United Nations
Educational, Scientific and
Cultural Organization

Institute for
Water Education
under the auspices
of UNESCO

Enhancing groundwater recharge while maintaining environmental flow in the Yongding River, Beijing, China

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Water scarcity in Beijing

Some facts

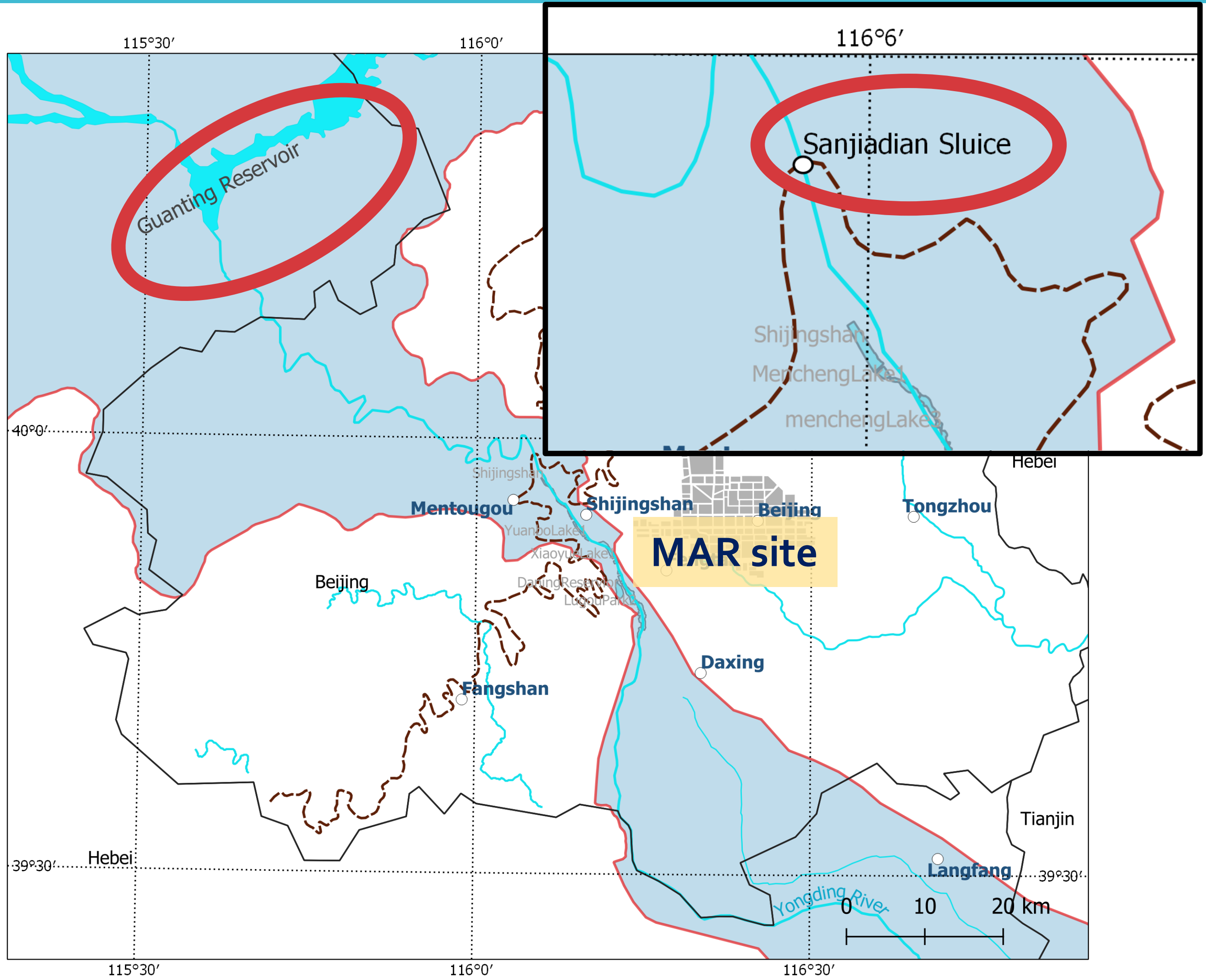
- 16,411 km^2
- Population: 21.9 million (2020). Rapid urban development
- Average annual precipitation: 585 mm, 75% during the flood season
- 60% water supply relies on groundwater
- 10-year drought during 1999-2009
  - surface water body degraded
  - groundwater heavily overexploited.
  - Other environmental problems

Opportunities

- Large-scale water transfer projects: Yellow River Diversion Project

Yellow River Diversion project

- Water release from the upstream reservoir
- - Maintain the environmental flow
- -Augmenting the groundwater recharge



Managed Aquifer Recharge (MAR) in Yongding River channel

- Lakes and we
  - Recreationa
  - Riverine ecosystem im
  - Augmenting the groun
    recharge

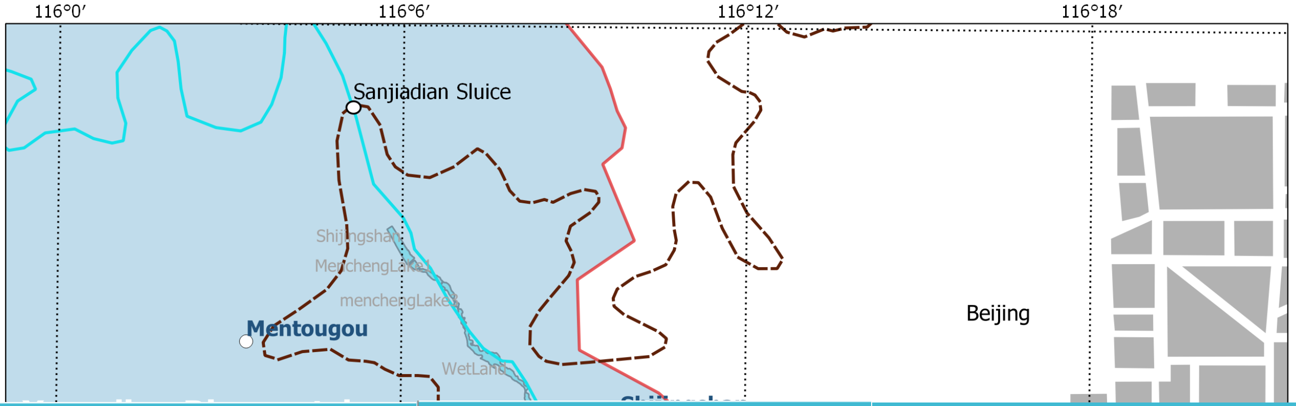
Source: https

Source: http://www.gov.cn/jrzg/2011-09/29/content_1959871.htm

Total infiltration area: 10.4 km²

Managed Aquifer Recharge (MAR) in Yongding River channel

- Water released from Sanjiadian Sluice before/after the flood season
- Different release rate and duration has been tested from 2019-2020



Water Release in 2019 Spring

93 days

132 million m³

Water Release in 2020 Spring

32 days

151 million m³

Water Release in 2020 Autumn

22 days

51 million m³

Groundwater modelling as tool to assess the impact the MAR project in Yongding River

Construct

- 3D-transient groundwater flow model by MODFLOW 2005

Compute

- The spatial distribution of the groundwater level change with time

Quantify

- The recovery of the groundwater storage.
- The infiltration rate and maximum infiltration capacity of the riverbed.

Identify

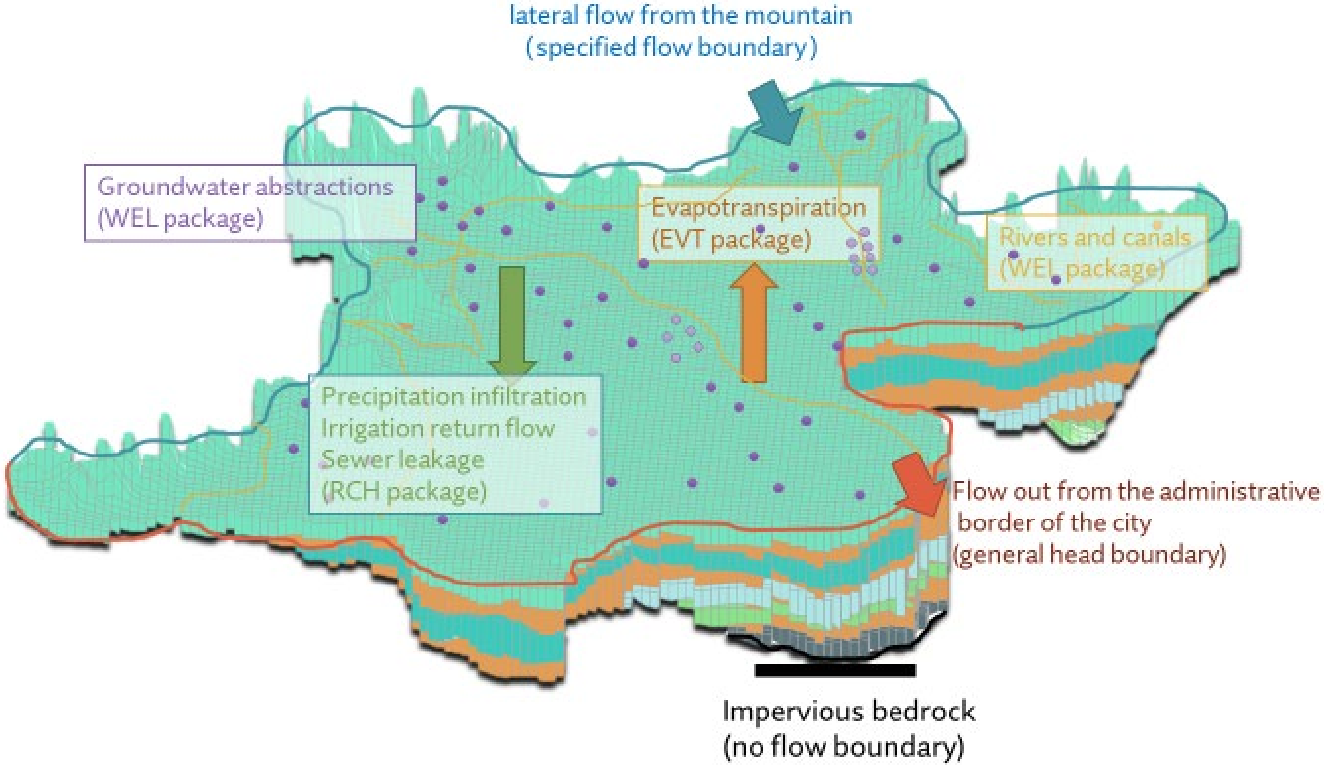
- The potential hazards related to the artificial recharge.

Optimize

- The future MAR management.

Multi-scale groundwater flow model

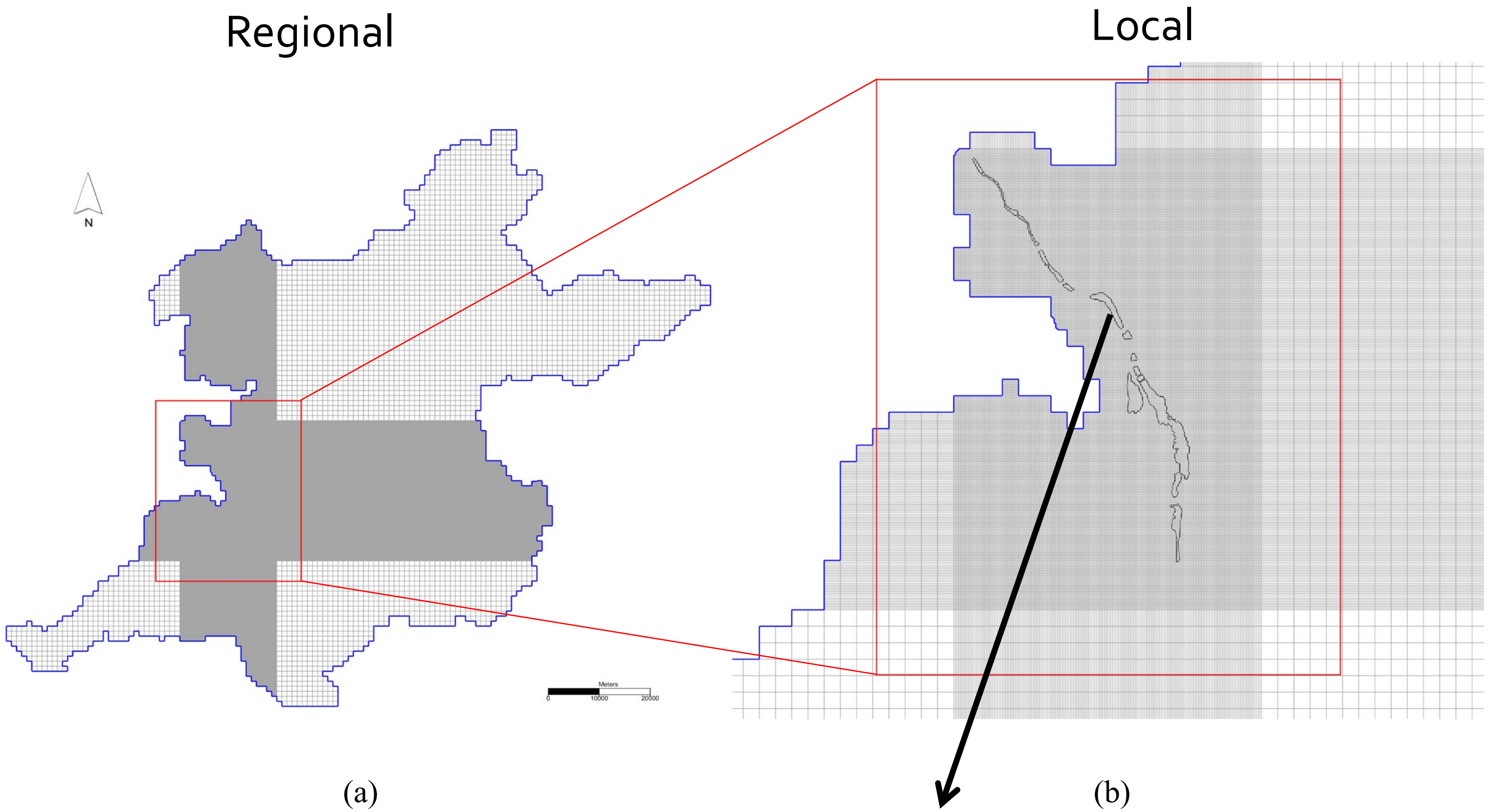
Regional model setting



Monthly transient groundwater flow model 1995-2018

Multi-scale groundwater flow model

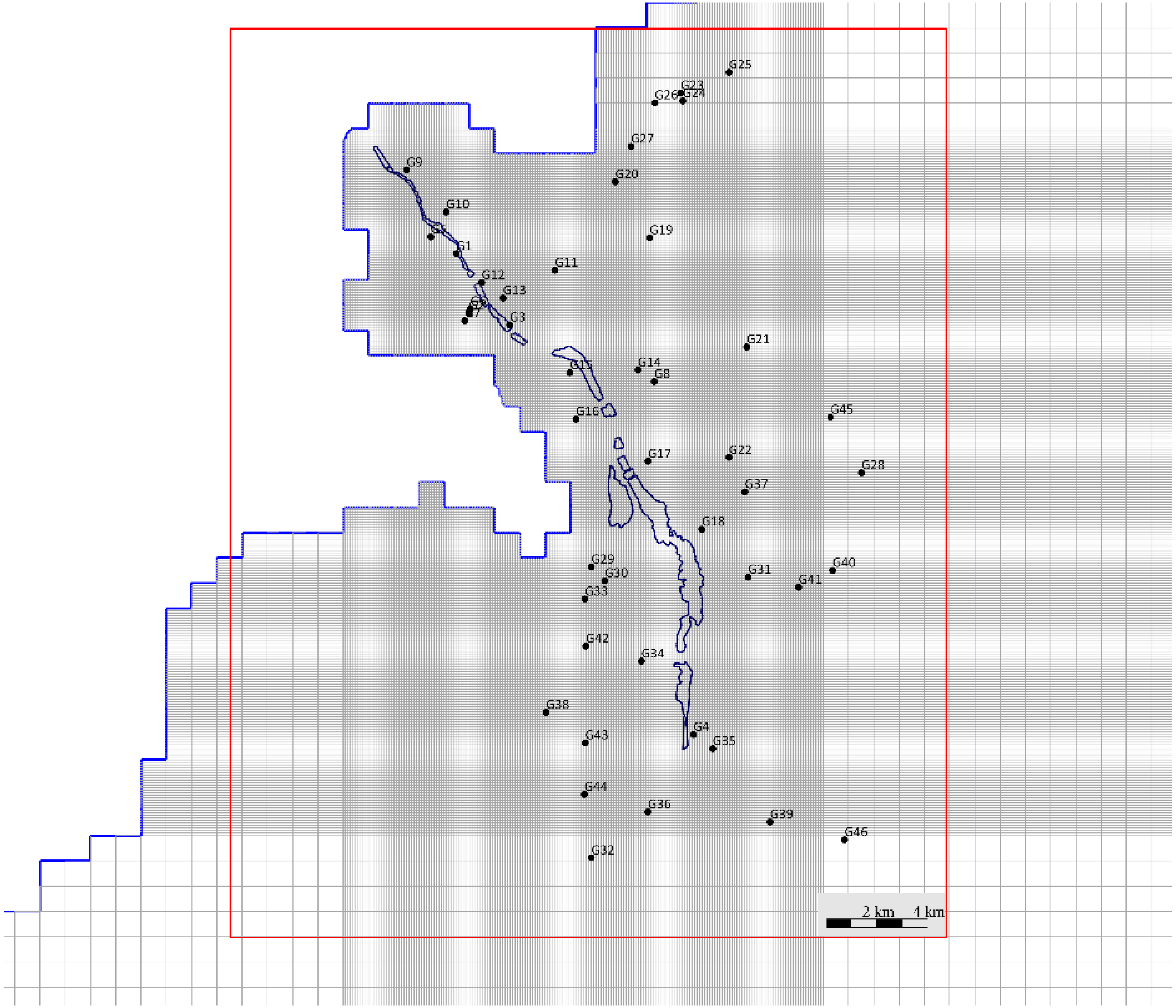
Grid Refinement



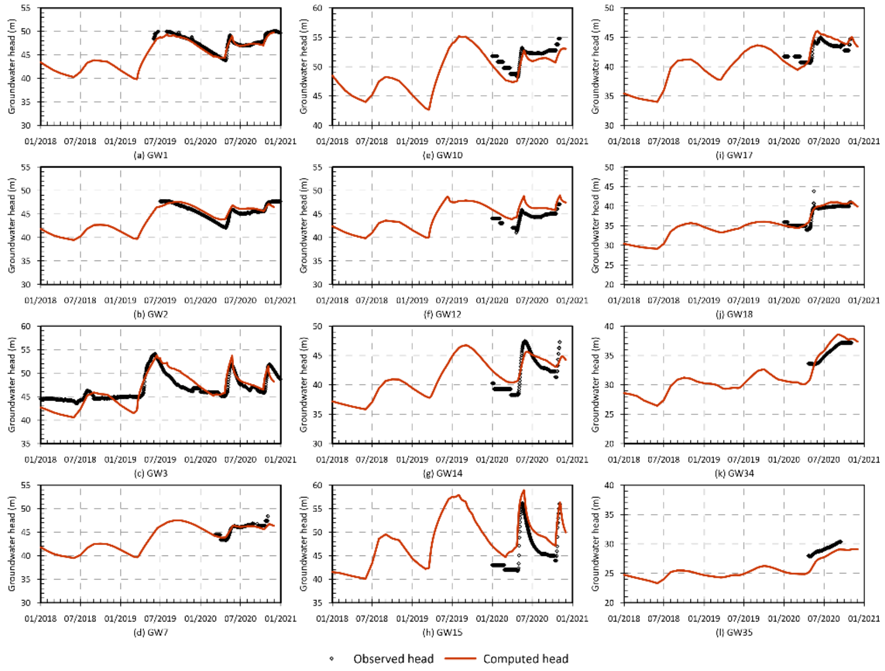
Locally refined daily groundwater flow model from 2018-2020

Multi-scale groundwater flow model

Observation Wells

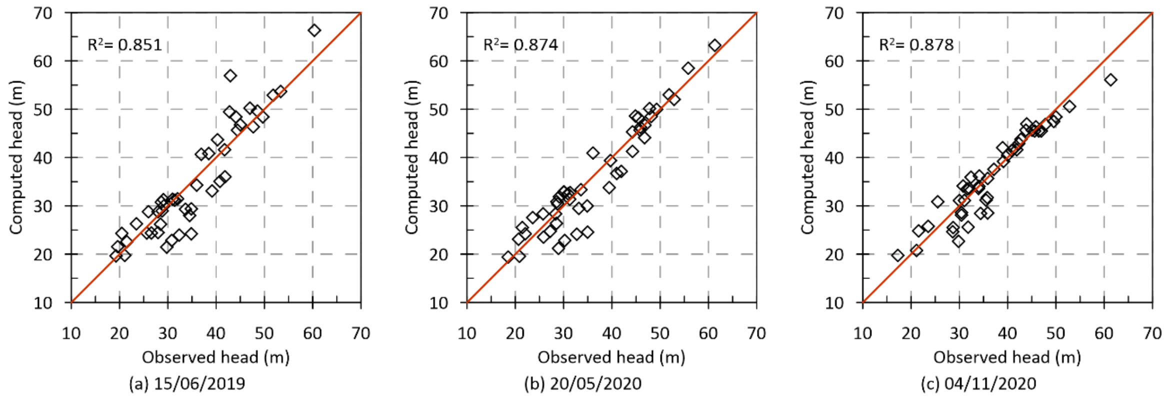


Model Calibration



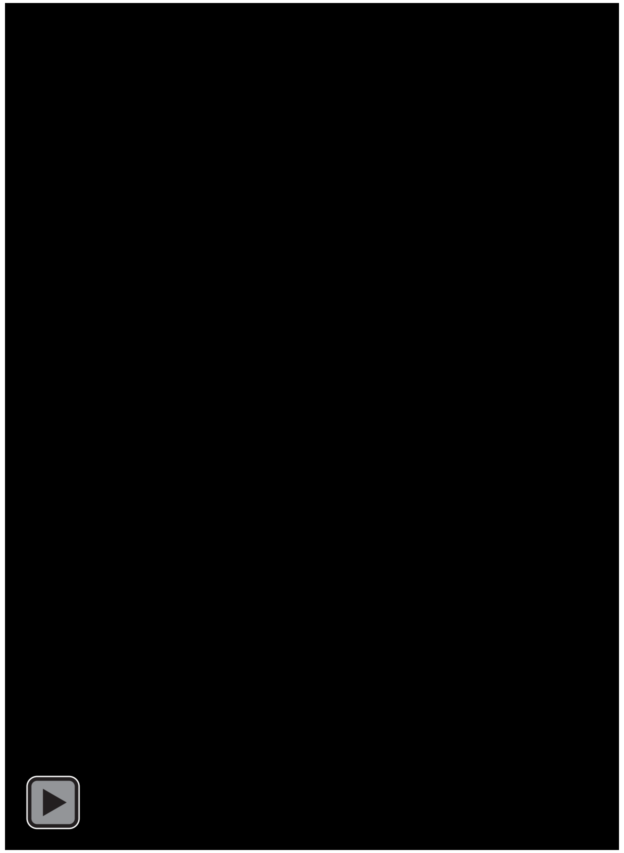
- Computed VS. Observed groundwater level time series data

- Computed vs. Observed groundwater level data during three water release events

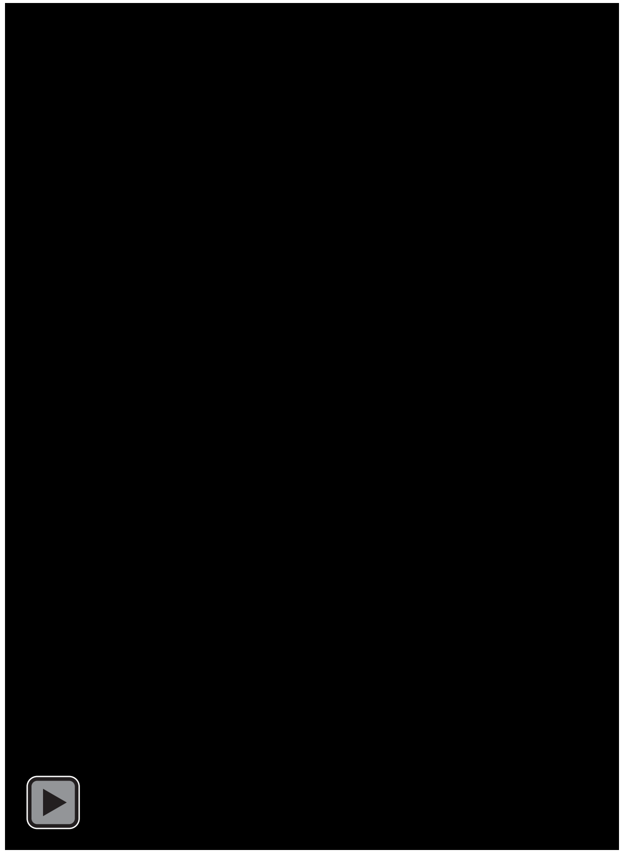


Groundwater level contours

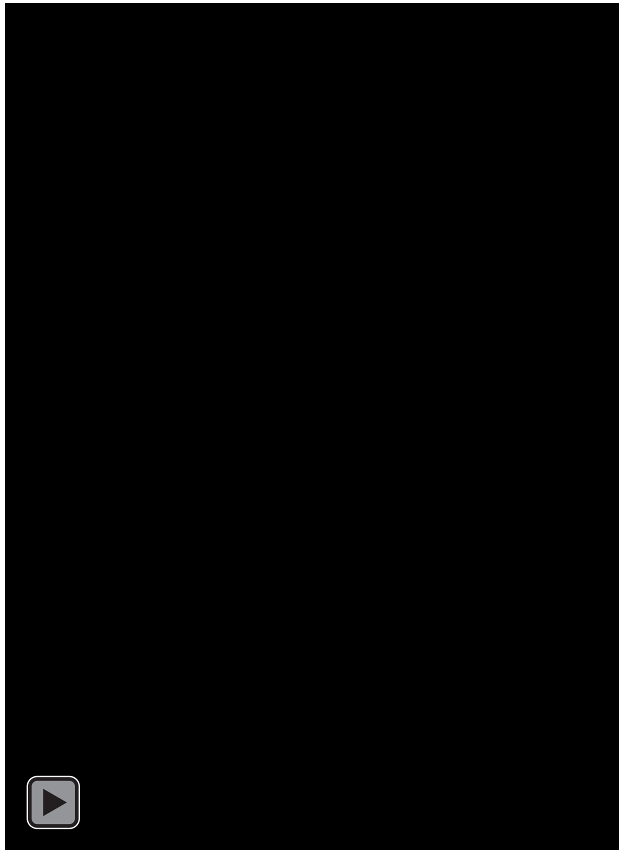
March 16th – June 17th 2019



April 21st – May 24th 2020

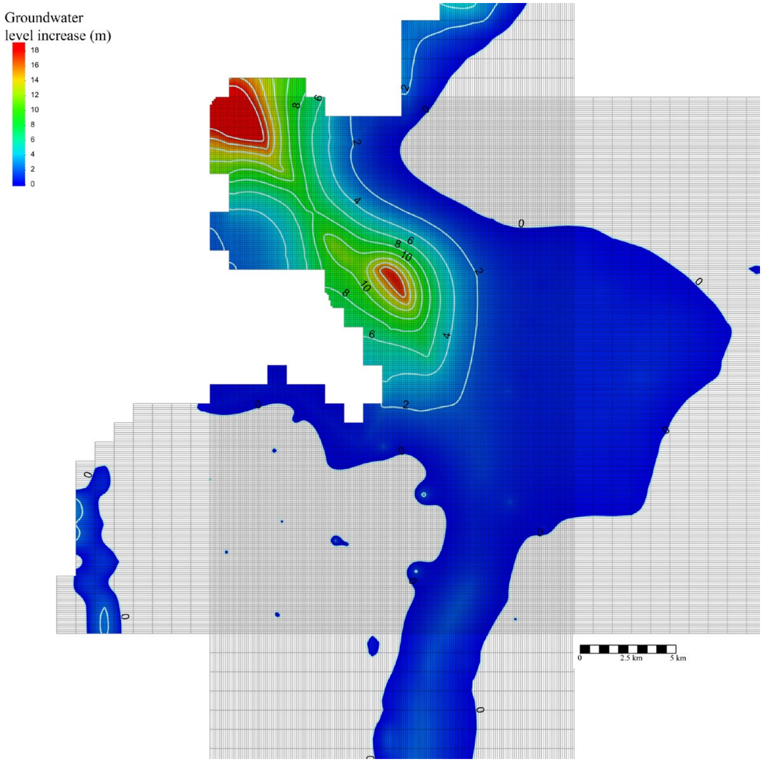


October 13th – November 4th 2020



Groundwater level increase

March 16th – June 17th 2019



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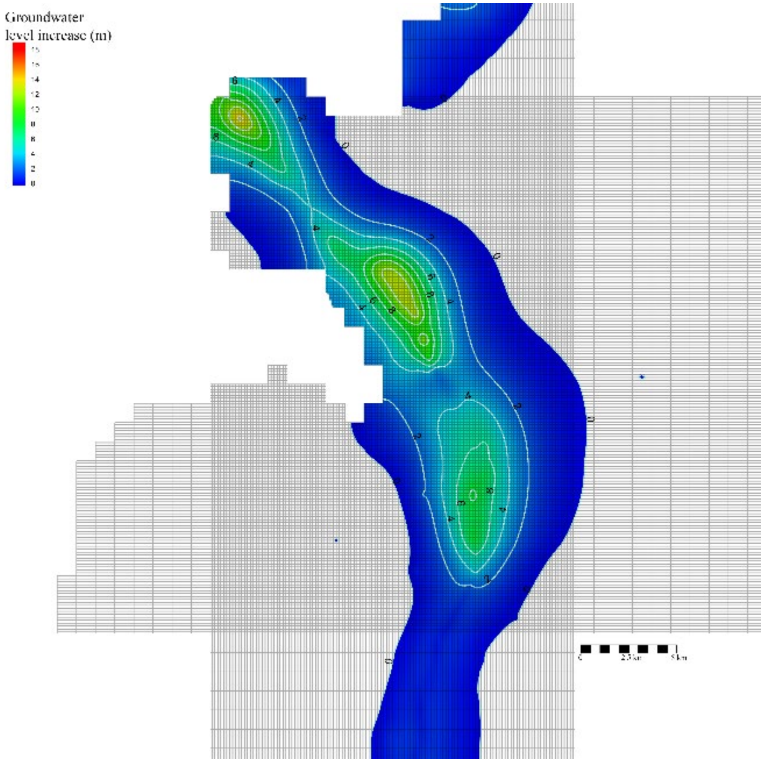

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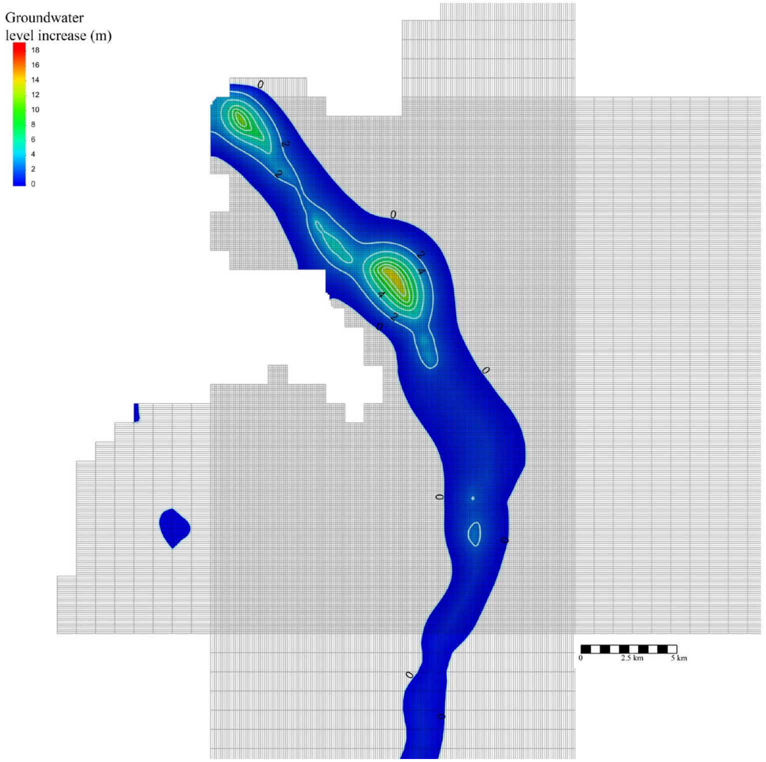
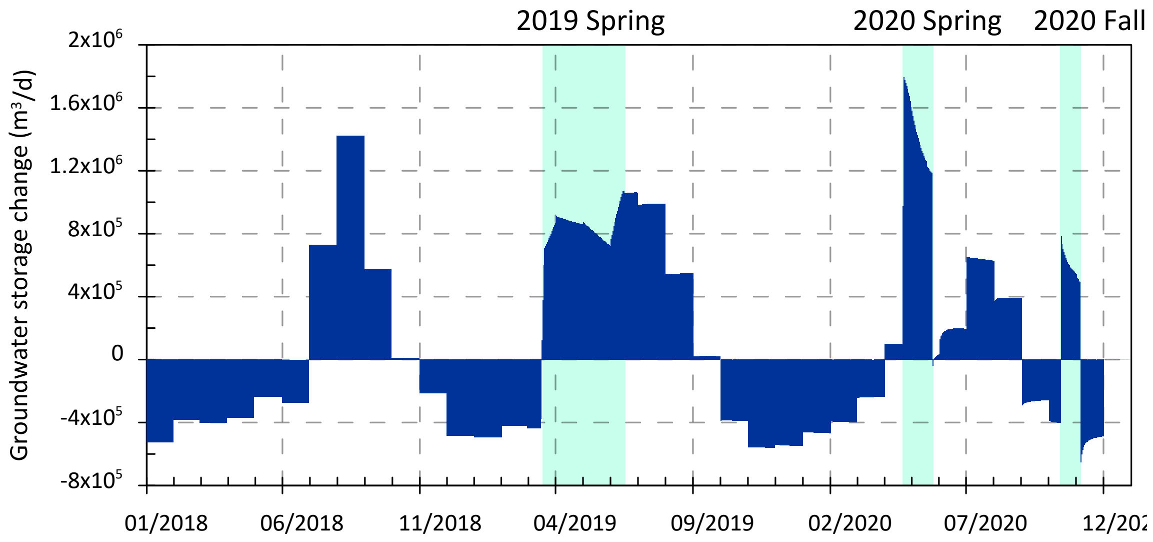
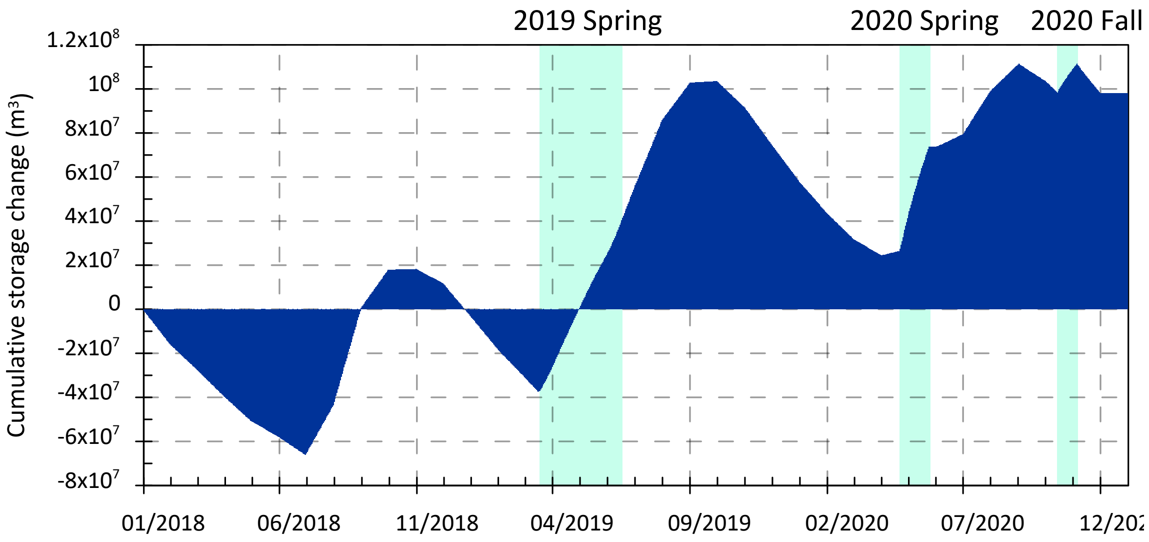


Groundwater storage restoration





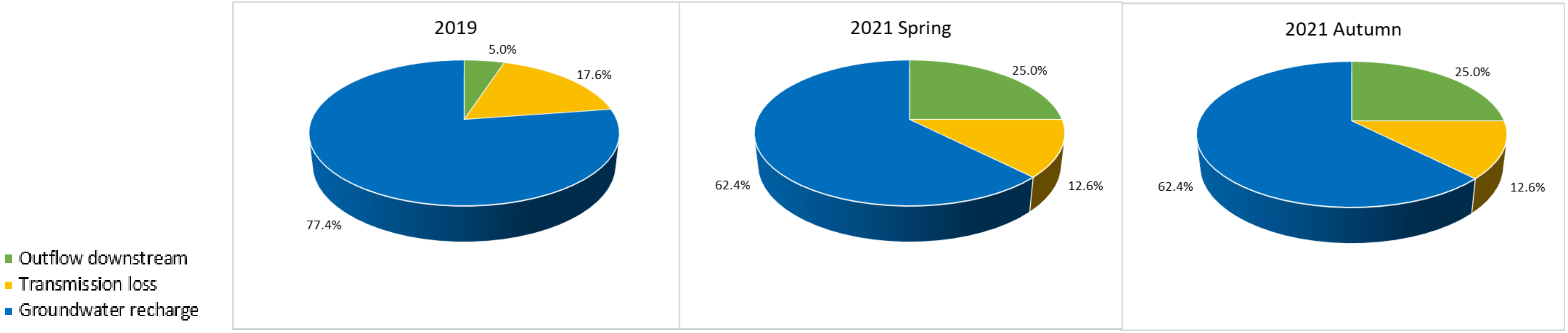
Annual aquifer storage change in Yongding River:

2018: -3,664,523 m^3
2019: 49,290,151 m^3
2020: 39,744,358 m^3

Cumulative aquifer storage from 2018 to 2020:

85,369,987 m^3

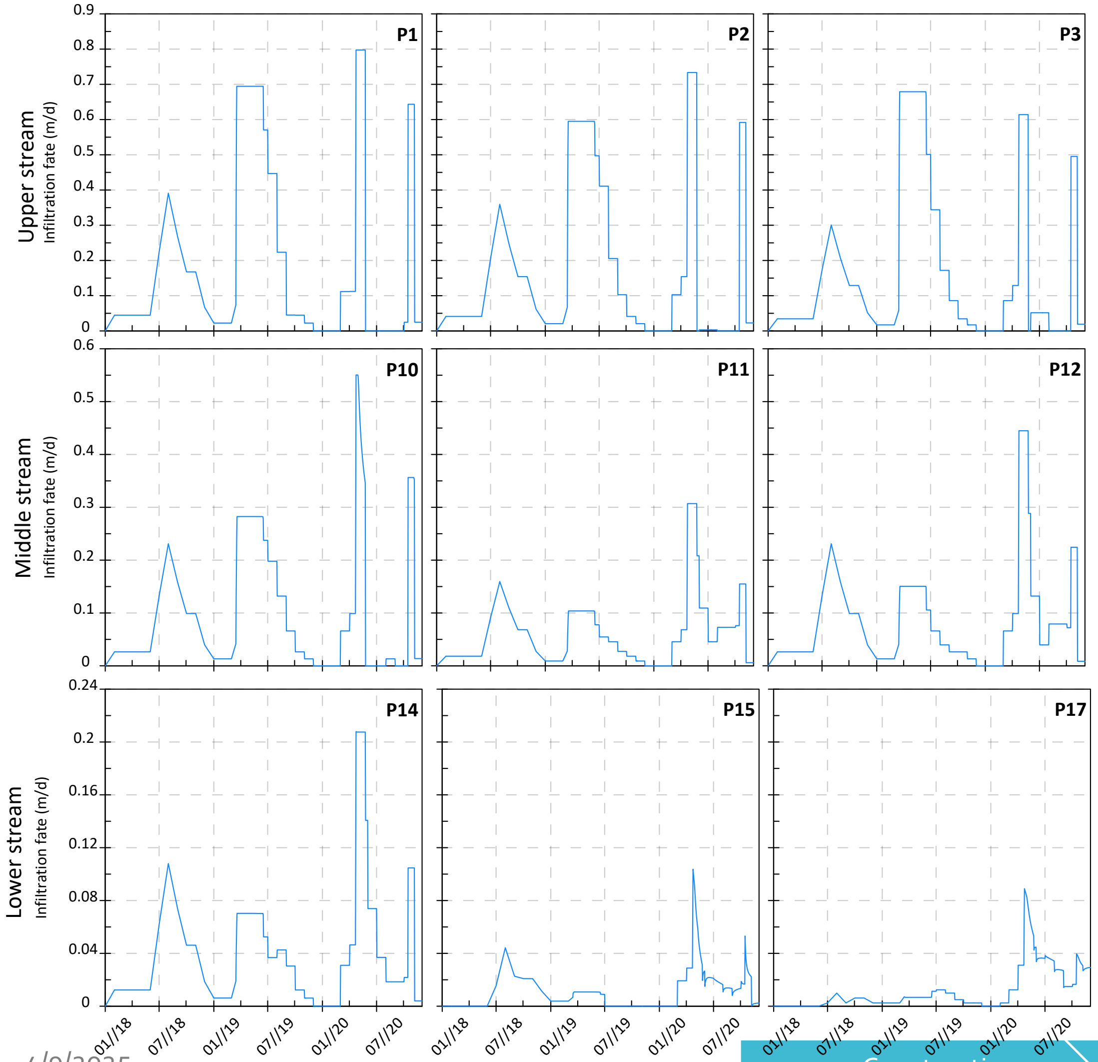
Groundwater recharge through the riverbed



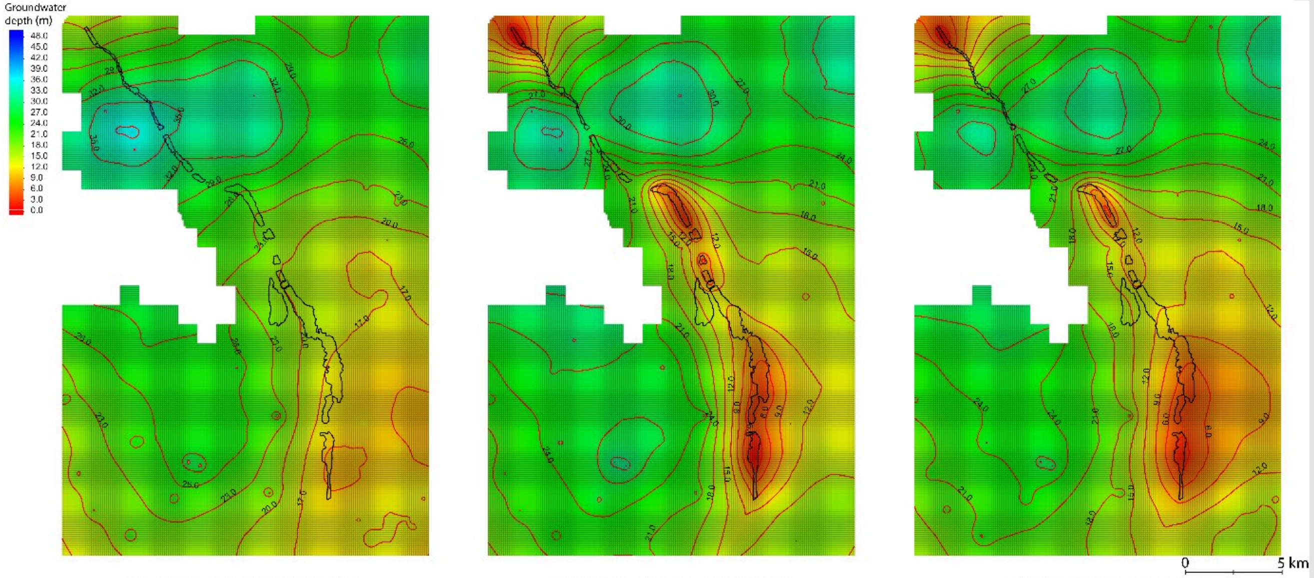
Event	Period (days)	Total water release (m³)	Outflow downstream (m³)	Transmission loss (m³)	Groundwater recharge (m³)	Groundwater recovery efficiency
2019 Spring	93	132,000,000	6,600,000	23,268,854	102,131,146	77.4%
2020 Spring	32	141,950,000	35,487,500	17,917,806	88,544,694	62.4%
2020 Fall	22	51,162,000	11,255,640	7,219,777	32,686,583	63.9%

Groundwater recharge through the riverbed

Infiltration rate at different part of the recharge site-different hydraulic properties of the riverbed



Map of the groundwater depth near the recharge site



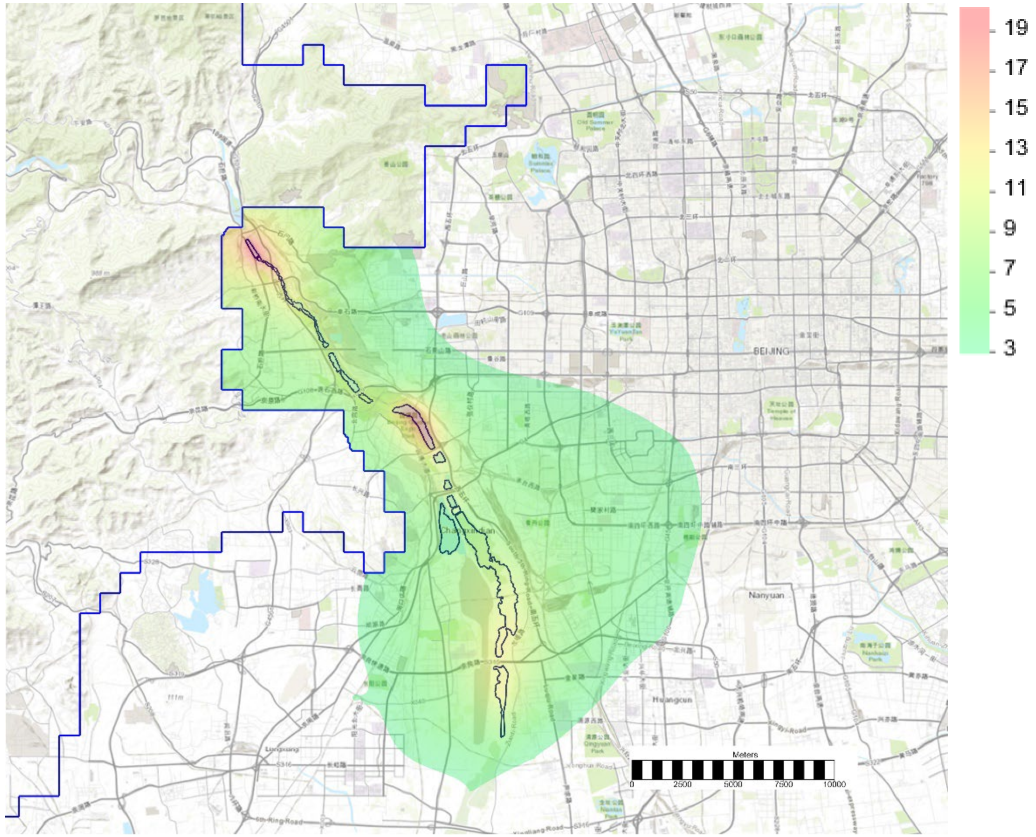
(a) Before 2019 spring water release

(b) Bofore 2020 spring water release

(c) After 2020 fall water release

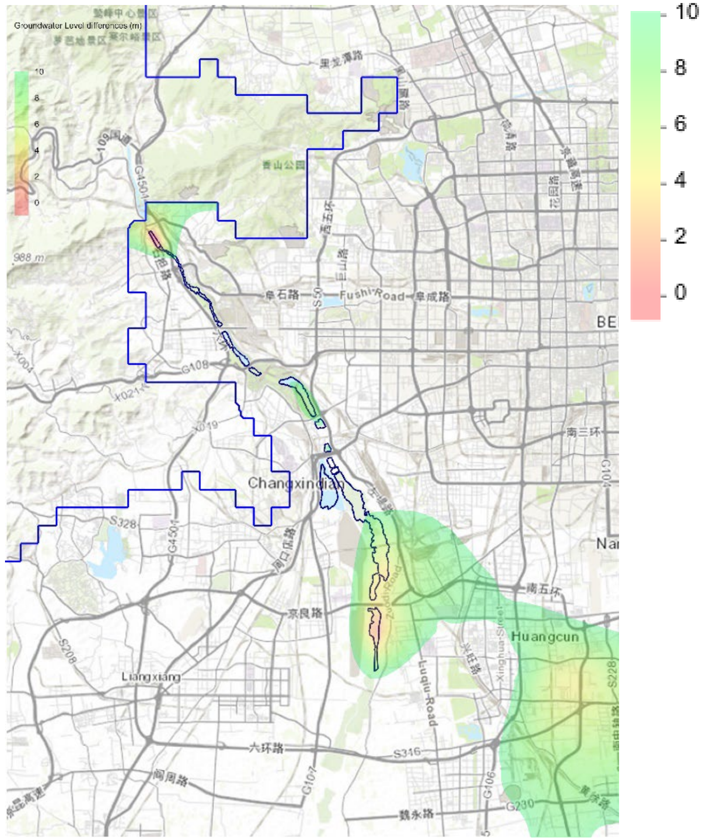
Potential hazards related to the artificial recharge

Increasing groundwater level after the long-term water release operation



Area with above 3 meters water level increase

Shallow groundwater depth after the water release event



Area with less than 10 meters groundwater depth

Recommendations for the future MAR management

- The ecological water release has been successfully in maintaining the environmental flow and improving the riverine ecosystem.
- Groundwater level near the recharge site increased in response to the water release events and groundwater storage also increased
- High groundwater level needs to be aware during the MAR implementation.
- Different future recharge scenarios can be tested by the groundwater model.


Thanks