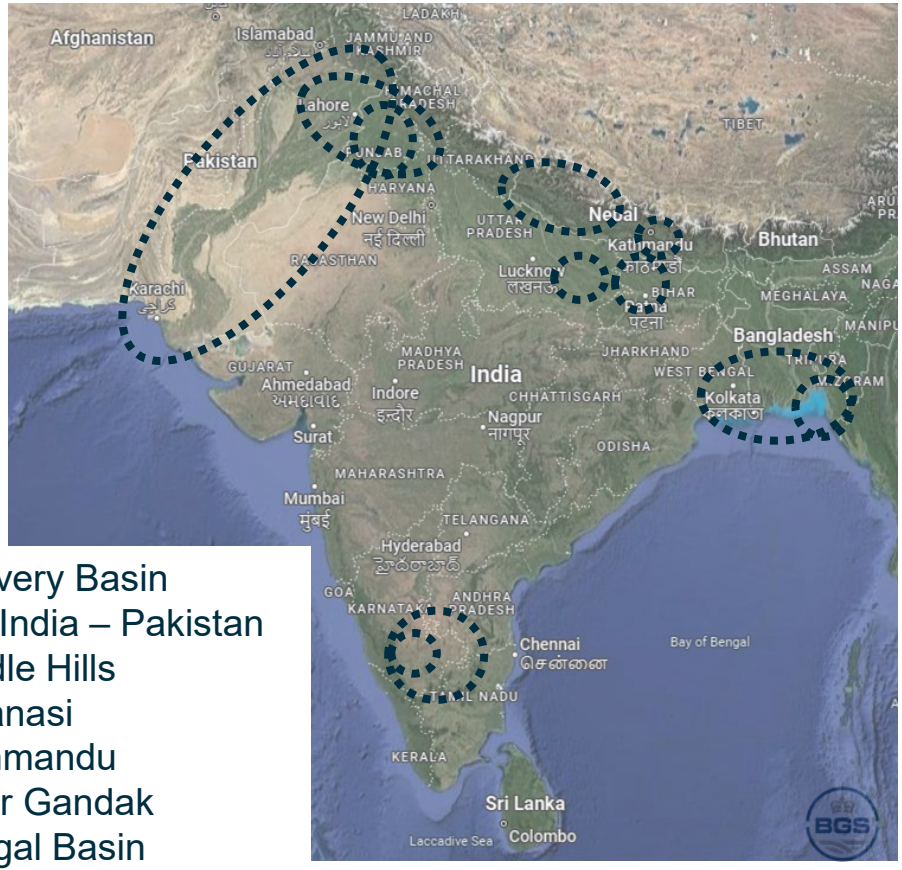
BGS Global Groundwater Science



- 40 + groundwater scientists
- Long-term engagement across India
- Strong partnership with NIH over the past 10 years

BGS Groundwater projects in India

- Hydrogeological typologies
- Mapping
- Modelling
- GW/SW interactions
- Recharge and residence times
- Water quality
- Long term GW levels



1. Cauvery Basin
2. NW India – Pakistan
3. Middle Hills
4. Varanasi
5. Kathmandu
6. River Gandak
7. Bengal Basin

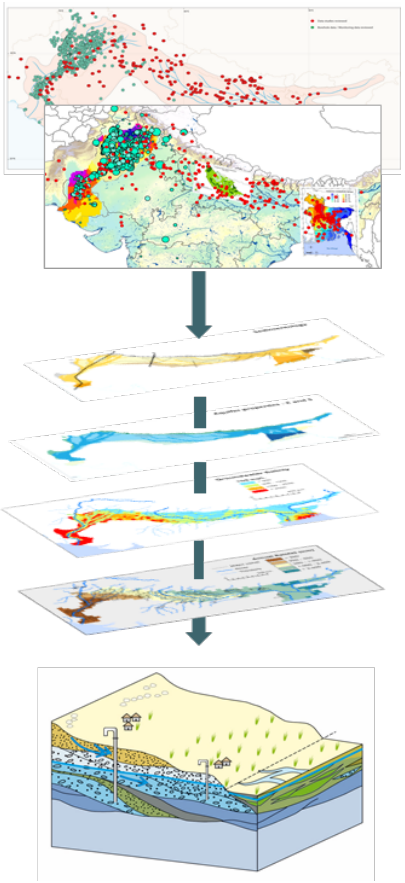
Improving understanding of the IGB aquifer

Groundwater in the Indo-Gangetic Basin (IGB)

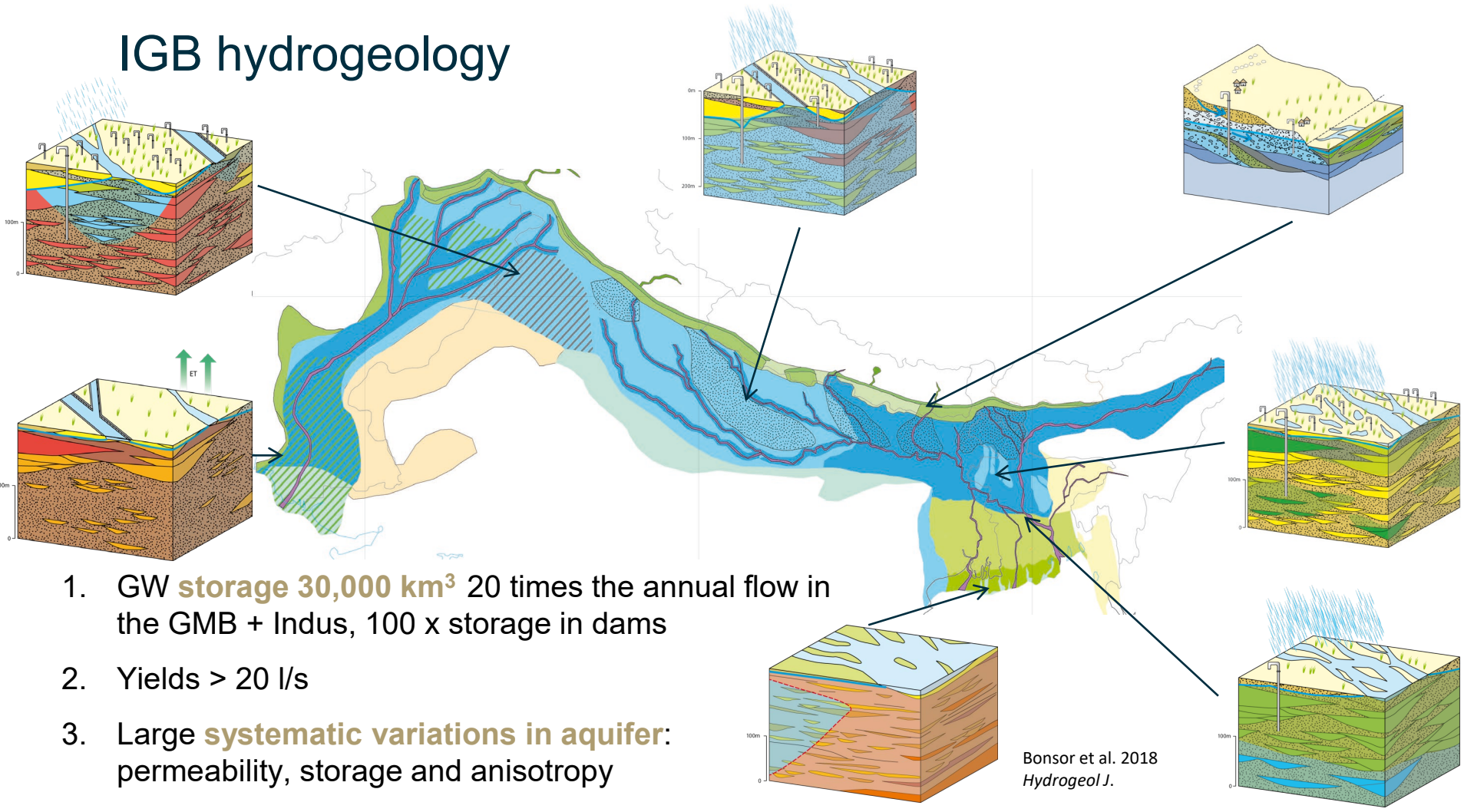
Data collation and review – from the four countries: > 500 reports and datasets reviewed

New basin-scale data maps of key groundwater parameters: alluvial geology, abstraction, groundwater quality, water level trends, aquifer properties

Delineation into 7 main typologies and 3 minor: 3D characterisation related to the resilience to change



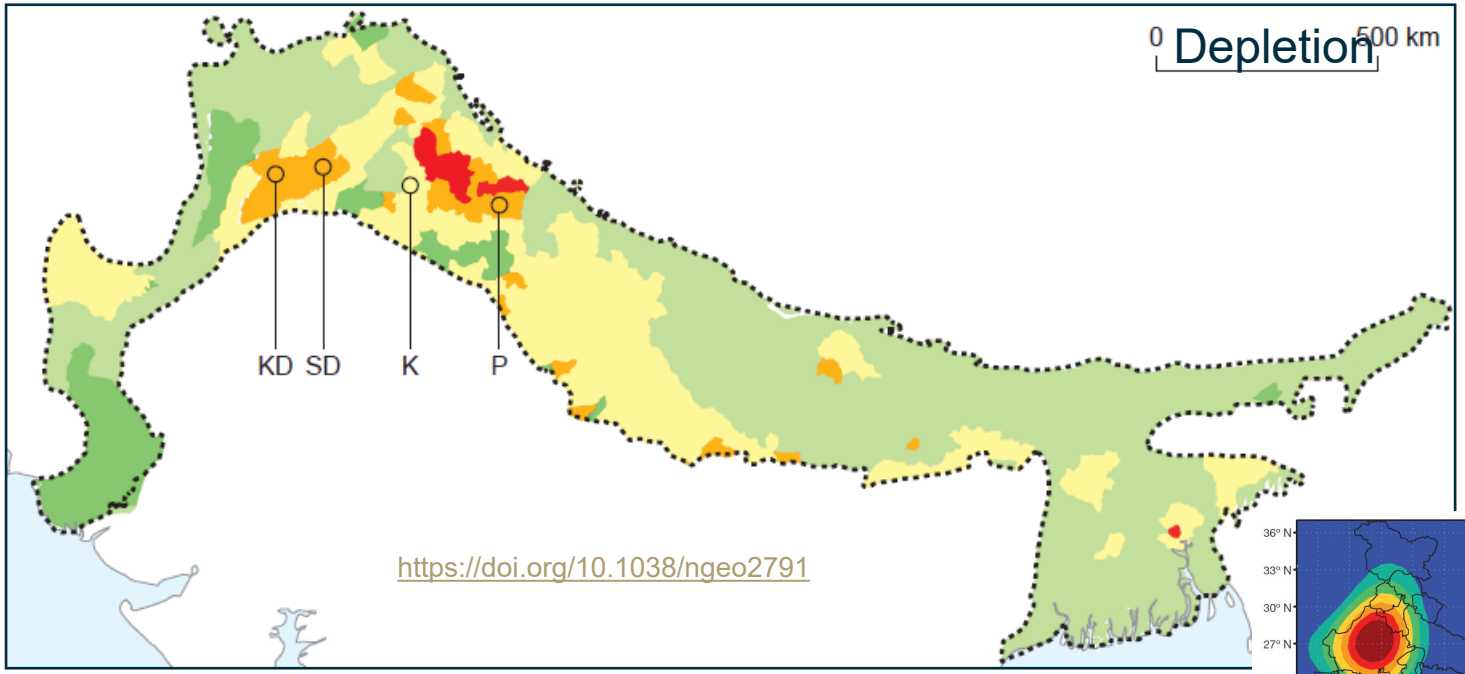
IGB hydrogeology

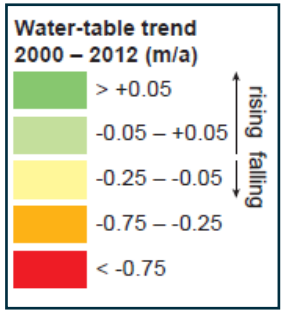


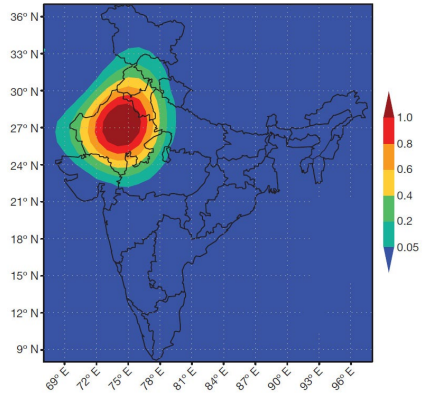
1. GW **storage 30,000 km^3** 20 times the annual flow in the GMB + Indus, 100 x storage in dams
2. Yields > 20 l/s
3. Large **systematic variations in aquifer**: permeability, storage and anisotropy

Bonsor et al. 2018
Hydrogeol J.

Groundwater depletion in the IGB

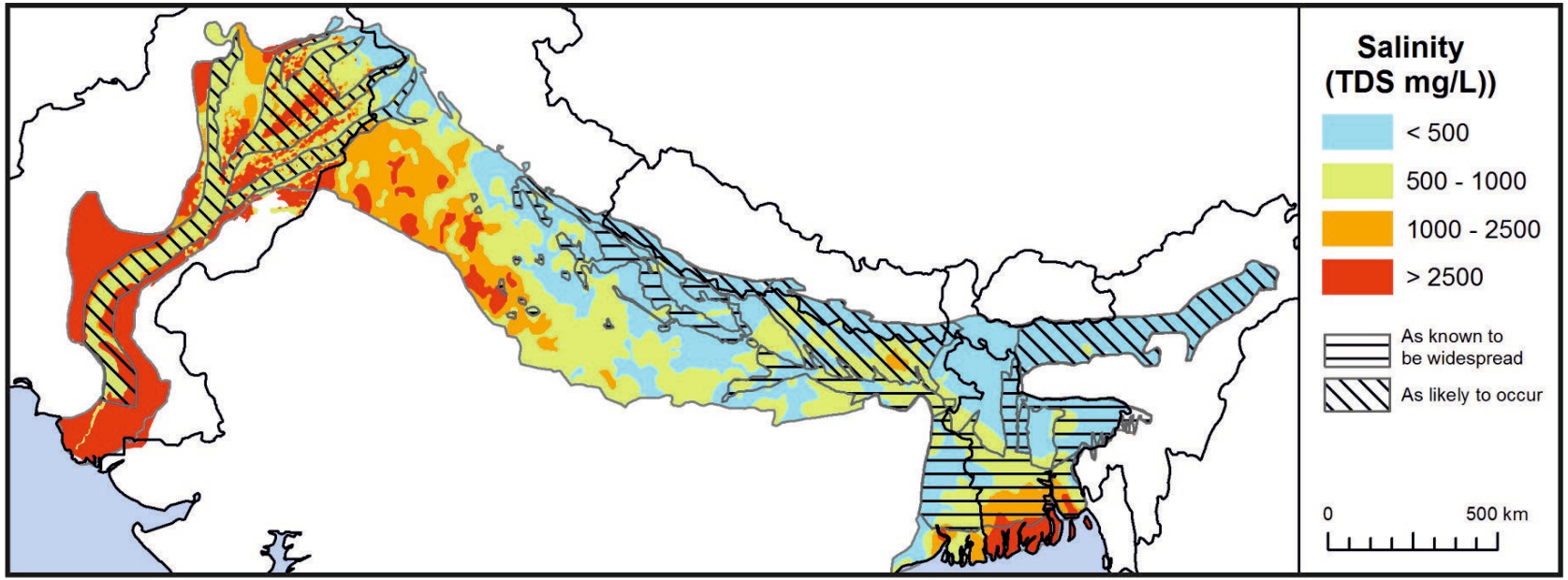






MacDonald et al. (2016) *Nature Geoscience*

Groundwater salinity and arsenic



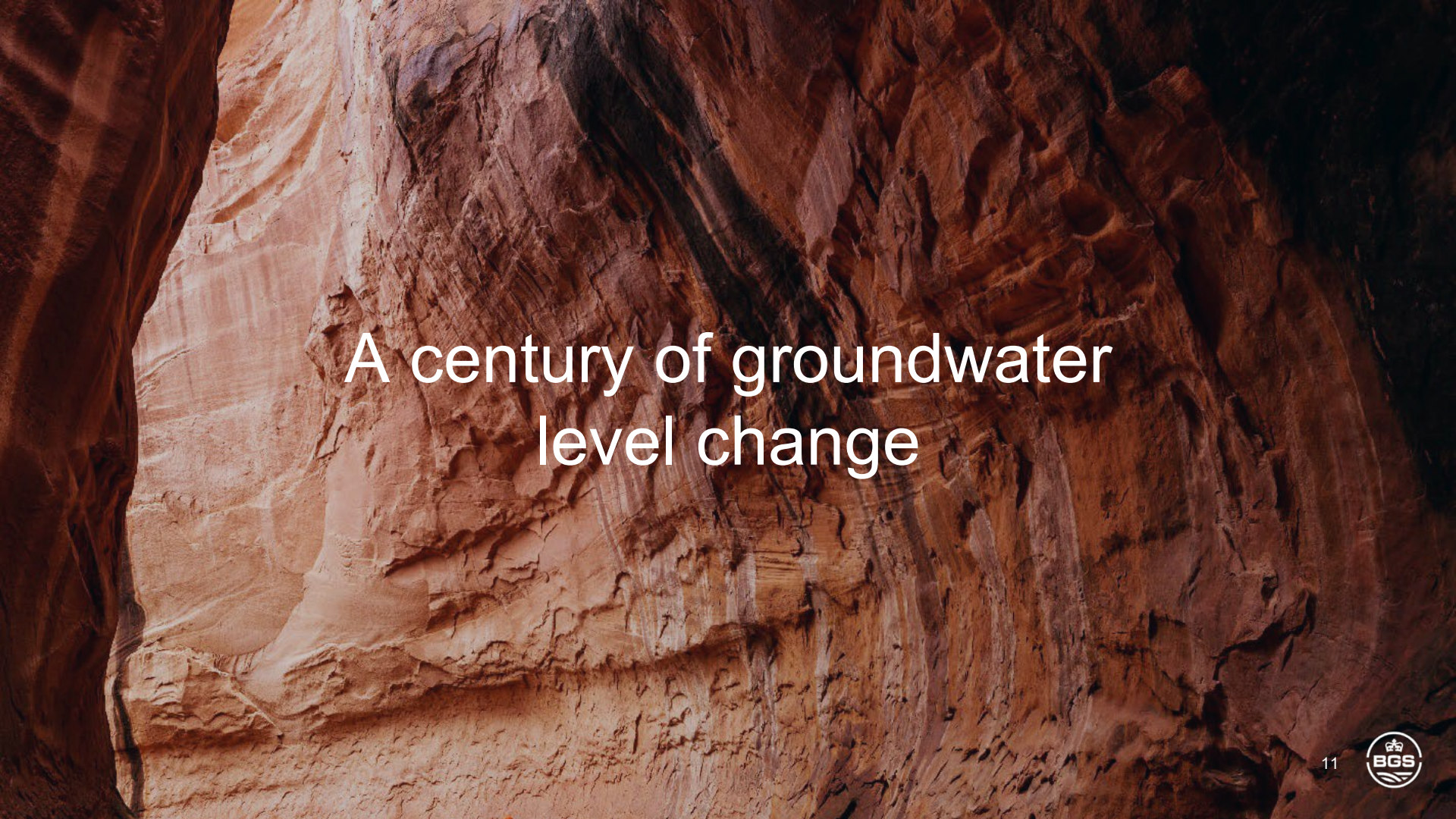
Salinity or arsenic impacts up to 60% of the aquifer area

Salinity is both natural and man made

Arsenic natural and associated with Holocene deposits and organic soils

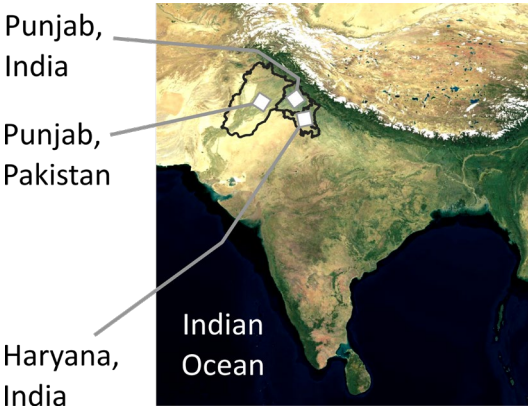
Other quality problems poorly constrained

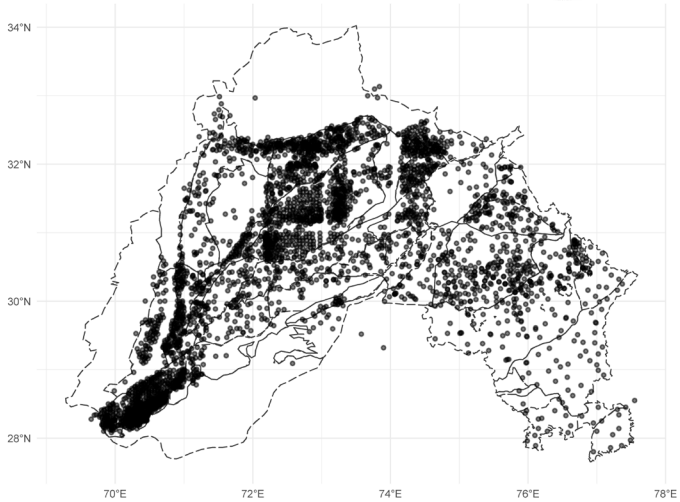
MacDonald et al. (2016) *Nature Geoscience*


A century of groundwater level change

Long-term groundwater level change in the IGB

- Groundwater depletion is a major concern.
- Groundwater used for > 100 years.
- Groundwater level change since 1900?
- 4028 observation wells from 1900 - 2010



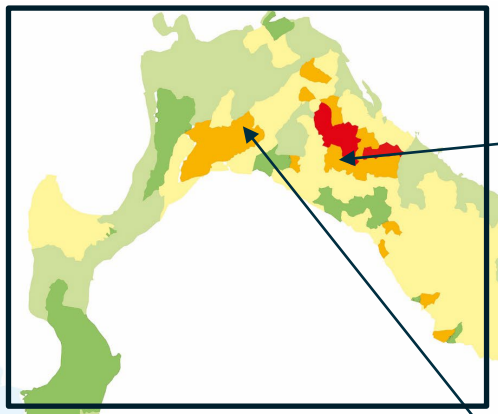


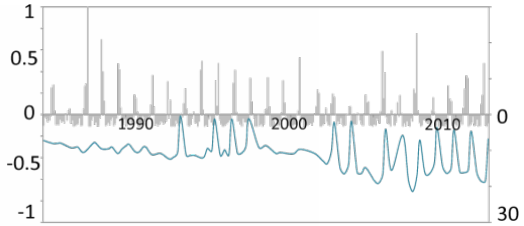
Pre1857

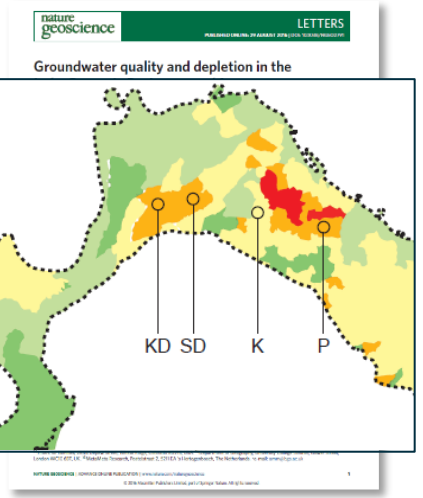
1800s - 1947

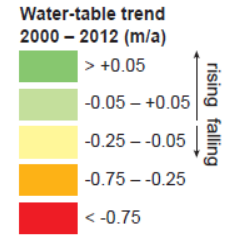
Post 1947

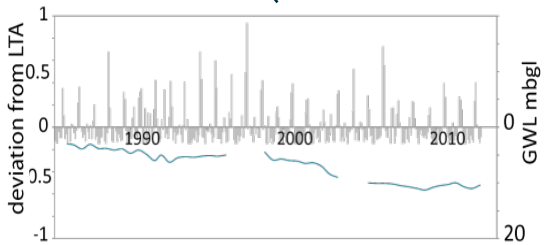
Motivation

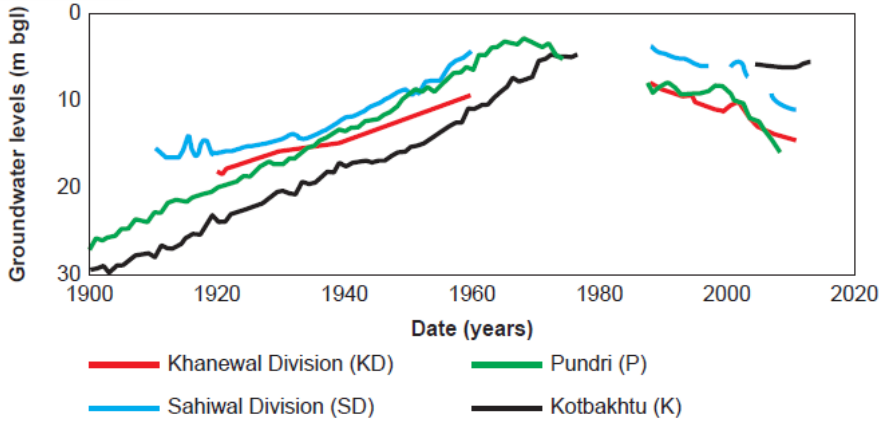






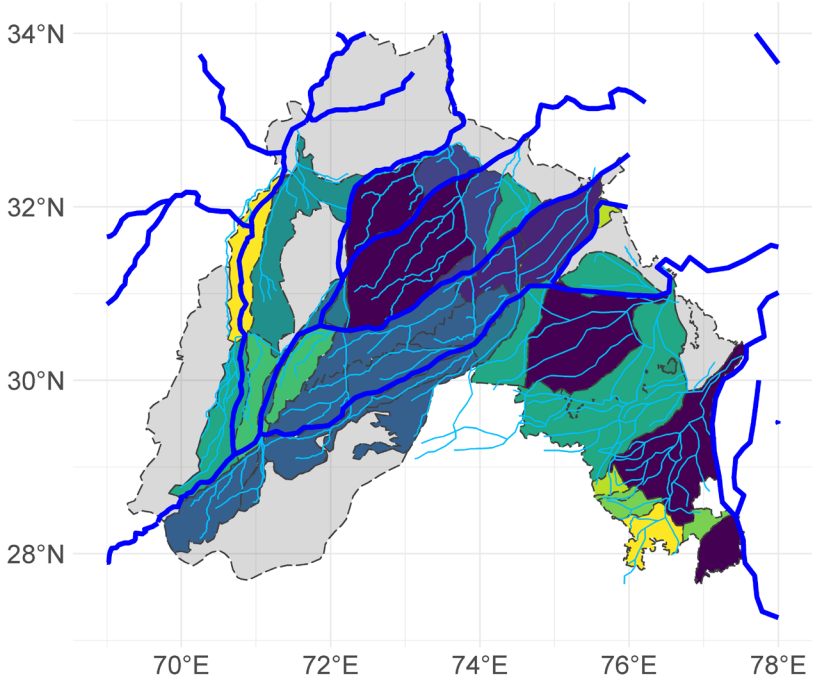






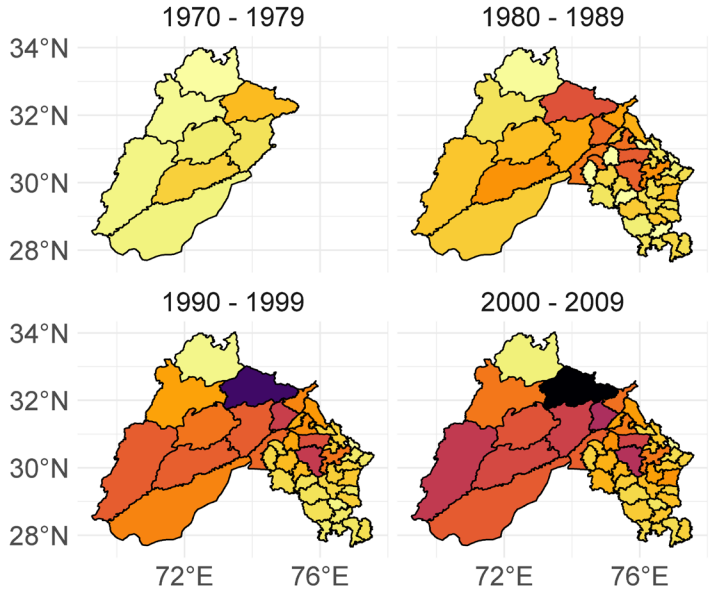
MacDonald et. al. 2016, Nat Geoscience

A century of water resource development



Canal command construction year

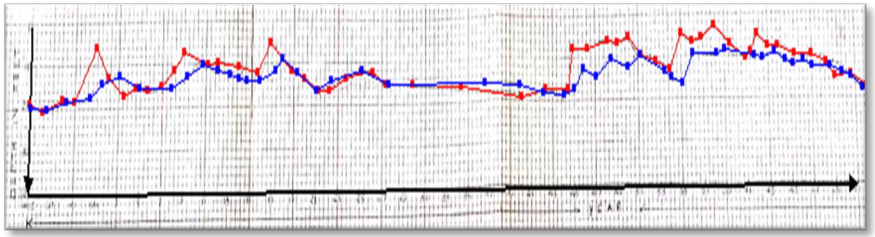
- < 1900
- 1900 - 1909
- 1910 - 1919
- 1920 - 1929
- 1930 - 1939
- 1940 - 1949
- 1950 - 1959
- 1960 - 1969
- 1970 - 1979
- 1980 - 1989
- 1990 - 1999
- Not a canal command

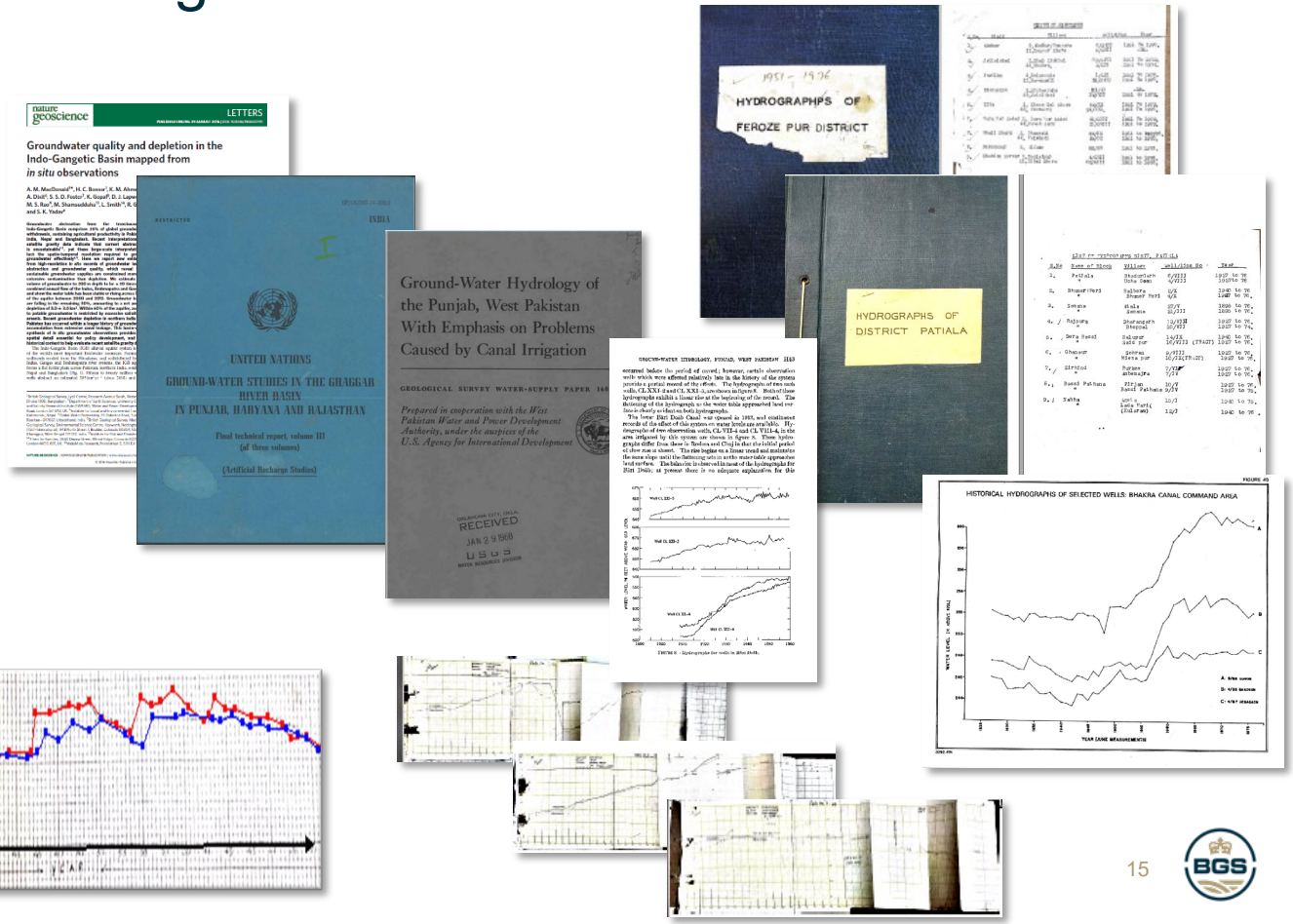


Tubewell numbers 0 50000 100000 150000 200000 250000

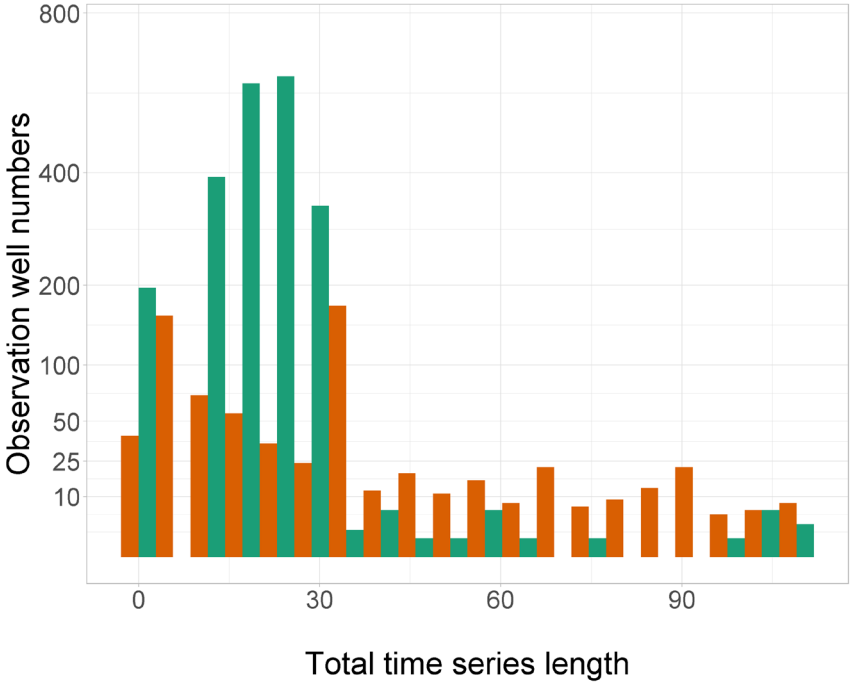
Compilation of historic groundwater data

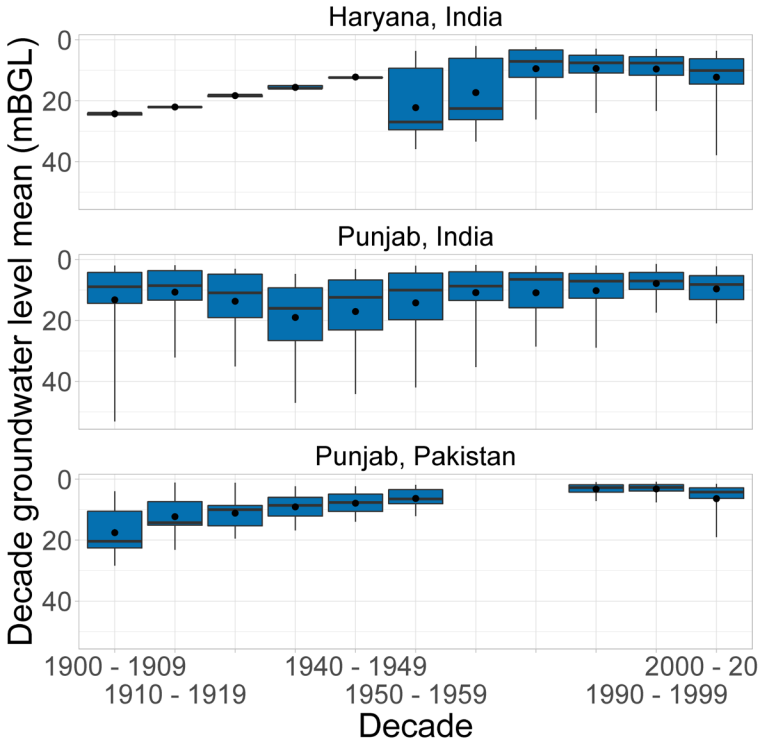
- > 100 hydrographs scans:
  - old reports
  - books
  - government archives
  - digital and hard copy



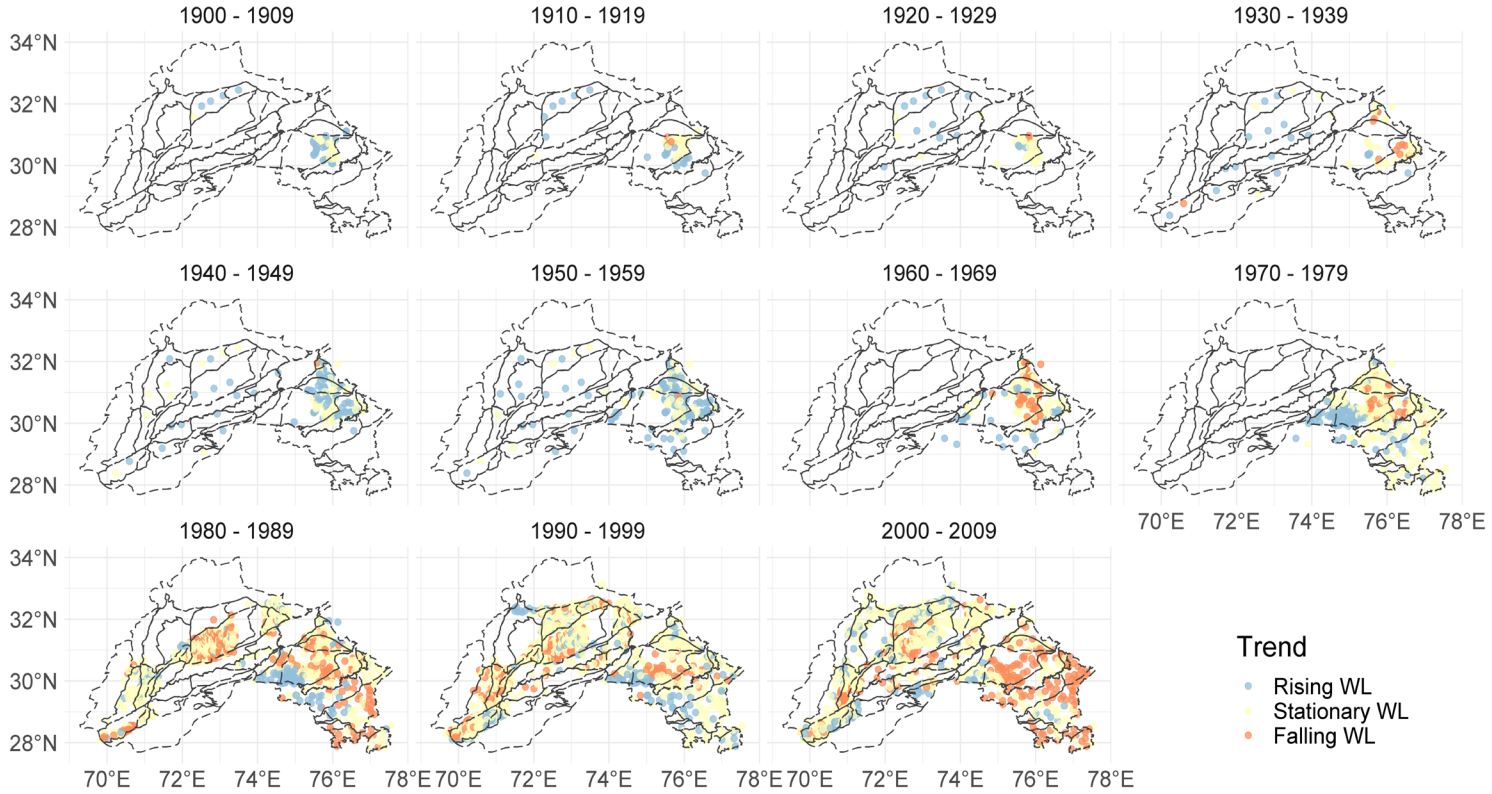


Tubewell numbers and groundwater levels

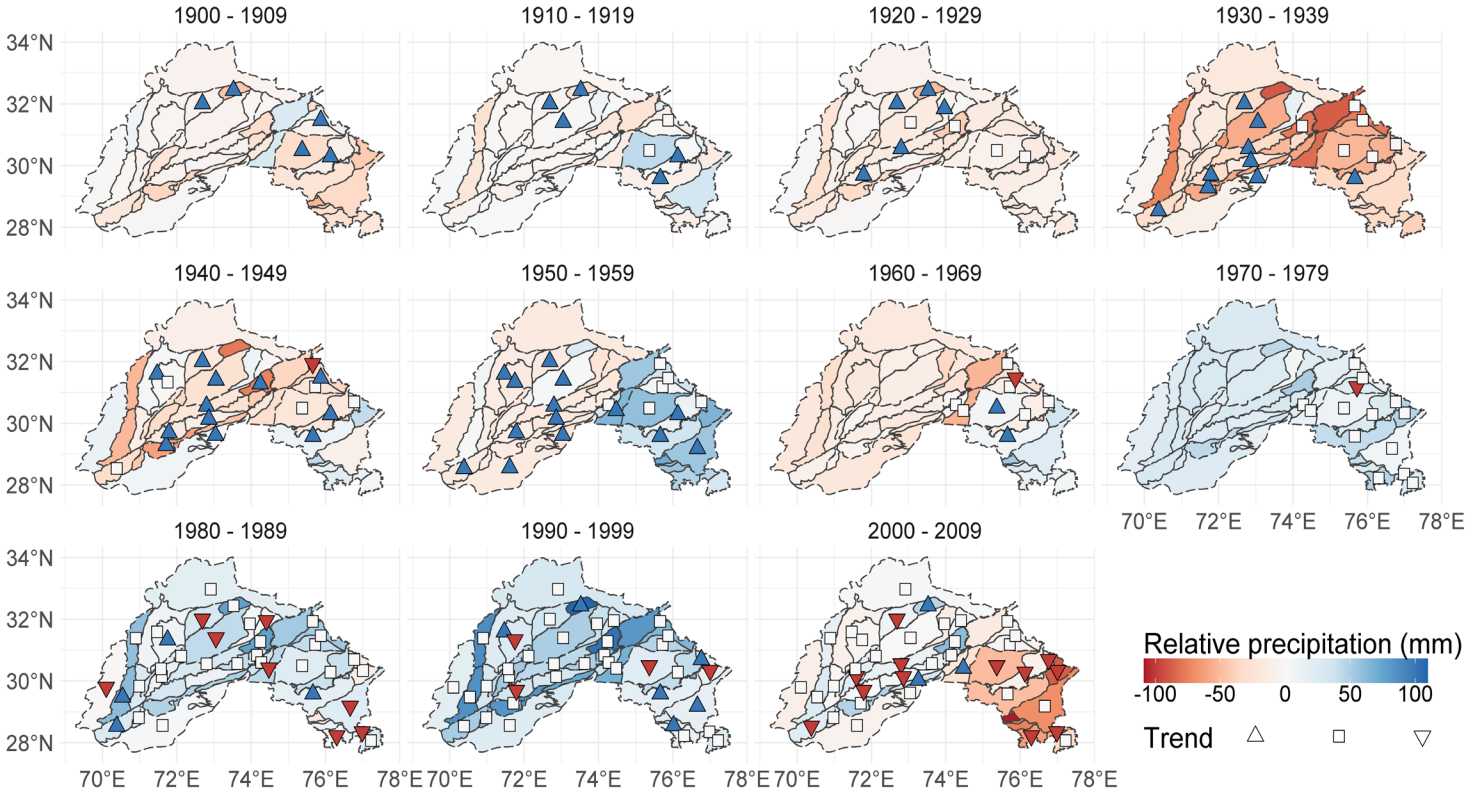




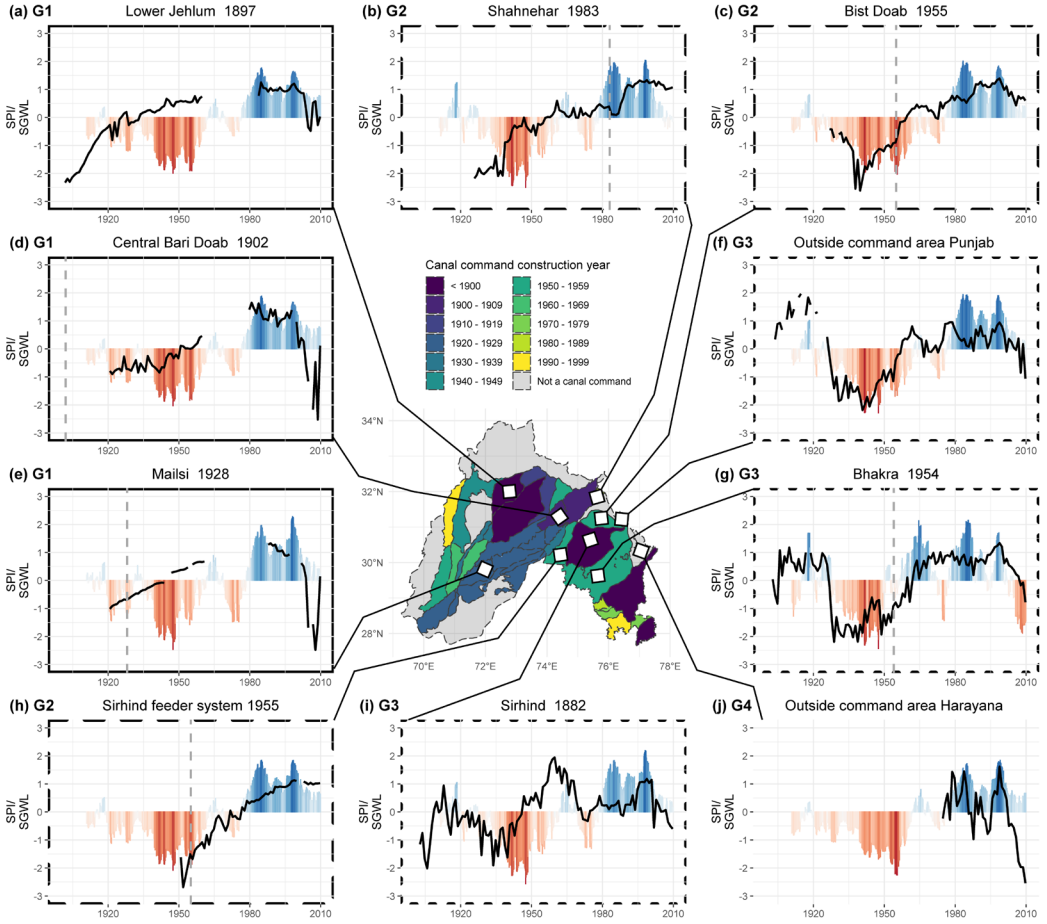
Groundwater level decadal trend



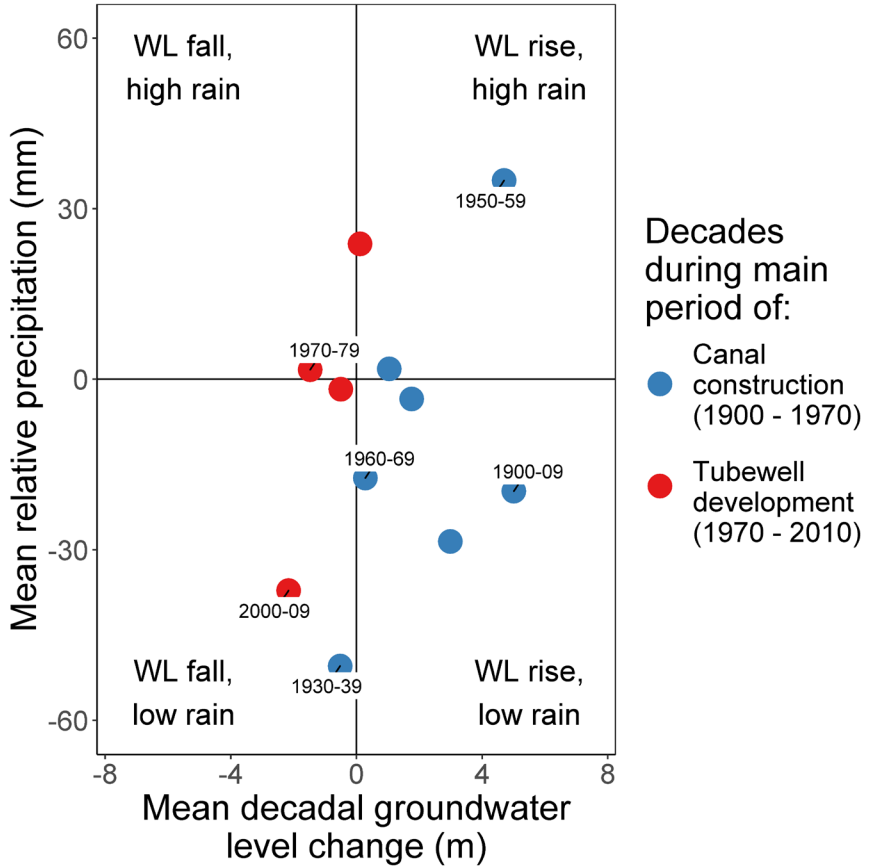
Groundwater level and precipitation trend



Regional groundwater level trends

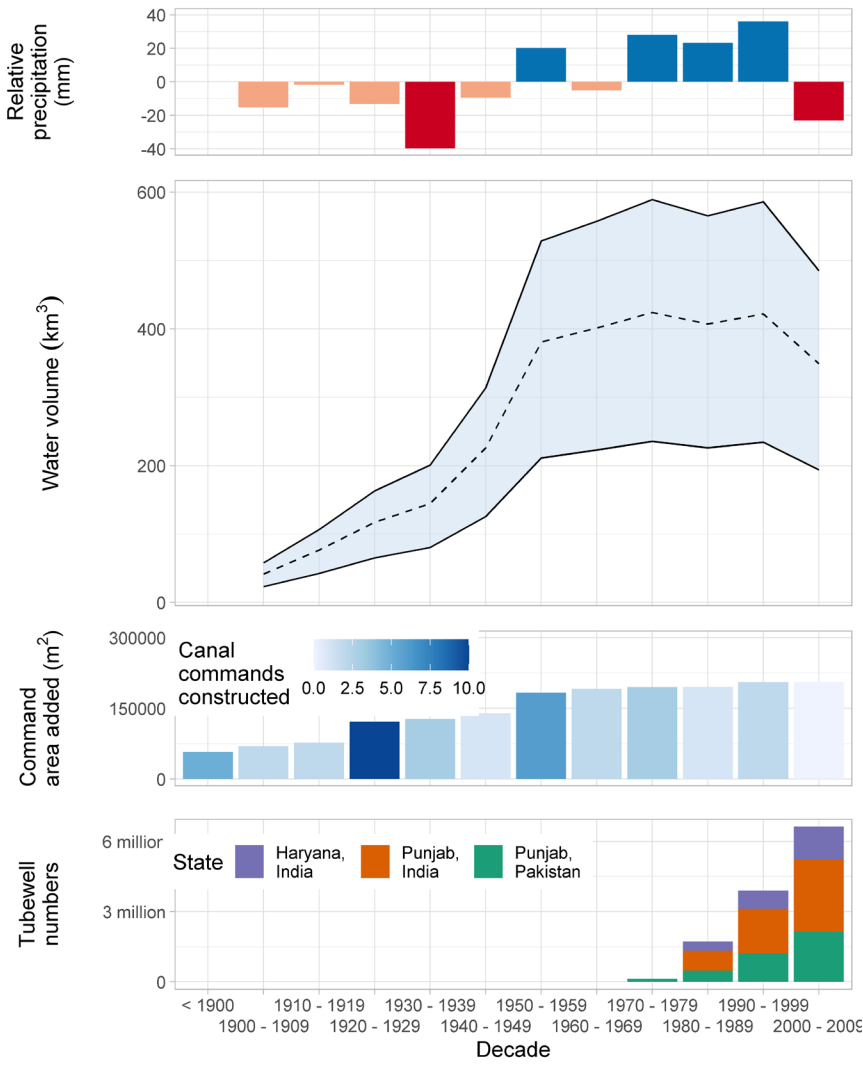


Influence of canals and tubewells on decadal trend



A century of accumulation

- 1900 – 1960:
  - Rainfall below period mean.
  - **125,000 km²** of canal area added.
  - Net groundwater accumulation:
    350 km³ (range: 150-450 km³)
- 1960 – 1990:
  - Rainfall above period mean.
  - Little additional canal area added.
  - Tubewell development began.
  - Groundwater stabilised.
- 1990 – 2010:
  - Rainfall below period mean.
  - Groundwater depletion
    75 km³ (range: 25-100 km³)



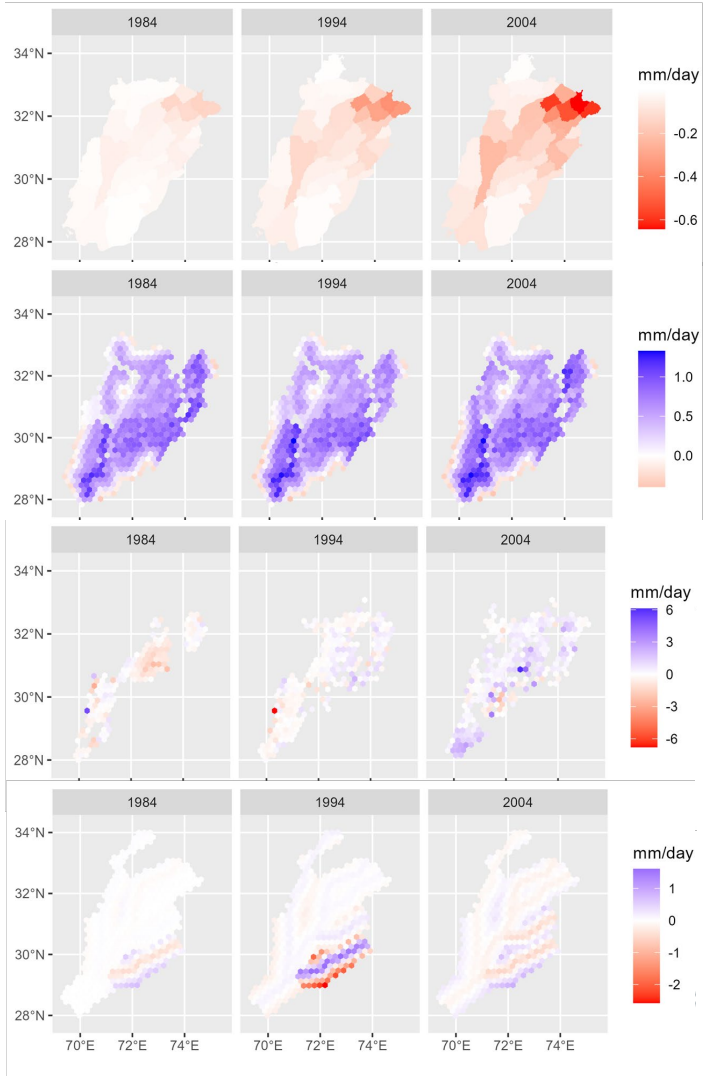
Long-term groundwater level change in north-western IGB

- For the majority of the last century groundwater levels were rising, net groundwater accumulation was c.350 km^3.
- Large scale irrigation development via canal construction played a defining role in groundwater accumulation.
- More recent groundwater depletion was driven by the superimposed effects of low average rainfall and large scale tubewell development.
- **Human activity in the early 20th century increased the total volume of groundwater available prior to large scale exploitation in the late 20th century.**

Quantifying relative importance of recharge sources

Quantifying recharge sources in the IGB

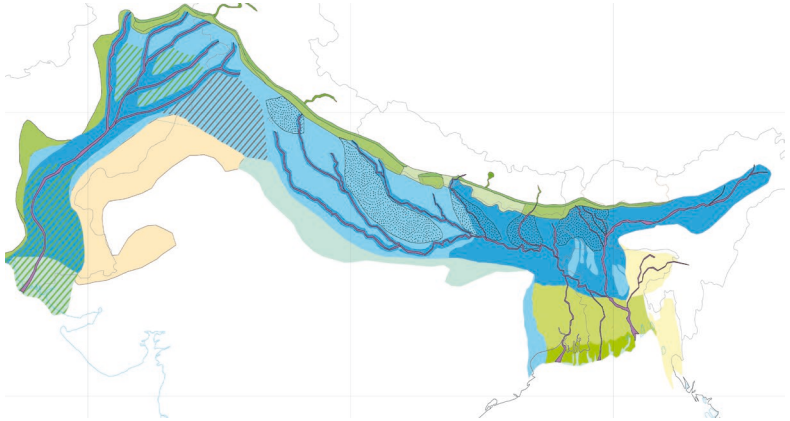
- Quantified recharge contributions using a spatially correlated linear model.
- **Tubewell effects**: the increasing importance of tubewell abstraction as more and more wells were drilled for irrigation
- **Canal irrigation effects**: The effect of high or low river/canal flows, decreasing with distance from each canal
- **Groundwater capture effects**: Increasing groundwater capture due to the slightly lower pre-monsoon water levels in 2000's than 1990's and in 1990's than 1980's.
- **River inflow effects**: decreasing effects with distance from rivers



Wrapping up

Summary and conclusions

- The IGB aquifer is an excellent buffer to human and climatic change
- It has been changing for more than 150 years
- Groundwater is more vulnerable to abstraction than climate change
- Degradation in groundwater quality is arguably a greater concern than depletion
- The aquifer properties and status vary considerably and need targeted governance
- Groundwater and surface water are linked – one resource



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THANK YOU

Any questions?