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Hydrological drivers of high groundwater levels on the left bank of the Lower Rhine

Discharge year 2024: Hydrological analysis and historical classification of precipitation as well as Rhine and groundwater levels on the left bank of the Lower Rhine

Flooding on the Rhine near Duisburg-Baerl in the 2024 discharge year.

The 2024 discharge year was characterized by high precipitation throughout Germany, which led to elevated levels in surface waters and high groundwater levels in many places. In the LINEG (Linksniederrheinische Entwässerungs-Genossenschaft) association area, months of constant precipitation led to saturated soils and local waterlogging. Persistently high water levels in the Rhine also prevented groundwater runoff and exacerbated the high groundwater levels. For a more detailed analysis of this condition, meteorological and hydrological observations were compared with historical data, focusing on the combined effect of precipitation and Rhine water levels on groundwater levels.

Coal and rock salt mining has caused subsidence in parts of the LINEG association's area. In regions affected by mining, LINEG therefore operates pumping stations for groundwater regulation, whose tasks are defined by law. The 2024 discharge year (November 1, 2023 – October 31, 2024) presented the association with particular challenges due to a pronounced high groundwater situation with numerous reports of waterlogging.

The aim of the project was to analyze meteorological and hydrological parameters and classify them in their historical context. The precipitation at the Xanten pluviometer station, the Rhine water levels at the Duisburg-Ruhrort gauge, the amount of groundwater extracted in the association's area, and the groundwater levels at 26 selected measuring points were examined.

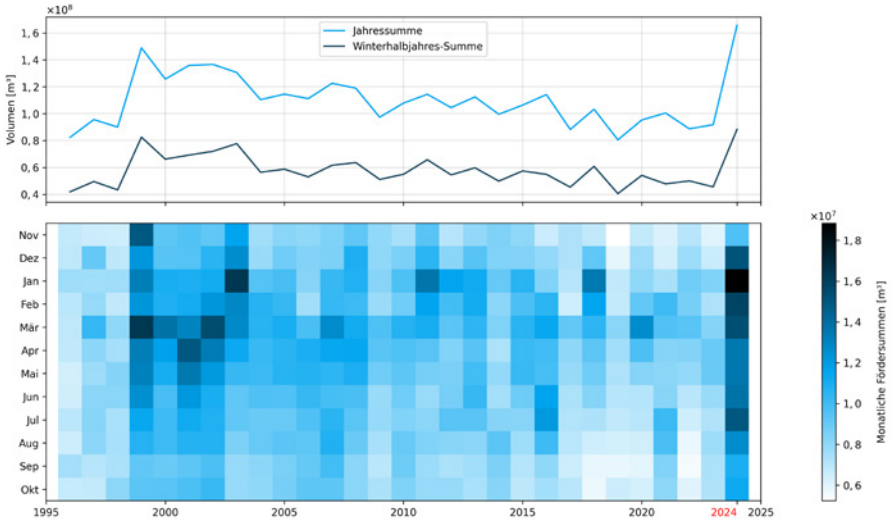

Fig. 1: Total (semi-)annual (top) and monthly (bottom) groundwater volume extracted in the mining areas from 1996 to 2024. © FiW e. V.

Although annual precipitation did not reach a historic high, it was significantly above the long-term average, with the third-highest total since 1972. Cumulative precipitation exceeded the 95th percentile of the reference period (1972–2024) throughout the year; the average annual precipitation had already been reached by the beginning of June. The Rhine water levels also showed an unusual situation. Although there were no flood events (>HQ_{10}), water levels were above the average water level on 85 % of days. Water levels exceeded the 90th percentile of the reference period, particularly in November, December, May, and June. The simultaneous combination of high precipitation and prolonged elevated Rhine water levels significantly impeded the discharge of newly formed groundwater into the Rhine.

As a result of these conditions, more groundwater was extracted than ever before in 2024 in the areas affected by mining in order to comply with legal requirements (see Fig. 1). The highest extraction volumes occurred in winter and early summer. Groundwater levels rose accordingly: all groundwater monitoring stations considered showed at least medium groundwater levels (25th–75th percentile) on an annual average, with almost two-thirds even showing high to very high groundwater levels (>75th percentile).

The combination of several hydrological factors led to an unprecedented strain on groundwater regulation in 2024. Such conditions could occur more frequently in the future as a result of climate change. Both the long-term trends in groundwater depletion and the more frequent short-term extreme events highlight the need to continuously develop strategies and technical capacities in water management and, if necessary, to adapt them to changing climatic conditions at short notice.

Project overview

PROJECT TITLE

Discharge year 2024: Hydrological analysis and historical classification of precipitation as well as Rhine and groundwater levels on the left bank of the Lower Rhine.

PROJECT PERIOD

05/2025 – 12/2025

CLIENT

Linksniederrheinische Entwässerungs-Genossenschaft (LINEG)

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