

*Budoucnost managementu toků povodí Labe v pohraničním regionu  
ČR a SRN 5. - 6. 10. 2022; Zámek Děčín*



**OSTRAVSKÁ UNIVERZITA**  
PŘÍRODOVĚDECKÁ FAKULTA  
FAKULTÄT DER NATURWISSENSCHAFTEN

**Wasserläufe aus Sicht  
fluvialer Geomorphologie**

**Vodní toky z pohledu  
fluviální geomorfologie**

Jan Hradecký & Tomáš Galia



KATEDRA  
FYZIKÉ GEOGRAFIE  
A GEOEKOLOGIE

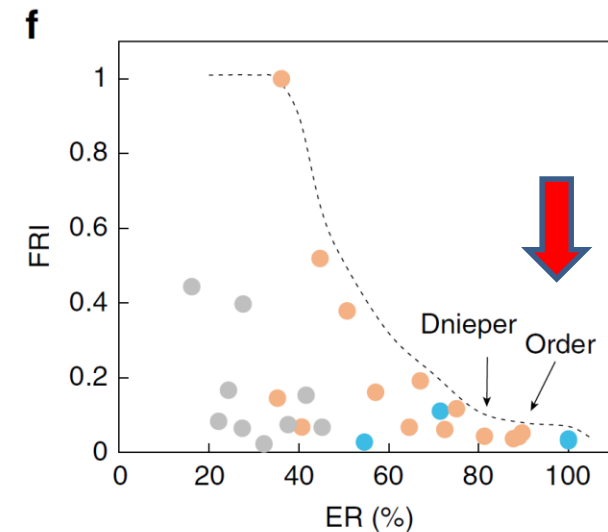
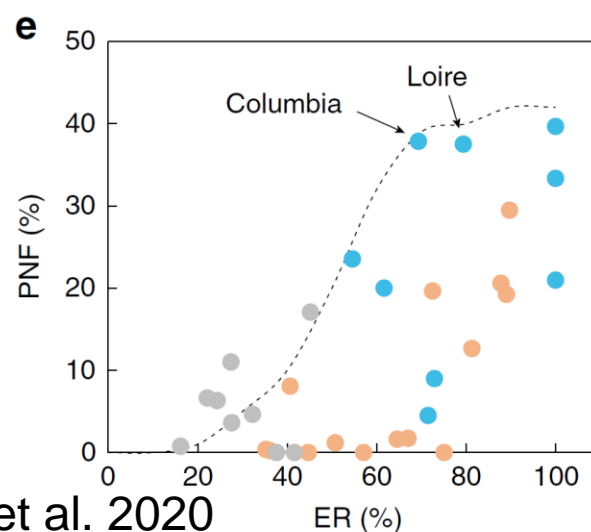
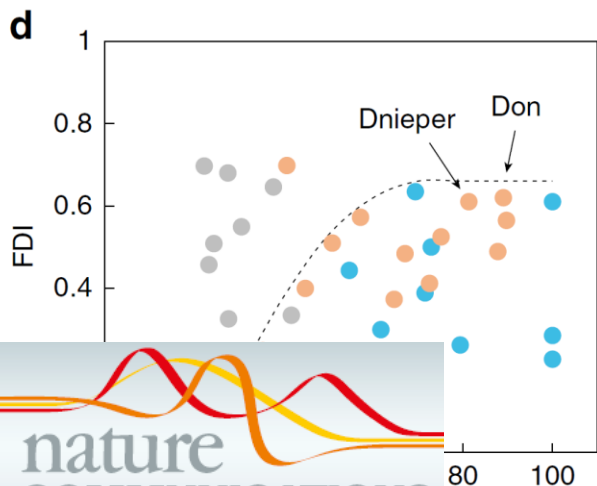
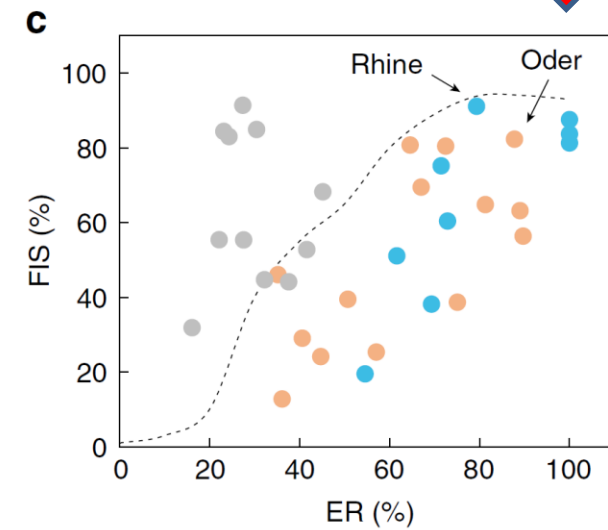
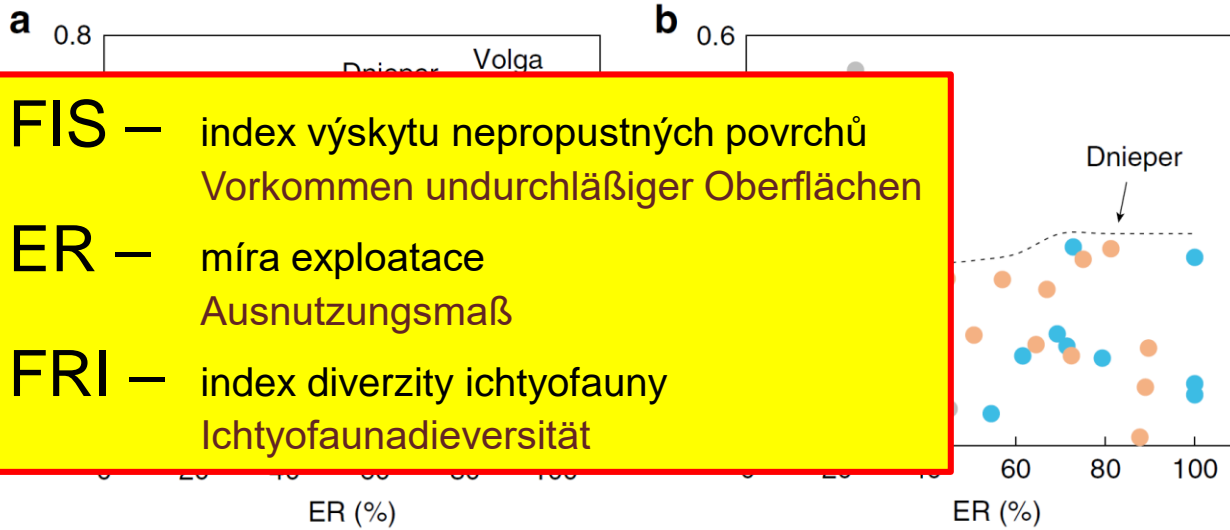


Ministerstvo životního prostředí

## Gesprochen wird u.a. über... O čem bude také řeč...

- Vodní toky a jejich ohrožení.
  - Fluviální procesy a jejich podmíněnost.
  - Sedimenty a bariéry.
  - Dynamika říčních koryt.
  - Něco málo o říčním dřevu.
  - Několik příkladů z našich luhů...
- 
- Wasserläufe und deren Gefährdung.
  - Fluviale Prozesse und deren Bedingtheit.
  - Sedimente und Barrieren.
  - Dynamik der Flussbette.
  - Etwas über das Holz auf/im Fluss.
  - Einige Beispiele aus unseren Auen...



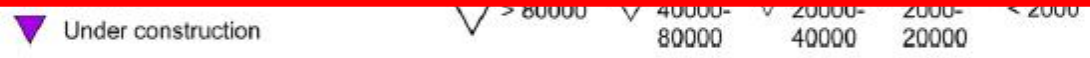


**River basin**

**Corresponding Threat**

Salween - Nu	Infrastructure - Dams
Danube	Infrastructure - Navigation
La Plata	Infrastructure - Dams and Navigation
Rio Grande - Rio Bravo	Water Over-extraction
Ganges	Water Over-extraction
Indus	Climate Change
Nile-Lake Victoria	Climate Change
Murray-Darling	Invasive Species
Mekong - Lancang	Over-fishing
Yangtze	Pollution

Grill  
Environ. Res. Lett. 2015



**Figure 1.** Overview of existing dams (GRanD, Lehner *et al* 2011) and planned and under construction future dams (Zarfl *et al* 2014) by storage volume class (volumes in million cubic meters from Lehner *et al* 2011 and own estimates).



# Flusslandschaft

# Říční krajina



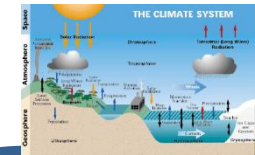
POVODEŇ  
HOCHWASSER



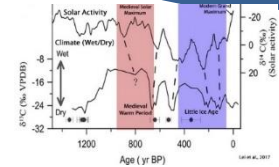
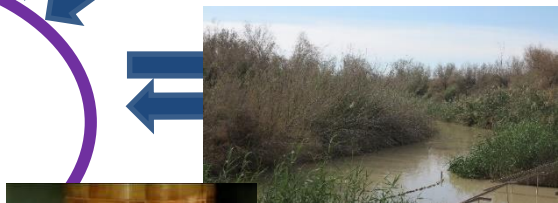
SUCHO  
DÜRRE



**ČLOVĚK  
MENSCH**  
-  
**SPOLEČNOST  
GESELLSCHAFT**



**KLIMATICKÝ  
SYSTÉM  
KLIMATISCHES  
SYSTEM**



# Ökosystemdienste der Flußlandschaften – was weiter?

## Ekosystémové služby říčních krajín – co dál?

### Dosud jsme říční ekosystém viděli hlavně jako:

- Zdroj potenciálního rizika (povodně, eroze),
- Zdroj vody (pitná/užitková),
- Recipient odpadních vod,
- Zdroj vodní energie,
- Vodní cesta,
- ...ostatní funkce byly marginalizovány a nebo neřešeny na úkor výše uvedených

### Bisher betrachteten wir das FlussJ. system hauptsächlich als:

- Quelle potentiellen Risikos (Hochwasser, Erosion),
- Wasserquelle (Trink-/Nutz-),
- Empfänger von Abwasser,
- Wasserenergiequelle,
- Wasserweg,
- ...andere Funktionen wurden marginalisiert oder zum Nachteil der oben genannten nicht in Betracht gezogen

#### Fluß/Bett

Süßwasser  
Selbstreinigung  
Abflußregulierung  
Erholung  
Primärproduktion  
Wasserzyklus  
Stoffkreislauf

#### Řeka/Koryto

Sladká voda  
Samočištění  
Regulace odtoku  
Rekreace  
Primární produkce  
Vodní cyklus  
Koloběh látek

#### Uferbiotops

Wasserreinigung  
Nutrientenrückhaltung  
Abflußregulierung  
Erosionsregulierung  
Erholung  
Bodenbildung  
Kohlenstofflieferung

#### Pobřežní biotopy

Čištění vody  
Zadržování nutrientů  
Regulace odtoku  
Regulace eroze  
Rekreace  
Pedogeneze  
Dodávka uhlíku

#### Aue/Feuchtgebiet

Holzproduktion  
Wasserreinigung  
Abflußregulierung  
Hochw.regulierung  
CO<sub>2</sub>-Sequestrierung  
Luftqualitätsregulierung  
Stoffkreislauf  
Bodenbildung  
Erholung  
Wasserzyklus  
Photosynthese

#### Niva/mokřady

Produkcce dřeva  
Čištění vody  
Regulace odtoku  
Regulace povodní  
Sekvestrace CO<sub>2</sub>  
Regulace kvality ovzduší  
Koloběh látek  
Pedogeneze  
Rekreace  
Vodní cyklus  
Fotosyntéza

Liefer-  
Regulierungs-  
unterstützende  
Kultur- ÖD

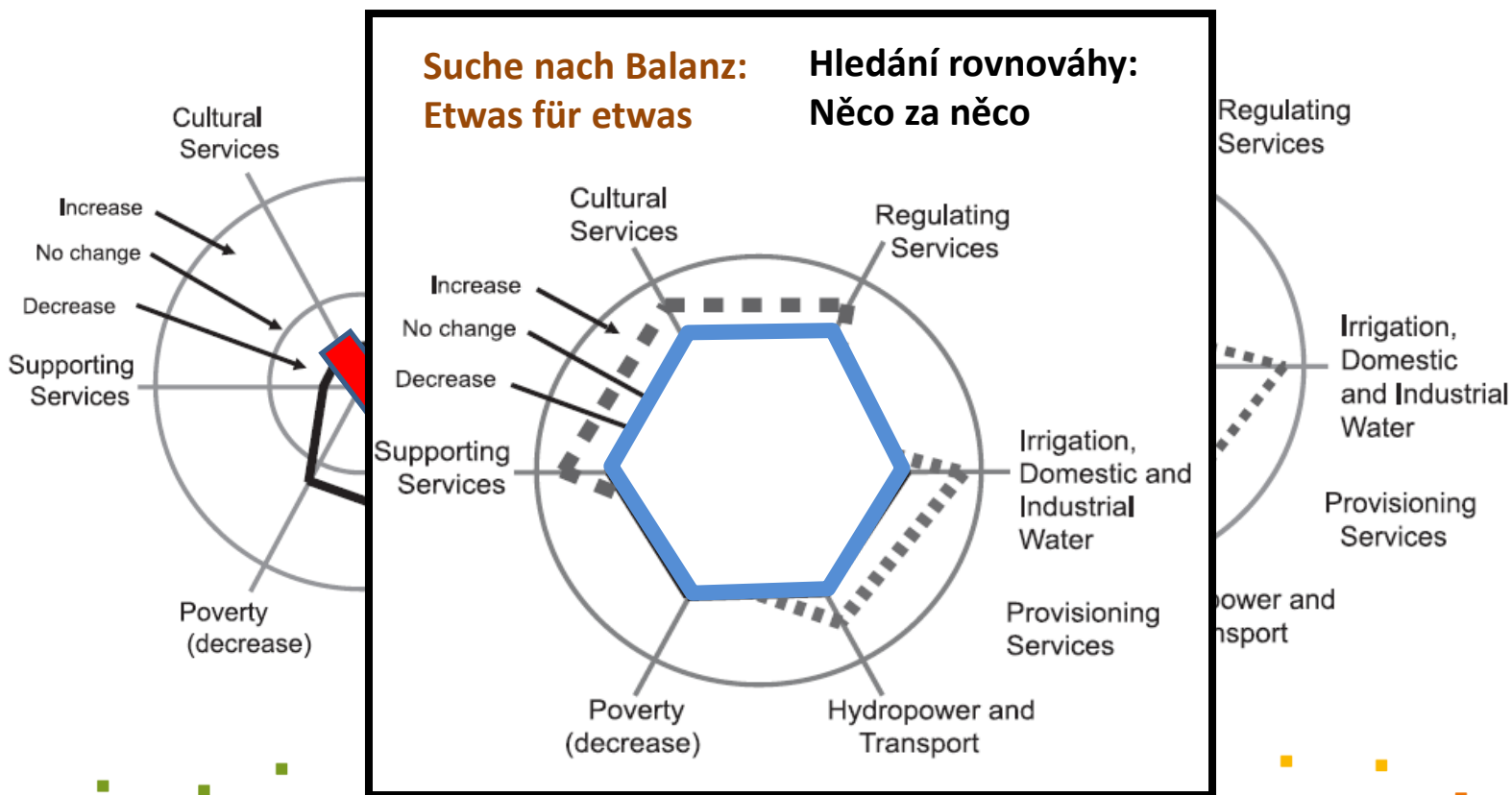
Zásobovací  
Regulační  
podpůrné  
Kulturní ES

### Umweltschonendes Szenario

### Environmentálně šetrný scénář

Gegenwart

Současnost



Klimatische  
Veränderung

Klimatická  
změna

Entwaldung

Odlesnění

Land-  
wirtschaft

Zemědělská  
činnost

Revitalisierung???

Revitalizace???

Siedlungen

Sídla

Flußbett-  
anpassungen

Úpravy  
koryt

Flysch Carpathian Mts.

zone of high-gradient  
streams

zone of intermountain  
streams

zone of anabranching  
streams

zone of meandering  
streams

Carpathian Mts.  
foreland

Carpathian  
Foredeep





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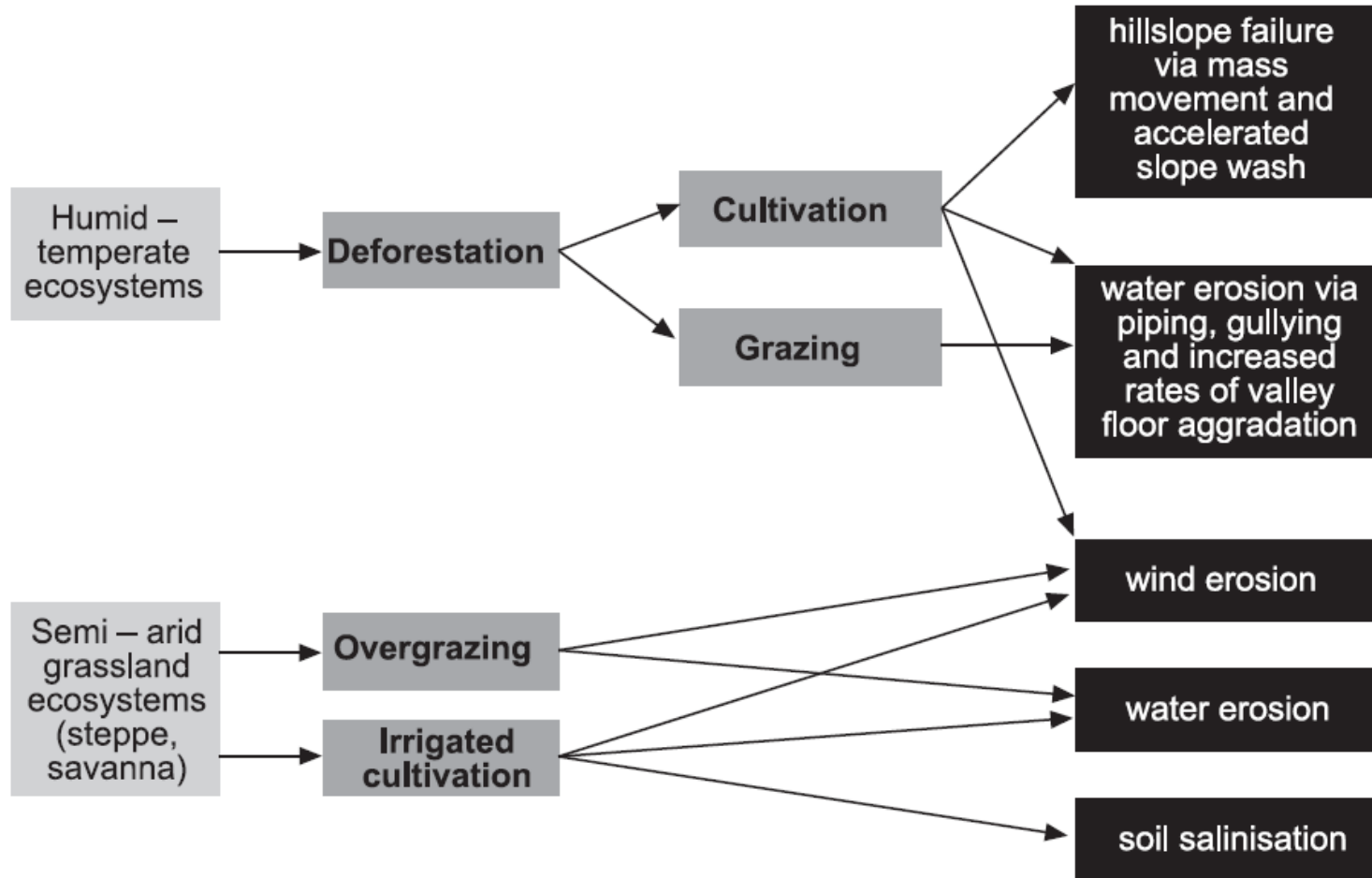
# Rolle des Menschen

# Role člověka

## Environmental setting

## Land use change

## Geomorphic response

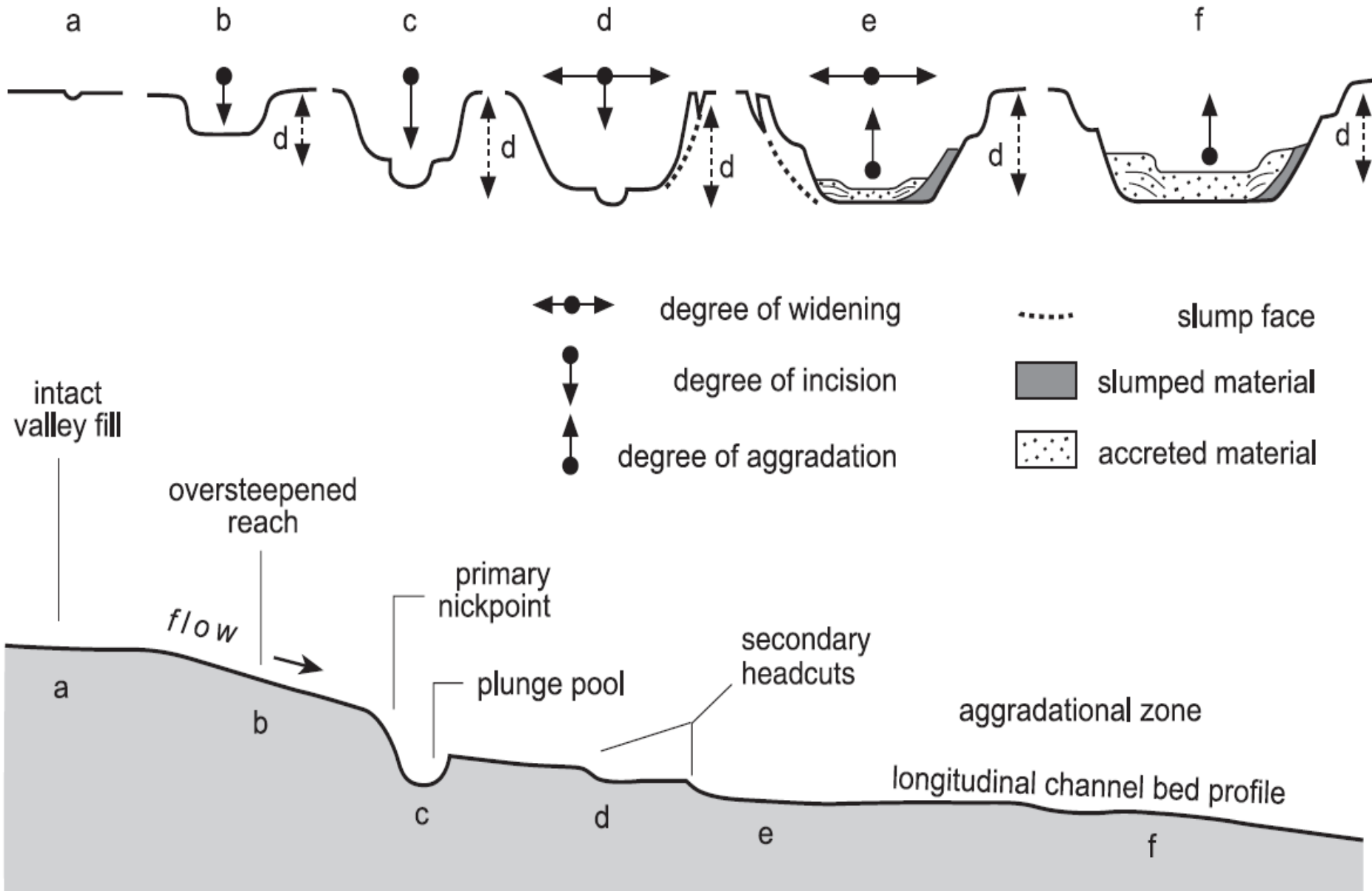


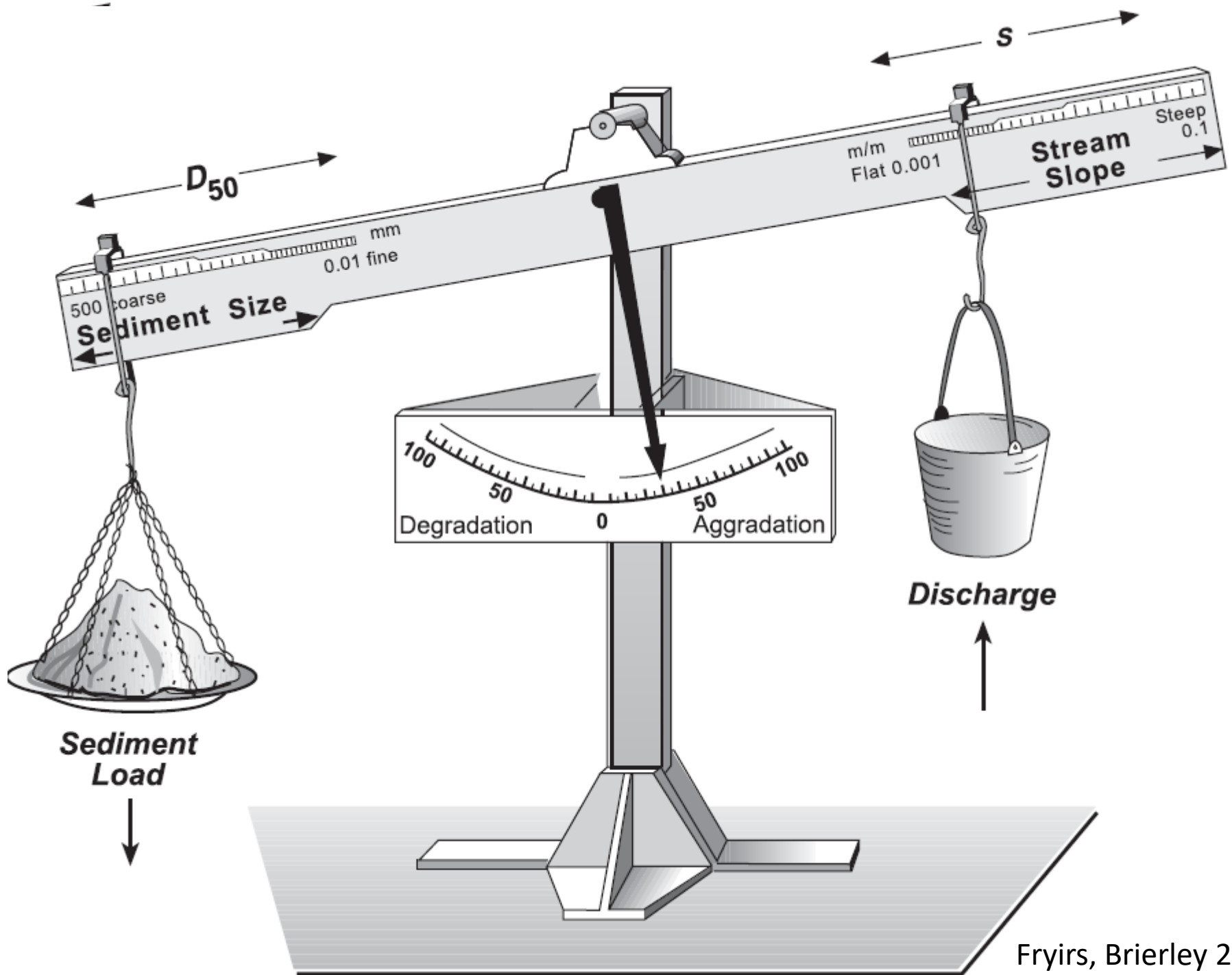
**Figure 13.1** Geomorphic responses to land use change in differing environmental settings. Modified from Starkel (1987).



# Warum sind Flüsse unterschiedlich?

# Proč jsou řeky různé?

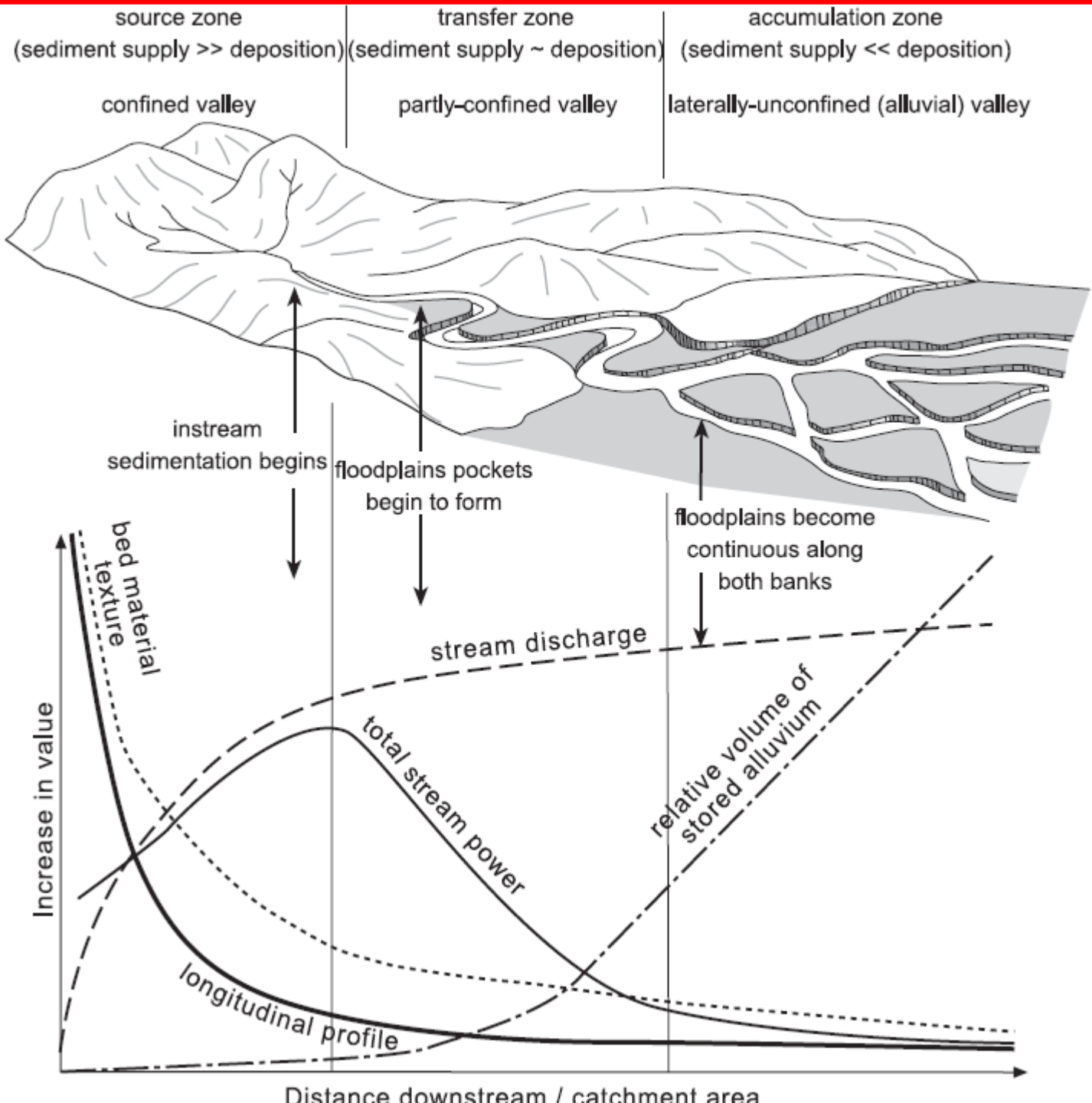








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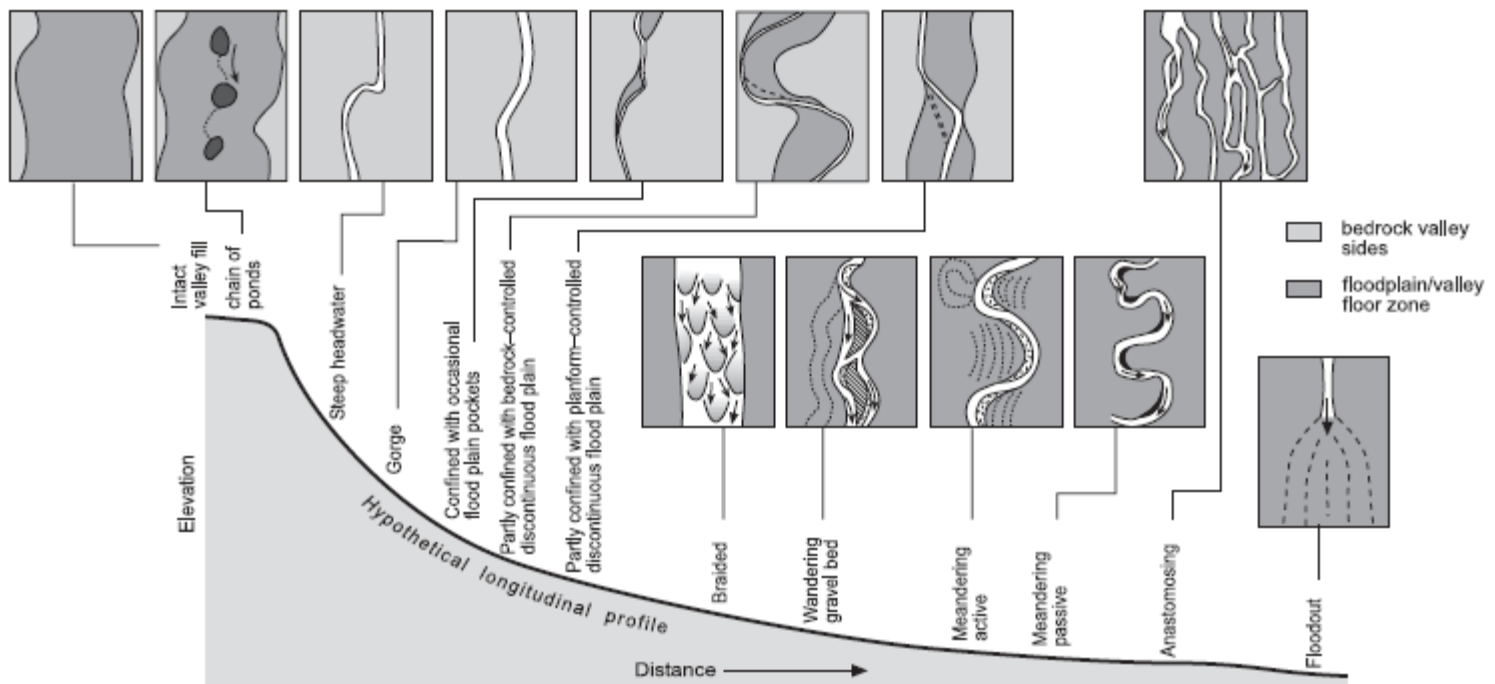
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Ostravská  
UNIVERZITA  
Přírodovědecká fakulta

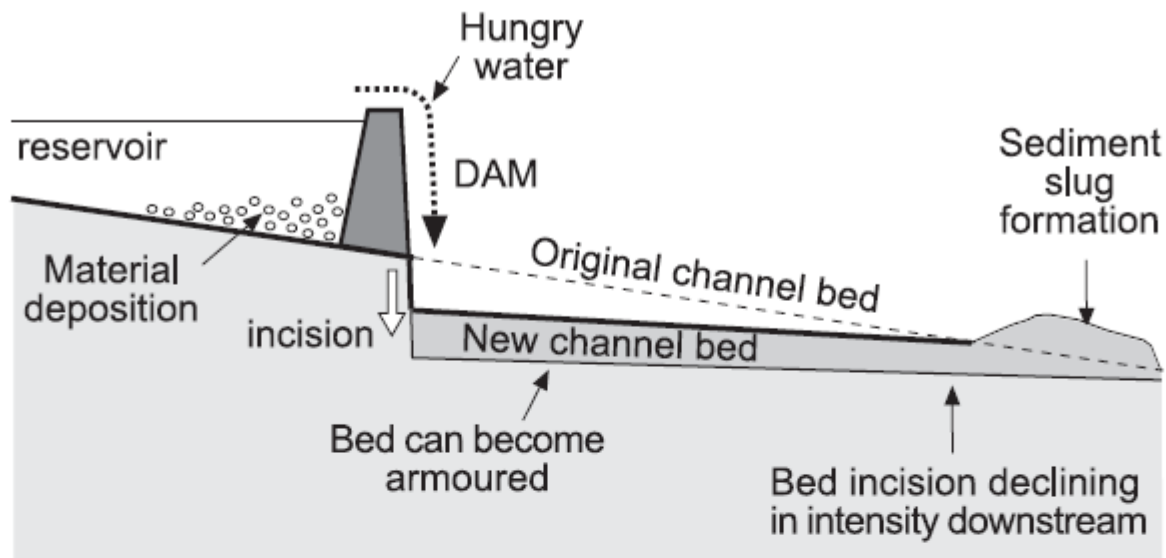


Valley setting	Laterally unconfined	Confined	Partly – confined	Laterally unconfined			
Dominant instream geomorphic units		Sculptured erosional bedrock	Sculptured or erosional and some depositional	Depositional mid-channel	Depositional bank-attached	Sculptured, erosional fine-grained	
Flood plain type	Low energy, fine-grained	n/a	High energy, non-cohesive or cohesive	Medium energy, non-cohesive		Low energy, fine-grained	
Dominant flood plain formation process	Vertical accretion	n/a	Vertical accretion	Lateral accretion and braid channel accretion		Vertical accretion	
Dominant forms of lateral instability		n/a	Channel expansion and contraction	Thalweg shift	Avulsion	Meander growth and shift	Avulsion
Number of channels	None	One		> 3	< 3	One	None
Sinuosity	n/a		1 – 1,05		Variable	> 1,3	n/a
Channel geometry	n/a	irregular	asymmetrical moderate w:d	irregular high w:d		asymmetrical moderate w:d	symmetrical or compound moderate w:d
Slope	Low	Decreasing channel gradient from very steep to low					
Stream power	Low	Decreasing stream power from very high to low					
Bed material texture	Fine-grained	Decreasing sediment calibre from boulders to fine-grained					
Primary controls on river	low slope fine-grained no channel	high slope confined valley imposed morphology	high slope & energy partly-confined valley sediment stores reworked	high energy non-cohesive banks bedload dominated	moderate energy freely-adjusting mixed load dominated	low energy cohesive banks suspended load dominated	

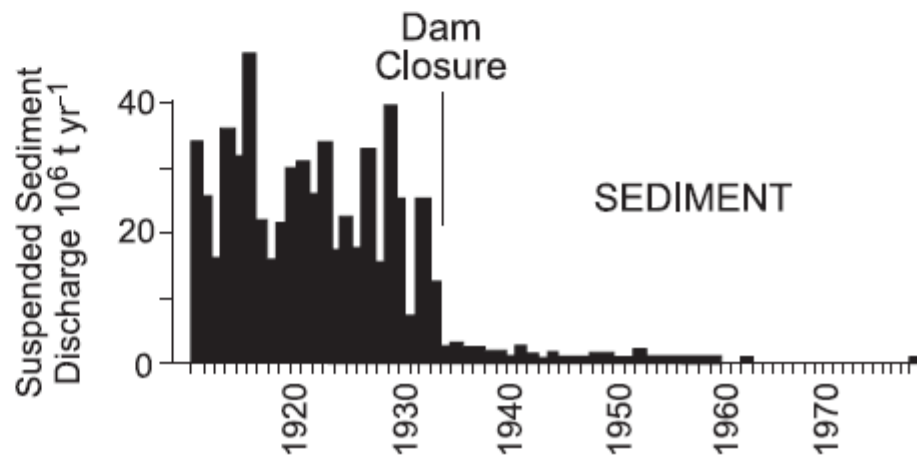
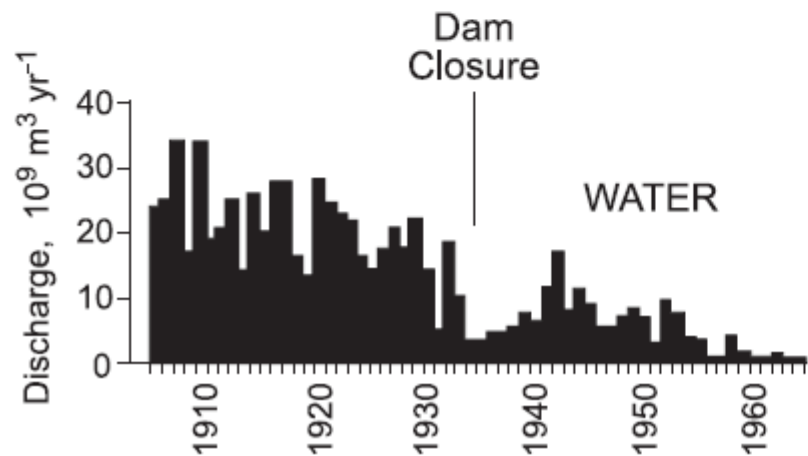
Fryirs, Brierley 2013



## (b) Longitudinal profile adjustments

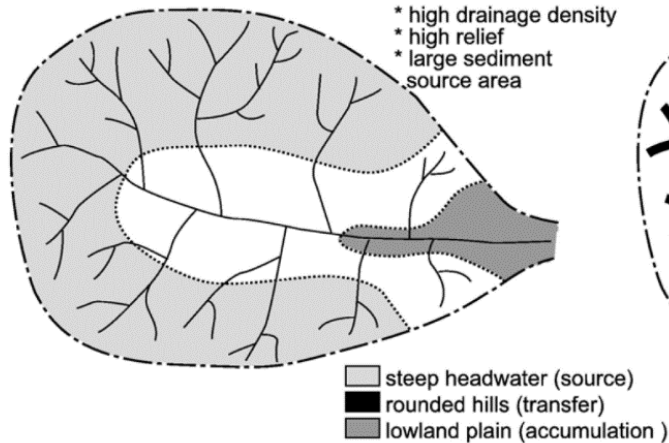


## (c) Effects on water and sediment discharge of the Hoover Dam, Colorado

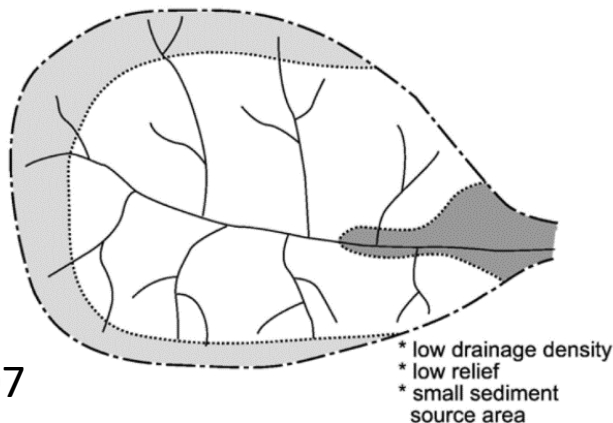


## Landscape units, process zones and drainage density

### (a) High relief, uplifting setting

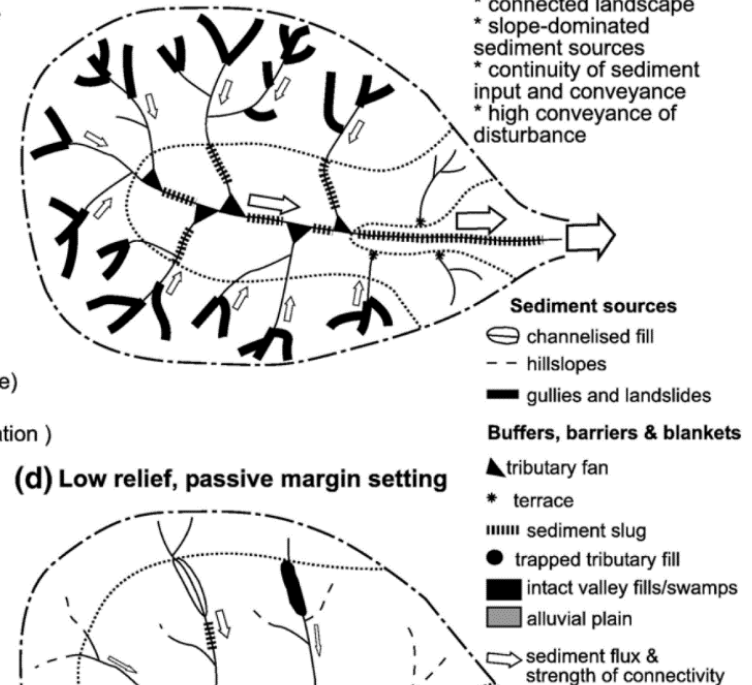


### (c) Low relief, passive margin setting

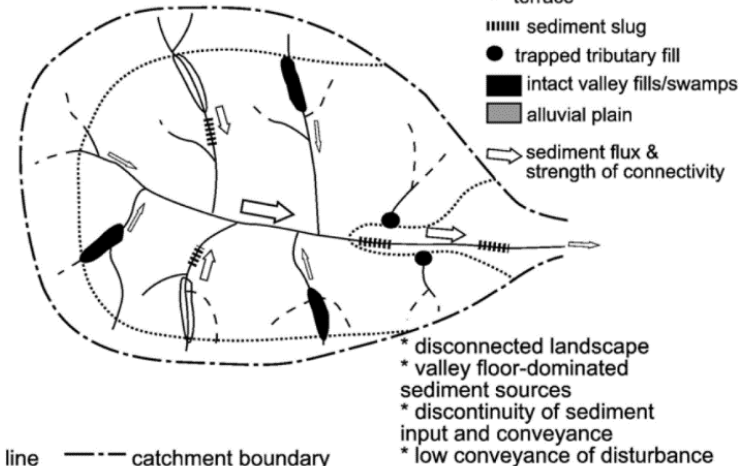


## Buffers, barriers & blankets, sediment flux and strength of connectivity

### (b) High relief, uplifting setting



### (d) Low relief, passive margin setting



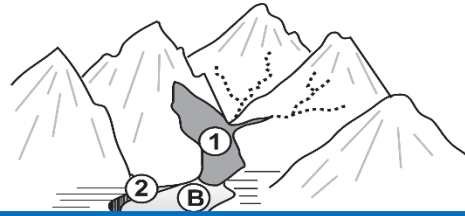
..... process zone boundary    — drainage line    - - - catchment boundary

Downstream changes in linkages

Typical linkages



**Headwaters**

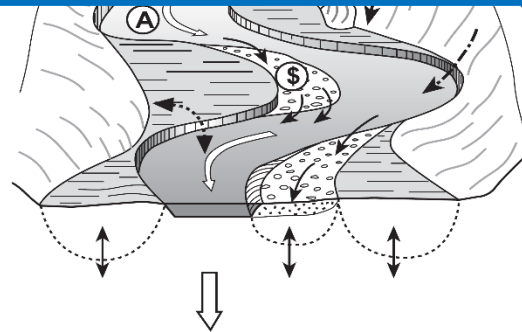


- Source zone
- Hillslopes and channels coupled
- Tributaries and trunk stream connected
- Efficient flow and longitudinal sediment transfer
- Limited vertical connectivity

- **Sedimentablagerung steigend**
- **Sedimente bleiben länger in Speichern**
- **Sedimentenzufuhr sinkend**
- **Verbindung Flußbett – Hang sinkend**
- **Steigende Verbindung Flußbett und Aue**

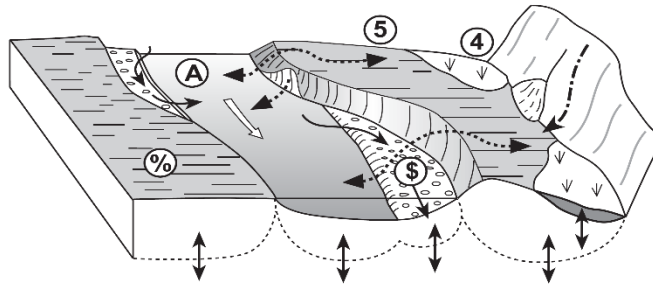
- **Nárůst ukládání sedimentů**
- **Delší čas setrvání sedimentů v zásobnících**
- **Klesající donáška sedimentů**
- **Klesající propojenost koryta a svahů**
- **Rostoucí propojenost koryta a nivy**

increasing sediment storage  
longer residence times of sediments  
decreasing sediment delivery  
increasing hillslope-channel  
increasing channel-floodplain



- Tributaries may be trapped and disconnected from the trunk stream
- Efficient flow and longitudinal sediment transfer
- Channel - floodplain connectivity is irregular
- Irregular vertical exchanges

**Lowland plain**

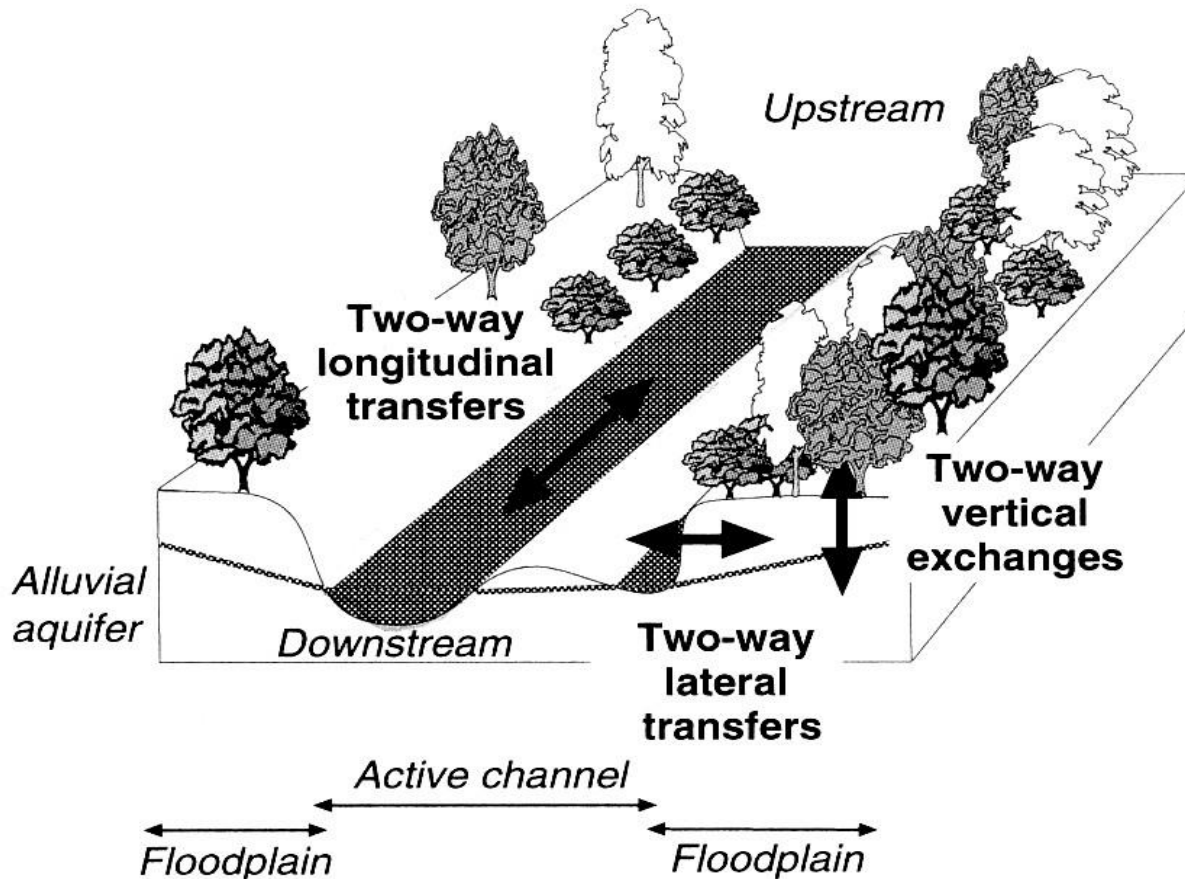


- Accumulation zone
- Hillslopes and channels decoupled
- Tributaries may be trapped or disconnected from the trunk system
- Significant sediment storage
- Inefficient longitudinal sediment transfer
- Channel-floodplain connectivity is high
- Strong vertical connectivity

Longitudinal linkages  
 Vertical linkages  
 Lateral linkage (channel – floodplain)  
 Lateral linkage (hillslope – channel)



# Koncept 3-D Hydrosystem



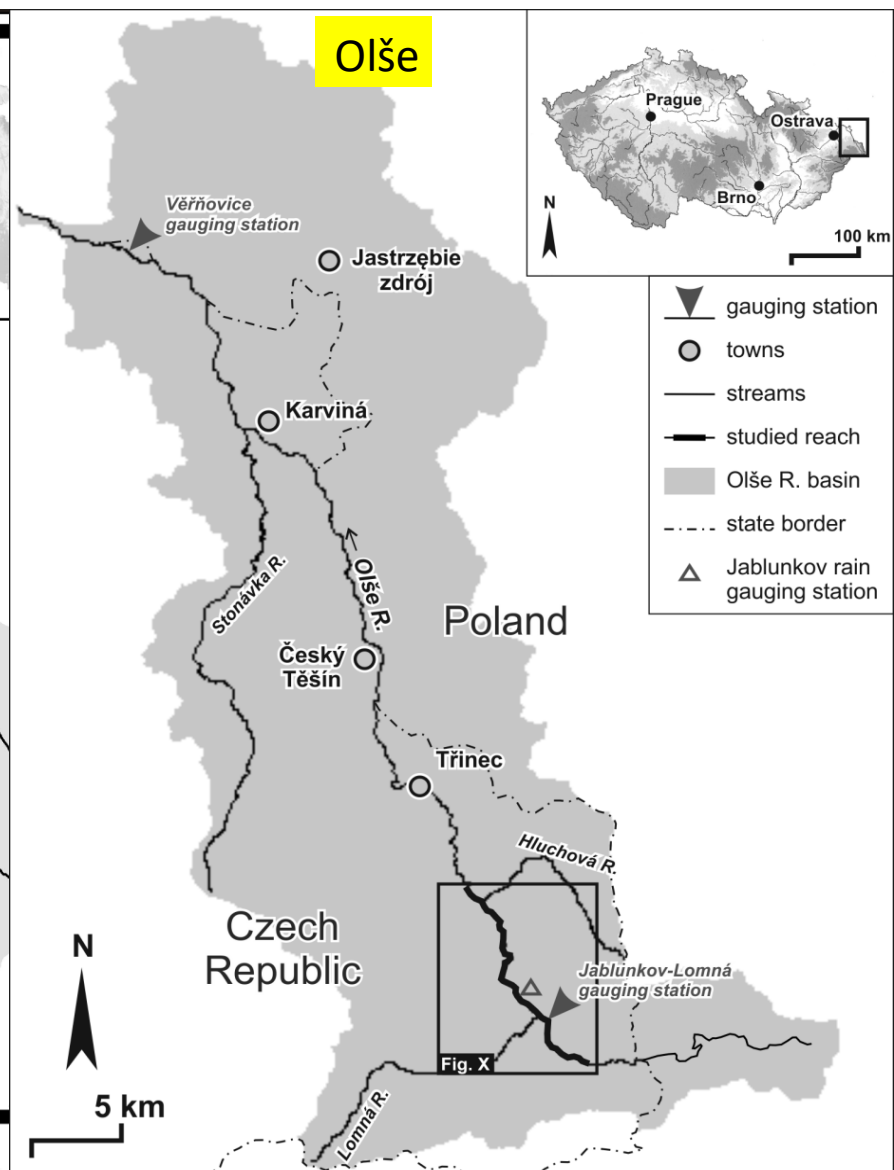
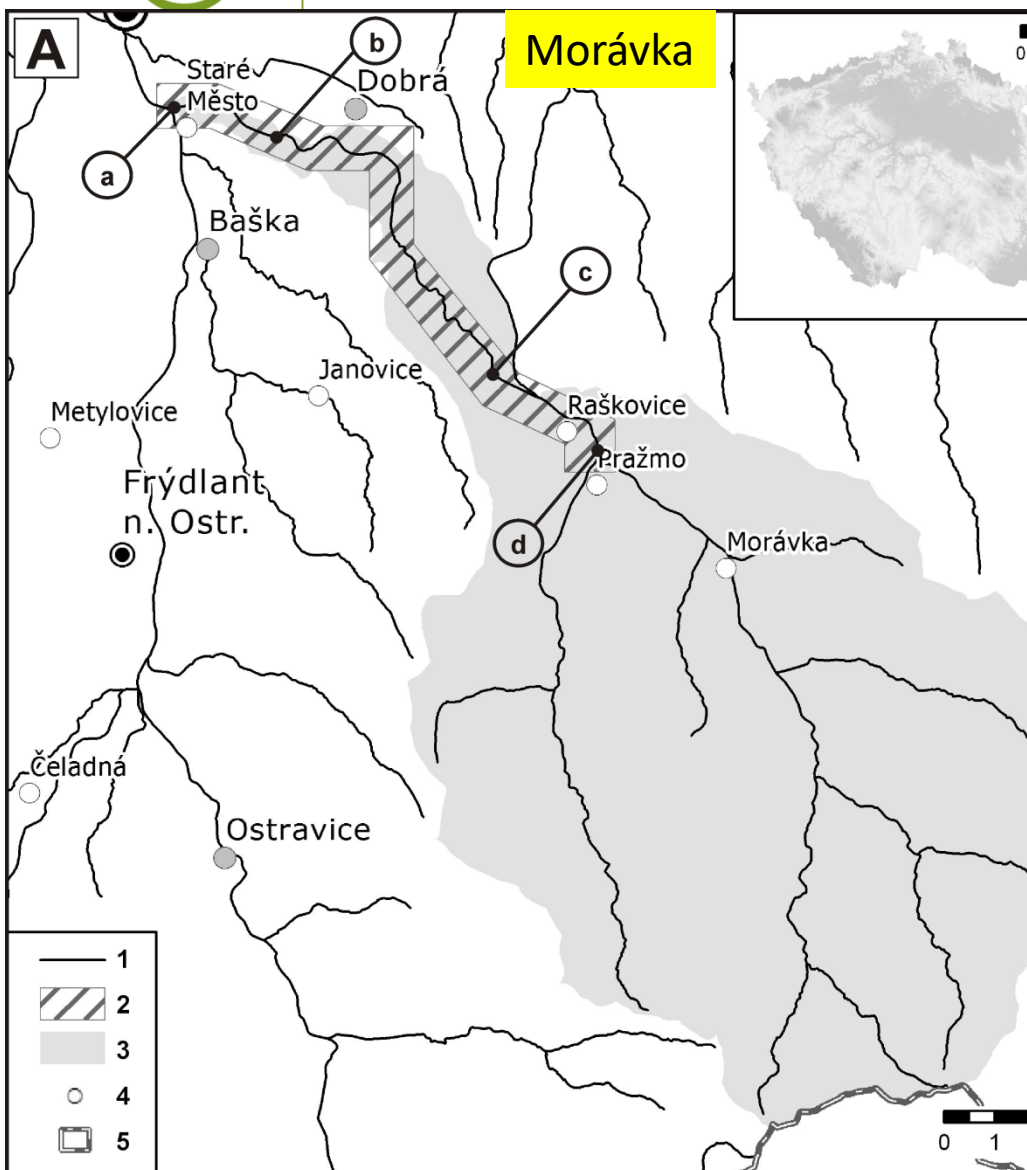
**Figure 5.2** The hydrosystem, a complex system with three bidirectional axes: upstream/downstream, channel/margins, surficial/underground environments





# Ein Paar Beispiele...

# Pár příkladů...



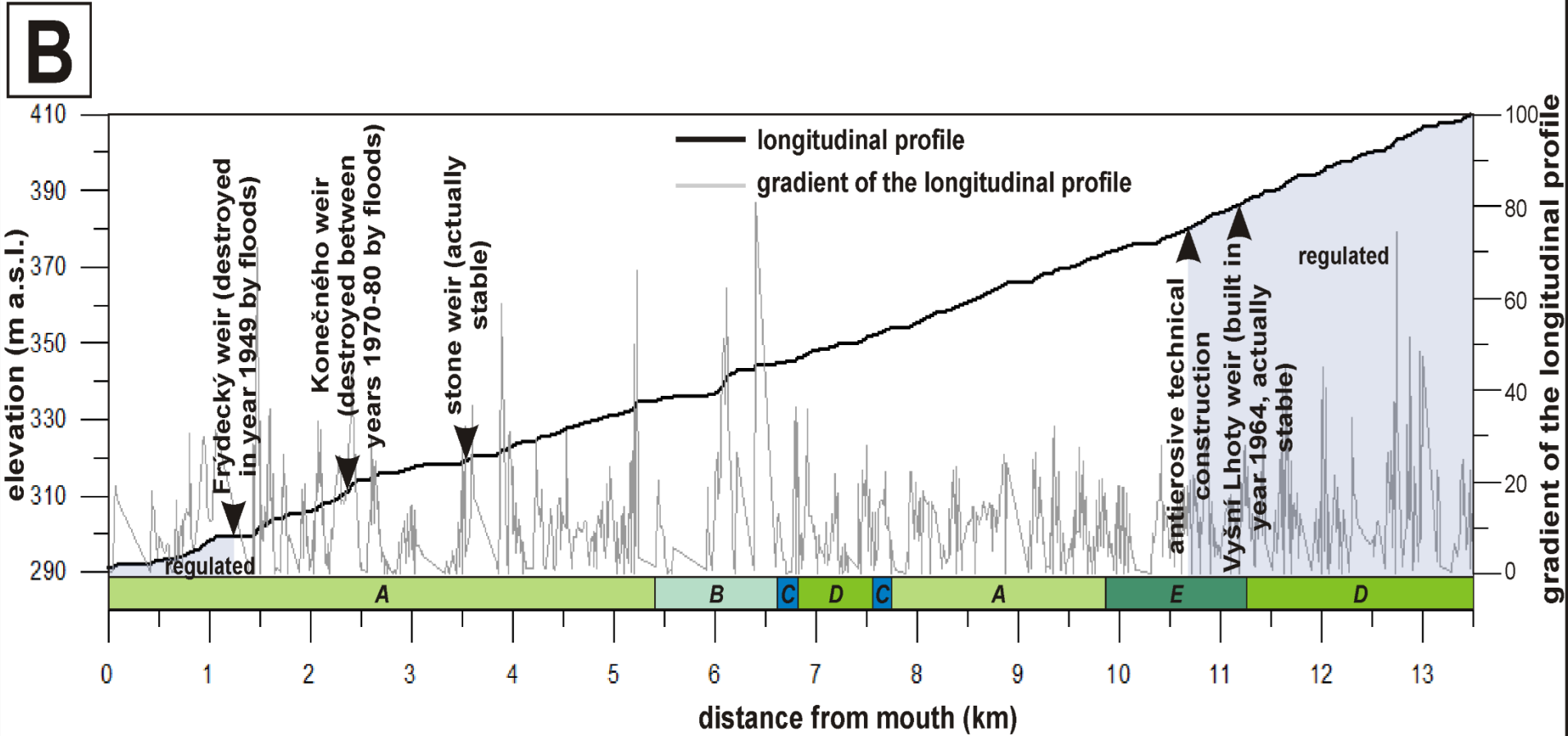
### B





# Bedingungen im Rahmen Laengsprofil

# Podmínky v rámci podélný profil



A Frýdek Formation (sandstone-claystone)

B Lower Těšín Member (clayey units)

C Těšín Limestone

D Těšín-Hradiště Formation (sandst., clayst., congl.)

E Třinec Member (claystones)



# Aktive Flußbettbreite – Verzweigungsindex

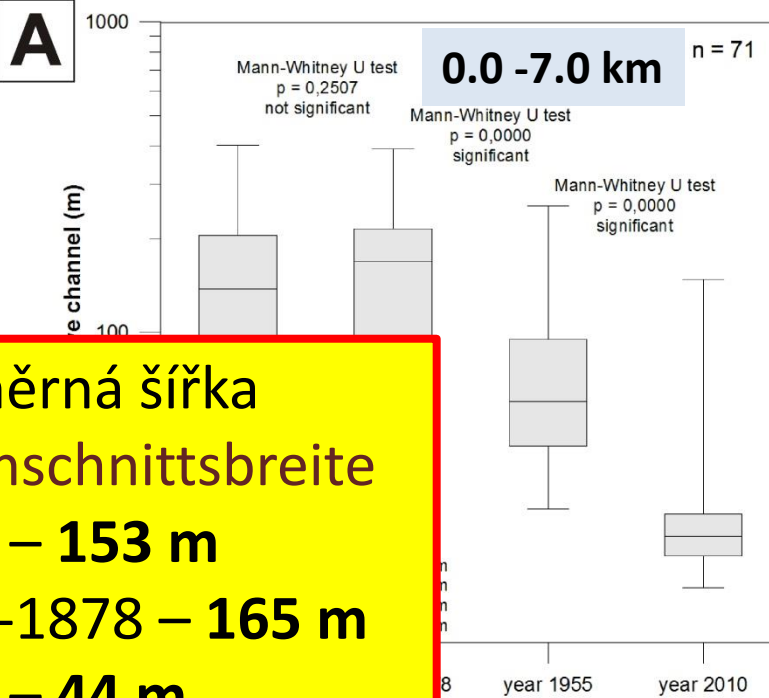
# Aktivní šířka koryta – index větvení



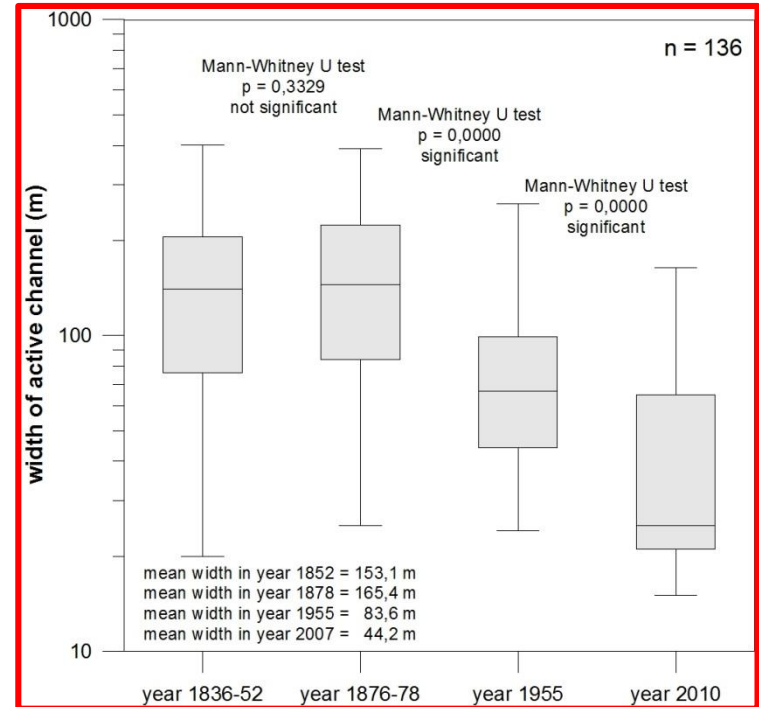
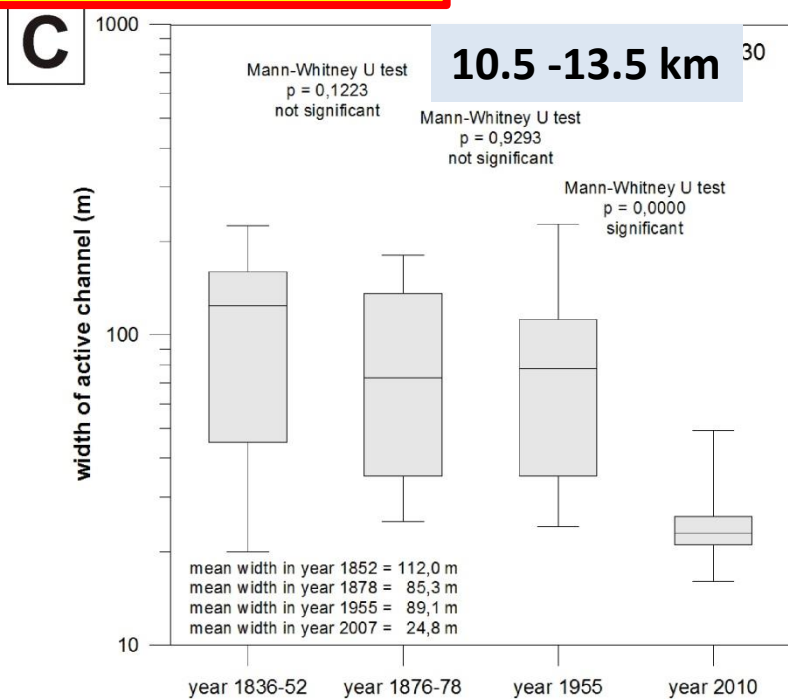
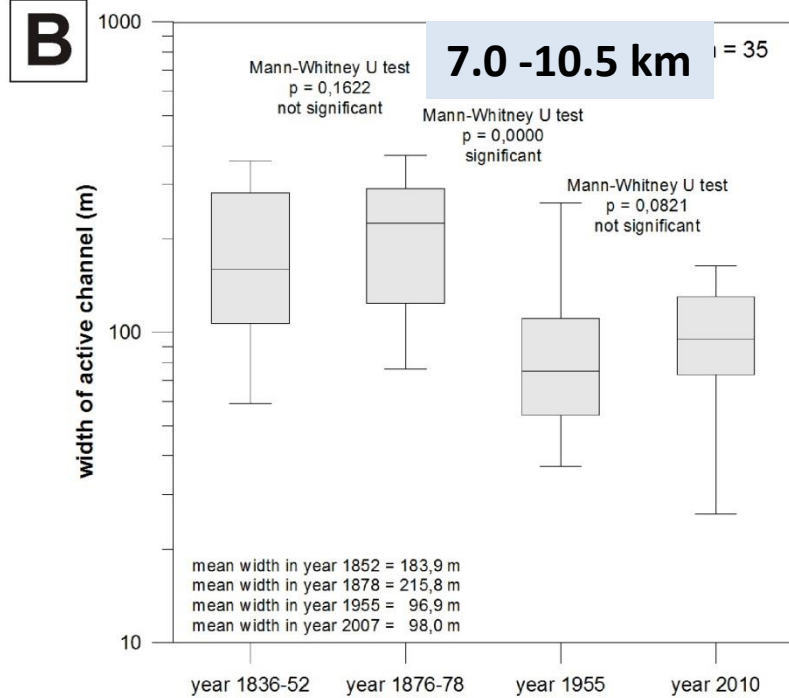
Study reach – distance from mouth (km)	B.I.			
	1836	1877	1955	2010
0,0 - 13,5	1,07	1,19	1,15	0,19
0,0 - 7,0	1,07	1,00	1,27	0,00
7,0 - 10,5	1,29	1,86	1,29	0,71
10,5-13,5	0,80	0,80	0,60	0,00





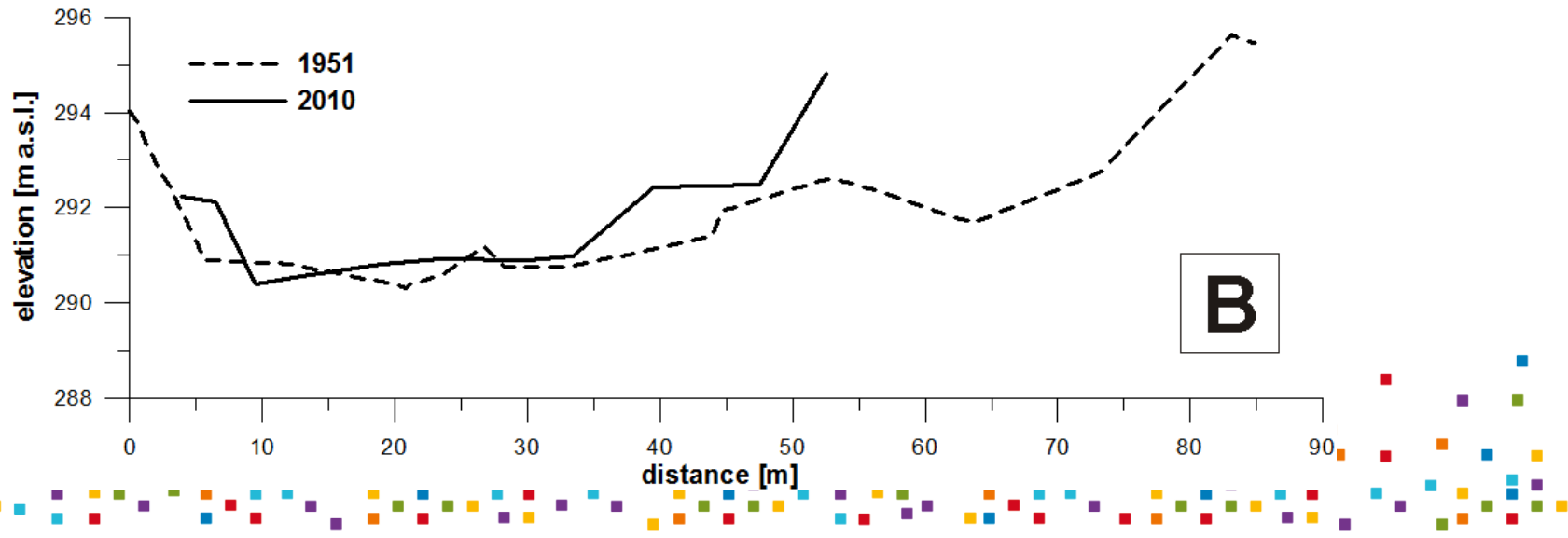
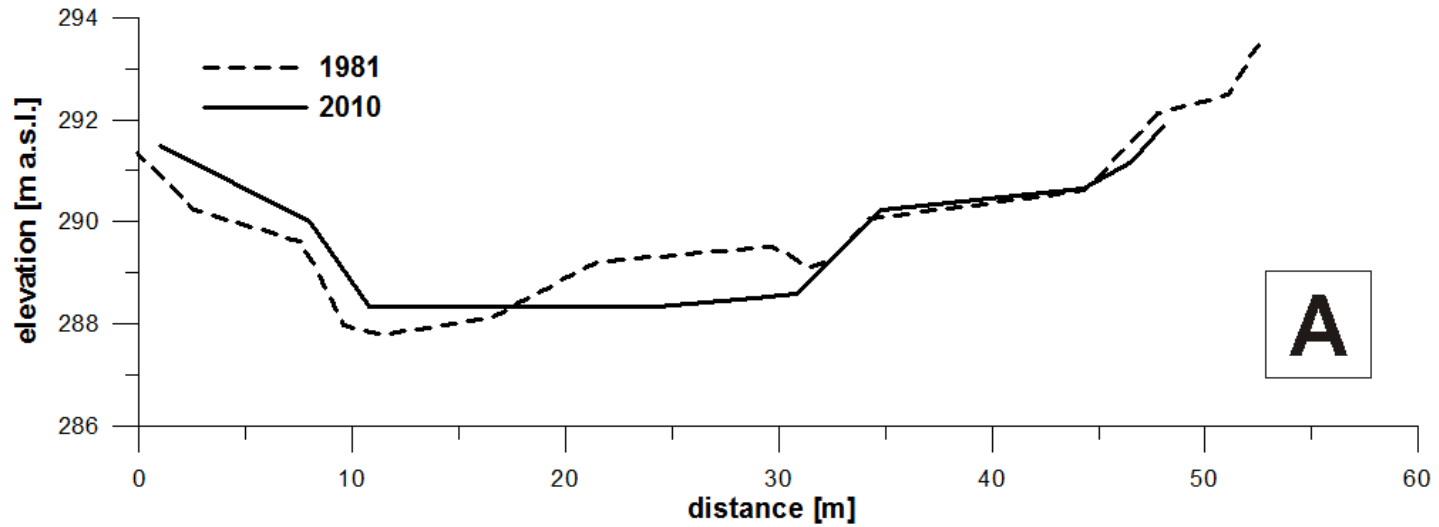


**Průměrná šířka  
Durchschnittsbreite  
1852 – 153 m  
1876-1878 – 165 m  
2010 – 44 m**



# Flußbettmorphologie

# Morfologie koryta



**A**

**1955**



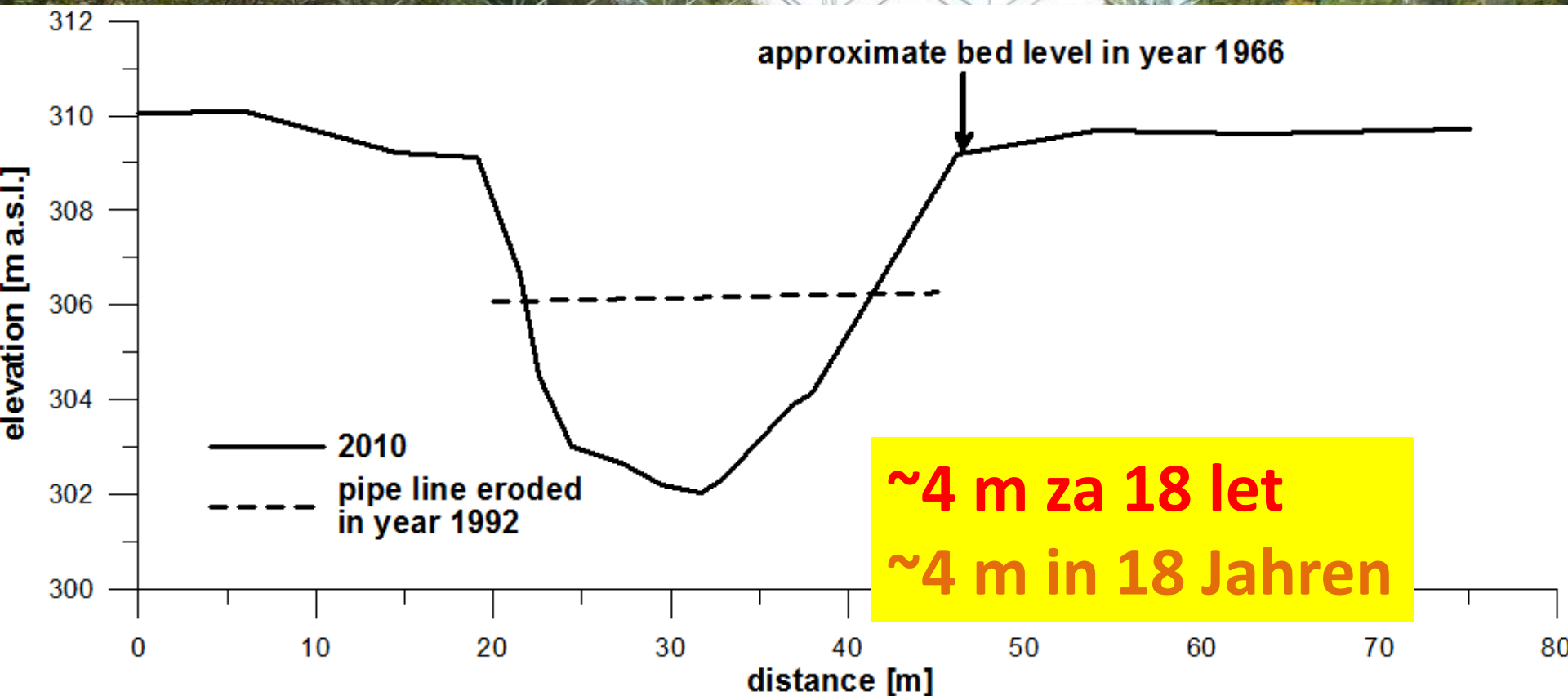
**B**

**2009**



# Intensität der Tiefenerosion

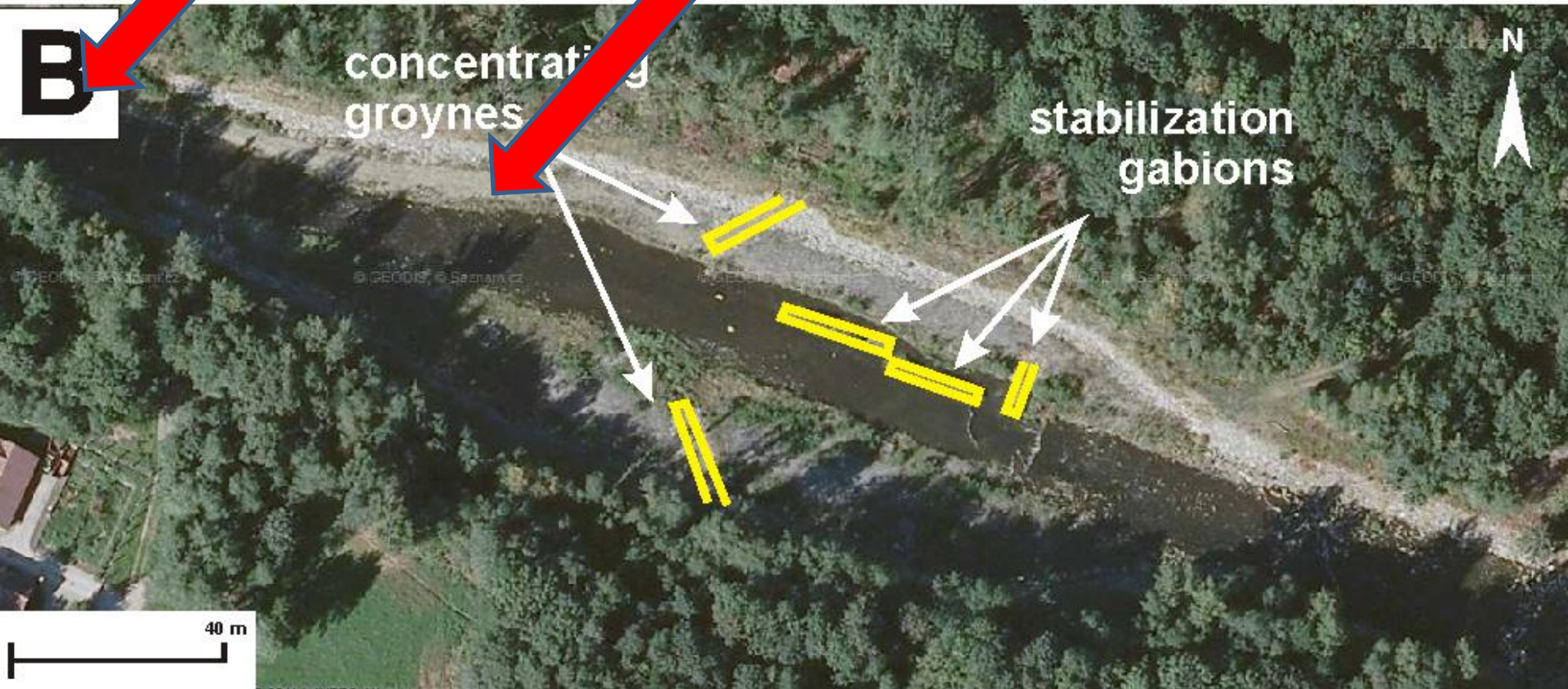
# Intenzita hloubkové eroze





# Monitoring der Flußbettdynamik

# Monitoring dynamiky koryta











???

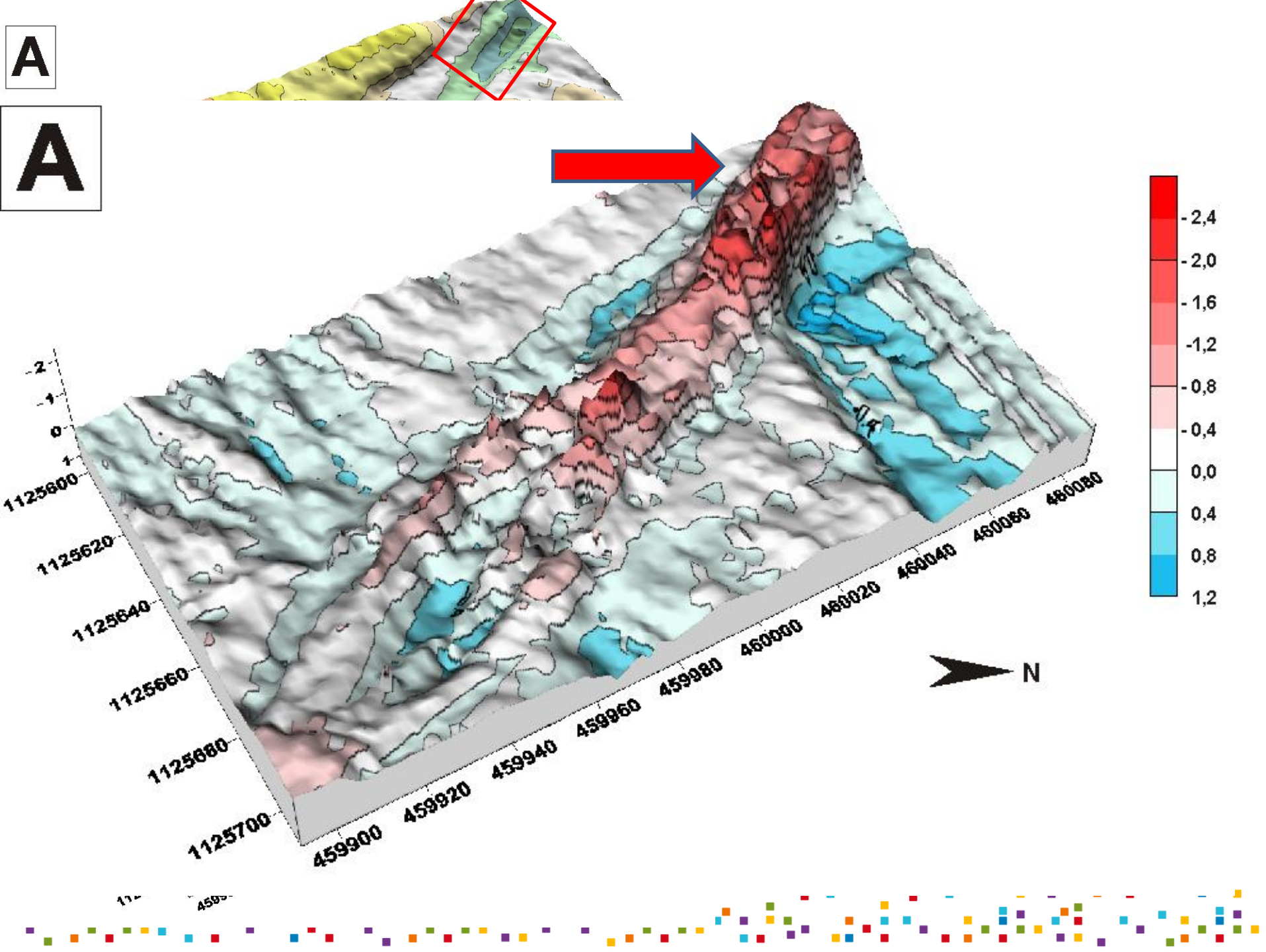




<b>Distance from mouth (km)</b>	<b>9,488</b>	<b>9,538</b>	<b>9,588</b>	<b>9,637</b>	<b>9,687</b>	<b>9,737</b>	<b>9,786</b>	<b>9,837</b>	<b>9,886</b>	<b>9,936</b>	<b>9,985</b>
<b>Average vertical change 2005 – 2010 (m)</b>	-1,01	-0,84	-0,87	-0,84	0,74	-0,08	-0,41	-1,59	-0,78	-2,42	-2,32
<b>Average vertical change 2009 – 2010 (m)</b>	-0,48	-0,87	-0,93	-0,96	-0,66	-0,34	-0,96	-1,62	-0,66	-1,84	-2,29
<b>Distance from mouth (km)</b>	<b>10,04</b>	<b>10,08</b>	<b>10,13</b>	<b>10,18</b>	<b>10,23</b>	<b>10,28</b>	<b>10,33</b>	<b>10,38</b>	<b>10,43</b>	<b>10,48</b>	<b>10,54</b>
<b>Average vertical change 2005 – 2010 (m)</b>	-0,98	-0,52	-0,53	-0,46	-0,99	-0,11	-0,41	-1,77	-0,83	-0,12	-0,82
<b>Average vertical change 2009 – 2010 (m)</b>	-1,36	-1,14	-1,06	-1,37	-1,41	-0,91	-1,21	-2,69	-2,02	-1,23	-1,22

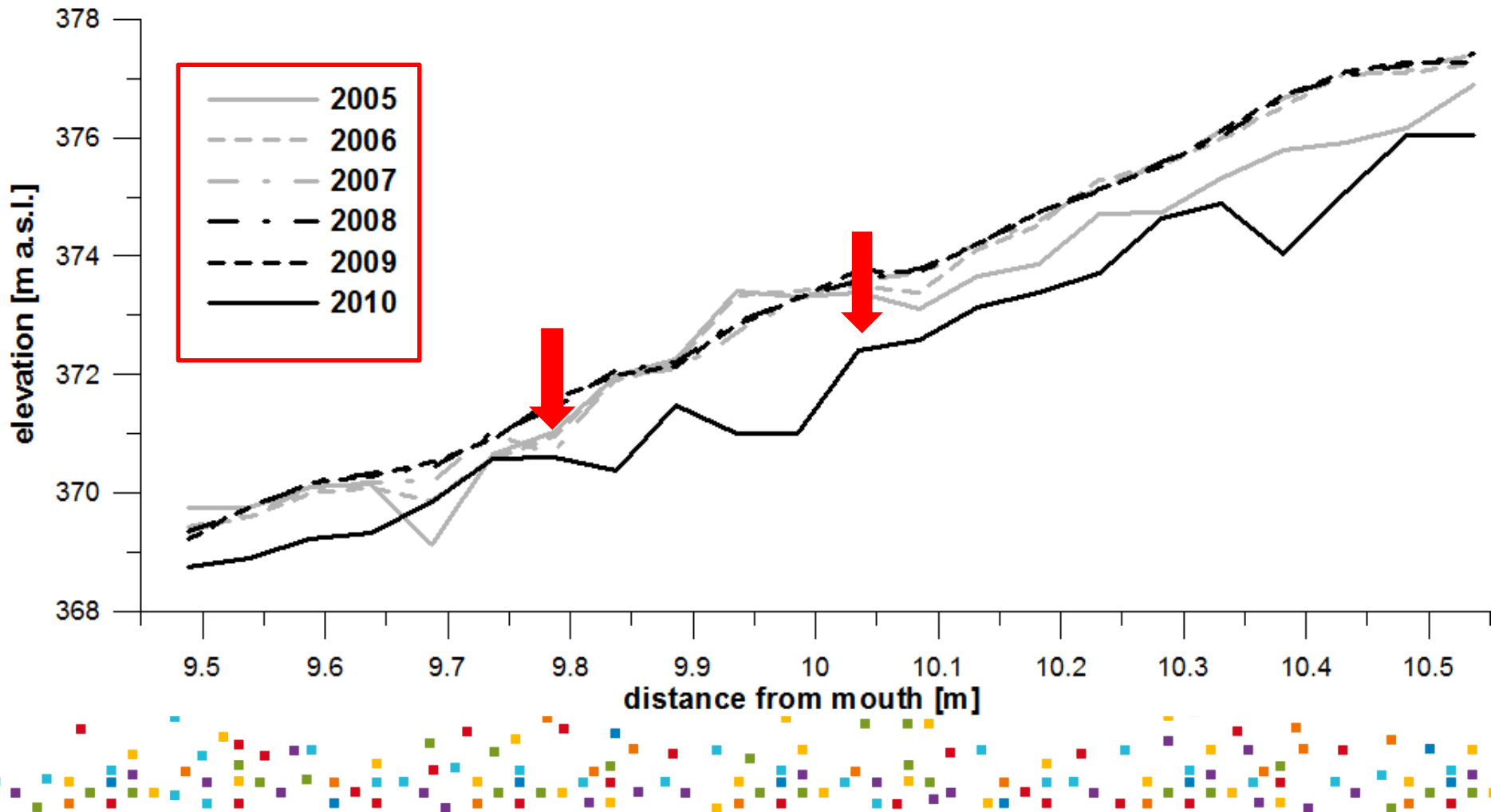




**A****A**

# Änderungen im Längsprofil 9.448 – 10.536

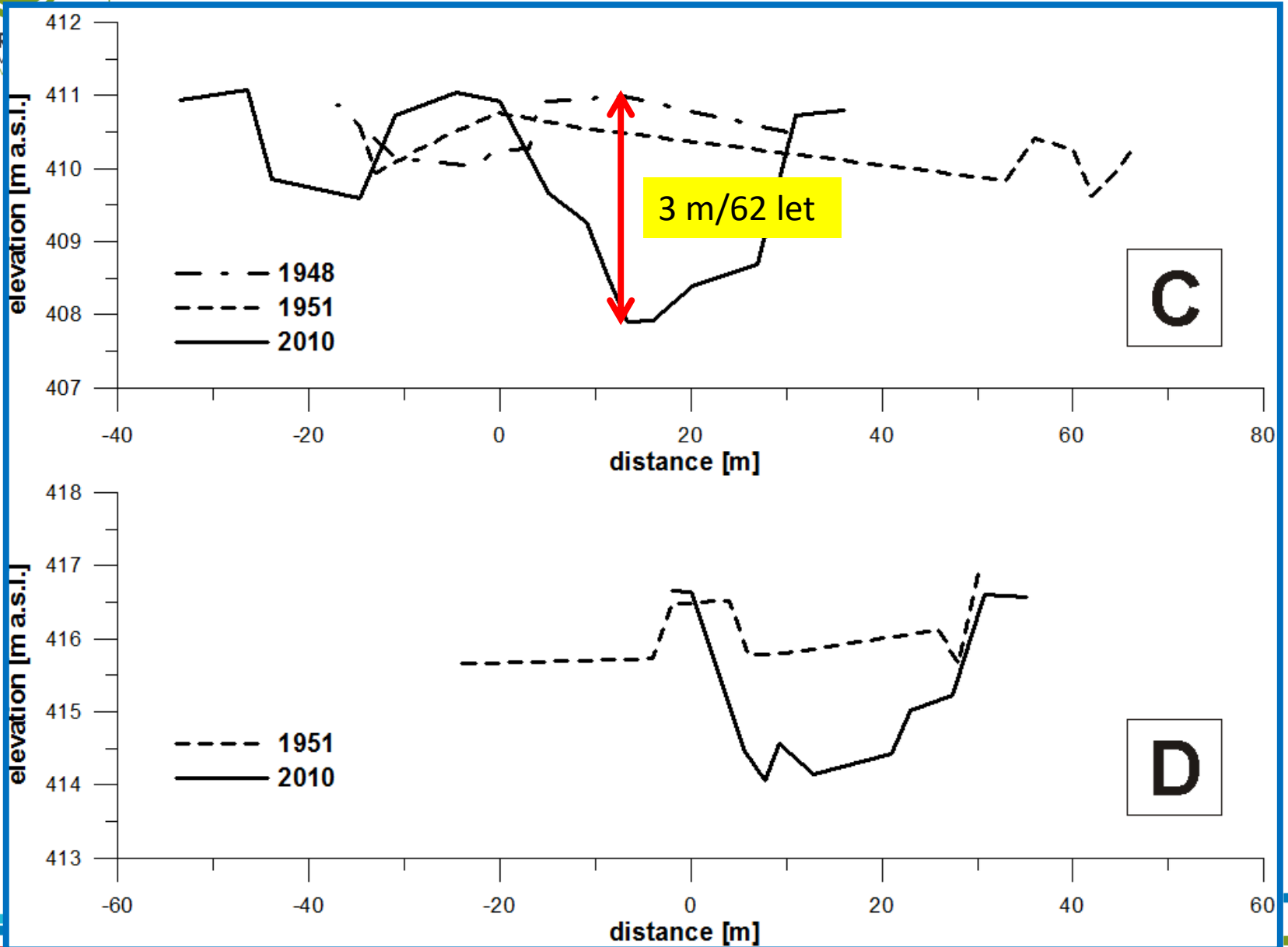
# Změny v podélném profilu 9.448 – 10.536



# Soutok Zusammenfluss Mohelnice + Morávka

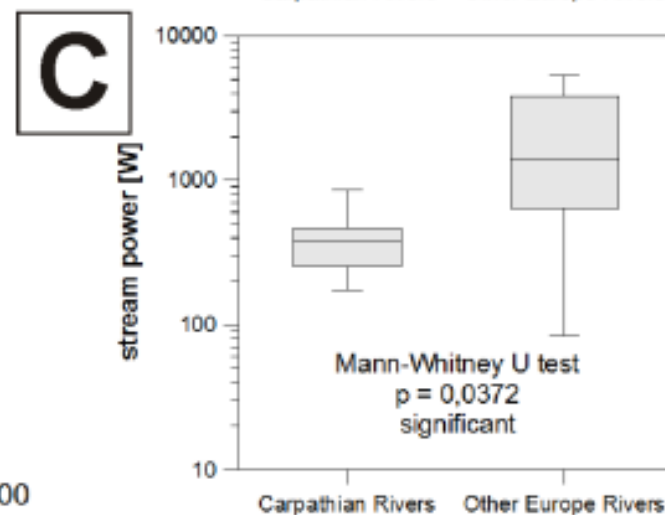
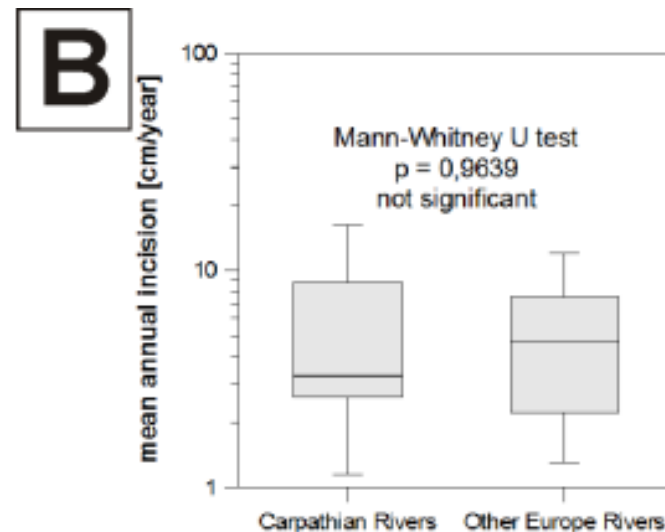
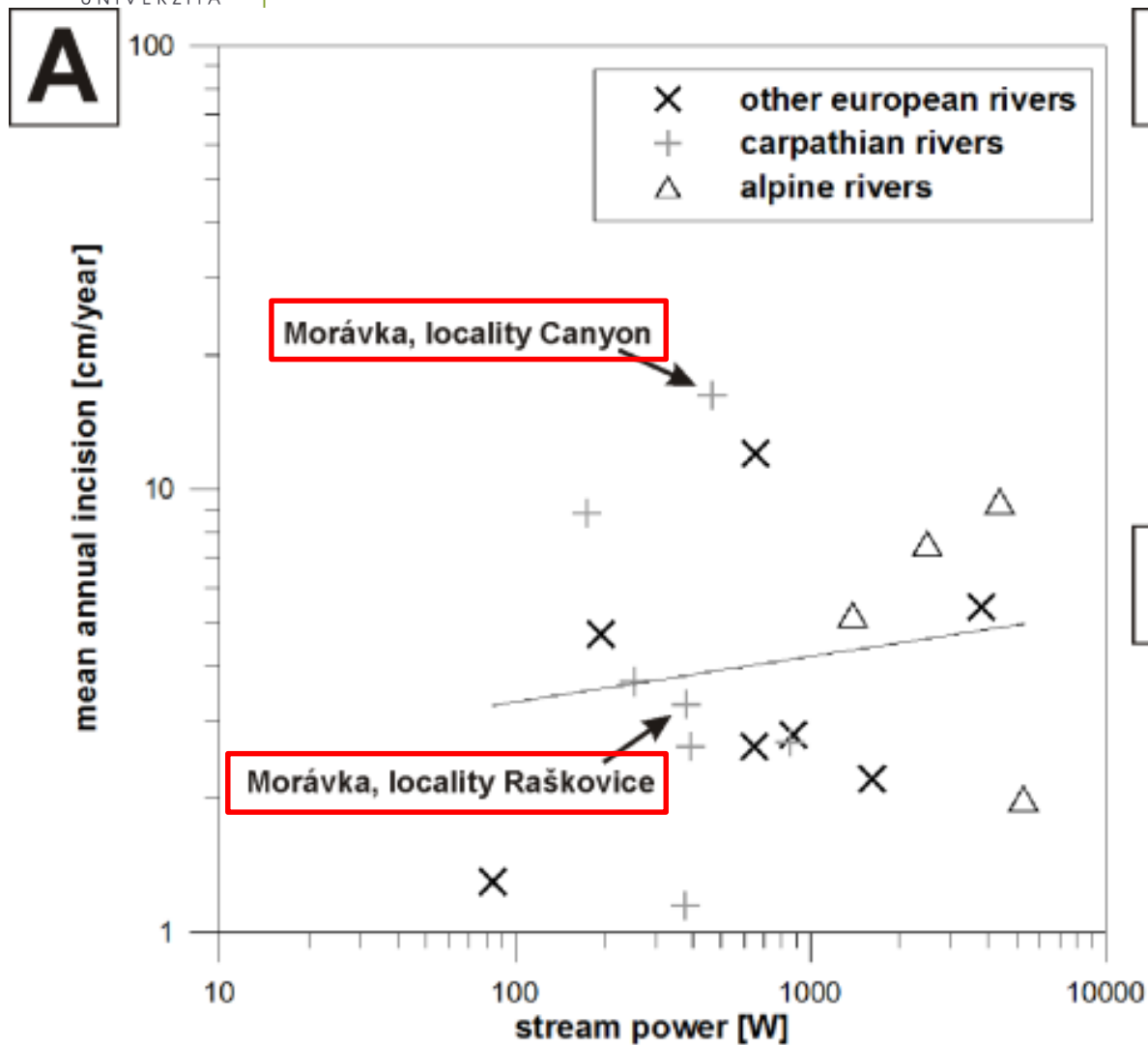


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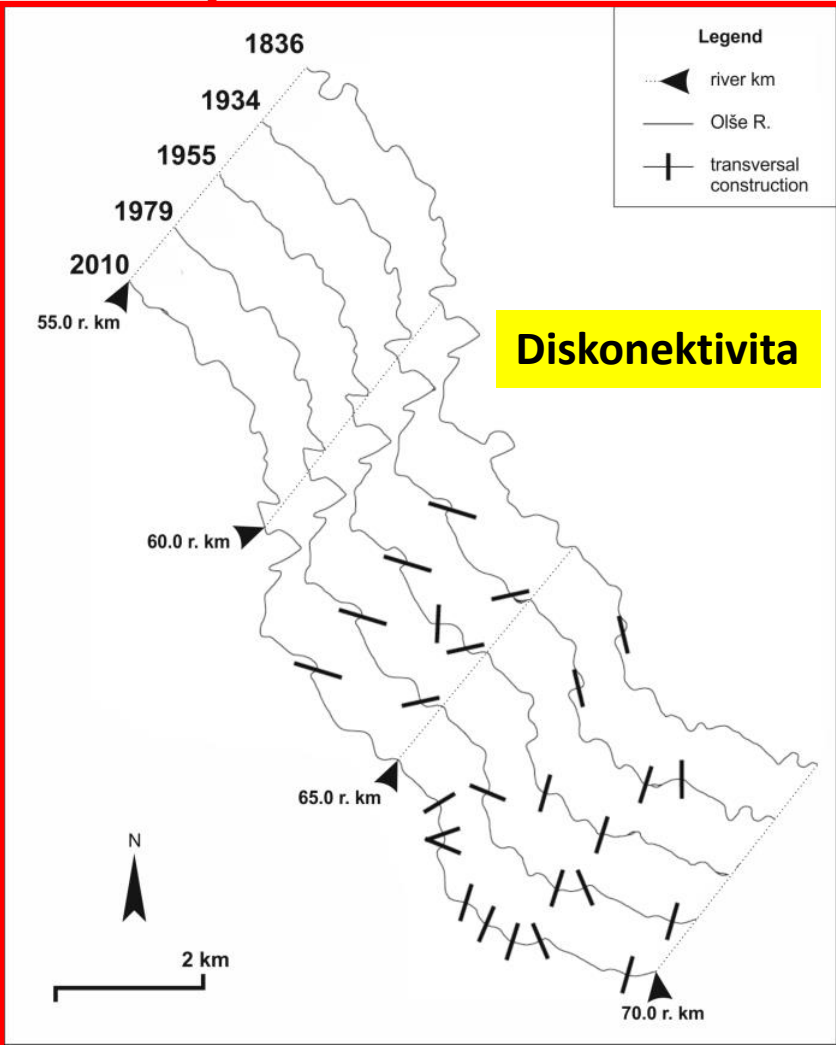
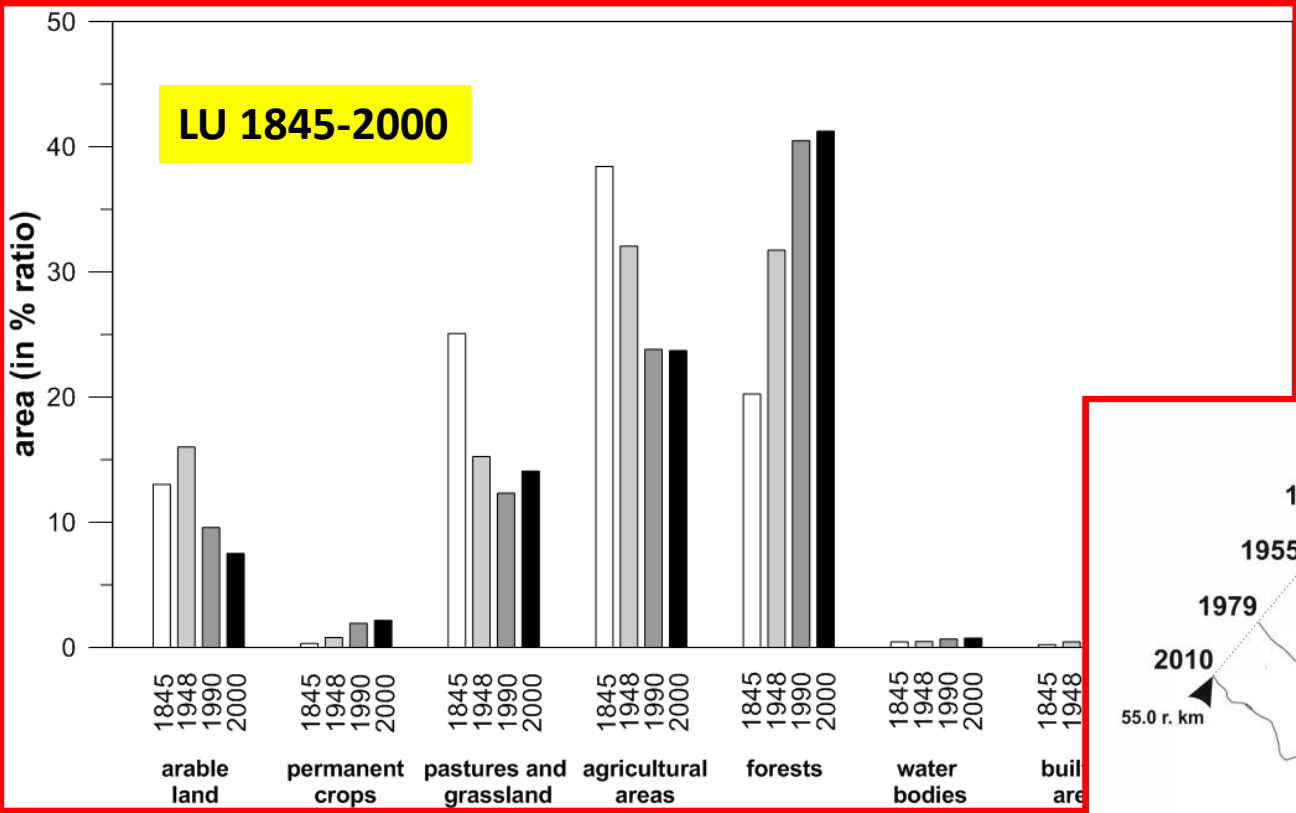


# Vergleich...

# Srovnání...



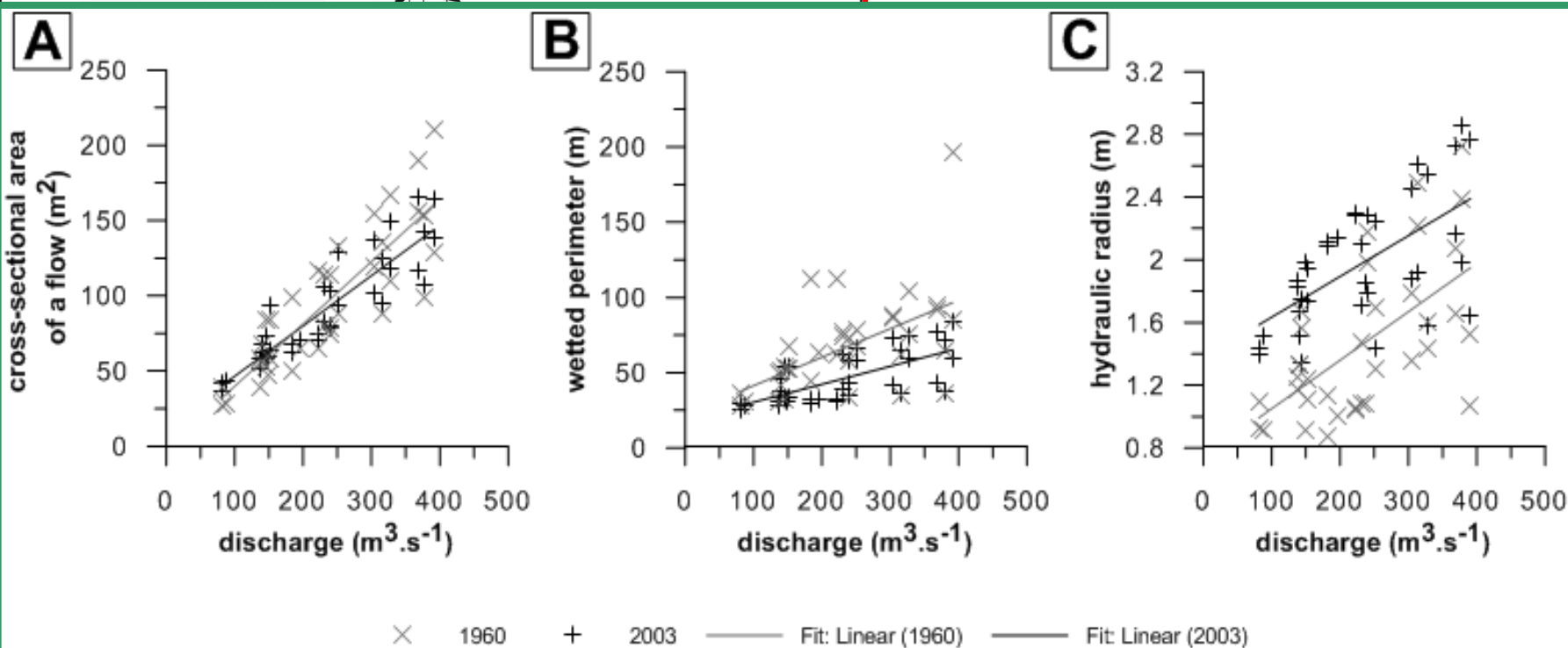
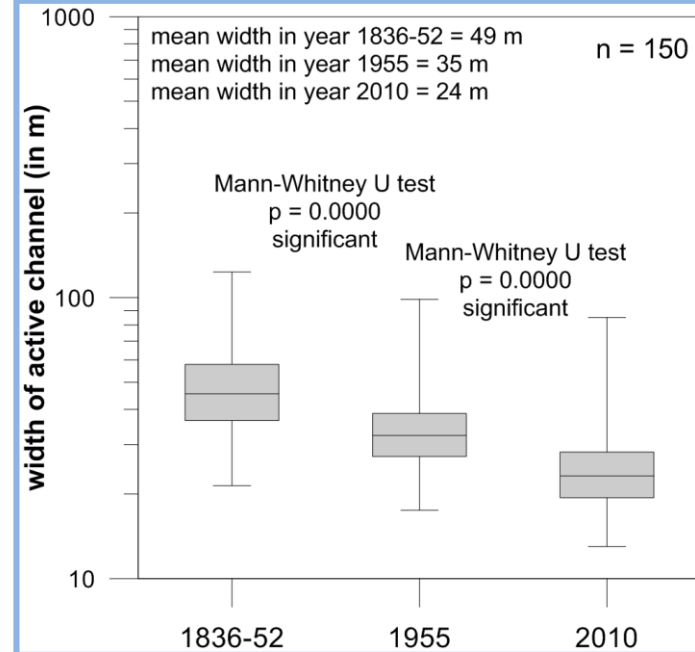
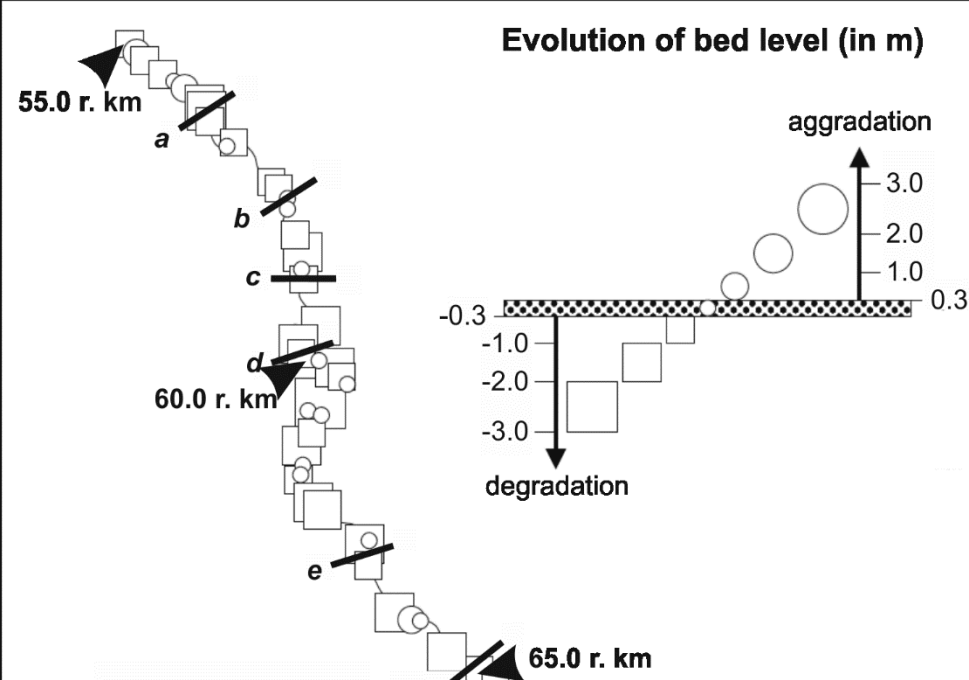
# Olše



**Impulse zur Änderung**

**Impulsy ke změně**

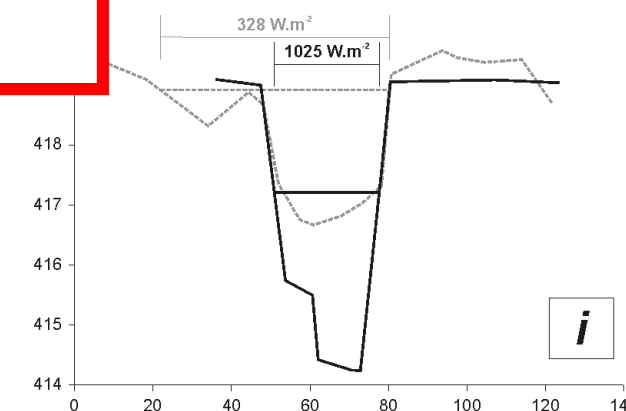
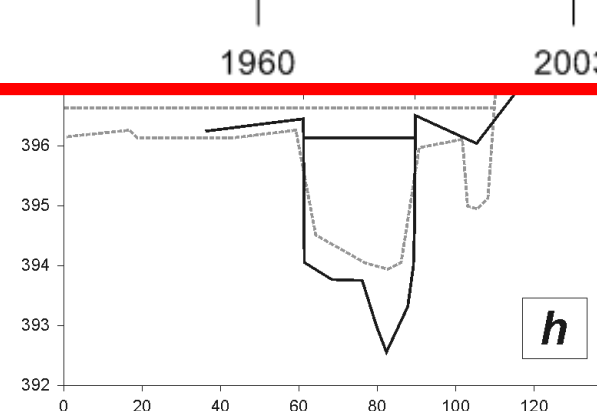
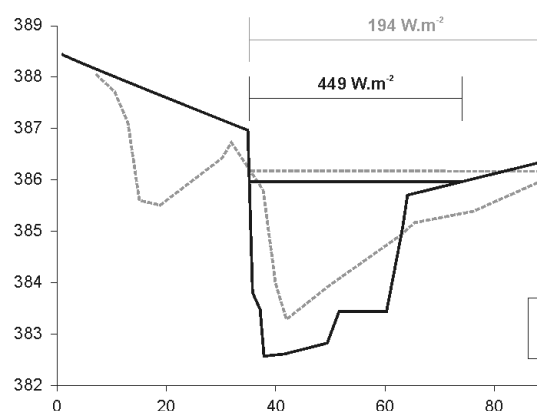
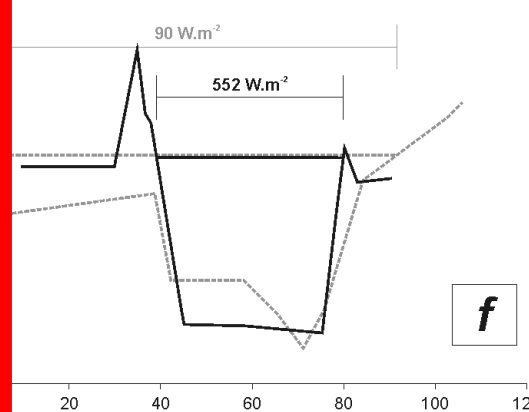
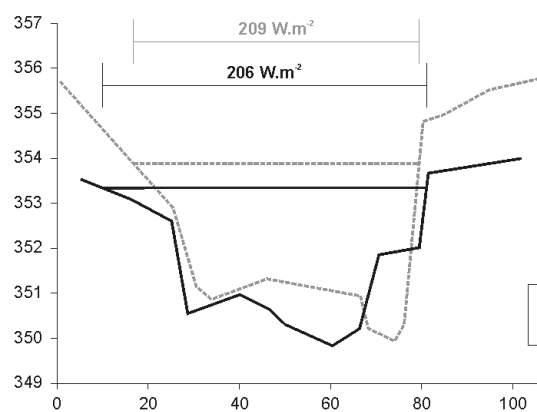
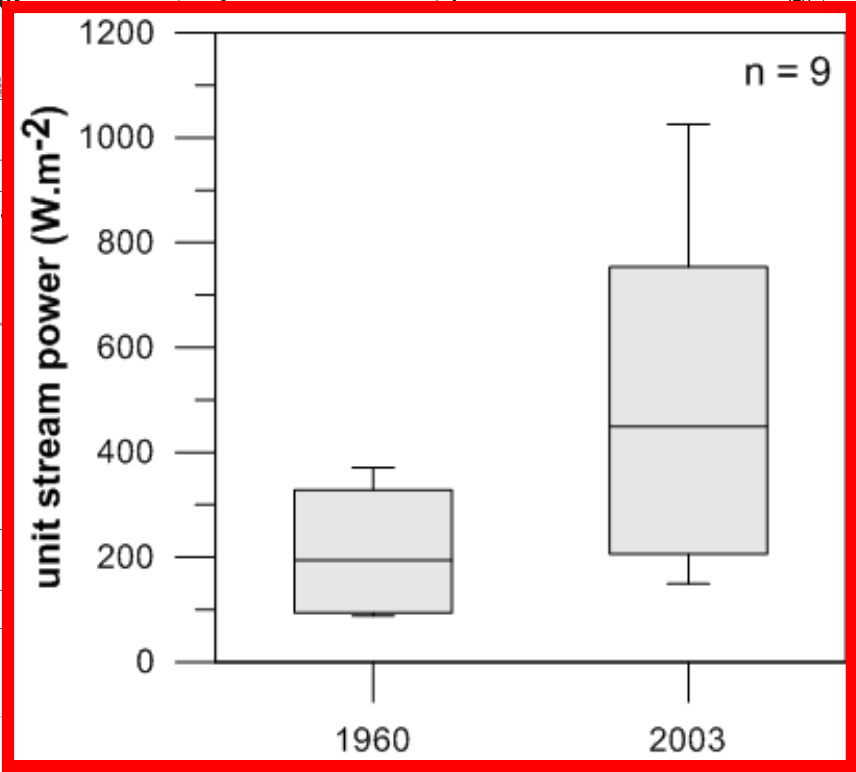
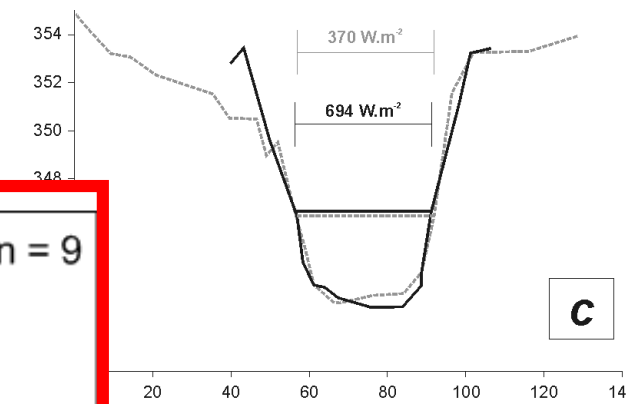
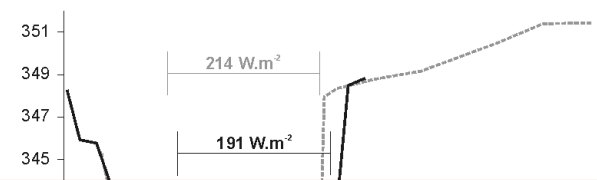
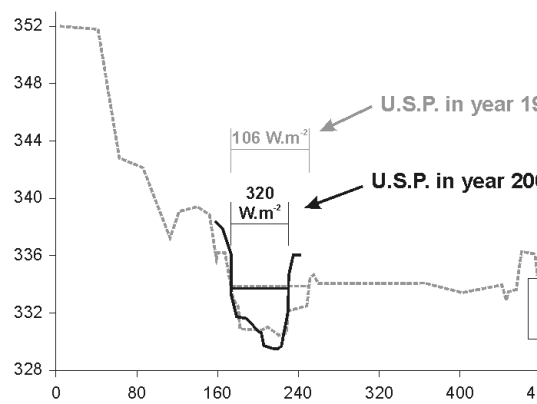




# Einheitsleistung eines Flusses

# Jednotkový výkon toku

$$\omega = (\rho * g * Q * S) / b$$





## Schottertragende Fließgewässer der Beskiden vs. Europa

## Beskydské štěrkonosné toky vs. Evropa

**Table 4**

Documented examples of the vertical change of bed level and basic characteristics of selected European rivers.

River	Region	Locality	Mean annual incision (cm/year)	Channel slope – S (m/m)	Drainage area – A (km <sup>2</sup> )	Mean annual discharge – (m <sup>3</sup> s <sup>-1</sup> )
Drome	Alps (France)	Upstream reach	5.22	0.007500	1147	18.6
Brenta	Alps (Italy)	Barziza	7.54	0.003500	1567	71.0
Piave	Alps (Italy)	Lower course	2.00	0.004000	3899	132.0
Tagliamento	Alps (Italy)	Lower course	9.38	0.004000	2580	109.0
Arno	Apennines Mts. (Italy)	Lower Valdarno	4.70	0.000200	8186	97.4
Arno	Apennines Mts. (Italy)	Upper Valdarno	2.79	0.001540	4080	56.7
Reno	Apennines Mts. (Italy)	Lower course	5.43	0.009000	3410	42.0
Morávka	Carpathian Mts. (Czech)	Lower reach	16.27	0.012435	146	3.7
Morávka	Carpathian Mts. (Czech)	Upper reach	3.27	0.010166	129	3.74
Dunajec	Carpathian Mts. (Poland)	Golkowice	1.15	0.001000	2047	37.8
Dunajec	Carpathian Mts. (Poland)	Zabno	2.68	0.001000	6735	85.5
Wisloka	Carpathian Mts. (Poland)	Labuzie	8.85	0.000656	2546	26.7
Skawa	Carpathian Mts. (Poland)	Wadowice	2.63	0.003100	835	12.7
Raba	Carpathian Mts. (Poland)	Gdów	3.68	0.001970	768	12.9
Wisloka	Carpathian Mts. (Poland)	Zolkow	4.67	0.003000	581	8.1
Tordera	Catalan Coastal Range (Spain)	Blanes Bridge	1.30	0.002000	894	4.2
Ain	Jura Mts. (France)	Lower course	2.22	0.001250	3672	130.0



**Postglacial River Incision French Western Alps 190 kyr of ~0.8 mm. yr<sup>-1</sup>  
(Brocard et al. 2003)**

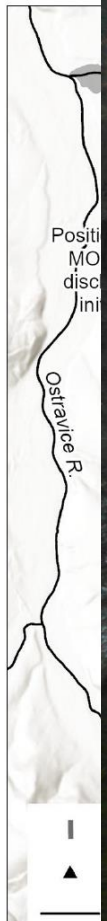
**Bedrock incision of Indus Basin rivers 0,1-1,2 cm per year (Leland et al. 1998)**



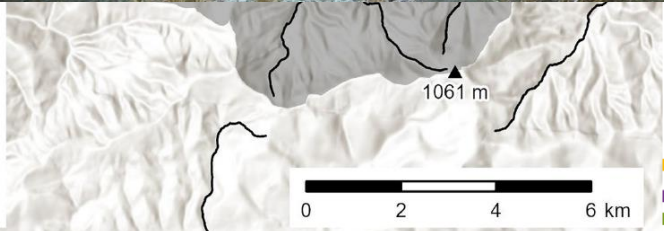


# Morávka erneut

# Morávka ještě jednou



-  nature reserve
-  Morávka Valley dam
-  Morávka R. basin
-  gauging station
-  cross-sections MOR1-3



Ecological Engineering  
 journal homepage: [www.elsevier.com/locate/ecoleng](http://www.elsevier.com/locate/ecoleng)

Degradation of multi-thread gravel-bed rivers in medium-high mountain settings: Quantitative analysis and possible solutions

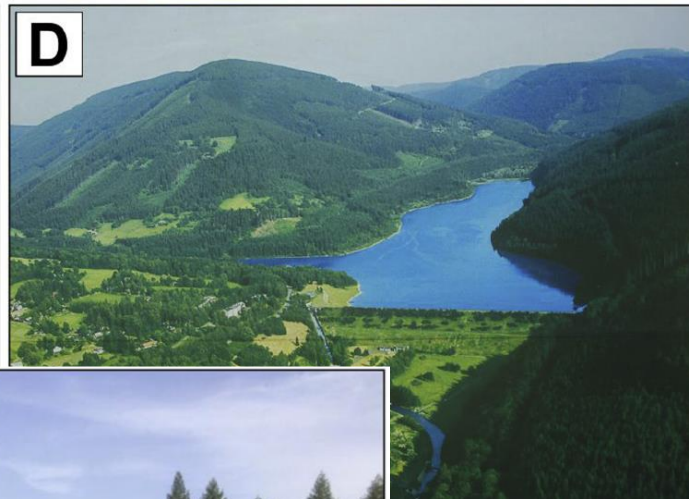
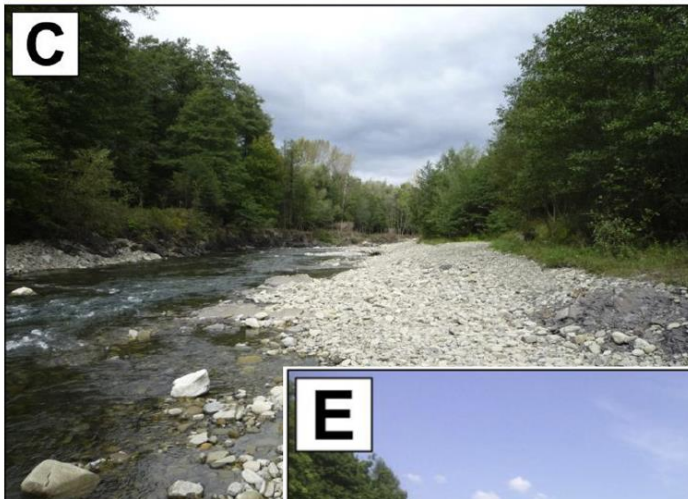
Václav Škarpich\*, Tereza Macurová, Tomáš Galia, Stanislav Ruman, Jan Hradecký  
 Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, Chimistho 10, 710 00 Ostrava, Czech Republic





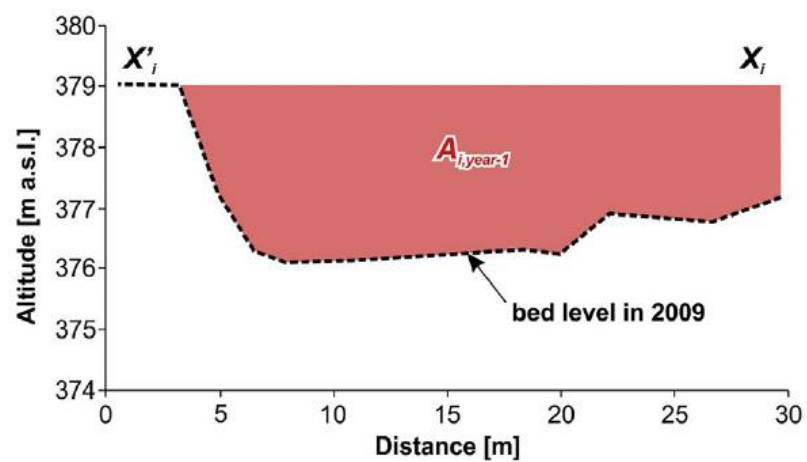
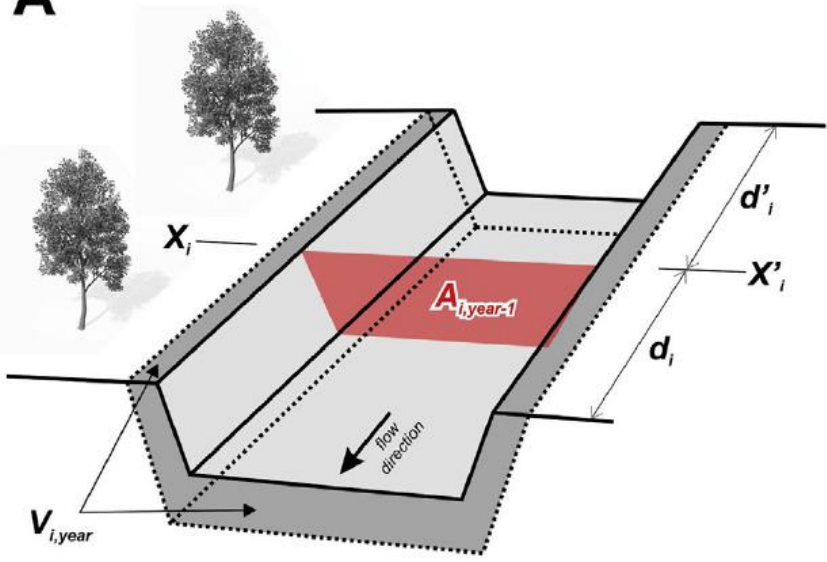


OSTRAVSKÁ  
UNIVERZITA  
PŘÍRODOVĚDECKÁ FAKULTA

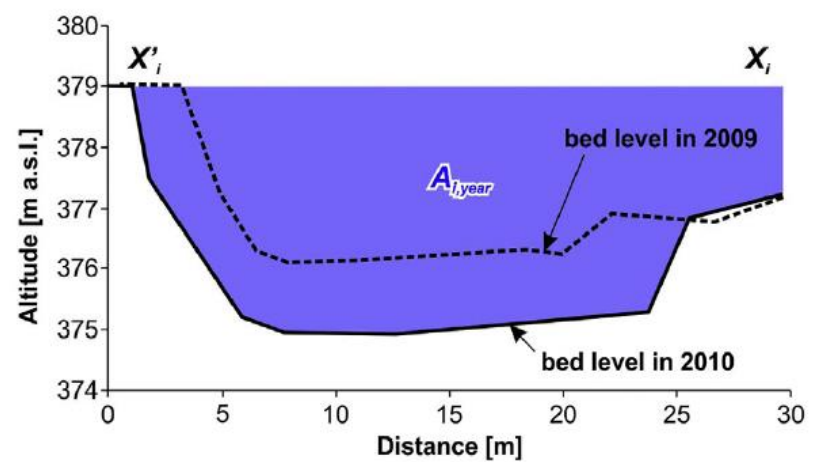
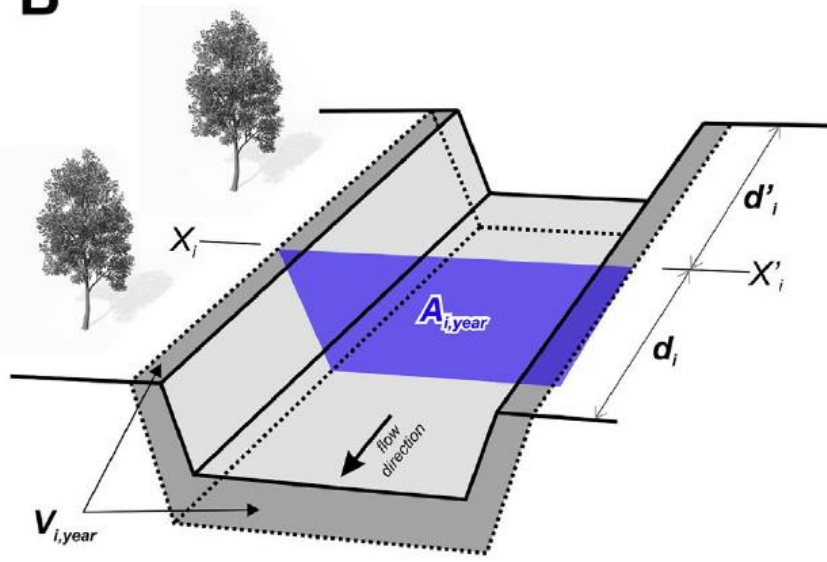




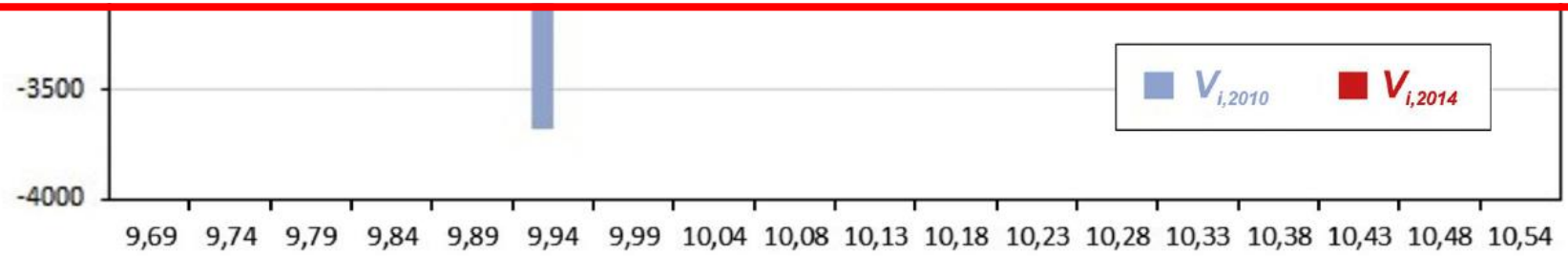
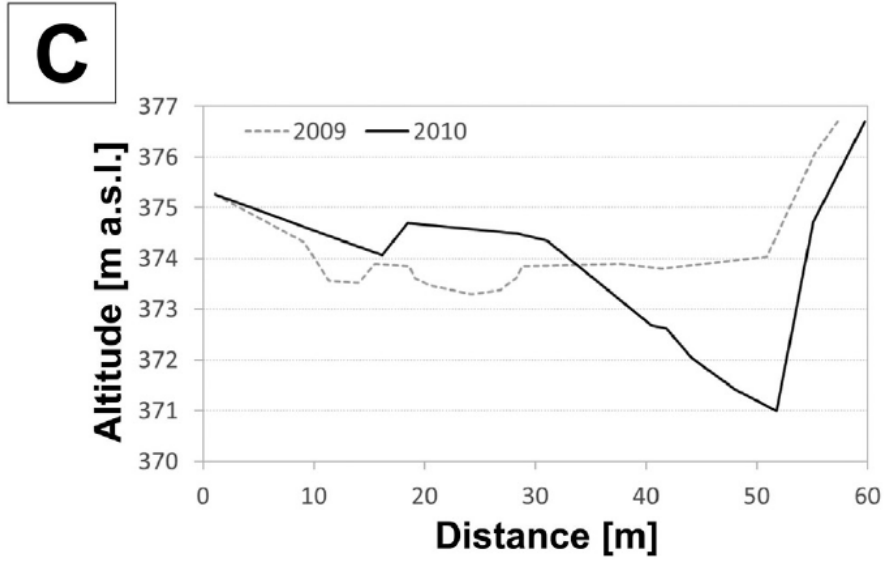
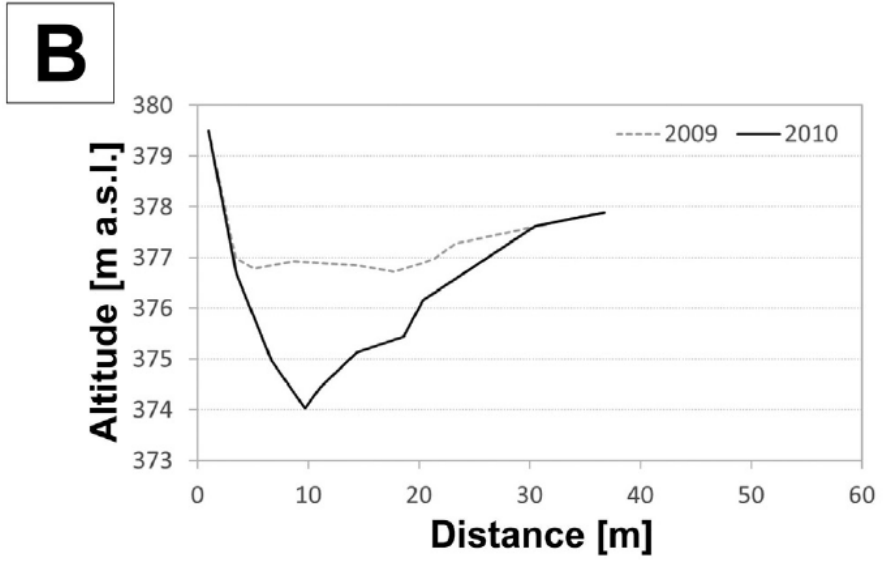
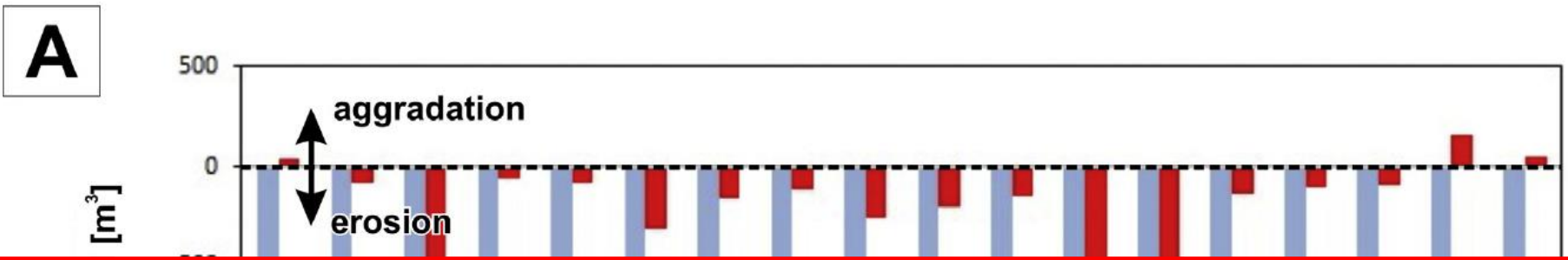
**A**



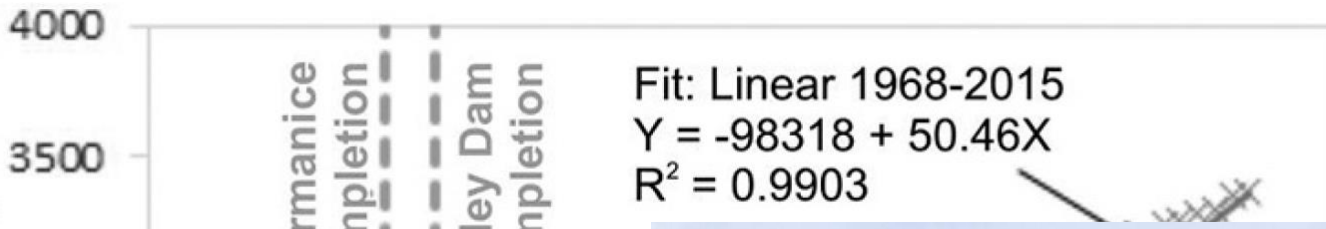
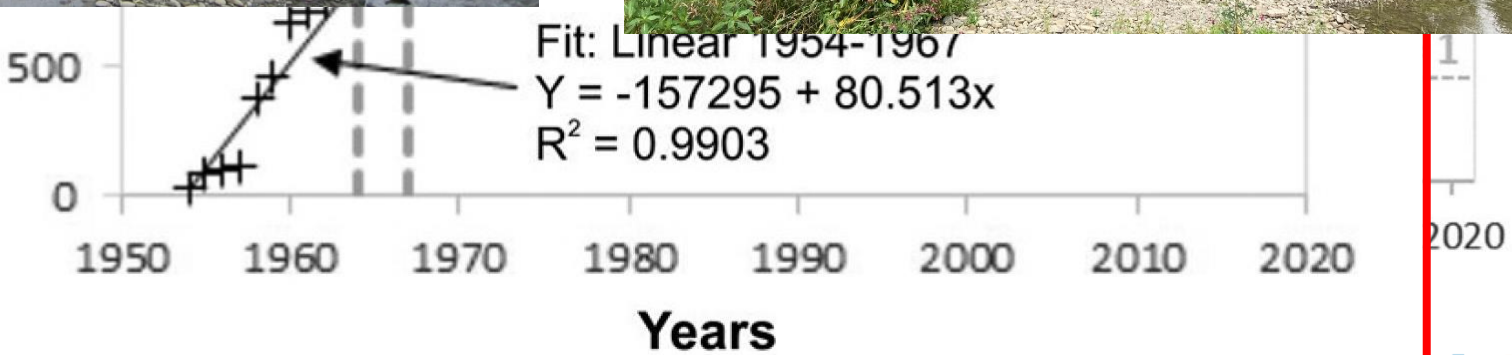
**B**









**A****B**Annual  
280  
300Annual  
280  
300Annual  
0  
20  
40  
60Annual  
0  
20  
40  
60

2020





## Mountain steep confined stream

## Foothill unconfined stream

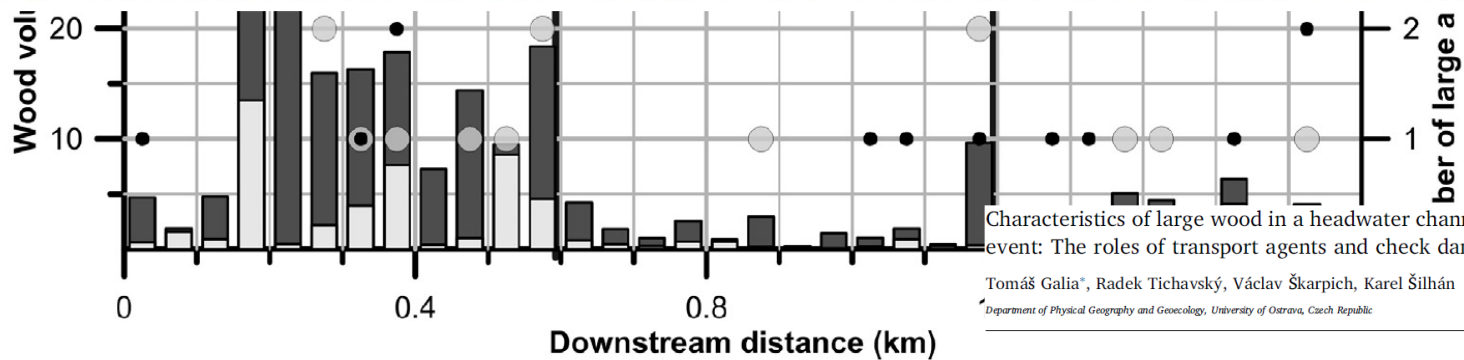
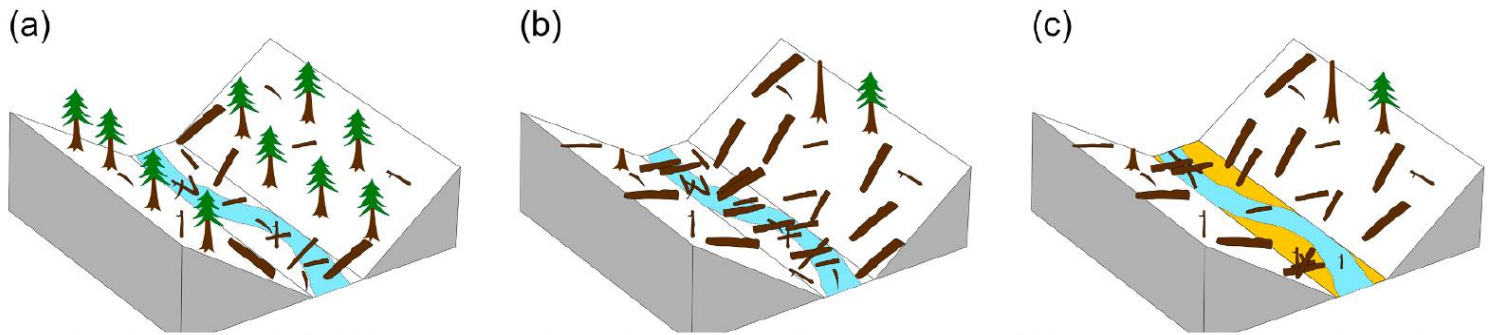


preservation of cross-sectional geometry  
lowering of bed slope and bed amplitudes  
lacks of very fine and very coarse bed particles

loss of longitudinal channel units (pools, riffles)  
degraded cross-sectional heterogeneity  
no significant change in bed material







Characteristics of large wood in a headwater channel after an extraordinary event: The roles of transport agents and check dams

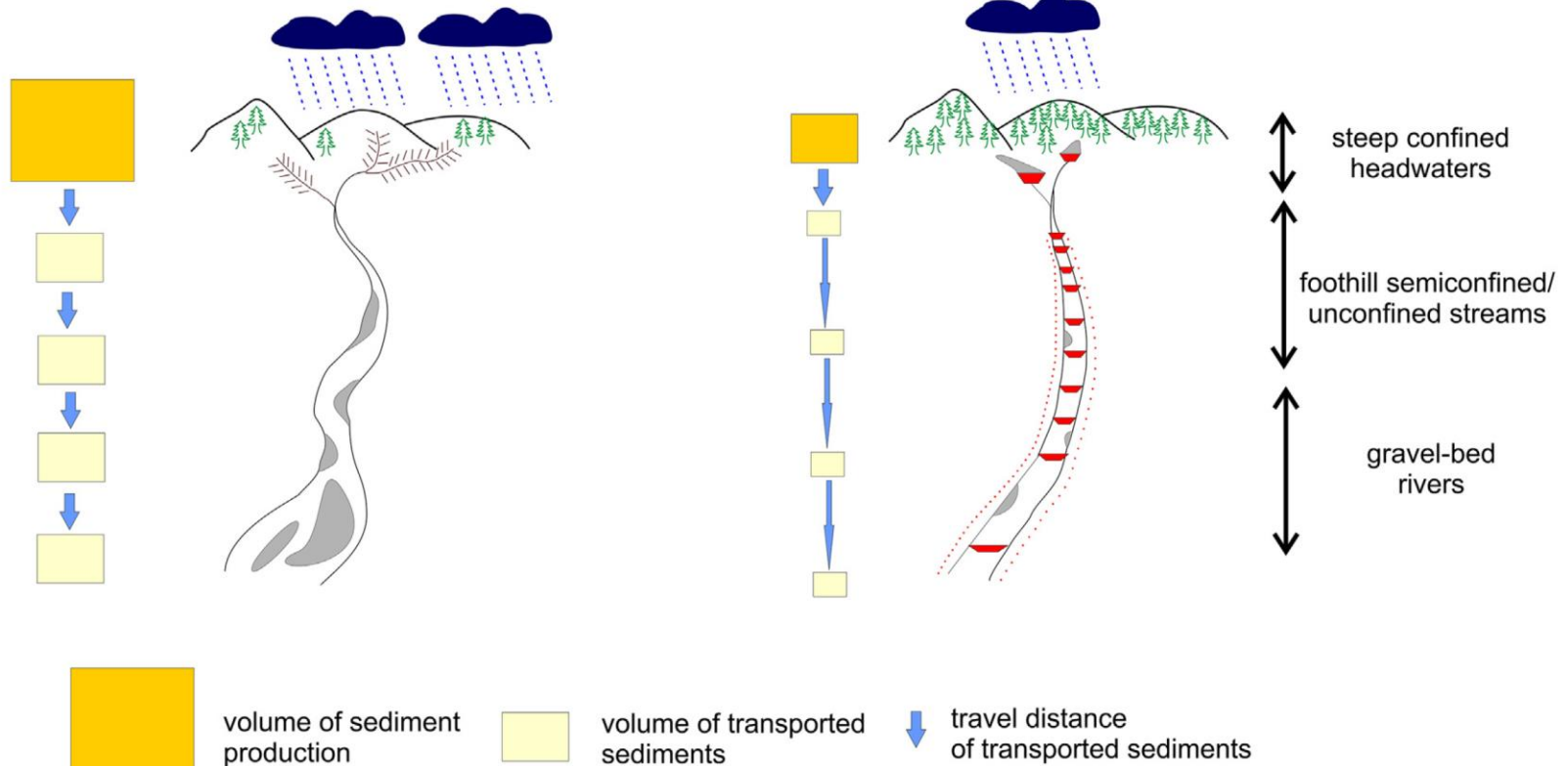
Tomáš Galia\*, Radek Tichavský, Václav Škarpich, Karel Šilhán  
 \*Department of Physical Geography and Geocology, University of Ostrava, Czech Republic

T. Galia, V. Škarpich and S. Ruman

Geomorphology 377 (2021) 107595

## 19th century

## present



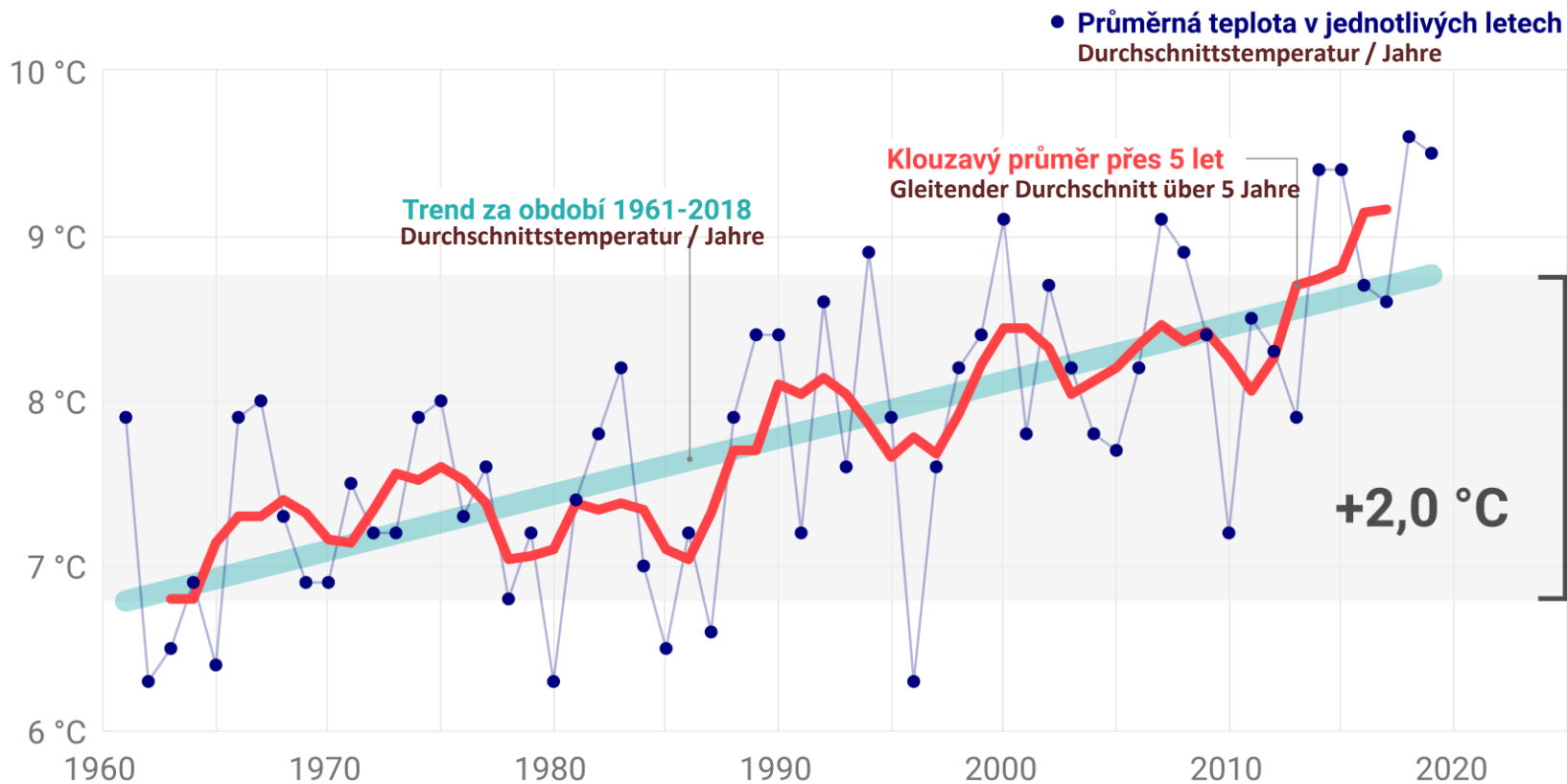


# PRŮMĚRNÁ ROČNÍ TEPLOTA V ČR

Durchschnittstemperatur in der ČR

Teplota se od 1961 zvýšila o 2,0 °C

Seit 1961 um 2,0 °C angestiegen



VERZE 2.0

více info na [faktaoklimatu.cz/teplota-cr](http://faktaoklimatu.cz/teplota-cr)

zdroj dat: ČHMÚ

Zdroj: @ed\_hawkins

**Děkuji za pozornost!!!**

**Vielen Dank für Ihre Aufmerksamkeit!!!**



## KONTAKT

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710 00 Ostrava

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[jan.hradecky@osu.cz](mailto:jan.hradecky@osu.cz)