Possibilities of using IVANOV's hydromorphological theory in mire-ecology

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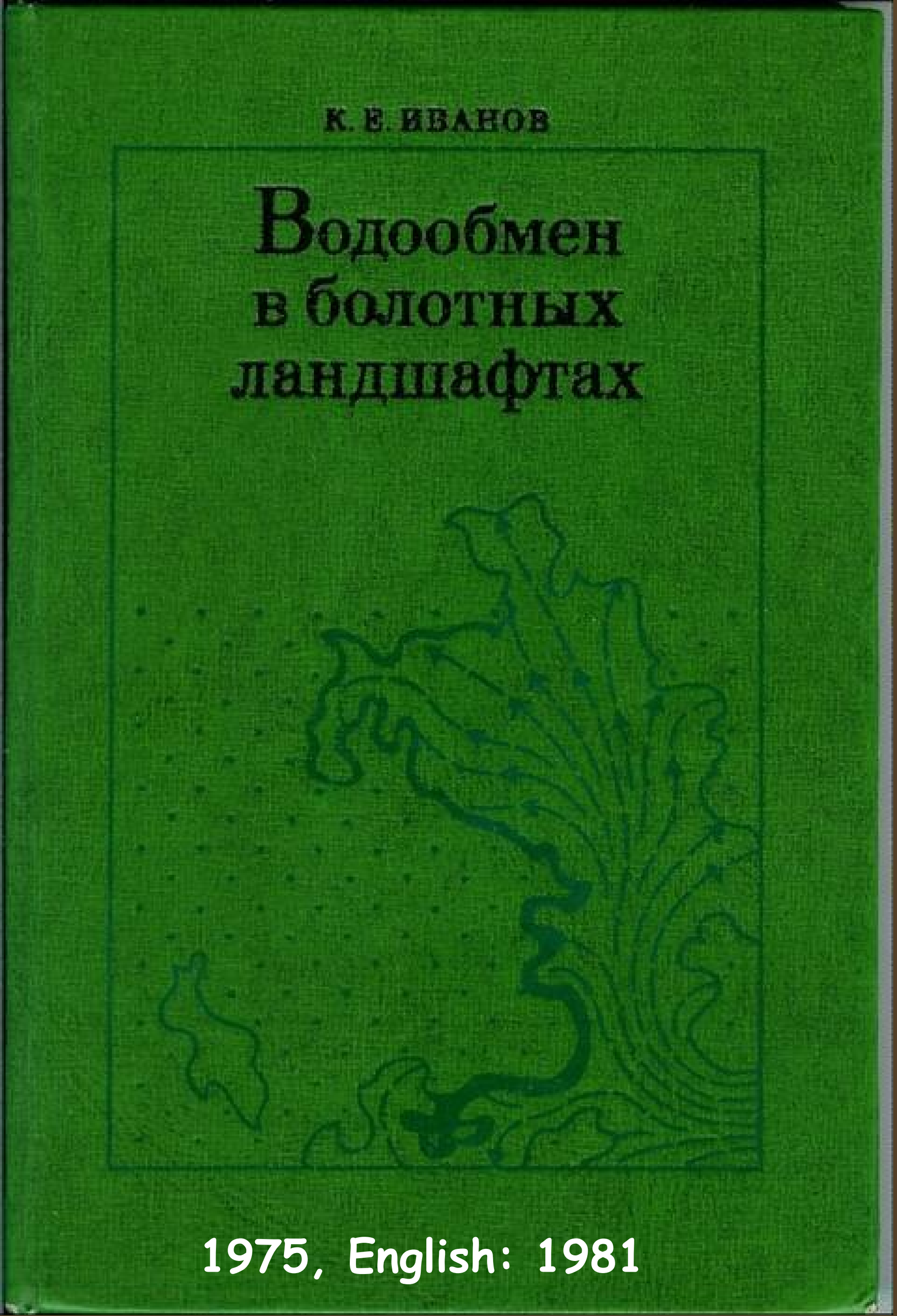


1975, English: 1981

Hydromorphology is that part of geomorphology concerning water-formed elements of the landscape and their interactions.

The **coupling with methods of quantitative hydrology** allows a causal explaining, mathematical modelling and predicting of water-formed elements.

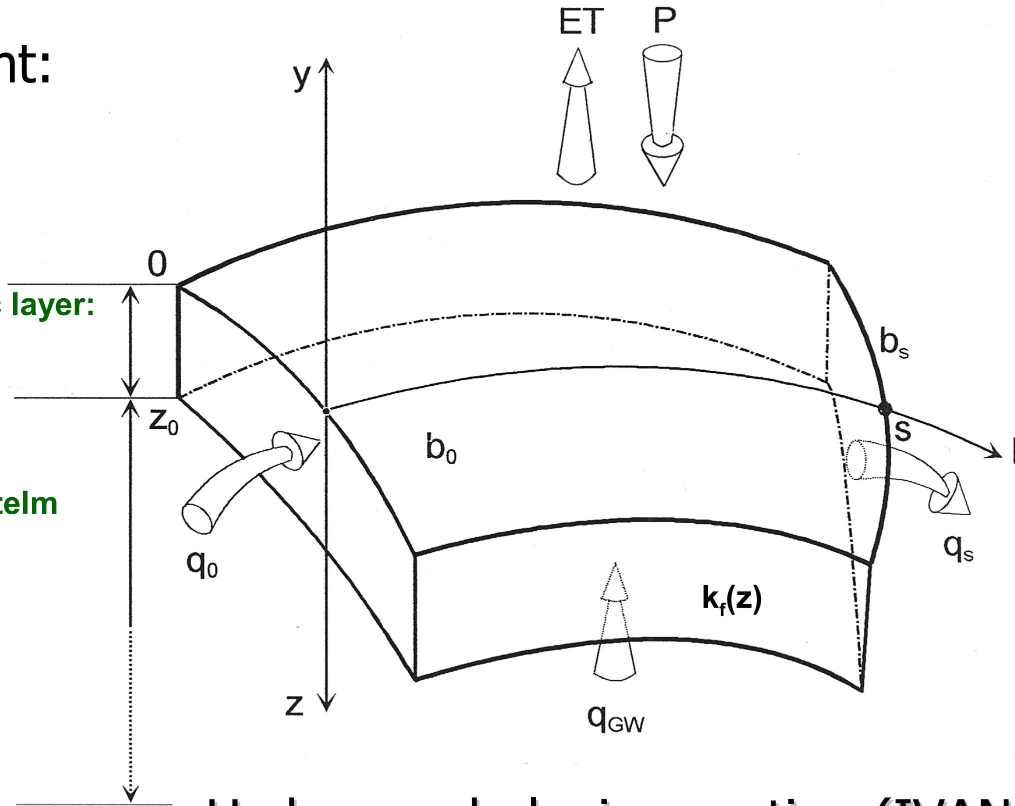
Mire-segment:

all peat

pedogenetic layer: akrotelm

katotelm

layers beneath the peat



layers beneath the peat

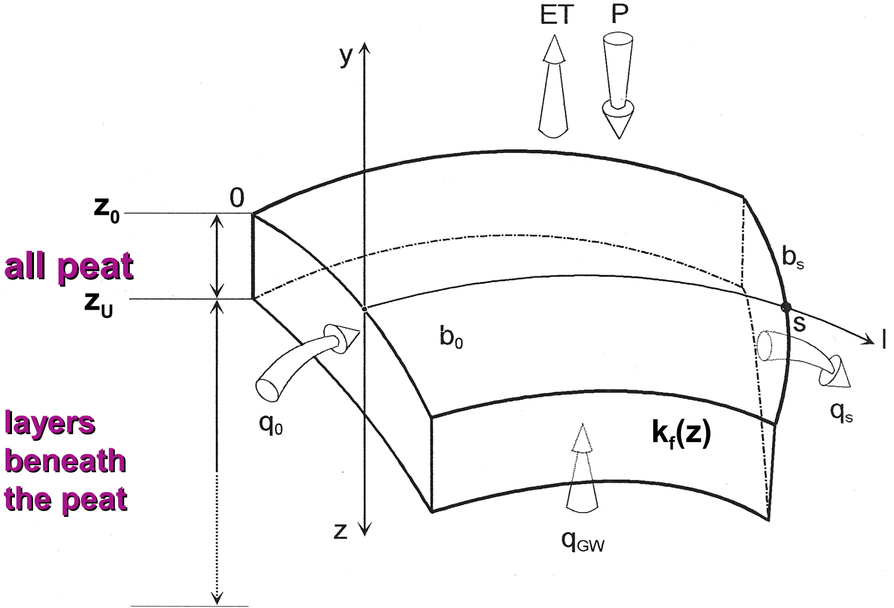
Hydromorphologic equation (IVANOV 1975):

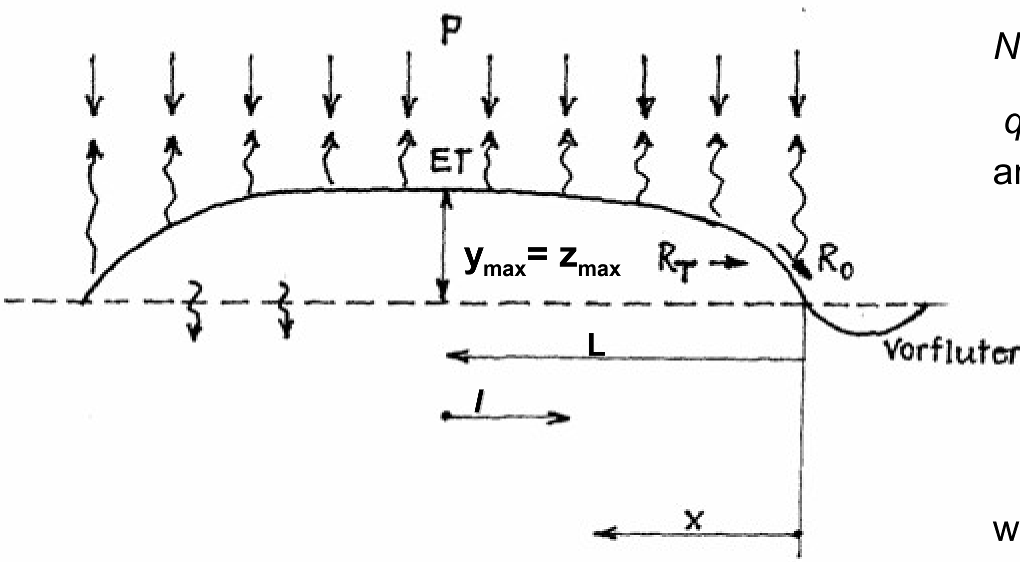
$$\frac{dy}{dl}(s) = \frac{q_0 \cdot b_0 + \int_0^s p_l \cdot b_l \, dl}{M_z(s) \cdot b_s} = \frac{q_0 \cdot b_0 + \int_0^s p_l \cdot b_l \, dl}{b_s \cdot \int_{z_u}^{z_m} k_f(z) \, dz}$$

Slope & morphologic parameters

water balance

Transmissivity as a distribution of hydraulic conductivity





Mire-segment (IVANOV 1975):

$$\frac{dy}{dl}(s) = \frac{q_0 \cdot b_0 + \int_0^s p_l \cdot b_l \, dl}{b_s \cdot \int_{z_u}^{z_m} k_f(z) dz}$$

Mire-form of an **ideal bog**:

For $k_f(z,l) = const$, $z_U = const$,

$N = P - ET \pm q_{GW} = p(l) = const > 0$,

$q_0 \cdot b_0 = 0$ & DUPUIT-approximation we get an **elliptic equation**:

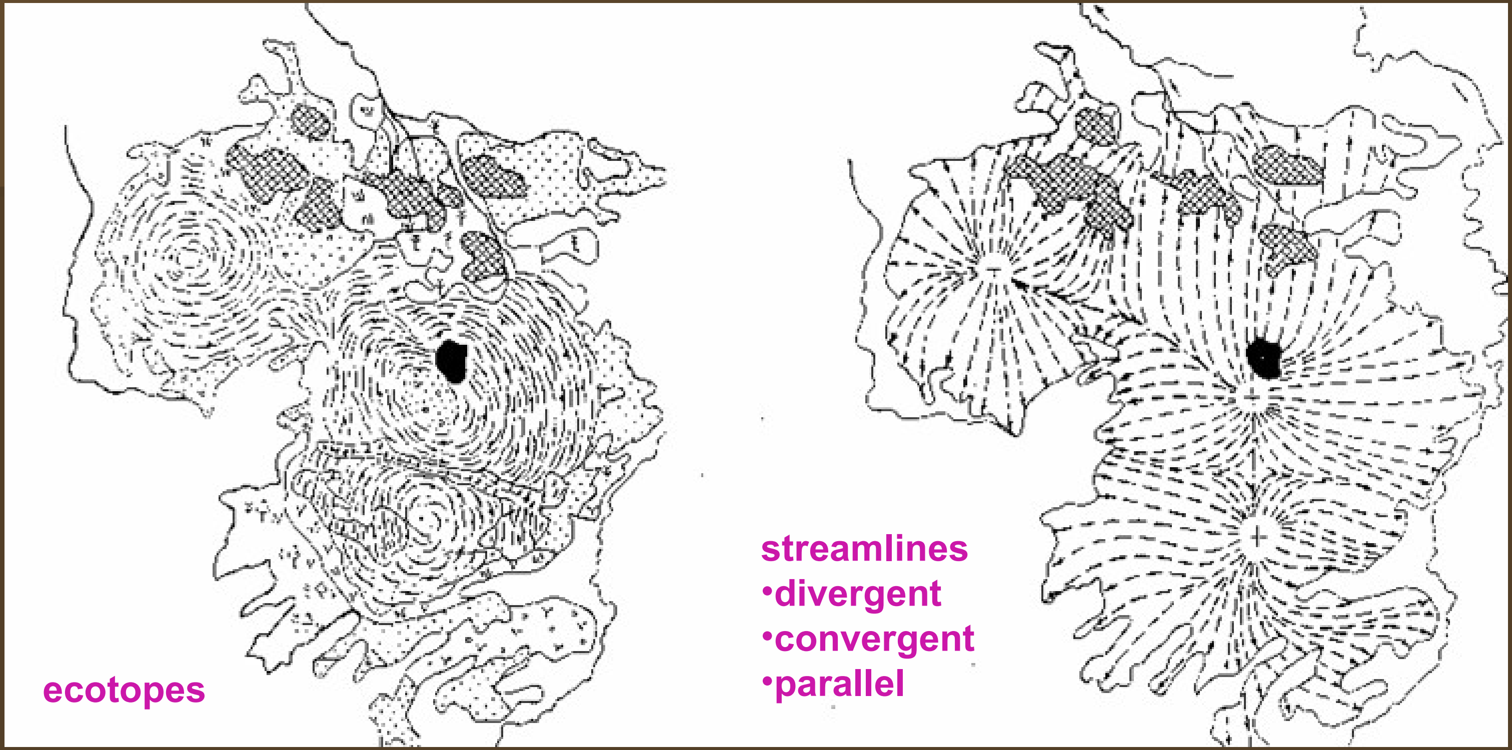
$$1 = \frac{n \cdot y^2}{L^2 \cdot \frac{N}{k_f}} + \frac{l^2}{L^2}$$

with:

(1) $n = 1$ for $b(l) = const.$ (used by INGRAM 1982 & SCHNEEBELI 1988)

(2) $n = 2$ for $b(l) \sim l$ (circular bog)

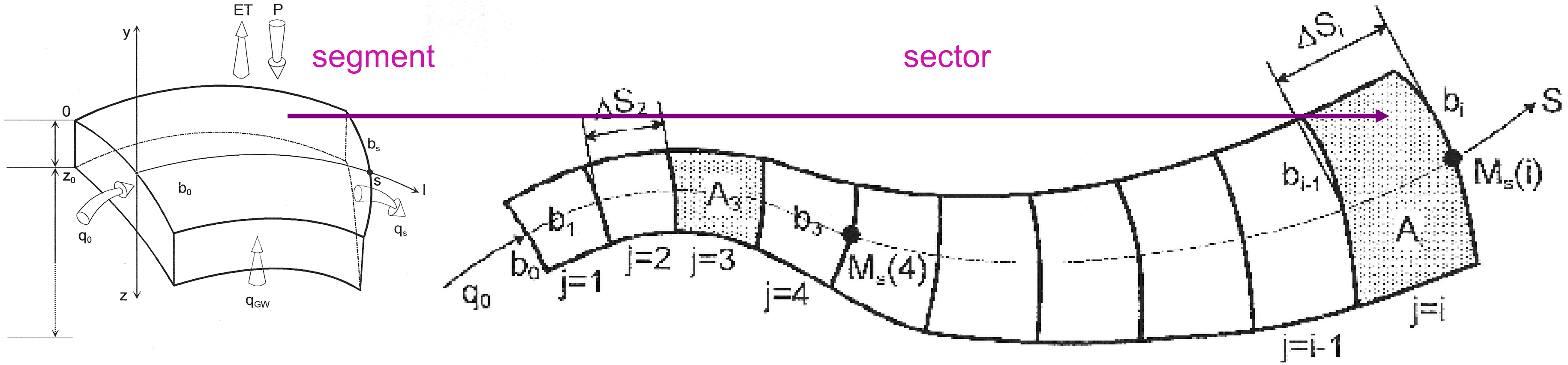
The diversity of mire-morphology is much more than an ideal bog. We have **distributed hydraulic parameters**, **variable** mire- and underground **topography.**



IVANOV 1975

Main-Principle of hydromorphologic theory:

In mires (growing peatlands) the mesorelief of the mire-surface is nearly parallel to the water-surface. That's why meso-surface-forms in mires can be described like a surface of a groundwater-body using the methods of geohydraulics. (3rd theorem of peatland-hydrology)



In a sector we can calculate for each segment for longterm-average water-balances:

- specific flow:

$$q_S(i) = \frac{q_0 \cdot b_0}{b(i)} + (P + q_{GW} - ET) \cdot \frac{\sum_{j=1}^{i} A_J}{b(i)}$$

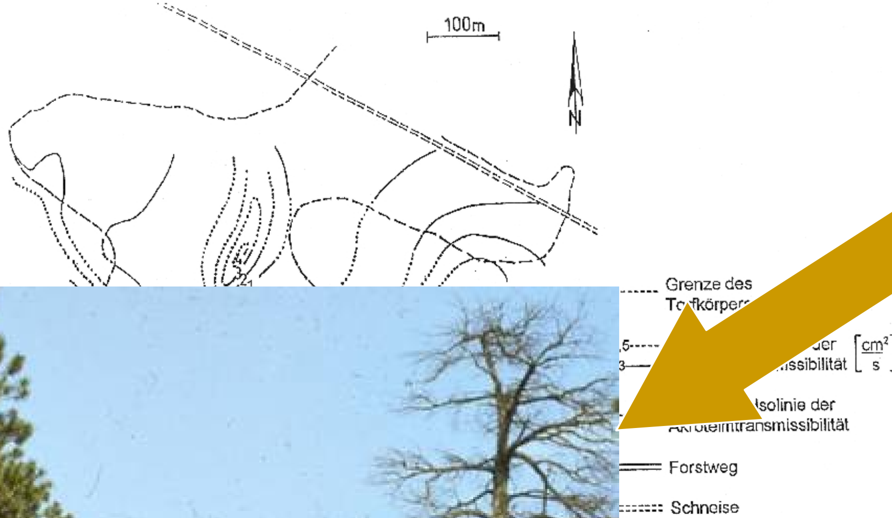
- “percolated” or “self regulated” or regenerating transmissivity (peatbody or akrotelm):

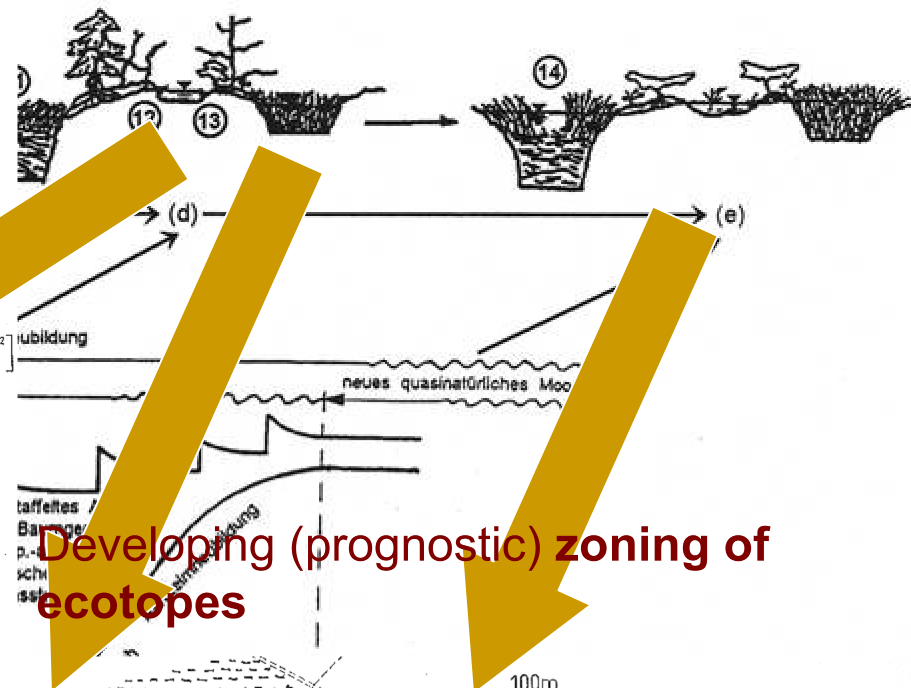
$$M_S(i) = \frac{q_0 \cdot b_0}{b(i) \cdot \frac{dy}{dl}(i)} + (P + q_{GW} - ET) \cdot \frac{\sum_{j=1}^{i} A_J}{b(i) \cdot \frac{dy}{dl}(i)}$$

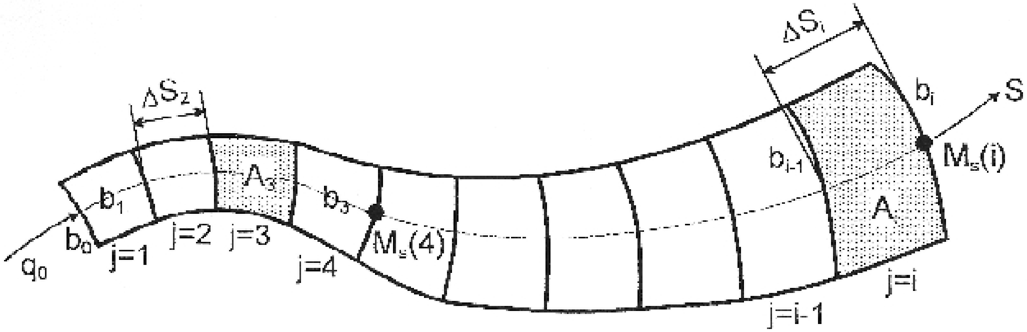
- part of catchment-water in relation to the full water-supply to the peat-body-site (“minerotrophy-coefficient”, fully water-mixing):

$$H_S(i) := \frac{q_0 \cdot b_0 + q_{GW} \cdot \sum_{j=1}^{i} A_j}{q_0 \cdot b_0 + (P - ET + q_{GW}) \cdot \sum_{j=1}^{i} A_j}$$

Developing (prognostic) **zoning of ecotopes**







Simulation of changes:

- No or less water from the catchment

  → less minerotrophic, more ombrotrophic for P-ET>0, but dryer

- climatic change: more ET

  → more minerotrophic, less ombrotrophic and dryer

- regeneration of only a part of the peatland

  → less minerotrophic, more ombrotrophic for P-ET>0, but dryer

$$q_S(i) = \frac{q_0 \cdot b_0}{b(i)} + (P + q_{GW} - ET) \cdot \frac{\sum_{j=1}^{i} A_J}{b(i)}$$

$$M_S(i) = \frac{q_0 \cdot b_0}{b(i) \cdot \frac{dy}{dl}(i)} + (P + q_{GW} - ET) \cdot \frac{\sum_{j=1}^{i} A_J}{b(i) \cdot \frac{dy}{dl}(i)}$$

$$H_S(i) := \frac{q_0 \cdot b_0 + q_{GW} \cdot \sum_{j=1}^{i} A_j}{q_0 \cdot b_0 + (P - ET + q_{GW}) \cdot \sum_{j=1}^{i} A_j}$$

Simulations for "Jägersgrüner Hochmoor" (ZINKE 1999)

1. Actual water-balance **without** water from the catchment – street as a water-barrier

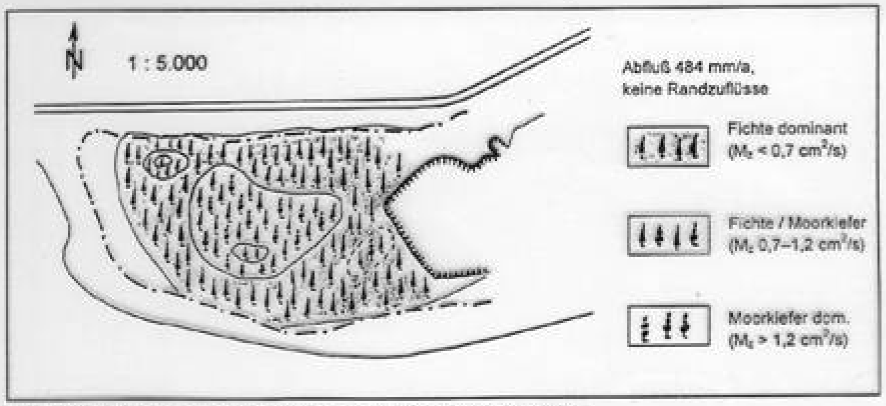


Abb. 3.3.3-4: Karte der potentiellen Moorökotope für die aktuelle Wasserbilanz

1. Actual water-balance **with** water from the catchment – street permeable

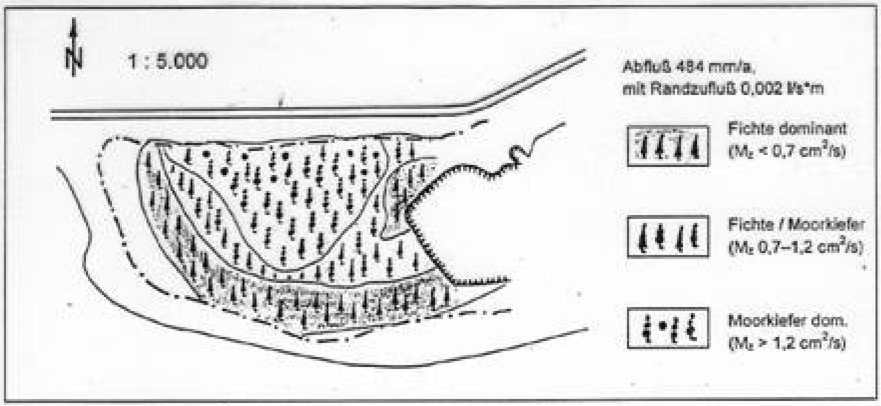


Abb. 3.3.3-6: Prognose der Ökotopzonierung bei Funktionsfähigkeit des Oberkantenlaggs

1. Climate change (dry) **without** water from the catchment – street as a water-barrier

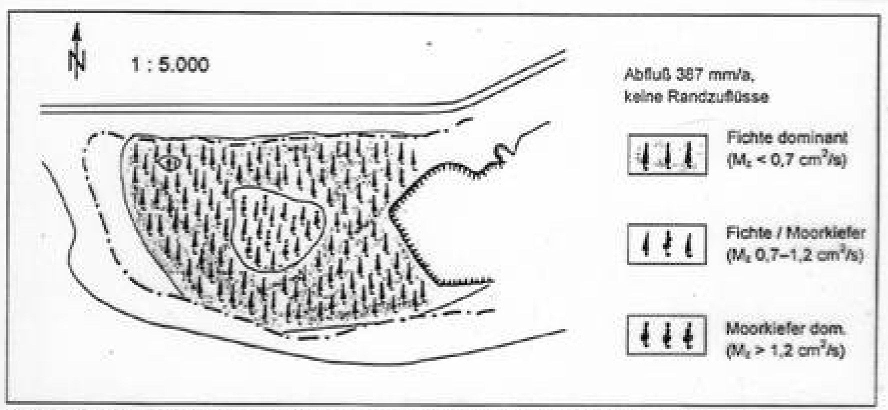
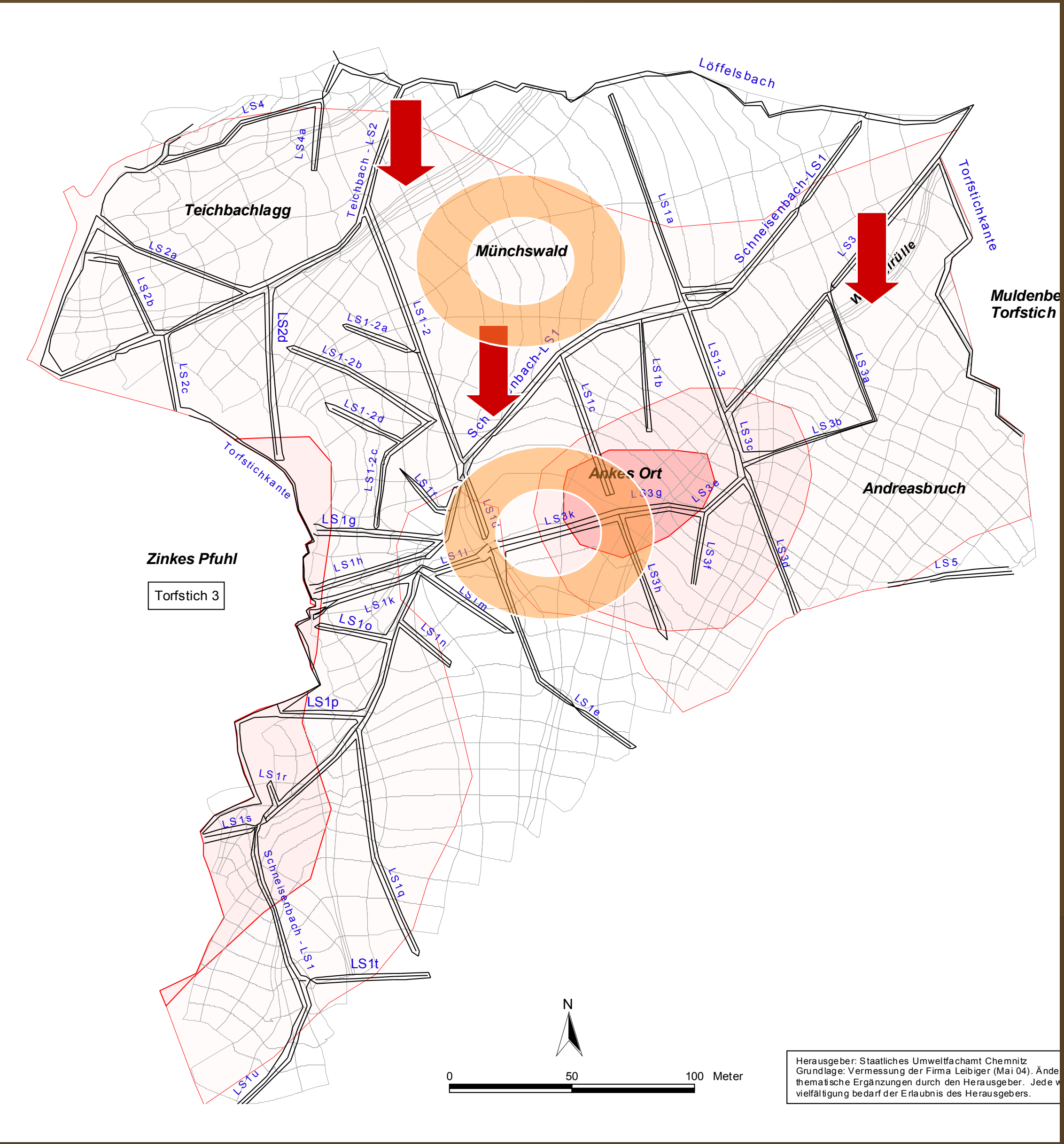


Abb. 3.4.3-3: Prognose der potentiellen Ökotopzonierung für das Jägersgrüner Hochmoor bei einer Verringerung des Jahresabflusses um 20 %

Hydromorphology and restauration- (revitalisation-) planning

- Map the peatland-topography, the ditches and all morphologic structures (geodetic survey, laser-scanning).
- Identify the catchment-area of the peatland.
- Make the water-balance.
- Calculate and simulate with the hydromorphologic methods.
- Make a set of maps and analyse them.
- Plan the measures and steps of restauration.
- Organise a monitoring.

Relief, streamlines, ditches and thickness of peat in the "Solbrigshaide" (Erzgebirge/ Krušne hory)

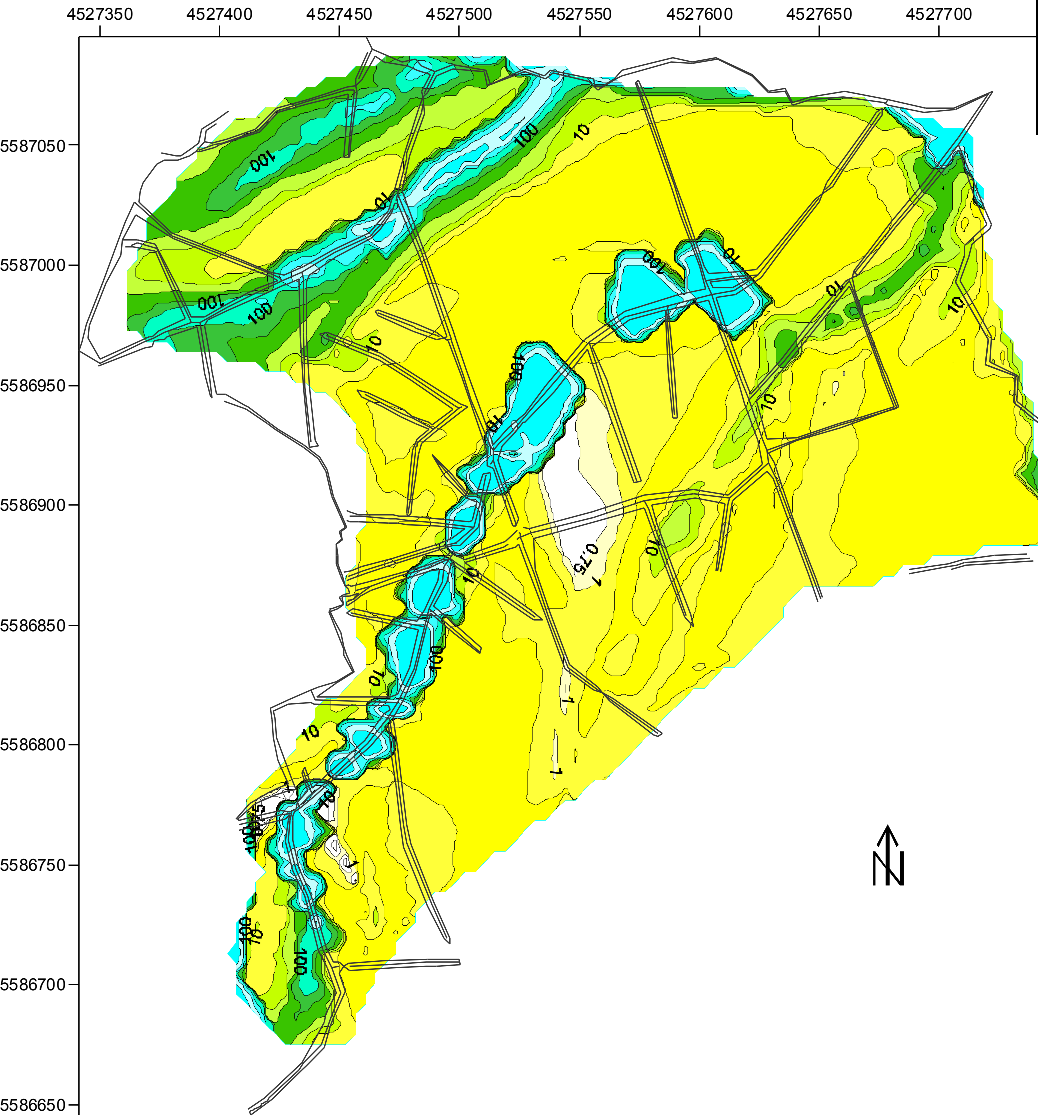


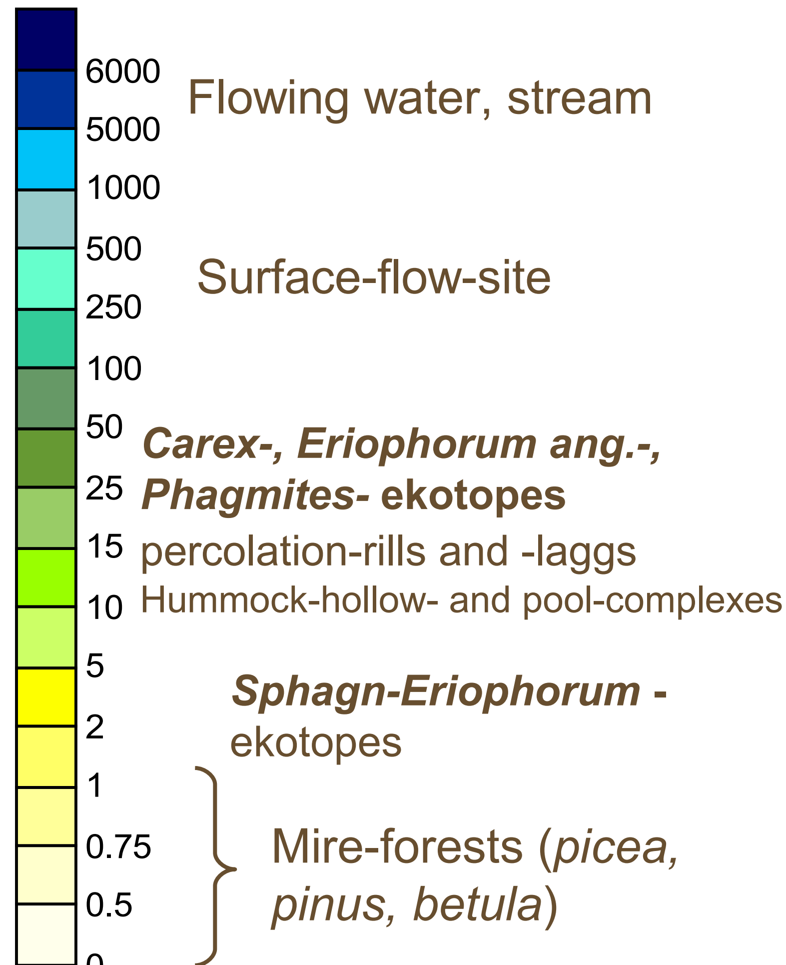
Convergent → increase of the specific flow: explaining of the natural drainage of the mire (rills (*germ.* Rüllen), brooks, karst) and rheotrophic phenomena

Divergent → decrease of the specific flow: explaining of growing ombrotrophy; often in central, „mire-typical" areas

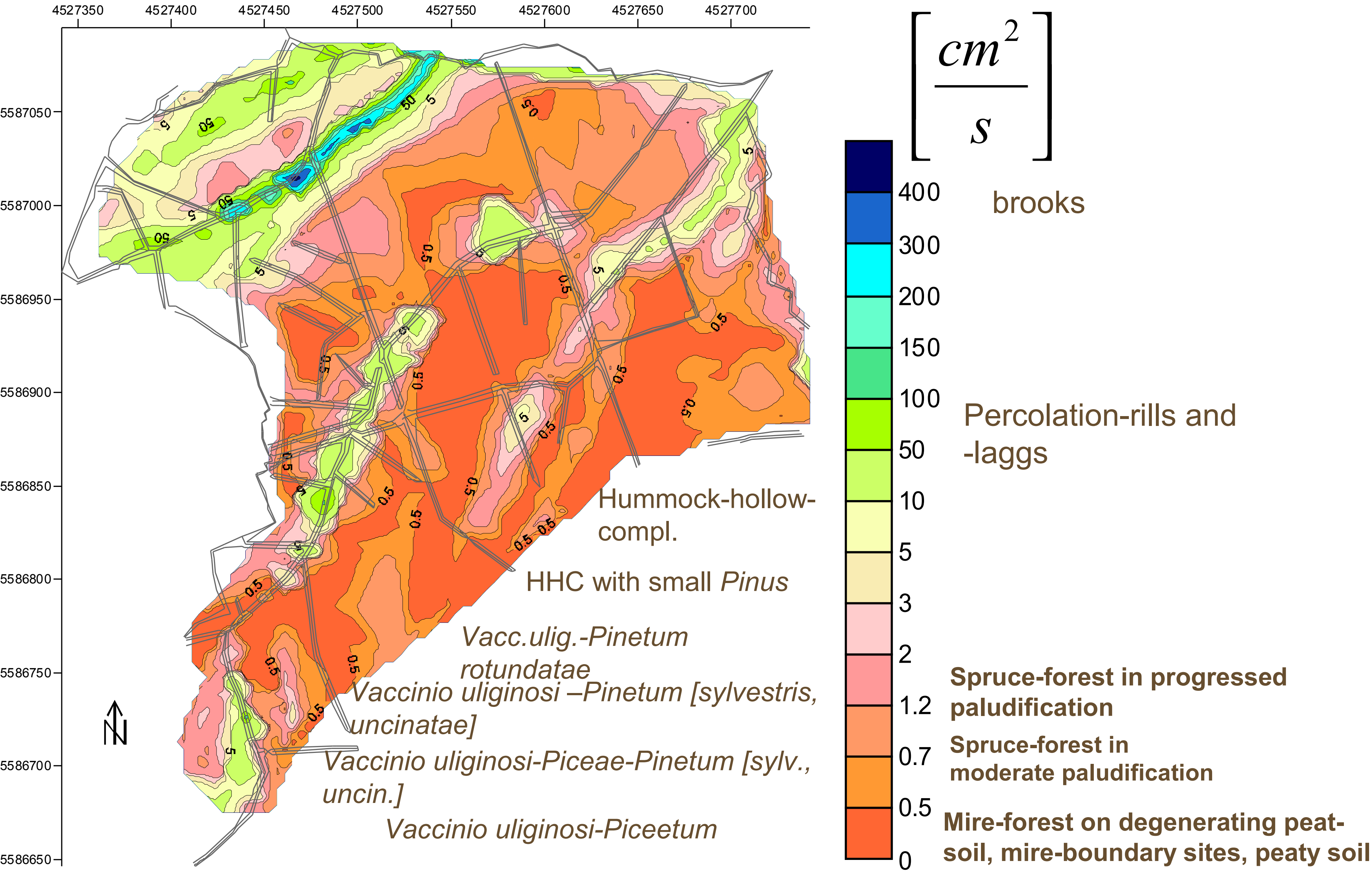
Calculated specific profile-flows in “Solbrigshaide”

$$\left[\frac{l}{s \cdot km}\right] = \left[3{,}6 \cdot \frac{l}{h \cdot m}\right]$$

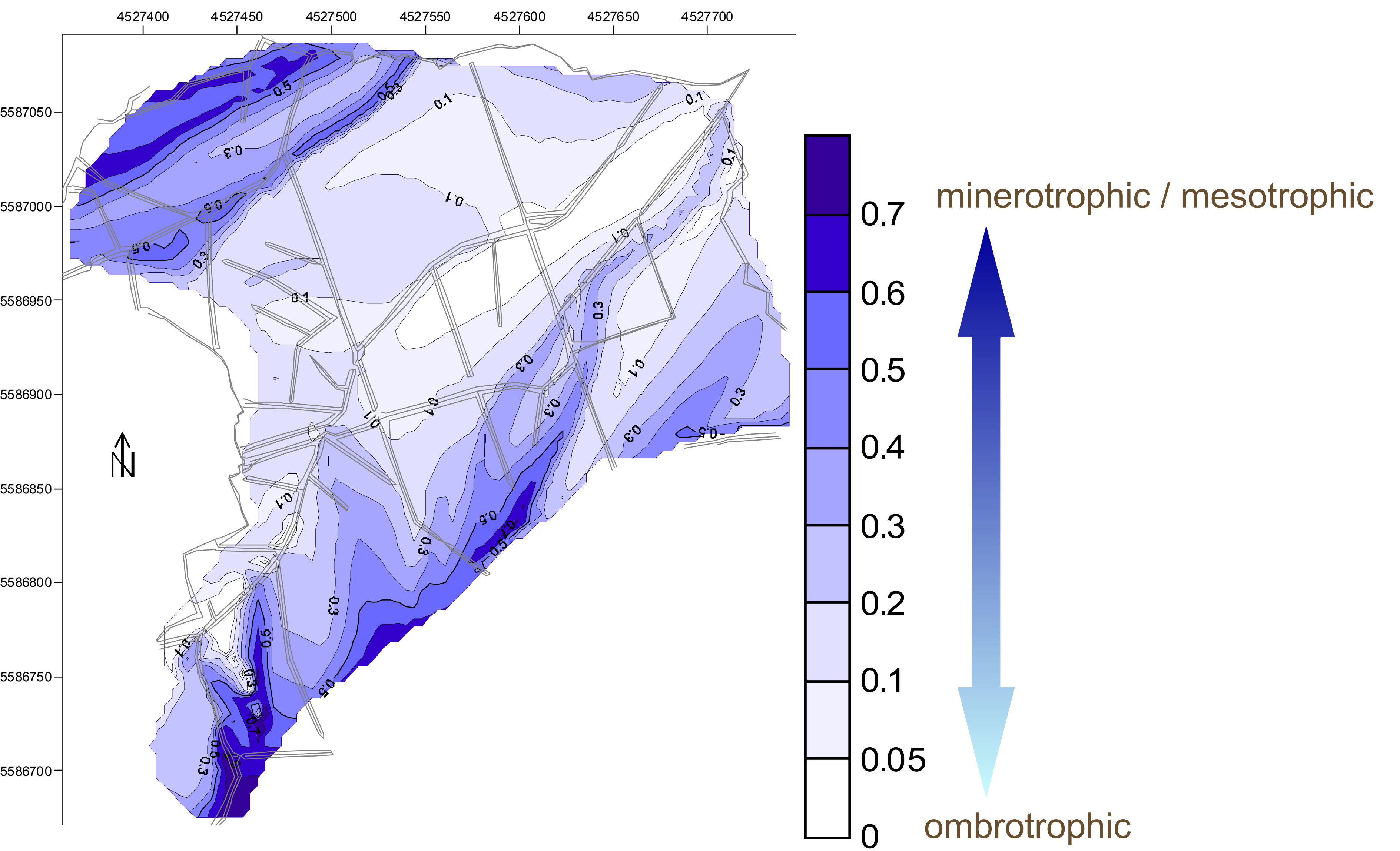




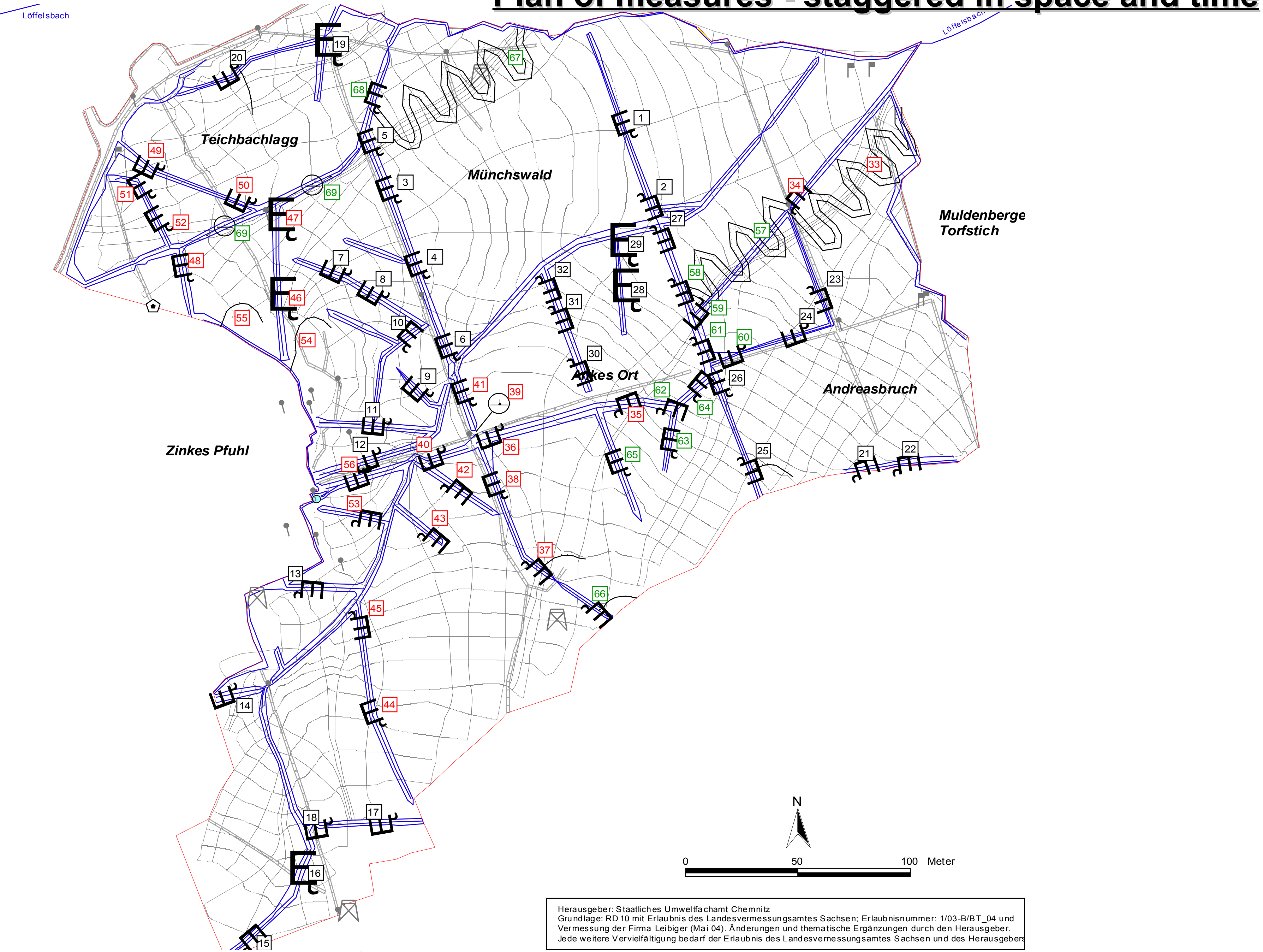
Potential or necessary transmissivities



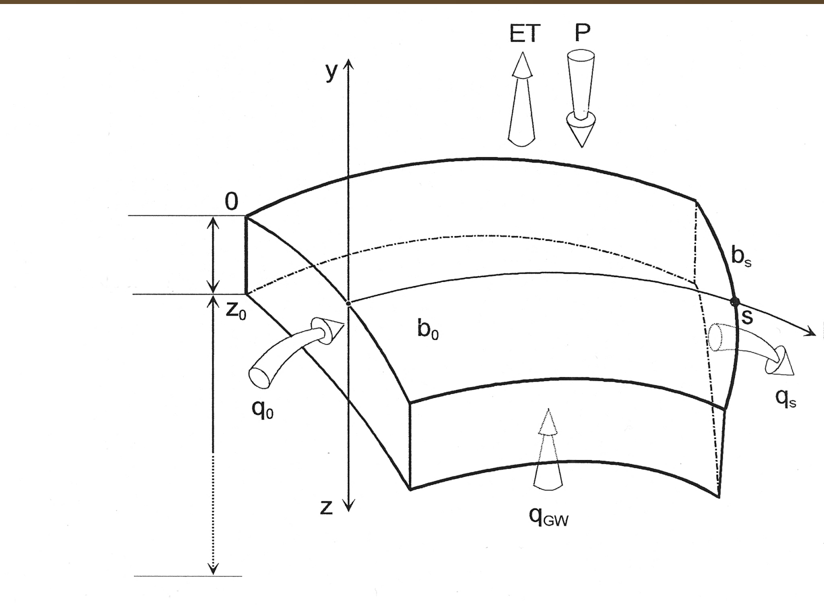
“Minerotrophy-coefficient”:

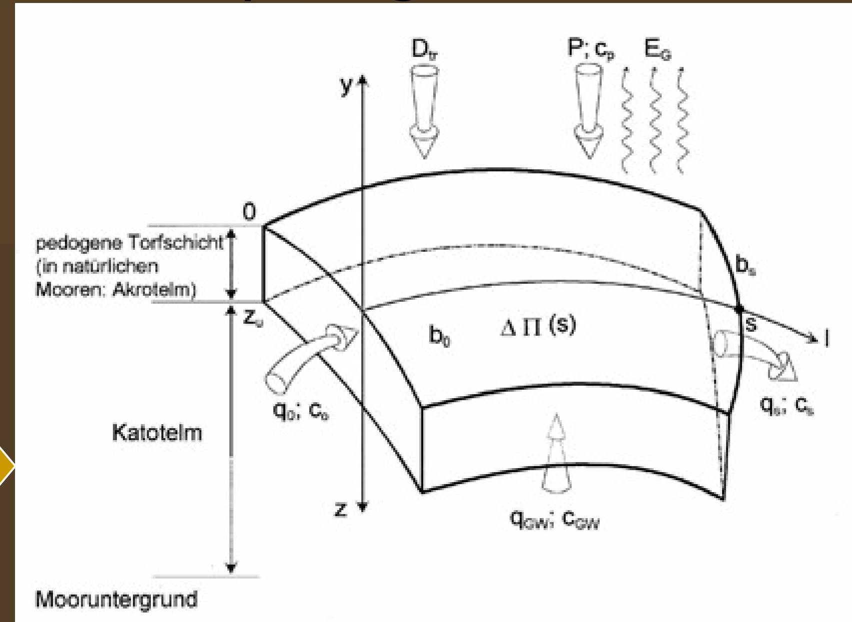


Plan of measures - staggered in space and time



A hydromorphological model of peat-growth





Hydromorphologic equation (akrotelm)

$$\frac{dy}{dl}(s) = \frac{q_0 \cdot b_0 + \int_0^s p_l \cdot b_l \, dl}{b_s \cdot \int_{z_u}^{z_m} k_f(z) \, dz}$$

IVANOV 1975

Element-accumulation in the akrotelm

$$\Pi_M(s) \cdot A_S = \int_0^S \Pi_M(l) b_l \, dl = q_0 \cdot b_0 \cdot c_0$$

$$+ \int_0^S (P \cdot c_P + q_{GW} \cdot c_{GW} + D_{tr} - E_G) \cdot b_l \, dl - q_S \cdot b_S \cdot c_S$$

IVANOV 1988

Combined akrotelm-equation

$$\frac{\Pi_{M-a}(s) \cdot A_S}{c_{S-a}{}^{r} - c_{S-a}} = \frac{dy}{ds} \cdot b_S \cdot \int_{Z_U}^{Z_m} k_f(z) \, dz$$

GOLUBCOV 1993

Combined akrotelm-equation

$$\frac{\Delta\Pi_{M-a}(s)\cdot A_S}{c_{S-a}^{\;r} - c_{S-a}} = \frac{dy}{ds}\cdot b_S \cdot \int_{Z_U}^{Z_m} k_f(z)\,dz$$

- Peat-production in akrotelm

→ element (P,N,C) will be accumulated

→ concentration decreases

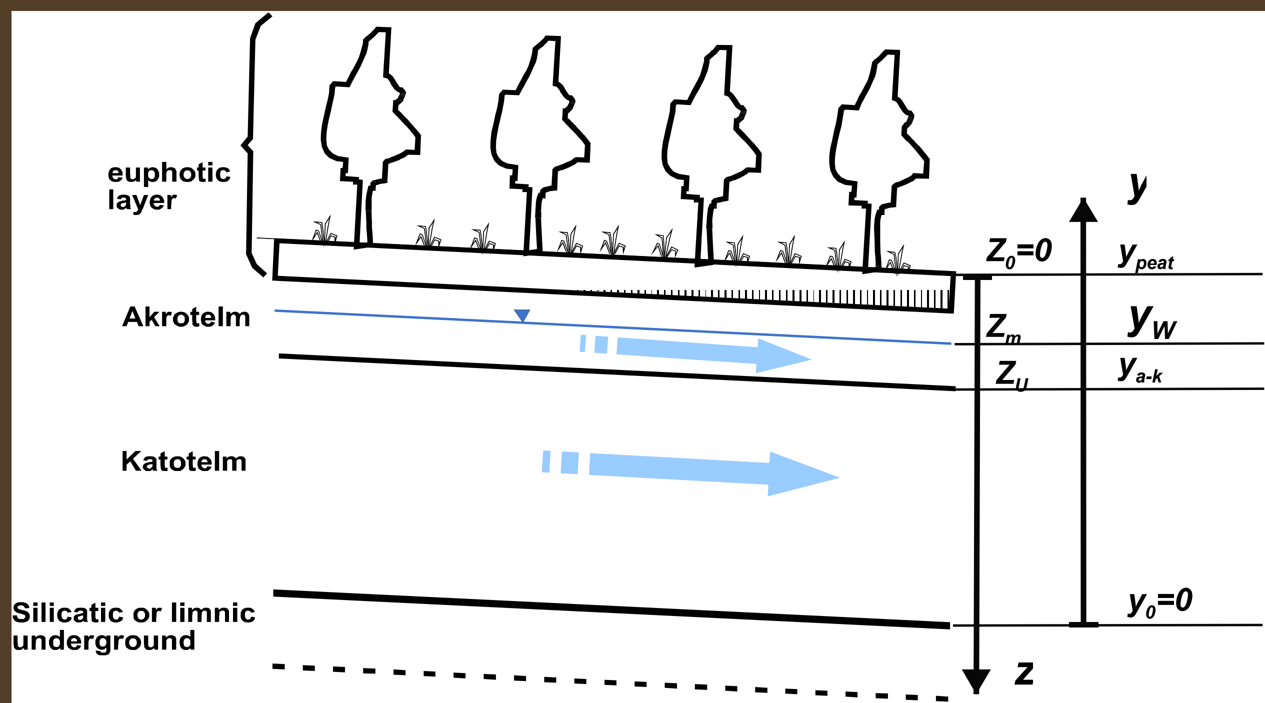
Combined katotelm-equation

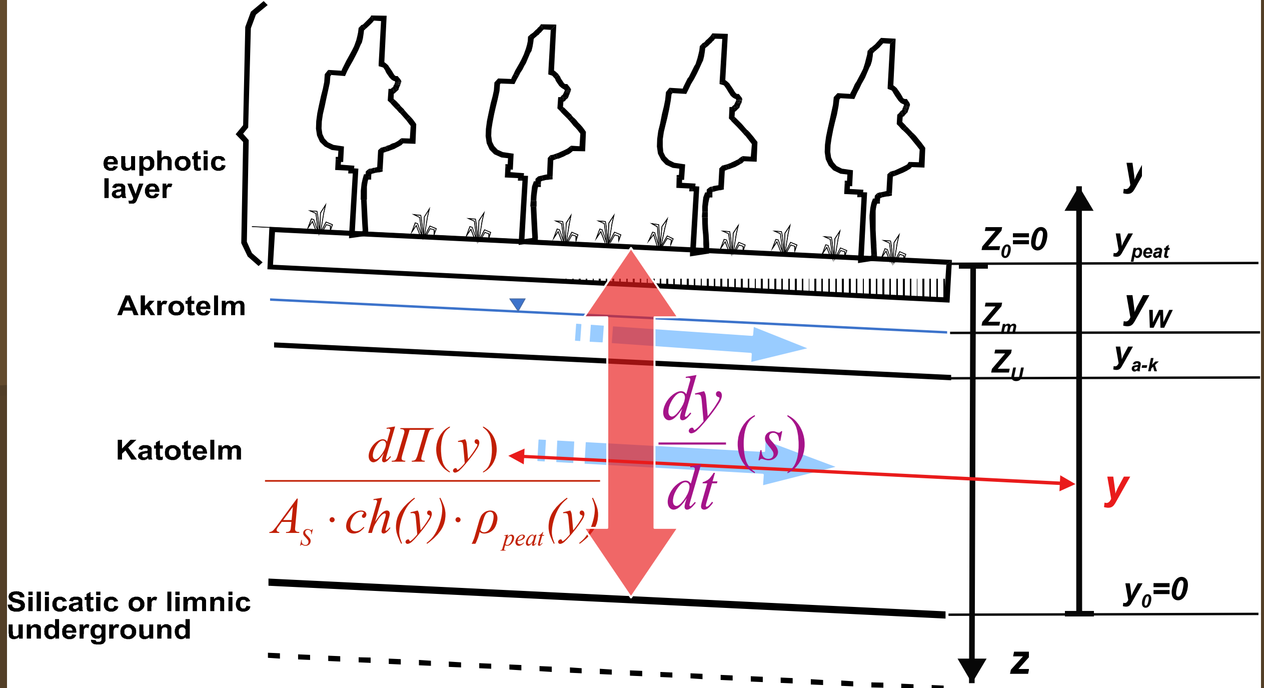
$$-\frac{\Pi_{M-k}(s)\cdot A_S}{c_{S-k} - c_{S-k}^{\;r}} = \frac{dy}{ds}\cdot b_S \cdot \int_{y_0=0}^{y_{a-k}} k_f(y)\,dy$$

- Anaerobic peat-decomposition in katotelm (very slow)

→ element (P,N,C) will be leached

→ concentration increases





Element-balance and mire-growing

$$\Pi_M(s) = ch_M \cdot \frac{dm}{dt} = ch_M \cdot A_S \cdot \rho_{peat-Moor} \cdot \frac{dy}{dt}$$

We get for a small layer at the place y:

$$\frac{dy}{dt}(y) = \frac{d\Pi(y)}{A_S \cdot ch(y) \cdot \rho_{peat}(y)}$$

and as an integral taken over the complete peat-column → the equation of peat-growing in a mire-segment :

$$\frac{dy}{dt}(s) = \frac{1}{y_{peat}} \cdot \int_{y_0=0}^{y_{peat}} \frac{dy(y)}{dt}\, dy = \frac{1}{y_{peat} \cdot A_S} \cdot \int_{y_0=0}^{y_{peat}} \frac{d\Pi(y)}{ch(y) \cdot \rho_{peat}(y)}\, dy$$

EDOM 2005

We divide the integral into akrotelm and katotelm:

$$\frac{dy}{dt}(s) = \frac{1}{y_{peat} \cdot A_S} \cdot \int_{y_0=0}^{y_{peat}} \frac{d\Pi(y)}{ch(y) \cdot \rho_{peat}(y)} dy$$

$$= \frac{1}{y_{peat} \cdot A_S} \cdot \left[\int_{Z=Z_U}^{Z_m} \frac{d\Pi(z)}{ch(z) \cdot \rho_{peat}(z)} dz + \int_{y_0=0}^{y_{a-k}} \frac{d\Pi(y)}{ch(y) \cdot \rho_{peat}(y)} dy \right]$$

If we make for the katotelm some simplifying assumptions:

1) $ch(y) = ch_k = const., \rho_{peat}(y) = \rho_k = const., k_f(y) = k_{f-k} = const.$

(The chemical und physical parameters are constant in all the katotelm of the segment)

The same we make for the akrotelm.

2) $\frac{dy_{a-k}}{dt}(s) \approx \frac{dy}{dt}(s)$ (Peat-growing is first of all katotelm-growing)

we get the CLYMO-equation:

$$\frac{dy_{a-k}}{dt}(s) = p_k - a_k \cdot y_{a-k}$$

CLYMO 1984

with:

$$p_k = \frac{\frac{dy}{dl}(s) \cdot b_s \cdot (c^r_{S-a} - c_{S-a}) \cdot M_Z(s)}{A_S^2 \cdot ch_a \cdot \rho_a}$$

EDOM 2005

and:

$$a_k = \frac{\frac{dy}{dl}(s) \cdot b_s \cdot (c_{S-k} - c^r_{S-k}) \cdot k_{f-k}}{A_S^2 \cdot ch_k \cdot \rho_k}$$

Common hydromorphological equation of peat growing (heigth) with distributed parameters (EDOM 2005):

$$\frac{dy}{dt}(s) = \frac{1}{y_{peat} \cdot A_S} \cdot \left[\int_{Z=Z_U}^{Z_m} \frac{d\Pi(z)}{ch(z) \cdot \rho_{peat}(z)} dz + \int_{y_0=0}^{y_{a-k}} \frac{d\Pi(y)}{ch(y) \cdot \rho_{peat}(y)} dy \right]$$

Assumptions and simplifications:

Conceptual-equation of CLYMO (1984):

$$\frac{dy_{a-k}}{dt}(s) = p_k - a_k \cdot y_{a-k}$$

With detailed chemical, physical and morphological parameters, which can be measured:

$$p_k = \frac{\frac{dy}{dl}(s) \cdot b_S \cdot (c^r_{S-a} - c_{S-a}) \cdot M_Z(s)}{A_S^2 \cdot ch_a \cdot \rho_a}$$

$$a_k = \frac{\frac{dy}{dl}(s) \cdot b_S \cdot (c_{S-k} - c^r_{S-k}) \cdot k_{f-k}}{A_S^2 \cdot ch_k \cdot \rho_k}$$

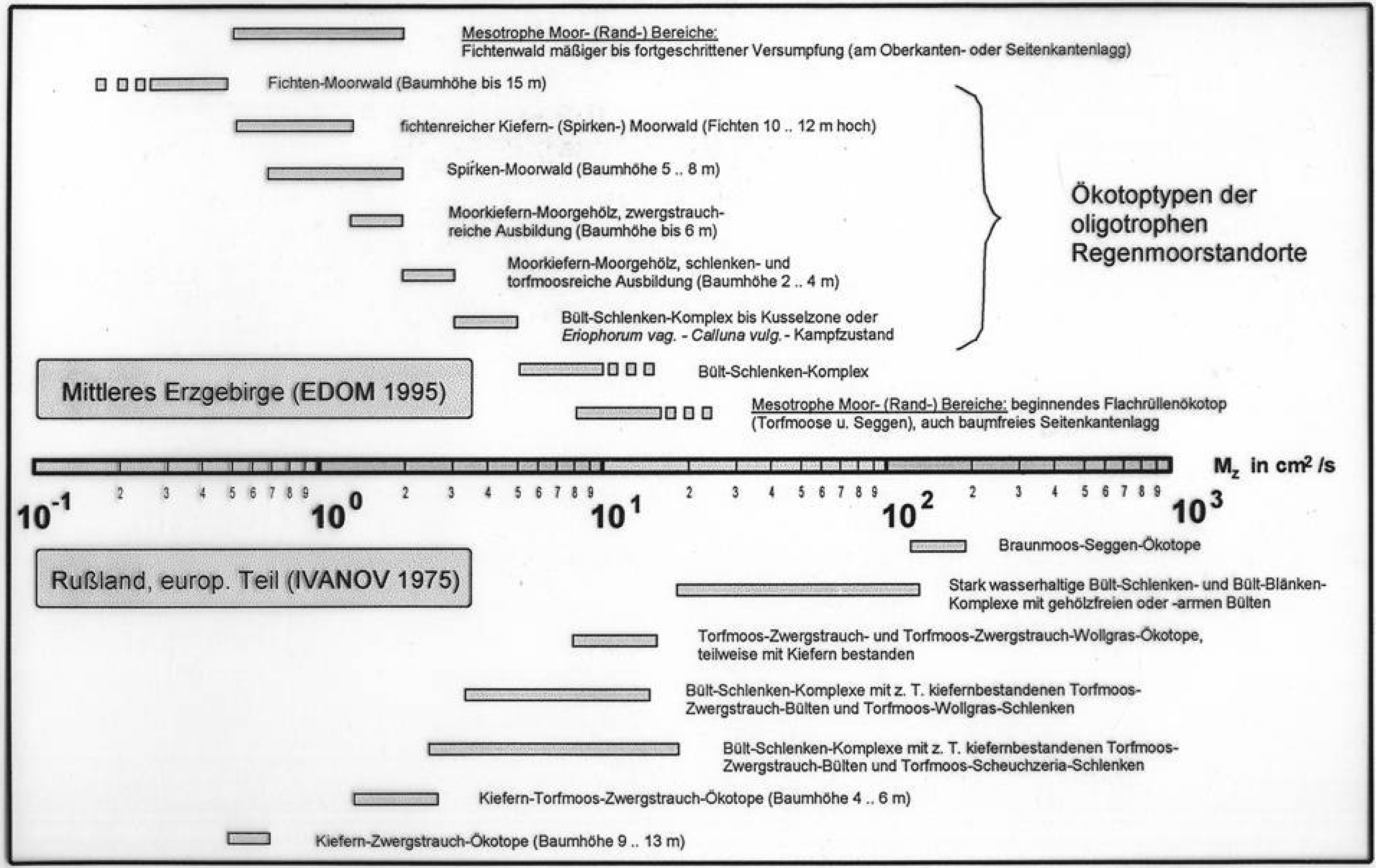
Hydromorphological theory (HT), summary and outlook

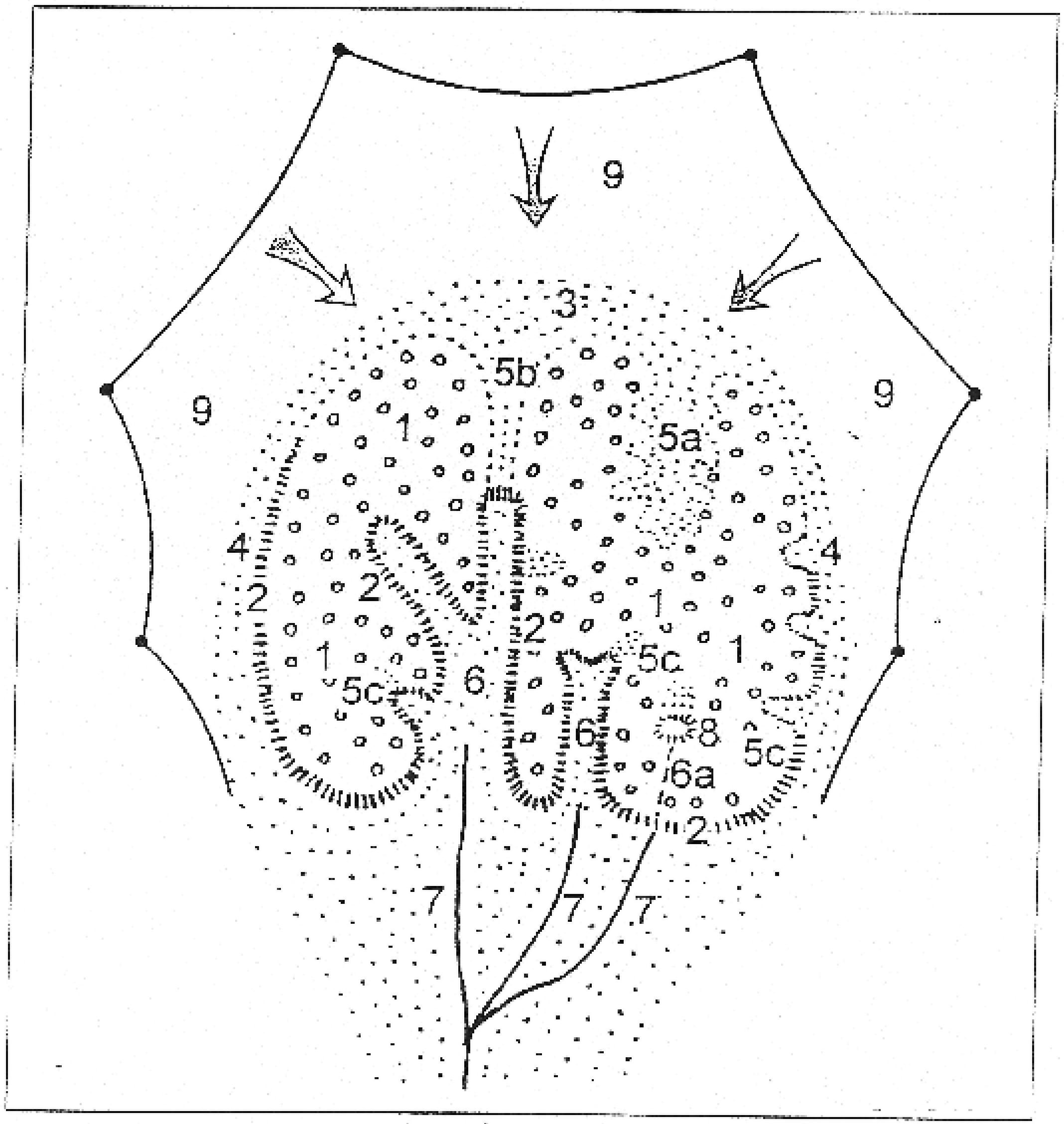
- The HT can explain morphologic mire-structures and zoning of ecotops causally.
- These can be modelled and predicted for growing mires and mires to be regenerated.
- The influence of climatic change and of changing of land-use in catchments can be modelled.
- The HT is a useful tool for mire-restauration-planning.
- The HT can explain peat-grow-processes using distributed parameters.
- Old West-European models (INGRAM, SCHNEEBELI, CLYMO) are a very simplified special case of the HT.
- We need more research on parameters for different types of mires in different biogeographic regions. The research must more be focussed on akrotelm-conditions. The research must better combine hydrologic and hydro-bio-geo-chemical with geobotanical characteristics.

For a better understanding of hydromorphological successions in space and in time!

Thank you for your attention!

Zuordnung der Durchlässigkeitsparameter zu den Ökotoptypen

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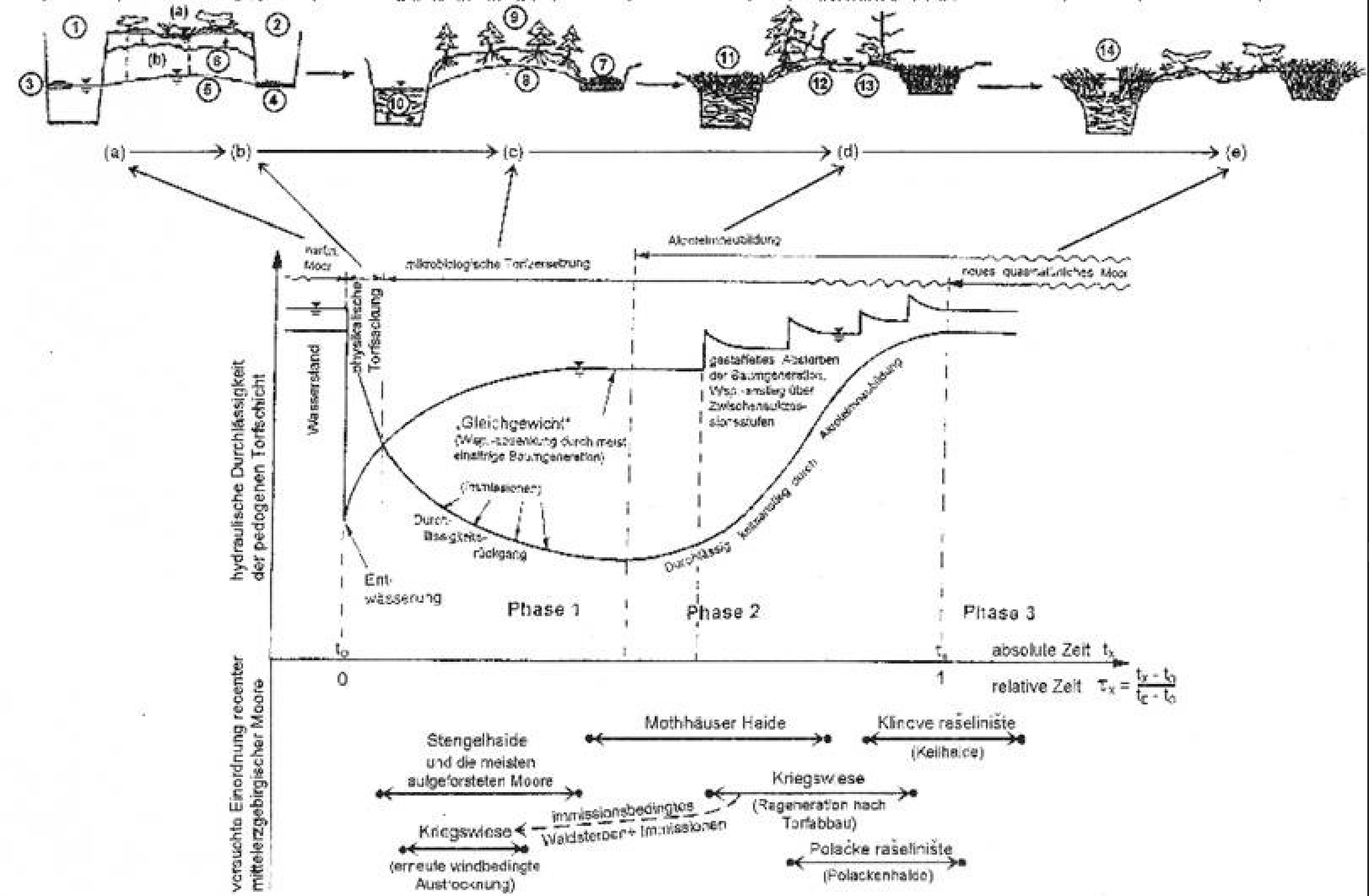
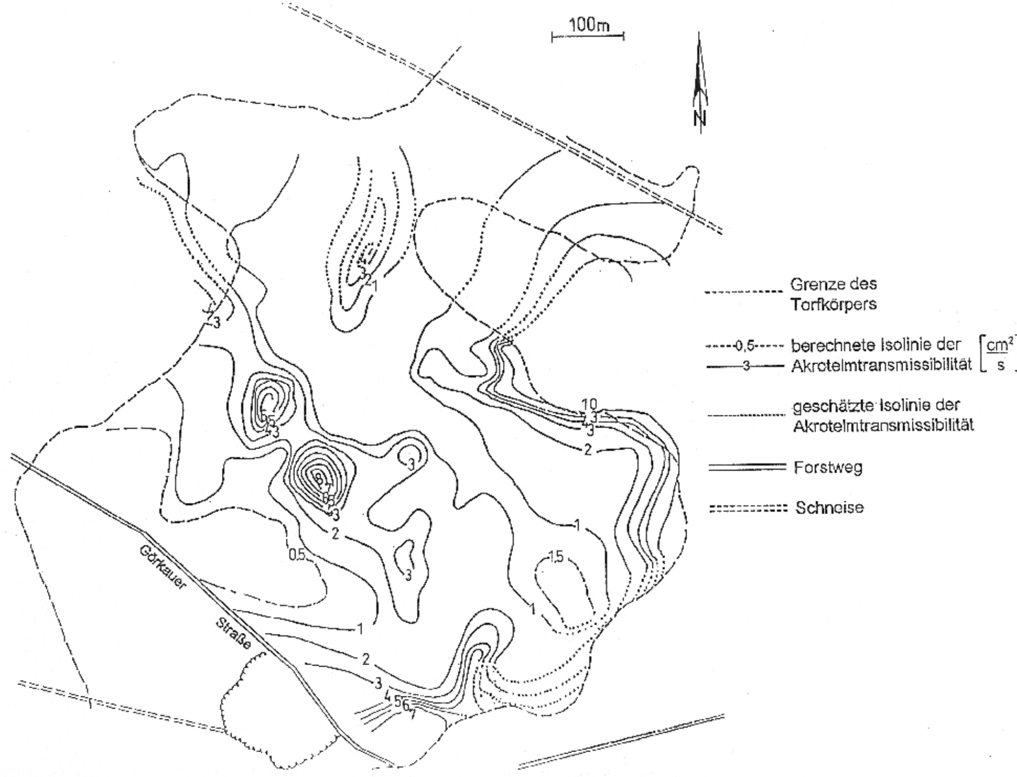
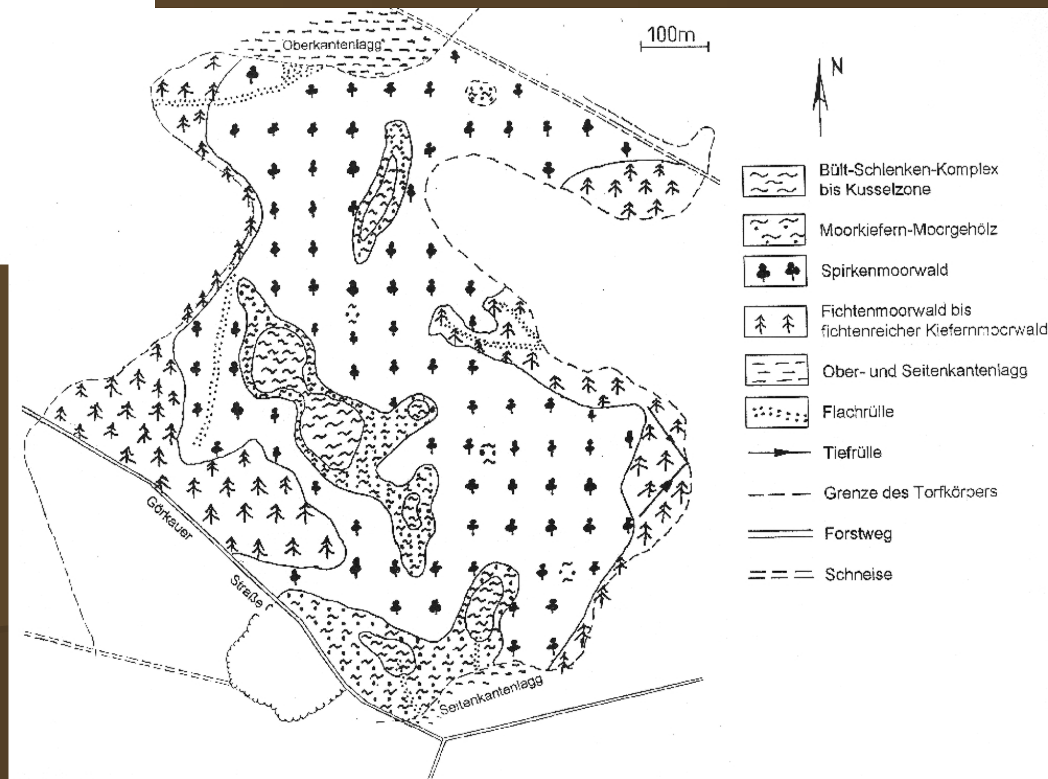


EDOM & WENDEL 1998, EDOM 2001



Developing (prognostic) **zoning of ecotopes**



Zoning of **potential (akrotelm-) transmissivity** for the mountain-bog "Mothhäuser Haide" (Erzgebirge, Krušne hory)

(GOLUBCOV & EDOM 1993)