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„The Interaction between Surface Water and Groundwater”
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A long-term river flow data as the base of the catchment groundwater resources evaluation

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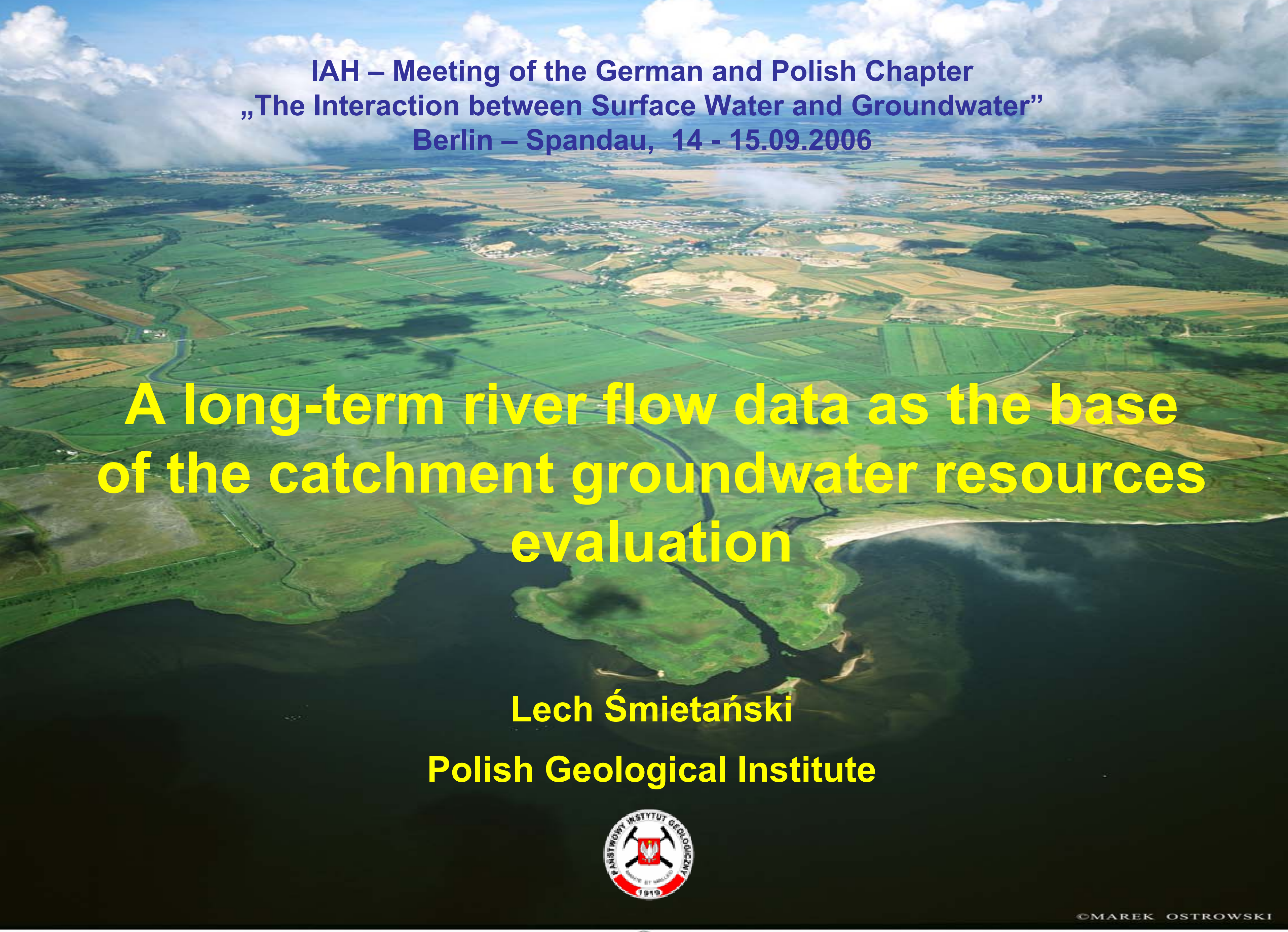

PRADOLINA REDY-ŁEBY
powstała w plejstocenie przez wody spływające z topniejącego lodowca

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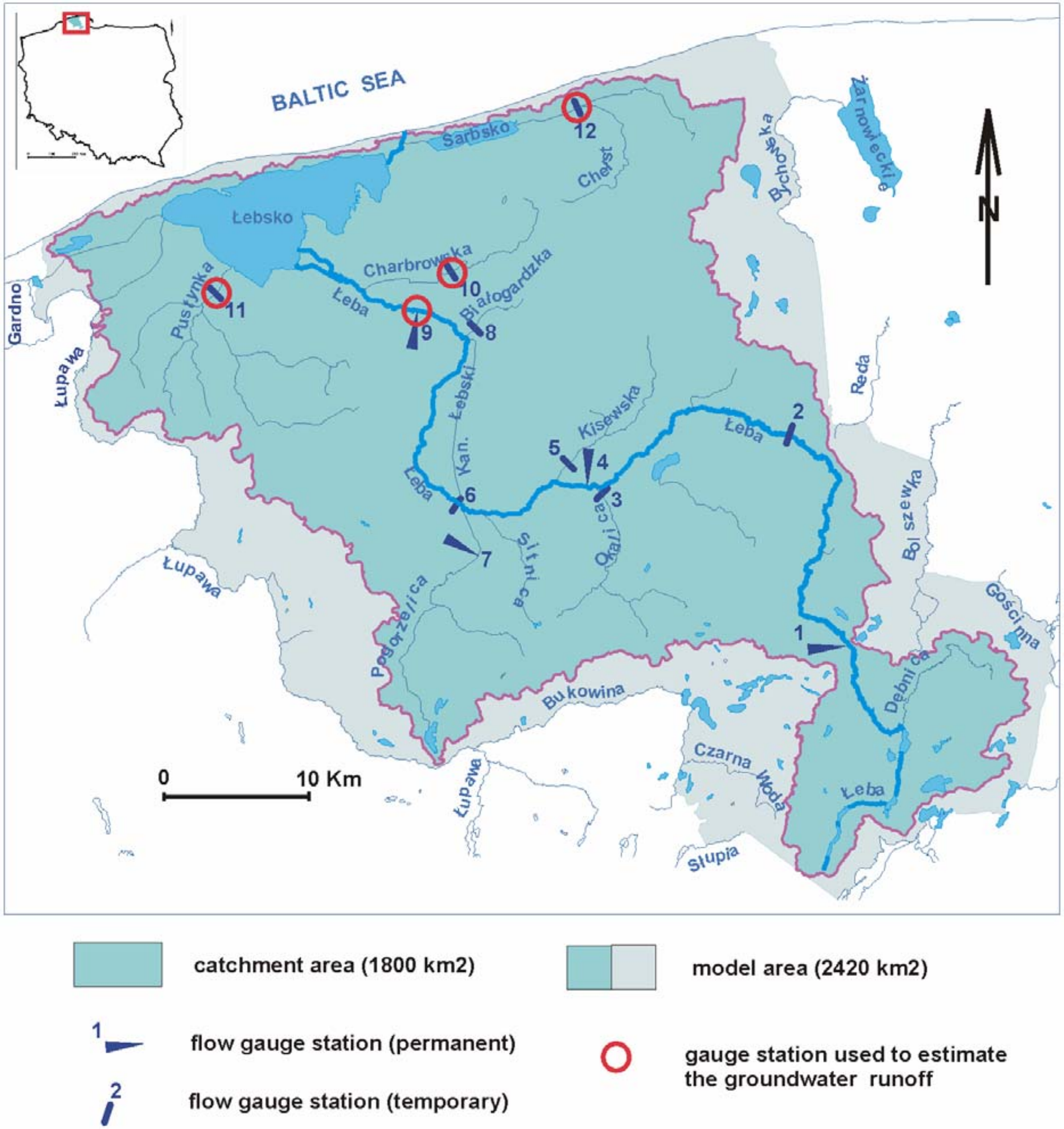
REDA-ŁEBA ICE-MARGINAL VALLEY
carved in the Quarternary by meltwaters from the Pleistocene ice-sheet

THE MAIN GOAL

To calculate the magnitude and distribution of the disposable groundwater resources in Cenozoic productive aquifers in the Łeba river catchment (N Poland).

Location of the investigated catchment



The characteristic flows Q [m^3/s] at gauge stations used to estimate the groundwater runoff from the catchment area. (period 1966 – 1995)

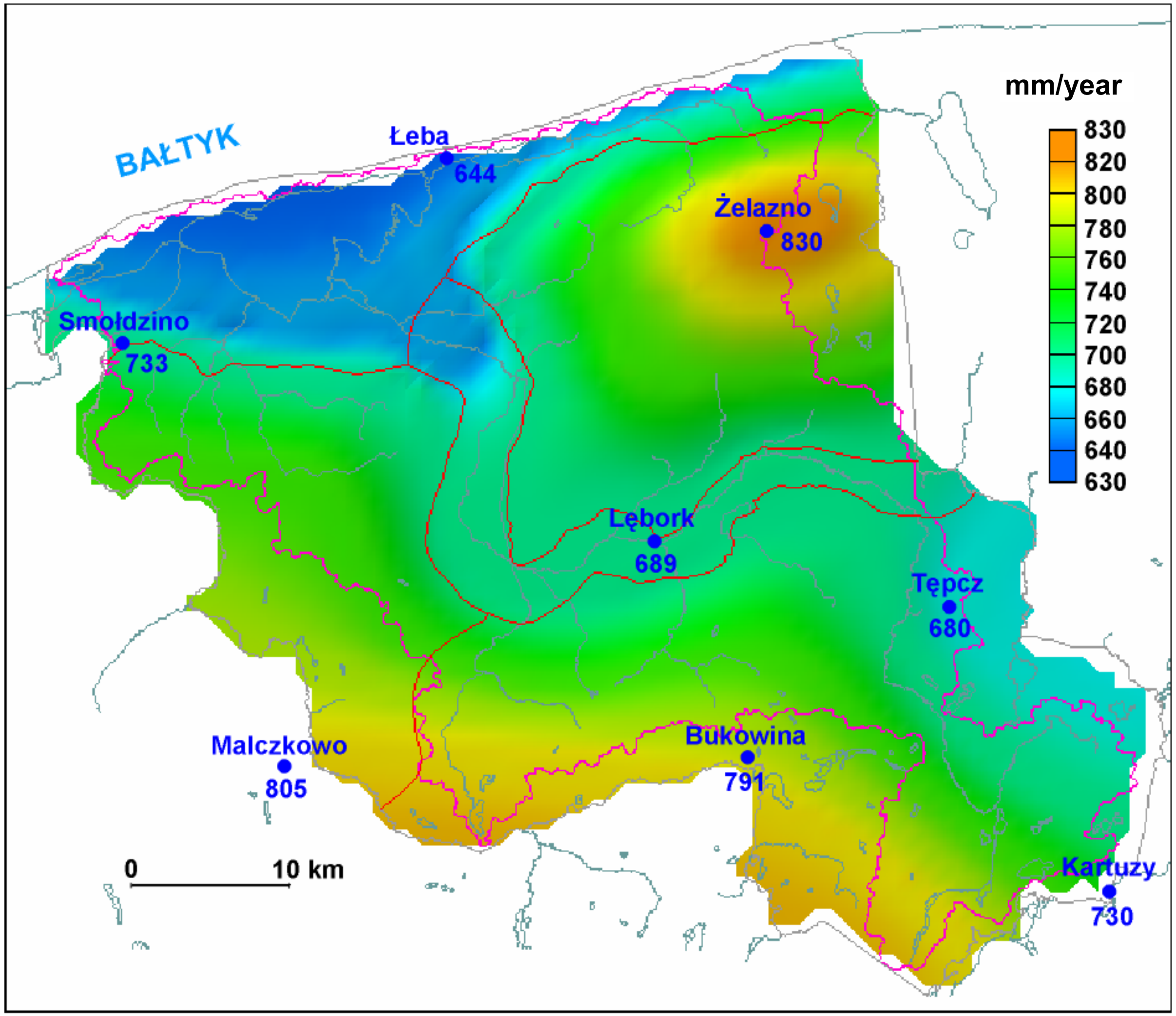
Gauge station nr	River	Gauge station	HHQ	MHQ	MMQ	MLQ	LLQ	Q_b
9	ŁEBA	CECENOWO	45,9	29,5	11,6	6,29	4,33	4,75
10	CHARBROWSKA STRUGA	CHARBROWO	1,41	0,84	0,35	0,17	0,14	0,14
11	PUSTYNKA	KLUKI	17,5	7,79	1,52	0,62	0,54	0,55
12	CHEŁST	OSETNIK	3,07	1,96	0,75	0,40	0,27	0,27

HHQ – highest flow, **MHQ** – mean high flow, **MMQ** – mean flow

MLQ – mean low flow, **LLQ** – lowest flow, **Q_b** – base flow

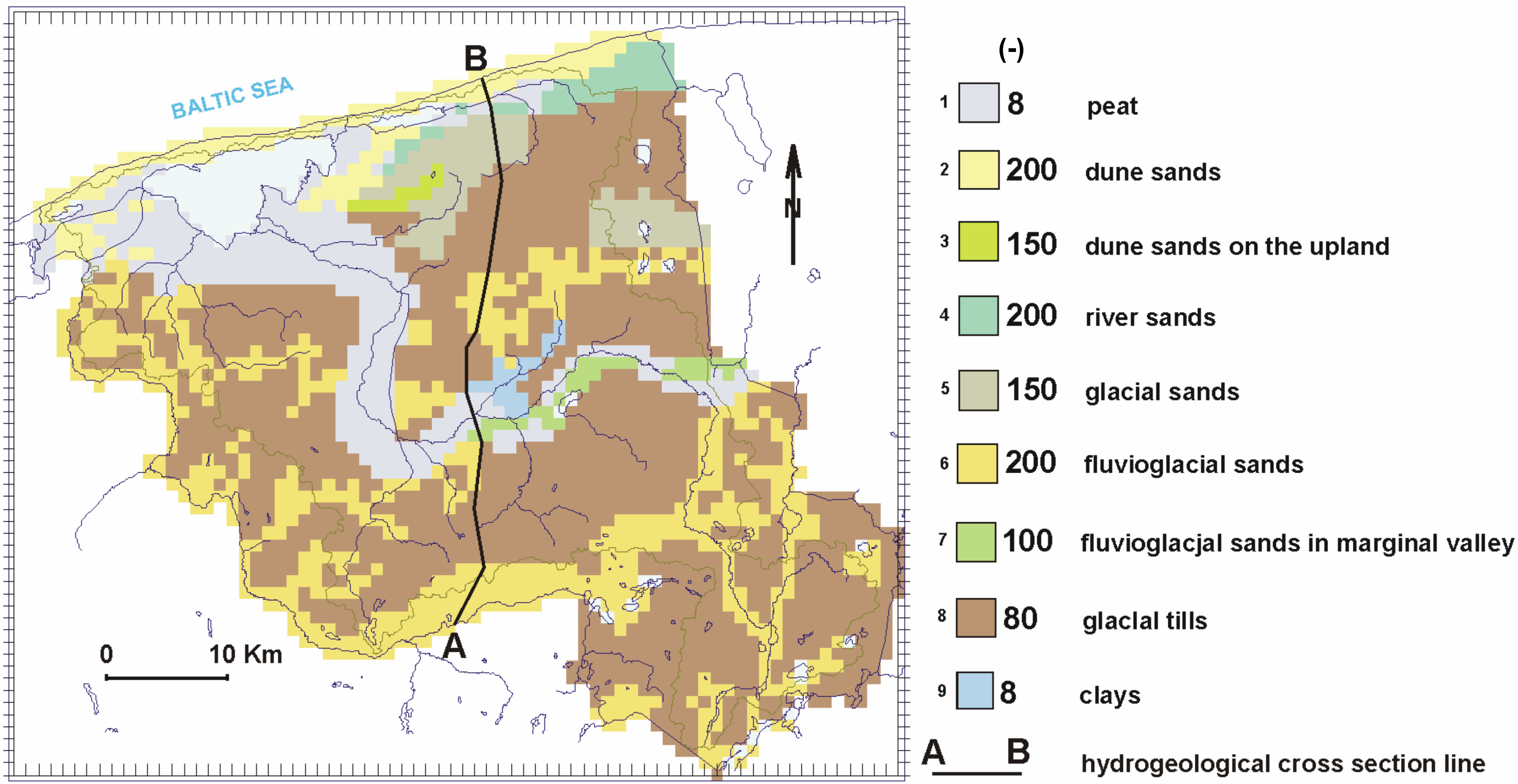
Kuroś L. (1999)

Distribution of the long-term yearly mean precipitation P. (period 1966 – 1995)

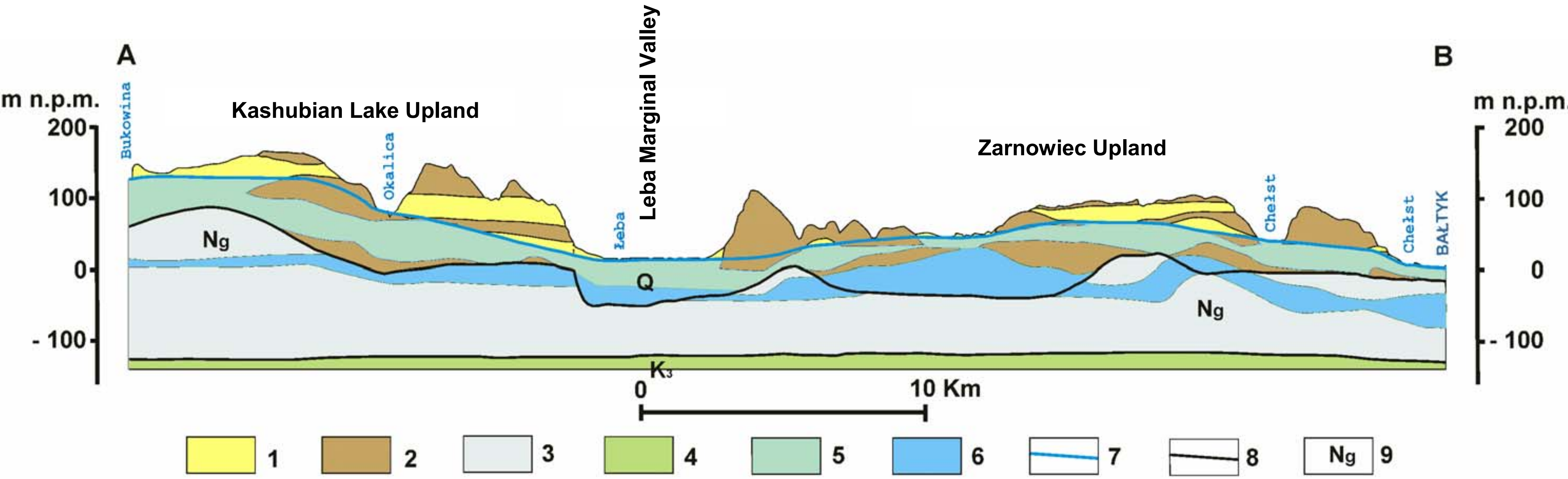


Infiltration weights W_{inf} assigned to surface soil types

(soils after the Geological Map of Poland 1:200 000, simplified)



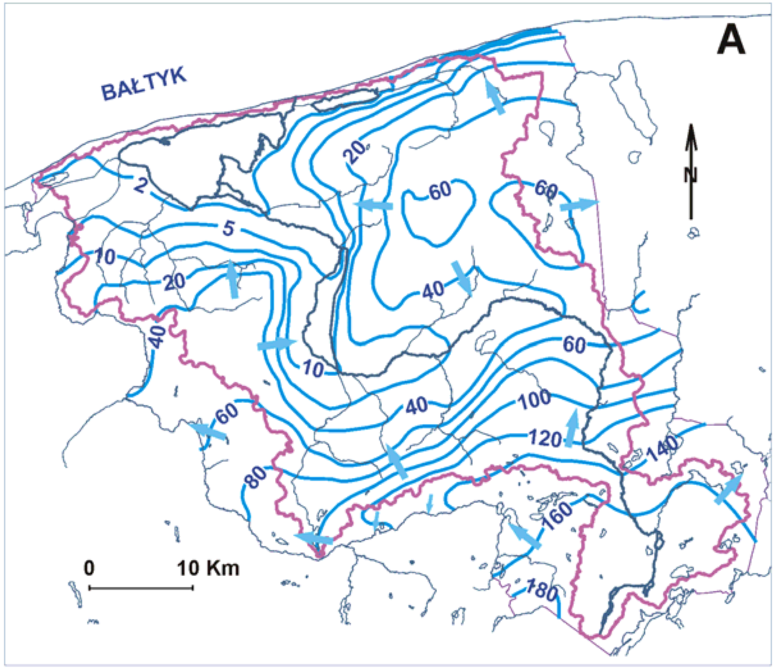
Hydrogeological section A- B
showing the upper and lower model layer

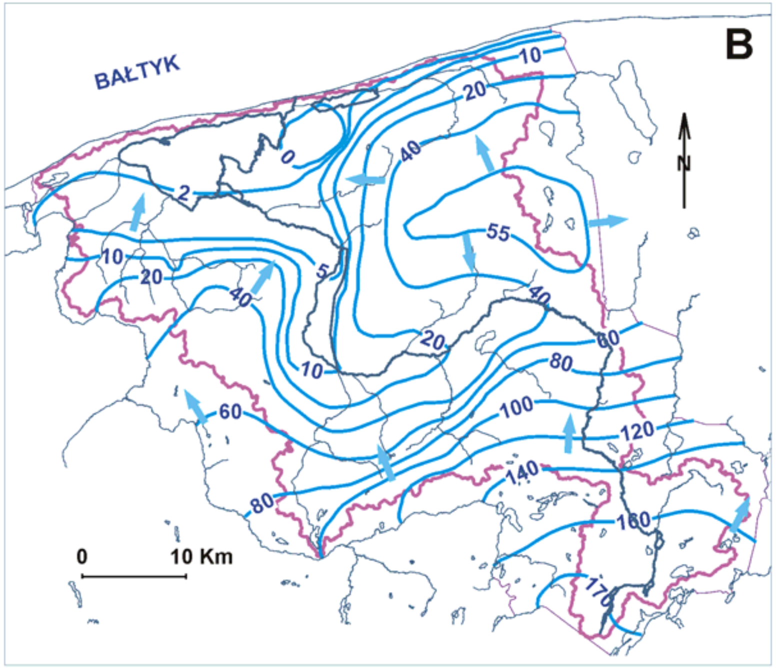


1 – sands (Q)
2 – glacial tills (Q)
3 – silts, silty sands, clays (N_g)
4 – sands, limestones, clays, siltstones (K3)
5 – upper model layer
6 – lower model layer
7 – piezometric level of the productive Cenozoic system
8 – stratigraphic boundary
9 – stratigraphic symbol

Kwaterkiewicz A., Śmietański L. (2001)

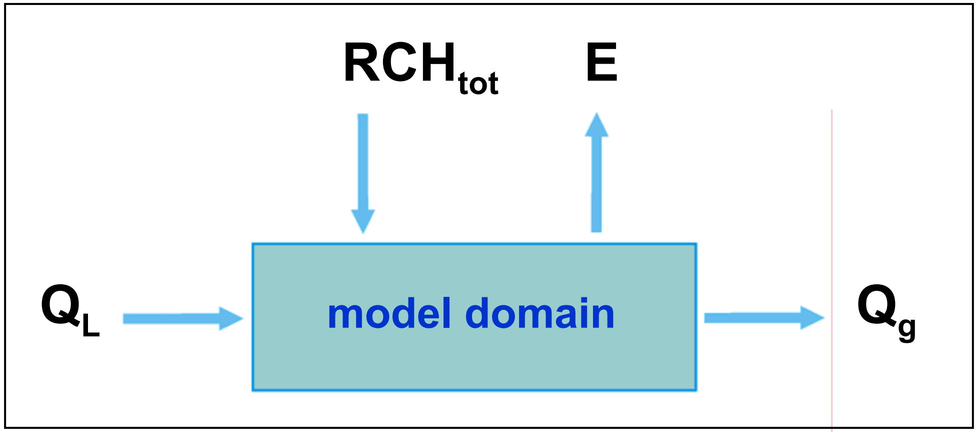
Piezometric surfaces H_{intrp} interpretated on the base of field measurements. Upper (A) and lower (B) model layer.





Kwaterkiewicz A., Śmietański L. (2001)

Assessment of the recharge RCH_g generating the groundwater runoff Q_g



RCH_{tot} – total recharge

Q_L - lateral inflow

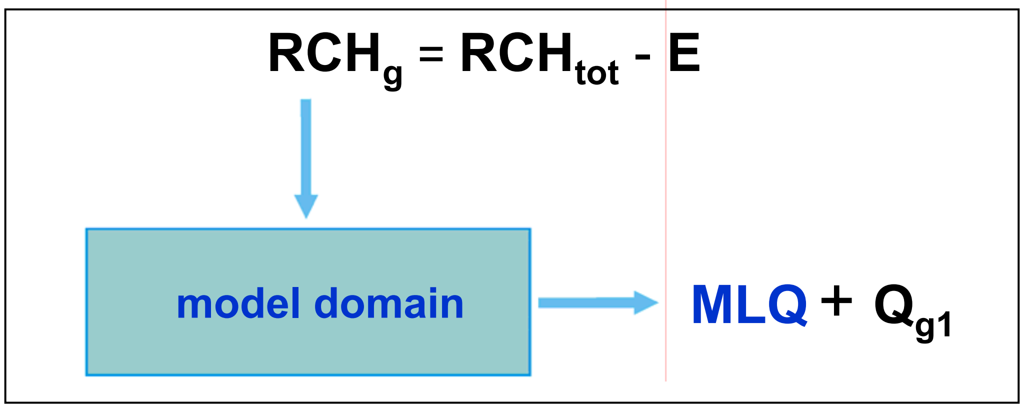
E - evaporation in drainage zones

MLQ - sum of mean low flows at the gauge stations nr 9,10,11,12

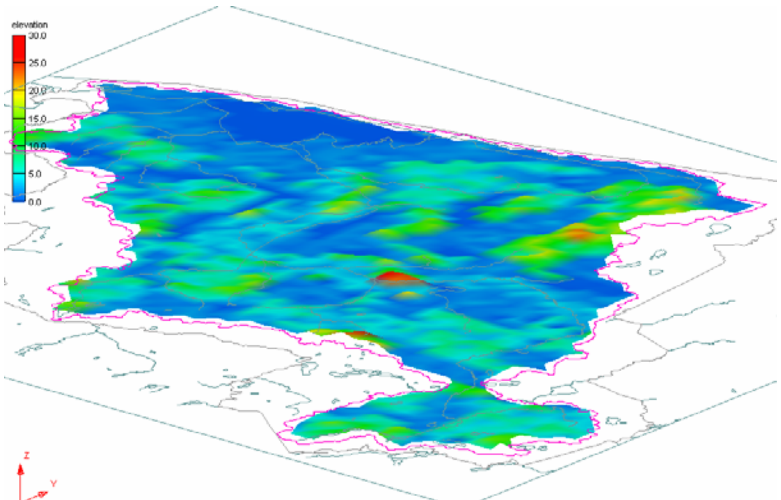
Q_{g1} - GW runoff from the part of the study area outside the gauge stations 9,10,11,12

$$\{ RCH_{tot} - E = RCH_g \; ; \; \boxed{Q_L \ll RCH_g} \} \rightarrow RCH_g = Q_g$$

$$\{ Q_g = MLQ + Q_{g1} \} \rightarrow RCH_g = MLQ + Q_{g1}$$

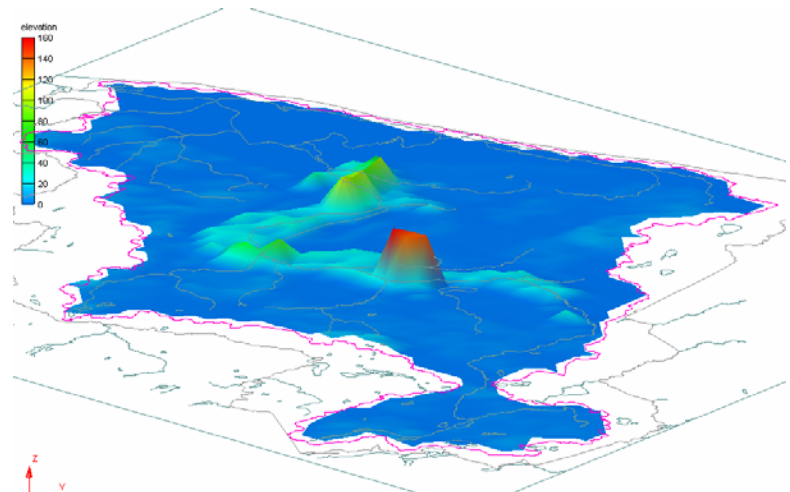


Constant-Volume Transformation



Surface M

T



Surface H

$$H(x,y) = T * M(x,y)$$

$$\int_{\Omega} M(x,y) = \int_{\Omega} H(x,y) = V$$

The Constant – Volume Transformation (CVT):

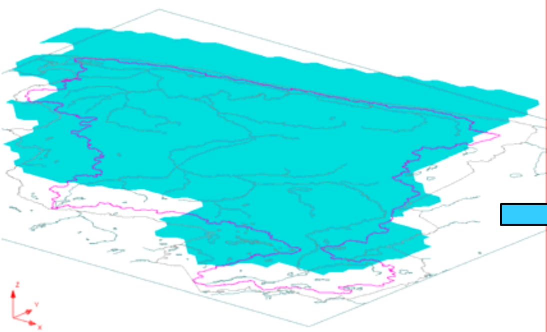
$$T = \frac{F(x,y) * \int_{\Omega} M(x,y)}{\int_{\Omega} (F(x,y) * M(x,y))}$$

$F(x,y)$ – the CVT control

$$F(x,y) = \prod_{i=1}^{N} W_i(x,y)$$

$W_i(x,y)$ - weight functions

The estimation of the recharge distribution $RCH_g(x,y)$ generating the groundwater runoff Q_g

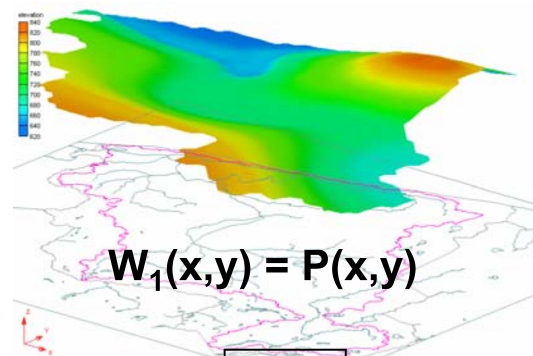


Surface M

$M(x,y) = q_g$

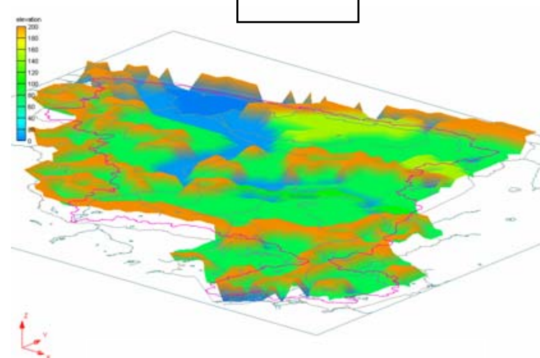
$$q_g = \frac{Q_g}{Area\_of\_the\_model\_domain}$$

q_g = 123 mm/year

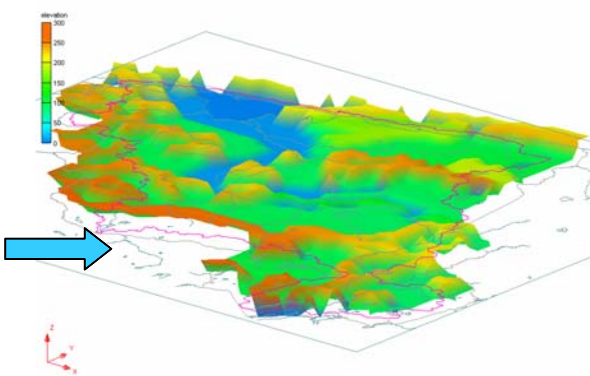


$W_1(x,y) = P(x,y)$

T



$W_2(x,y) = W_{inf}(x,y)$

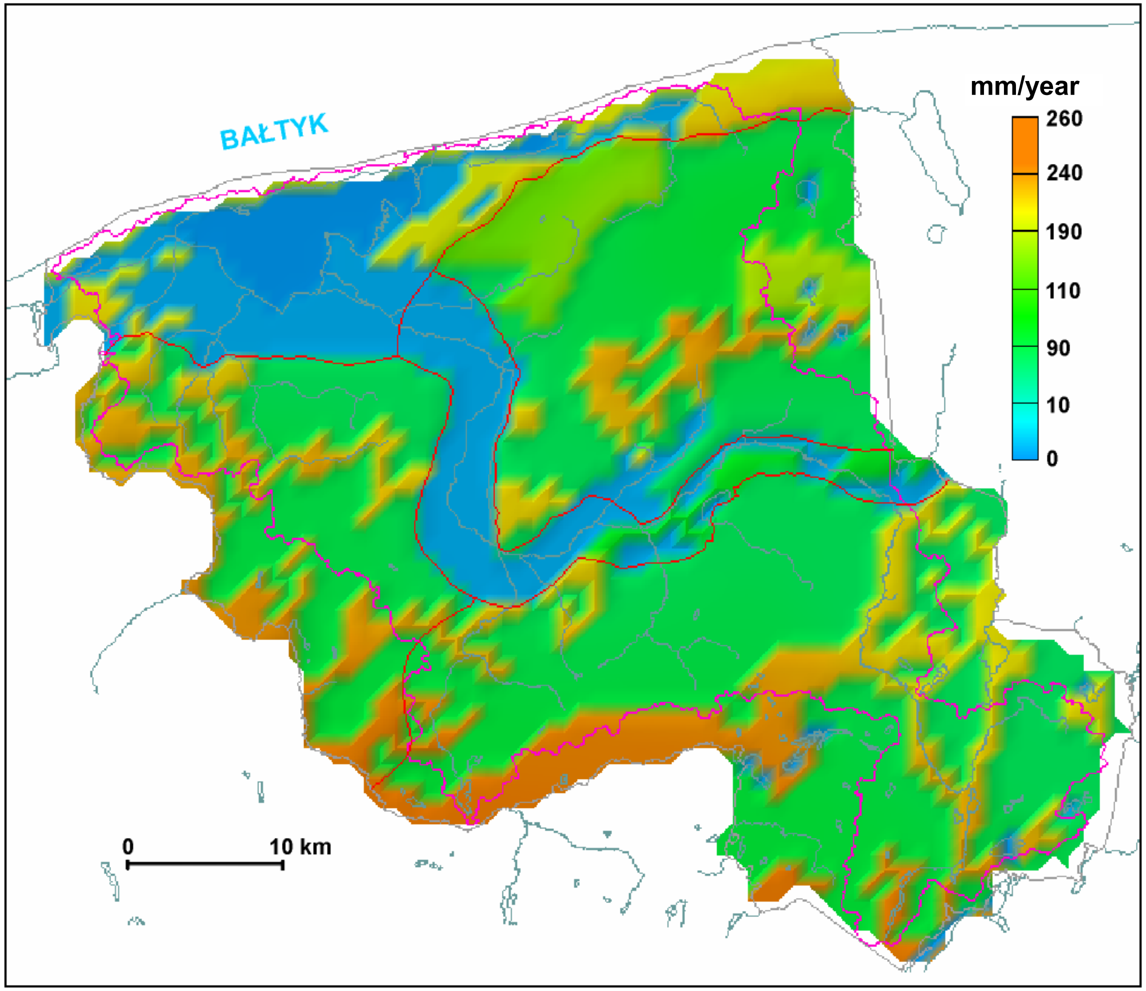


Surface H

$H(x,y) = RCH_g(x,y)$

The CVT control $F(x,y) = W_1(x,y) * W_2(x,y) = P(x,y) * W_{inf}(x,y)$

The distribution of the recharge RCH_g over the studied area with the recharge index $RI = q_g = 123$ mm/year $RCH_g = 9{,}5\ m^3/s\ (34000\ m^3/h)$

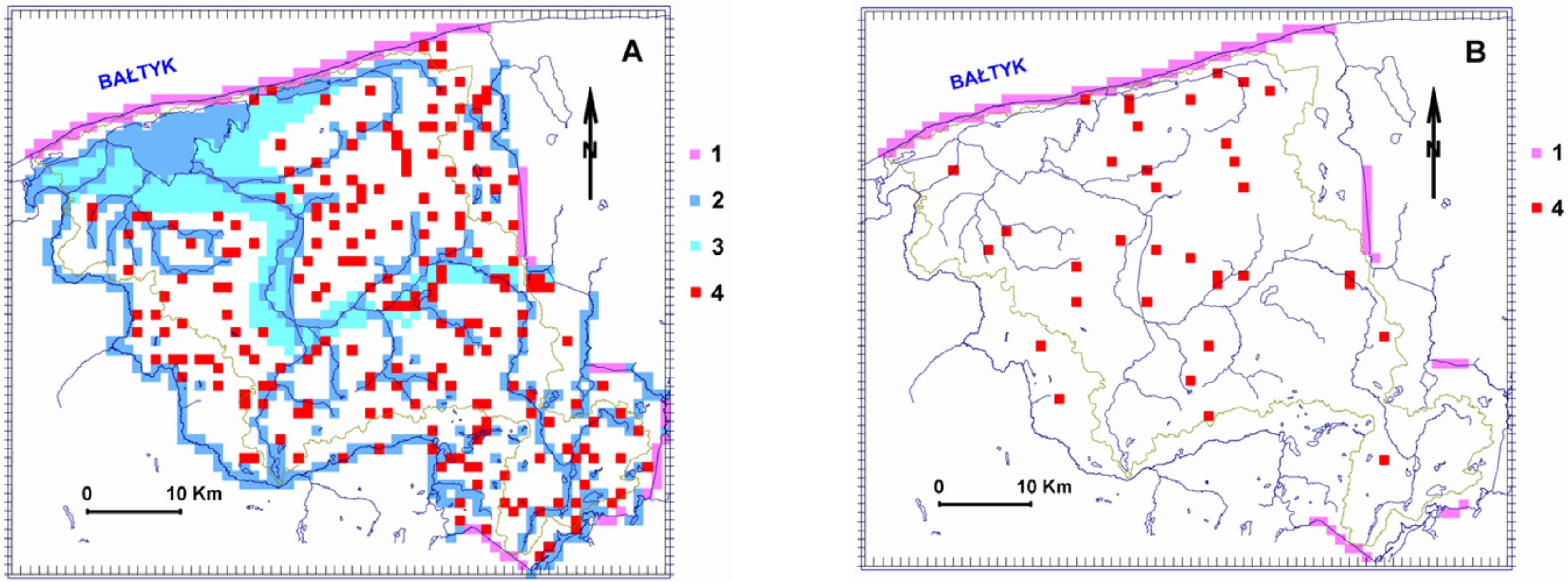


For the catchment area:

$RCH_{catch} = 6{,}0\ m^3/s$ (21 700 m^3/h)

$RI_{catch} = 106$ mm/year (12 $m^3/h \cdot km^2$)

Boundary conditions. (A) – upper layer, (B) lower layer.



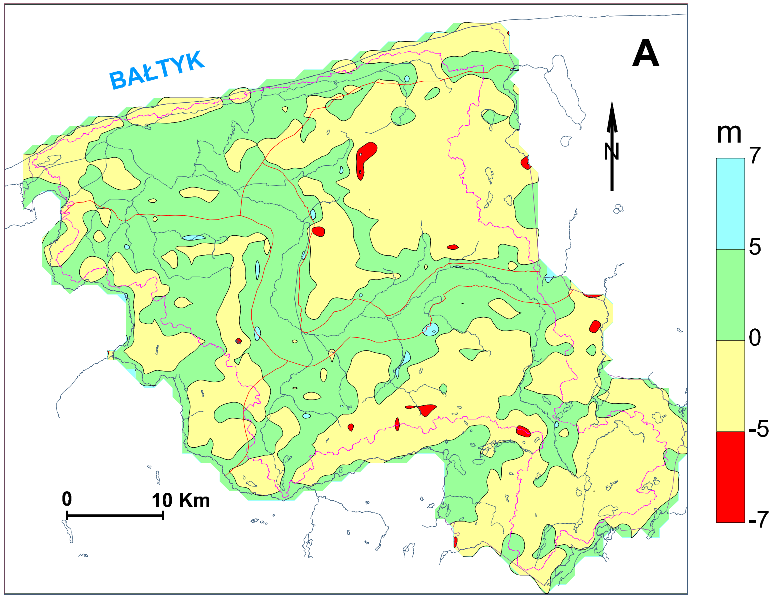
1 – Dirichlet BC

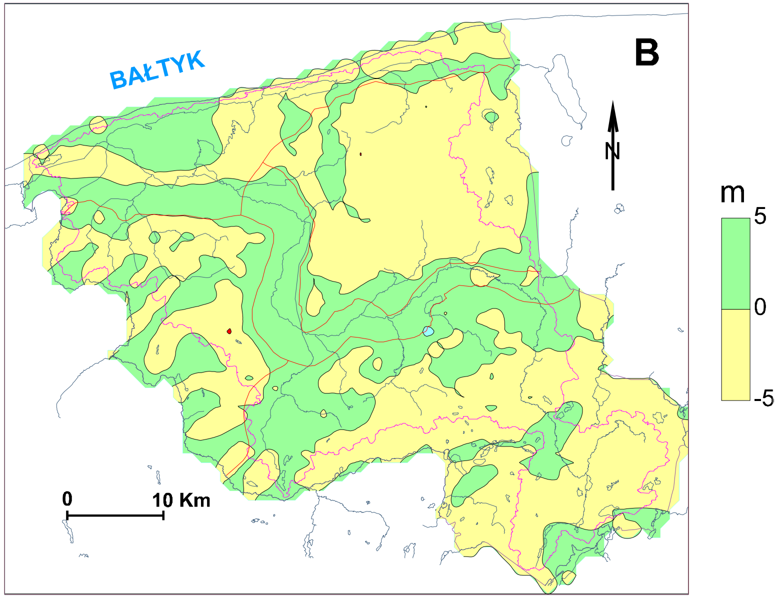
2 – Cauchy BC

3 – Cauchy BC

4 – Neuman BC

The difference maps $H_{intrp} - H_{cal}$ for the upper (A) and lower (B) model layer after the calibration





The estimation of the Disposable Groundwater Resources in the Łeba river catchment (1)

The magnitute of the Disposable GroundWater Resources (DGWR) in the Cenozoic productive aquifers in the Łeba catchment is a certain fraction of the recharge RCH_{catch} from the precipitation within this catchment area:

$$\mathbf{DGWR = C * RCH_{catch} = C * 21700}\ m^3/h$$

$$\mathbf{0 \leq C \leq 1}$$

The estimetion of the Disposable Groundwater Resources in the Łeba river catchment (2)

The Disposable Groundwater Resources it is a sum of the existing GW exploitation Q_{EXPL} and the reserve RSV_{DGWR}.

The RSV_{DGWR} is a fraction of the $RECH_{catch}$.

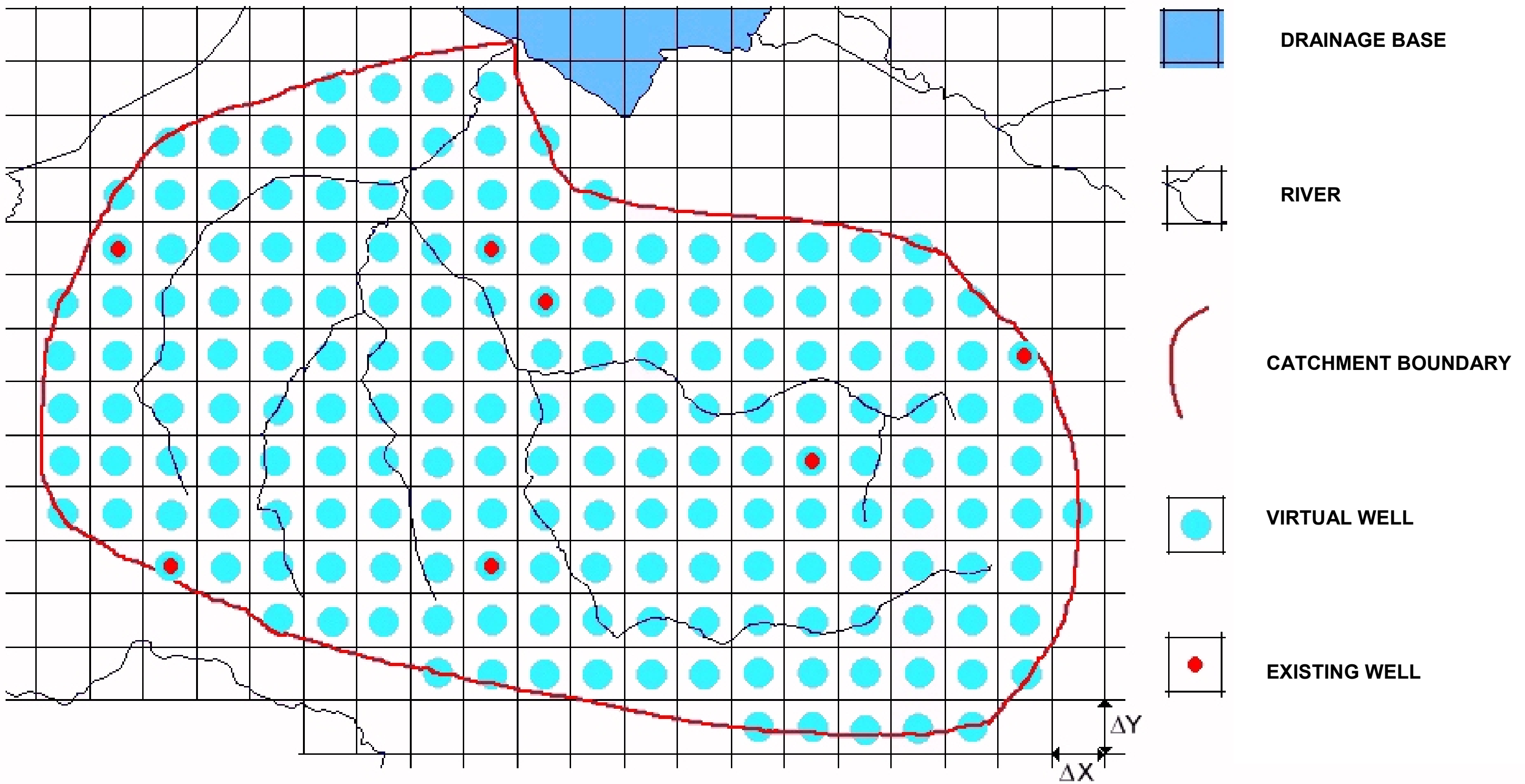
$$RECH_{catch} = 21\ 700\ m^3/h.$$

$$DGWR = Q_{EXPL} + RSV_{DGWR} = Q_{EXPL} + C_{RSV} * 21\ 700\ m^3/h$$

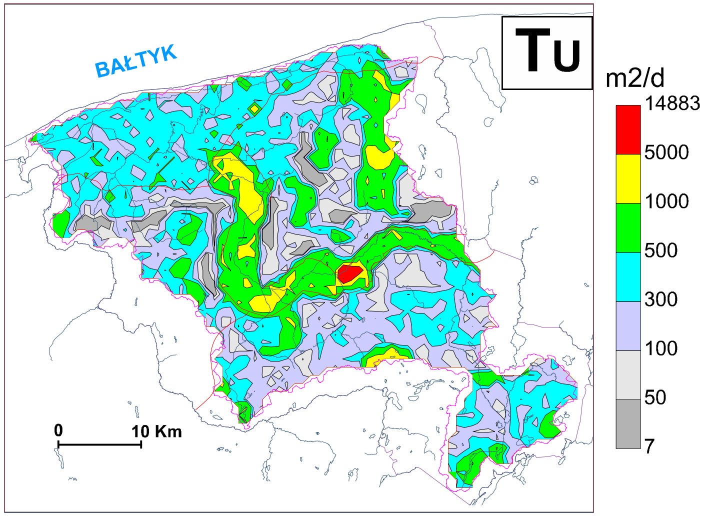
$$0 \leq C_{RSV} \leq 1$$

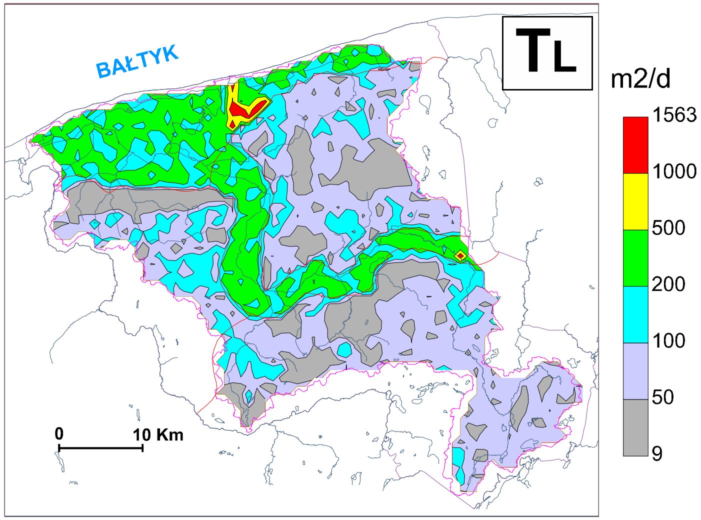
The concept of the reserve RSV_{DGWR} of the Disposable Groundwater Resources

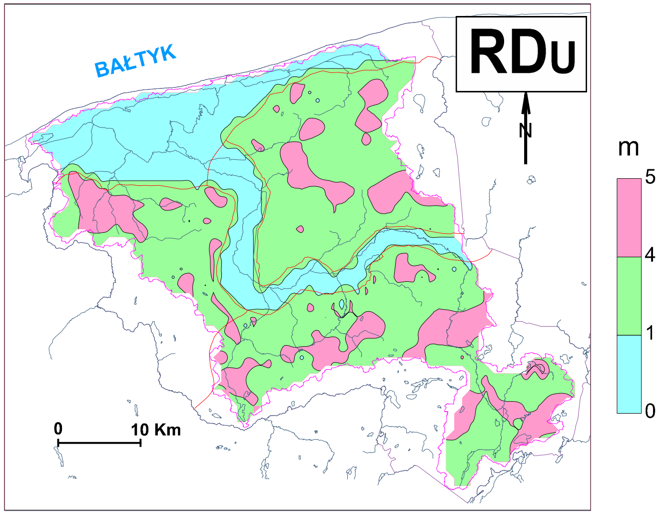
Virtual wells in the regular grid within the catchment area
(J. Szymanko, 1980)

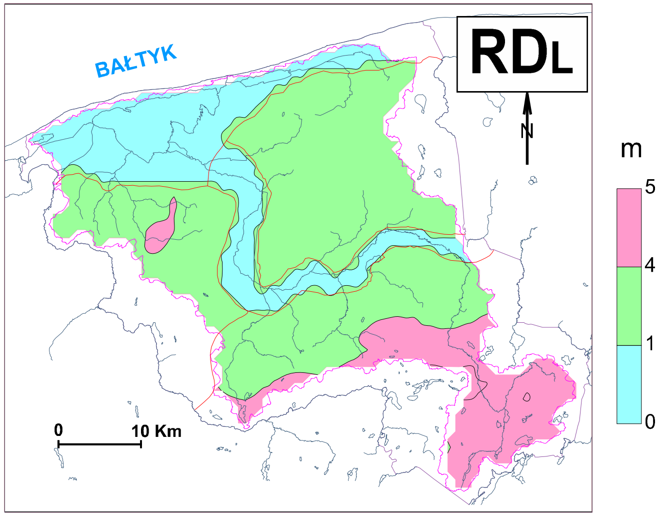


The weight functions T_U, T_L, RD_U, RD_L

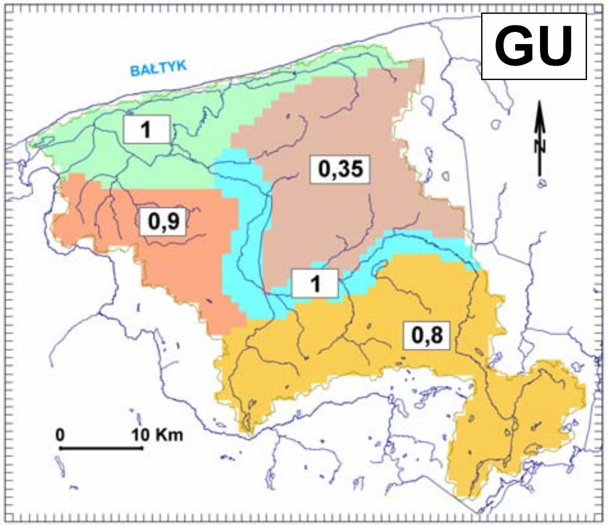


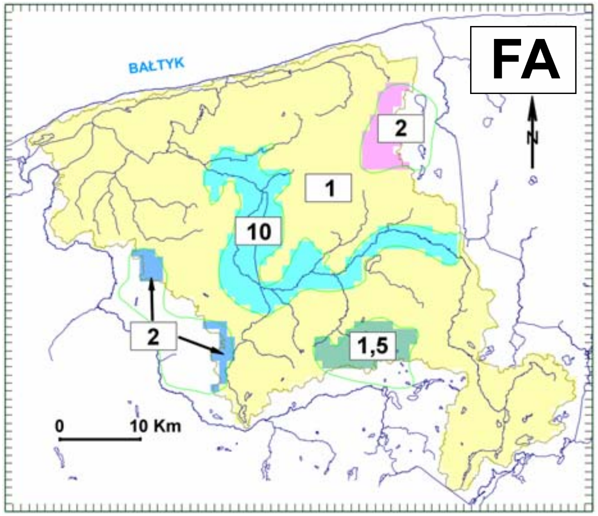


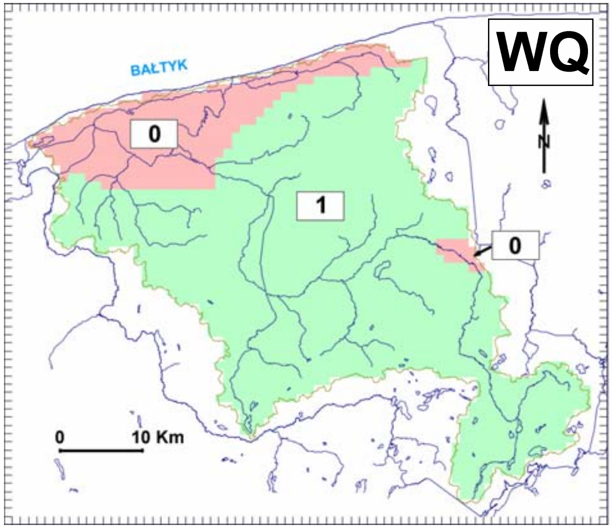




The weight functions GU, FA, WQ defined to calculate the ultimate AGWR distribution in the catchment

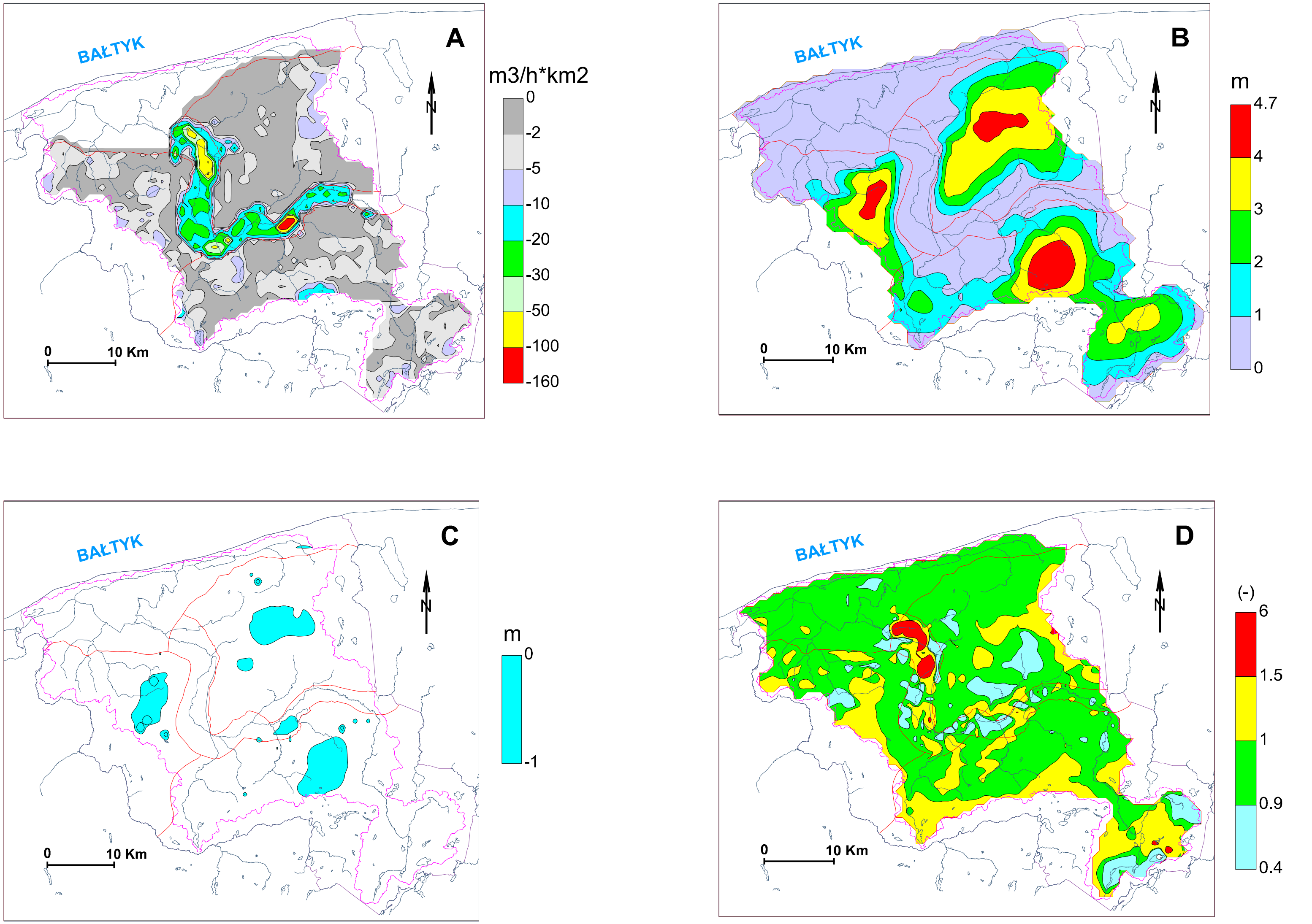






The DGWR reserve calculated for the upper model layer

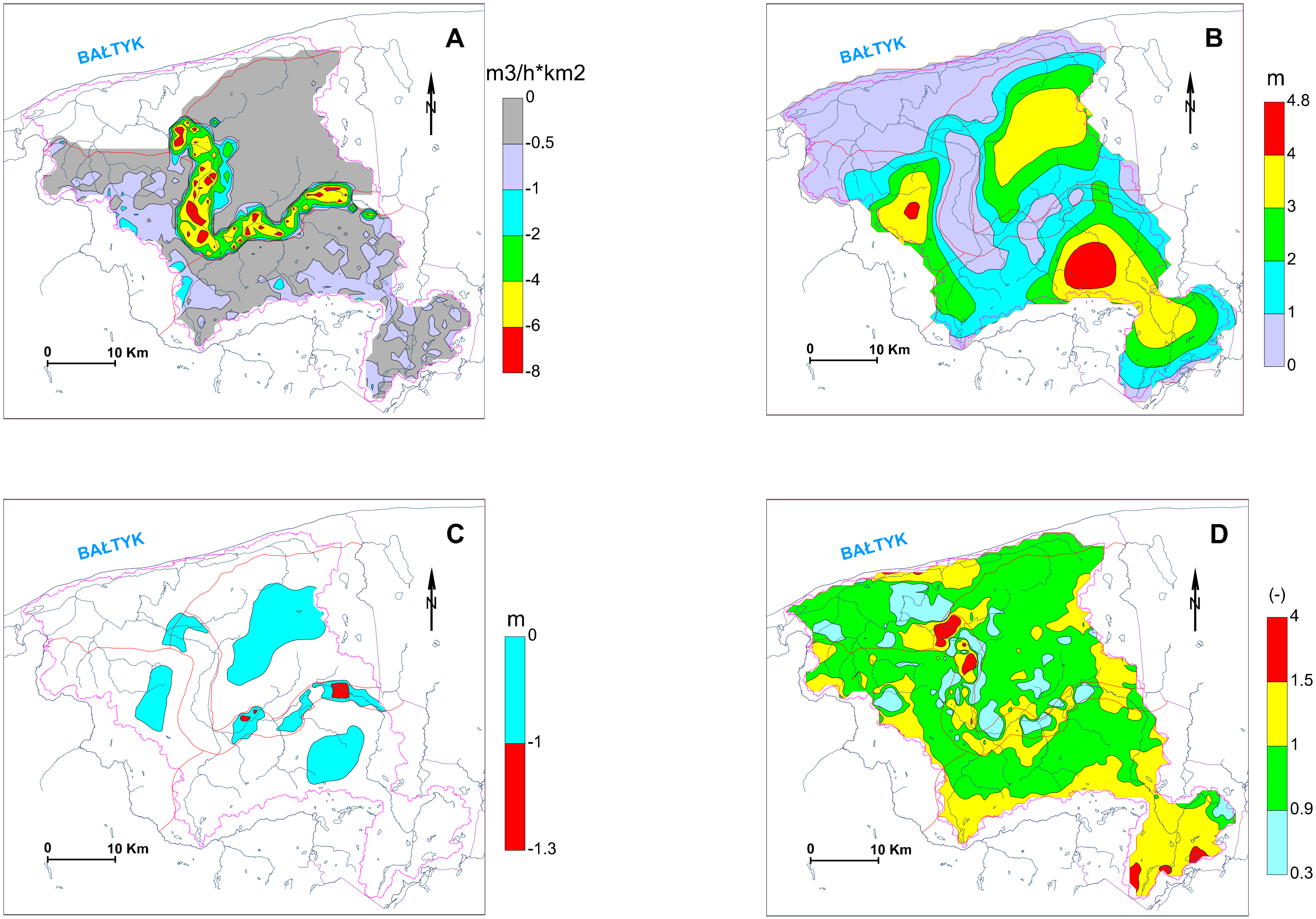
A – distribution of the reserve (**7400 m³/h**, **C_{RSV}=0,4**), B – regional drawdown
C – beyond the allowable RD, D – groundwater dynamics change



The DGWR reserve calculated for the lower model layer

A – distribution of the reserve (**1300 m³/h**, $\mathbf{C_{RSV}=0{,}4}$), B – regional drawdown

C – beyond the allowable RD, D – groundwater dynamics change



The catchment GW flow budget without and with the use of the DGWR reserve

	No use of the DGWR reserve	Full use of the DGWR reserve
Inflow:	m^3/h	m^3/h
Inflow across the catchment boundary	4668,7	5288,9
Recharge from the precipitation	21716,0	21716,0
Recharge from rivers and lakes	201,3	1444,6
TOTAL INFLOW	26586,0	28449,5
Outflow:	m^3/h	m^3/h
Outflow across the catchment boundary	5600,3	5032,9
Exploitation by wells	1021,5	1021,5
The use of the DGWR reserve	0	8686,4
Outflow to ditches	4442,2	2545,0
Outflow to rivers and lakes	15519,0	11167,0
TOTAL OUTFLOW	26583,0	28452,8
The model budget gap	3,0	- 3,3

CONCLUSIONS

1. The presented method to calculate the disposable GW resources in the river catchment directly links these resources in the modeling process to the groundwater runoff from the investigated area.
   The groundwater runoff is estimated from the long-term river flow data.

CONCLUSIONS

2. The presented method is a 4 step procedure:

- The estimation of the groundwater runoff,
- The estimation of the recharge distribution using the constant-volume transformation (CVT),
- The construction of the GW flow mathematical model,
- The model based calculation of the magnitude and distribution of the disposable GW resources in the catchment using the CVT.

CONCLUSIONS

3. The calculated reserve of the disposable GW resources in the Łeba river catchment is about 8 700 m^3/h . It is 40% of this catchment recharge.

   The present GW withdrawal rate in the catchment is about 1 000 m^3/h.

   The sum of the withdrawal and reserve is about 9700 m^3/h what is the estimated magnitude of the disposable GW resources in this catchment.

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