

Investigation of Groundwater Flow in the area of a Former Open-Pit Mine Margin

Project Background

To support the remediation planning of two local groundwater contaminations in the vicinity of the former margin of a backfilled open-pit mine, several groundwater monitoring wells were installed for groundwater flow modelling. However, the model did not provide sufficiently reliable results for the planned remediation measures. Therefore, in-situ groundwater flow measurements were carried out in critical areas to verify the model assumptions and to provide a reliable basis for decision-making.

Hydrogeological Setting

Heterogeneous porous aquifer consisting of backfill material and natural sediments (sand and silt)

Purpose of Investigation

Detailed investigation on local groundwater flow for remediation planning

Key Findings

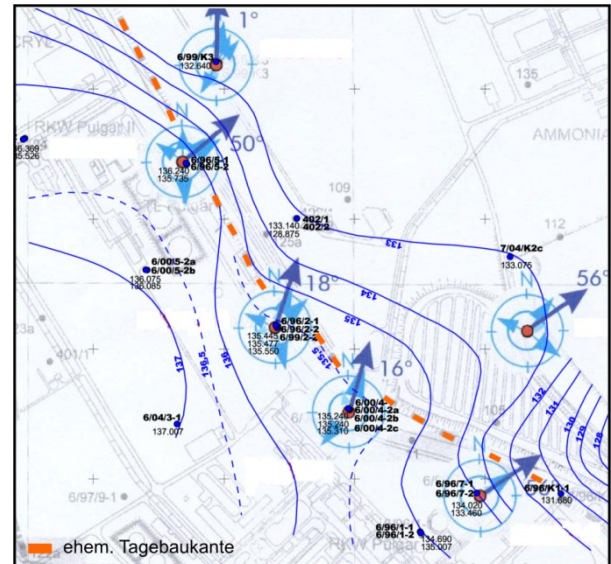
The in-situ flow measurements largely confirmed the existing groundwater flow model. In addition, different groundwater flow conditions within the profile of the investigated aquifer were identified as a result of the interlocking of artificial and natural sediment bodies with contrasting hydraulic properties. The additional flow data enabled reliable remediation planning and reduced the need for additional monitoring wells and further hydraulic investigations.

Client Benefits

- Additional data for remediation planning and decision-making
- Validation of existing groundwater flow model assumptions and provision of data for detailed groundwater flow modelling
- Identification of different groundwater flow conditions within the aquifer profile caused by the interlocking of sediment bodies with contrasting hydraulic properties
- Improved understanding of the aquifer system
- Information on well construction and condition

Client

Chemical industry



Groundwater Flow Investigation in a Connecting Mine Gallery at a Depth of 200 m

Project Description

Two mines are hydraulically connected by a connecting gallery located approximately 200 m below ground level. This connection creates a potential pathway for the migration of contaminants from one mine to the other. To determine groundwater flow within the approximately 3 m high and 3 m wide gallery and to assess the potential for contaminant transport, a borehole was drilled to a depth of more than 200 m into the connecting gallery. Horizontal in-situ flow measurements were then carried out at several vertical positions within the intersected gallery section.

Hydrogeological Setting

Free-flowing mine gallery within bedrock

Purpose of Investigation

Investigation of horizontal flow within the connecting mine gallery, including flow direction and velocity at several vertical positions across the gallery profile, to provide directly measured data for assessing potential contaminant transport between the two mines.

Key Findings

Horizontal in-situ flow measurements were carried out at several vertical positions across the height of the intersected gallery. Low flow velocities ranging from approximately 0.1 to 4 mm/s were measured at all investigated positions.

Due to the low flow velocities and the considerable hydraulic degrees of freedom within the free-flowing gallery, the measurements showed a time-variable, transient flow pattern over the individual measurement periods of one to two hours. By evaluating and balancing the measured flow vectors over time, the prevailing flow direction and characteristic flow velocities could be reliably determined. The results demonstrated that the flow conditions

within the gallery were not represented by a single constant flow vector but showed temporal and spatial variations across the gallery vertical profile. The measured flow directions and velocities were subsequently assessed for plausibility as part of a modelling study and numerical simulations and were confirmed by the modelling results.

Customer Benefits

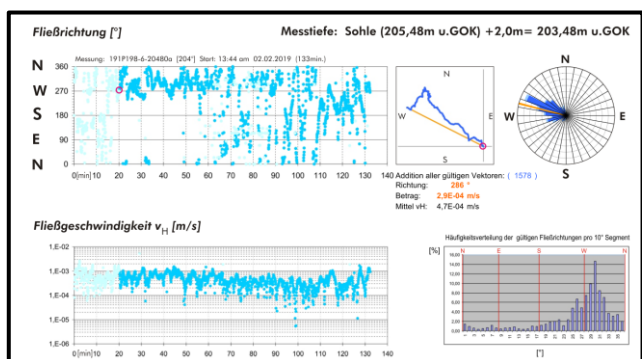
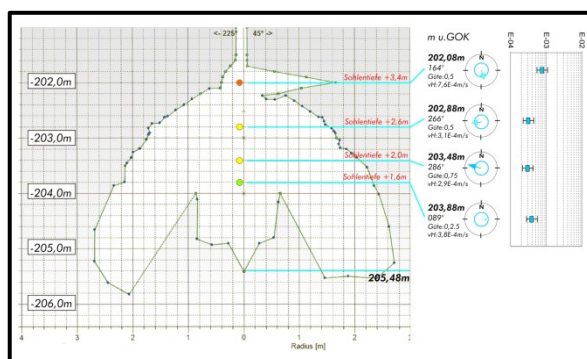
- Direct determination of flow direction and velocity within the connecting mine gallery
- Vertically resolved characterization of flow across the gallery profile
- Information on time-variable flow behaviour over extended measurement periods
- Directly measured data for assessing potential contaminant transport between the connected mines
- Data basis for subsequent modelling and numerical simulation
- Additional camera inspection of the borehole and intersected gallery section

Hydrogeological Challenge

The large hydraulic degrees of freedom within the approximately 3×3 m free-flowing gallery results in spatially and temporally variable flow conditions. Individual measurements therefore represented only snapshots of the flow situation. Extended measurement periods and time-integrated evaluation of the measured flow vectors made it possible to distinguish short-term variations from the prevailing flow direction and to reliably characterize the overall flow behaviour within the gallery.

Client

Municipal Environmental Agency



Groundwater Flow Investigation in a Connecting Mine Gallery at a Depth of 200 m

Services

- Borehole camera inspection
- Horizontal in-situ groundwater flow measurements
- Data evaluation, interpretation and project documentation

Project Scope

- one monitoring borehole (6-inch diameter)
- Measurement depth: 206 m

Project Location

Lower Saxony, Germany

Project Duration

3 days

Special Requirements

- Installation of the measurement equipment to a depth of 200 m
- Exact depth positioning of the probe in 200m
- Water pressure at measurement point exceeding 15 bar

191P198

Investigation on Groundwater Flow at the Margin of a Former Open-Pit Mine

Project Description

A section of a backfilled former open-pit mine was used as a tar-sludge disposal site, releasing large quantities of contaminants into the surrounding porous aquifer. Due to the site's location at the former margin of the open-pit mine, naturally occurring sediments are interbedded and interfingered with heterogeneous mine backfill material, resulting in a complex hydrogeological setting. Existing groundwater flow models did not provide sufficiently conclusive results for reliably assessing contaminant migration. In-situ groundwater flow measurements were carried out within the existing monitoring well network to obtain direct information on groundwater flow at critical model boundaries and at different depths within the aquifer. The measured data were intended to support refinement of the groundwater flow model, assessment of contaminant migration pathways, and subsequent remediation planning.

Hydrogeological Setting

Natural porous aquifer (silt-sand), interfingering with heterogeneous open-pit mine backfill (sand-gravel)

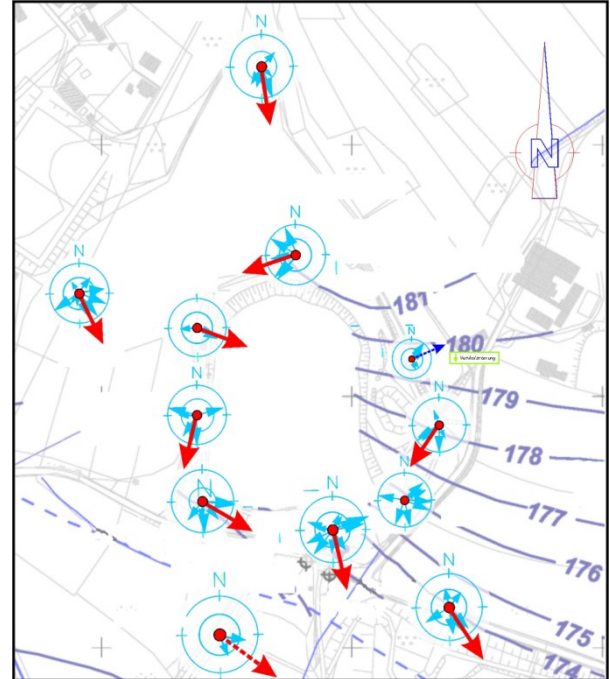
Purpose of Investigation

- Detailed investigation for risk assessment and remediation planning
- Verification and refinement of the existing groundwater flow model
- Direct measurement of groundwater flow at critical model boundaries and at different depths within the aquifer
- Improved assessment of potential contaminant migration pathways
- Provision of additional data for the selection of locations for further monitoring wells

Investigation Results

In an initial pilot investigation, in-situ groundwater flow measurements were carried out in three monitoring wells. Based on the results, the investigation was subsequently extended to a further 13 monitoring wells.

The directly measured groundwater flow data provided additional information on local flow directions and flow behaviour within the heterogeneous aquifer system. In particular, the measurements helped to characterize groundwater flow in areas where the complex interbedding of naturally occurring sedi-



ments and heterogeneous mine backfill material limited the reliability of interpretations based on groundwater levels alone.

The results supported the refinement of the existing groundwater flow model and were used to identify suitable locations for additional monitoring wells. The expanded data basis provided further information for assessing contaminant migration and for the further development of the remediation concept.

Hydrogeological Challenge

At the former margin of the open-pit mine, naturally occurring sediments and heterogeneous backfill materials form a complex three-dimensional aquifer structure with strongly varying hydraulic properties. This geological heterogeneity results in locally variable groundwater flow conditions that cannot always be reliably characterized from groundwater level measurements alone. Directly measured flow directions and velocities therefore provided valuable additional information for verifying model assumptions and improving the representation of groundwater and contaminant flow paths.

Customer Benefits

- Verification and refinement of existing groundwater flow model assumptions
- Improved understanding of the heterogeneous aquifer system

Investigation on Groundwater Flow at the Margin of a Former Open-Pit Mine

- Direct information on local groundwater flow conditions and potential contaminant migration pathways
- Optimized selection of locations for additional monitoring wells
- Provision of directly measured data for detailed groundwater flow and contaminant transport modelling
- Improved data basis for risk assessment and remediation planning
- Verification of monitoring well construction and condition for follow-up investigations

Client

Engineering consultancy and well construction company on behalf of a state environmental authority

Services

- Monitoring well camera inspections
- Horizontal in-situ groundwater flow measurements
- Data analysis and project documentation

Location

Saxony, Germany

Scope of Field Work

16 monitoring wells / DN100–DN125 (4–5")
Measurement depths: 14–37 m
Total measurement time: 94 hours

Duration of Field Work

14 days

Special Requirements

High levels of contamination, locally including up to 0.3 m of floating free-phase contamination

051P062 / 061P083

Groundwater Flow Investigation in Flooded Borehole-Intersected Mine Workings

Project Description

To investigate groundwater flow conditions within flooded mine workings with regard to potential geothermal utilization and hydraulic interactions with the connected groundwater system, several boreholes were drilled into the mine gallery system and completed as groundwater monitoring wells. The screened sections were positioned within the intersected mine galleries. Horizontal in-situ groundwater flow measurements were carried out at several vertical positions across the intersected gallery profiles to characterize flow direction and velocity within the mine gallery system and to provide directly measured data for further hydrogeological assessment.

Hydrogeological Setting

Free-flowing mine galleries within limestone and dolomite formations, accessed by boreholes with screened sections positioned within the intersected galleries

Purpose of Investigation

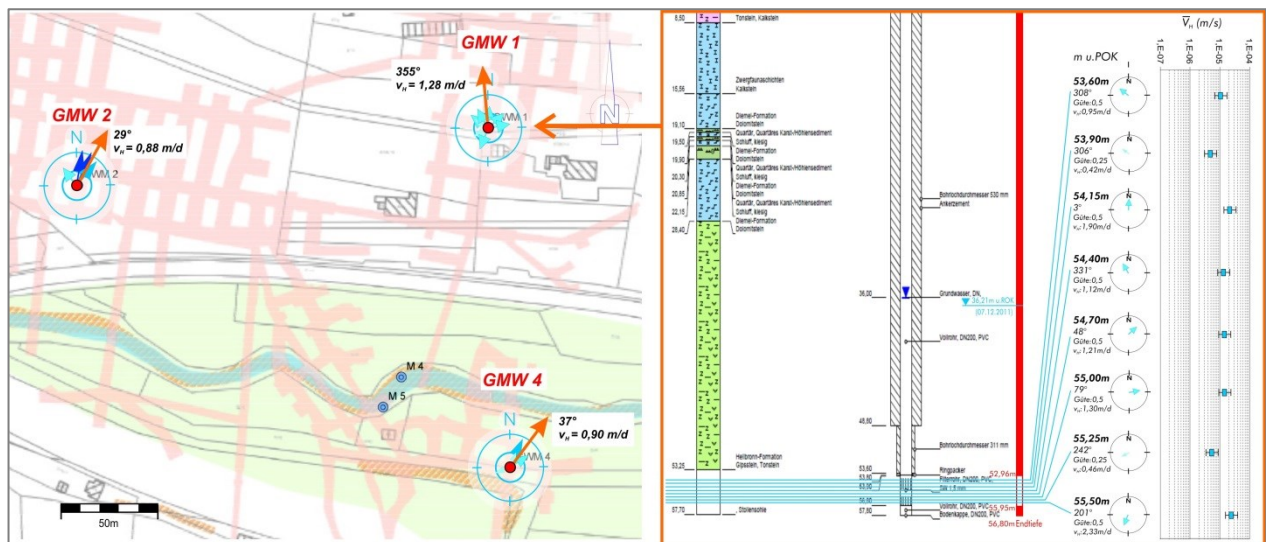
- Investigation of groundwater flow conditions within the flooded mine gallery system
- Provision of hydraulic data for assessing the potential for geothermal utilization
- Assessment of hydraulic interactions with the connected groundwater system
- Data basis for risk assessment with particular regard to drinking water protection
- Provision of directly measured flow data for groundwater flow modelling

Investigation Results

Horizontal in-situ groundwater flow measurements were carried out at several vertical positions across the gallery profiles intersected by the boreholes. In all four investigated monitoring wells, the measurements indicated a prevailing northward flow, with mean flow velocities ranging from approximately 0.5 to 1.5 m/day. However, the vertically resolved measurements showed that flow conditions were not uniform across the individual gallery profiles. Local deviations in flow direction were observed, including partially counter-directional flow near the gallery floor. Due to the low flow velocities and the considerable hydraulic degrees of freedom within the free-flowing galleries, the measurements showed a time-variable, transient flow pattern over the individual measurement periods of one to two hours. By evaluating and balancing the measured flow vectors over time, the prevailing flow directions and characteristic flow velocities could nevertheless be reliably determined. The results therefore demonstrate both an overall prevailing flow within the mine gallery system and local as well as temporal variations in flow conditions across the individual gallery profiles.

Hydrogeological Challenge

The considerable hydraulic degrees of freedom within the free-flowing mine galleries, combined with low flow velocities, result in spatially and temporally variable flow conditions. Individual measurements therefore represent only snapshots of the actual flow situation. Extended measurement periods and time-integrated evaluation of the measured flow vectors made it possible to distinguish short-



Groundwater Flow Investigation in Flooded Borehole-Intersected Mine Workings

term variations from the prevailing flow pattern and to reliably determine characteristic flow directions and velocities.

Customer Benefits

- Direct determination of the prevailing flow direction and velocity within the mine gallery system
- Vertically resolved characterization of flow conditions across the gallery profiles
- Identification and analysis of local and partially counter-directional flow
- Characterization of time-variable flow behaviour over extended measurement periods
- Hydraulic data basis for assessing potential geothermal utilization
- Provision of directly measured flow data for groundwater flow modelling
- Verification of monitoring well construction and condition

Client

Public-Sector Authority

Services

- Monitoring well camera inspections
- Horizontal groundwater flow measurements
- Data analysis and project documentation

Scope of Work

4 monitoring wells / 5–8" diameter
Measurement depths: 28–55 m

Location

Baden-Württemberg, Germany

Duration of Field Work

4 days

011P139

Groundwater Flow Investigation near Mine Workings at Depths of up to 300 m

Project Background

Large-scale ground subsidence occurs in the vicinity of a site affected by salt mining and is associated with ongoing dissolution processes in the subsurface. Groundwater inflow into flooded mine workings also contributes to these processes. To obtain additional information on groundwater flow within the deep aquifer and in the vicinity of the mine workings, horizontal in-situ groundwater flow measurements were carried out in completed deep boreholes at depths of up to 300 m. The measurements were intended to provide additional directly measured data for hydrogeological assessment and further groundwater flow modelling. The monitoring wells are completed with 4–4.5" steel liners. In sections intersecting fracture zones or cavities, the liners are designed as longitudinally slotted screens. No gravel pack is installed in the annular space. In subsequent projects, additional measurements were conducted in other monitoring wells at similar depths.

Hydrogeological Setting

Fractured to cavernous bedrock aquifer containing highly mineralized groundwater (Q-brine)

Purpose of Investigation

- Investigation of groundwater flow direction and velocity within fracture zones in the deep aquifer
- Acquisition of hydraulic data in deep aquifer zones associated with flooded mine workings
- Supplementary data for assessing potential

groundwater inflow into the mine workings

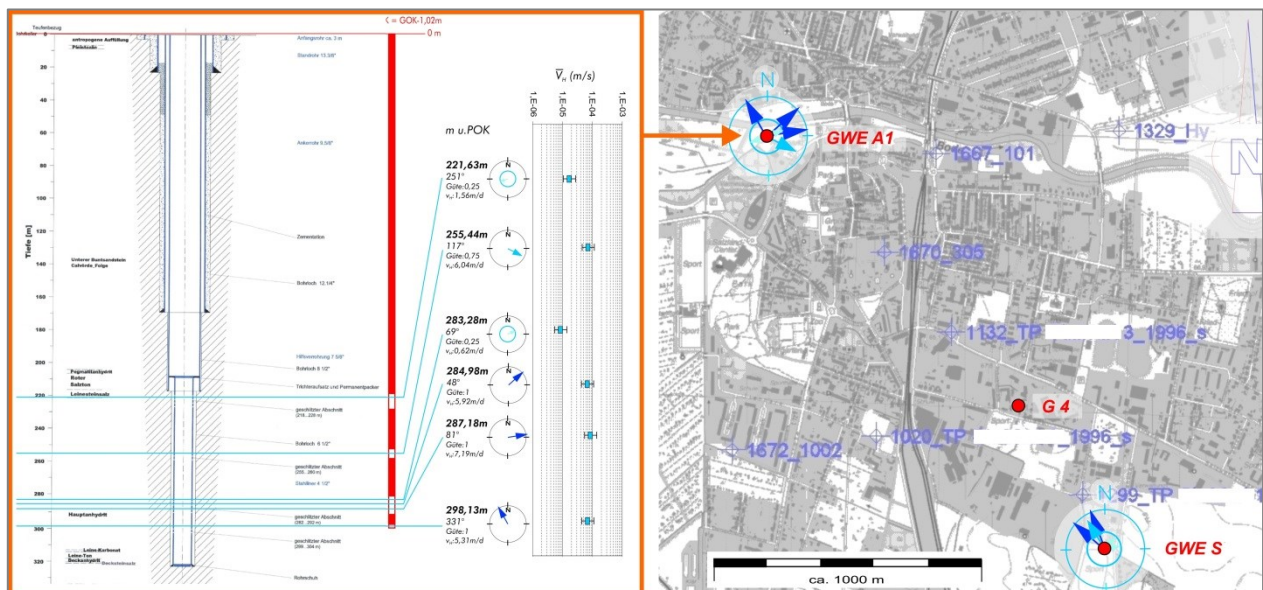
- Provision of directly measured flow data for groundwater flow modelling

Investigation Results

The location and condition of the longitudinally slotted screen sections were located by the probe-integrated inspection camera. Horizontal in-situ groundwater flow measurements were subsequently carried out within the identified screened intervals. The measurements showed predominantly northward to eastward flow directions. Measured flow velocities ranged from approximately 0.5 to 7 m/day and were in some cases considerably higher than expected based on the existing conceptual and modelling assumptions. The results therefore indicated pronounced flow dynamics within the intersected fracture and cavity systems.

However, due to the specific well construction without a gravel pack and the incompletely known hydraulic connection between the individual screened intervals and the surrounding fracture and cavity system, the measured velocities and flow directions cannot be directly equated with undisturbed aquifer flow velocities. Convection and hydraulic balancing flows within the annular space may also influence the measurements.

The results were therefore interpreted as site-specific indications of groundwater flow direction and flow intensity and used as supplementary data for further hydrogeological interpretation and modelling.



Groundwater Flow Investigation near Mine Workings at Depths of up to 300 m

Technical Challenges

- Deployment and precise positioning of the measurement probe at depths of up to 300 m
- Optical identification of screened intervals under partially severely restricted visibility due to water turbidity
- Operation in highly mineralized groundwater with salinity increasing with depth
- Increased hydrostatic pressure due to the high water density caused by salinity (35–37 bar at 300 m depth)
- Highly corrosive conditions due to high mineralized groundwater

Customer Benefits

- Directly measured information on groundwater flow direction and flow intensity within the deep aquifer
- Evidence of increased flow dynamics within fracture and cavity systems
- Supplementary data for assessing potential groundwater inflow into flooded mine workings
- Provision of directly measured flow data for groundwater flow modelling
- Verification of the location, construction and condition of the screened intervals by a probe integrated well camera

Client

Public-Sector Client

Services

- Monitoring well camera inspections
- Horizontal in-situ groundwater flow measurements
- Data analysis, project documentation and presentation

Scope of Field Work

- 2 monitoring wells
- Measurement depths: 200–300 m

Location

Saxony, Germany

Duration of Field Work

4 days

091P118/101P122/ /101P126