User manual of the tool **SEPP** (Soil Evaluation for Planning Procedures)

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Content

1. Introduction

The tool SEPP (Soil Evaluation for Planning Procedures) enables an automated evaluation of 13 soil functions based on common profile- and horizon-based soil parameters as well as additional site characteristics (see Table 1). All sampled horizons are considered by SEPP. The evaluation results are profile-based and provide for each soil function a level of function fulfilment ranging from 1 (very low) to 5 (very high). The algorithms implemented in SEPP are based on soil evaluation methods from the Bayerische Landesamt für Umwelt (BayGLA and BayLfU 2003), from Lehmann et al. (2008), from Bundesverband Boden (BVB 2005; coordination: A. Beylich), from Umweltministerium Baden-Württemberg (1995; coordination: M. Lehle), von Müller et al. (2004), from Gerstenberg & Smettan (2005) and from Ad-hoc-AG Boden (2000; coordination: V. Hennings) and were partly modified.

Table 1: Name of soil function in the SEPP tool, Evaluation criteria, input parameters and methods behind the evaluation of the function fulfilment degree.

SEPP Soil function	**Evaluation criteria**	**Input parameter**	**Method**
1a.2 **Habitat for plants and animals**	Extreme site conditions *(dry, wet)*	Available field capacity (nFK) within the pot. rooting depth *derived from texture, bulk density, humus content, horizon thickness and stone content*	*BayGLA und BayLfU 2003; Lehmann et al. 2008* *(modified)*
		Groundwater level	
		Land use	
		Soil type	
1a.3 **Habitat for soil organisms**	Conditions for soil organisms	Texture of the topsoil *derived from texture and horizon name*	*BVB 2005* *(modified)*
		pH of the topsoil *derived from pH and horizon name*	
		Soil moisture	
		Land use	
		Soil type	
1a.4 **Habitat for crops**	General site conditions	Potential rooting depth	*Lehmann et al. 2008* *(modified)*
		Aggregate structure	
		Bulk density of the topsoil and the subsoil *derived from bulk density and horizon name*	
	Water availability	Available field capacity (nFK) within the pot. rooting depth *derived from texture, bulk density, humus content, horizon thickness and stone content*	
		Groundwater level	
	Aeration	Air capacity (LK) within the pot. rooting depth *derived from texture, bulk density, humus content, horizon thickness and stone content*	
	Nutrients availability	Stock of exchangeable alkaline cations *derived from pH, texture, humus content, horizon thickness and stone content*	
	Climate	Mean temperature of the vegetation period or mean annual temperature or climatic altitudinal belt	
	Terrain	Slope	

1c.1 **Retention of precipitation**	Percolation rate	Saturated hydraulic conductivity (minimal or average kf value) within the *considered depth* *derived from texture, bulk density, stone content, aggregate structure, soil type and partly horizon name or groundwater level*	*Umweltministerium Baden-Württemberg 1995;* *BayGLA und BayLfU 2003* *(modified)*
	Available pore space	Water storage capacity within the *considered depth* *derived from texture, bulk density, humus content, stone content, horizon thickness, slope, soil type and partly horizon name or groundwater level*	
1c.2 Short-term retention of heavy precipitation	Available pore space	minimal saturated hydraulic conductivity (kf value) within the *considered depth* *derived from texture, bulk density, stone content, aggregate structure, soil type and partly horizon name or groundwater level*	*Lehmann et al. 2008* *(modified)*
		Air capacity (LK) within the *considered depth* *derived from texture, bulk density, humus content, horizon thickness, stone content, soil type and partly horizon name or groundwater level*	
	Design event precipitation	Design event precipitation (heavy precipitation: duration of 60 min, return period of 10 a)	
1c.3 **Groundwater recharge (qualitative)**	Residence time of percolating water in the soil	Saturated hydraulic conductivity (kf value) *derived from texture, bulk density, stone content and aggregate structure*	*Lehmann et al. 2008* *(modified)*
	Available pore space	Water storage capacity *derived from texture, bulk density, humus content, stone content, horizon thickness and slope*	
1c.4 **Nutrient provision to plants**	Nutrients stock within the pot. Rooting depth	Cation exchange capacity *derived from texture, humus content, horizon thickness, stone content and pH*	*Müller 2004* *(modified)*
		Base saturation *derived from pH*	
		Pot. rooting depth	
		Amount of fine earth *derived from bulk density, horizon thickness und stone content*	
		Groundwater level	
		Soil type	
1c.5 **Carbon storage**	Humus amount in the profile	Land use	*Gerstenberg und Smettan 2005* *(modified)*
		Humus amount *derived from humus content, horizon thickness, bulk density und stone content*	
1d.1 **Retention of heavy metals**	Binding capacity for heavy metals	Humus content	*Ad-hoc-AG Boden (2005);* *BayGLA und BayLfU 2003* *(modified)*
		Clay content	
		Horizon thickness	
		Stone content	
		pH value	
		Groundwater level	
		Horizon name	
		Soil type	

1d.2 **Transformation of organic contaminants**	Ability to transform organic substances (microbial activity)	Horizon name	*Umweltministerium Baden-Württemberg 1995* *(modified)*
		Humus content	
		Clay content	
		Amount of fine earth *derived from bulk density, horizon thickness and stone content*	
		pH value	
		Humus form	
1d.3 **Retention of organic contaminants**	Binding capacity for organic substances	Horizon name	*Müller 2004* *(modified)*
		Humus content	
		Clay content	
		Stone content	
		Horizon thickness	
		Peat decomposition stage	
		Soil type	
1d.4 **Retention of water- soluble substances**	Exchange rate for soil water	Field capacity *derived from texture, bulk density, humus content, horizon thickness und stone content*	*BayGLA und BayLfU 2003*
		Texture	
		Mean annual precipitation	
		Mean annual evaporation	
1d.5 **Buffering of acidic substances**	Buffer capacity for acids	Amount of fine earth *derived from bulk density, horizon thickness and stone content*	*BayGLA und BayLfU 2003*
		Carbonate content	
		Humus form	
		Cation exchange capacity *derived from texture, humus content, horizon thickness, stone content and pH*	
		Base saturation *derived from pH*	
		Horizon thickness	

2. Data: sampling, import and export

2.1. General

The data need to be sampled according to the standards of the KA5 (AD-HOC-AG BODEN 2005), which is the common manual for pedological sampling in Germany and partly in other German-speaking countries. An exception is texture, since SEPP works with the Austrian, not the German classification.
The classification of the input parameters must follow the classes of the Austrian soil information system BORIS (Bodeninformationssystem), as published originally by Schwarz et al. (1999). Since there have been several changes since 1999, the annex provides an updated version (status as of 2021) of the BORIS classification that is identical to the one implemented in the SEPP tool. Since SEPP was originally developed for German users, the Java implementation as well as this user manual works with German terms for most soil and site parameters and for all soil functions. To ensure an easier readability for non-German speaking users, we translated the terms into English. But we kept the abbreviations and the column names of SEPP input and output files in German, to ensure the functionality of the tool.

2.2. Sampling

The parameters in Table 2 and Table 3 that belong to the category „A“, so called A-parameters, are obligatory. This means they are required for a correct evaluation of the soil functions. Parameters of the category „B” are relevant for the evaluation, but if they are missing, the relevant properties can be derived from A-parameters.
In Table 2 and Table 3 all relevant parameters are briefly described. The tables also show, to which BORIS parameter the input parameters correspond and hence, which classification needs to be used.

Table 2: Relevant profile-based input parameters

Field in SEPP	Description	Category	Unit	BORIS parameter	Input file column
Profilnummer	*Profile number:* *Any alphanumeric code to uniquely identify the profile*	*A*	*Text*	*S105*	*profilnummer*
Rechtswert	*Easting: x-coordinate of the profile site*	*A*	*m / °*	*S116*	*rechtswert*
Hochwert	*Northing: y-coordinate of the profile site*	*A*	*m / °*	*S117*	*hochwert*
klimatische Höhenstufe	*Climatic altitudinal belt: For individual functions it can be used instead of temperature information* **only A-parameter, if temperature data is lacking (Project properties – Klima)*	*A**	*Class*	*S181*	*hoehenstufe*
Hangneigung (mikro)	*Slope: Slope at the profile site*	*A*	*Degree*	*S132*	*neigungmikro*
Hangneigung (Klasse)	*Slope class: Slope class can be used instead Hangneigung (mikro)* **only A-parameter, if Hangneigung (mikro) is lacking*	*A**	*Class*	*S135*	*hangneigung*
Gründigkeit	*Potential rooting depth: Entire area above solid rock or other very dense substrate. It represents the area that plant roots can potentially penetrate. Chemistry or groundwater influence are not considered* *Note: This value is very important, as (with few exceptions) the rooting depth is otherwise set to 100 cm, which can lead to signifi-*	*B*	*cm*	*S177*	*gruendigkeit_wert*

	cant deviations in the evaluation results				
Grundwasserflurabstand	Groundwater level: Distance from the upper limit of the uppermost mineral soil horizon to the groundwater level in meters If not within the profile depth, enter value 10	A	m	S153	flurabstand
Entwässerungsgrad von Mooren	Drainage level of bogs/moors: Classification on how strongly a moore/bog is drained. Values from 1 (not drained) to 3 (strongly drained.) *only B-parameter if soil type is peat; for other soil types, the parameter is not relevant	B*	Class	from S327 or S323	entwaesserungsgrad
Ökologische Feuchte	Soil moisture: ecological moisture level of the soil	A	Class	S161	oekofeuchte
Öst. Bodensystematik 2000	Soil type: Soil type according to the Austrian Soil Classification (Nestroy et al. 2000)	A	Class	S322	bodentyp_oe
Basenreichtum	Base richness: Differentiation between base rich, medium and base poor substrates *only A-parameter, if pH for Cv-horizon is missing	A	Class	S165	basenreichtum
Ol - Mächtigkeit	Thickness of Ol-horizon (L layer)	A	cm	Header	ol_maecht
Of - Mächtigkeit	Thickness of Of-horizon (F layer)	A	cm	Header	of_maecht
Oh - Mächtigkeit	Thickness of Ol-horizon (H layer)	A	cm	Header	oh_maecht
M - Mächtigkeit	Thickness of root felt (“Wurzelfilz”)	B	cm		m_maecht
Torf - Zersetzung	Peat decomposition stage: Classification, how well the original organic substance is still recognisable. Values from 1 (very little decomposed) to 5 (strongly decomposed) *only A-parameter if there is at least one peat horizon; B-parameter for peat soils; for other soil types, the parameter is not relevant	A*	Class	from S327 or S323	torf_zersetzung
Humusform	Humus form: Characterisation of the humus form considering organic surface layers and mineral soil	A	Class	S175	humusform
Naturarchiv	Natural archive and cultural archive: Estimation, if the soil is relevant regard to its function as a natural or cultural archive Those two parameters are not relevant for any other function Values form 1 (very low) to 5 (very high) The two archive functions are not evaluated by SEPP. The entered expert estimation is part of the export file and helps to create a comprehensive estimation of the functionality of an evaluated site	B	Class	-	naturarchiv
Kulturarchiv					kulturarchiv
Landnutzung	Land use: current land use	A	Class	S178	landnutzung

Table 3: Relevant horizon-based input parameters

Field in SEPP	Description	Category	Unit	BORIS parameter	Input file column
Bezeichnung	Horizon name: Symbol plus potential pre- and suffixes according to the Austrian Soil Classification (Nestroy et al. 2000) Exception: Solid rock and other dense substrate that cannot be dug need to be assigned the horizon name “mC”, if it functions as a waterlogging layer	A	Text	Header	bezeichnung

Tiefe	*Depth: Distance between the lower limit of the respective horizon to the upper limit of the uppermost mineral soil horizon (or T-horizon in the case of a peat soil)*	*A*	*cm*	*Header*	*tiefe*
Umlagerung	*Rearrangement: Indication, if the soil of the horizon was rearranged by humans*	*B*	*1 / 0* *(j / n)*	*-*	*umlagerung*
pH-Wert	*pH value: pH as an indicator for soil acidity*	*A*	*No unit*	*P149*	*ph_wert*
Bodenart (Labor)	*Texture: 13 classes according to the Austrian texture triangle (ÖNORM L 1050) measured in the laboratory*	*A*	*Class*	*B209*	*bodenartlabor*
Bodenart	*Texture: 13 classes according to the Austrian texture triangle (ÖNORM L 1050) estimated in the field* **only A-parameter, if Bodenart (Labor) is lacking*	*A*	*Class*	*P140*	*bodenart*
Tongehalt	*Clay content: Mass fraction of particles <2 µm in the mineral fine earth*	*B*	*%*	*B200*	*ton*
Schluffgehalt	*Silt content: Mass fraction of particles ≥2 µm and <63 µm in the mineral fine earth*	*B*	*%*	*B201*	*schluff*
Humusgehalt (Wert)	*Humus content (value): Mass fraction of (dead) organic substance measured in the laboratory*	*A*	*%*	*from B101*	*humus_wert*
Humusgehalt (Klasse)	*Humus content (class): Mass fraction of (dead) organic substance estimated in the field* **only A-parameter, if Humusgehalt (Wert) is lacking*	*A**	*Class*	*P168*	*humus_klasse*
Skelettgehalt (Wert)	*Stone content (value): Volume fraction of coarse fragments (≥2 mm) at the total volume of the respective horizon.* *Note: a stone content of 100% leads within the SEPP Tool to a very high saturated water conductivity. Thus, for waterlogging horizons (e.g. solid rock) the horizon name must be „mC“!*	*A*	*Vol.-%*	*P117*	*skelett_wert*
Skelettgehalt (Klasse)	*Stone content (class): Classified volume fraction of coarse fragments (≥2 mm) at the total volume of the respective horizon.* *See note at Skelettgehalt (Wert)* **only A-parameter, if Skelettgehalt (Wert) is lacking*	*A**	*Class*	*P116*	*skelett_klasse*
Lagerungsdichte (Wert)	*Bulk density (value): BD measured in the laboratory from dried samples*	*A*	*g/cm^3*	*B210*	*dichte_wert*
Lagerungsdichte (Klasse)	*Bulk density (class): BD estimated in the field in 5 classes* **only A-parameter, if Lagerungsdichte (Wert) is lacking*	*A**	*Class*	*P162*	*dichte_klasse*
Carbonatgehalt (Wert)	*Carbonate content (value): Mostly calcium carbonate ($CaCO_3$), partly also dolomite ($CaCO_3$. $MgCO_3$) measured in the laboratory (e.g. after Scheibler)*	*A*	*%*	*B100*	*carbonat_wert*
Carbonatgehalt (Klasse)	*Carbonate content (class): Mostly calcium carbonate ($CaCO_3$), partly also dolomite ($CaCO_3$. $MgCO_3$) estimated in the field (reaction with HCl).* *Note: as the HCl-methods does not allow further differentiation at carbonate contents >10 %, the use of this information can lead to significant uncertainties of the evaluation results* **only A-parameter, if Carbonatgehalt (Wert) is missing*	*A**	*Class*	*P127*	*carbonat_klasse*
Gefüge I	*Soil structure: Dominant aggregate structure that can be identified*	*A*	*Class*	*P128*	*gefuege1*
Gefüge I – Anteil	*Proportion of dominant soil structure: If there are two (or more) clearly distinguishable soil structures in one horizon, the proportion of the dominant one. If there is only one soil structure, the value should be set to 100.*	*A*	*%*	*-*	*gefuege1_anteil*

2.3. Data import

The data can be entered manually in the GUI of the SEPP tool or imported via two CSV-files (1) profile-based information, 2) horizon-based information (same name as 1) but with suffix "_hor").

Additionally, climatic information needs to be entered in the GUI of SEPP:

- Annual precipitation
- design event precipitation
- annual evaporation

2.4. Date export

After the evaluation, the results can be exported:

- Protocol: The protocol is automatically saved in the project folder as *evaluation_protocoll.txt*
- Evaluation results: The results are shown in the GUI and can be exported as two CSV-files, analogue to the input files with the "_hor"-suffix for horizon-related properties

Apart from the input parameters, the export files also contain evaluation results of complex parameters and sum parameters as well as the evaluation results of the soil functions (see Table 4 and Table 5). Complex parameters (e.g. humus amount) are calculated from so-called primary parameters (e.g. humus content, stone content), and are always horizon-related. To get the profile-related sum parameters, horizon-related primary and complex parameters are added up for the entire profile (e.g. humus amount in the profile).

How the complex and sum parameters are calculated, is explained in chapter 3.
Table 4 and Table 5 contain all parameters of the two output files, that are not yet included in Table 2 and Table 3 (input parameters).

Table 4: Profile-related output parameter

Parameter	Column in output file
Sum parameter (profile)	
Amount of fine earth in the entire profile [kg/m²]	Sx01_FBges
Clay amount in the entire profile [kg/m²]	Sx02_TMges
Humus amount in the entire profile [kg/m²]	Sx03_HMges
Available field capacity in the entire profile [l/m²]	Sx04_nFKges
Available field capacity within the pot. rooting depth [l/m²]	Sx04a_nFKwp
Field capacity in the entire profile [l/m²]	Sx05_FKges
Field capacity within the pot. rooting depth [l/m²]	Sx05a_FKwp
Air capacity in the entire profile [l/m²]	Sx06_LKges
Air capacity within the pot. rooting depth [l/m²]	Sx06a_LKwp
Air capacity above a waterlogging horizon in the uppermost 100 cm of the profile [l/m²]	Sx07_LKoben
Water storage capacity in the entire profile [l/m²]	Sx08_WSVges

Water storage capacity within the pot. rooting depth [l/m^2]	Sx09_WSVges
Minimal kf value in the entire profile [cm/d]	Sx10_kfmin
kf value of the relative waterlogging horizon in the uppermost 100 cm of the profile [cm/d]	Sx10a_kfStauer
Mean kf value in the entire profile [cm/d]	Sx11_kfave
Potential rooting depth [cm]	Sx12_Wp
Effective cation exchange capacity in the entire profile [cmol_c/m^2]	Sx13_KAKges
Effective cation exchange capacity within the potential rooting depth [cmol_c/m^2]	Sx14_KAKWp
Stock of exchangeable alkaline cations within the potential rooting depth [cmol_c/m^2]	Sx15_MbWp
Soil function (profile)	
1a.2 Habitat for drought-tolerant species	Leben_Tr
1a.2 Habitat for moisture-tolerant species	Leben_Fe
1a.3 Habitat for soil organisms	Leben_Org
1a.4 Habitat for crops	Leben_Kult
1c.1 Retention of precipitation (calculated with kf_{ave})	Retent_ave
1c.1 Retention of precipitation (calculated with kf_{min})	Retent_min
1c.2 Short-term retention of heavy precipitation	Retent_stark
1c.3 Groundwater recharge (qualitative)	GWneu
1c.4 Nutrient provision to plants	Naehrstoff
1c.5 Carbon storage	Kohlenstoff
1d.1 Retention of heavy metals	Retent_SM
1d.2 Transformation of organic contaminants	Transform_Org
1d.3 Retention of organic contaminants	Retent_Org
1d.4 Retention of water-soluble substances (e.g. nitrate)	Retent_Nit
1d.5 Buffering of acidic substances	Puff_sauer
2a Natural archive	Arc_Nat
2b Cultural archive	Arc_Kult

Table 5: Horizon-related output parameter

Parameter	**Column in output file**
Primary parameter (horizon)	
Humus content (value) [%]	Px01_Hu
Stone content (value) [%]	Px02_Sk
Bulk density (class)	Px03_Ld
Bulk density (value) [g/cm³]	Px03a_LdZ
Complex parameter (horizon)	
Amount of fine earth [kg/m²]	Px04_FB
Clay amount [kg/m²]	Px05_TM
Humus amount [kg/m²]	Px06_HM
Available field capacity [l/m²]	Px07_nFK
Field capacity [l/m²]	Px08_FK
Air capacity [l/m²]	Px09_LK
Water storage capacity [l/m²]	Px10_WSV
Total pore space [l/m²]	Px11_GPV
Saturated water conductivity [cm/d]	Px12_kf
Potential cation exchange capacity [$\mathrm{cmol_c}$/kg]	Px13_KAKpot
Effective cation exchange capacity [$\mathrm{cmol_c}$/kg]	Px14_KAKeff
Base saturation [%]	Px15_Mb

3. Evaluation algorithms

3.1. Relevant parameters for the evaluation

Px01 – Humus content

Humus content (P168 or B104)

The humus content of a horizon determines numerous soil functions. If the exact humus content is available **Px01 = B104** applies, otherwise, the mean value from the class of **P168** is used:

Table 6: Determination of the humus content

Code P168	Term P168	English term	Value range B104	Px01 [%] =
0	humusfrei	humus free	0 %	**0**
10	sehr schwach humos	very low humus content	<1 %	**0,5**
20	schwach humos	low humus content	1 - <2 %	**1,5**
30	mittel humos	medium humus content	2 - <4 %	**3**
40	stark humos	high humus content	4 - <8 %	**6**
50	sehr stark humos	very high humus content	8 - <15 %	**11,5**
60	anmoorig, äußerst humos	extremely high humus content	15 - <30 %	**22,5**
70	Torf	peat	>30 %	**50**

Px02 – Stone content

Input parameter:

Stone content (B224, P116 or P117)

The stone content of a horizon determines numerous soil functions. If the exact stone content is available **Px02 = B224** or **Px02 = P117**). If only the stone content class (**P116**) is available, the mean value of the class is assigned to Px02, see table 7.

Table 7: Determination of the stone content

Code P116	Term P116	English term	Value range P117	Px02 [Vol.-%] =
0	kein	none	0 %	**0**
199	gering	low	>0 to 10 %	**5**
299	mäßig	medium	>10 to 20 %	**15**
399	hoch	high	>20 to 40 %	**30**
499	sehr hoch	very high	>40 to 80 %	**60**
599	vorwiegend	predominant	>80 %	**90**

Px03 and Px03a - Bulk density

Input parameters:

Bulk density (P162 or B210)

If field **B210** is occupied, this information is directly taken over for the numerical value stored in Px03a (**Px03a = B210**) and assigned in Px03 to the required classes (Ld1-5) for the determination of available field capacity, air capacity, kf value etc. (Eisenhut 1990, Kuderna et al. 2000). If the determination of the bulk density was not done in the laboratory, but only approximately in the field (**P162**), Px03 and Px03a are set using the following key:

Table 8: Determination of the bulk density

Code P162	Term P162	English term	Value range B210	Px03a [g/cm³] =	Px03=
10	lose / sehr locker	loose / very loose	<1,2 g/cm³	**1,0**	**Ld1**
20	locker	loose	1,2 to <1,4 g/cm³	**1,3**	**Ld2**
30, 40	normal / mittel / schwach dicht	normal / medium / weakly dense	1,4 to <1,7 g/cm³	**1,55**	**Ld3**
50	dicht	dense	1,7 to 1,9 g/cm³	**1,8**	**Ld4**
60	sehr dicht	very dense	>1,9 g/cm³	**2,0**	**Ld5**

Px04 - Amount of fine earth (FB)

Input parameters:

Horizon thickness
Bulk density (Px03a)
Stone content (Px02)

Calculation of the amount of fine earth for each horizon:

FB [kg/m²] (Px04) = bulk density [g/cm³] *(Px03a)* * thickness [cm] * 10 * (100 - stone content [%] *(Px02))* / 100

Total amount of fine earth for the profile:

FB$_{ges}$ [kg/m²] (Sx01) = sum of Px04 for the entire profile

Px05 - Clay amount (TM)

Input parameters:

Clay content (B200)
or:
Texture (P140)
Amount of fine earth (Px04)

If the clay content has been accurately determined in the laboratory, this value should be used (B200). Otherwise, the clay content can be derived approximately from the soil type (by finger test in the field (**P140**)) according to the following table:

Table 9: Determination of the clay content

Code P140/B209	Term P140/B209	English term	Short name	Clay content [%] =
101	Sand	sand	S	**2,5**
121	schluffiger Sand	silty sand	uS	**2,5**
212	sandiger Schluff	sandy silt	sU	**7,5**
202	Schluff	silt	U	**10**
231	lehmiger Sand	loamy sand	lS	**10**
332	lehmiger Schluff	loamy silt	lU	**20**
341	toniger Sand	clayey sand	tS	**20**
313	sandiger Lehm	sandy loam	sL	**20**
423	schluffiger Lehm	silty loam	uL	**30**
403	Lehm	loam	L	**30**
414	sandiger Ton	sandy clay	sT	**30**
534	lehmiger Ton	loamy clay	lT	**45**
504	Ton	clay	T	**70**

If two texture classes are specified for a horizon, the mean value is calculated: e.g. lS/SL = 15, sU/lU = 5, etc.

Calculation of the clay amount (grain size <2 µm) for each horizon:

TM [kg/m^2] (Px05) = amount of fine earth [kg/m^2] *(Px04)* * clay content / 100 [%] (*B200 or clay content [%] accord. to Table 9*)

Total amount of clay for the profile:

TM_{ges} [kg/m^2] (Sx02) = sum of Px05 [kg/m^2] for the entire profile

Px06 - Humus amount (HM)

Input parameters:

Amount of fine earth (Px04)
Humus content (Px01)

Calculation of the humus amount for each horizon:

HM [kg/m^2] (Px06) = amount of fine earth [kg/m^2] *(Px04)* * humus content [%] *(Px01)* / 100

Total amount of humus for the profile:

HM_{ges} [kg/m^2] (Sx03) = sum of Px06 [kg/m^2] for the entire profile

Px07 - Available field capacity (nFK)

Input parameters:

Texture (P140 or B209)
Horizon thickness
Humus content (Px01)
Bulk density (Px03)
Stone content (Px02)

Available field capacity (nFK) is a measure of the water available to plants. It is defined by the total volume of pores in the soil that are small enough to hold water against gravity (≤10 µm) or move slowly enough for the roots to absorb (≤10-50 µm), and large enough (>0.2 µm) to release the water back to the plants.

The nFK is given in vol.-% or mm/dm if it describes the volume share of the nFK-relevant pores in the total volume of the soil sample under consideration. However, if the nFK describes the total volume of the nFK-relevant pores in a horizon or profile, the nFK is given as l/m².
The proportion of pores that can hold water available to plants in the soil (nFK [vol.-%]) is derived from the following table of texture (**P140** or **B209**) and bulk density (**Px03**):

Table 10: Determination of nFK [vol.-%] according to texture and bulk density (Px03)

Code P140/B209	**Short name P140/B209**	**nFK (pores >0,2 to 50 µm) [vol.-%] =**		
		Px03: Ld1+2 *(B210: <1,4 g/cm³)*	**Ld3** *(1,4 to 1,7 g/cm³)*	**Ld4+5** *(>1,7 g/cm³)*
101	S	16	14,5	12
121	uS	26	23	20
212	sU	26	23,5	21
202	U	26	24	22,5
231	lS	25	21	18
332	lU	22	19	17
341	tS	19	15	13
313	sL	22	17	14,5
423	uL	20,5	16	12,5
403	L	19	15,5	11,5
414	sT	18	15,5	11,5
534	lT	21	14,5	11
504	T	21,5	14,5	11

Source: Derived from Müller (2004: 103ff.), adapted to Austrian texture classes according to Kuderna et al. (2000: 9)

<u>Addition according to humus content</u>

The modification of the available field capacity depending on the organic matter (P168 or B104) must be differentiated according to grain size and is to be read off with the corresponding value from the following table and added to the nFK [vol.-%] (Müller 2004: 107, modification based on the data from the Austrian soil map of Kufstein, based on Kuderna et al. 2000: 9f.).

Table 11: Modification of nFK [vol.-%] according to humus content (P168)

Code P140/B209	Short name P140/B209	Addition according to humus content [vol.-%]				
		P168: 10 *(B104: <1 %)*	**20** *(1-<2 %)*	**30** *(2-<4 %)*	**40** *(4-<8 %)*	**50** *(8-<15 %)*
101, 121	S, uS	0	0,5	1	3	3,5
231, 341	lS, tS	0	0,5	1	3	4
202, 212	sU, U	0	0,5	1	3,5	4,5
313, 332, 403, 423	lU, sL, uL, L	0	0,5	1,5	4	7
414, 504, 534	sT, lT, T	0	1	2,5	5,5	10

According to Müller (2004: 105), the available field capacity of very humus-rich soils and bogs/moors is largely independent of the texture. For horizons with a humus content of >15 %, fixed values for the relevant pore volume are therefore assumed:

Peats (Code 70 in field P168 or >30 % in field B104):
nFK [Vol.-%] **= 50**

very humus-rich soils (Code 60 in field P168 or 15-30 % in field B104):
nFK [Vol.-%] **= 37**

Calculation of the available field capacity [l/m²] taking into account horizon thickness, stone content (Px02) and nFK [vol.-%] for each horizon:

nFK [l/m²] (Px07) = thickness [cm] * 10 * (100 - stone content [%] *(Px02)*) / 100
*** (nFK** [vol.-%] **/ 100)**

Total available field capacity of the profile:

nFK$_{ges}$ [l/m²] (Sx04) = sum of nFK [l/m²] *(Px07)* for the entire profile

Total available field capacity within the potential root depth of the profile:

nFK$_{Wp}$ [l/m²] (Sx04a) = sum of nFK [l/m²] *(Px07)* within the pot. rooting depth

For the determination of Sx04a, the nFK-values up to the depth defined in Sx12 (pot. rooting depth) are added up for all horizons. Horizons that are only partially above the physiological depth are only taken into account proportionally.

Px08 - Field capacity (FK)

Input parameters:

Texture (P140 or B209)
Horizon thickness
Humus content (Px01)
Bulk density (Px03)
Stone content (Px02)

Field capacity (FK) is defined by the total volume of pores in the soil that have a diameter of up to 50 µm. It is the sum of the plant unavailable soil water the available field capacity.

Analogous to the nFK, the FK is given in vol.-% or mm/dm if it describes the volume share of the FK-relevant pores in the total volume of the soil sample under consideration. However, if the FC describes the total volume of FC-relevant pores in a horizon or profile, the FC is given as l/m².

The proportion of pores that can hold water in the soil (FC [vol.-%]) is derived from the following table of texture (P140 or B209) and bulk density (Px03):

Table 12: Determination of FC [vol.-%] according to texture and bulk density

Code P140/B209	**Short name P140/B209**	**FK (pores ≤50 µm) [vol.-%] =**		
		Px03: Ld1+2 *(B210: <1,4 g/cm³)*	**Ld3** *(1,4 to 1,7 g/cm³)*	**Ld4+5** *(>1,7 g/cm³)*
101	S	23	20	17,5
121	uS	36	30	28
212	sU	39	33,5	31
202	U	39	35,5	33,5
231	lS	35,5	30,5	27,5
332	lU	41,5	36	33
341	tS	29	26,5	26
313	sL	41	34	30,5
423	uL	47	38,5	34
403	L	48,5	39,5	35
414	sT	42	36	31
534	lT	56,5	48	42
504	T	58	49	42,5

Source: Derivation according to Müller (2004: 109ff.), transferred to Austrian texture classification according to Kuderna et al. (2000: 9)

Addition according to humus content

The modification of the field capacity depending on the organic matter (P168 or B104) must be differentiated according to grain size and is to be read off with the corresponding value from the following table and added to the FC [vol.%] (Müller 2004: 113, modification based on data from the Austrian soil map of Kufstein, based on Kuderna et al. 2000: 9f.).

Table 13: Modification of FK [Vol.-%] according to humus content

Code P140/B209	**Short name P140/B209**	**Addition according to humus content [vol.-%]**				
		P168: 10 *(B104: <1 %)*	**20** *(1-<2 %)*	**30** *(2-<4 %)*	**40** *(4-<8 %)*	**50** *(8-<15 %)*
101, 121	S, uS	0	1,5	3,5	7,5	10
231, 341	lS, tS	0	1,5	3,5	8	11,5
202, 212	sU, U	0	1,5	3,5	7,5	10
313, 332, 403, 423	lU, sL, uL, L	0	2,5	4	10	13,5
414, 504, 534	sT, lT, T	0	3	6	11,5	17

According to Müller (2004: 111), the field capacity of very humus-rich soils and bogs/moors is largely independent of the texture. For horizons with a humus content of >15 %, fixed values for the relevant pore volume are therefore assumed:

Peats (Code 70 in field P168 or >30 % in field B104):

FK [Vol.-**%] = 76**

very humus-rich soils (Code 60 in field P168 or 15-30% in field B104):

FK [Vol.-**%] = 56** (for texture classes S, lS, tS – P140: 101, 231, 341)

FK [Vol.-**%] = 67** (for other texture classes)

Calculation of the available field capacity [l/m²] taking into account horizon thickness, stone content (Px02) and relevant pore volume (FK [vol.-%]) for each horizon:

FK [l/m²] (Px08) = thickness [cm] * 10 * (100 - stone content [%] *(Px02)*) / 100 * (FK [vol.-**%] / 100)**

Total field capacity of the profile:

FK_{ges} [l/m²] (Sx05) = sum of FK [l/m²] *(Px08)* for the entire profile

Total field capacity within the pot. rooting depth:

FK_{Wp} [l/m²] (Sx05a) = sum of FK [l/m²] *(Px08)* within the pot. rooting depth

For the determination of Sx05a, the nFK values up to the depth defined in Sx12 (pot. rooting depth) are added up for all horizons. Horizons that are only partially above the physiological depth are accordingly only taken into account proportionally (see Sx04a - nFK_{Wp}).

Px09 - Air capacity (LK)

Input parameters:

Texture (P140 or B209)
Horizon thickness
Humus content (Px01)
Bulk density (Px03)
Stone content (Px02)

Air capacity (FK) is defined by the total volume of pores in the soil that have a diameter greater than 50 µm.

Analogous to nFK and FK, the FK is given in vol.-% or mm/dm if it describes the volume fraction of LK-relevant pores in the total volume of the soil sample under consideration. However, if the LK describes the total volume of LK-relevant pores in a horizon or profile, the LK is given as l/m².

The proportion of pores that are only filled with water for a short time (e.g. after a heavy rainfall event) and quickly drain again (LK [vol.-%]) is derived from the following table of texture (**P140** or **B209**) and bulk density (**Px03**):

Table 14: Determination of the air capacity [vol.-%] according to texture and bulk density

Code P140/B209	**Short name P140/B209**	**LK (pores >50 µm) [Vol.-%] =**		
		Px03: Ld1+2 *(B210: <1,4 g/cm³)*	**Ld3** *(1,4 to 1,7 g/cm³)*	**Ld4+5** *(>1,7 g/cm³)*
101	S	19	16	13
121	uS	9,5	7	4
212	sU	8,5	5,5	3
202	U	8,5	4,5	2
231	lS	10	7,5	5
332	lU	8	6	3,5
341	tS	15	12	9
313	sL	8,5	6,5	5
423	uL	7	5,5	4
403	L	7	5	3,5
414	sT	8,5	7,5	6
534	lT	4,5	3	2
504	T	4	3	2

Source: Derivation according to Müller (2004: 115ff.), transferred to Austrian texture classification according to Kuderna et al. (2000: 9)

Modification according to humus content

The air capacity of the organic matter (P168 or B104) is to be considered depending on the texture. The corresponding value from the following table is to be added to LK [vol.-%] (Müller 2004: 117, modification based on the data of the Austrian soil map of Kufstein based on Kuderna et al. 2000: 9f.).

Table 15: Modification of the air capacity [Vol.-%] according to humus content

Code P140/B209	**Short name P140/B209**	**Modification according to humus content [vol.-%]**				
		P168: 10 *(B104: <1 %)*	**20** *(1-<2 %)*	**30** *(2-<4 %)*	**40** *(4-<8 %)*	**50** *(8-<15 %)*
101, 121	S, uS	0	-1,5	-1	-1	0
231, 341	lS, tS	0	0	1	2	2,5
202, 212	sU, U	0	0,5	1,5	2,5	5,5
313, 332, 403, 423	lU, sL, uL, L	0	0,5	1,5	3	5
414, 504, 534	sT, lT, T	0	0,5	1,5	2,5	4,5

According to Müller (2004: 117), the air capacity of very humus-rich or very skeleton-rich soils and bogs/moors is largely independent of the texture. For horizons with a humus content of >15 %, fixed values for the relevant pore volume are therefore assumed:

Peats (Code 70 in field P168 or >30 % in field B104):
LK [Vol.-%] = 20

very humus-rich soils (Code 60 in field 168 or 15-30 % in field B104):
LK [Vol.-%] = 11 (for texture classes S, lS, tS – P140: 101, 231, 341)
LK [Vol.-%] = 6 (for other texture classes)

for soils with a stone content >60 % (in P117 or code 599 in field P116):
LK [Vol.-%] = 25 (Lehmann 2008: 55)

Calculation of air capacity [l/m²] taking into account horizon thickness, stone content (Px02) and relevant pore volume (LK [vol.-%]) for each horizon:

LK [l/m²] (Px09) = thickness [cm] * 10 * (100 - stone content [%] *(Px02)*) / 100 * (LK [Vol.-%] / 100)

Total air capacity in the profile (Sx06), within the potential rooting depth (Sx06a) and above a waterlogging horizon in the top 100 cm (Sx07):

LK_{ges} [l/m²] (Sx06) = sum of LK [l/m²] for the entire profile

LK_{Wp} [l/m²] (Sx06a) = sum of LK [l/m²] within the pot. rooting depth

LK_{oben} [l/m²] (Sx07) = sum of LK [l/m²] above a waterlogging horizon (max depth: 100 cm)

For the determination of Sx06a, the LK values are summed up to the depth defined in Sx12 (pot. rooting depth) for all horizons. If the depth defined there deviates from a horizon boundary, the FK of the horizon in consideration is taken into account proportionally (see Sx04a - nFK_{Wp}).

The calculation of Sx07 includes the LK values of all horizons above a (relative) sealing horizon. A sealing horizon can be groundwater (bog, Gley), impermeable, solid rock or a waterlogging horizon (e.g. Pseudogley). The relative waterlogging horizon is the horizon with the lowest saturated water conductivity within the top 100 cm of the profile. Relative waterlogging horizons are only taken into account if no absolute waterlogging horizon (groundwater, rock, S-horizon) is present (see assessment 1c.2).

Px10 - Water storage capacity (WSV)

Input parameters:

Air capacity (Px09)
Available field capacity (Px07)
Slope (S132 or S135)

The water storage capacity indicates the volume of those pores that are not permanently saturated with water and can therefore absorb water (e.g. rainwater) that accumulates on the surface (absolute in l/m²). For soils in flat or weakly inclined areas (slope <9 %), the water storage capacity corresponds to the sum of the available field capacity and the air capacity; for (steeper) slopes, only the available field capacity is used (BayGLA and BayLfU 2003: 40).

Slope < 9 %:	**WSV [l/m²] (Px10) = LK *(Px09)* + nFK *(Px07)***
Slope ≥ 9 %:	**WSV [l/m²] (Px10) = nFK *(Px07)***

Total water storage capacity of the profile:

WSV_{ges} [l/m²] (Sx08) = sum of WSV [l/m²] *(Px10)* for the entire profile

Total water storage capacity within the pot. rooting depth of the profile:

WSV_{Wp} [l/m²] (Sx09) = sum of WSV [l/m²] *(Px10)* within the pot. rooting depth

For the determination of Sx09, the WSV values are summed up to the depth defined in Sx12 (pot. rooting depth) for all horizons. If the depth defined there deviates from a horizon limit, the water storage capacity of the horizon in consideration is taken into account proportionally (see Sx04a - nFK_{Wp}).

Px11 – Soil porosity (GPV)

Input parameters:

Texture (P140 or B209)
Horizon thickness
Humus content (Px01)
Bulk density (Px03)
Stone content (Px02)

The soil porosity is the total volume of all soil pores. The value is composed of air capacity (coarse pores), available field capacity (medium pores) and plant unavailable soil water (fine pores) (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

The soil porosity (GVP [vol.-%]) is derived from texture (**P140** or **B209**) and bulk density (**Px03**) according to the following table:

Table 16: Determination of GPV [Vol.-%] according to texture and bulk density

Code P140/B209	**Short name P140/B209**	**Soil porosity – GPV [Vol.-%] =**		
		Px03: Ld1+2 *(B210: <1,4 g/cm³)*	**Ld3** *(1,4 to 1,7 g/cm³)*	**Ld4+5** *(>1,7 g/cm³)*
101	S	42	36	30,5
121	uS	45,5	37	32
212	sU	47,5	39	34
202	U	47,5	40	35,5
231	lS	45,5	38	32,5
332	lU	49,5	42	36,5
341	tS	44	38,5	35
313	sL	49,5	40,5	35,5
423	uL	54	44	38
403	L	55,5	44,5	38,5
414	sT	50,5	43,5	37
534	lT	61	51	44
504	T	62	52	44,5

Source: Derivation according to Müller (2004: 119ff.), transferred to Austrian texture classification according to Kuderna et al. (2000: 9).

Addition according to humus content

The organic matter (P168 or B104) is to be considered depending on the texture. The corresponding value from the following table is to be added to GPV [vol.-%] (Müller 2004: 123, modification based on the data of the Austrian soil map of Kufstein based on Kuderna et al. 2000: 9f.).

Table 17: Modification of GPV [vol.-%] according to humus content

Code P140/B209	**Short name P140/B209**	**Addition according to humus content [vol.-%]**				
		P168: 10 *(B104: <1 %)*	**20** *(1-<2 %)*	**30** *(2-<4 %)*	**40** *(4-<8 %)*	**50** *(8-<15 %)*
101, 121	S, uS	0	0	2,5	6,5	10
231, 341	lS, tS	0	1,5	4,5	10	14
202, 212	sU, U	0	2	5	11,5	17,5
313, 332, 403, 423	lU, sL, uL, L	0	3	5,5	13	18,5
414, 504, 534	sT, lT, T	0	3	6,5	13	19,5

According to Müller (2004: 121), the air capacity of very humus-rich soils and bogs/moors is largely independent of the texture. For horizons with a humus content of >15 %, fixed values for the relevant pore volume are therefore assumed:

Peats (Code 70 in field P168 or >30 % in field B104):

GPV [Vol.-%] = 85

very humus-rich soils (Code 60 or 15-30 % in field B104):

GPV [Vol.-%] = 67 (for texture classes S, lS, tS – P140: 101, 231, 341)

GPV [Vol.-%] = 73 (for other texture classes)

Calculation of the total pore volume [l/m²] for the profile taking into account thickness, stone content (Px02) and soil porosity (GPV [vol.-%]) of each horizon.

GPV [l/m²] (Px11) = thickness [cm] * 10 * (100 - stone content [%] *(Px02)*) / 100
*** GPV [Vol.-%] / 100**

Px12 – Saturated water conductivity (kf value)

Input parameters:

Texture (P140 or B209)
Soil structure (P128)
Bulk density (Px03)
Stone content (Px02)
Rearrangement
only for bogs and moors:
  Drainage level of bogs/moors (from S327, S323)
  or:
    Bulk density (Px03)
  Peat decomposition stage (from S327, S323)
  or:
    Humus content (P168)
Soil type (S322)

This regards the determination of the speed at which water passes through the soil / the respective horizon, which is decisive for the functions in the water cycle (in cm/d, for the geological subsoil often also m/s).

Since laboratory values are often not available and can be very variable, an approximation is made according to the following table and the modifications described below:

Table 18: Determination of the saturated water conductivity

Code P140/B209	**Short name P140/B209**	**Saturated water conductivity (kf value) – Px12 [cm/d] =**		
		Px03: Ld1+2 *(B210: <1,4 g/cm^3)*	**Ld3** *(1,4 to 1,7 g/cm^3)*	**Ld4+5** *(>1,7 g/cm^3)*
101	S	196	117	61
121	uS	40	20	13
212	sU	32	11	4
202	U	27	8	4
231	lS	45	20	11
332	lU	29	14	5
341	tS	*60*	*48*	*22*
313	sL	32	16	8
423	uL	28	19	7
403	L	19	12	5
414	sT	*15*	*11*	*4*
534	lT	18	6	2
504	T	20	5	1

Source: Derivation according to Müller (2004: 125f.), transferred to Austrian texture classification according to Kuderna et al. (2000: 9)

Under the following specific conditions, kf values deviating from those given in the table are applied (according to Lehmann et al. 2008: 28, 53):

Topsoil

Loosely bedded horizons with a crumb or subpolyhedral structure have a higher permeability than horizons with the same texture without such a pronounced soil structure. Therefore: If the value 470 (crumbly) or 450 (blocky-edge-rounded) is given for the dominant soil structure (field P128) AND the bulk density (Px03) corresponds to the classes Ld1 or Ld2, Px12 = 300 (="extremely high") is applied.

Horizons with Stone content ≥60 %

According to Lehmann et al. 2008, for horizons with a stone content (Px02) ≥ 60 %, Px12 = 300 (= "extremely high") is applied.

Rearranged soils

For horizons that have been artificially rearranged AND where the bulk density (Px03) corresponds to classes Ld1 or Ld2, Px12 = 300 (="extremely high") is applied.

Solid rock

Under a "worst case" assumption, it is assumed that bedrock (horizon designation "mC" AND with a coarse fraction of 100 %) acts as a waterlogging horizon and Px12 = 1 (= "very low") is applied.

Note: "mC" horizon designation is only assigned to solid rock or massive, non-excavatable substrate that acts as a waterlogging horizon.

Bogs and moors

According to Müller (2004: 126), the permeability of peat soils (S322 (Soil type) = 2100, 2110, 2111, 2112 or 2120) depends on the decomposition stage of the peat, which describes the degree of progressive humification of the organic matter. The second essential factor is the substance volume (SV), which indicates the proportion of solid substance in the total volume and is comparable in its significance with the bulk density in mineral soils (Ad-hoc-AG Boden 2005: 127 (KA5)).

In KA5, the degrees of decomposition are summarised in five decomposition stages (z1 to z5) (Ad-hoc-AG Boden 2005: 128).

The five classes of substance volume (SV1 to SV5) proposed by Ad-hoc-AG Boden (2005: 127) are summarised here into three classes depending on the drainage level of the respective bog: SV1 "not drained", SV3 "weakly/moderately drained" and SV5 "strongly drained".

Both the peat decompositions stage (values: 1, 2, 3, 4, 5) and the drainage level (values: 1, 2, 3) must be classified and indicated by the person processing the data.

If the drainage level is not specified, it can be derived from the bulk density (Px03) of the respective horizon as follows:

Px03 = Ld1 or Ld2 → SV1
Px03 = Ld3 → SV3
Px03 = Ld4 or Ld5 → SV5

Table 19: Determination of the saturated water conductivity of bogs/moors

Peat decomposition stage	**Saturated water conductivity (kf value) – Px12 [cm/d] =**		
	SV1 *not drained*	**SV3** *moderately drained*	**SV5** *strongly drained*
not decomposed (z1) / weakly decomposed (z2)	300	70	25
decomposed (z3)	70	25	5
strongly decomposed (z4) / earthed (z5)	25	5	1

Source: Derived according to Müller (2004: 126)

If the peat decomposition stage is not known, Px12 = 25 is assumed for all horizons of the peat soil.

In addition, Px12 = 25 is also set for peat horizons (humus content > 30 % (field P168 = code 70)) in soils that are not peat soils according to the soil type.

The relevant parameters at profile level - minimum kf value (Sx10), average kf value (Sx11) (harmonic mean) and kf value of the (relative) waterlogging horizon (Sx10a) - are determined following the calculation of the horizon-related values:

kf_{min} [cm/d] (Sx10) = minimum kf value in the profile, i.e. kf value of the relative waterlogging horizon

kf_{ave} [cm/d] (Sx11) = total profile thickness / sum (horizon thickness x / kf value for horizon x)

kf_{Stauer} [cm/d] (Sx10a) = kf value of the relative waterlogging horizon in the uppermost 100 cm

Note: kf_{Stauer} is not calculated if waterlogging is caused by solid rock or groundwater influence (Gley or bog)).

Sx12 – Potential rooting depth

Input parameters:

Horizon name
Horizon thickness
Stone content (Px02)

Delimitation of the depth range that plants can penetrate with their roots (potential rooting depth) in order to obtain water and nutrients from it. The potential rooting depth is crucial for the calculation of many complex parameters and for the evaluation of some soil functions. Therefore, if possible, the value should always be estimated and noted by the mapper in the field.

If existing soil data are used that lack information about the potential rooting depth, this value must be derived. It can be carried out according to the following criteria:

- in the case of groundwater influence: upper limit of the Gr horizon (or G2 horizon, if the following horizon designations A-G1-G2 or similar) minus 10 cm (cf. Müller 2004: 99)
- for peat soils: 60 cm for arable land use, 40 cm for grassland use or non-agricultural use
- for soils over solid rock: upper limit of the "mC" horizon (if stone content = 100 %)
- for all other soils: Sx12 = 100 cm

Px13 – Potential cation exchange capacity (KAK_{pot})

Input parameters:

Humus content (Px01)
Clay and silt content (B200, B201)
or:
Texture (P140 or B209)

The potential cation exchange capacity (KAK_{pot}) refers to the maximum number of cation binding sites in the soil under optimal, i.e. slightly basic conditions (at pH value 7-8, depending on the method used) (Blume et al. 2011).

The cation exchange capacity is composed of the equivalent values of the exchangeable bound, basic cations (Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+) and the equivalent values of the exchangeable bound, acidic cations (especially H^+, Al^{3+}, Fe^{3+}).

KAK_{pot} is determined in two steps:

<u>KAK_{pot} of mineral soil components</u>

This depends on the clay and silt content of the soil and can be determined approximately with the following formula (Ad-hoc-AG Boden 2005: 369 (KA5)):

KAK_{pot_min} [$cmol_c$/kg] = 0,5 * clay content [%] (B200) + 0,05 * silt content [%] (B201)

If the exact grain size distribution is not known, the values can be derived approximately from the texture (P140):

Table 20: Determination of the KAK_{pot} of mineral soil components

Code P140/B209	**Short name P140/B209**	**KAK_{pot_min} [$cmol_c$/kg]**
101	S	3
121	uS	4
212	sU	8
202	U	10
231	lS	7
332	lU	14
341	tS	9
313	sL	13
423	uL	18
403	L	18
414	sT	18
534	lT	27
504	T	30

Source: Derivation according to Müller (2004: 147, VKR 6.2.3), Ad-hoc-AG Boden (2005: 369 (KA5)), as for the pore-related parameters modified according to Kuderna et al. (2000: 9).

KAK_{pot} of organic soil components

To account for the cation exchange capacity of organic matter, 2 $cmol_c$/kg per mass % humus are assigned (Ad-hoc-AG Soil 2005: 369 (KA5)):

KAK_{pot_hum} [$cmol_c$/kg] = 2 * humus content [%] *(Px01)*

The total potential cation exchange capacity is the sum of these two components:

KAK_{pot} [$cmol_c$/kg] (Px13) = (KAK_{pot_min} + KAK_{pot_hum})

Px14 – Effective cation exchange capacity (KAK_{eff})

Input parameters:

pH (B105)
KAK_{pot} (Px13)

The effective cation exchange capacity (KAK_{eff}) describes the number of cation binding sites in the soil at current pH.

To determine the KAK_{eff}, the KAK_{pot} (Px13) is reduced by a conversion factor because the KAK - especially that of humic substances - decreases in acidic soils:

Table 21: Determination of the conversion factor to derive KAK_{eff} from KAK_{pot}

pH *($CaCl_2$)* **B105**	**conversion factor**
≥7,0	1
6,0 to <7,0	0,9
5,0 to <6,0	0,7
4,0 to <5,0	0,5
3,0 to <4,0	0,3
<3,0	0,25

Quelle: Müller 2004: 151, VKR 6.2.5

KAK_{eff} [$cmol_c$/kg] (Px14) = KAK_{pot} *(Px13)* * conversion factor

To assess nutrient supply to plants, the total effective cation exchange capacity (in absolute values) can be calculated by multiplying Px14 by the amount of fine earth (Px04) of each horizon:

Effective cation exchange capacity in the entire profile:

KAK_{absGes} [$cmol_c/m^2$] (Sx13) = KAK_{eff} [$cmol_c$/kg] *(Px14)* * amount of fine earth [kg/m^2] *(Px04)* for the entire profile

Total effektive cation exchange capacity within the potential rooting depth of the profile::

KAK_{absWp} [$cmol_c/m^2$] (Sx14) = KAK_{eff} [$cmol_c$/kg] *(Px14)* * amount of fine earth [kg/m^2] *(Px04)* for the pot. rooting depth#

Sx15 – Site-specific nutrient capacity within the potential rooting depth (Mb_{Wp})

Alternatively, in other approaches, the supply of exchangeable bound basic cations (Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+) within the potential rooting depth is of interest (Mb_{Wp}), as the basic cations are important plant nutrients.

The supply of exchangeable bound basic cations can therefore be used to infer the potential site-specific nutrient supply and thus soil fertility. In the procedure described by Müller (2004: 150, VKR 6.2.4 and 153f., VKR 6.2.7), the calculation is carried out - analogous to the calculation of the KAK_{eff} - by multiplying the potential cation exchange capacity (Px13) with a conversion factor (see table 24) and subsequent multiplication with the amount of fine soil (Px04) of each horizon within the potential rooting depth.

Mb_{Wp} [$cmol_c/m^2$] (Sx15) = KAK_{pot} [$cmol_c$/kg] *(Px13)* * conversion factor * amount of fine earth [kg/m^2] *(Px04)* within the pot. rooting depth

For the determination of Sx15, the Mb-values up to the depth defined in Sx12 are added up for all horizons. If the defined depth does not match with the lower limit of a horizon, the amount of fine earth of this horizon is taken into account proportionally (see Sx04a - nFK_{Wp}).

Table 22: Determination of the conversion factor to derive Mb_{Wp} from KAK_{pot}

pH *($CaCl_2$)* – **B105**	**Conversion factor**
≥7,5	1
7,0 to <7,5	0,95
6,5 to <7,0	0,9
6,0 to <6,5	0,75
5,5 to <6,0	0,6
5,0 to <5,5	0,45
4,5 to <5,0	0,3
4,0 to <4,5	0,2
3,5 to <4,0	0,1
<3,5	0,02

Source: Müller 2004: 150, VKR 6.2.4

Px15 – Base saturation

Input parameters:

pH (B105)

The degree of base saturation [%] indicates the proportion of basic cations (Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+) in the total potential cation exchange capacity (KAK_{pot}). Since there is an equilibrium between the cations of the soil solution and the adsorbable cations, the degree of base saturation can be approximately derived from the pH:

Table 23: Determination of the base saturation

pH *($CaCl_2$)* – **B105**	**Px15 [%] =**
≥7,5	100
7,0	95
6,5	90
6,0	80
5,5	70
5,1	60
4,8	50
4,5	40
4,2	30
3,8	20
3,5	10
3,3	5
3,0	2
2,5	0

Source: Müller (2004: 152, VKR 6.2.6)

3.2. Soil functions

1a.2) Habitat for plants and animals

Short name: *Leben_Tr; Leben_Fe*

Input parameters:
Available field capacity within the pot. rooting depth (Sx04a)
Soil type (S322)
Groundwater level (S153) (only for moist habitat)
Land use (S178) (only for dry habitat)

Method: *BayGLA* und BayLfU *(2003: 36f.), Lehmann et al. (2008: 24) – modified*

The extent to which the soil has special site characteristics to serve as a habitat for rare animal and plant species is assessed; microorganisms are excluded. Basically, it is considered whether particularly dry or particularly wet conditions are to be expected due to the composition of the soil and thus a contribution can be made to a high biodiversity in a study area. Suitability as a habitat for crops (suitability for agricultural and forestry use) is generally very limited on such soils; this is assessed separately under 1a.4.

1a.2.1 – Habitat for drought-tolerant species

Table 24: Evaluation „Habitat for drought-tolerant species“

1) Land use *(S178)*	**2) Soil type** *(S322)*	**3) nFK$_{Wp}$** *(Sx04a)*	**Evaluation Leben_Tr**
Ruderal site (de: Ruderalstandort) (870)	Cultivated raw soil (de: Kulturrohboden) (1720-1722)	≤30 l/m²	**5**
-	-	>30 to 60 l/m²	**4**
-	-	>60 to 90 l/m²	**3**
-	Gleys and Pseudogleys (de: Gleye, Pseudogleye) (1900-2033)	>90 to 220 l/m²	**2**
Uncultivated bogs and moors (de: Moore, unkultiviert) (950)	Peat soils (de: Moore) (2100-2120)	>220 l/m²	**1**

First, a classification is made according to land use, then according to soil type for those evaluation units that do not fall into the categories " Ruderalstandort" (ruderal site) or " unkultivierte Moore" (uncultivated bogs and moors). The nFK$_{Wp}$ is only used as a criterion if the site is not characterized by of the two forms of land use listed under 1) and by none of the soil types listed under 2). If Gleys or Pseudogleys have an nFK$_{Wp}$ of more than 220 l/m^2, the corresponding sites also fall into the function fulfilment level 1.

1a.2.2 – Habitat for moisture-tolerant species

Table 25: Evaluation „Habitat for moisture-tolerant species“

1) Soil type *(S322)*	**2) Groundwater level** *(S153)*	**3) nFK$_{Wp}$** *(Sx04a)*	**Evaluation Leben_Fe**
Peat soils (de: Moore) (2100-2120)	<0,2 m	-	**5**
Gleys and Pseudogleys (de: Gleye, Pseudogleye) (1900-2033)	0,2 to <0,5 m	>220 l/m²	**4**
Alluvial soils (de: Auböden, Schwemmböden) (1800-1842)	0,5 to ≤1 m	>140 to 220 l/m²	**3**
-	-	>60 to 140 l/m²	**2**
-	-	≤60 l/m²	**1**

The soil type is used as the primary classification criterion. If this is not known, the evaluation is carried out using the groundwater level, measured over a longer period of time, or the current groundwater level, which is easier and more accurate to determine.

The available field capacity within the potential rooting depth (nFK$_{Wp}$) is relevant for evaluation for all soil types not listed and for a groundwater level of >1 m, as it significantly controls the living conditions for water-tolerant species by storing water that accumulates on the surface. Alluvial soils with an nFK$_{Wp}$ of >220 mm are upgraded to level 4.

1a.3) Habitat for soil organisms

Short name: *Leben_Org*

Input parameters:

Horizon name
Texture of the topsoil (P140 or B209)
pH of the topsoil (P149 or B105)
Soil moisture (S161)
Soil type (S322)
Land use (S178)

Method: *BVB (2005) – modified*

Through their burrowing, decomposing and transforming activities, soil organisms have a great influence on the development, composition and structure of the soil. Conversely, certain soil properties favour the occurrence of soil organisms, whereby the number of species (diversity), the number of individuals (abundance) and the total weight (biomass) are common parameters for assessing biological activity. However, an evaluation of habitat function is severely limited by the composition of the edaphon (totality of all soil organisms including microorganisms) from a multitude of life forms with very different demands on their habitat. In this respect, only tendencies can be shown with the following, simple methods.

As a rule, therefore, certain groups that can be identified even without expert soil zoological knowledge are used as indicators of the composition of soil life. Earthworms (Lumbricidae) are of particular importance, as they can form up to 90 % of the biomass of the fauna in the topsoil. As a result, they also exert the greatest influence on the physical composition (structure, stability due to clay-humus complexes) and the mixing of the soil as well as the associated properties in the water and nutrient balance. The larger the biomass of earthworms, the stronger the bioturbation and, usually, the better the soil can fulfil its functions in the natural material cycles.

In the procedure of BVB (2005), known correlations between the species spectrum of the edaphon and individual soil factors are used to determine a "target state", i.e. the composition of the edaphon to be expected on the basis of the soil properties. Relevant soil parameters are pH, texture, humus form and soil moisture (alternatively the available field capacity within the potential rooting depth). With regard to soil life, 14 "soil biocoenosis types" (Bodenlebensgemeinschaftstypen – BLGT) are distinguished on four hierarchical levels.

Step 1 – Differentiation according to pH

BLGT A if pH ≥4,2: anecic and/or endogeic earthworm species ("soil burrowers") occur; usually mull humus forms

BLGT B if pH <4,2: anecic and endogeic earthworm species are absent, epigeic species occur in low abundance, microarthropods in high abundance; usually thick top organic layers (moder or raw humus).

Step 2 – Differentiation according to soil moisture (Müller 2004: 211ff.)

Soil moisture 2 to 8 (medium dry to medium moist)

= **BLGT A1:** soil biocoenosis without special characteristics

= **BLGT B1:** often high abundance of enchytraea and horn mites (BLGT B1), aeromorphic thick top organic layers (moder or raw humus) dominate

Soil moisture 9 or 10 (very moist to wet)

= **BLGT A2**: moisture-loving and air-deficiency-tolerating soil biocoenosis, anecic worm species are absent; aerohydromorphic and hydromorphic mull humus forms dominate

= **BLGT B2**: moisture- and acid-tolerant enchytraea; aerohydromorphic and hydromorphic thick top organic layers (moder or raw humus) dominate

Soil moisture 0 or 1 (arid to very dry)

= **BLGT A3**: thermophilic and drought-tolerant soil biocoenosis

= **BLGT B3**: drought- and acid-tolerant soil biocoenosis

Step 3.1 – Differentiation according to land use (*only for BLGT A1*)

BLGT A1.1 for forest: epigaeic, endogaeic and anecic earthworms as well as other macrofauna and mesofauna within the top organic layer (e.g. horn mites, millipedes and isopods) occur

BLGT A1.2 for grassland (soil moisture 2-7): epigaeic, endogaeic and anecic earthworms occur

BLGT A1.3 for wet grassland (soil moisture 8): epigeic, endogeic and anecic earthworms as well as moisture-loving horn mites and predatory mites occur

BLGT A1.4 for arable land: no top organic layer

For the land uses (S178) "Grassland (no longer used)" (“Grünland (nicht mehr genutzt)“, code 2A0) and "grassland natural" („Grünland natürlich”, code 2A1), the user must manually assign the code 2990, as the data type in the SEPP tool is an integer (whole number value). For areas with heavy dwarf shrub cover, the category coniferous forest (“Nadelwald”, code 120) is to be selected for land use. For the evaluation of this function, all other uses are automatically reclassified by SEPP into the classes forest, grassland or arable land according to the following table:

Table 26: Reclassification of land use

Land use classes according to BORIS-Code	**SEPP intern land use classes for the evaluation of several soil functions**
Forest (de: Wald) (100-130), energy wood area (de: Energieholzfläche) (940)	forest (de: Wald)
Grassland (de: Grünland) (200-290, 2A0*, 2A1* (*recoded in 2990)), vineyard (de: Weingarten) (400), lawn (de: Rasen) (622), areas close to traffic (de: Verkehrsbegleitende Flächen) (700), build up area (de: Verbautes Gebiet) (800-870), Others (900, 910, 911, 920), wasteland (de: Ödland) (960), Mining (de: Bergbau) (970)	(wet) grassland (de: Grünland or Feuchtgrünland)
Arable lang (de: Acker) (300-340), intensive orchards (de: Intensivobstanlagen) (500), garden (de: Garten) (600, 610, 620, 621), tree nursaries (de: Baumschulen) (630), deposit area (de: Ablagerungsfläche) (930), Other (990)	arable land (de: Acker)

Step 3.2 – Differentiation according to topsoil pH (*only for BLGT A2*)

BLGT A2.1 if pH 4,2 to 5,5: characteristic earthworm species *Eisenella tetraedra*
BLGT A2.2 if pH >5,5: characteristic earthworm species *Octolasion tyrtaeum*

Step 4 – Differentiation according to topsoil texture (*only for BLGT A1.2 and A1.4*)

BLGT A1.2.1 if **S, uS, lS, tS**: medium microbial biomass, high earthworm biomass
BLGT A1.2.2 if sU, U, lU, sL, uL, L: high microbial biomass, medium to very high earthworm biomass
BLGT A1.2.3 if T, lT and bogs/moors: very high microbial biomass, high earthworm biomass
BLGT A1.4.1 if S (*according to the Austrian classification only if T ≤ 8 % and U ≤ 50 %*): low microbial biomass, low earthworm biomass, anecic species absent
BLGT A1.4.2 if uS, lS, tS, sU, U, lU, sL, uL, L: medium microbial biomass, medium to high earthworm biomass
BLGT A1.4.3 if T, lT and bogs/moors: high microbial biomass, medium earthworm biomass

The implementation of the described scheme for classification into 14 soil biocoenosis types (BLGT) can be summarised as follows:

Table 27: Evaluation of the habitat for soil organisms

BLGT	**Topsoil* pH**	**Soil moisture** *(S161)*	**Land use** *(SEPP intern)*	**Topsoil* texture**	**Evaluation Leben_Org**
A1.1	≥4,2	dry to moist (tr to fe: 120-160, 180, 190, 220-260, 280-288)	forest	-	**3**
A1.2.1	≥4,2	dry to medium moist (tr to mfe: 120- 150, 180, 190, 220-250, 280-288)	grassland	S, uS, lS, tS (101,121,231,341)	**4**
A1.2.2	≥4,2	dry to medium moist (tr to mfe: 120-150, 180, 190, 220-250,280-288)	grassland	sU, U, lU, sL, uL, L (212,202,332,313,423,403)	**5**
A1.2.3	≥4,2	dry to medium moist (tr to mfe: 120- 150, 180, 190, 220-250,280-288)	grassland	T, lT (504,534) *oder Soil type (S322) = Moor (2100-2120)*	**4**
A1.3	≥4,2	moist (fe:160, 260)	wet grassland	-	**3**
A1.4.1	≥4,2	dry to moist (tr to fe: 120-160, 180, 190, 220-260, 280-288)	arable land	S (101)	**2**
A1.4.2	≥4,2	dry to moist (tr to fe: 120-160, 180, 190, 220-260, 280-288)	arable land	uS, lS, tS, sU, U, lU, sL, uL, L (121-423)	**4**
A1.4.3	≥4,2	dry to moist (tr to fe: 120-160, 180, 190, 220-260,	arable land	T, lT (504,534) *oder soil type (S322) = Moor (2100-2120)*	**3**

		280-288220-260,280)			
A2.1	≥5,5	wet (nass: 170, 270)	-	-	**2**
A2.2	≥4,2 to <5,5	wet (nass: 170, 270)	-	-	**2**
A3	≥4,2	very dry (str: 110, 210)	-	-	**2**
B1	<4,2	dry to moist (tr to fe: 120-160, 180, 190, 220-260, 280-288)	-	-	**2**
B2	<4,2	wet (nass: 170, 270)	-	-	**1**
B3	<4,2	very dry (str: 110, 210)	-	-	**1**

Source: BVB (2005: 42), modified

* pH and texture are adopted from the thickest topsoil horizon. The following horizons are identified as topsoil:

- bogs/moors (S322 with codes 2100-2120): Txx
- terrestrial soils: Axx
- if there is neither a T- nor an A-horizon, the uppermost horizon is defined as topsoil

If data of sufficient quality are available, the procedure provides information on the expected composition of the soil fauna. Ideally, this target state is checked in the field at selected sites ("target-actual comparison") and the impact of a planned measure on the physico-chemical composition of the soil and subsequently on the biocoenosis of the soil is estimated within the framework of test procedures.

It should be mentioned that the relationships between soil organisms and abiotic soil properties are not equally well established for all BLGT (BVB 2005: 40). Heavily anthropogenically influenced soils (e.g. gardens) can only be assessed with great uncertainty. Depending on the land use, a note is issued in the evaluation protocol for corresponding sites. The climatic conditions, which vary considerably depending on the altitude, are also not taken into account and are only indirectly included in the evaluation via the soil moisture level.

With regard to the evaluation itself, it could also be argued the other way round, following the function of habitat for plants and animals (1a.2), that rather "extreme" conditions with regard to moisture/drought and soil acidity lead to a good evaluation, since such conditions are the prerequisite for the occurrence of rare and thus species worthy of protection (e.g. very good evaluation of BLGT A2.1, A2.2, A3, B1, B2, B3).

BVB (2005: 53) recommends a verbal-argumentative evaluation of this function due to the uncertainties mentioned and the principle suitability of all soils as habitats for one or another life form. The semi-quantitative evaluation in the present procedure is nevertheless carried out in order to be able to integrate the results into an overall evaluation of a site. However, a supplementary textual explanation of the situation in the respective study area should definitely be provided when applying the method in planning and approval procedures!

1a.4) Habitat for crops

Short name: *Leben_Kult*

Input parameters:

Horizon name
Soil structure (P128)
Proportion of dominant soil structure
Base saturation (Px15)
Amount of fine earth (Px04)
KAK_{pot} (Px13)
Bulk density (Px03)
Air capacity within the pot. rooting depth (Sx06a)
Available field capacity within the pot. rooting depth (Sx04a)
Potential rooting depth (Sx12)
Slope (S132 or S135)
Groundwater level (S153)
Mean temperature in the vegetation period (Project properties - Klima)
or:
Mean annual temperature (Project properties - Klima); alternative: climatic altitudinal belt (S181)

Method: *Lehmann et al. (2008: 40ff.) – modified*

The potential natural yield capacity of the soil depends on the prevailing conditions for plant growth, which are assessed in this approach using complex soil parameters. In addition, there are climatically limiting factors. In mountainous areas these are above all the temperature, which decreases with altitude, the aspect and the mountain shade, and in very dry or very humid areas also precipitation.

The approach used here, which was developed by Lehmann et al. (2008) within the framework of the EU Interreg III B Alpine Space project TUSEC-IP, makes it possible to assess the agricultural production potential on soils currently used for other purposes in addition to grassland and arable land. The evaluation results are only to be understood as a rough orientation, as various parameters can change in the course of land use change, e.g. change in soil structure and bulk density due to soil management with (heavy) agricultural machines or decrease in humus contents and increase in pH value after clearing forest sites.

The evaluation of the function "habitat for crops" is carried out by the individual evaluation of five criteria with a total of seven steps, which are included in the overall evaluation with equal weighting. Finally, this value is modified depending on the slope in order to take into account the relevant difficulty of cultivation on slopes.

Table 28: Criteria and steps for evaluating habitat for crops

Criteria	Step	Parameter
General site conditions	A1	Pot. rooting depth
	A2	Soil structure and density
Water availability	B1	nFK within the pot. rooting depth
	B2	Groundwater level
Aeration	C	Air capacity within the pot. rooting depth
Nutrients availability	D	Stock of exchangeable alkaline cations
Climate	E	Temperature
Total Evaluation	**F**	-
Terrain	G	Modification according to slope

A – General site conditions:

A1 – Potential rooting depth

The physical soil conditions for plant growth are determined on the basis of potential rootability and soil structure. The evaluation of this criterion is carried out by means of the pot. rooting depth:

Table 29: Evaluation of the potential rooting depth

Pot. rooting depth *(Sx12)*	**Eval. A1=**
≥100 cm	**5**
80 to <100 cm	**4**
60 to <80 cm	**3**
40 to <60 cm	**2**
<40 cm	**1**

A2 – Soil structure and density

For the evaluation of the soil structure, the topsoil is to be delimited from the subsoil in a first step, as they are considered separately. Analogous to the evaluation of 1.a3 habitat for soil organisms, the delimitation of the topsoil is done via the horizon designation:

- bogs/moors (S322 with codes 2100-2120): **Txx**
- terrestrial soils: **Axx**
- if there is neither a T- nor an A-horizon, the uppermost horizon is defined as topsoil

For the subsoil, only those remaining horizons are taken into account that lie above the potential rooting depth, i.e. to the depth indicated in Sx12.

To determine the structure of the topsoil, the thickest topsoil horizon is used.

To determine the respective bulk density, those horizons are to be selected that have the highest density within the topsoil or subsoil and thus potentially represent a limiting factor for plant growth.

The evaluation of the criterion A2 results from the combination of the structure of the topsoil and the bulk densities of topsoil and subsoil (Table 30). If the soil does not show of the combinations listed in Table 30, step A2 is set to 1.

Table 30: Evaluation of step A2 according to combinations of soil structure and bulk density

1) Soil structure of the topsoil	**2) Bulk density of the topsoil** *(Px03)*	**3) Bulk density of the subsoil** *(Px03)*	**Eval. A2=**
≥50 % crumb (*P128 = 470, share >= 50*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	**5**
≥50 % crumb (*P128 = 470, share >= 50*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	Ld3, Ld4, Ld5,* (*Px03a: ≥ 1,4 g/cm³*)	**4**
≥25-50 % crumb (*P128 = 470, share >= 25 & <50*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	**4**
≥25-50 % crumb (*P128 = 470, share >= 25 & <50*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	Ld3, Ld4, Ld5,* (*Px03a: ≥ 1,4 g/cm³*)	**3**
≥50 % subangular, granular, single grain (*P128 = 450, 480, 299, share >= 50*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	**3**
≥50 % subangular, granular, single grain (*P128 = 450, 480, 299, share >= 50*)	Ld1, Ld2 (*Px03a: <1,4 g/cm³*)	Ld3 (*Px03a: 1,4 to 1,7 g/cm³*)	**2**

* if subsoil is absent; e.g. if the topsoil lies directly on a mC-horizon, if no bulk density is given for a subsoil horizon (possible with 100% stone content) or if no information on the subsoil is generally available.

B – Water availability:

B1 – nFK within the pot. rooting depth

For the evaluation of water conditions, the potential amount of plant-available water represented by the available field capacity within the potential rooting depth (nFK_{Wp}) is considered.

Table 31: Evaluation of the water availability through the nFK

nFK_{Wp} *(Sx04a)*	**Eval. B1=**
>220 l/m	**5**
>140 to 200 l/m²	**4**
>90 to 140 l/m²	**3**
>60 to 90 l/m²	**2**
≤60 l/m²	**1**

B2 - Groundwater level

Furthermore, soils that are potential wetland sites due to their proximity to groundwater or slope water and are only suitable for agricultural land use to a limited extent (cf. evaluation 1a.2.2) are rated worse. Suitability can also be limited for flat sites (slope <= 5°) or those that cannot be supplied with water by capillary rise due to their remoteness from groundwater. This consideration represents a simplification, as the rise height is strongly dependent on the characteristics of the subsoil or substrate and, for example, capillary rise generally does not take place in very skeleton-rich substrates.

Table 32: Evaluation of the water conditions due to the groundwater level

Slope (S132; S135) <= 5°	
Groundwater level *(S153)*	**Eval. B2=**
≤0,5 m	**1**
>0,5 to 1 m	**3**

Slope (S132; S135) > 5°	
Slope water level *(S153)*	**Eval. B2=**
≤0,5 m	**1**
>0,5 m	**3**

C – Aeration

The air capacity within the potential rooting depth (LK_{Wp} – Sx06a) allows estimating about the degree of oxygen supply to plant roots and soil organisms. In the absence of coarse pores and the resulting lack of soil air, plant growth is impaired.

Table 33: Evaluation of aeration

LK_{Wp} *(Sx06a)*	**Eval. C=**
>120 l/m^2	**5**
>100 to 120 l/m^2	**4**
>70 to 100 l/m^2	**3**
>40 to 70 l/m^2	**2**
≤40 l/m^2	**1**

D – Nutrients availability

The site-specific nutrient potential is derived from the stock of exchangeabe bound, basic cations (Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+). This is derived from the potential cation exchange capacity (KAK_{pot}), a pH-dependent conversion factor and the total amount of fine earth within the potential rooting depth (see Sx15).

Table 34: Evaluation of the nutrients availability

Mb_{Wp} stock *(Sx15)*	**Eval. D=**
>600 $cmol_c/m^2$	**5**
>450 to 600 $cmol_c/m^2$	**4**
>300 to 450 $cmol_c/m^2$	**3**
>150 to 300 $cmol_c/m^2$	**2**
≤150 $cmol_c/m^2$	**1**

E – Climate

With decreasing temperature (e.g. due to increasing altitude), the biological activity in soils and thus the potential yield capacity decrease (cf. Müller 2004: 293, VKR 6.7.1.2).
The criteria listed in the following table are not combined, but used alternatively: If known, the mean temperature during the vegetation period ("mean summer temperature") is to be used, otherwise the mean annual temperature. If both values are not available, the evaluation can also be made approximately using the climatic altitudinal belt (S181). The temperature values are given per project (project description in the SEPP user interface (GUI)), climatic altitudinal belt refers to a single profile (input mask in the GUI or input file).

Table 35: Evaluation of the climate

Mean temperature in the vegetation period [°C]	**Mean annual temperature** [°C]	**Climatic altitudinal belt** *(S181)*	**Eval. E=**
≥18	≥9,5	Low lying (de: Tieflage) (10): sub-montane (de: submontan) (12)	**5**
15 to <18	8 to <9,5	Medium altitude (de: Mittellage) (20): low-montane (de: tiefmontan) (21)	**4**
12 to <15	6,5 to <8	Medium and high altitude (de: Mittel- / Hochlage): medium-montane (de: mittelmontan) (22)	**3**
9 to <12	5 to <6,5	Medium and high altitude) (de: Mittel- / Hochlage: high-montane (de: hochmontan) (23) or low-subalpine (de: tief-subalpin) (31)	**2**
<9	<5	High altitude (de: Hochlage) (30): high-subalpine (de: hoch-subalpin) (32) or alpine (de: alpin) (33)	**1**

F – Overall evaluation A to E

The following table combines the 7 steps presented above into an overall evaluation. Each step is equally weighted in the evaluation:

Table 36: Overall evaluation „Habitat for crops“

Steps A1, A2, B1, B2, C, D, and E	**Term**	**Evaluation Leben_Kult**
min. 2 evaluations = 5, max. 1 x 3	extremely productive	**5**
min. 2 evaluations ≥ 4, max. 1 x 3	very productive	**4**
min. 2 evaluations ≥3, max. 1 x 2	medium productive	**3**
min. 2 evaluations ≥2	little productive	**2**
max. 1 evaluations = 2, all others 1	very little productive	**1**

G – Modification according to slope

Due to the more difficult cultivation of soils at steep slopes, deductions are made in the evaluation from a certain slope inclination.

Table 37: Modification according to slope

Slope *(S132 or S135)*	**Correction**
≤ 10°	**0**
>10 to 20°	**-1**
>20 to 30°	**-2**
>30°	**Leben_Kult = 1**

1c.1) Retention of precipitation

Short name: *Retent_ave; Retent_min*

Input parameters:
Horizon name
Horizon thickness
Saturated water conductivity (Px12)
    to derive: average and minimal kf-Wert
Water storage capacity (Px10)
Soil type (S322)
Groundwater level (S153)
Slope (S132 oder S135)

Method: *Umweltministerium Baden-Württemberg (1995: 25f.), BayGLA* und BayLfU *(2003: 40ff.) – modified*

The ability of the soil to absorb water that accumulates on the respective surface or flows in from neighbouring (possibly sealed) surfaces, especially during prolonged precipitation, is assessed. In the coarse pores of the soil (>50 µm = air capacity) the water is absorbed for a short time and – depending on the permeability of the underlying horizons – released more or less quickly as intermediate runoff (especially on slopes) or to the groundwater, while in the pores of medium size (0.2 to 50 µm = available field capacity) the infiltrated water is stored and released again with a time delay to plants or ultimately to the atmosphere through transpiration and evaporation. These processes reduce the amount of water running off the surface, so the soil makes an important contribution to attenuating surface runoff and thus to flood protection. In addition, water retention also plays an important role in filtering pollutants (see 1c.3), regulating the micro- and mesoclimate, and supplying plants with water.
Two methods are used to evaluate this function, which differ in one respect: The permeability of the soil is evaluated on the one hand via the average kf value (see step 3a) and on the other hand via the minimum kf value (see step 3b). Accordingly, there are two evaluation results for this function (Retent_ave and Retent_min).

Step 1 – Determination of the *considered depth*

It should be noted that for the evaluation of groundwater-influenced soils (Gleys, bogs/moors), only the horizons above the Gr-horizon (almost continuously water saturated due to groundwater influence) is taken into account, and for soils influenced by backwater (Pseudogleys), above the Sd-horizon (lowest permeability horizon). In the evaluation of undrained bogs/moors, the current groundwater level is to be used to delimit the *considered depth*.

According to these criteria, the following delimitation of the *considered depth* results:

Bogs and moors: (*S322: code 2100-2120*):
    groundwater level (S153)

Groundwater influence (*S322: code 1820-1822 or 2000-2033*):
    upper limit of Gr-horizon (or G2-horizons, if horizon sequence is A-G1-G2)

Backwater influence (*S322: code 1900-1950*):
    upper limit of uppermost S-horizon

Soils above solid rock or a waterlogging horizon:
upper limit of the horizon with a kf value of 1 cm/d

All other soils:
total profile depth (= lower limit of lowest horizon)

Exception: If the upper limit of a waterlogging horizon or the groundwater influence is at the ground surface (*considered depth* = 0 cm), the lower limit of the uppermost horizon is defined as *considered depth*.

For the further evaluation, only horizons that are entirely within the *considered depth* are considered.

Step 2 – Summing up of the WSV values (Px10) for all horizons within the *considered depth*

Since this sum value, as explained in the previous step, can deviate from Sx08 (water storage capacity for the entire profile) under certain conditions, it must be determined separately for the evaluation of 1c.1. The sites are also differentiated according to the slope (cf. Px10).

Step 3a – Determination of the average kf value (Px12) for all horizons within the *considered depth*

Following the procedure described by BayGLA and BayLfU (2003), the kf value averaged over the entire *considered depth* of the profile is used.

Step 3b – Determination of the minimum kf value (Px12) for all horizons within the *considered depth*

In an adaptation of the procedure described in BayGLA and BayLfU (2003), the minimum kf value, i.e. that of the least permeable horizon, which ultimately limits infiltration into the subsoil, is used instead of the average kf value. In this way, soils with pronounced changes in water conductivity (especially loose over dense layers) can be evaluated more adequately.

Step 4 - Overall assessment

Table 38: Evaluation „Retention of precipitation“

kf value [cm/d] *(Step 3a/b)*	**Water storage capacity** [mm or l/m²] *(Step 2)*					
	≤60	>60 - 90	>90 - 140	>140 - 220	>220 - 300	>300
≤7	**1**	**1**	**1**	**1**	**2**	**2**
>7 - 15	**1**	**1**	**2**	**2**	**3**	**3**
>15 - 30	**1**	**2**	**2**	**3**	**4**	**4**
>30 - 40	**1**	**2**	**3**	**4**	**4**	**4**
>40 - 100	**3**	**3**	**4**	**4**	**4**	**5**
>100	**5**	**5**	**5**	**5**	**5**	**5**

1c.2) Short-term retention of heavy precipitation

Short name: *Retent_stark*

Input parameters:

Horizon name
Horizon thickness
Saturated water conductivity (Px12)
    to derive: minimal kf value (kf_{Stauer} = Sx10a)
Air capacity (Px09)
    to derive: relevant air capacity (LK_{oben} = Sx07)
Soil type (S322)
Groundwater level (S153)
Design event precipitation (project properties - Klima)

Method: *Lehmann et al. (2008: 51ff.) – modified*

This evaluation was developed within the EU Interreg III B Alpine Space project TUSEC-IP by Lehmann et al. (2008) and is an extension of the retention capacity evaluation described in 1c.1 (Lehmann et al. 2008). In the procedure of 1c.1, a dry soil is assumed (i.e. even the pores of medium size are emptied and can absorb water) and the potential water absorption and infiltration capacity is evaluated independently of concrete precipitation events. In reality, however, it turns out that with regard to flood protection, this hypothetical value is not very meaningful insofar as the greatest risk of flooding occurs during heavy precipitation on soil that is already saturated up to the field capacity, as can be the case, for example, during thunderstorms after a prolonged period of rain. Therefore, the following basic assumptions (worst-case scenario) are made:

- The fine and medium pores of the soil are saturated with water, i.e. only the rapidly draining coarse pores (>50 µm = air capacity) are available for the short-term absorption of precipitation water.
- The coarse pore space of the entire profile is not available, as rapid infiltration is limited by (relative) waterlogging horizons, i.e. horizons with a low water conductivity. Therefore, only the horizons above this waterlogging horizon are used for the evaluation. Furthermore, the considered depth for this function is set to 1 m, as deeper areas can usually only be reached by percolation in macropores. However, the inclusion of macropores in soil descriptions is very time-consuming, which is why this information is not available in most cases. Also, a derivation of more common soil parameters is not possible with sufficient accuracy. Therefore, macropores are not considered in the evaluation of this soil function. A considered depth of 1 m means that the horizon with minimum kf value is only searched for in the uppermost 100 cm. The relevant pore volume then corresponds to the air capacity above this horizon.
- The water absorption capacity can be calculated in l/m² - of course with the procedural limitations already mentioned under 1c.1. In order to be able to estimate whether surface runoff occurs during heavy precipitation, this water absorption capacity is compared with a defined design event precipitation.

For the respective study area, a 60-minute heavy rainfall with a return period of 10 years is proposed as the design event.

Step 1 – Determination of the depth of the waterlogging horizon

Analogous to 1c.1, the *considered depth* is delimited on the basis of hydrogeological criteria. However, if the lower limit of the BB would be below 100 cm, it is set to 100 cm for the evaluation of this function:

Bogs and moors: (*S322: code 2100-2120*):
groundwater level (S153) (only if upper limit ≤ 100 cm)

Groundwater influence (*S322: code 1820-1822 or 2000-2033*):
upper limit of Gr-horizon (or G2-horizons, if horizon sequence is A-G1-G2) (only if upper limit ≤ 100 cm)

Backwater influence (*S322: code 1900-1950*):
upper limit of uppermost S-horizon (only if upper limit ≤ 100 cm)

Soils above solid rock or a waterlogging horizon:
upper limit of the horizon with a kf value of 1 cm/d (only if upper limit ≤ 100 cm)

All other soils:
upper limit of the horizon with the lowest kf value (Px12) within the top 100 cm of the profile.
Special case: if all horizons have a very high water conductivity (Px12 = 300 cm/d), the top 100 cm are considered.

Exception: If the upper limit of a waterlogging horizon or the groundwater influence is at the ground surface (*considered depth* = 0 cm), the lower limit of the uppermost horizon is defined as *considered depth*.

For the further evaluation, only horizons that are entirely within the *considered depth* are considered.

Step 2 – Calculation of the total volume of the coarse pores (= air capacity) above the waterlogging horizon

This step corresponds to the calculation of Sx07 (LK_{oben}) and involves summing up the air capacity of all horizons to the depth determined in step 1.

Step 3 – Determination and correction of the design event precipitation

Subsequently, it is estimated whether the amount of water of one extreme event can be absorbed by the available coarse pores. This comparative value results from the design event precipitation minus the amount of water (limited by the kf_{Stauer} (kf value of the waterlogging horizon)) that percolates during the same period (1 hour), i.e. is transferred to the subsoil or groundwater. In the case of soils that are influenced by groundwater in the uppermost 100 cm (bogs/moors or Gleys), shallow soils on solid rock (important: horizon name = "mC") or soils in which the uppermost horizon acts as a (relative) waterlogging horizon, this correction does not apply; the design precipitation is included unchanged in the comparison. The following applies to "normal" soils and soils affected by backwater:

$$\text{Corrected design event precipitation [mm/h]} = \text{Design event precipitation [mm/h]} - (kf_{Stauer}\ \text{[cm/d]}\ /\ 2{,}4)$$

Step 4 – Overall assessment

The final overall assessment is made by comparing the water absorption capacity with the corrected design event precipitation:

Table 39: Evaluation „short-term retention of heavy precipitation"

Ratio of **corrected design event precipitation** [mm/h] (*Step 3*) / **water absorption capacity** [l/m²] *(*LK_{oben} *= Sx07)*	**Evaluation Retent_stark**
≤ 0,9	**5**
>0,9 to 1,2	**4**
>1,2 to 2,0	**3**
>2,0 to 3,0	**2**
>3,0 [or groundwater level *(S153)* <1 m]	**1**

1c.3) Groundwater recharge (qualitative)

Short name: *GWneu*

Input parameters:

Horizon name
Horizon thickness
Saturated water conductivity (Px12)
  to derive: minimal kf value (kf_{min} = Sx10)
Available field capacity (Px07)
Soil type (S322)
Groundwater level (S153)

Method: *Lehmann et al. (2008: 26ff.) – modified*

This evaluation was also developed within the framework of the EU Interreg III B Alpine Space project TUSEC-IP by Lehmann et al. (2008) and represents a further development of the procedure described under 1c.1 for an additional evaluation of the hydrological potential of soils. In the original form, the retention capacity of a soil is considered and evaluated higher, the more water is absorbed (total volume of pores with >0.2 µm diameter = water storage capacity WSV) and the faster water can be transferred into the subsoil (kf value).

While a high water storage capacity also plays a positive role in groundwater recharge, the permeability of the soil must be considered in a differentiated manner. On the one hand, a certain hydraulic conductivity is required so that water can reach deeper layers in the first place and thus contribute to groundwater recharge. On the other hand, however, too rapid percolation enables pollutants to get carried with the percolating water to the groundwater. In order for non-degradable substances to be immobilised (see 1d.1 and 1d.3) or for the transformative and degradative processes in the soil to take place (see 1d.2) and thus ensure higher water quality, a certain minimum residence time of the water in the biologically active uppermost soil horizons is necessary. Lehmann et al. (2008: 26) assume an optimal percolation time of one to two weeks.

For soils influenced by groundwater (Gleys, bogs/moors), only the area above the Gr horizon and, in the case of soils influenced by backwater (Pseudogleys), above the Sd horizon is relevant for the evaluation. All soils on sites with a groundwater level of less than 1 m (incl. Gleys) can be rated at most as “low” (2) with regard to the qualitative aspects of groundwater recharge.
Peat soils generally receive the evaluation "very poor" (1), as they can be problematic on the one hand due to their proximity to the groundwater body, and on the other hand due to the possible formation of soluble organic complexes (Umweltministerium Baden-Württemberg 1995: 13, BayGLA and BayLfU 2003: 48).

Step 1 – Determination of the *considered depth*

As explained in 1c.1, limitations arise in the evaluation of soils with groundwater or backwater influence, which lead to a delimitation of the *considered depth*:

Bogs and moors: (*S322: code 2100-2120*):
  groundwater level (S153)

Groundwater influence (*S322: code 1820-1822 or 2000-2033*):
  upper limit of Gr-horizon (or G2-horizons, if horizon sequence is A-G1-G2)

Backwater influence (*S322: code 1900-1950*):
upper limit of uppermost S-horizon

Soils above solid rock or a waterlogging horizon:
upper limit of the horizon with a kf value of 1 cm/d

All other soils:
total profile depth (= lower limit of lowest horizon)

Exception: If the upper limit of a waterlogging horizon or the groundwater influence is at the ground surface (*considered depth* = 0 cm), the lower limit of the uppermost horizon is defined as *considered depth*.

For the further evaluation, only horizons that are entirely within the *considered depth* are considered.

Step 2 - Summing up the nFK values (Px07) for all horizons within the *considered depth*

This value can – if no exception listed in step 1 applies - be taken from the corresponding assessment step in 1c.1.

Step 3 – Determination of the minimal kf value (Px12) for all horizons within the *considered depth*

This value can be taken from the corresponding assessment step in 1c.1 or - if no exception listed in step 1 applies - from Sx10.

Step 4 – Overall assessment

The table for the final overall assessment of qualitative groundwater recharge (GWneu) is adopted without modifications from Lehmann et al. (2008):

Table 40: Evaluation „Groundwater recharge (qualitative)"

kf value [cm/d] *(Step 3)*	**Available field capacity** [mm or l/m²] *(Step 2)*			
	< 50	50 - < 140	140 - ≤ 200	> 200
<5	**1**	**1**	**2**	**3**
5 - < 10	**1**	**2**	**3**	**4**
10 - < 20	**2**	**3**	**4**	**5**
20 - ≤ 50	**1**	**2**	**3**	**4**
> 50	**1**	**1**	**2**	**3**

Step 5 – Modification for groundwater-near soils

Bogs and moors (*S322: code 2100-2120*): **GWneu = 1**

Gleys (*S322: code 1820-1822* or *2000-2033*):
if evaluation acc. to step 4 = 5 or 4: **GWneu = 2**
if evaluation acc. to step 4 = 3, 2 or 1: **GWneu = 1**

1c.4) Nutrient provision to plants

Short name: *Naehrstoff*

Input parameter:
Mb value (Sx15)

Method: *Müller (2004: 153f.) – modified*

Soils have the ability to absorb and bind inorganic and organic substances from the seepage water that are important for plant growth. The extent to which a soil can absorb nutrients and make them available to plants depends mainly on the amount of basic cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_4^{+}) that are or can be exchangeable bound within the potential rooting depth of the soil. This quantity, called "Cation exchange capacity (CEC; de:KAK)", is mainly dependent on texture and humus content of the soil due to the important role of clay minerals and humic substances as ion exchangers (for calculation see Px13). In acidic soil conditions, however, this "potential" CEC cannot be fully utilised, as in this case many ion exchangers available for nutrients under neutral conditions are occupied by H+ ions.
The nutrient potential at a site also depends on how much fine earth is present within the pot. rooting depth and which part of the potential CEC can be taken up by the basic cations at the prevailing pH value – the calculation of the so-called Mb value within the potential rooting depth is described under Sx15.

Due to the fuzziness of the method, the value determined in this way is not divided into five classes, as is the case with all other functions, but only into three classes according to the following table:

Table 41: Evaluation „Nutrient provision to plants“

Mb_{Wp} stock [$cmol_c/m^2$] *(Sx15)*	**Evaluation**	**Evaluation Naehrstoff**
<3.000	low	**1**
3.000 to 6.000	medium	**3**
>6.000	high	**5**

1c.5) Carbon storage

Short name: *Kohlenstoff*

Input parameters:
Humus amount in the profile (Sx03)
Land use (S178)

Method: *Gerstenberg & Smettan (2005: 102f.) – modified*

The evaluation of soils as carbon reservoirs depends on a number of complex interrelationships. Due to its role in the carbon cycle, soil is increasingly attracting public interest in connection with the discussion about climate change, which means that understanding for soil protection concerns must be aroused ("soil protection = climate protection"). On the other hand, it is still a challenge to assess this potential in detail. Due to the current lack of understanding of processes, it is therefore not possible to make any reliable statements about under which conditions and for which periods of time which soil is a carbon source or long-term carbon sink. Since large amounts of carbon can be retained in vegetation, sites with forests are rated very highly in the assessment with SEPP.
There is a consensus soil carbon storage is directly dependent on the humus or peat content and that the release of CO_2 is avoided if these proportions are maintained or increased, whereas when organic matter is decomposed (e.g. through drainage of peatlands or intensification of agricultural use) the soil acts as a CO_2 source.

In the explanations of the soil function maps in the Berlin Environmental Atlas (Gerstenberg & Smettan 2005), two soil forms are mentioned that in principle have a high potential as CO_2 sinks and as carbon reservoirs:

- Raw soils with a future potential to absorb carbon if development is undisturbed.
- Soils with a currently high organic content (e.g. peat soils), which are worth protecting because their destruction would lead to a considerable release of CO_2.

Since the same amount of CO_2 can be released much faster than it can be sequestered, the protection of humus-rich soils is considered a priority and taken into account accordingly in the evaluation (Gerstenberg & Smettan 2005: 102f.).

Step 1 – Evaluation according to land use

Forests and bogs/moors get the best rating:

> Land uses: forest (code of S178: 100), deciduous forest (110), coniferous forest (120), mixed forest (130) and uncultivated bogs/moors (950) **Evaluation CO2_Senke = 5**

Step 2 – Evaluation according humus content (HM_{ges})

For all land uses not considered in step 1, the evaluation is carried out according to the humus amount in the entire profile using the following table:

Table 42: Evaluation „Carbon storage“

Humus amount in the profile [kg/m²] *(Sx03)*	**Evaluation Kohlenstoff**
≥100	**5**
50 to <100	**4**
20 to <50	**3**
10 to <20	**2**
<10	**1**

1d.1) Retention of heavy metals

Short name: *Retent_SM*

Input parameters:

Horizon name
Horizon thickness
Humus content (Px01)
pH (P149 or B105)
or:
Base richness of the substrate (S165) (if pH of Cv-horizon is missing)
Stone content (Px02)
Clay content (B200)
or:
Texture (P140 or B209)
Soil type (S322)
Groundwater level (S153)

Method: *Ad-hoc-AG Boden (2000), BayGLA* and BayLfU *(2003: 46ff.) – modified*

Heavy metals released in industrial production, road traffic or agricultural use (e.g. fertilisation with sewage sludge) can enter the soil via the air or with precipitation water. If these substances are further discharged into the groundwater or absorbed into the food cycle of animals and humans via the soil-plant pathway, they pose a threat to human health due to their toxic effects.
Clay minerals and organic components of the soil can immobilise these pollutants to varying degrees depending on the pH and thus temporarily or – under unchanged conditions – even permanently remove them from the natural cycles. This function is particularly important in areas near groundwater or on agricultural land.
A method presented for the first time by the Ad-hoc-AG Soil (2000) is used, whereby the retention capacities are not assessed individually for all relevant metals. As a proxy, cadmium, which is particularly easy to mobilise in the case of soil acidification, is evaluated and thus the "minimum" retention capacity of the soil is assessed. The relative binding strengths of other substances (Mn, Ni, Co, Zn, Al, Cu, Cr, Pb, Hg, Fe) can be taken from the original work of the Ad-hoc-AG Boden (2000) or the collection of methods by Müller (2004: 316f.) if required.
Furthermore, it should be noted that the method used only gives an estimate on the ordinal scale of the relative retention capacity for heavy metals, so that the soils of different areas can be compared with each other - however, it is not possible to quantify the amount of heavy metals that can be retained ("mg Cd / kg fine soil" or similar).

In a first step, the basic binding strength of sandy, humus-free or slightly humic soils is estimated as a function of soil acidity. This value is then modified for clay- and humus-rich soils and a weighted average value is calculated for the entire profile. Peat soils (S322: code 2100-2120) are generally assigned assessment level 1 (very poor), as there is a risk of the formation of soluble organic complexes, which can quickly reach the groundwater, especially in the case of fens (low moor) (cf. BayGLA and BayLfU 2003: 47). For all other soil types, only those horizons located above the groundwater table (S153 or Gr-horizon) are used for evaluation.

Step 1 – Determination of the relative binding strength for cadmium (Cd) at different pH values

For each horizon, the relative binding strength for cadmium (Cd_rel) is determined as the initial value of the evaluation using the following table. For the pH value, either exact laboratory values (B105) or – If these are not available – approximate field values (P149) can be used.

Table 43: Determination of the relative binding strength for cadmium according to pH

pH ($CaCl_2$) *(B105 or P149)*	**Relative binding strength** (Cd_rel)
<2,8	**0,0**
2,8 to <3,3	**0,5**
3,3 to <3,8	**1,0**
3,8 to <4,3	**1,5**
4,3 to <4,8	**2,0**
4,8 to <5,3	**2,5**
5,3 to <5,8	**3,5**
5,8 to <6,3	**4,0**
6,3 to <6,7	**4,5**
≥6,7	**5,0**

If no pH is given for a C-horizon with fine earth content, the following values are estimated depending on the base richness of the parent material (S165):

Table 44: Determination of the relative binding strength for cadmium according to the base richness of the parent material

base richness *(S165)*	**Relative binding strength** (Cd_rel)
base rich (1)	**5,0**
base poor (2)	**1,0**
intermediate (3)	**3,0**

Step 2 – Upgrading the relative binding strength for cadmium in humus-rich soils

The relative binding strength determined in step 1 is modified, if necessary, depending on the humus content. If the humus content is not specified, the value from step 1 is retained unchanged, otherwise the addition results from the specification of parameter Px01 as follows:

Table 45: Addition to the relative binding strength for cadmium according to humus content

Humus content [%] *(Px01)*	**Addition to Cd_rel**
<2	**0**
2 to <8	**+0,5**
8 to <15	**+1,0**
≥15	**+1,5**

Step 3 – Upgrading the relative binding strength for cadmium in clay-rich soils

For soils with a clay content of at least 12 %, the relative binding strength must also be corrected. If the clay content is exactly determined, the value from B200 is to be used. If this is not known, the categorisation is based on the texture (by measurement in the laboratory: B209, by finger test in the field: P140):

Table 46: Addition to the relative binding strength for cadmium according to clay content

Clay content [%] *(B200)*	**Texture**	**Code P140 or B209**	**Addition to Cd_rel**
<12	S, uS, sU, U, lS	101 to 231	**0**
≥12	lU, tS, sL, uL, L, sT, lT, T	313 to 534	**+0,5**

Step 4 – Modification of the relative binding strength for cadmium according to stone content

Since only the fine earth can contribute to retention, the relative binding strength is reduced by the percentage of the stone content (Px02):

Cd_rel_mod = Cd_rel * (100 - Px02) / 100

Step 5 – Determination of the relative binding strength for cadmium for the entire profile

The evaluation steps 1 to 4 are carried out for all horizons in the profile, with the exception of groundwater-affected soils, which are evaluated up to the upper limit of the Gr or G2 horizon (if horizon name sequence is A-G1-G2) or – if known – up to the depth of the groundwater level specified in S153.

To obtain the relative binding strength for the overall profile, the horizontal-related values are summed up weighted according to the respective thickness of the horizons 1 to n.

Cd_rel_ges = Σ (Cd_rel_mod (*n*) * thickness (*n*) [cm] / 100)

Step 6 – Overall evaluation

For the overall assessment of the retention of heavy metals, the relative binding strength for cadmium for the overall profile (step 5) is categorised according to the following table:

Table 47: Evaluation „Retention of heavy metals“

Rel. binding strength *(step 5)*	**Evaluation Retent_SM**
≥4,5	**5**
3,5 to <4,5	**4**
2,5 to <3,5	**3**
1,5 to <2,5	**2**
<1,5	**1**

1d.2) Transformation of organic contaminants

Short name: *Transform_Org*

Input parameters:

Horizon name
Humus content (Px01)
pH (P149 or B105)
Amount of fine earth (Px04)
Humus amount (Px06)
Clay amount (Px05)
Humus form (S175)

Method: *Umweltministerium Baden-Württemberg (1995: 27ff.) – modified*

Organic pollutants in the soil are decomposed and degraded to a small extent by acids, but to a far greater extent by microorganisms. Since the microbial degradation increases with increasing biological activity in the topsoil, the evaluation of the transformation of organic contaminants can be done indirectly by assessing the living conditions for soil microorganisms.

These living conditions depend on various factors such as temperature, moisture, acidity (pH) and humus content as well as texture, structure and porosity with regard to the air and water supply of the soil. As already mentioned in 1a.3 ("Habitat for soil organisms"), there are so far only first approaches to evaluate this function. In some methods already used in practice, humus form is considered as an indicator of the soil biological status (cf. Hochfeld et al. 2003: 17, 67f.). Conclusions can be drawn from the humus form as to how quickly organic matter is converted and incorporated. Therefore, the humus form is also used as a central evaluation criterion in the present procedure (cf. Umweltministerium Baden-Württemberg 1995: 27ff.).

For the assessment in planning procedures, this functional assessment plays a role especially when decisions are to be made on plans/projects that are potential sources of organic pollutants (e.g. road traffic, certain industries). However, due to the lack of differentiation by substance groups, the procedure described here only represents a rough assessment of the basic ability of a soil to degrade organic pollutants.

Step 1 – Calculation of the humus amount in the topsoil (*HM_ges*)

The humus amount in kg/m² determined in Px06 for each horizon is summed up for all horizons that fulfil one of the following two criteria:

- Horizon name = „T“ or „A“ (with any prefix or suffix)
- Humus content (Px01) > 2,0 % (*Limitation: in the case of groundwater influence, only horizons above Gr/G2 are considered; in the case of backwater influence, only horizons above Sd/S are considered*)

Step 2 – Calculation of the clay amount in the topsoil (*TM_ges*)

The clay amount in kg/m² determined in Px05 for each horizon is summed up for all horizons that were also considered in step 1.

Step 3 – Calculation of the mean pH value in the topsoil (*pH_mitt*)

For pH, either exact laboratory values (B105) or – If these are not available – estimated values from the field (P149) can be used. If more than one topsoil horizon was considered in assessment steps 1 and 2, the pH for these n horizons is to be averaged (weighted according to their amount of fine earth (Px04)):

$$pH\_mitt = \Sigma \left(\text{amount of fine earth } (n) \text{ (Px04) / amount of fine earth\_topsoil} * pH\ (n)\right)$$

Step 4 – Classification of microbial degradation capacity according to humus form and pH

The microbial degradation capacity is classified into three categories according to the following table, whereby acidic soil conditions (pH <5.0) result in a lower evaluation for individual humus forms. Not each individual humus form of the Austrian classification system, but only the umbrella terms were analogously translated into English.

Table 48: Determination of the microbial degradation capacity

Humus form *(S175)*	**averaged pH** *(step 3)*	**mikro_abbau**
none, others (900, 000)	-	**low**
Raw humus (de: Rohhumus / Typischer Rohhumus / Moderartiger Rohhumus / Xeromorpher Rohhumus / Kalkrohhumus (Tangelhumus) / Rohhumusartiger Moder) (130, 430, 131, 132, 133, 134, 123)	-	
Moist moder (de: Feuchtmoder) (220, 520)	<5,0	
Moist raw humus (de: Feuchtrohhumus) (230, 530)	-	
Rainwater-fed peat (de: Hochmoortorf, Übergangsmoortorf) (240, 540, 250)	-	
Anmoor humus (de: Anmoorhumus) (260, 560)	<5,0	
Mull (de: Mull / Typischer Mull) (110, 410, 111)	-	**medium**
Moder-like mull and similar (de: Moderartiger Mull / Kalkmull / Modermull oder mullartiger Humus) (112, 113, 411)	-	
Anmoor Mull (de: Anmoormull) (114, 412)	<5,0	
Moder (de: Moder / Typischer Moder, Mullartiger Moder / Xeromorpher Moder / Kalkmoder) (120, 420, 121, 122, 124, 125)	-	
Moist moder (de: Feuchtmoder) (220, 520)	≥5,0	
Anmoor humus (de: Anmoorhumus) (260, 560)	≥5,0	
Groundwater-fed peat (de: Niedermoortorf) (310, 610)	<5,0	
Anmoor Mull (de: Anmoormull) (114, 412)	≥5,0	**high**
Moist mull (de: Feuchtmull) (210, 510)	-	
Groundwater-fed peat (de: Niedermoortorf) (310, 610)	≥5,0	

Note: The indication of "-" means that the pH is irrelevant for the evaluation of this humus form.

Step 5 – Overall evaluation

The overall evaluation of the soil's function to transform organic pollutants (Transform_Org) results from the synopsis of humus amount, clay amount and microbial degradation capacity based on humus form and pH (steps 1 to 4):

Table 49: Evaluation „Transformation of organic contaminants“

		Microbial degradation capacity *(mikro_abbau, step 4)*		
Humus amount [kg/m²] *(HM_ges, step 1)*	**Clay amount** [kg/m²] *(TM_ges, step 2)*	low	medium	high
<13	<100	1	1	1
	100-300	1	2	3
	>300-450	1	3	3
	>450	2	3	4
13 - 25	<100	1	1	2
	100-300	2	3	3
	>300-450	3	3	4
	>450	3	4	5
>25 - 40	<100	1	2	3
	100-300	3	3	4
	>300-450	3	4	5
	>450	4	5	5
>40	<100	2	3	4
	100-300	4	4	5
	>300-450	4	5	5
	>450	5	5	5

1d.3) Retention of organic contaminants

Short name: *Retent_Org*

Input parameters:

Horizon name
Horizon thickness
Humus content (Px01)
Stone content (Px02)
Clay content (B200)
or:
  Texture (P140)
Soil type (S322)
Peat decomposition stage (from S327)

Method: *Müller (2004: 283ff.) – modified*

The worst-case consideration of elements that can be bound to a particularly low degree (cf. cadmium in 1.d1) is difficult here, as the assessment ranges are very wide and e.g. benzene or dichloromethane can only be retained in extremely humus-rich (>15 % humus content) and/or very clayey soils.
Therefore, as an alternative, simplified approach, an "average" binding capacity for organic contaminants is assumed for both the clay and the humus content.
Analogous to 1.d1, only a relative retention capacity for organic contaminants is assessed here as well – which enables comparability of areas – but no absolute value is quantified.

Step 1 – Determination of the horizons relevant for evaluation

Relevant for the evaluation are all top organic horizons as well as mineral topsoil horizons, which are defined as follows:

- Horizon name = „T“ or „A“ (with any prefix or suffix)
- Humus content (Px01) > 2,0 % (*Limitation: in the case of groundwater influence, only horizons above Gr/G2 are considered; in the case of backwater influence, only horizons above Sd/S are considered*)

Step 2 – Determination of the "average" binding strength for organic pollutants by the humus fraction (*Org_rel_hum*)

For mineral soils, the "average" relative binding strength is determined as a function of the humus content (Px01) according to the following table for each horizon (Müller 2004: 287):

Table 50: Determination of the binding capacity for organic contaminants according to humus content

Humus content [%] *(Px01)*	**Org_rel_hum**
<1	**1,0**
1 to <2	**1,5**
2 to <4	**2,0**
4 to <8	**2,0**
8 to <15	**2,5**
15 to <30	**3,0**

For peat horizons (horizon name = "T") and top organic horizons, the following table is used for this assessment step:

Table 51: Determination of the binding capacity for organic contaminants according to peat and top organic horizons

Peat decomposition stage	**Top organic horizon**	**Org_rel_hum**
(very) strongly decomposed (z5; z4)	Oh	**3,0**
decomposed (z3)	Of	**2,5**
(very) weakly decomposed (z2; z1)	Ol / L	**2,0**

<u>Step 3 – Determination of the "average" binding strength for organic contaminants by the clay fraction (*Org_rel_ton*)</u>

If the clay content is determined exactly in the laboratory, the value from B200 should be used. Otherwise, the clay content can be derived approximately according to Table 9 from the texture (cf. Px05):
Subsequently, the "average" relative binding strength is assigned for each relevant horizon according to the following table (Müller 2004: 288, modified):

Table 52: Determination of the binding strength for organic contaminants according to clay content

Clay content [%]	**Org_rel_ton**
<5	**1,0**
5 to <15	**1,5**
15 to <25	**2,0**
25 to <50	**2,5**
≥50	**3,0**

Step 4 – Determination of the "average" binding strength for organic contaminants for each horizon

In this step, the partial results from steps 2 and 3 are summed up:

$$Org\_rel\_ges = Org\_rel\_hum + Org\_rel\_ton$$

Step 5 – Modification of the "average" binding strength for organic contaminants according to stone content

Since only the fine earth can serve for retention, the relative binding strength is reduced by stone content (Px02):

$$Org\_rel\_mod = Org\_rel\_ges * (100 - Px02) / 100$$

Step 6 – Determination of the "average" binding strength for organic pollutants for the entire profile

In order to obtain the "average" binding strength for the entire profile, the horizon-related values are summed up weighted by the respective thickness of the horizons 1 to n.

$$Org\_rel\_Profil = \Sigma\ (Org\_rel\_mod\ (n) * thickness\ (n)\ [cm] / 100\ cm)$$

Step 7 – Overall evaluation

For the overall evaluation of the retention of organic contaminants, the relative binding strength for the entire profile (step 6) is categorised according to the following table:

Table 53: Overall evaluation „Retention of organic contaminants“

rel. binding strength *(Org_rel_Proifil, step 5)*	**Evaluation** **Retent_Org**
≥5,0	**5**
4,3 to <5,0	**4**
3,7 to <4,3	**3**
3,0 to <3,7	**2**
<3,0	**1**

When considering the evaluation results, it should be noted that this is only a very rough estimate of the basic ability of a soil to bind organic pollutants. Since the behaviour of different organic pollutants in the soil differs significantly, the actual conditions for individual substances can deviate widely from this assessment.

To an even greater extent than in 1c.1 and 1c.2, it is therefore necessary to determine the relevant substance groups for specific planning cases and to carry out a comparative evaluation according to the information in Müller (2004: 284ff., VKR 6.7.1.1).

1d.4) Retention of water-soluble contaminants

Short name: *Retent_Nit*

Input parameters:
Texture (P140 or B209)
Field capacity within pot. rooting depth (Sx05a)
Annual precipitation (Project properties – Klima)
Annual evaporation (Project properties – Klima)

Method: *BayGLA* and BayLfU *(2003: 44f.) according to DIN 19732 (cf. Müller 2004: 325, VKR 6.7.3.2)*

Nitrate (NO_3^-) enters the soil mainly through nitrogen fertilisation of agricultural land, but also naturally, or is formed there by bacteria from other compounds in the course of so-called nitrification. Nitrate is water-soluble and thus there is a risk of leaching into the groundwater if the nitrate content of the soil exceeds the amount that can be absorbed by plants as a nutrient. There is a risk to human health when groundwater is used as drinking water, as nitrate is reduced to nitrite in the human intestine and forms carcinogenic nitrosamines.

In addition to the amount of fertiliser applied, depending on the nitrogen requirements of the vegetation, the retention capacity of the soil for water-soluble nitrate is therefore the most important factor in assessing the extent to which there is a risk of it entering the groundwater.
Specifically, according to DIN 19732 it is assessed how long seepage water remains within the pot. rooting depth and can be absorbed there by plants before it seeps into deeper layers and contributes to groundwater recharge. Hydrological parameters (precipitation, evaporation, runoff) are also taken into account and, in combination with the field capacity of within the pot. rooting depth, the annual soil water exchange rate [1/a] is calculated.

Step 1 – Determination of the amount of annual leachate

The amount of annually accumulating leachate can be determined in a simplified way from the total annual precipitation (JNS) minus the mean annual evaporation (MJV) and the amount of surface runoff.

The share of surface runoff (OFA) in total runoff averaged over the year, is derived from a measurement series of seven climate stations in Bavaria taking into account the dominant texture of the topsoil (BayGLA and BayLfU 2003: 46).

Table 54: Determination of the share of annual surface runoff in annual total runoff

Code P140	**Term (P140)**	**English term**	**Short name**	**Share of surface runoff** *(OFA)* [%]
101	Sand	sand	S	**1,5**
121	schluffiger Sand	silty sand	uS	
231	lehmiger Sand	laomy sand	LS	
341	toniger Sand	clayey sand	tS	
202	Schluff	silt	U	**4,5**
212	sandiger Schluff	sandy silt	sU	
313	sandiger Lehm	sandy loam	sL	
332	lehmiger Schluff	loamy silt	lU	
341	toniger Sand	clayey sand	tS	
403	Lehm	loam	L	
423	schluffiger Lehm	silty loam	uL	
414	sandiger Ton	sandy clay	sT	**8**
534	lehmiger Ton	loamy clay	lT	
504	Ton	clay	T	

The annual seepage rate is accordingly derived from the formula:

$$SW\ [mm/a] = (JNS - MJV) * (1 - OFA/100)$$

Step 2 – Calculation of the annual exchange rate for soil water

For this purpose, the leachate rate (SW) determined in step 1 and the field capacity within the potential rooting depth (Sx05a) are correlated. In other words, it is assessed how often per year the plant-available water in the small and medium pores is exchanged and, subsequently, how much of the annual seepage water can enter the groundwater body.

$$SW\_aus\ [1/a] = SW / FK_{Wp}\ (Sx05a)$$

Step 3 – Overall evaluation

Table 55: Evaluation „Retention of water-soluble contaminants“

Excahnge rate *(SW_aus, step 2)*	**Evaluation Retent_Org**
<0,7	**5**
0,7 to <1,0	**4**
1,0 to <1,5	**3**
1,5 to <2,5	**2**
≥2,5	**1**

1d.5) Buffering of acidic substances

Short name: *Puff_sauer*

Input parameters:

Carbonate content (B100 or P127)
Horizon thickness
Base saturation (Px15)
Amount of fine earth (Px04)
KAK_{pot} (Px13)
Humus form (S175)

Method: *BayGLA* und BayLfU *(2003: 50ff.)*

The buffering capacity for acids (buffering of H^+ protons) is mainly dependent on the carbonate content in addition to the base content. However, the $CaCO_3$ equivalent of the fine earth can only be determined very inaccurately with conventional field methods ("HCl sample", i.e. sprinkling the sample with 10% hydrochloric acid and observing the reaction, see e.g. Ad-hoc-AG Boden 2005: 169 (KA5)). The addition of HCl already causes a "strong, persistent foaming" at a carbonate content of >10 %, which does not allow further differentiation of the higher values. Therefore, $CaCO_3$ values should be determined according to Scheibler (gas volumetric method) or comparably accurate methods (B100). If the carbonate content is determined in the field (P127), the evaluation results of this function are subject to greater uncertainties. Soils with very high carbonate contents may be underestimated in their buffer capacity, as the parameter P127 can assume a value of at most 5 %.

Step 1 - Calculation of the carbonate-dependent buffer capacity for each (mineral soil) horizon

According to BayGLA and BayLfU (2003: 50), a buffer capacity of 20 mol protons per 1 mol carbonate in the soil is assumed. This results in:

Carb_Puff [mol H^+/m²] = amount of fine earth [kg/m²] (Px04) * carbonate content [%] (B100) / 100 * 20 [mol H^+/kg]

Step 2 – Calculation of the supply of exchangeable basic cations at the KAK_{pot} for each (mineral soil) horizon

Analogous to the evaluation of 1a.4 (Crop habitat = potential for agricultural production), step D - nutrient supply, the supply of basic cations (Mb-value) is determined by the potential cation exchange capacity (KAK_{pot}), a pH-dependent conversion factor and the total amount of fine soil:

Mb [$cmol_c$/m²] = amount of fine earth (Px04) * (KAK_{pot} (Px13) * base saturation (Px15) / 100)

Step 3 – Calculation of the buffer capacity of the entire mineral soil

Summation of the carbonate-dependent buffer capacity and the exchangeable basic cations for all n mineral soil horizons:

Miner_Puff [$cmol_c$/m²] = Σ (Carb_Puff *(n)* * 100 + Mb *(n)*)

Step 4 – Determination of base content and bulk density for each top organic horizon

Depending on the humus form, the following values are applied (see BayGLA and BayLfU 2003: 61):

Table 56: Determination of base content and bulk density

Humus form (S175)	**base content** [cmol_c/kg]	**bulk density** [g/cm³]
Mull (110, 111, 112, 113, 114, 210, 410, 411, 412, 510)	61	0,07
Moder (120, 121, 122, 124, 125, 220, 420, 520)	39	0,13
Raw humus (123, 130, 131, 132, 133, 134, 230, 430, 530)	32	0,20

Note: All other humus forms lead to Org_Puff = 0.

<u>Step 5 – Calculation of the buffer capacity of the top organic layers</u>

Summing up the buffer capacity for all n top organic horizon

Org_Puff [cmol_c/m^2] = Σ (base content *(n)* * bulk density *(n)* * thickness *(n)* * 10

<u>Step 6 – Calculation of the buffer capacity of the entire profile</u>

Ges_Puff [cmol_c/m^2] = Miner_Puff *(step 3)* + Org_Puff *(step 5)*

<u>Step 7 – Overall evaluation</u>

Table 57: Evaluation „Buffering of acidic substances”

Total buffer capacity *(Ges_Puff* [cmol_c/m^2]*, step 6)*	**Evaluation Puff_sauer**
≥30.000	**5**
10.000 to <30.000	**4**
3.000 to <10.000	**3**
1.000 to <3.000	**2**
<1.000	**1**

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Abbreviations

BLGT	soil biocoenosis types (de: **B**oden**l**ebens**g**emeinschafts**t**ypen)
BORIS	soil information system (de: Bodeninformationssystem)
BS	Base saturation
eHYD	electronic hydrographic data (de: **e**lektronische **Hyd**rographische Daten)
FB	Amount of fine earth (de: **F**ein**b**odenmenge)
FK	Field capacity (de: **F**eld**k**apazität)
GPV	Soil porosity (de: **g**esamtes **P**oren**v**olumen)
HÄO	Hydrological atlas of Austria (de: **H**ydrologischer **A**tlas **Ö**sterreich)
HM	Humus amount (de: **H**umus**m**enge)
KAK	Cation exchange capacity (CEC; de: **K**ationen**a**ustauch**k**apazität)
KAK$_{eff}$	Effective cation exchange capacity
KAK$_{pot}$	Potential cation exchange capacity
LK	Air capacity (de: **L**uft**k**apazität)
Mb$_{Wp}$	Site-specific nutrient capacity within the potential rooting depth
nFK	Available field capacity (de: **n**utzbare **F**eld**k**apazität)
ÖKOSTRA	Austria-wide coordinated heavy rainfall regionalisation and analysis (de: **Ö**sterreichweit **ko**ordinierte **S**tarkniederschlags**r**egionalisierung und **-a**uswertung)
SEPP	Soil Evaluation for Planning Procedures
TM	Clay amount (de: **T**on**m**enge)
TUSEC	Technique of Urban Soil Evaluation in City Regions
VKR	Linking rule (de: **V**er**k**nüpfungs**r**egel)
Wp	Potential rooting zone (de: **p**otenzieller **W**urzelraum)
WSV	Water storage capacity (de: **W**asser**s**peicher**v**ermögen)

Annex: BORIS classifications (german)

Status as of March 2021

Codezahl	Bezeichnung
B209 – Bodenart-Labor	
100	Schwereklasse I (sehr leicht)
101	Sand
121	schluffiger Sand
200	Schwereklasse II (leicht)
202	Schluff
212	sandiger Schluff
231	lehmiger Sand
300	Schwereklasse III (mittelschwer)
313	sandiger Lehm
332	lehmiger Schluff
341	toniger Sand
400	Schwereklasse IV (schwer)
403	Lehm
414	sandiger Ton
423	schluffiger Lehm
500	Schwereklasse V (sehr schwer)
504	Ton
534	lehmiger Ton
600	Schwereklasse I-II (sehr leicht - leicht)
700	Schwereklasse II-III (leicht - mittelschwer)
800	Schwereklasse III-IV (mittelschwer-schwer)
900	Schwereklasse IV-V (schwer - sehr schwer)
P116 – Skelettgehalt - Code	
000	kein Skelettgehalt
110	geringer Grobanteil, Grus
111	0-10% Grobanteil, Feingrus
112	0-10% Grobanteil, Mittelgrus
113	geringer Grobanteil, Grobgrus
120	geringer Grobanteil, Steine
130	geringer Grobanteil, Blöcke (eckig-kantig)
140	geringer Grobanteil , Kies
141	0-10% Grobanteil, Feinkies
142	0-10% Grobanteil, Mittelkies
143	geringer Grobanteil, Grobkies
150	geringer Grobanteil, Schotter
160	geringer Grobanteil, Blöcke
190	geringer Grobanteil an Blöcken (allgemein)
199	geringer Grobanteil, keine Angabe zu Form und Größe
210	mäßiger Grobanteil, Grus
211	10-20% Grobanteil, Feingrus

212	mäßiger Grobanteil, Mittelgrus
213	mäßiger Grobanteil an Grobgrus
220	mäßiger Grobanteil, Steine
230	mäßiger Grobanteil, Blöcke (eckig-kantig)
240	mäßiger Grobanteil, Kies
241	10-20% Grobanteil, Feinkies
242	10-20% Grobanteil, Mittelkies
243	10-20% Grobanteil, Grobkies
250	mäßiger Grobanteil, Schotter
260	10-20% Grobanteil, Blöcke (abgerundet)
290	mäßiger Grobanteil an Blöcken (allgemein)
299	mäßiger Grobanteil, keine Angabe zu Form und Größe
310	hoher Grobanteil, Grus
311	hoher Grobanteil, Feingrus
312	hoher Grobanteil, Mittelgrus
313	hoher Grobanteil an Grobgrus
320	hoher Grobanteil, Steine
330	hoher Grobanteil, Blöcke (eckig-kantig)
340	hoher Grobanteil, Kies
341	20-40% Grobanteil, Feinkies
342	20-40% Grobanteil, Mittelkies
343	20-40% Grobanteil, Grobkies
350	hoher Grobanteil, Schotter
360	20-40% Grobanteil, Blöcke (abgerundet)
390	hoher Grobanteil an Blöcken (allgemein)
399	hoher Grobanteil, keine Angabe zu Form und Größe
410	sehr hoher Grobanteil, Grus
411	sehr hoher Grobanteil an Feingrus
412	sehr hoher Grobanteil an MIttelgrus
413	sehr hoher Grobanteil an Grobgrus
420	sehr hoher Grobanteil, Steine
430	sehr hoher Grobanteil, Blöcke
440	sehr hoher Grobanteil, Kies
441	40-80% Grobanteil, Feinkies
442	40-80% Grobanteil, Mittelkies
443	40-80% Grobanteil, Grobkies
450	sehr hoher Grobanteil, Schotter
460	40-80% Grobanteil, Blöcke (abgerundet)
490	sehr hoher Grobanteil an Blöcken (allgemein)
499	sehr hoher Grobanteil, keine Angabe zu Form und Größe
510	vorwiegend Grobanteil, Grus
511	vorwiegend Grobanteil, Feingrus
512	vorwiegend Grobanteil, Mittelgrus
513	vorwiegend Grobanteil an Grobgrus
520	vorwiegend Grobanteil, Steine
530	vorwiegend Grobanteil, Blöcke
540	vorwiegend Grobanteil, Kies
541	über 80% Grobanteil, Feinkies
542	vorwiegend Grobanteil, Mittelkies

543	über 80% Grobanteil, Grobkies
550	vorwiegend Grobanteil, Schotter
560	vorwiegend Grobanteil, Blöcke
590	vorwiegend Grobanteil an Blöcken (allgemein)
599	vorwiegend Grobanteil, keine Angabe zu Form und Größe
910	Grus, keine Angabe zu Anteil des Skelettgehalts
911	keine Angabe zu Anteilen an Feingrus
912	keine Angabe zum Anteil, Mittelgrus
920	Steine, keine Angabe zu Anteil des Skelettgehalts
930	Blöcke (eckig-kantig), keine Angabe zu Anteil des Skelettgehalts
940	Kies, keine Angabe zu Anteilen des Skelettgehalts
950	Schotter, keine Angabe zu Anteil des Skelettgehalts
960	Blöcke (abgerundet), keine Angabe zu Anteil des Skelettgehalts
990	keine Angabe zum Anteil an Blöcken (allgemein)
P128 – Karbonatgehalt im Gelände	
1	kalkfrei (0 %)
2	kalkarm (<0,5 %)
3	schwach kalkhaltig (0,5-1,5 %)
4	mäßig kalkhaltig (1,5-5,0 %)
5	stark kalkhaltig (>5 %)
12	kalkfrei bis kalkarm (unter 0,5 %)
13	Kalkfrei bis schwach kalkhaltig (0-1,5 %)
P128 – Primär Bodenstruktur (Bodengefüge)	
199	ohne Aggregatstruktur (auch nicht lose, massiv od. kohärent)
299	Einzelkornstruktur
399	Massiv- oder Kohärentstruktur
410	Aggregatstruktur, plattig
420	Aggregatstruktur, prismatisch-scharfkantig (prismatisch)
430	Aggregatstruktur, prismatisch-kantengerundet (kolumnar)
440	Aggregatstruktur, blockig-scharfkantig (polyedrisch)
450	Aggregatstruktur, blockig-kantengerundet (subpolyedrisch)
460	Aggregatstruktur, körnig (granular)
470	Aggregatstruktur, krümelig
480	Aggregatstruktur, Bröckel (<50 mm)
490	Aggregatstruktur, Klumpen (Schollen) (>50 mm)
499	Aggregatstruktur ohne nähere Angabe
P140 – Bodenart im Gelände (Fingerprobe)	
100	Schwereklasse I (sehr leicht)
101	S-Sand
121	uS-schluffiger Sand
200	Schwereklasse II (leicht)
202	U-Schluff
212	sU-sandiger Schluff
231	lS-lehmiger Sand
300	Schwereklasse III (mittelschwer)
313	sL-sandiger Lehm

332	lU-lehmiger Schluff
341	tS-toniger Sand
400	Schwereklasse IV (schwer)
403	L-Lehm
414	sT-sandiger Ton
423	uL-schluffiger Lehm
500	Schwereklasse V (sehr schwer)
504	T-Ton
534	lT-lehmiger Ton
600	I-II: sehr leicht-leicht
700	II-III: leicht-mittelschwer
800	III-IV: mittelschwer-schwer
900	IV-V: schwer-sehr schwer
P162 – Lagerung	
10	lo – lose
20	lk – locker
30	n – normal
40	d2 – schwach dicht
50	d3 – dicht
60	d4 – sehr dicht
70	Wela – Wechsellagerung
P168 – Humusgehalt in Böden (2.VwV Bodschg. B.-W.)	
10	sehr schwach humos, < 1% Humus
20	schwach humos, 1-2% Humus
30	mittel humos, 2-4% Humus
40	stark humos, 4-8% Humus
50	sehr stark humos, 8-15% Humus
60	anmoorig bzw. äußerst humos, 15-30% Humus
70	Torf, > 30% Humus
S135 – Hangneigungsklasse	
11	FW-eben, 0-2°, 0-3%
12	FW-schwach geneigt, 2-5°, 3-9%
13	FW-mäßig geneigt, 5-10°, 9-17%
14	FW-stark geneigt, 10-20°, 17-36%
15	FW-steil, 20-30°, 36-58%
16	FW-schroff, 30-45°, 58-100%
17	FW-sehr schroff, >45°, >100%
21	LW-eben, 0-2°, 0-3%
22	LW-schach geneigt, 2-5°, 3-9%
23	LW-leicht hängig, 5-10°, 9-17%
24	LW-hängig, 10-15°, 17-27%
25	LW-stark hängig, 15-20°, 27-36%
26	LW- steilhängig, 20-30°, 36-58%
27	LW- sehr steilhängig, >30°, >58%
S161 – Bodenwasserverhältnisse	

110	FW: sehr trocken
120	FW: mäßig trocken
130	FW: mäßig frisch
140	FW: frisch
150	FW: sehr frisch
160	FW: feucht
170	FW: naß
180	FW: wechselfeucht
190	FW: wechseltrocken
210	LW: sehr trocken
220	LW: trocken
230	LW: normal, mäßig trocken
240	LW: normal, gut versorgt
250	LW: mäßig feucht
260	LW: feucht
270	LW: naß
280	LW: wechselfeucht
282	LW: wechselfeucht- überwiegend trocken
284	LW: wechselfeucht- überwiegen feucht
286	LW: mäßig wechselfeucht
288	LW: extrem wechselfeucht
S175 – Humusform	
000	Sonstiges
Terrestrische Humusformen	
110	FW: Mull
111	FW: Typischer Mull
112	FW: Moderartiger Mull
113	FW: Kalkmull
114	FW: Anmoormull
120	FW: Moder
121	FW: Typischer Moder
122	FW: Mullartiger Moder
123	FW: Rohhumusartiger Moder
124	FW: Xeromorpher Moder
125	FW: Kalkmoder
130	FW: Rohhumus
131	FW: Typischer Rohhumus
132	FW: Moderartiger Rohhumus
133	FW: Xeromorpher Rohhumus
134	FW: Kalkrohhumus (Tangelhumus)
Semiterrestrische Humusformen	
210	FW: Feuchtmull
220	FW: Feuchtmoder
230	FW: Feuchtrohhumus
240	FW: Hochmoortorf
250	FW: Übergangsmoortorf
260	FW: Anmoorhumus
Subhydrische Humusformen	

310	FW: Niedermoortorf
Terrestrische Humusformen	
410	LW: Mull
411	LW: Modermull oder mullartiger Humus
412	LW: Anmoormull
420	LW: Moder
430	LW: Rohhumus
Semiterrestrische Humusformen	
510	LW: Feuchtmull
520	LW: Feuchtmoder
530	LW: Feuchtrohhumus
540	LW: Hochmoortorf
560	LW: Anmoorhumus
Subhydrische Humusformen	
610	LW: Niedermoortorf
900	keine Auflage/Humus
S178 – Landnutzung	
100	Wald
110	Laubwald
120	Nadelwald
130	Mischwald
200	Grünland
210	intensives (mehrschnittiges) Dauergrünland
220	intensiv bewirtschaftete Weide
230	extensives (einschnittiges) Dauergrünland
231	Grünland - Wiese, Mähnutzung
240	extensive Weide (Hutweide)
250	Alm
260	Bergmahd
270	Streuwiese
280	Feldrain
290	Steuobstwiese
2A0	Grünland (nicht mehr genutzt)
2A1	Grünland natürlich
300	Acker
310	Dauer-Ackerfläche
320	Wechselland
321	Ackergrünland
322	Grünlandacker
330	Ackerfläche (nicht mehr genutzt)
340	Segetalstandorte
400	Weingarten
500	Intensivobstanlagen (incl. Beerenobstbestand)
600	Gartenanlagen
610	Erwerbsgartenanlagen
620	Hausgärten
621	Beet
622	Rasen

630	Baumschulen
700	Verkehrsbegleitende Flächen
800	Verbautes Gebiet
810	Kinderspielplatz
811	Kinderspielplatz im locker verbauten Gebiet
820	Park, Friedhof
830	Freizeitanlagen im verbauten Gebiet
840	Sportplatz
850	Industrie- und Gewerbeflächen
860	städtische Grünfläche (allgemein)
870	Ruderalstandort
900	Sonstige
910	Freizeitanlagen
911	Kinderspielplatz größtenteils angrenzend an landwirtsch. Flächen
920	Rekultivierungsfläche
930	Ablagerungsfläche
940	Energieholzfläche
950	Moore (unkultiviert)
960	Ödland, offene Fläche
970	Bergbau, Abbau
990	Sonstiges
99999	keine Angabe
S181 – Klimatische Höhenstufen	
10	Tieflage
11	Kollin-planar
12	submontan
20	Mittellage
21	tiefmontan
22	mittelmontan
23	hochmontan
30	Hochlage
31	tief-subalpin
32	hoch-subalpin
S322 – Bodentyp - Österreichische Bodesystematik 2000	
1100	Terrestrische Rohböden
1110	Grobmaterial Rohboden (CG)
1111	Carbonatfreier Grobmaterial-Rohboden
1112	Carbonathaltiger Grobmaterial-Rohboden
1120	Feinmaterial - Rohboden (CF)
1121	carbonatfreier Feinmaterial - Rohboden
1122	carbonathaltiger Feinmaterial - Rohboden
1200	Auflagehumusböden und entwickelte A-C-Böden
1210	Fels-Auflagehumusboden (RA)
1220	Rendzina (RN)
1221	Proto - Rendzina
1222	Mull-Rendzina
1223	Mullartige Rendzina

1224	Moder-Rendzina
1225	Tangel-Rendzina
1226	Pech-Rendzina
1230	Kalklehm-Rendzina (RT)
1231	Mull - Kalklehm-Rendzina
1232	Moder - Kalklehm-Rendzina
1240	Pararendzina
1241	Proto - Pararendzina
1242	Mull-Pararendzina
1243	Moder - Pararendzina
1250	Ranker (RR)
1251	Proto - Ranker
1252	Mull - Ranker
1253	Mullartige Ranker
1254	Moder - Ranker
1255	Tangel - Ranker
1260	Tschernosem (ST)
1261	Carbonathaltiger Tschernosem
1262	Carbonathaltiger brauner Tschernosem
1263	Carbonatfreier Tschernosem
1270	Rumpf - Tschernosem (SR)
1271	Carbonatfreier Rumpf - Tschernosem
1272	carbonathaltiger Rumpf - Tschernosem
1300	Braunerden
1310	Braunerde (BN)
1311	carbonatfreie Braunerde
1312	carbonathaltige Braunerde
1313	carbonatfreie Relikt-Braunerde
1314	carbonathaltige Relikt-Braunerde
1320	Parabraunerde (BP)
1321	rezente Parabraunerde
1322	Relikt - Parabraunerde
1400	Podsole
1410	Semipodsol (OS)
1420	Podsol (OT)
1421	Eisen - Humus - Podsol
1422	Eisen - Podsol
1423	Humus - Podsol
1430	Staupodsol (OW)
1431	Eisen - Humus - Staupodsol
1432	Eisen - Staupodsol
1433	Humus - Staupodsol
1500	Kalklehme
1510	Kalkbraunlehm (TB)
1520	Kalkrotlehm (TR)
1600	Substratböden
1610	Farb - Substratboden (UF)
1620	Textursubstratboden (UT)
1700	Kolluvien und Anthrosole

1710	Kolluvisol (YK)
1711	karbonatfreier Kolluvisol
1712	karbonathaltiger Kolluvisol
1720	Kultur - Rohboden (YR)
1721	karbonatfreier Kulturrohboden
1722	karbonathaltiger Kulturrohboden
1730	Gartenboden (YG)
1731	karbonatfreier Gartenboden
1732	karbonathaltiger Gartenboden
1740	Rigolboden (YW)
1741	karbonatfreier Rigolboden
1742	karbonathaltiger Rigolboden
1750	Schüttungsboden (YS)
1751	Planieboden
1752	Haldenboden
1760	Deponieboden (YD)
1761	karbonatfreier Deponieboden
1762	karbonathaltiger Deponieboden
1800	Auböden
1810	Auboden (AT)
1811	karbonatfreier Auboden
1812	karbonathaltiger Auboden
1820	Augley (AG)
1821	carbonatfreier Augley
1822	carbonathaltiger Augley
1830	Schwemmboden (AS)
1831	karbonatfreier Schwemmboden
1832	karbonathaltiger Schwemmboden
1840	Rohauboden (AR)
1841	karbonatfreier Rohauboden
1842	karbonathaltiger Rohauboden
1900	Pseudogleye
1910	typischer Pseudogley (PT)
1920	Stagnogley (PS)
1921	typischer Stagnogley
1922	anmooriger Stagnogley
1930	Hangpseudogley (PH)
1940	Haftnässe - Pseudogley (PW)
1950	Reliktpseudogley (PR)
2000	Gleye
2010	Gley (GT)
2011	typischer Gley
2012	brauner Gley
2020	Nassgley (GW)
2021	typischer Nassgley
2022	anmooriger Nassgley
2023	Torf-Nassgley
2030	Hanggley (Quellgley) (GH)
2031	typischer Hanggley

2032	anmooriger Hanggley
2033	Torf-Hanggley
2100	Moore, Anmoore und Feuchtschwarzerden
2110	Niedermoor (NH)
2111	typisches Niedermoor
2112	Übergangsmoor
2120	Anmoor (MN)
2130	Feuchtschwarzerde (MS)
2131	karbonatfreie Feuchtschwarzerde
2132	karbonathaltige Feuchtschwarzerde
2200	Unterwasserböden
2210	Dy (WD)
2220	Gyttja (WG)
2230	Saprobel (WS)
2300	Salzböden
2310	Solontschak (ZK)
2320	Solonetz (ZZ)
2330	Solontschack - Solonetz (ZS)
2400	nicht identifizierbare Böden
S327 – primärer Bodentyp-Zusatz	
0	keine Zusatzangabe
11	vergleyt
12	pseudovergleyt
13	verbraunt
14	podsolig
15	versalzt
16	aggradiert
17	zersetzt
18	vererdet
19	entwässert oder trockengefallen
20	anmoorig
21	überlagert
22	extreme Ausbildung eines bestimmten Bodentyps
23	degradiert
24	rigolt
25	kolluvial beeinflusst