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VIGYAN BHAWAN, NEW DELHI

Post-flood Period Serial Geomorphic Analysis (POPSEGA) - structure and application

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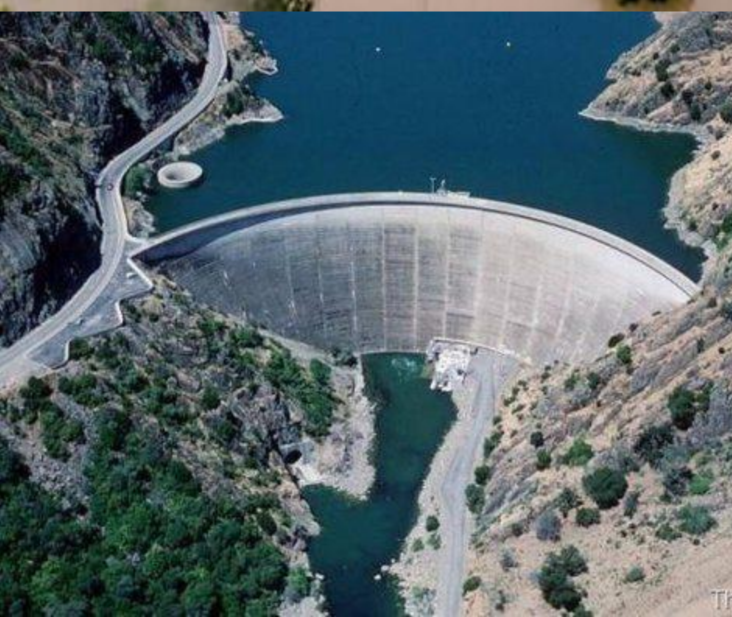
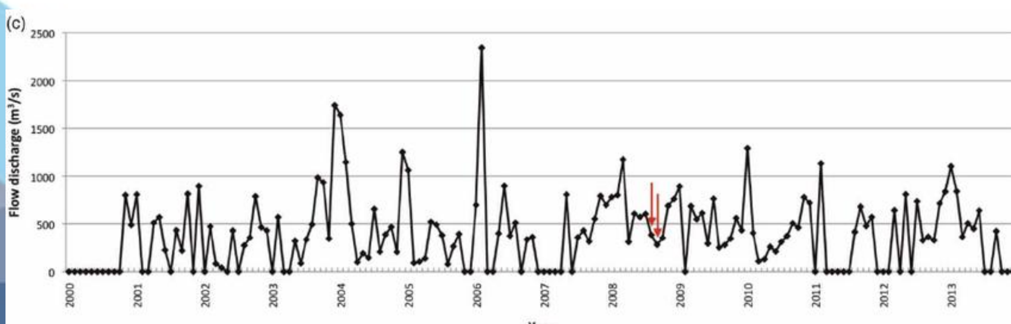
Response to flood variability and environmental changes

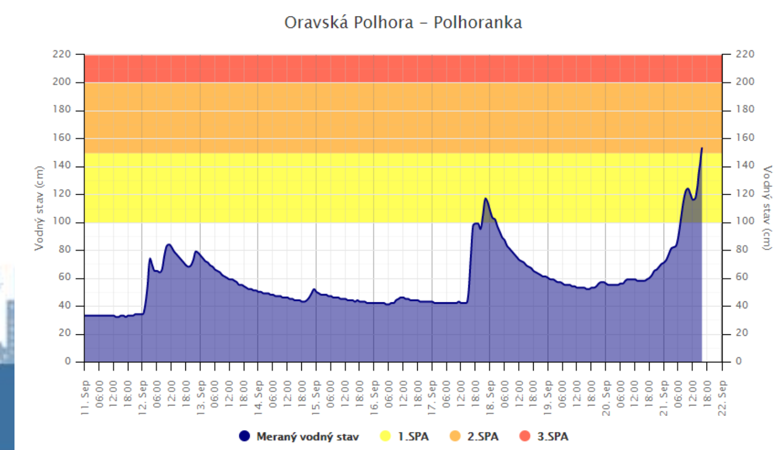


The majority of channel changes in braided river systems are associated with changes in bed morphology **during high discharges** (Smith, 1974; Rust, 1978; Ashmore, 1982; Rundle, 1985).

In order to better understand long-term patterns of channel behaviour, relating observed changes to long-term trends in flood flows is necessary.

Extreme floods are known to accomplish **large morphological changes** in a channel and move large volumes of sediment (Schumm, 1977; Osterkamp and Costa, 1987; Magilligan et al., 1998; Fitzpatrick and Knox, 2000).





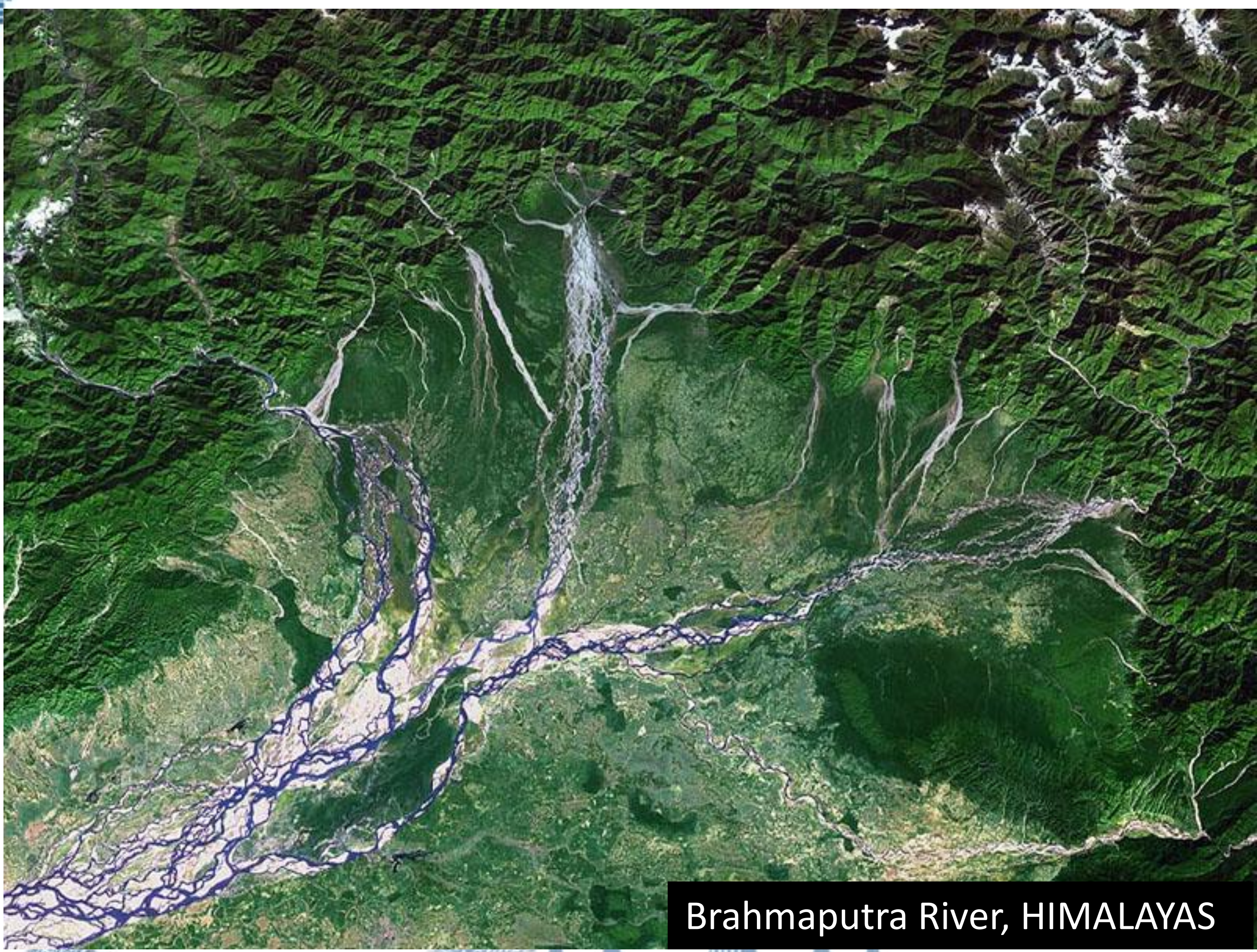
EXPANSION AND CONTRACTION OF BRAIDED RIVERS

A braided river typically aggrades and widens when sediment supply is high, thereby progressively occupying an increasingly large portion of the valley bottom; this is referred to as an ***expansion phase***. The active channel shifts laterally, either by bank erosion or avulsion.

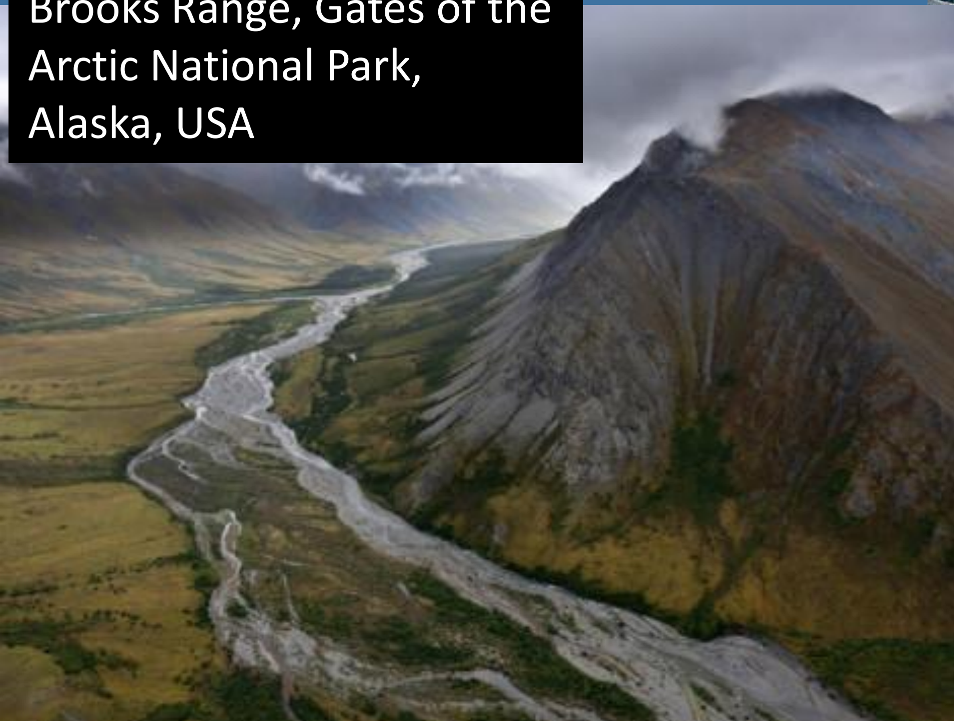
When sediment supply or peak flows are reduced, braided rivers typically narrow and incise their beds, that is referred to here as an ***contraction phase*** (Piégay et al., 2006). Channel narrowing and incision cause then isolation of the rivers isolation from their floodplains. Stabilisation of potential channel forms such as the transformation of bars into islands is observed as well.

DYNAMIC BRAIDED RIVERS

Braided channels are also typical of environments that dramatically decrease channel depth, and consequently channel velocity, such as **river deltas, alluvial fans** and **peneplains.**



Brahmaputra River, HIMALAYAS



Braided Itkiluk River, Brooks Range, Gates of the Arctic National Park, Alaska, USA

Resurrection River, ALASKA

Matanuska River, ALASKA

Gulkana River, ALASKA

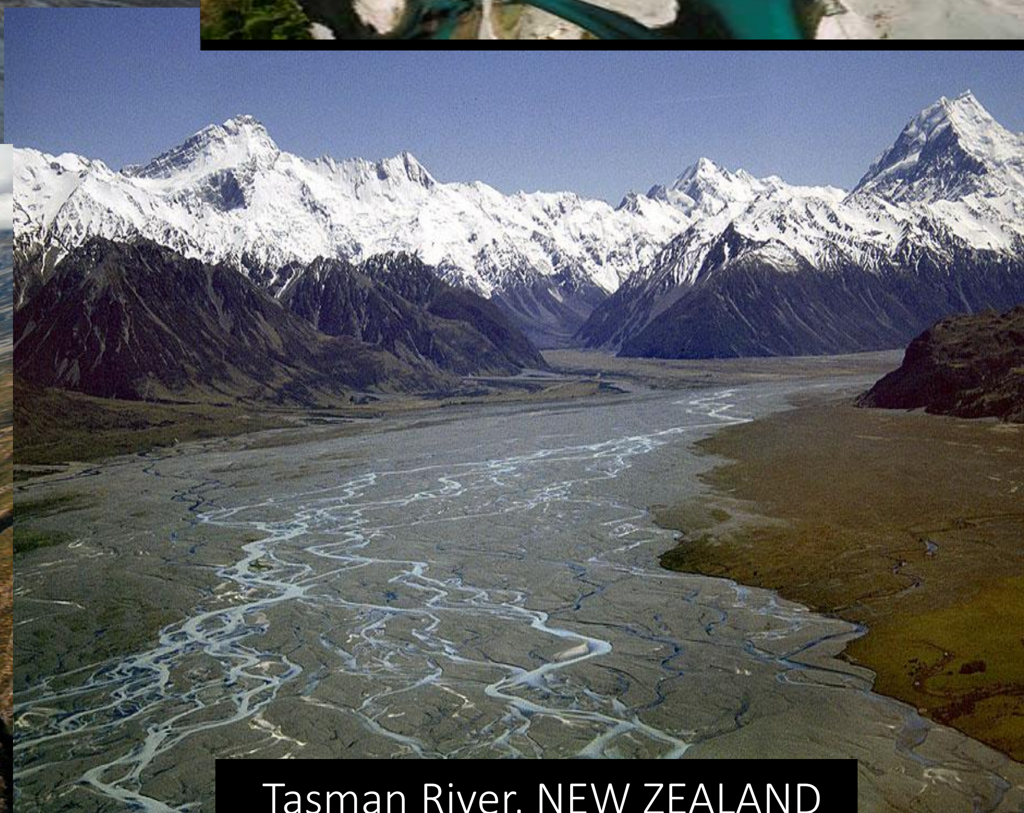
Kicking Horse River, BRITISH COLUMBIA, CANADA

Sunwapta River, JASPER NATIONAL PARK, ALBERTA

Waimakariri River, NEW ZEALAND

Rakaia River, NEW ZEALAND

Murchison River, NEW ZEALAND

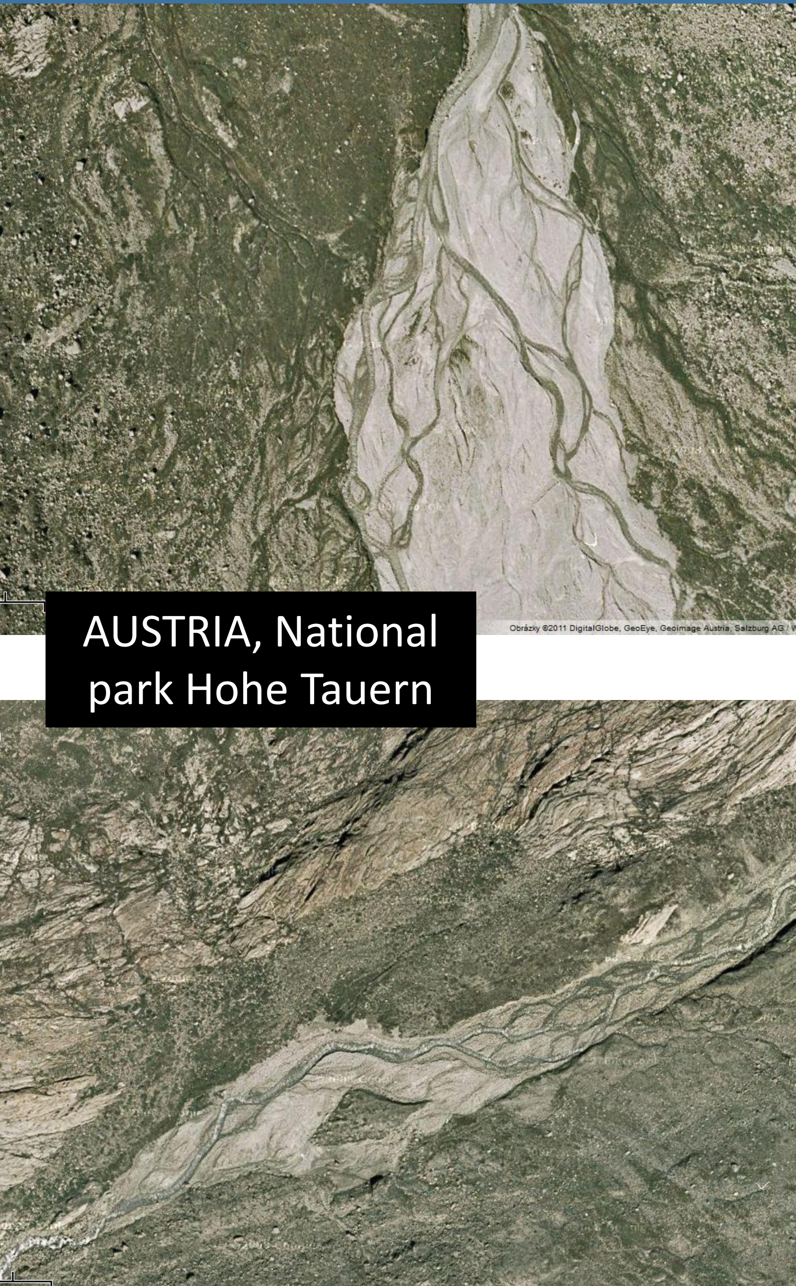


Tasman River, NEW ZEALAND

MELVILLE ISLAND, NORTHERN TERRITORY, AUSTRALIA

Lena River, SIBERIA

EUROPE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AUSTRIA, National park Hohe Tauern


Piave river, ITALY


Tagliamento river, ITALY

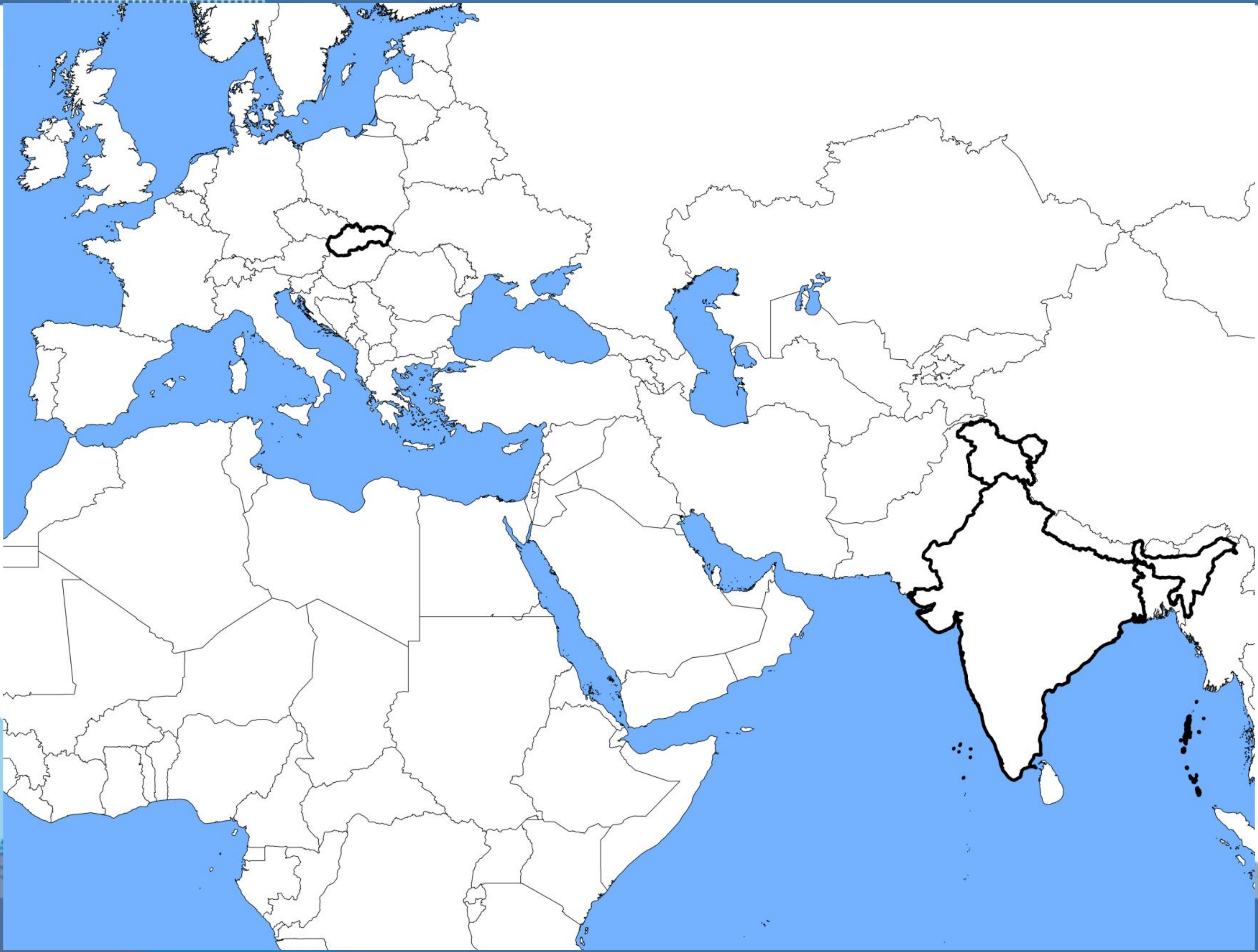
Bialka river, POLAND

Drôme river, FRANCE

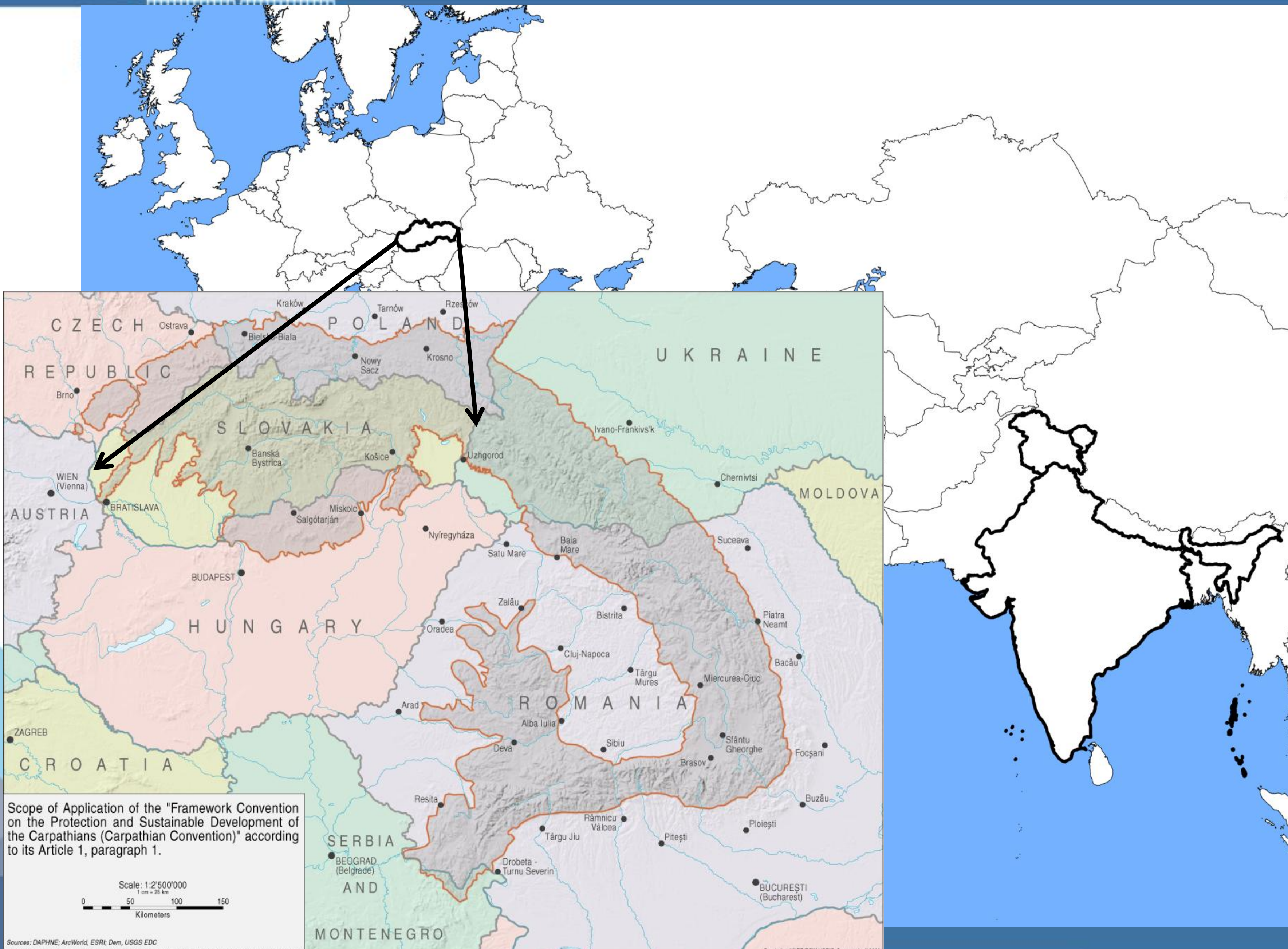
Teresva river, UKRAINE

Prahova river, ROMANIA

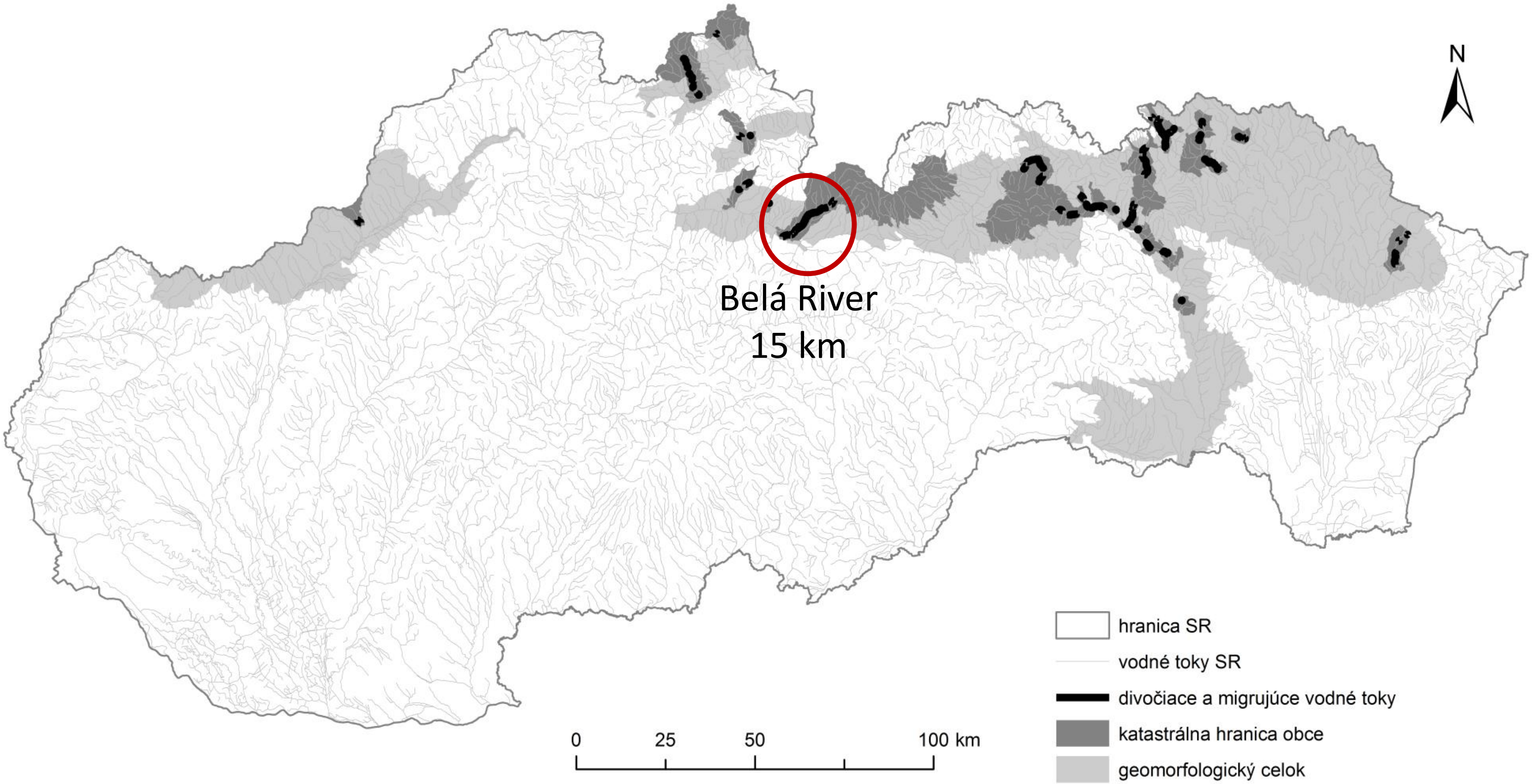
STUDY AREA – THE BELÁ RIVER, Slovak Carpathians



STUDY AREA – THE BELÁ RIVER, Slovak Carpathians

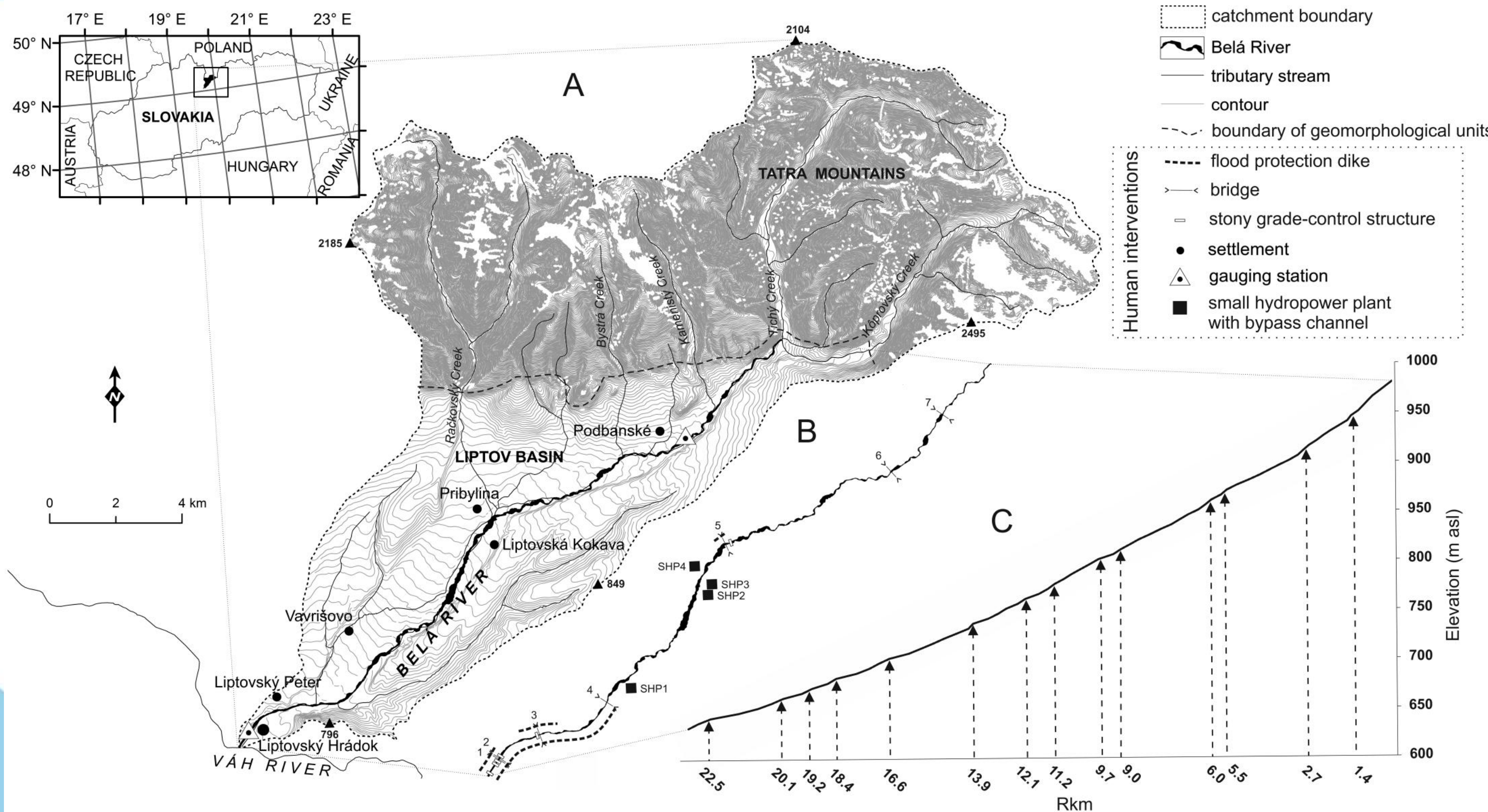


STUDY AREA – THE BELÁ RIVER, Slovak Carpathians



Braided river reaches in Slovakia (Kidová and Lehotský, 2012)

STUDY AREA – THE BELÁ RIVER, Slovak Carpathians



$Q_{Podbanské}$ = 3,5 $m^3.s^{-1}$

$Q_{Lipt.\ Hrádok}$ = 6,8 $m^3.s^{-1}$

Max. Altitude 2 494 m asl **Min. Altitude 630 m asl**

SOURCE DATA AND METHODOLOGY

for the post-flood period serial geomorphic analysis (POPSEGA):

- **(i)** **analysis of maximum annual discharges**;
- **(ii)** **identification of flood periods**;
- (iii) selection of sets of remotely sensed data and their georeferencing in **GIS**;
- (iv) extraction of channel and floodplain forms in GIS in each flood period;
- (v) division of a river course into regular (100-m long) segments along channel centreline;
- (vi) disaggregation of landform polygons into sets of landform parameters;
- (vii) assessment of landform parameter changes at successive time series of floods, i.e. by the comparision of two flood periods;
- **(viii)** **estimation of the Shannon's diversity index and cores for each flood period using GUIDOS and FRAGSTAT softwares**;
- **(ix)** **analysis of nodes as confluence-diffluence pairs for each flood period and for the whole time span;**
- **(x)** **analysis of erosion and deposition area using erosion/deposition index for each two consecutive flood periods**;

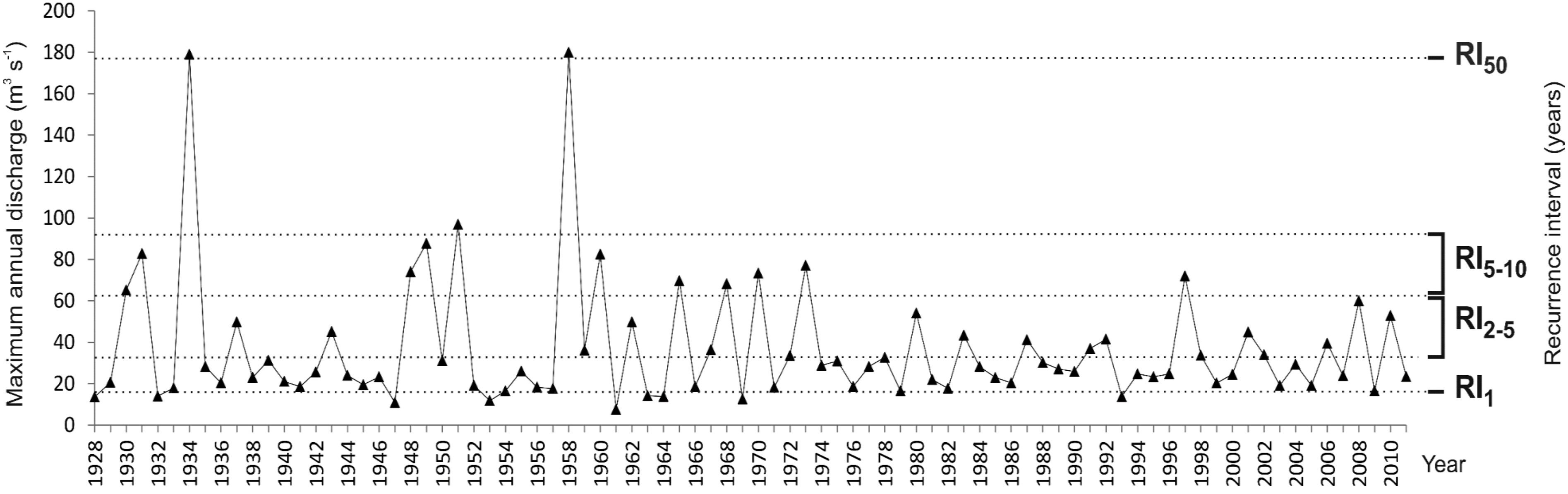
SOURCE DATA AND METHODOLOGY

(xi) **aggregation of river segments into larger units – river reaches – based on a statistical analysis of channel parameters;**

(xii) classification of river reaches using environmental variables (valley setting);

(xiii) **identification of contraction, stable or expansion phases of river reaches on the basis of a change in erosion/deposition areas in particular time series of floods**

(i) analysis of maximum annual discharges, (ii) identification of flood periods

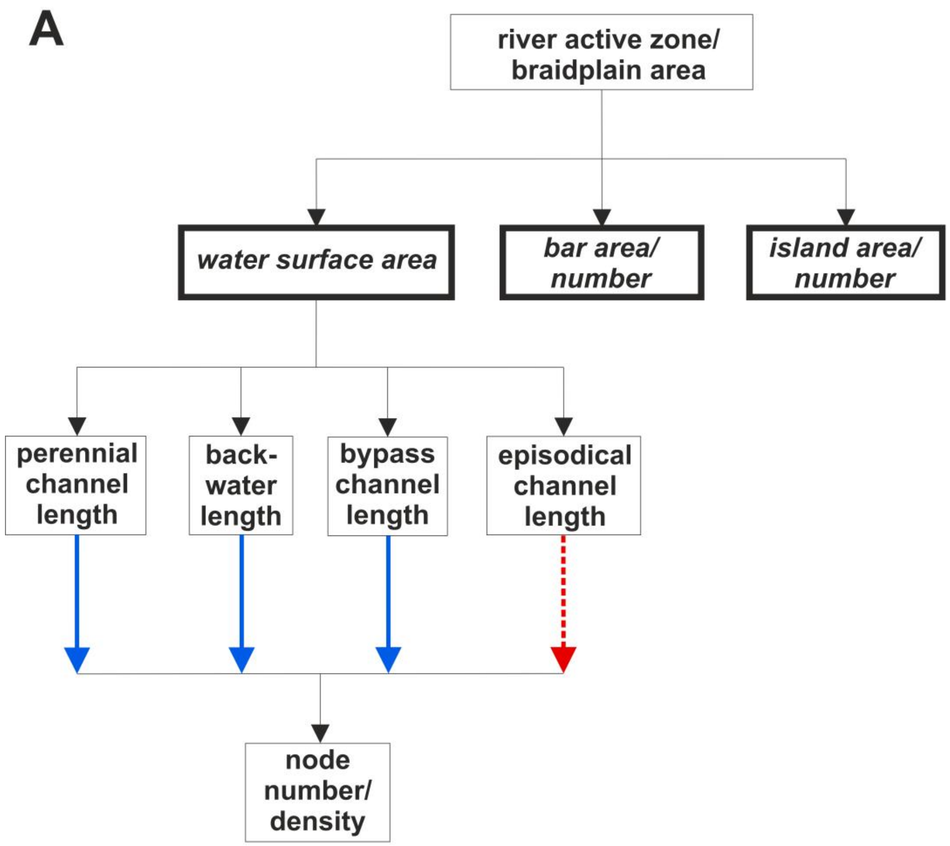


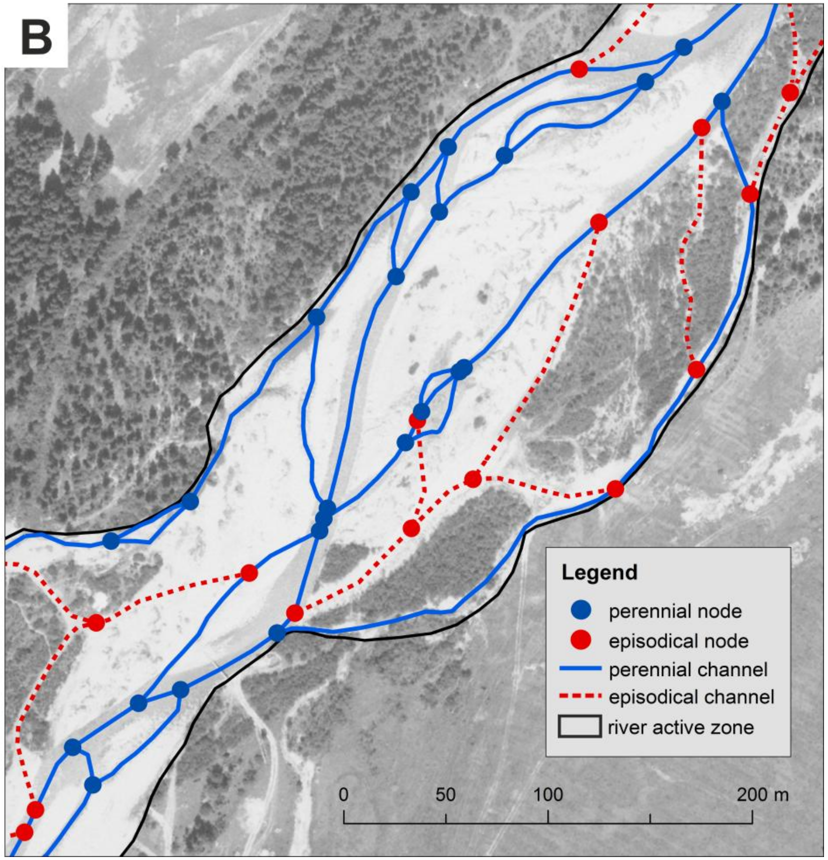
Flood period (FP)	***REFERENCE FP 1928-1948***	***1st FP 1949-1961***	***2nd FP 1962-1973***	***3rd FP 1974-1986***	***4th FP 1987-1992***	***5th FP 1993-2002***	***6th FP 2003-2008***
Average maximum discharge	38.5 $m^3 s^{-1}$	48.6 $m^3 s^{-1}$	40.5 $m^3 s^{-1}$	28.1 $m^3 s^{-1}$	33.8 $m^3 s^{-1}$	31.6 $m^3 s^{-1}$	31.8 $m^3 s^{-1}$
Source data	1949	1961	1973	1986	1992	2003	2009

7 time horizons

(iii)-(vii) GIS analysis

(ix) analysis of nodes as confluence-diffluence pairs for each flood period and for the whole time span





Categories of the dynamics of mid-channel forms – Jenk´s Natural Breaks Classification:

Low dynamic/ Medium dynamic/ Highly dynamic/ Very highly dynamic

(x) analysis of erosion and deposition area using **erosion/deposition index** for each two consecutive flood periods

DA is the deposition area resulting from lateral accretion, bar and island formation processes and channel abandonment (m^2)

EA is the area eroded as a result of bank erosion, bar and island destruction and floodplain reworking processes (m^2)

i is the number of 100-m-long segments in reach ***r***

t is flood period (1–7)

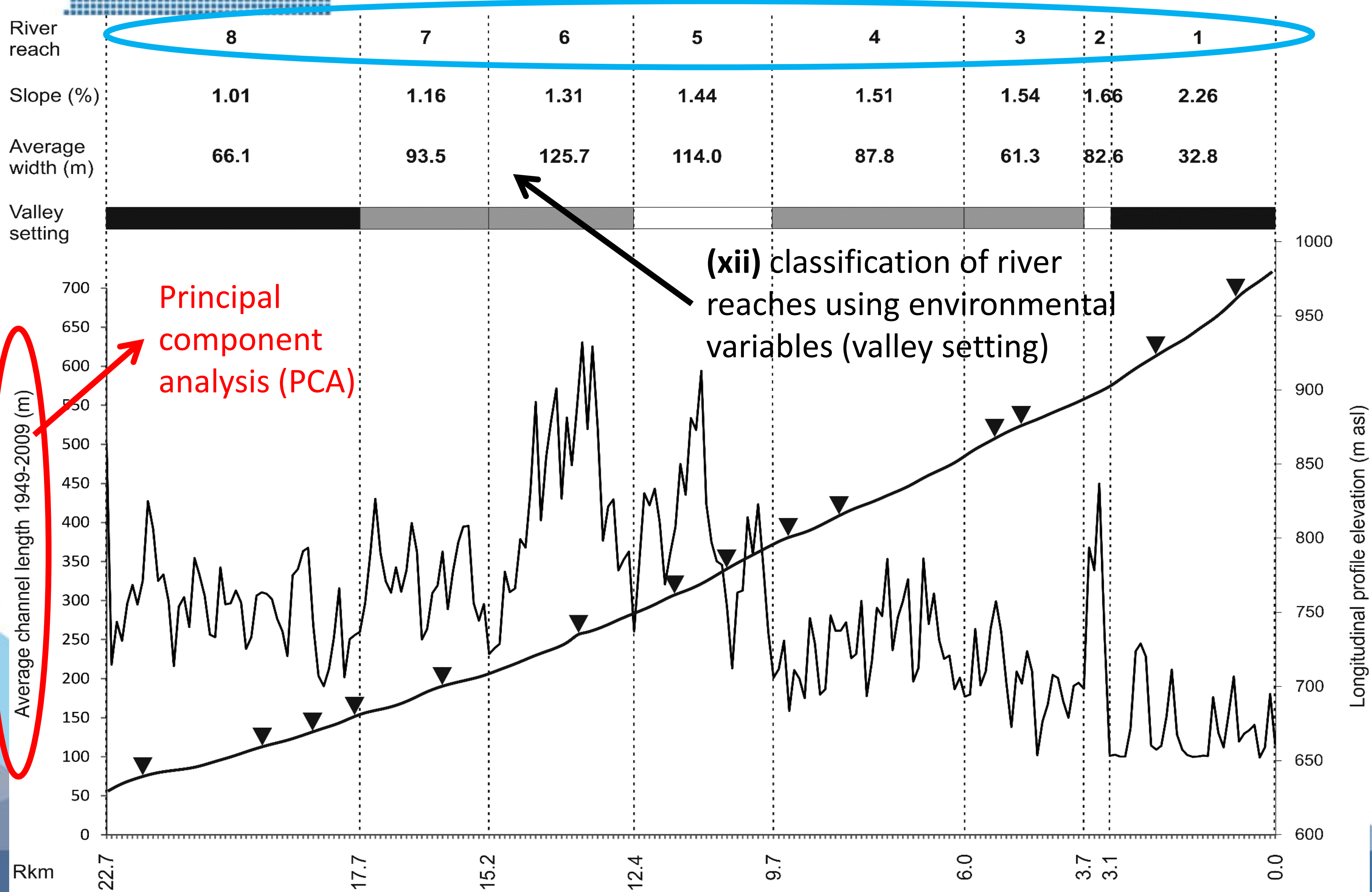
$$ED_r = \frac{\sum_{i=1}^{n} EA_t}{\sum_{i=1}^{n} DA_{t+1}}$$

(xiii) identification of contraction, stable or expansion phases of river reaches on the basis of a change in erosion/deposition areas in particular time series of floods

***ED* index values:**

< 0.8	CONtraction phase	0.8 - 1.2	STAble phase	> 1.2	EXPansion phase

(xi) aggregation of river segments into larger units – river reaches – based on a statistical analysis of channel parameters

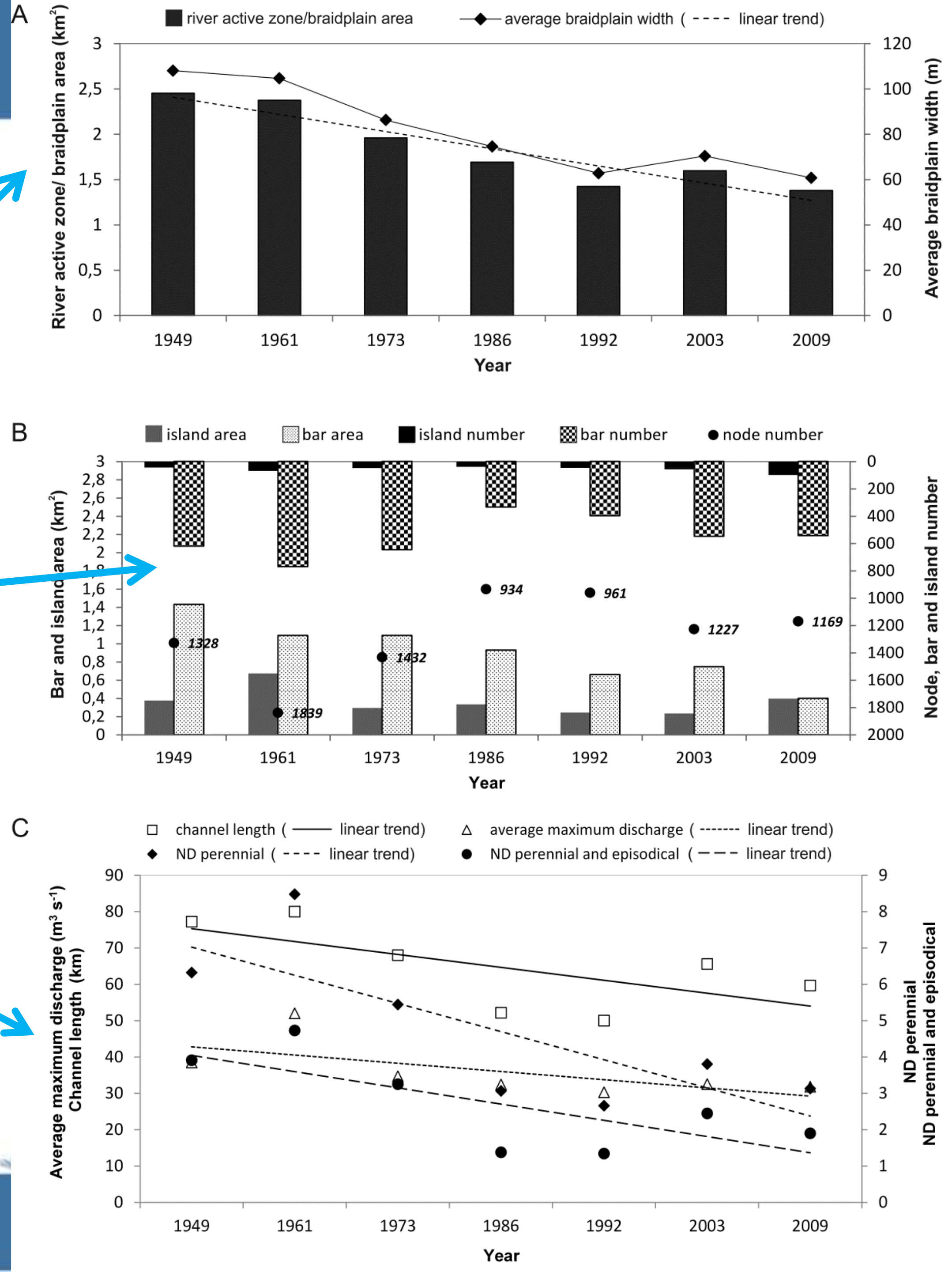


RESULTS

Changes in braidplain area and average braidplain width.

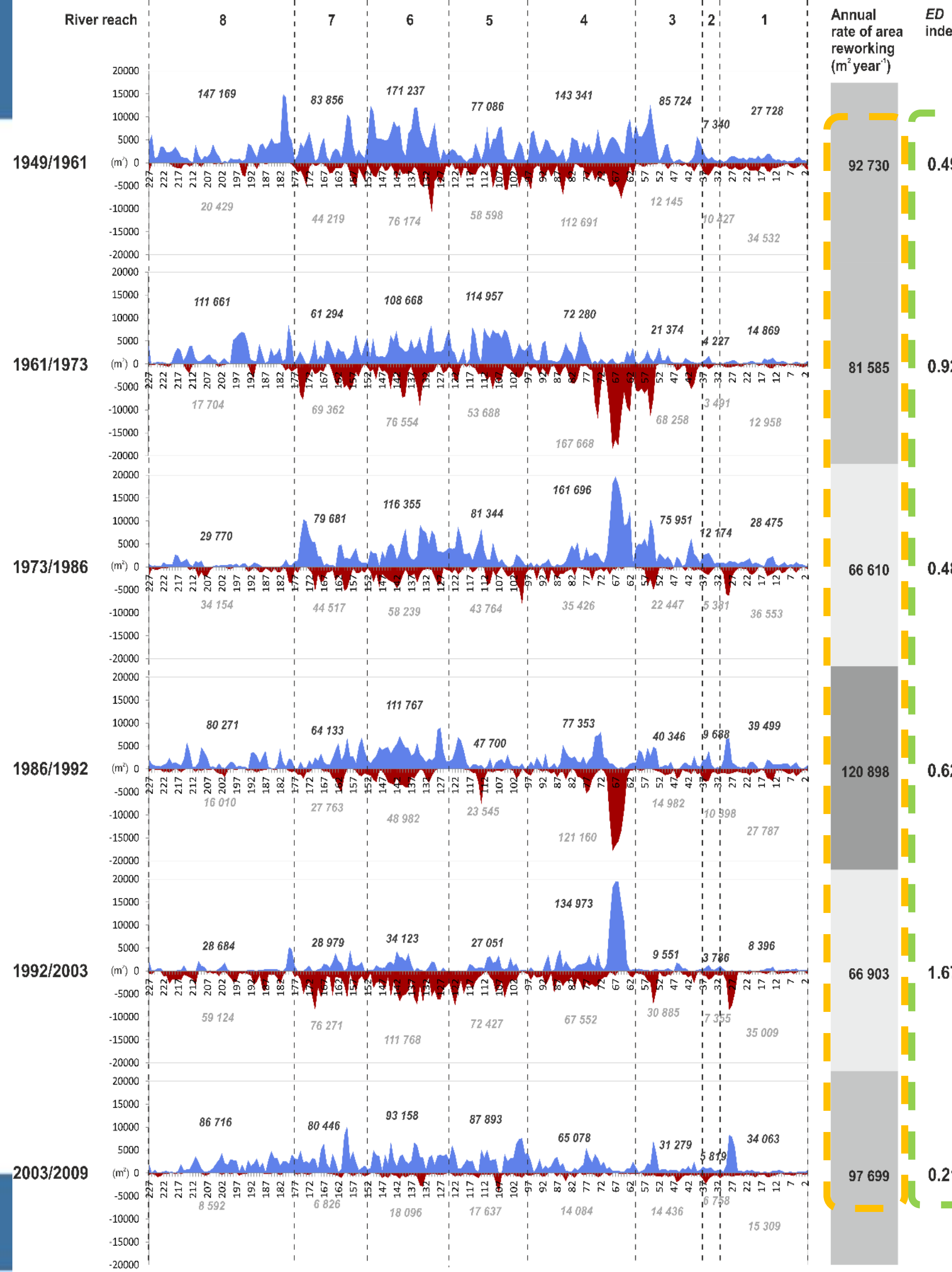
Changes in islands and bars area and bars, islands, and nodes number.

Linear trends and changes in node density, in total channel length and in the average maximum discharge between consecutive flood periods.



RESULTS

Variability of the areas of deposition (D, blue colour) and erosion (E, red colour) in the pairs of successive flood periods.



RESULTS *CON-STA-EXP phases*

upstream → *downstream*

Successive time series	*River reach **1***	*River reach **2***	*River reach **3***	*River reach **4***	*River reach **5***	*River reach **6***	*River reach **7***	*River reach **8***
1. 1949/1961	STA	EXP	CON	CON	CON	CON	CON	CON
2. 1961/1973	STA	EXP	EXP	EXP	CON	CON	STA	CON
3. 1973/1986	STA	CON	CON	CON	CON	CON	CON	STA
4. 1986/1992	CON	STA	CON	EXP	CON	CON	CON	CON
5. 1992/2003	EXP	EXP	EXP	CON	EXP	EXP	EXP	EXP
6. 2003/2009	CON	STA	CON	CON	CON	CON	CON	CON

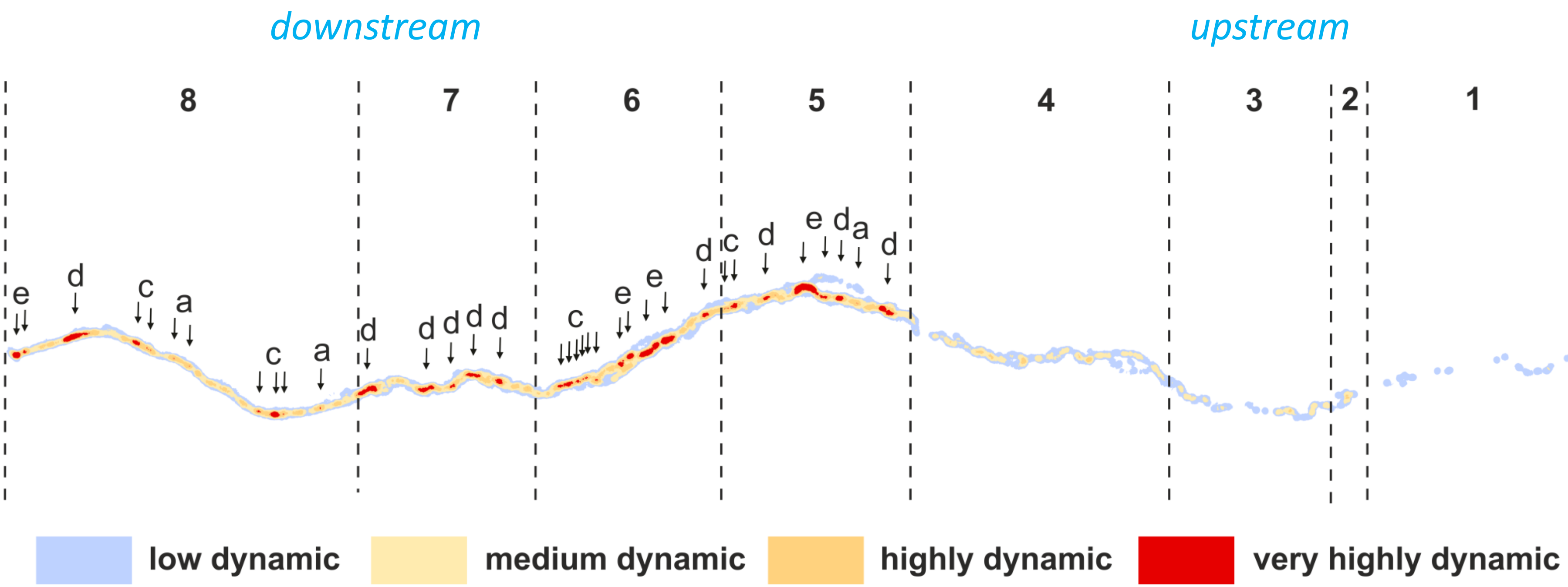
***ED* index values:** **< 0.8** **CONtraction phase** **0.8 - 1.2** **STAble phase** **> 1.2** **EXPansion phase**

Channel narrowing, straightening, incision,mid-channel bar stabilization, and island development are typical for the **CONTRACTION PHASE**.

↔

The **EXPANSION PHASE** is characterized mainly by such processes as bank erosion, avulsion, chute cutoffs, lateral and vertical accretion.

RESULTS *dynamics of mid-channel forms*



geomorphic diversity

Year	1949	1961	1973	1986	1992	2003	2009
Island core frequency	58	84	49	39	49	68	98
Bar core frequency	418	359	354	346	123	217	126
Shannon's Diversity Index	1.53	1.55	1.52	1.46	1.40	1.46	1.36

CONCLUSIONS *response to floods*

The recent variability of flood periods has been typified by a decreasing tendency of flood magnitude resulting in the change of the braided Belá River in terms of

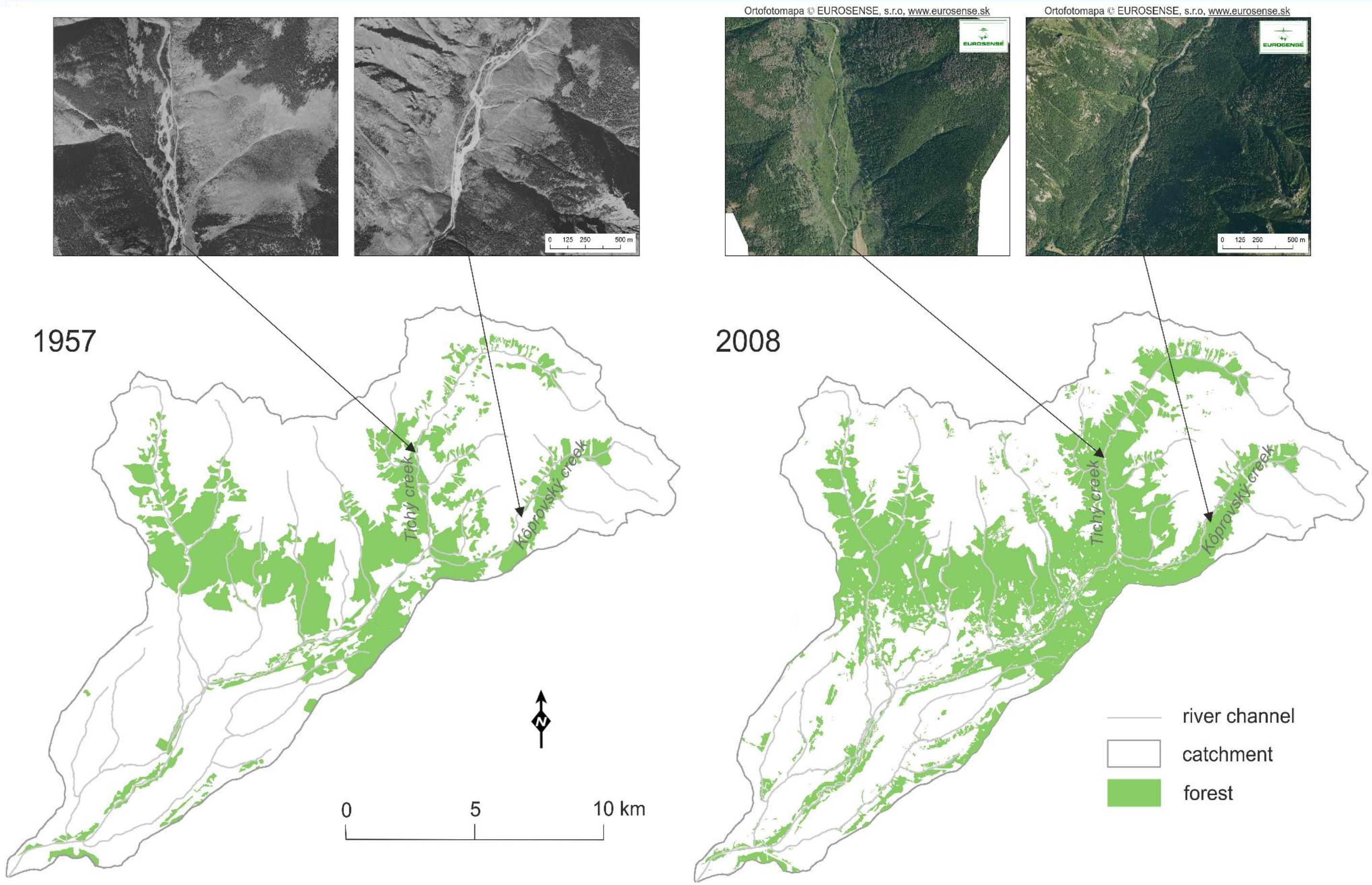
(i) a decrease in geomorphic diversity and channel straightening;
(ii) an increase in the area of islands;
(iii) a reduction in the river's ability to shift its banks, resulting from changes in flood pulses during the last decades;
(iv) channel narrowing and incision (locally into the bedrock).

before floods in 2008 (RI 2-5-years)

in 2011

CONCLUSIONS *other impacts*

• a reduction in catchment sediment supply (an increase in forest cover in the catchment from 22.7% in 1957 to 34.8% in 2008)



• the setting on several tectonically active lines and blocks,

• channelization of reach 8 (downstream), other human impact in the upper part

• lowering of the erosion base as a result of incision of the Váh

CONCLUSIONS

The application of the POPSEGA approach to the analysis of the Belá River system allowed us to identify different styles of channel change as a constant adjustment to the changing environment.

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Geomorphic diversity in the braided-wandering Belá River, Slovak Carpathians, as a response to flood variability and environmental changes

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Kidová et al. (2016)

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