02.22 Hydraulic Permeability of the Subsurface (Edition 2019)

Overview

A local and near-natural percolation of rainwater is generally preferable to rainwater drainage systems, due to legal, ecological and economic reasons and those related to water-management (Printed Matter of the House of Representatives of Berlin 18/0212 and 18/0447). Percolation describes the technical process of introducing precipitation into the subsurface using appropriate systems. Whether precipitation can directly percolate locally largely depends on the geological and hydrogeological conditions, such as the subsurface layers, hydraulic permeability and groundwater conditions. When planning percolation facilities, influencing factors that need to be considered, other than the properties of the subsurface, include the potential pollution of the soil or contaminated sites, properties of adjacent areas, the availability of areas and requirements imposed by water authorities and legal regulations.

An accurate knowledge of both the local geological and hydrogeological conditions and the hydraulic permeability of the percolation area is therefore a prerequisite for planning percolation facilities. Hydraulic permeability is the property of the subsurface to conduct water within its porous space, which depends primarily on the grain size of the loose sediments, their distribution, the structure and thus the effective pore volume of the subsurface. Loose sediments with high sand contents have a much higher permeability than clayey, silty sediments, e.g. those consisting of boulder marl. To characterise the hydraulic permeability of the subsurface, the saturated hydraulic conductivity (k_f value, permeability coefficient) is used as the soil characteristic value.

Percolation facilities are subject to hydraulic requirements of the subsurface, for example, ranging from k_f= 1*10^{-3} m/s and k_f= 1*10^{-6} m/s, according to A-138 DWA regulations. Depending on the design of the percolation facility, differences in thickness of the subsurface layers are relevant for designing the facilities. In the case of surface percolation, the property of the topsoil (0.3 to 0.5 m below ground level) is decisive. For swales or deep beds, the decisive horizon is located between 0.6 m and 1.0 m below ground level. Significantly greater depths (1.0 m to 2.5 m or deeper), however, need to be considered in the design of swale-infiltration trench systems.

Obtaining direct measurements of hydraulic permeability and saturated hydraulic conductivity is laborious; therefore, only few measurements are available for Berlin. Hydraulic permeability is often determined using soil type and bulk density. Berlin’s data on soil-scientific characteristics that is essential for determining the hydraulic permeability of the subsurface is either only partially available as part of a concept map or not comprehensive. It should also be noted that deeper layers that are not covered in the soil maps are also relevant for percolation facilities. The Engineer’s Geological Map of Berlin 1 : 5,000 (SenStadtWohn 2017a) presents the geological structure of loose rock generally to a depth of 10 m. However, topsoil and landfills with a thickness of less than 5 m are not presented. As an addition to the Engineer’s Geological Map, which currently covers only about half of the Berlin area, a map of the percolation capacity of loose rock at the surface was produced in the 1990s for a selected small number of sheet lines (SenStadt 1990).

Approx. 160,000 boreholes are recorded in the geological database of the State of Berlin. They contain information on the geological structure of the subsurface, such as the stratigraphy (chronological sequence), petrography (rock composition) and genesis (formation), as well as some soil-physical characteristic values. The method used to develop the percolation potential map for the Hanseatic City of Hamburg (Stadt Hamburg 2018) was adapted to Berlin conditions to form the method employed here. Information on existing boreholes was assessed to derive and present the hydraulic permeability of the subsurface. For this purpose, the individual rock layers and petrographic analyses were classified and combined into rock classes, whereby distinguishing between a hydraulic permeability of “high to medium” and “medium to low”. The area-based hydraulic permeability of the subsurface is presented in a map displaying the thickness of the topmost layer with a high to medium hydraulic permeability from the surface to a depth of 5.0 m below ground level (cf. Map 02.22.1). An additional map displays the thickness of the layer with a high to medium hydraulic permeability between a depth of 1.0 to 5.0 m below ground level, as this area alone is relevant for the design of percolation systems (swale-infiltration trench systems) in some cases (cf. Map 02.22.2).

The map on the hydraulic permeability of the subsurface primarily serves as an overview of potential measures for the decentralised percolation of rainwater, in terms of their planning implementation and feasibility. On the one hand, it is intended as a strategic instrument for managing city-wide processes. On the other hand, it may serve as a source of information for its "users", e.g. administrators, planners and building owners, and offer advice on percolation measures.

The map on the hydraulic permeability of the subsurface does not exempt individual projects from the obligation to provide evidence for the hydraulic site conditions for percolation facilities by means of probing and on-site boreholes.

Statistical Base

The map is based on approximately 160,000 drilling profiles from the geological database of the State of Berlin by the Geological Survey Working Group of the Senate Department for the Environment, Transport and Climate Protection. The Digital Terrain Elevation Model (DGM 10), the map "Expected Mean Highest Groundwater Level" (EMHGL), 2016, and, for drinking water conservation areas, the map "Expected Highest Groundwater Level" (EHGL), 2018, were used to calculate the depth to groundwater in the glacial spillway and the Panke Valley (SenStadtUm 2016, SenStadtWohn 2017b, SenStadtWohn 2018b).

Methodology

The borehole data of the geological database of the State of Berlin was checked for plausibility and prepared accordingly. Therefore, 130,615 boreholes were used in subsequent processes. Based on the borehole database, the rock descriptions of each of the approx. 840,000 layers of the boreholes were assigned to ten rock classes with their associated hydraulic permeability (Table 1). The relevant rules to assign rock classes previously used in the process of deriving the Geothermal Potential were developed further, whereby both the genesis and the petrography were taken into account (HGC 2018, G.E.O.S. 2019, SenStadtWohn 2018a). The permeability coefficients typical of these sediments were then used to assign the hydraulic permeability categories high to medium or medium to low. Anthropogenic landfills oftentimes located near the surface were assigned the hydraulic permeability category high to medium, as it is assumed that they are rather friable in nature and possess a relatively loose bulk density. This also applies to sediments at the surface that are classified as soil. Based on the available data, it was impossible to differentiate hydraulic permeability any further.

Rock	Number of layers	Total thickness in m	Hydraulic permeability
Landfill / anthropogenic	115,625	144,924	high to medium
Soil	40,130	25,969	high to medium
Gyttja	10,634	12,508	medium to low
Peat / peat gyttja	18,356	19,187	medium to low
Sand	458,867	640,364	high to medium
Gravel	23,902	30,055	high to medium
Boulder clay	53,677	86,007	medium to low
Boulder marl	99,486	183,022	medium to low
Clay / silt	19,092	24,018	medium to low
Brown coal	711	129	medium to low

Tab. 1: Rock classes with associated hydraulic permeability

Based on this classification, the thickness of the upper layer with high or medium hydraulic permeability is determined for each individual borehole. The thickness was measured from the ground level to the top of the first cohesive layer. Additionally, the thickness was calculated starting at one metre below the ground level to the first cohesive layer.

To develop the maps, the numbers obtained on the thickness (to the top of the first cohesive layer) for each borehole were then interpolated by kriging.

Map Description

These maps illustrate the thickness of the sediments with a high to medium hydraulic permeability down to the first cohesive layer, i.e. those sediments whose hydraulic permeability is only medium to low, for the State of Berlin.

The calculation from the ground level to the first cohesive layer was carried out in Map 02.22.1; Map 02.22.2 presents the calculation starting at one metre below the ground level to the first cohesive layer.

The thickness of sediments with a high to medium hydraulic permeability is shown in four or three colour shades on the map (0 - 1 m, 1 - 2 m, 2 - 5 m, >5 m); in the case of measurements disregarding the first metre, the map only displays three classes (1 - 2 m, 2 - 5 m, >5 m). The selected classification is based on the requirements of different types of percolation facilities (surface, swale or swale-infiltration trench).

Table 2 illustrates the classification of individual boreholes into the thickness class of sediments with a high to medium hydraulic permeability down to the first cohesive layer.

Class [m below ground level]	Boreholes, Map 02.22.1 (130,615 in total)		Boreholes, Map 02.22.2 (130,514 in total)	
	Number	%	Number	%
≤1.0	37,278	28.5	54,164	41.5
>1.0 - 2.0	18,436	14.1		
>2.0 - 5.0	22,191	17.0	23,055	17.7
>5.0	52,710	40.4	53,295	40.8

Tab. 2: Hydraulic permeability distribution by class (borehole-based)

The distribution (in percent) of the individual thickness classes down to the cohesive layer across Berlin reveals that, unlike in the borehole-based overview, almost 50 % of the area is assigned to the class >5.0 m (Table 3).

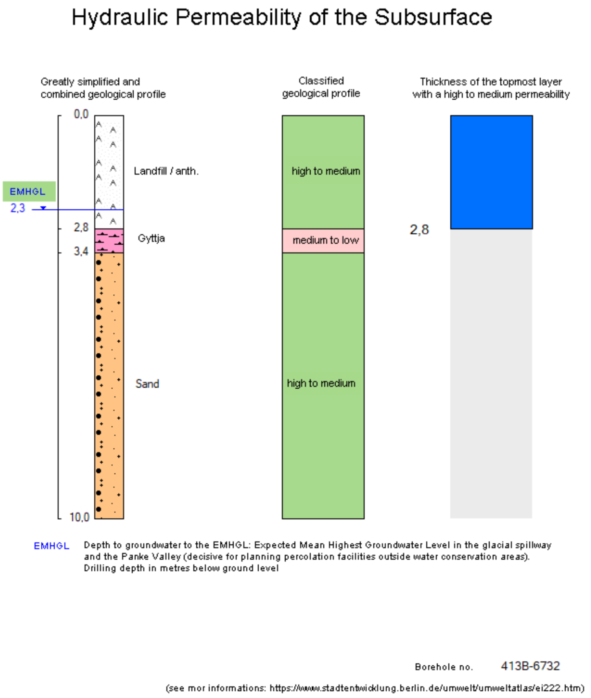
Class [m below ground level]	Proportion of area in [%] Map 02.22.1	Proportion of area in [%] Map 02.22.2
≤1.0	13.5	24.6
>1.0 - 2.0	15.1	
>2.0 - 5.0	23.9	26.0
>5.0	47.4	49.4

Tab. 3: Hydraulic permeability distribution by class (area-based)

Presenting individual boreholes

In addition to an area-based presentation illustrating the thickness of the topmost layer with a high to medium hydraulic permeability, a borehole-related diagram may be accessed by clicking onto the connected borehole. This includes a greatly simplified geological profile, the classified geological profile and the thickness of the topmost layer with a high to medium hydraulic permeability for a specific borehole (Fig. 4a, 4b). Furthermore, depths to groundwater relevant for designing percolation facilities are displayed, whereby a distinction is made between the following cases based on the location of the borehole:

- in the glacial spillway and the Panke Valley outside water conservation areas: depth to groundwater to the EMHGL (decisive for planning percolation facilities outside water conservation areas).
- inside water conservation areas: depth to groundwater to the EHGL (decisive for planning percolation facilities inside water conservation areas).
- plateaus: currently, no EMHGLs are available for the plateaus



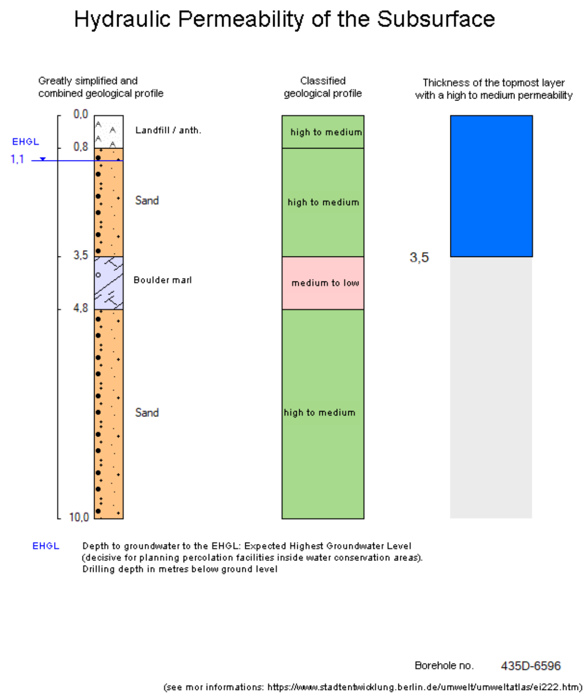


Fig. 4a: Diagram of a borehole incl. information on the thickness of the layer with a high to medium hydraulic permeability and the depth to groundwater.

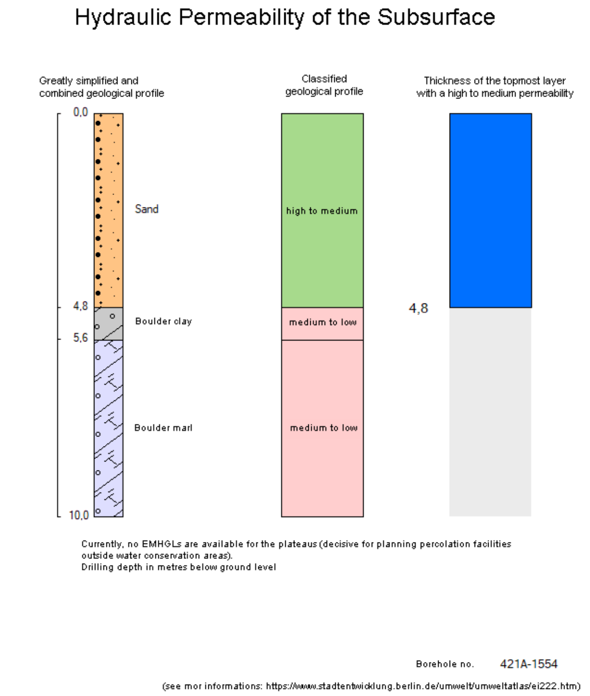


Fig. 4b: Diagram of a borehole incl. information on the thickness of the layer with a high to medium hydraulic permeability

The maps on the hydraulic permeability of the subsurface and the classified profiles form a high-level resource for planning and guiding the construction of decentralised rainwater percolation facilities. They do not allow for a small-scale investigation of the percolation potential, due to the methodology chosen here and as ambiguities may occur in the rock characterisation for the individual boreholes; the information in the geological database of the State of Berlin serves the purpose of a general geological survey and was not primarily compiled to assess the percolation performance of the top five metres and their layers. The project leader is therefore obliged to carry out on-site investigations, such as boreholes or percolation trials, prior to constructing a rainwater percolation facility.

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