# Soil hydraulic characteristics in a wide range of saturation and soil properties
(https://doi.org/10.5880/fidgeo.2023.012)

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## 1. Licence



## 2. Citation

**When using the data please cite:**

Hohenbrink, T. L.; Jackisch, C.; Durner, W.; Germer, K.; Iden, S. C.; Kreiselmeier, J.; Leuther, F.; Metzger, J. C.; Naseri, M.; Peters, A. (2023): Soil hydraulic characteristics in a wide range of saturation and soil properties. GFZ Data Services. https://doi.org/10.5880/fidgeo.2023.012

**The data are supplementary material to:**
Hohenbrink, T. L., Jackisch, C., Durner, W., Germer, K., Iden, S. C., Kreiselmeier, J., Leuther, F., Metzger, J. C., Naseri, M., & Peters, A. (2023). Soil water retention and hydraulic conductivity measured in a wide saturation range. Soil water retention and hydraulic conductivity measured in a wide saturation range. Earth System Science Data. https://doi.org/10.5194/essd-15-4417-2023

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## 3. Data Description

Soil hydraulic properties (SHP), especially soil water retention and hydraulic conductivity of unsaturated soils, belong to the key properties determining hydrological functioning of terrestrial systems. A few large collections of SHP data like UNSODA (Nemes et al., 2001) and HYPRES (Wösten et al., 1999) exist for more than two decades. They have provided an essential basis for many critical zone studies and pedotransfer functions. However, these data provide only limited information about soil hydraulic characteristics in the full saturation range due to methodological constraints at their time.

Today, SHP can be determined in a wider saturation range and with higher resolution by combining some recently developed laboratory methods. Here, we provide 572 rigorously quality-controlled SHP data sets from undisturbed ring samples covering a wide range of soil texture, bulk density and organic carbon content. Our original purpose to collect these data was improving and testing the PDI model of SHP (Peters et al., 2021) and associated pedotransfer functions.

Undisturbed and disturbed soil samples were taken by researchers from five German institutions and analysed in their laboratories. The data collection contains: (i) soil water retention and conductivity data determined by the evaporation method, supplemented by dew point method data and measurements of saturated conductivity, (ii) particle size distribution determined with sieving and sedimentation analyses, bulk density and organic carbon content, as well as (iii) meta data like the coordinates of sampling locations. Additionally, we provide soil hydraulic parameters for the widely established van Genuchten/Mualem model and for the more sophisticated PDI Model, which also considers non-capillary retention and conductivity.

The combination of the high level of standardisation following the HYPROP laboratory protocol and a consistent and rigorous quality filtering by always the same person ensured that only trustworthy data sets entered this data base. More details about the data and the underlying methods are provided in the file description section and in Hohenbrink et al. (2023).

### 3.1. Sampling method and analytical procedure

Sampling and measurements were performed in several projects with various purposes. The undisturbed soil cores had a sample volume of 250 cm3 (692 cm3 in 30 cases). They are the basis for the SHP data. For soil texture, and Corg additional disturbed and mixed samples have been used as indicated in the meta data table.

Soil water retention in the wet and medium moisture range and hydraulic conductivity in the medium moisture range were simultaneously determined with the simplified evaporation method (Schindler, 1980; Peters and Durner, 2008) using the HYPROP device (METER Group, AG, Germany). The air entry points of the tensiometer cups have been used as additional measuring point (Schindler et al., 2010) in cases where the duration of the evaporation experiments was long enough. Soil water retention information has been supplemented in the dry moisture range by measurements with the dewpoint method (Campbell et al., 2007) using the WP4C device (METER Group, Inc., USA). Hydraulic conductivity of the saturated soil was measured in the undisturbed samples either with the falling head or the constant head method using the KSAT device (METER Group, AG, Germany).

Particle size distributions of the disturbed soil samples have been determined by sieving for the sand fractions and different sedimentation methods for the silt fractions and clay content, which are listed in the Metadata table for each data set. Bulk density of each sample resulted from the evaporation method measurements by relating dry weight to sample volume. Organic carbon content was determined with high-temperature combustion using different elemental analysers, which are listed in the Metadata table.

## 3.2. Data processing

All SHP measurements have been compiled with HYPROP-FIT (Pertassek et al., 2015). The original binary files are provided, including the required manual adjustments to the raw data for consistency. Dew point measurements smaller than pF 4 and clearly mismatching data have been excluded. The exported SHP data have been used in SHYPFIT 2.0 (Peters and Durner, 2015) to fit two SHP models to the data using a shuffled complex evolution on the retention and conductivity curves simultaneously. The measured value for saturated hydraulic conductivity has not been considered in this operation. We fitted parameters for the well-established van Genuchten/Mualem model (VGM, (Mualem, 1976; Van Genuchten, 1980) and the more advanced Peters-Durner-Iden (PDI) model (Peters et al., 2021, 2023). The used parameter boundaries are provided by Hohenbrink et al. (2023) in Table 1.

# 4. File description

The data are arranged in several files following a unique sample identifier across all tables. The files contain metadata (MetaData.csv), measured soil hydraulic retention and conductivity curves (RetMeas.csv, CondMeas.csv), derived soil hydraulic property model parameters (Param.csv) and respective curves (HydCurves.csv), and general soil properties (BasicProp.csv). The original binary files for HYPROP-FIT (Pertassek et al., 2015) are provided in an extra folder using the original sample identifiers as file name.

## 4.1. Metadata

| Column header | unit | Description |
|---|---|---|
| Sample_ID | - | Unique sample identifier |
| Orig_SampleName | - | Original sample name (used for HYPROP-FIT files) |
| Source | - | Institution contributing single data set |
| Lat | °N | Latitude of sampling location (WGS84, EPSG:4326) |
| Lon | °E | Longitude of sampling location (WGS84, EPSG:4326) |
| SamplingDepth | cm | Sampling depth at the centre of the undisturbed sample |
| HyProp | T/F | HyProp measured retention and conductivity data available |
| AirEntry | T/F | Air entry value of tensiometers considered during HyProp measurement |
| WP4 | T/F | At least one WP4 retention data pair available |
| KSAT | T/F | KSAT data available |
| BD | T/F | Bulk density available |
| Porosity | T/F | Porosity available |
| Texture_SSC | T/F | Fractions of main texture groups (sand, silt, clay) available |
| Texture_subgroups | T/F | Fractions of texture subgroups (coarse/medium/fine sand and coarse/medium/fine silt) available |
| Stone | T/F | Stone content available |
| Corg | T/F | Organic carbon content available |
| N | T/F | Nitrogen content available |
| S | T/F | Sulfur content available |
| Elemental_analyser | - | Laboratory device used for elemental analyses (C, N, S) |
| Method_Texture_analysis | - | Laboratory method used for soil texture analyses |
| Sample_volume | $cm^3$ | Volume of metal ring for undisturbed soil sampling |
| Note | - | Specifics of individual data sets |

*Metadata describing the content of the data collection. File:* ***MetaData.csv****.*

## 4.2. Soil hydraulic properties

| Column header | unit | Description |
|---|---|---|
| Sample_ID | - | Unique sample identifier |
| MeasType | - | Type of measurement. “HyProp”: HyProp-tensiometers; “AirEntry”: Air entry value of HyProp-tensiometers; “WP4”: dew-point method |
| pF | - | pF value |
| theta | $cm^3\ cm^{-3}$ | Volumetric soil water content |

*Measured soil water retention data. File: **RetMeas.csv**.*

| Column header | unit | Description |
|---|---|---|
| Sample_ID | - | Unique sample identifier |
| MeasType | - | Type of measurement. “HyProp”: simplified evaporation method; “AirEntry”: Derived from air entry value of HyProp-tensiometers; “KSAT”: KSAT device |
| pF | - | pF value |
| k | $cm\ d^{-1}$ | Soil hydraulic conductivity |

*Measured hydraulic conductivities of the saturated and unsaturated soil. File: **CondMeas.csv**.*

| Column header | unit | Description |
|---|---|---|
| Sample_ID | - | Unique sample identifier |
| al_VGM | $cm^{-1}$ | Fitted van Genuchten/Mualem parameter α (shape parameter) |
| n_VGM | - | Fitted van Genuchten/Mualem parameter n (shape parameter) |
| ths_VGM | $cm^3\ cm^{-3}$ | Fitted van Genuchten/Mualem parameter θs (saturated water content) |
| thr_VGM | $cm^3\ cm^{-3}$ | Fitted van Genuchten/Mualem parameter θr (residual water content) |
| ks_VGM | - | Fitted van Genuchten/Mualem parameter Ks (hydr. conductivity of saturated soil) |
| lambda_VGM | $cm\ d^{-1}$ | Fitted van Genuchten/Mualem parameter λ (tortuosity correction) |
| al_PDI | $cm^{-1}$ | Fitted PDI/Mualem parameter α (shape parameter), basic model: VG |
| n_PDI | - | Fitted PDI/Mualem parameter n (shape parameter), basic model: VG |
| ths_PDI | $cm^3\ cm^{-3}$ | Fitted PDI/Mualem parameter θs, basic model: VG (saturated water content) |
| thr_PDI | $cm^3\ cm^{-3}$ | Fitted PDI/Mualem parameter θr, basic model: VG (residual water content of capillary component) |
| ks_PDI | $cm\ d^{-1}$ | Calculated PDI/Mualem parameter Ks, basic model: VG (hydr. conductivity of saturated soil matrix) |
| lambda_PDI | - | Fitted PDI/Mualem parameter λ, basic model: VG (tortuosity correction) |
| th_1_8_PDI | $cm^3\ cm^{-3}$ | Volumetric water content at pF 1.8 (upper limit of field capacity); derived from PDI model |
| th_2_5_PDI | $cm^3\ cm^{-3}$ | Volumetric water content at pF 2.5 (lower limit of field capacity) ; derived from PDI model |
| th_4_2_PDI | $cm^3\ cm^{-3}$ | Volumetric water content at pF 4.2 (permanent wilting point); derived from PDI model |

*Fitted parameters of the van Genuchten/Mualem model and the PDI/Mualem model with van Genuchten basic model. File: **Param.csv**.*

| Column header | unit | Description |
|---|---|---|
| Sample_ID | - | Unique sample identifier |
| pF | - | pF value, log-equidistant series with 101 values between pF=-2 and pF=6.8 per sample |
| theta_VGM | $cm^3\ cm^{-3}$ | Volumetric water contents by the Genuchten/Mualem model |
| k_VGM | $cm\ d^{-1}$ | Hydraulic conductivity of the unsaturated soil by the Genuchten/Mualem model |
| theta_PDI | $cm^3\ cm^{-3}$ | Volumetric water contents by the PDI model with the van Genuchten basic model |
| k_PDI | $cm\ d^{-1}$ | Hydraulic conductivity of the unsaturated soil by the Genuchten/Mualem model with the van Genuchten basic model |

*Soil hydraulic curves described by the van Genuchten/Mualem model (VGM) and the PDI/Mualem model (PDI) using the fitted parameters. File:* ***HydCurves.csv****.*

## 4.3. Basic soil properties

| Column header | unit | Description |
|---|---|---|
| Sample_ID | - | Unique sample identifier |
| BD | $g\ cm^{-3}$ | Bulk density |
| Porosity | $cm^3\ cm^{-3}$ | Porosity |
| Sand_KA5 | % mass | Sand fraction in German “KA5” system (63 µm … 2000 µm) |
| Silt_KA5 | % mass | Silt fraction in German “KA5” system (2 µm … 63 µm) |
| Clay_KA5 | % mass | Clay fraction German “KA5” system (< 2 µm) |
| cSand_KA5 | % mass | Coarse sand fraction in German “KA5” system (630 µm … 2000 µm) |
| mSand_KA5 | % mass | Medium sand fraction in German “KA5” system (200 µm … 630 µm) |
| fSand_KA5 | % mass | Fine sand fraction in German “KA5” system (63 µm … 200 µm) |
| cSilt_KA5 | % mass | Coarse silt fraction in German “KA5” system (20 µm … 63 µm) |
| mSilt_KA5 | % mass | Medium silt fraction in German “KA5” system (6.3 µm … 20 µm) |
| fSilt_KA5 | % mass | Fine silt fraction in German “KA5” system (2 µm … 6.3 µm) |
| TexClass_KA5 | - | Texture class in German “KA5” system |
| Sand_USDA | % mass | Sand fraction in USDA system calculated from KA5 data (50 µm … 2000 µm) |
| Silt_USDA | % mass | Silt fraction in USDA system calculated from KA5 data (2 µm … 50 µm) |
| Clay_USDA | % mass | Clay fraction in USDA system identical with KA5 data (< 2 µm) |
| TexClass_USDA | - | Texture class in USDA system |
| Stone | % mass | Stone fraction (> 2000 µm), sieved from very small 250 ml samples (CAUTION! Might not be representative) |
| Corg | % mass | Organic carbon content |
| N | % mass | Nitrogen content |
| S | % mass | Sulphur content |

*Basic soil properties. File:* ***BasicProp.csv****.*

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