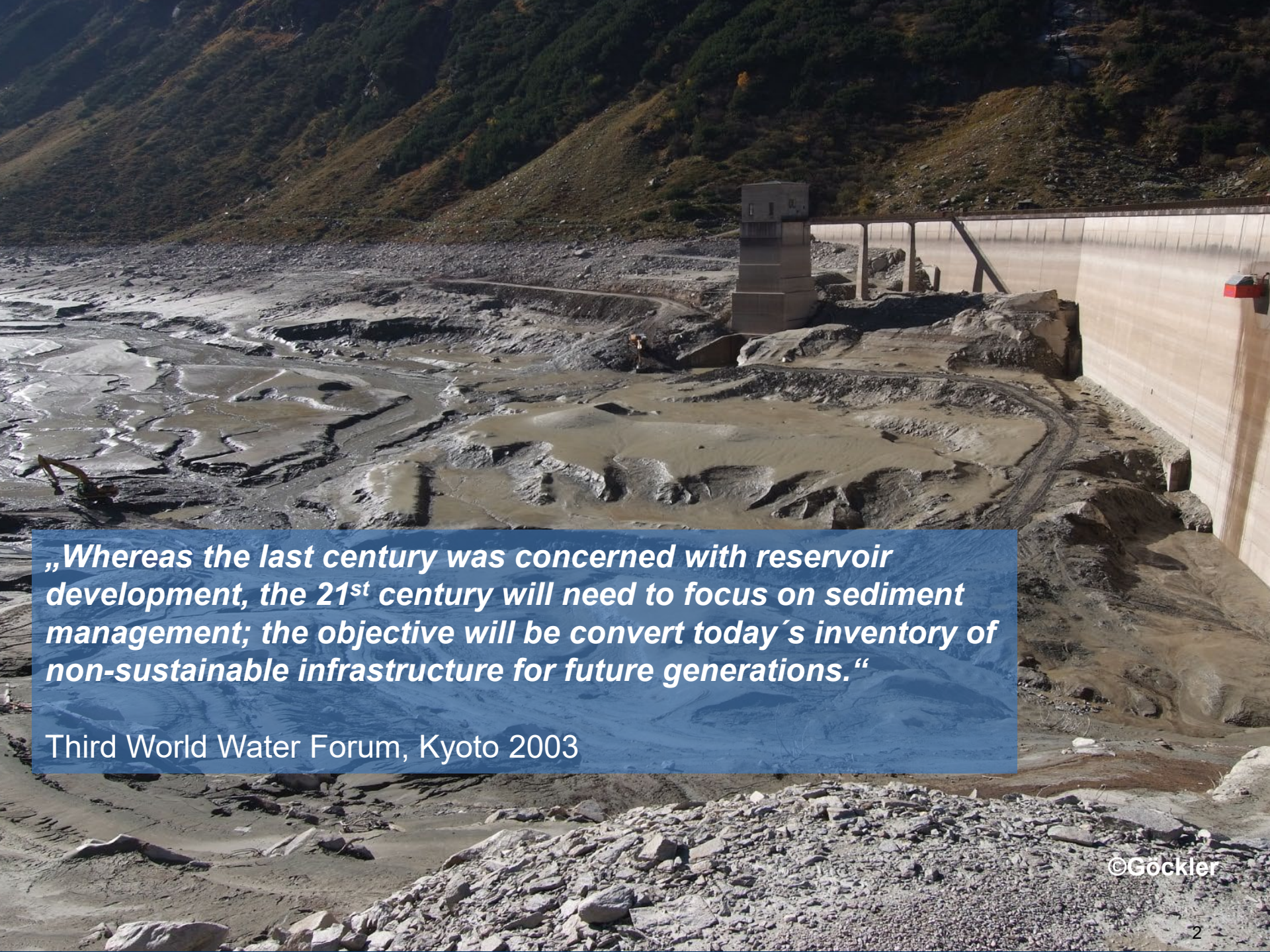
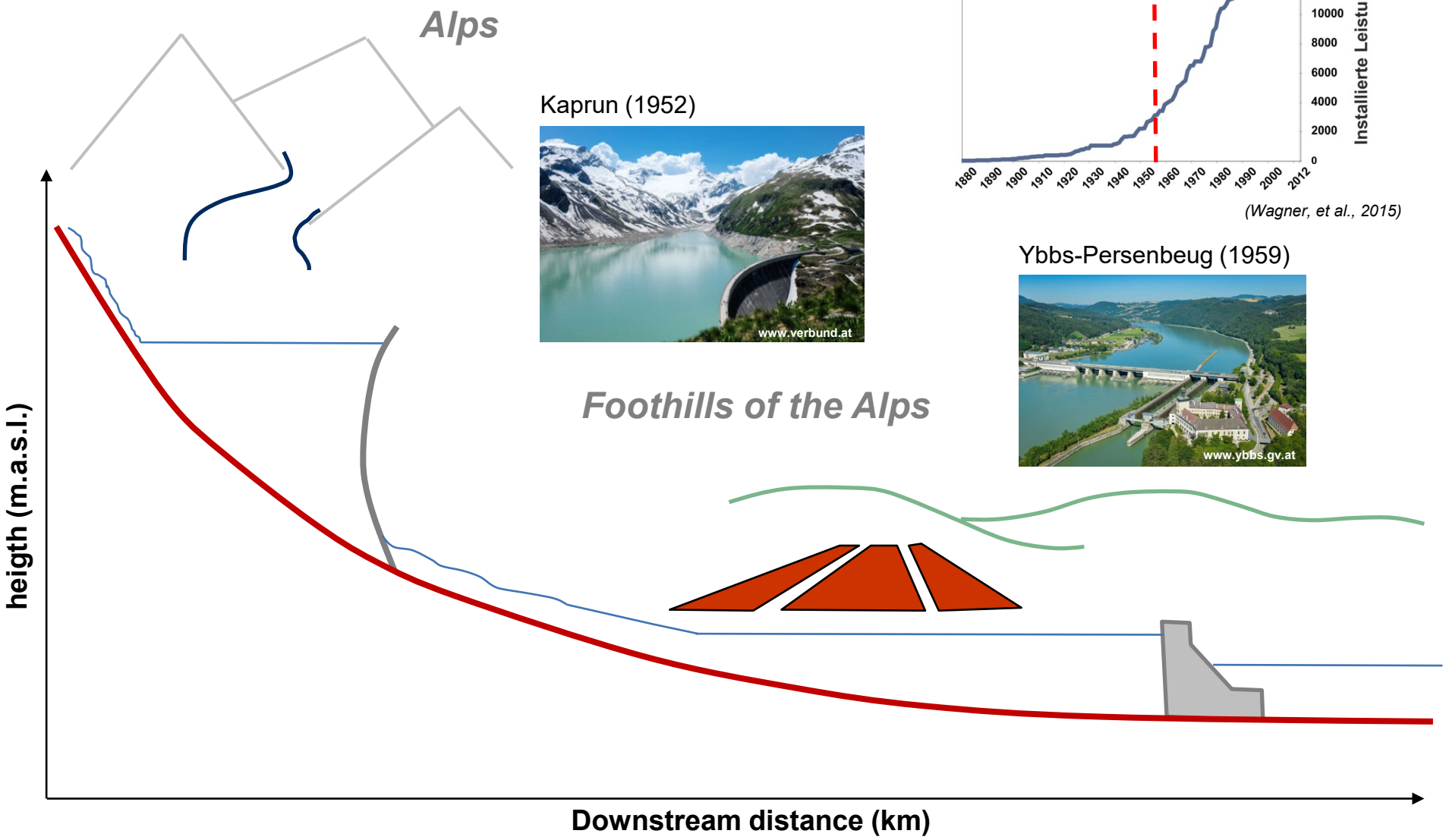
Sustainable sediment management for hydropower: Results of the CD-Laboratory "Sediment research and management"

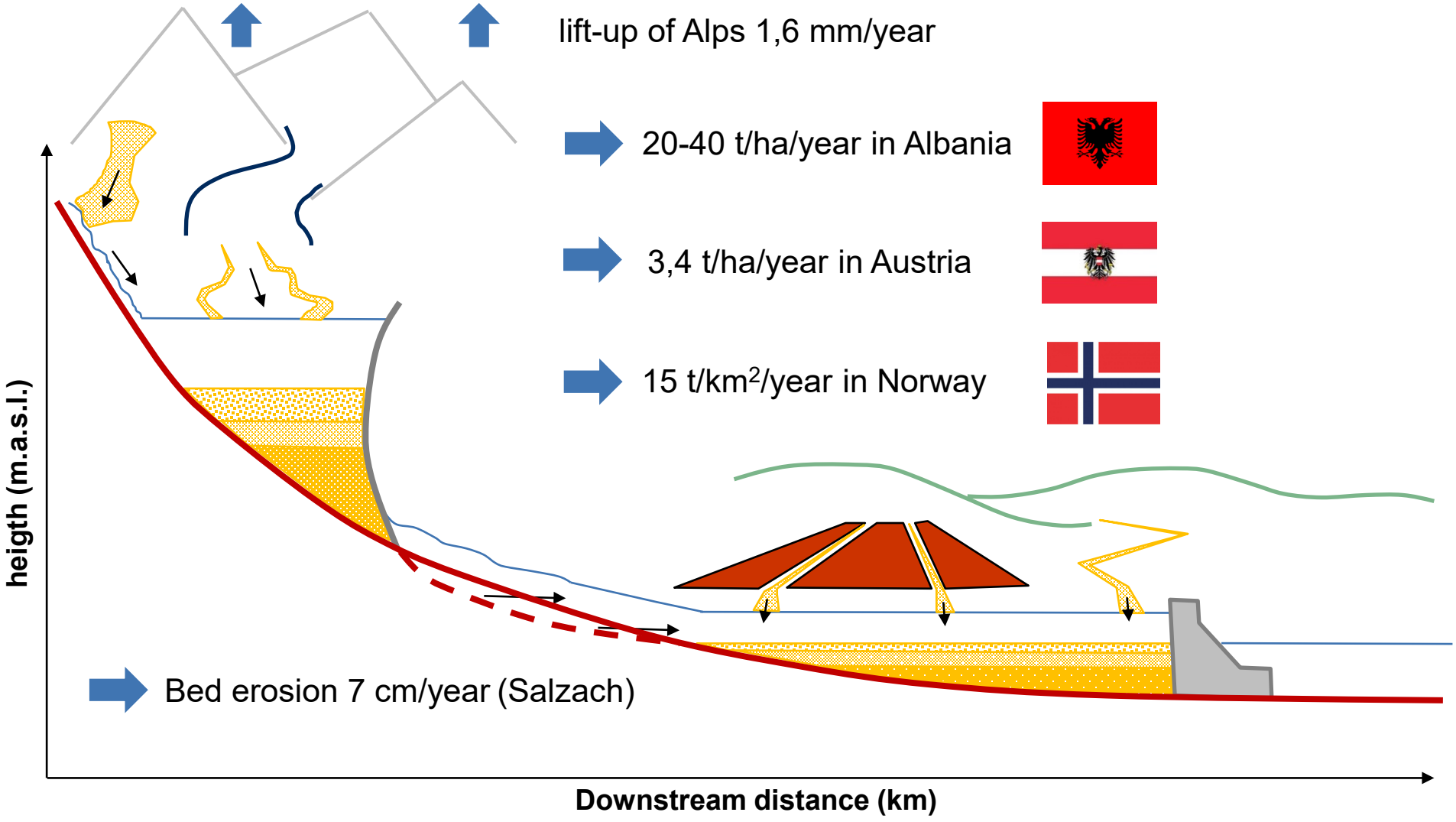
Christoph Hauer
Christian Doppler Laboratory for Sediment Research and Management
15.06.2022


„Whereas the last century was concerned with reservoir development, the 21st century will need to focus on sediment management; the objective will be convert today´s inventory of non-sustainable infrastructure for future generations.“
Third World Water Forum, Kyoto 2003
©Göckler

Hydropower in Austria



Hydropower / sedimentation



Sedimentation in reservoirs (global view)

Region	Storage capacity for hydropower use: 80% of the reservoir is filled up with sediment
Africa	2100
Asia	2035
Australia & Oceania	2070
Central America	2060
Europe	2080
Middle East	2060
North America	2060
South America	2080

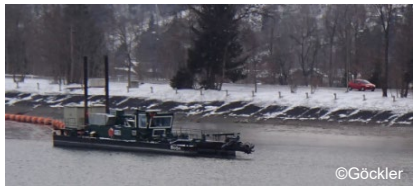
ICOLD, Basson (2009)

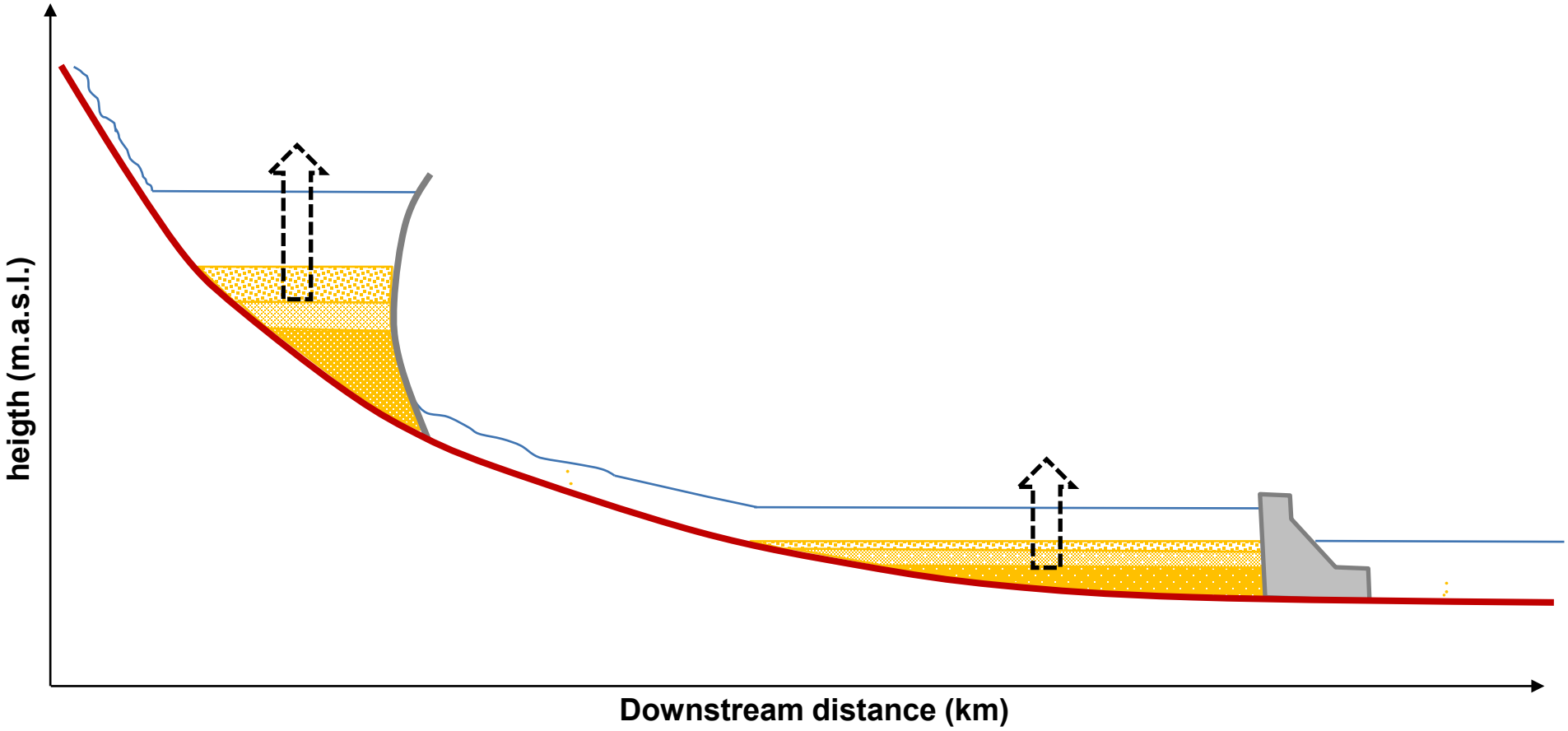
measures / costs

economic importance

At the moment **costs** for **depositing** of dredged material in Austria **10 – 20 €** per m^3.

dredging



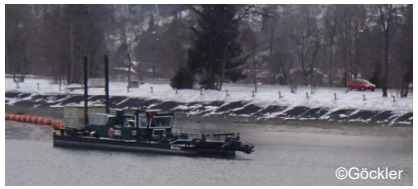


measures / costs

economic importance

At the moment **costs** for **depositing** of dredged material in Austria **10 – 20 €** per m^3.

dredging



flushing

economic importance

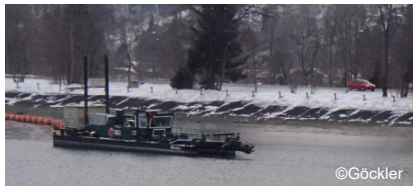
Cost due to production stop
e.g. **flushings**, **non-operation** of HPP (up to **several 100.000 €** - **Millions € per flushing**) or high additional costs due to **rigorous thresholds**

measures / costs

economic importance

At the moment **costs** for **depositing** of dredged material in Austria **10 – 20 €** per m^3.

dredging



flushing

economic importance
Cost due to production stop
e.g. **flushings**, **non-operation** of HPP (up to **several 100.000 €** - **Millions € per flushing**) or high additional costs due to **rigorous thresholds**

ecological / economic importance

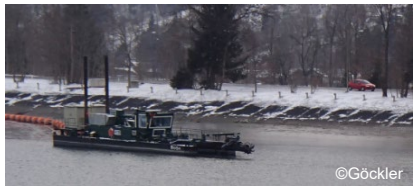
Payment of compensation: up to **100.000 € per flushing event**

measures / costs

economic importance

At the moment **costs** for **depositing** of dredged material in Austria **10 – 20 €** per m^3.

dredging



flushing

economic importance
Cost due to production stop
e.g. **flushings**, **non-operation** of HPP (up to **several 100.000 €** - **Millions € per flushing**) or high additional costs due to **rigorous thresholds**

Socioeconomic importance
e.g. floods 2002, 2013 (Inn, Donau)

ecological / economic importance

Payment of compensation: up to **100.000 € per flushing event**

heigth (m.a.s.l.)

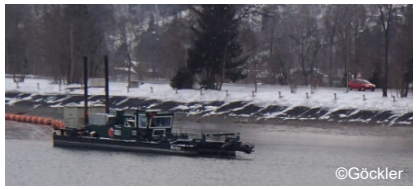
Downstream distance (km)

measures / costs

economic importance

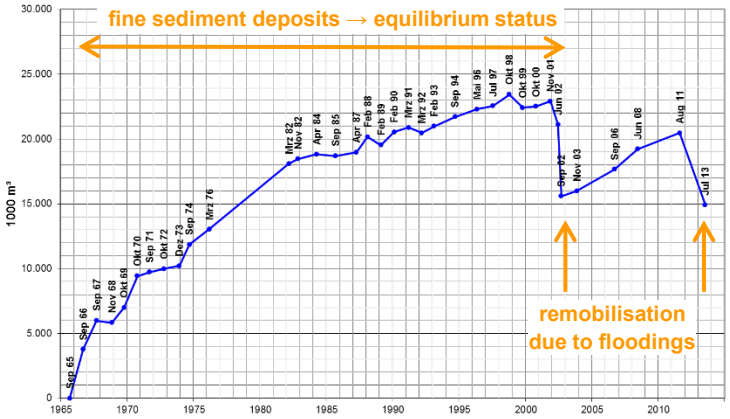
At the moment **costs** for **depositing** of dredged material in Austria **10 – 20 €** per m^3.

dredging



Flood impacts

flushing



economic importance

Cost due to production stop
e.g. **flushings**, **non-operation** of HPP (up to **several 100.000 €** - **Millions € per flushing**) or high additional costs due to **rigorous thresholds**

Socioeconomic importance

e.g. floods 2002, 2013 (Inn, Donau)

ecological / economic importance

Payment of compensation: up to **100.000 € per flushing event**

…..Why the CD-Lab was established

Sustainable sediment management was not possible:

(i) Lack of basic information / technologies for reservoir management

(ii) Lack of process understanding

(iii) Missing adjustment of sediment management opportunities in reservoirs

(iv) Insufficient infos of the interaction sediment dynamics / aquatic ecology

(v) No concepts concerning the (re-)use of deposited sediments

…..since 2017

CD-Laboratory „Sediment research and management“

Module 1 (Verein für Ökologie und Umweltforschung)

Verbund · Vorarlberger Illwerke AG · tiroler wasserkraft · Salzburg AG · kelag · ÖBB · ENERGIE AG Oberösterreich · Ennskraft · EVN · oesterreichs energie. · Kleinwasserkraft Österreich

Module 2 (viadonau)

viadonau

Module 3 (Andritz / Voith)

ANDRITZ · VOITH

assistance by:

M. Golja
since 3/2022

B. Wagner
10/2017 – 3/2022

CD-Laboratory (scientific cooperation)

"Application and validation of seismic profiling as a basis for sustainable sediment management in hydropower plants - case study Rottau"

C. Eichkitz

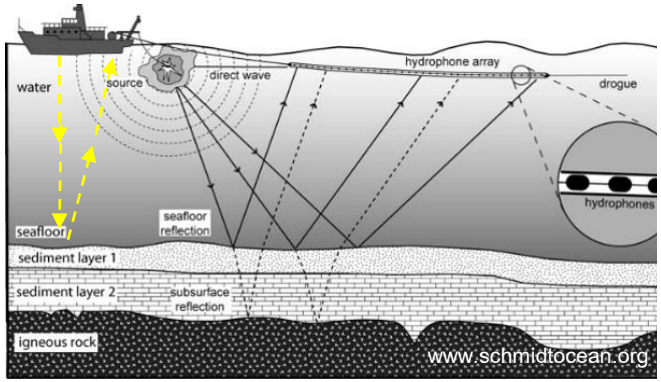
Module 1 – Hydropower

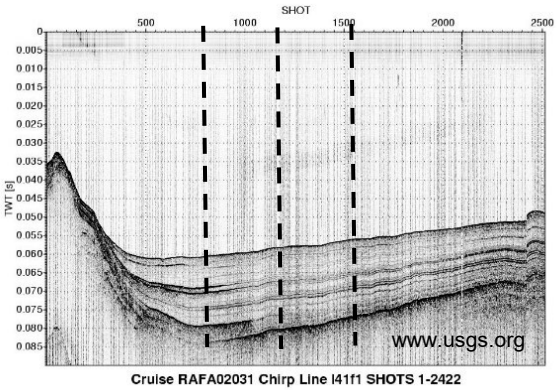
(i) Lack of data for sediment management

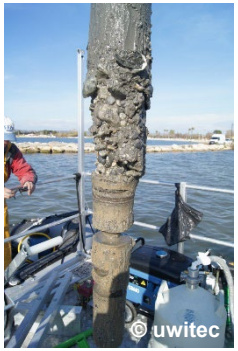
Insufficient data of sediment deposits (degree of density, layer-depths, etc.) in reservoirs (basic data for management / numerical modelling)

Methods in the CD-Laboratory:

Testing and development of **new** and **innovative technologies**: **Seismic profiling (offshore-technology)**







➡ To standardize seismic profiling according to (i) GSD, (ii) degree of (iii) density and layer depths

CD-Laboratory (scientific cooperation)

"Application and validation of seismic profiling as a basis for sustainable sediment management in hydropower plants - case study Rottau"

C. Eichkitz

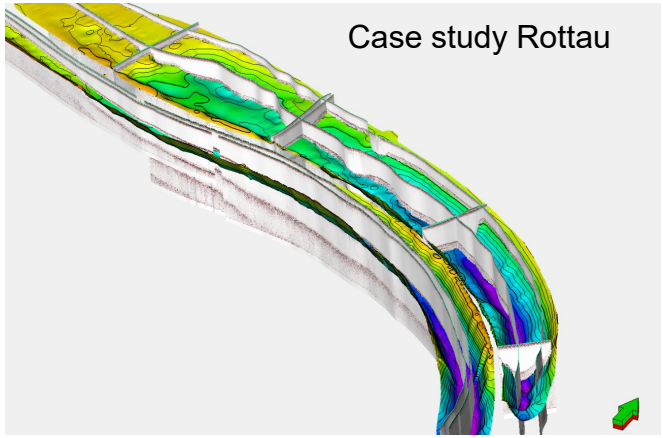
Module 1 – Hydropower

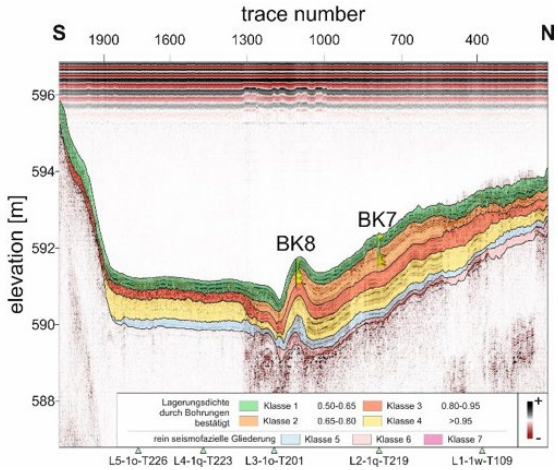
(i) Lack of data for sediment management

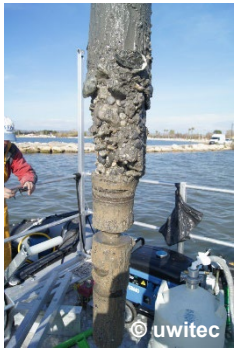
Insufficient data of sediment deposits (degree of density, layer-depths, etc.) in reservoirs (basic data for management / numerical modelling)

Methods in the CD-Laboratory:

Testing and development of **new** and **innovative technologies**: **Seismic profiling (offshore-technology)**







➡ To standardize seismic profiling according to (i) GSD, (ii) degree of (iii) density and layer depths

CD-Laboratory (scientific cooperation)

"Application and validation of seismic profiling as a basis for sustainable sediment management in hydropower plants - case study Rottau"

C. Eichkitz

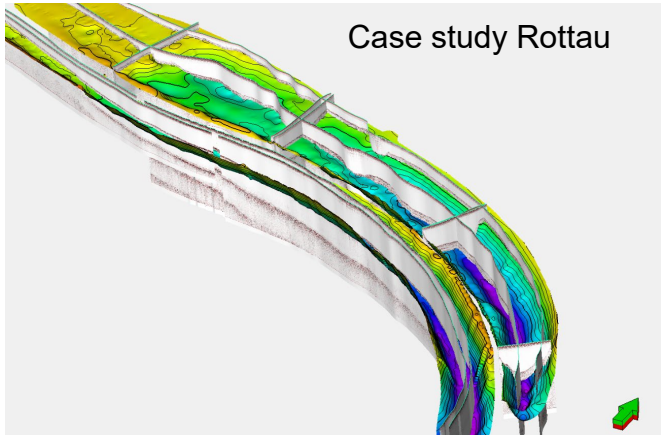
Module 1 – Hydropower

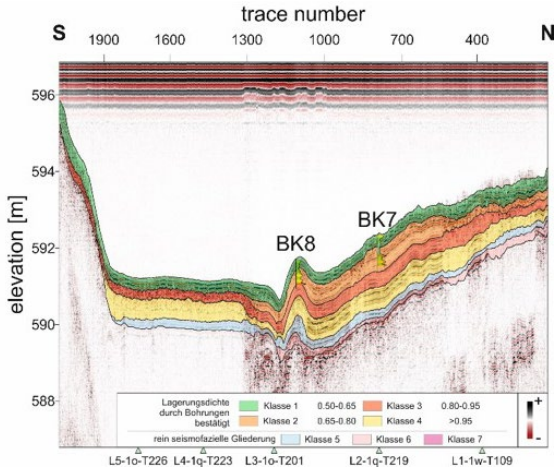
(i) Lack of data for sediment management

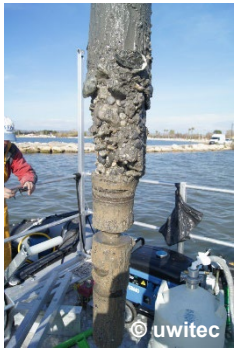
Insufficient data of sediment deposits (degree of density, layer-depths, etc.) in reservoirs (basic data for management / numerical modelling)

Methods in the CD-Laboratory:

Testing and development of **new** and **innovative technologies**: **Seismic profiling (offshore-technology)**







➡ To standardize seismic profiling according to (i) GSD, (ii) degree of (iii) density and layer depths

➡ Data for physical laboratory studies according to erosion, remobilisation and consolidation of sediments

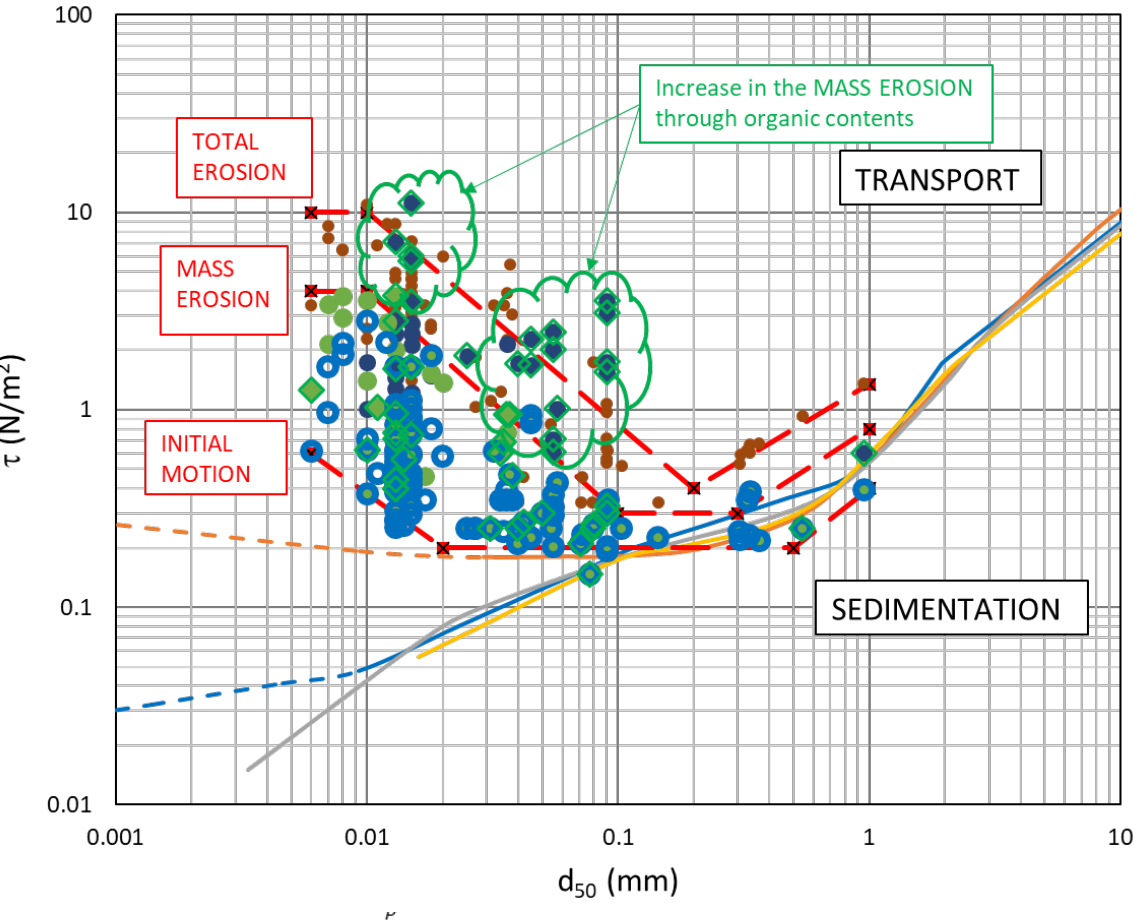
Module 1 – Hydropower

CD-Laboratory


"Critical shear stresses of cohesive reservoir sediments investigated on a new laboratory test rig with modern optical measurement systems"

P. Lichtneger & M. Golja

(ii) Lack of process understanding



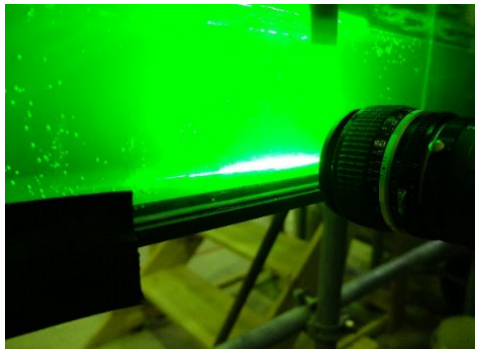
d_{50} (mm)	τ_c (N/m²)		
	SE1	SE2|ME	TE
0.006	0.6	4	10
0.01		4	10
0.02	0.2		
0.1		0.3	
0.2			0.4
0.3		0.3	
0.5	0.2		
1	0.4	0.8	1.35

(ii) Lack of process understanding

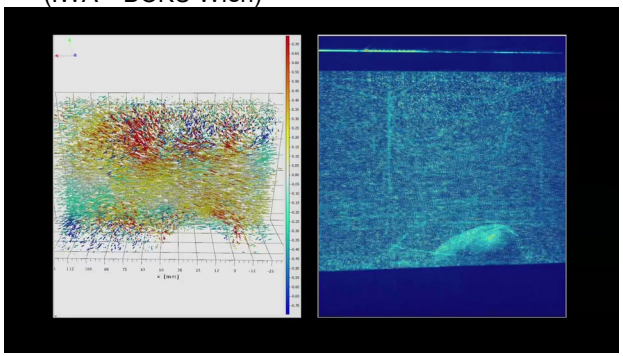
Interaction sediment transport and ***turbulence / single grains*** and mathematical descriptions: PIV – measurements in combination with LES (Large Eddy Simulations)

(PIV) BOKU: 1000 hz (detection of coherent structures) – analysis Reynolds-Stress terms

Measurements of shear stress and flow velocity



PIV and PTV measurements of sediment dynamics (IWA – BOKU Wien)

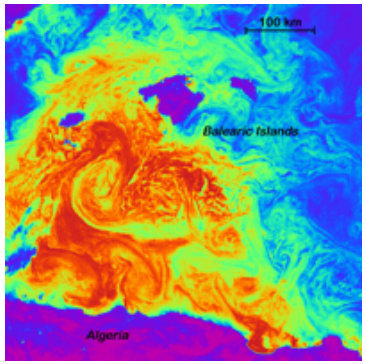


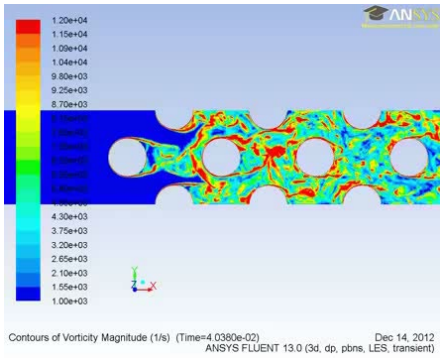
CD-Laboratory

"Influence of coherent structures on sediment particle entrainment under threshold conditions of motion"

J. Schobesberger

Large Eddy Simulations (LES):





CD-Laboratory

"Interaction of Very Large Scale Motion of coherent structures with sediment particle exposure"

S. Yücesan

New hydraulic laboratory

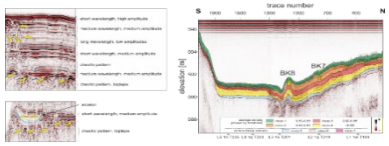
➡ up to 10 m^3s^{-1} experimental discharge

the ***higher*** the selected ***model scale***, the ***lower*** the ***risk*** of ***unavoidable errors*** in nature.

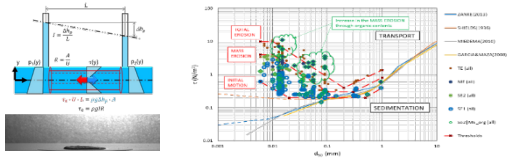
Sustainable sediment management

Technical

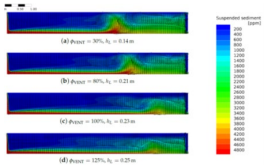
Monitoring and measurement technologies



Process understanding



Numerical modelling tools



Ecological

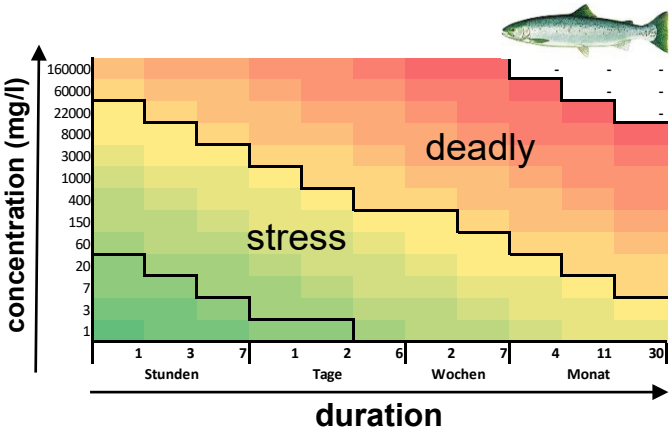
!

…especially for downstream parts

(iv) Insufficient infos of the interaction sediment dynamics / aquatic ecology

shortcomings:

Lack of scientific based methods for the evaluation of the impact of sediment management measures on aquatic ecology



Newcombe & Jensen (1996)

⟹ moderate stress: **y = 327,8x$^{-0,9}$**

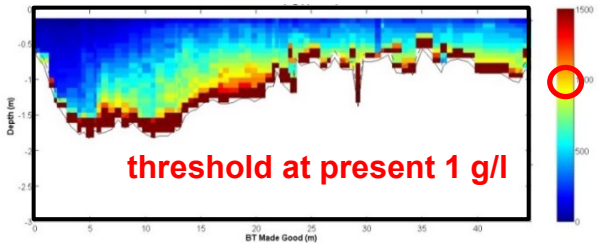
⟹ loss in habitats: **y = 2616,7x$^{-0,8}$**

⟹ deadly: **y = 48008,5x$^{-0.9}$**

planned studies CD-Lab:

flume (Laboratory)

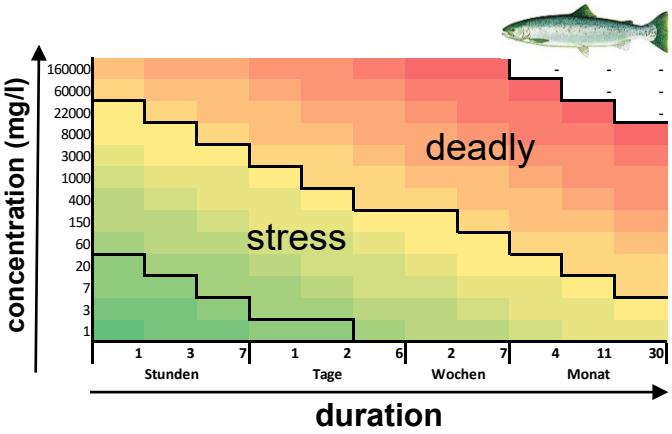
suspended sediment distribution Inn River



(iv) Insufficient infos of the interaction sediment dynamics / aquatic ecology

shortcomings:

Lack of scientific based methods for the evaluation of the impact of sediment management measures on aquatic ecology



Newcombe & Jensen (1996)

⟹ moderate stress: **y = 327,8x$^{-0,9}$**

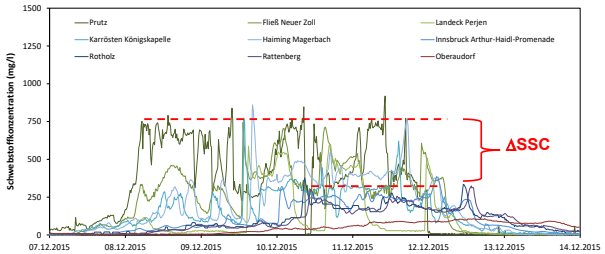
⟹ loss in habitats: **y = 2616,7x$^{-0,8}$**

⟹ deadly: **y = 48008,5x$^{-0.9}$**

planned studies CD-Lab:

flume (Laboratory)

suspended sediment distribution Inn River

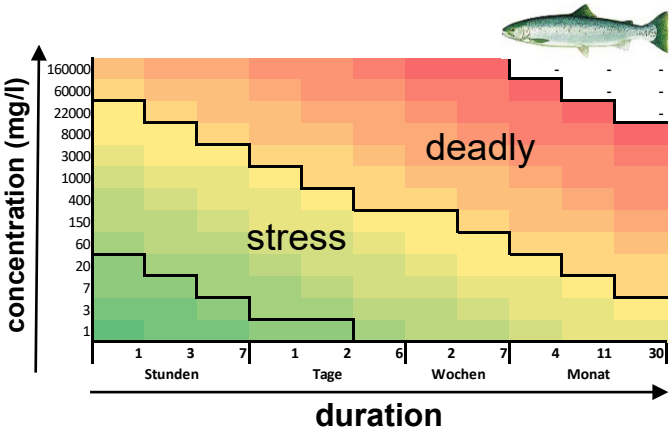


Haimann et al. (2022) in prep.

(iv) Insufficient infos of the interaction sediment dynamics / aquatic ecology

shortcomings:

Lack of scientific based methods for the evaluation of the impact of sediment management measures on aquatic ecology



Newcombe & Jensen (1996)

⟹ moderate stress: **y = 327,8x$^{-0,9}$**

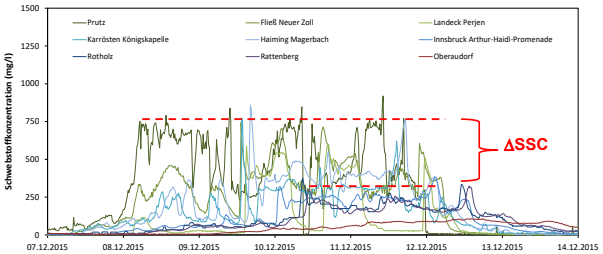
⟹ loss in habitats: **y = 2616,7x$^{-0,8}$**

⟹ deadly: **y = 48008,5x$^{-0.9}$**

planned studies CD-Lab:

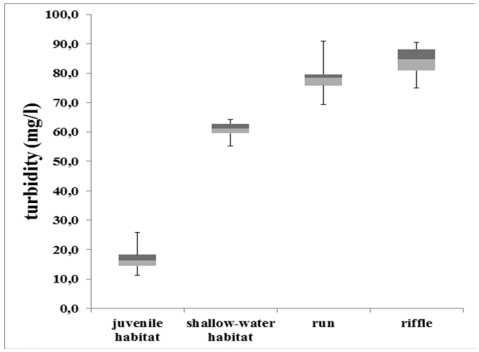
flume (Laboratory)

suspended sediment distribution Inn River



Haimann et al. (2022) in prep.

Variability in hydro-morphological units



Hauer et al. (2020)

CD-Laboratory

"Ecohydraulic assessment of suspended sediment concentrations in rivers and the novel the Gravel Bar Consolidation Meter"

P. Holzapfel

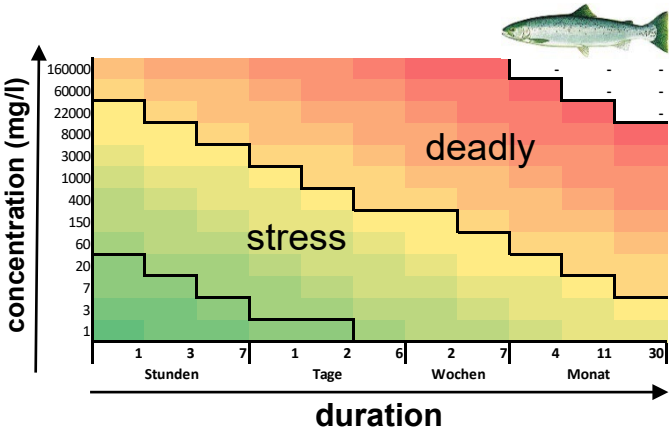
Field ➡ Numerics

CD-Laboratory (group leader)

"Spatio-temporal variability of suspended sediments in rivers and ecological implications of reservoir flushing operations"

M. Tritthart

Lack of scientific based methods for the evaluation of the impact of sediment management measures on aquatic ecology



Newcombe & Jensen (1996)

⟹ moderate stress: **y = 327,8x$^{-0,9}$**

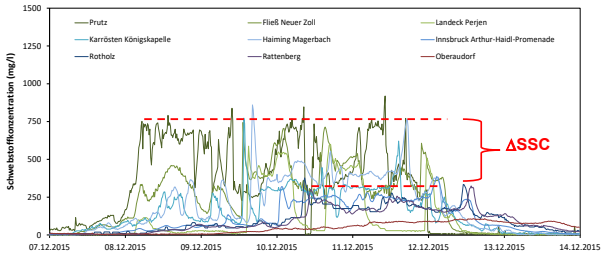
⟹ loss in habitats: **y = 2616,7x$^{-0,8}$**

⟹ deadly: **y = 48008,5x$^{-0.9}$**

planned studies CD-Lab:

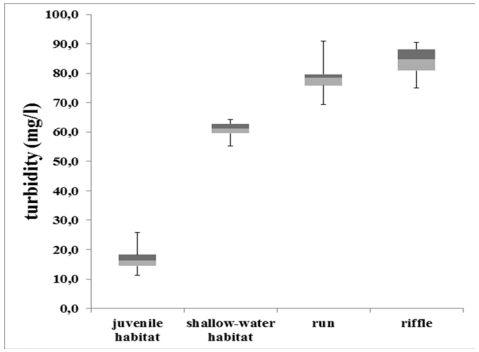
flume (Laboratory)

suspended sediment distribution Inn River



Haimann et al. (2022) in prep.

Variability in hydro-morphological units



Hauer et al. (2020)

(iv) Insufficient infos of the interaction sediment dynamics / aquatic ecology

Aim: „rivers getting fit for more sediments“

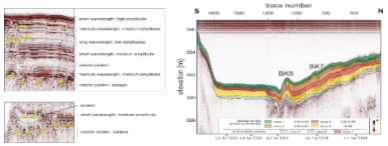
„two-class-society“

„together“

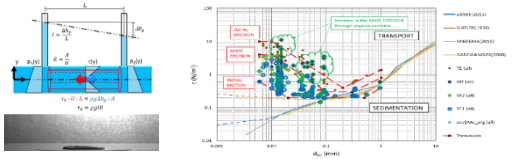
Sustainable sediment management

Technical

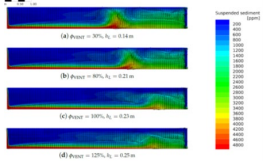
Monitoring and measurement technologies

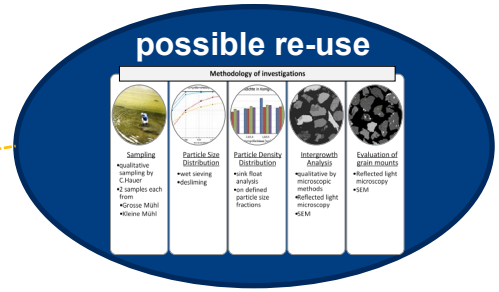


Process understanding

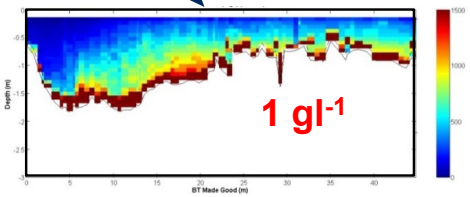


Numerical modelling tools

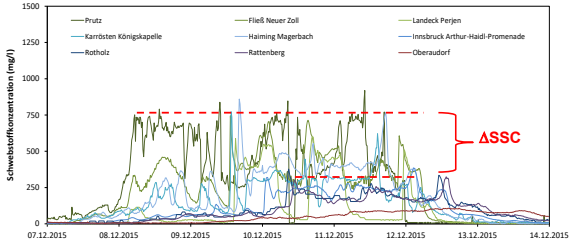




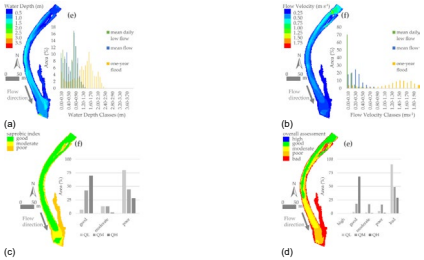
Ecological



Monitoring and measurement technologies

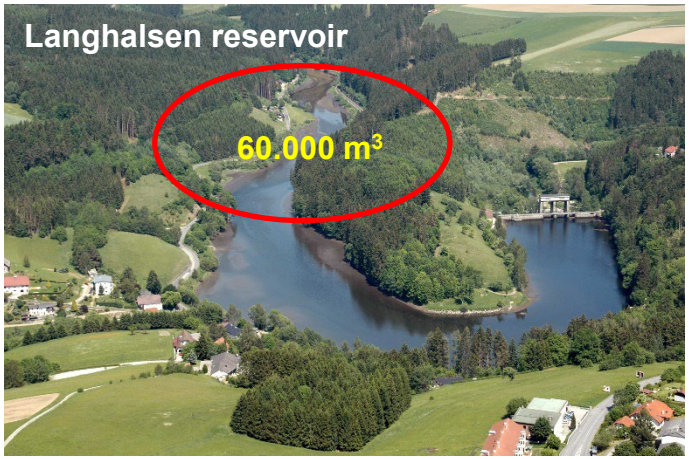


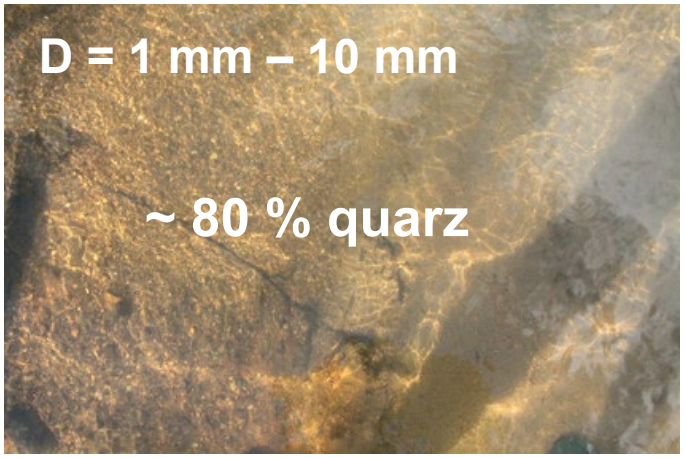
Process understanding



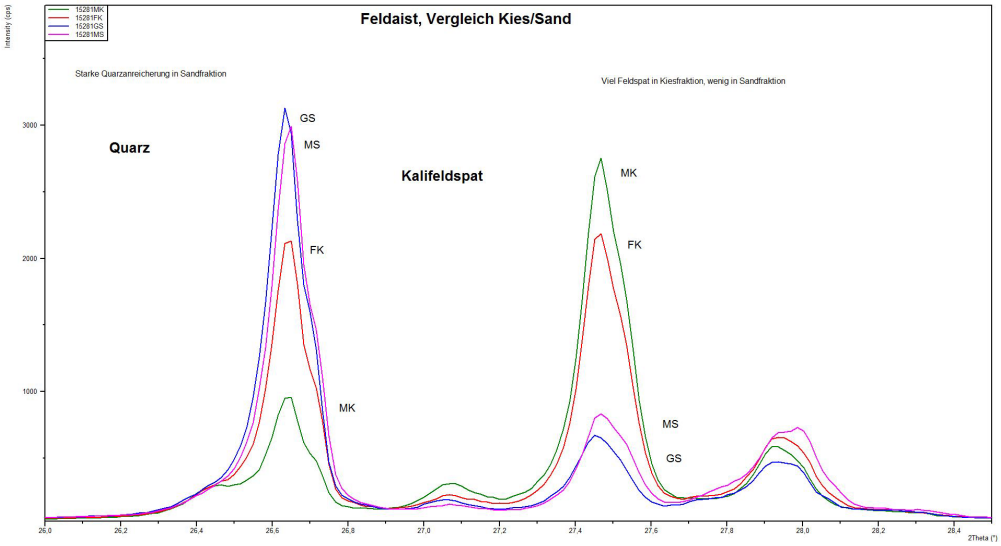
Numerical modelling tools

(v) re-use of dredging material





Bohemian glass



CD-Laboratory

&

B. Wagner

MONTAN UNIVERSITÄT
WWW.UNILEOBEN.AC.AT

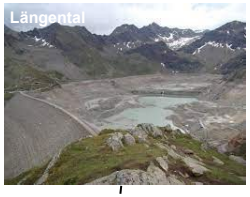
CD-Lab „Sediment research and management“ – Facilities & Study sites

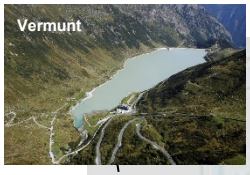
Case study (M1)

Case study (M1)

Field sites (M2)

Field site (M2)





Gravel washing (M1)

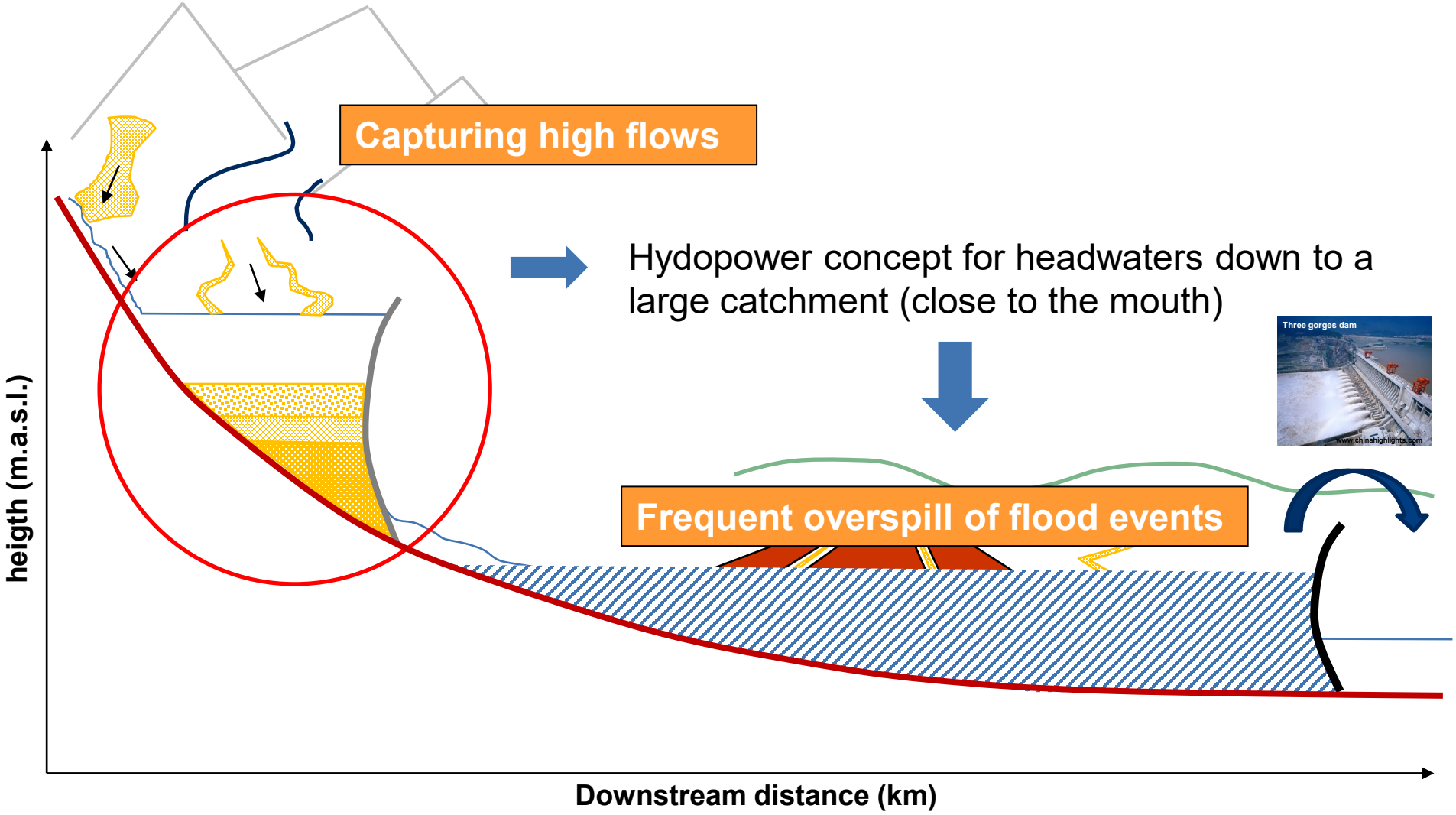
Hydraulic lab (M1 & M2)

- 3D-LDA system
- Low-speed PIV system
- High-speed PIV system
- Outdoor research channel

Monitoring (M1 & M2)

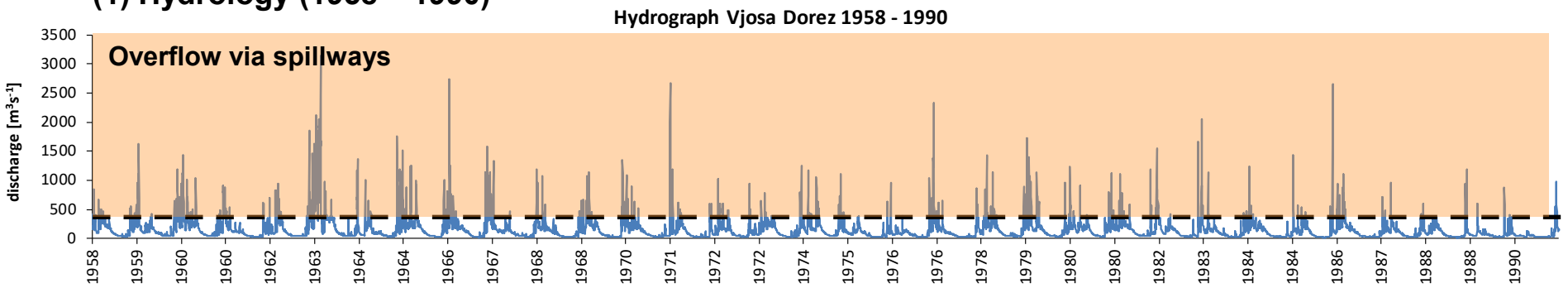
- 2 ADV Vector, NORTEK (1 viadonau)
- ADCP Stream Pro
- ADCP Rio Grande (viadonau)
- Adapted BfG basket sampler for bedload measurements
- USP 61A suspended load s.

Unusal concept of Vjosa dams!



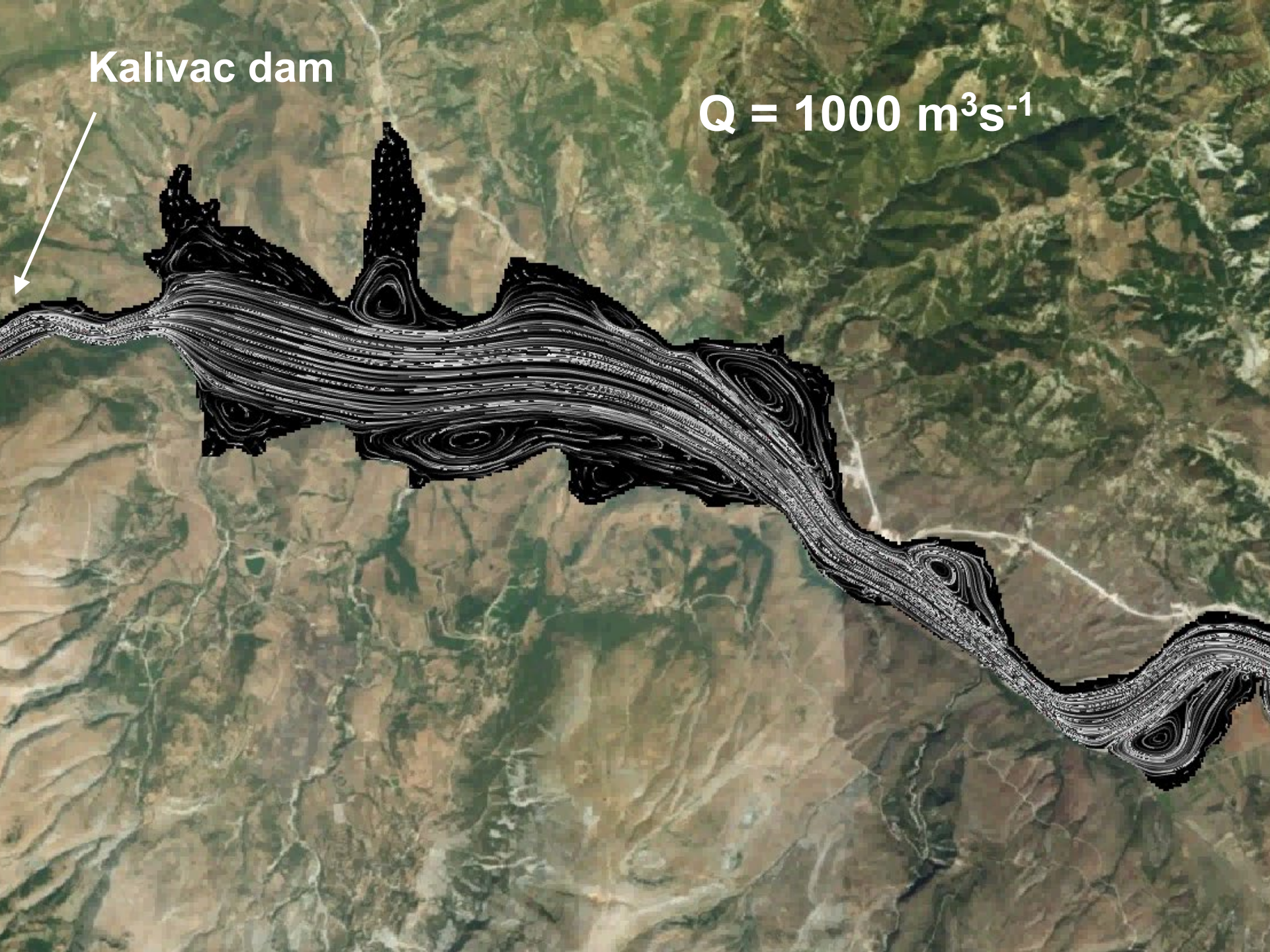
Why?

(1) Hydrology (1958 – 1990)



Turbines operate to a maximum discharge level!

Impact on flow dynamics and sedimentation in the reservoir!

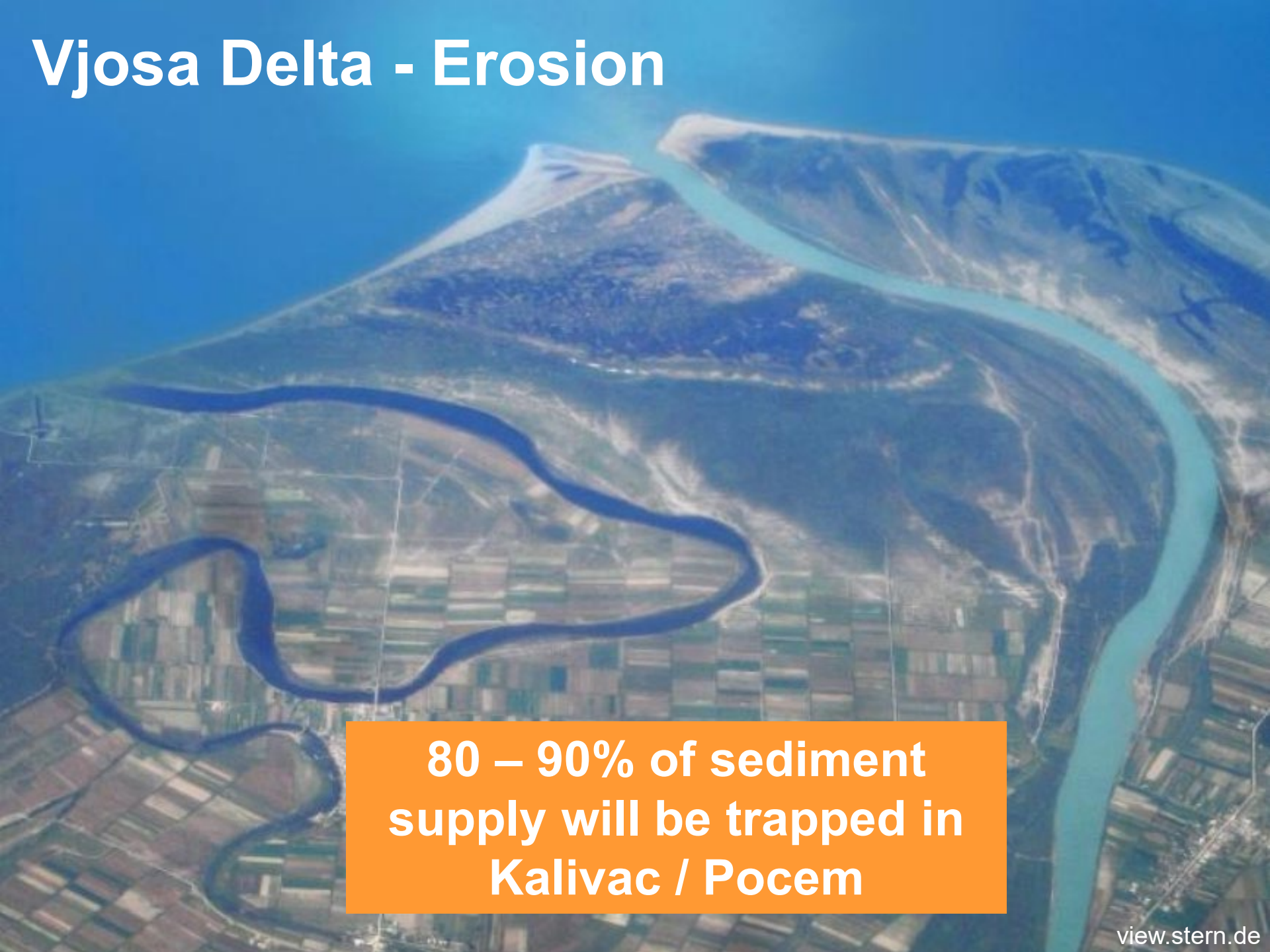

Kalivac dam
Q = 1000 m3s-1

Albania already has already a „case study“ which is discussed on an international scale concerning sediment management problems

„Devoll HP“

Bottom outlet as c

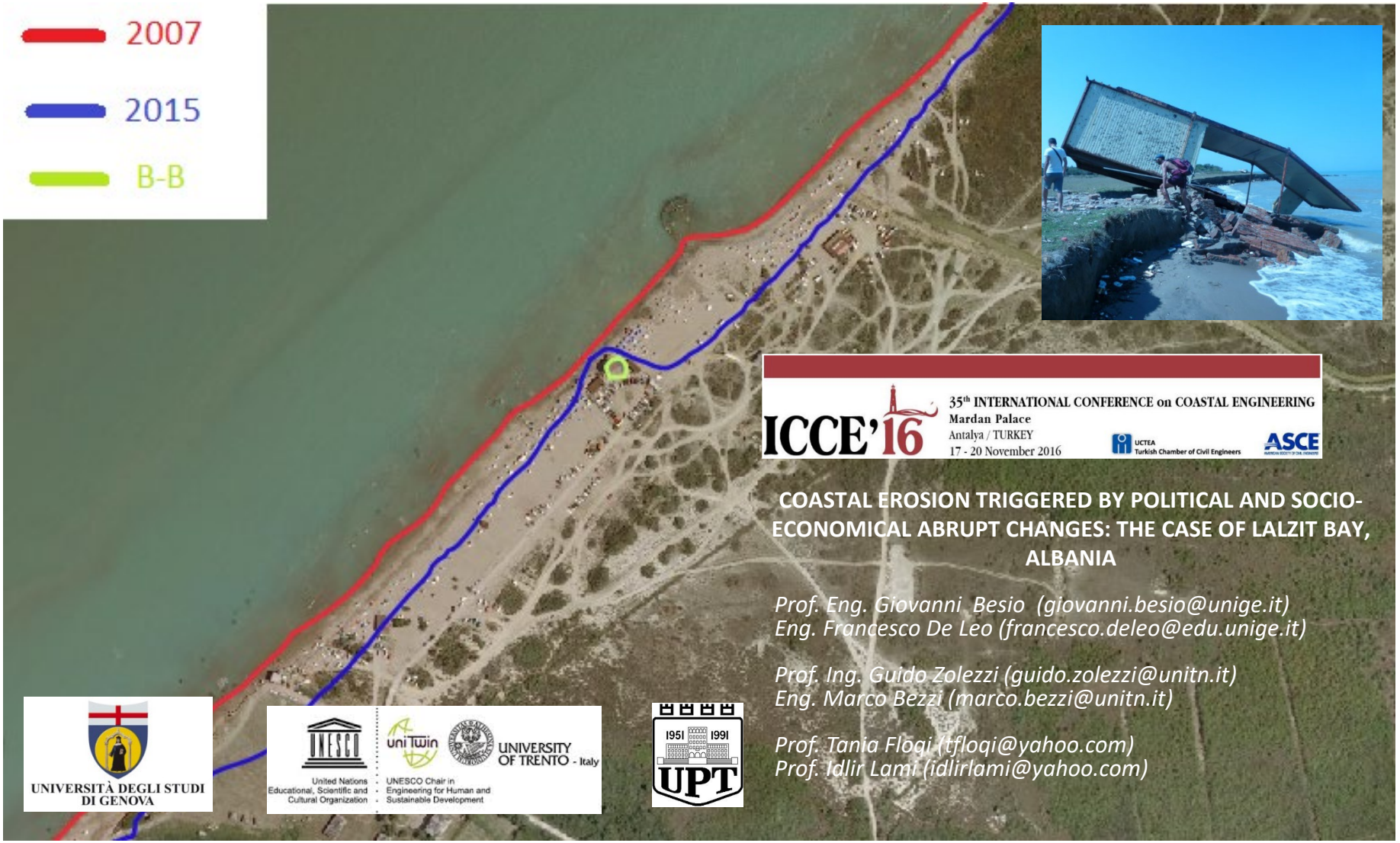
Vjosa Delta - Erosion



80 – 90% of sediment supply will be trapped in Kalivac / Pocem

view.stern.de

Coastal erosion Albania



ICCE'16 35th INTERNATIONAL CONFERENCE on COASTAL ENGINEERING
Mardan Palace
Antalya / TURKEY
17 - 20 November 2016
UCTEA Turkish Chamber of Civil Engineers
ASCE

COASTAL EROSION TRIGGERED BY POLITICAL AND SOCIO-ECONOMICAL ABRUPT CHANGES: THE CASE OF LALZIT BAY, ALBANIA

Prof. Eng. Giovanni Besio (giovanni.besio@unige.it)
Eng. Francesco De Leo (francesco.deleo@edu.unige.it)

Prof. Ing. Guido Zolezzi (guido.zolezzi@unitn.it)
Eng. Marco Bezzi (marco.bezzi@unitn.it)

Prof. Tania Floqi (tfloqi@yahoo.com)
Prof. Idlir Lami (idlirlami@yahoo.com)

UNIVERSITÀ DEGLI STUDI DI GENOVA

UNESCO United Nations Educational, Scientific and Cultural Organization
UNESCO Chair in Engineering for Human and Sustainable Development
uniTwin
UNIVERSITY OF TRENTO - Italy

1951 1991 UPT

How important are river sediments for Albanian tourism?

…..very, very important!

2005

Imagery Date: 2/7/2019 41°25'17.07" N 19°28'38.66" E elev

River sediments = Albanian tourism

Alk

Cape of Rodon

Shetaj

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2019 TerraMetrics
© 2018 Google
Image © 2019 DigitalGlobe

Summary & Conclusions

- **Sustainable Hydropower must include sediment management!**
- ***Sediments*** are the ***backbone*** for the ***river morphology (habitats)*** (Priority 1: Sediments for the rivers)
- ***Technical*** and ***economical optimization*** is possible and should be ***targeted***
- Avoid ***„old fashioned“ concepts*** and ***long term impacts*** for the facility itself and the downstream reaches (even to the sea) ***must be incorporated*** in the ***EIAs***
- Still a ***strong need*** for ***basic*** and ***applied research*** and for ***scientific collaboration***

Thank you for your attention!