FlexSTOR

SCCER SoE

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

FLEXSTOR

Solutions for flexible operation of storage hydropower plants in changing environment and market conditions - progress @ 15.09.2017

In cooperation with the CTI

Energy
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

Dr Pedro Manso

Birmensdorf, 15th September 2017

FlexSTOR

ORGANIZATIONAL CHART

Project Management

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LCH-EPFL

Prof. Robert Boes (deputy)
VAW-ETHZ

STEERING GROUP

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Project coordination (WP0)

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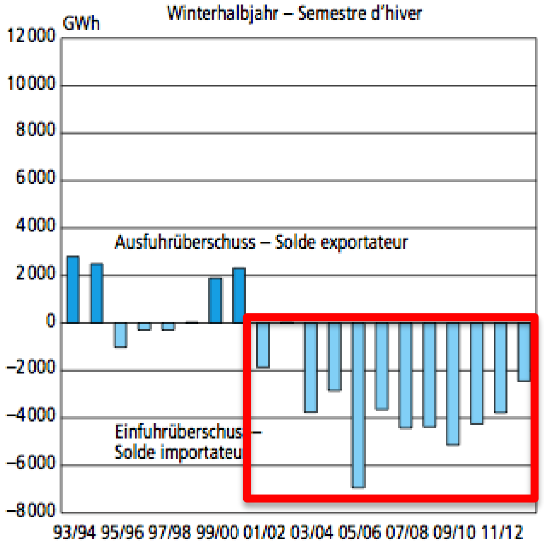
WP7 Outreach Activities

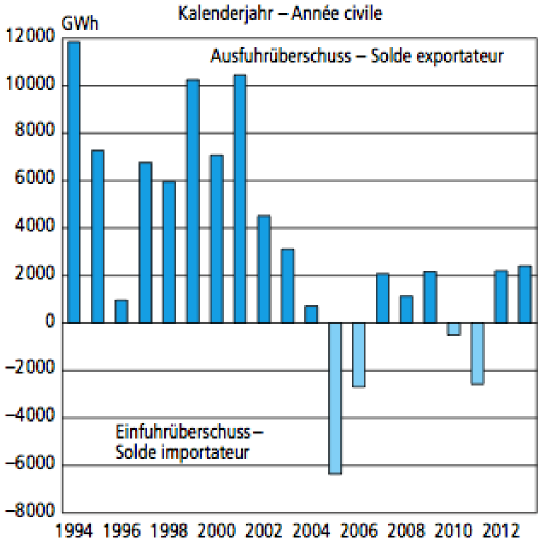
WP1	WP2	WP3	WP4	WP5	WP6
Riverpeaking	**Impulse Waves**	**Storage/Demand**	**Cascade Flushing**	**Turbine abrasion**	**Turbine instability**
EAWAG LCH-EPFL	VAW-ETHZ WSL	LCH-EPFL	LCH-EPFL	VAW-ETHZ	HES-SO LMH-EPFL

INNOVATION BUSINESS CASE

Swiss hydropower role in domestic /regional energy mix

- CH hydropower is net provider of revenues annually, but on negative trend
- *Winter production* deficit, covered by importers
- Hydro-*storage* is paramount for intermittent Solar/Wind integration & grid balancing





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INNOVATION BUSINESS CASE

Develop approaches for cutting-edge issues that represent

- new environmental liabilities with undefined contours (e.g. HPK, SedBal)
- market “trends” with un-documented/ unproven interest
- threats with yet un-mastered risks

New social balance between water use and ecosystem safeguard

Proof-of-concept at KWO and later replication

RELEVANCE OF FLEXSTOR

Hydropower rehabilitation, extension or new projects face new issues linked with operation flexibility and sediment management, with direct impact on their intra-day or intra-annual competitive profile.

Intra-day operation

- Hydropeaking (WP1)
- Turbine start/stops (WP6)

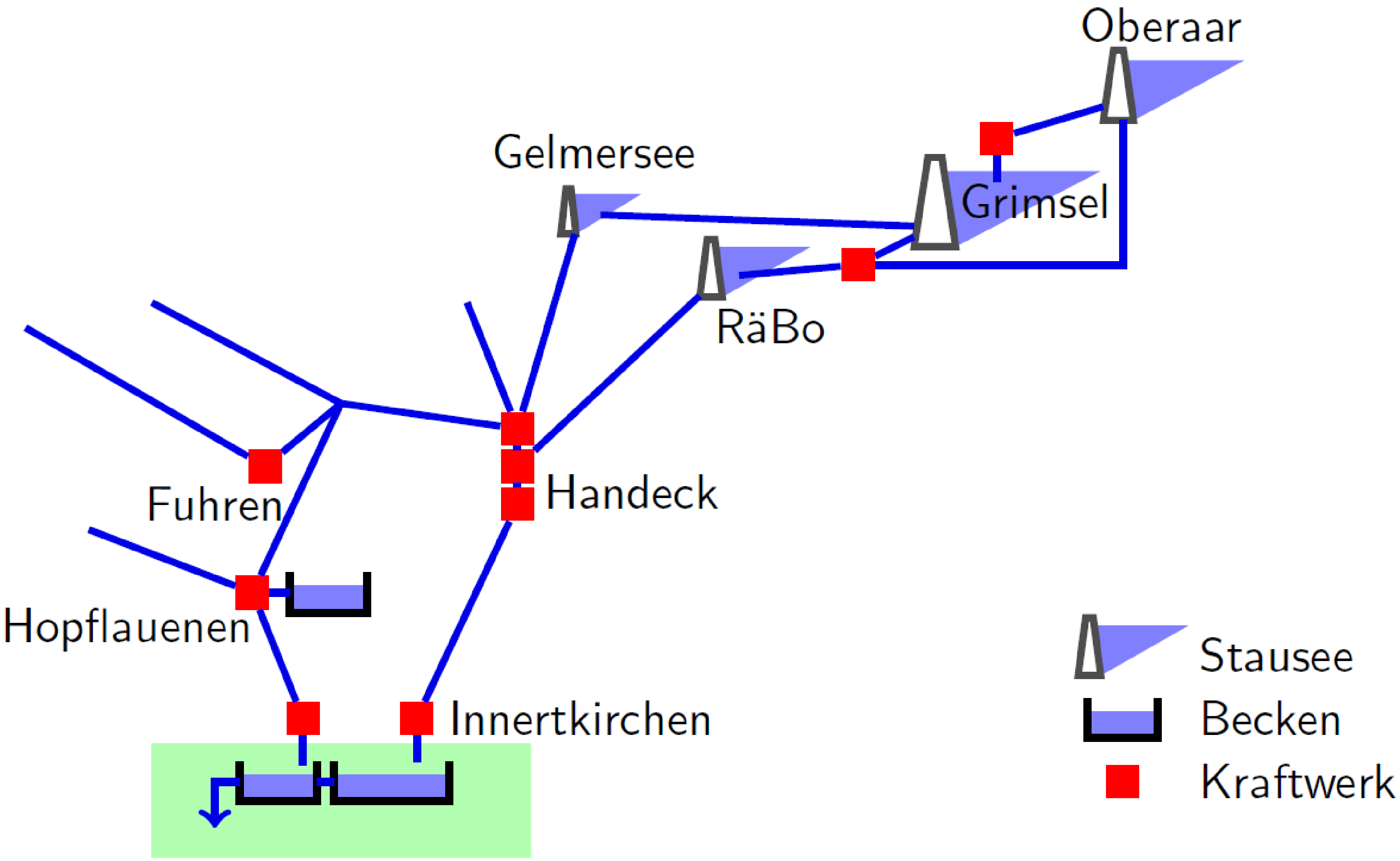
Intra-annual operation

- Limit the duration of preventive lake drawdown due to risk of impulse waves (WP2)
- Optimal storage management (WP3)
- Cascade sediment flushing (WP4)
- Turbine abrasion by fine sediment (WP5)

KWO SYSTEM

~ 600 hm^3

~ 2.5 TWh/ a


Oberaar
Gelmersee
Grimsel
RäBo
Fuhren
Handeck
Hopflauenen
Innertkirchen
Stausee
Becken
Kraftwerk

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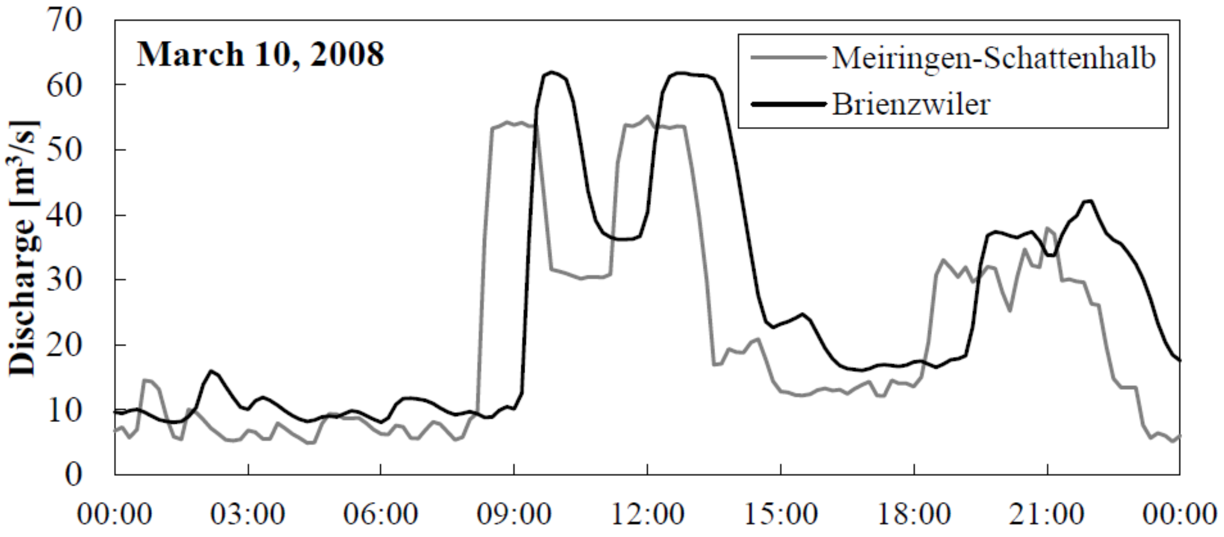
WP1 Hydropeaking mitigation



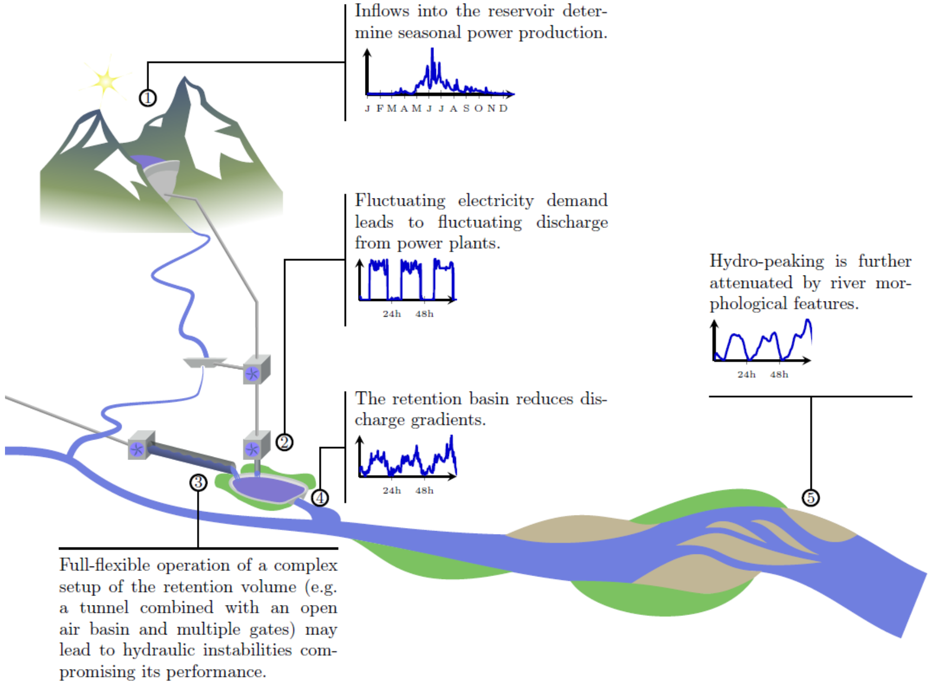
HYDROPEAKING (WP1) - MOTIVATION

Bottom-up operational questions:

- Demodulation basin design & operation criteria?
- Threshold values of critical criteria, where?
- Attenuation targets at tailrace outlet
- Complementary attenuation in rivers
- Avoid unstable flow conditions

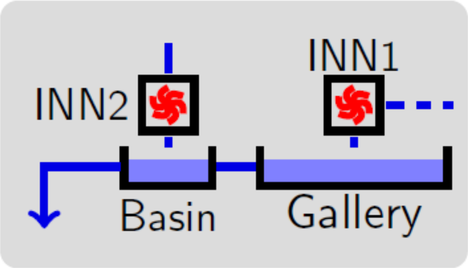
Research questions:

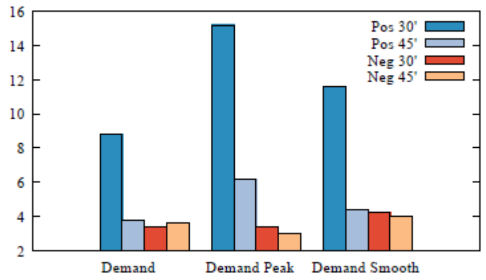
- Which degree of granularity is required for modelling?
- What optimisation procedure is adequate?
- What is the adequate lead time for decision-making?
- What are the governing river morphology variables?
- Which are the best hydrometric data for operation & design?



HYDROPEAKING (WP1) - OUTPUT

Winter/Spring future scenarios → System Modelling & optimisation → Scenario generator (portal) → Hydraulic stability and N-1 → Influence of river morphology (field tests)

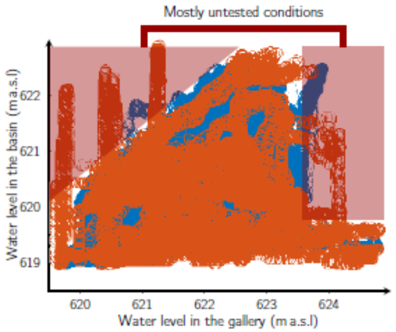


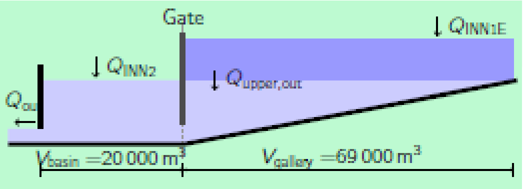


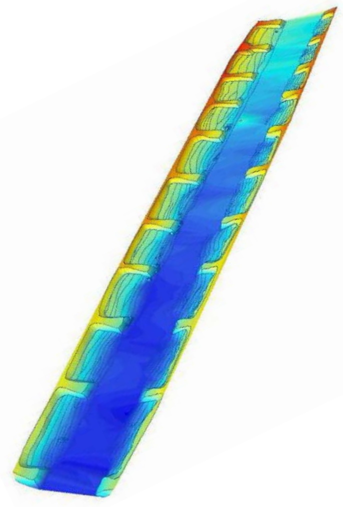
Scenario generator or hydropower systems

- Reproduces potential variability of turbine discharge
- System defined as network
  - Multiple inflows (water intakes)
  - One reservoir and one power plant
- Follows seasonal cycle
- Time step of 15 minutes
- Different turbine types selectable

→ Web based tool for scenario generation







WP2 Natural Hazards (Impulse waves)

IMPULSE WAVES – MOTIVATION

Bottom-up operational questions:

- What is the risk of impulse waves & dam overtopping in the KWO catchment?
- How can impulse waves be better predicted?
- What mitigation measures can be implemented?
- If preventive reservoir lowering is needed, how can the duration be limited?

Research questions:

- Do the laboratory test scale up to prototype field data?
- Improvement of mathematical description of physical events
- Improved design guidelines for impulse wave hazard assessment

IMPULSE WAVES – WORK DONE / ONGOING

Impulse wave hazard assessment report for future Trift reservoir → Laboratory tests (1:50) Preparation of field tests → Field Test 2018 & Analysis → Improved design guidelines


Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der Eidgenössischen Technischen Hochschule Zürich

Impulswellenabschätzung
Projekt Trift

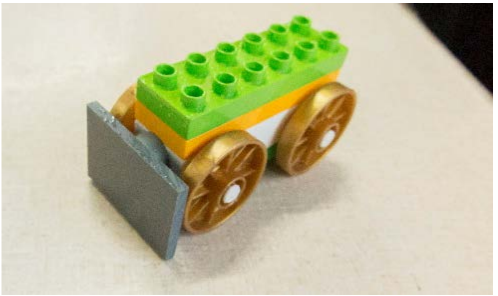
Analytische Abschätzung der zu erwartenden Wellenhöhen, Auflaufhöhen und Überschwappvolumen für festgelegte Lawinen- und Gletscherabbruchszenarien

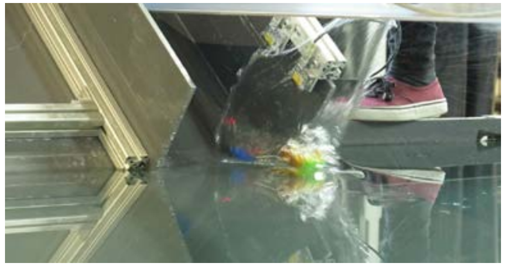
Schlussbericht

Im Auftrag der
Kraftwerke Oberhasli AG

VAW 4333

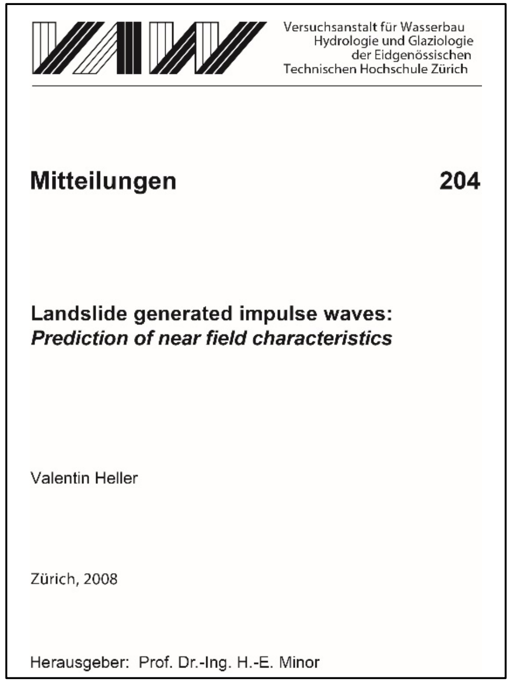
Zürich, März 2016





IMPULSE WAVES – OUTPUT

- Hazard assessment tool for process chain:
  "Landslide generation" → "Reservoir impact" → "Impulse wave generation and propagation"
- Small and large scale data on impulse wave generation
- Improved knowledge on upscaling
- Improved design guidelines for impulse wave hazard assessment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Hydrologie und Glaziologie
der Eidgenössischen
Technischen Hochschule Zürich

Mitteilungen **204**

Landslide generated impulse waves:
Prediction of near field characteristics

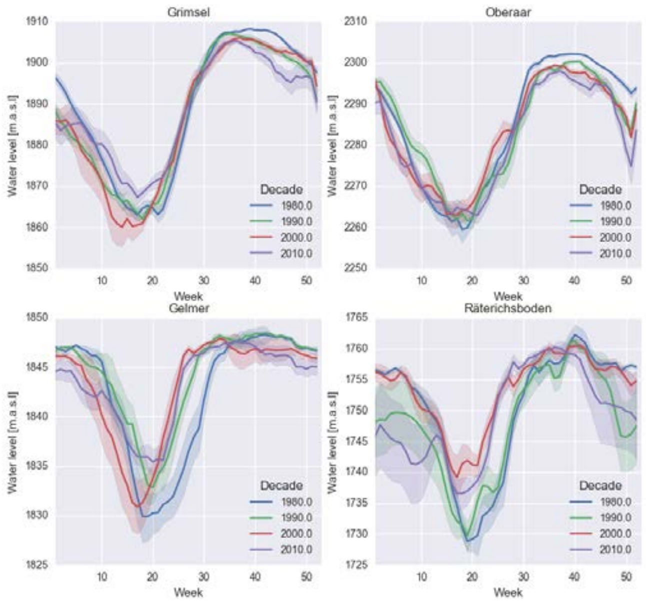
Valentin Heller

Zürich, 2008

Herausgeber: Prof. Dr.-Ing. H.-E. Minor

Test site at Grimsel Lake (Source: KWO)

WP3 Optimizing storage use



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STORAGE MANAGEMENT – MOTIVATION

Bottom-up operational questions:

- o Which past operation strategies can be re-used and when?
- o In future climate, what is the energy potential of the system?
- o What future hydropower operations are to be expected?
- o How to adapt the system to better meet future market needs?

Research questions:

- What drove historical changes in hydropower production operations?
- How can past events inform possible future trends?
- How will climate change affect the hydropower production potential of the KWO system?

STORAGE MANAGEMENT– WORK DONE / ONGOING

Analysis using two complementary approaches backed up by market and climate data from partners (FoNEW and WSL).

- Learn from the past (“soft” approach):

  Mathematical and statistical models

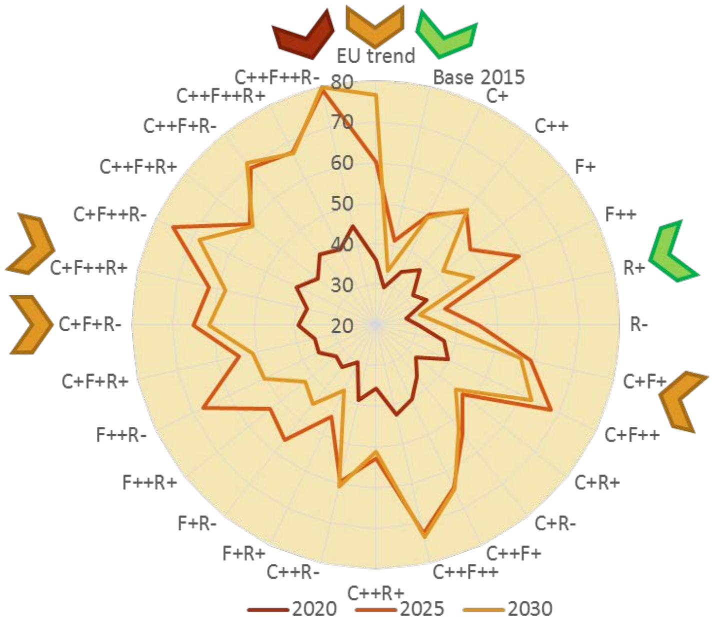
  Visualization tools

- Rule-based production model (“hard” approach):

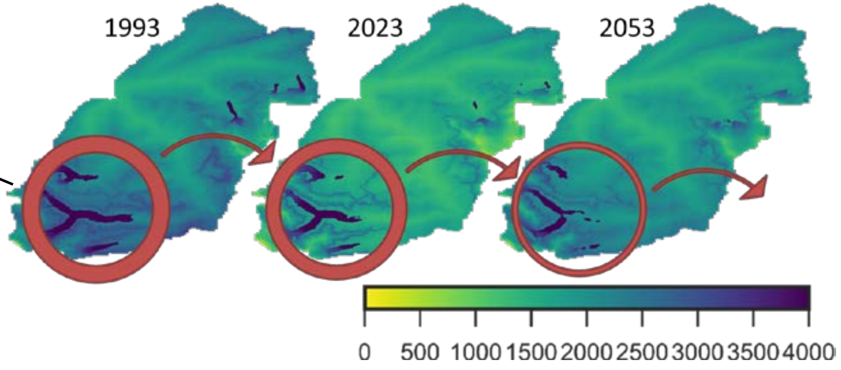
  Based on Routing System 3 (Hydrique Ltd.).

  Hydraulic model + Optiprod.

  Different scenarios (climate and markets).



Analysis of future market scenarios on production.



Evolution of runoff from downscaling models [mm/yr]

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STORAGE MANAGEMENT– OUTPUT

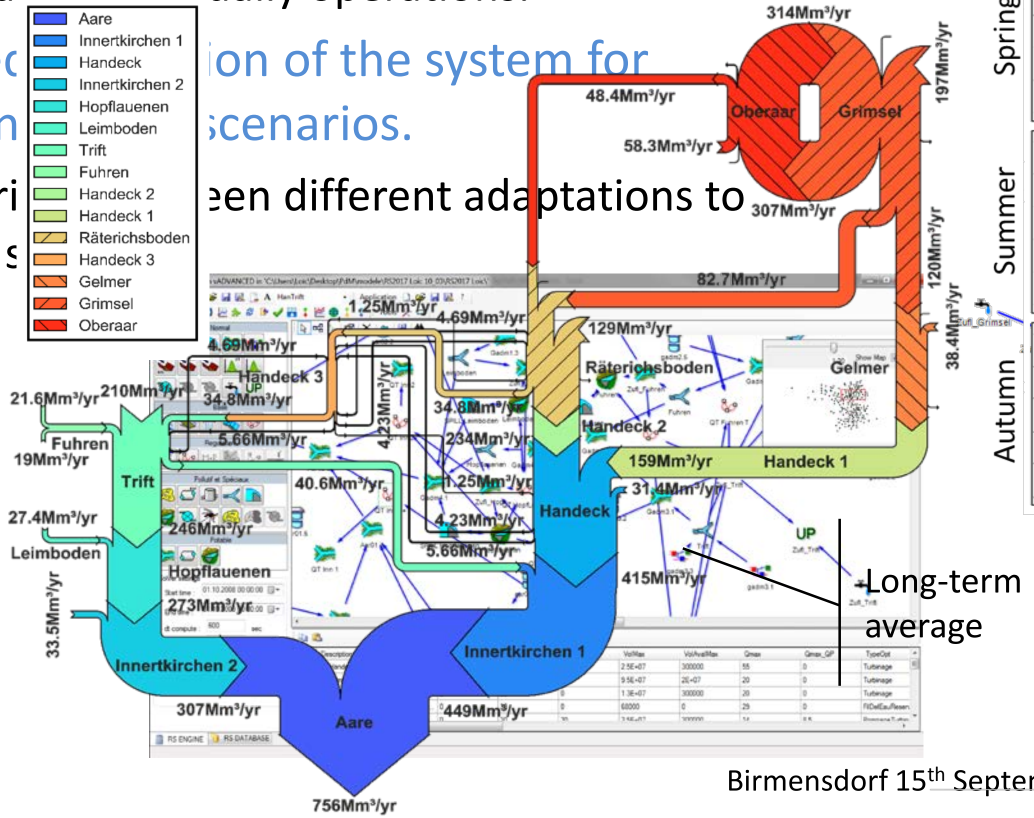
- Understanding of the system’s operation modes and what drives them.

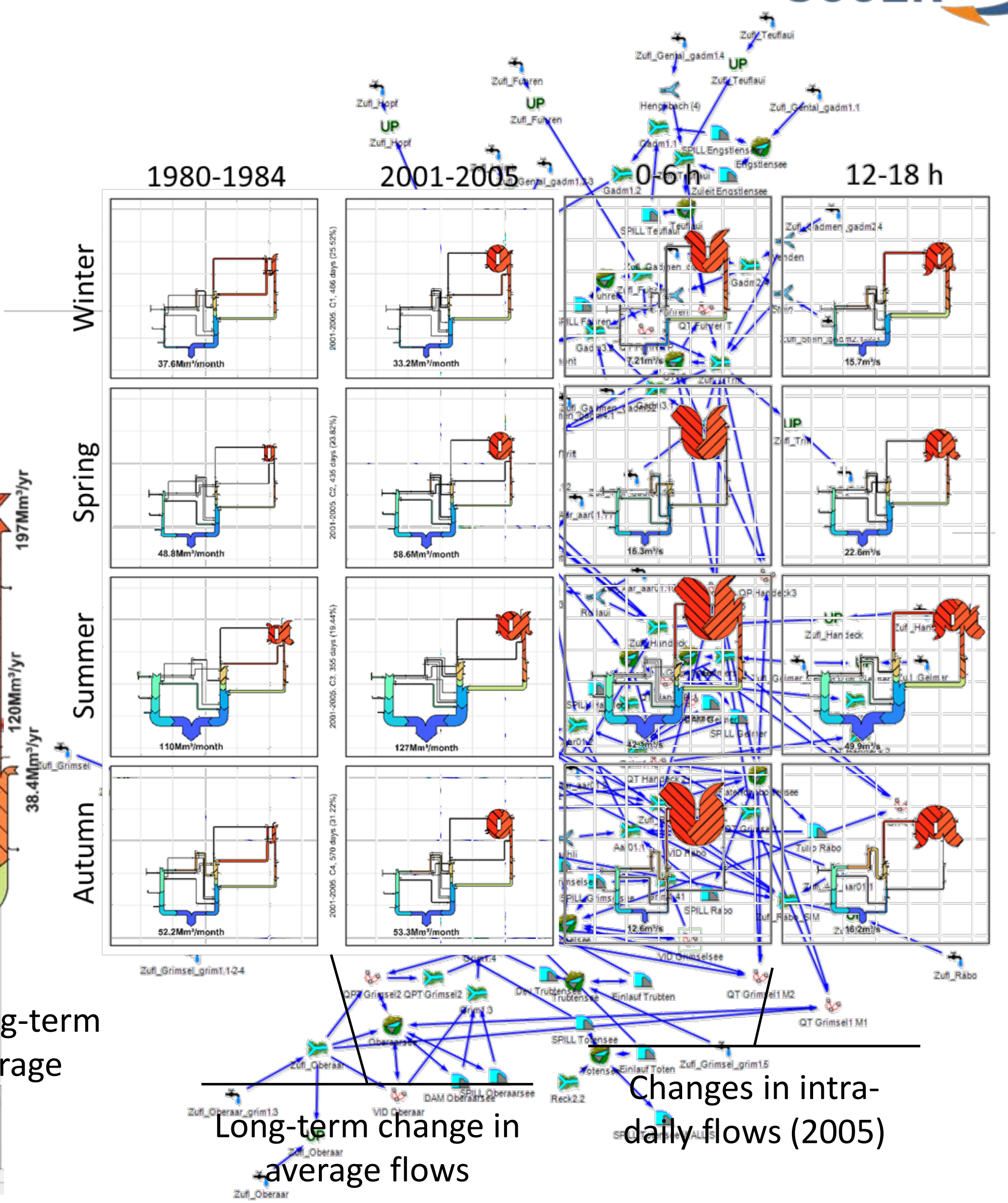
  Hydrology vs. market.

  Seasonal vs. intra daily operations.

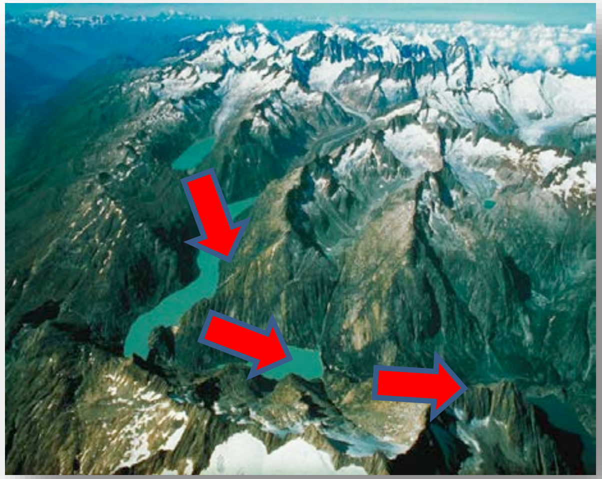
- Detailed ... ion of the system for differen... scenarios.

  Compari... een different adaptations to the s...





WP4 Sediment routing through a cascade



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SEDIMENT ROUTING (WP4) – MOTIVATION

Bottom-up operational questions:

- What is the current sediment balance of the catchment?
- How does this sediment balance evolve in time?
- How is the sediment settling affected by pump & turbine operations?
- Location of new inlets/outlets which favours lake turbulence?

Research questions:

- Parameters that characterize the level of turbulence in a reservoir?
- Minimum level of turbulence that inhibits sediment settling?

SEDIMENT ROUTING (WP4) – WORK DONE / ONGOING

Multiannual Sediment balance → **Sediment settling vs Level of turbulence** → Case study → Guidelines of Sediment Management Plan

Multiannual Sediment balance

- Sediment yield
- Pump storage exchanges (PSE)
- Sedimentation rate
- % of fine sediments

Sediment settling vs Level of turbulence

Parametrical study:

- Geometry
- Hydrodynamics
- Sediment characteristics

Case study

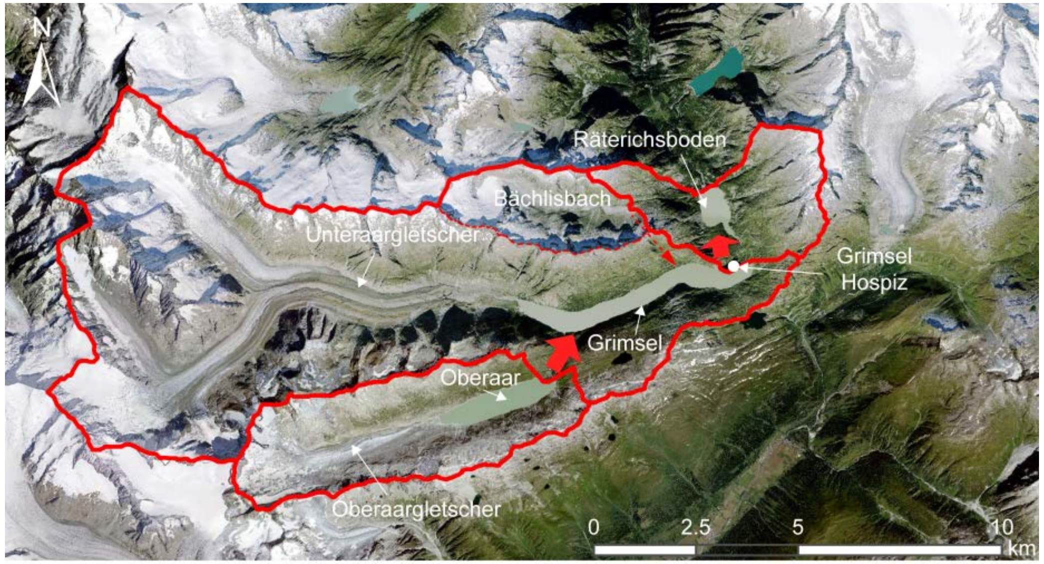
- Layout optimization (angles, relative distances, …)
- Pump-storage operations
- Flushing operations

Guidelines of Sediment Management Plan

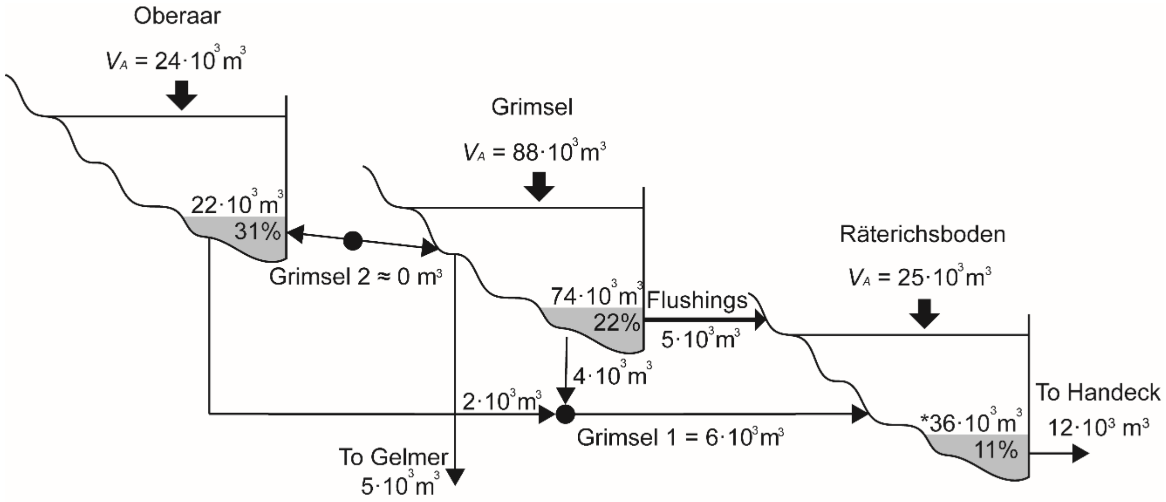
Compilation of the knowledge and insights achieved from this project to reduce the negative effects caused by sediments in reservoirs

SEDIMENT ROUTING (WP4) – OUTPUT

Sediment balance of a system of alpine reservoirs in cascade

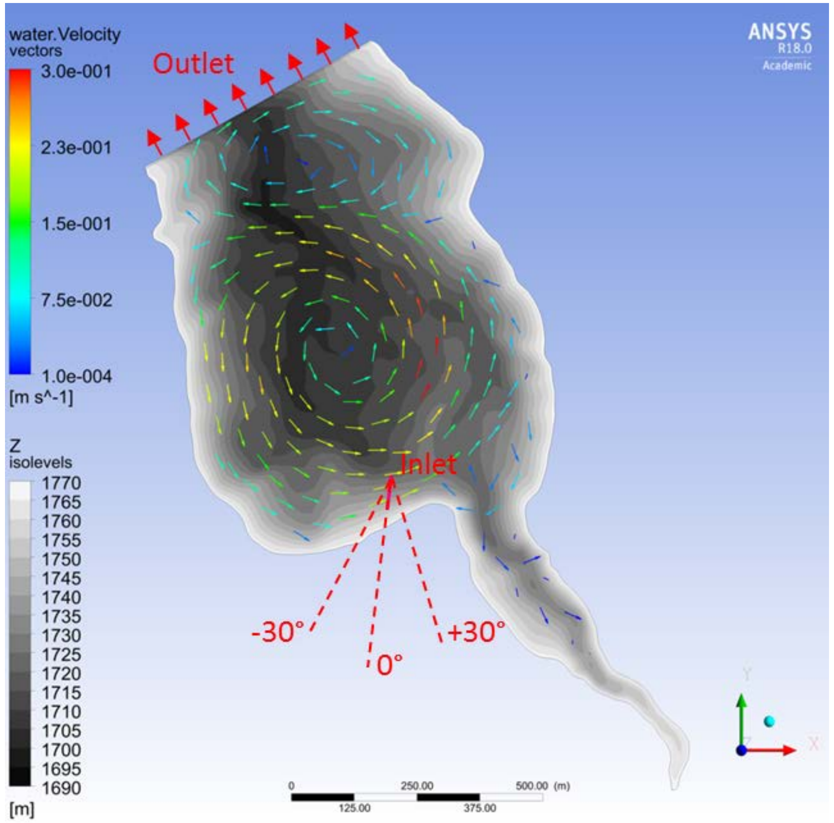


Aerial view of the system formed by the reservoirs of Oberaar, Grimsel, and Räterrichsboden

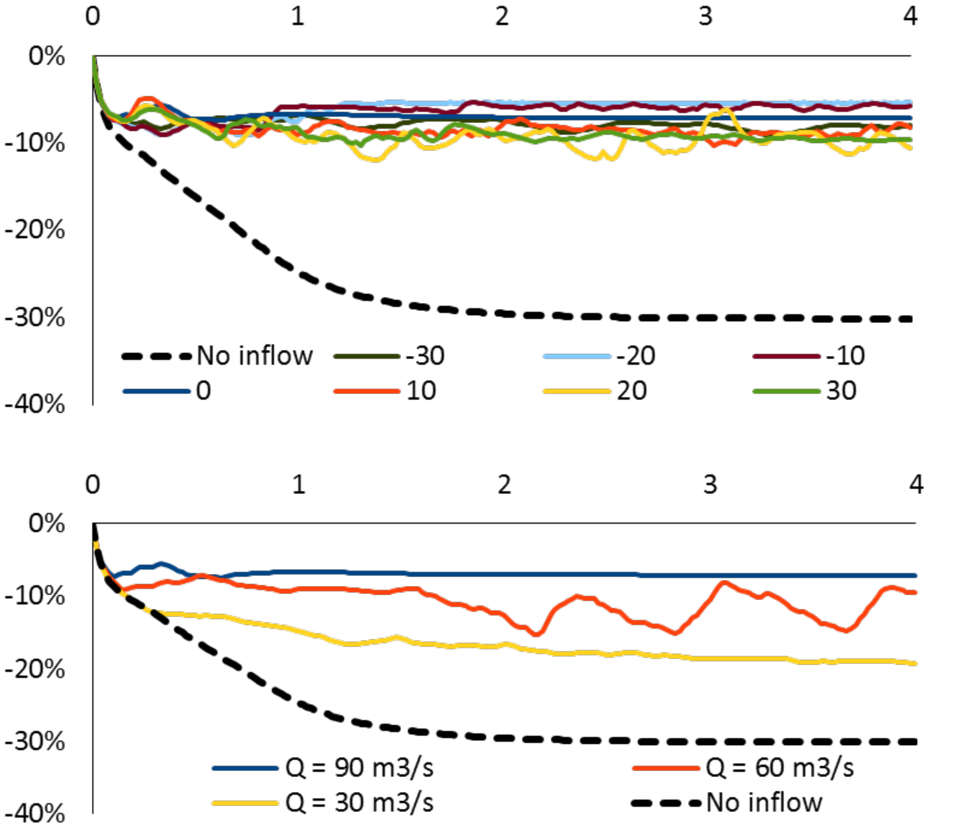


Sediment balance of the system of reservoirs in cascade

SEDIMENT ROUTING (WP4) – OUTPUT

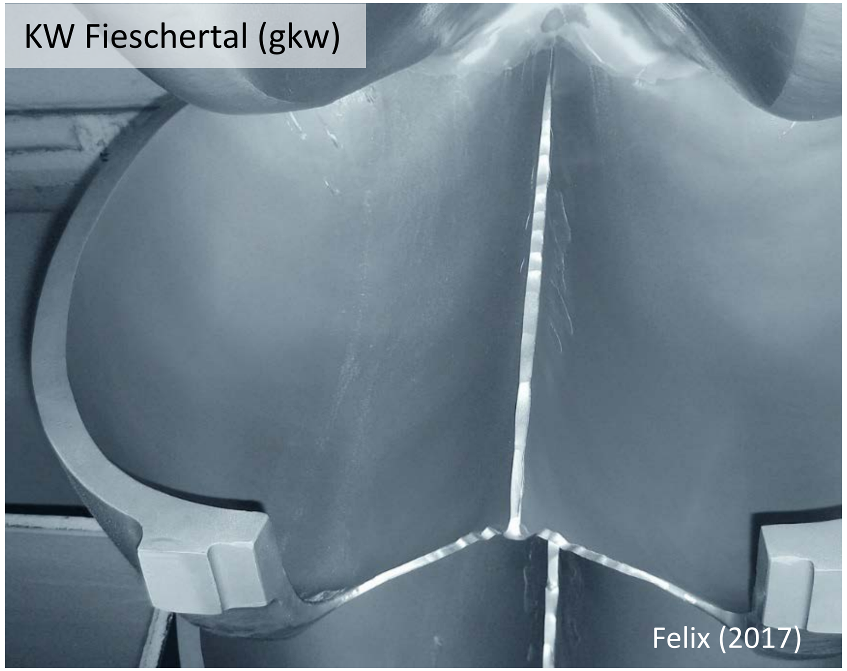


Flow velocity vectors at the water surface for Q = 90 m³/s and α = 0º



Deposition of fine sediments for different orientations and discharges of the jet-like inflow

WP5 Turbine abrasion



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TURBINE ABRASION (WP5) – MOTIVATION

Bottom-up operational questions:

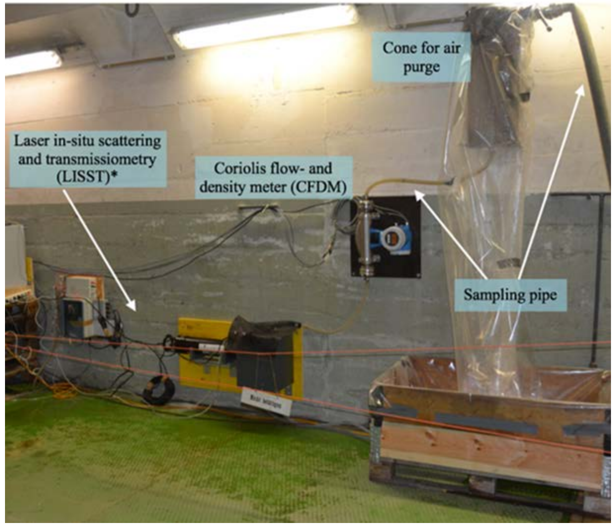
- During a reservoir drawdown, which part of the storage volume can be emptied via the turbines (rest via bottom outlet)?
- How does the suspended sediment concentration increase as the reservoir level drops and deposited sediment is re-mobilized?
- How high are the turbine abrasion and the efficiency reductions?
- How can the sediment concentration in the turbine water be increased in normal operation to reduce reservoir sedimentation?

Research questions:

- Which sediment concentration and particle sizes are acceptable in the turbine water?
- Is fine-sediment evacuation from reservoirs through the power waterway economically viable and efficient?

TURBINE ABRASION (WP5) – WORK DONE / ONGOING

2016 Monitoring of sediment load and turbine erosion during drawdown of Räterichs-bodensee → 2017 Investigation of lake sediment properties → Develop methodology (tools) for technical-economical analyses → Acceptable sediment concentrations and sizes in the turbine water → Recommend operational optimisation and further research



Analyses:

- Erosion depths (IEC 62364, HPP Fieschertal, Kaunertal)

$$\Delta d\left(t\right) = C_{\mathrm{i}}\ w^{3}\ (PL_{\mathrm{b}}(t) - PL_{\mathrm{b},0})$$

$$PL_{\mathrm{b}}(t) = \frac{z_0}{z_2} \sum_i SSC_i\ \ k_{\mathrm{size},i}\ \ldots$$

$$\ldots k_{\mathrm{shape},i}\ k_{\mathrm{hardness},i}\ \ \Delta t$$

- Turbine efficiency reductions

$$\Delta\eta = \mathrm{f}\ (s / B)$$

- Sediment-induced costs

TURBINE ABRASION (WP5) – OUTPUT

- Full monitoring of a reservoir drawdown with moderate sediment remobilisation (data sets of sediment load and turbine erosion)
- Improved knowledge on lake sediment properties (mineralogical composition, particle sizes, shape and density) as an input for erosion prediction models

- Methodology (tools) to estimate acceptable sediment concentration and particle sizes (thresholds) for sediment transport through the power waterway to reduce reservoir sedimentation
- Recommendations on acceptable concentration and particle sizes for an alpine HPP (example Räterichsboden - Handeck 2)
- Example of a technical concept for sediment mobilisation, sorting and control of the supply rate

WP6 Turbine instabilities

TURBINE INSTABILITIES (WP6) – MOTIVATION

Bottom-up operational questions:

- Alternative start/stop paths to move from stoppage to full load without instabilities?
- How can turbine units be monitored to identify instabilities and inform mitigation?

Research questions:

- How can the instabilities be described?
- Is it feasible to measure runner stresses/strain?
- What type of equipment can be employed for on-board measurements?
- Can non-intrusive monitoring be employed?

TURBINE INSTABILITIES (WP6) – WORK DONE / ONGOING

Test preparation

CFD + Workshop

1st test campaign

Dec. 2016

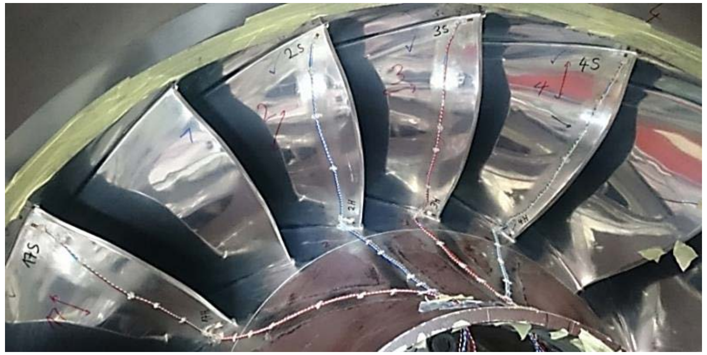
2nd test campaign

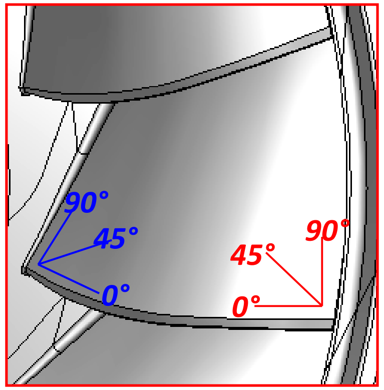
June 2017

3rd test campaign

Feb. 2018

Guidelines





Detailed presentation by Prof. Cécile Münch right afterwards!

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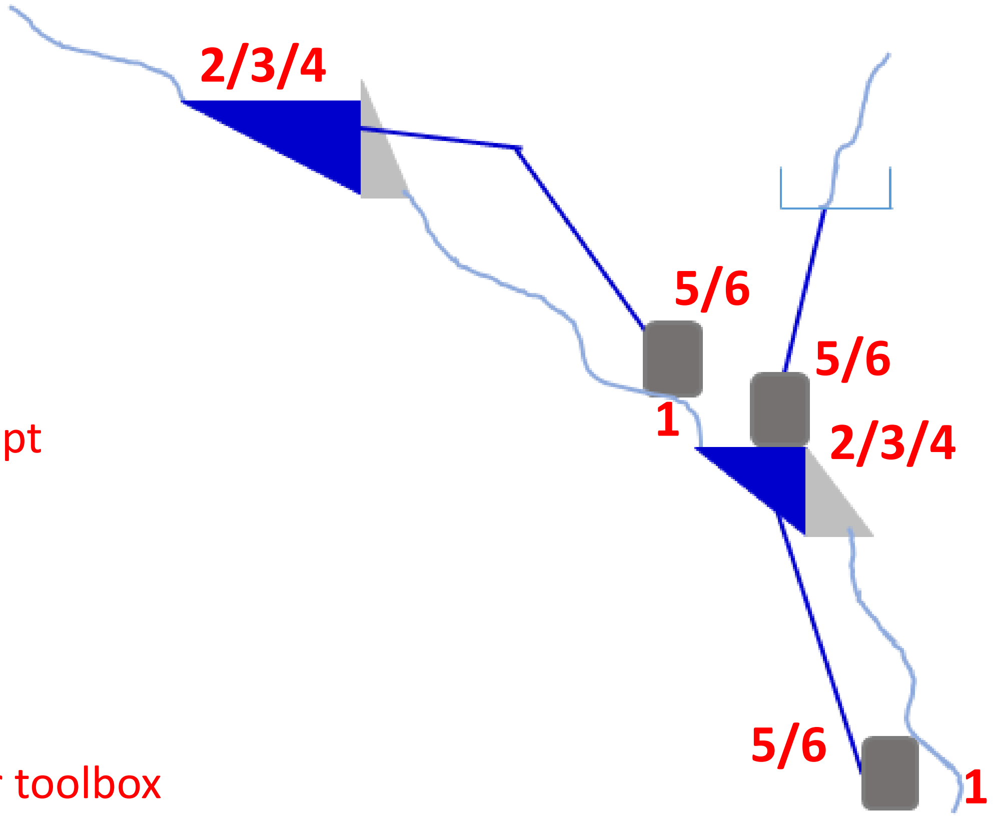
TAKE HOME

Typical Swiss high-head storage scheme



1 – Surge Attenuation toolbox

2 – Impulse Predictor f/ Freeboard Opt

3 – Optimal storage model

4 – Sediment routing model

5 – Turbine abrasion model

6 – Alternative start/stop path finder toolbox

POSTERS !!!

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