WP 5 Projects

Title

Pilot & Demonstration projects

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Preliminary discussion on the use of raw monthly hydrological forecasts during the summer 2018 drought in Switzerland
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GEo-01 : The first GEothermie 2020 P&D well in the Canton of Geneva - Preliminary results.
SIG Services Industriels de Genève - Canton of Geneva, Service de géologie, sols et déchets, Hydro-geo Environment Sarl - Geneva Geo-Energy Sarl - University of Geneva, Department of Earth Sciences

CO_2 sequestration: progress in the ELEGANCY-ACT project
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Computational Modelling of an Innovative Water Stirring Device for Fine Sediment Release: The test case of the Future Trift Reservoir.
Anass Chraibi, Samuel Luke Vorlet, Azin Amini, Pedro Manso.

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L'influence de la disposition relative des ouvrages d'entrée/sortie sur la déposition de sédiments fins dans les retenues profondes

KWO GRIMSELSTROM

*Samuel L. Vorlet [1] *, Sebastián Guillén Ludeña [2], Pedro Manso [1], Anton J. Schleiss [1]*

1) Platform of Hydraulic Construction (PL-LCH), École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
2) Hidr@m Group, Universidad Politécnica de Cartagena, Spain
**Corresponding author: samuel.vorlet@epfl.ch*

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Contexte

Les ouvrages hydroélectriques alpins sont sujets à la sédimentation, un des problèmes principaux pour la durabilité de ces ouvrages. Cette sédimentation se traduit par le remplissage des réservoirs par déposition de sédiments fins, ce qui a un impact négatif sur la production hydroélectrique. Cela pose de nombreux problèmes, notamment la réduction du volume de stockage ou le blocage des ouvrages annexes.
Il y a donc une nécessité de mieux connaître les mécanismes de la sédimentation qui a lieu dans les retenues profondes, afin d'avoir à terme un management adéquat des sédiments.

***Figure 1**: Ouvrages annexes et sédimentation observés lors de l'abaissement du niveau de l'eau*

Méthodes

Des simulations numériques sur un logiciel de mécanique des fluides computationelle ont été réalisées sur **quatre configurations de retenues profondes** rectangulaires ($B = 250m, L = 500m, H = 85m$) avec entrée et sortie modélisées par des tubes $D = 4m, v = 1m/s$), situés à mi-profondeur. Des simulations avec de l'eau claire uniquement et des simulations incluant des **sédiments fins** ($d = 4\mu m, C_0 = 88mg/L$) ont été effectuées. Le modèle de turbulence $k - \epsilon$ et un modèle inhomogène multiphase Eulerien pour modéliser l'interphase eau-sédiment ont été utilisés.

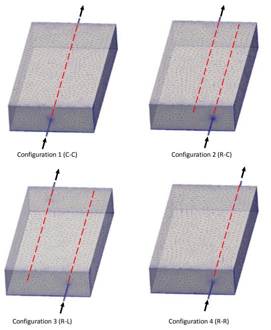

***Figure 2**: Modèle computationnel et maillage*

Champs d'écoulement dans les retenues profondes

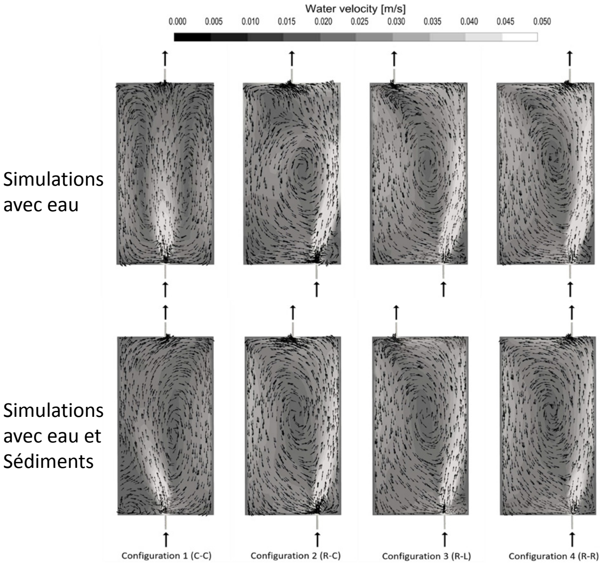

***Figure 3**: Vitesses d'écoulement de l'eau à mi-profondeur [m/s] pour simulations avec eau claire (en haut) et avec sédiments (en bas) à l'état stationnaire; vitesses d'écoulement (contours) et projection 2D de la direction de l'écoulement (flèches)*

Déposition des sédiments fins et champs de turbulence

Parmi d'autres paramètres turbulents analysés, le taux de variation spatiale de ε est celui qui présente la meilleure corrélation avec les dépôts.

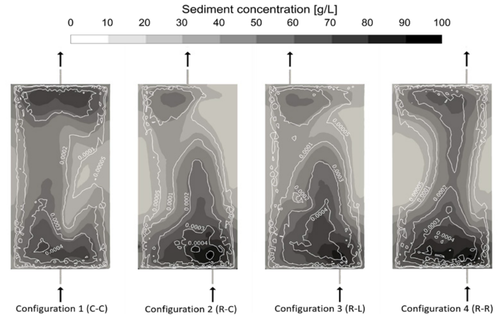

***Figure 4**: Déposition de sédiments fins au fond de la retenue [g/L] et taux de dissipation d'énergie cinétique turbulente ε [m²/s³] au fond de la retenue; simulations avec sédiments à l'état stationnaire*

Evolution temporelle des niveaux de turbulence

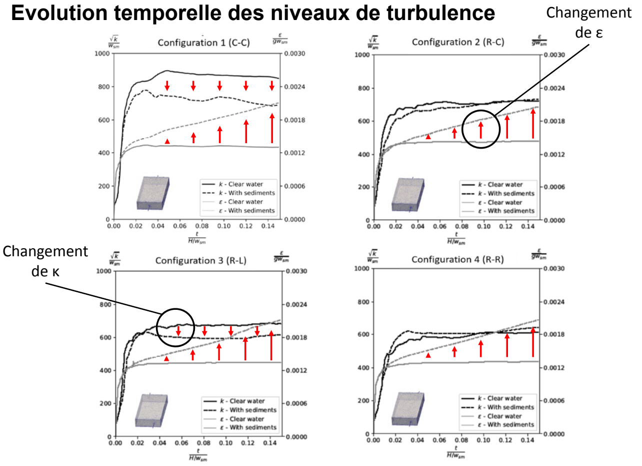

***Figure 6**: Evolution de l'énergie cinétique de turbulence k et taux de dissipation d'énergie cinétique de turbulence ε moyennés sur le volume*

Discussion

Les champs d'écoulement dépendent de la configuration entrée/sortie, de la profondeur, de la présence de sédiments, et semblent avant tout conditionnées par les débits entrants.
La déposition de sédiments fin est plus importante proche des entres/sorties et dépend du taux de dissipation d'énergie cinétique de turbulence ϵ. Plus le taux de dissipation d'énergie est important, plus la déposition de sédiments est importante, et inversement.
La présence de sédiments fins modifie l'hydrodynamique et les niveaux de turbulence des retenues. On observe un changement au niveau des valeurs pour l'énergie cinétique de turbulence *k*, avec des valeurs plus faibles en présence de sédiments, et un changement de comportement pour le taux de dissipation d'énergie cinétique de turbulence ε.

Conclusions

La déposition des sédiments dépend des champs d'écoulement et des niveaux de turbulence dans les retenues. Contrairement aux réservoirs peu profonds, les champs d'écoulement des réservoirs profonds varient en fonction de la hauteur. Pour anticiper le champ de déposition des sédiments, les champs d'écoulement et les niveaux de turbulence doivent être considérés au fond du réservoir.

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CFD and FEM investigations of a Francis turbine at speed no-load

J. Decaix[1], V. Hasmatuchi[1], M. Titzschkau[2], L. Rappilard[1], P. Manso[3], F. Avellan[4], C. Münch-Allingé[1]

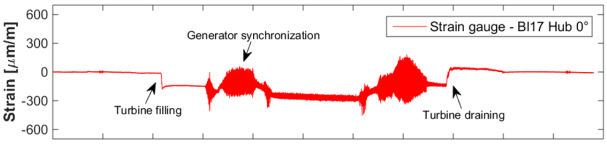
[1]*HES SO Valais, Haute École d'Ingénierie, Hydroelectricity Group, Sion* [2] *Kraftwerke Oberhasli AG, Grimsel Hydro, Innertkirchen* [3]*EPFL, PL-LCH, Lausanne* [4]*EPFL, LMH, Lausanne*

Motivation

Due to the development and the integration of renewable energies, the electrical grid undergoes instabilities [1]. Hydraulic turbines and pump-turbines are a key technology to stabilize the grid. However to reach this objective, the hydraulic machines have to extend their operating range. Such an extension requires to deal with start-up and stand-by operations, which often leads to a reduction of the lifespan of the machines [2].
Nowadays, CFD and FEM simulations allow dealing with fluid-structure interactions, which help better understanding of the life time of hydraulic machines [3].

Context

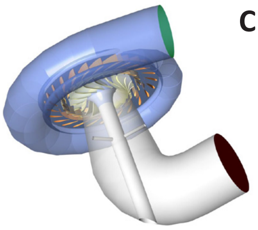
The Grimsel 2 hydropower plant is equipped with horizontal ternary units with a complete motor-generator coupled with a Francis turbine on one hand and a single stage radial pump on another hand.
The Francis turbine undergoes cracks at the junction between the trailing edge of the blades and the hub. The cracks appeared after the operating conditions of the turbine changed from a few to a large daily number of start and stops.
The origin of the cracks is however not yet fully understood despite the fact that the case has been already studied [4].
A recent measurement campaign put in evidence the large fluctuations of the strain rate at the trailing edge of the runner blades close to the junction with the hub during the operation of the turbine at speed no-load (*i.e* during synchronization procedure) [5].

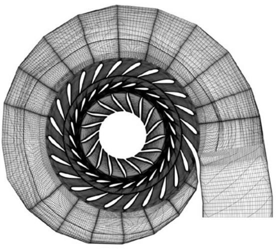


CFD and FEM set up

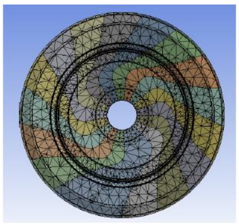
For the CFD analysis, the SST-SAS turbulence model is used to compute the flow. The inlet flow discharge is set at the inlet of the spiral according to the measured value at speed no-load.
For the stress analysis, the pressure field provided by the CFD simulation is applied on the runner blade, whereas no displacement is imposed at the junction between the runner and the shaft.
For the modal analysis of the runner, the surrounding water is taken into account in order to capture the damping of the natural runner frequency due to the added mass effect.

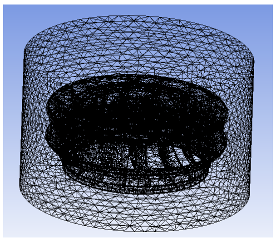
CFD





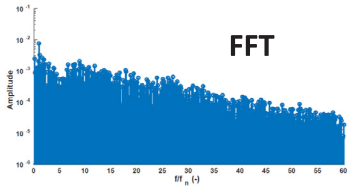
FEM

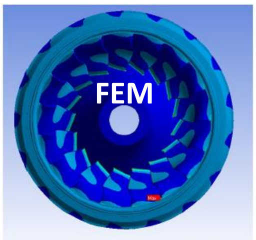


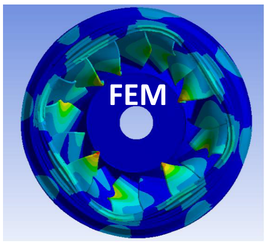


Results

The CFD simulation shows the presence of several vortices close to the trailing edge of the blade. The vortices lead to local pressure fluctuations. However, no specific frequency is observed on the pressure spectra of a probe located at the junction between the runner blade and the hub.
The stress analysis confirms that the maximum stresses are located at the junction between the runner blade and the hub.
The modal analysis put in evidence the existence of a natural mode of the runner around 600 Hz close to the dominant frequency deduced from the signal provided by the strain gauges.







Conclusions & Perspectives

The CFD simulation does not show any evident excitation at the frequency observed on the strain gauges. The FEM analysis confirms the weakness region at junction between the runner blade and the hub. The modal analysis suggests the existence of a natural mode of the runner close to the frequency observed on the strain gauges. Therefore, this mode could be excited by a source, which does not seem for instance clearly related to the fluid.

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Preliminary discussion on the use of raw monthly hydrological forecasts during the summer 2018 drought in Switzerland

Massimiliano Zappa[1], Luzi Bernhard[1], Konrad Bogner[1], Samuel Monhart[1,2,3], Käthi Liechti[1], Norina Andres[1], Christoph Spirig[2], Manfred Stähli[1]

[1] **Swiss Federal Research Institute, WSL**
[2] Federal Office of Meteorology and Climatology, MeteoSwiss
[3] ETH Zurich, Institute for Atmospheric and Climate Science

MONTHLY FORECASTS UP AND RUNNING IN REALTIME !

The summer of 2018 in Switzerland has been characterized by a severe DROUGHT.

In the framework of the **NRP70** project “**HEPS4POWER**” (separate poster) and **NRP61** “**drought.ch**”, tools for elaborating monthly predictions of water resources for hydropower and early prediction of hydrological droughts have been elaborated.

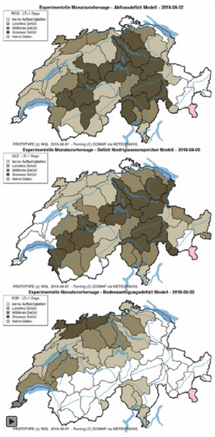
Starting from August 9th 2018, WSL and MeteoSwiss agreed to run a **pilot operation period** of such forecasts, with the goal of obtaining users feedback on such new forecasts tool going far beyond the lead time of hydrological predictions currently available in Switzerland.

The 2018 drought recorded lowest precipitation amounts from April until mid-August. It has been accompanied by an heatwave during the second half of July. The public interest on predictions concerning the drought situation and its possible end has been huge (Figure 1).

Methods

- 51 numerical weather forecasts by ECMWF for the next month every Tuesday and Friday
- Hydrological model PREVAH forced by weather forecasts and by MeteoSwiss observations
- Applications for the Thur basin as in Fundel et al. (2012) and for Switzerland as in Bogner et al. (2018)
- Realtime since August 9th 2018. Reruns for July 2018 completed
- Publication of forecasts (as deviation from climatology, Figure 2) for precipitation (**P**), runoff (**R**), soil moisture (**SM**), and baseflow storage (**B**) on WWW.DROUGHT.CH (Zappa et al., 2014)
- Communication on social media (Figure 4)

Figure 2: Forecast 2.8.18



Results (Thur basin) **BOXPLOTS: Forecast** **LINE: Actual values**

Fig. 3a: ECMWF: 5, July 2018

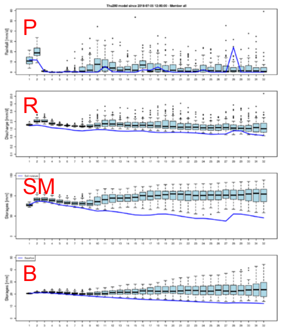


Fig. 3b: ECMWF: 19, July 2018

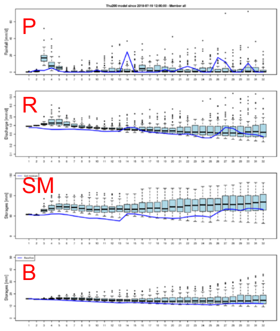


Fig. 3c: ECMWF: 26, July 2018

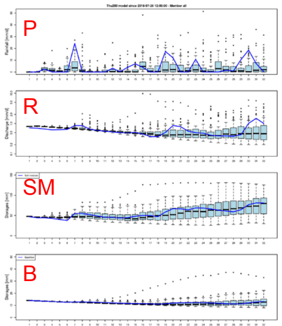
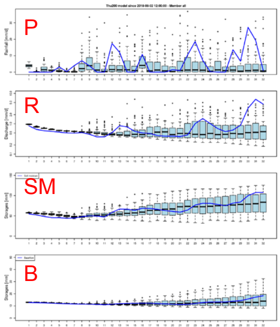


Fig. 3d: ECMWF: 2, August 2018



Motivation and feedback in the news

«Es müsste über Wochen stark regnen»

Das Ende der Trockenheit könnte voraussagbar sein

Die üblichen Prognosen in der Schweiz schauen nur fünf Tage in die Zukunft – technisch möglich wären bis zu dreissig Tage

MATTHIAS SANDER

Wann endet die Trockenheit? Diese Frage stellen sich derzeit in der Schweiz Landwirte, Schiffskapitäne, Fischer, Hobbygärtner und viele mehr. Die Antwort: Keiner weiss es. Aber Experten wären womöglich in der Lage, das Ende der Trockenheit zu prognostizieren – wenn sie genügend Ressourcen hätten. Das sagt der Hydrologe Massimiliano Zappa.

Vor Trockenheit könnte man warnen

30-Tage-Prognose

BIRMENSDORF | Hydrologen der Forschungsanstalt WSL testen derzeit eine 30-Tage-Trockenheitsvorhersage. Demnach könnten sich die ausgetrockneten Böden zumindest in manchen Gebieten der Schweiz bis Ende August erholen. Bisher konnten Hydrologen der Forschungsanstalt für Wald, Schnee und Landschaft (WSL) auf der Webplattform trockenheit.ch eine 5-Tage-Prognose anbieten. Für diesen Zeitraum liefern Wettermodelle ausreichend sichere Daten über Niederschläge. Angesichts der angespannten Lage testen die WSL-Forschenden nun aber in Zusammenarbeit mit MeteoSchweiz eine 30-Tage-Trockenheitsprognose, wie die Forschungsanstalt am Donnerstag mitteilte. Ab sofort sei die Monatsvorhersage online abrufbar. **sda**

TROCKENHEIT: Erstmals ist eine Langzeitprognose verfügbar

Leichte Entspannung in Sicht

Die Töss bei Saland am 4. August 2018: Das Flussbett ist vollständig trocken. *(Bild: Gottardo Pestalozzi)*

ge-Modellrechnungen des Europäischen Zentrums für mittelfristige Wettervorhersage EZMW gefüttert. Diesen Pilotbetrieb werden sie während der nächsten drei Wochen weiterführen. «Wir möchten zeigen, wie weit unsere Methoden sind, und der Öffentlichkeit die Möglichkeit geben, den Nutzen der Monatsvorhersage zu prüfen», sagt Zappa.

Mit Unsicherheiten

Und hier nun die – vorsichtige – Vorhersage für die nächsten drei Wochen: Ausgehend von der Situation am 2. August

Figure 1

Sources: NZZ, sda, WSL, Landbote, 20Minuten
17. July to 11. August 2018

Figure 4

Massimiliano Zappa
@Hydrology_WSL

Sixt update of our operational pilot monthly predictions for #drought. @ECMWF run 20180823. #Optimistic

Sechste Aktualisierung unserer Pilotversuch mit Monatsvorhersagen für die #Trockenheit. #EZmW Lauf 20180824. #EsBewegtSichDoch

Link: drought.ch/Prognosen/Mona...

1:16 pm - 24 Aug 2018

4 Retweets 7 Likes

Feedback and Discussion

- Monthly hydrological forecasts well received by media and users
- Visitors on www.drought.ch from 8000 in June to 20000 in July and August
- Very timely demonstration of possibilities of hydrological forecasts using raw meteorological input. HEPS4POWER by NRP70 showed the potential of further improvement by bias correcting such forecasts (Monhart et al., 2018)
- Forecasts issued since the end of July (Fig. 3c and 3d) were well able to confirm that drought in soil moisture would slightly recover within 30 days, while drought in runoff and baseflow would hold-on
- Recalculations of forecasts in early July (Fig. 3a and 3b) indicate, that only few scenarios would have hinted to such a severe drought.
- Previous analyses on the potential of monthly forecasts for water resources management during drought situations is confirmed
- The use of this information for management of hydropower in Switzerland has been explored in the HEPS4POWER project in case of the reservoir of the Verzasca river. A study for runoff river plants along the major rivers would be an interesting outlook

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Implementation of an operational seamless nowcast to short range forecast system for the small hydropower plant at Gletsch

K. Bogner. M. Buzzi, M. Schirmer, M. Zappa

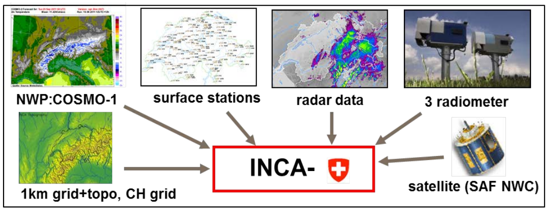
Motivation

In order to highlight the possibilities of increasing the flexibility in managing Small Hydropower Plants (SHP) with very limited storage capacities high resolution forecasts have been adapted to the small alpine catchment at Gletsch (VS) within the Demonstrator Project **SmallFlex**. Therefore the meteorological nowcast system INCA – CH has been combined with the short range weather forecast system COSMO-1. These two forecast are taken as input for the hydrological model PREVAH in order to produce stream-flow forecasts. Because of the differences in the initialization the forecasts need to be integrated into one seamless forecast system.

Methods

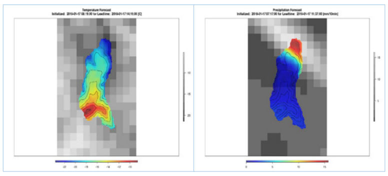
The forecast chain consists of :

- Meteorological forecasts:
  INCA – CH system + COSMO 1 (+ COSMO-E)

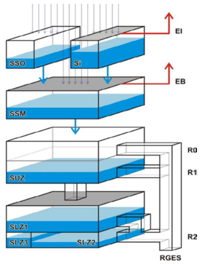


INCA – CH: Spatial resolution ~ 1km
Temporal resolution: Precipitation: 10 min
Temperature: 1h

- Hydrological model PREVAH (+ Post-Processing of the inflow forecasts)



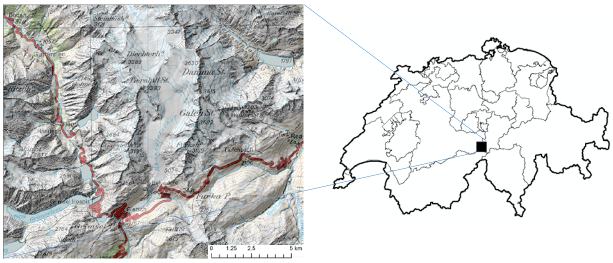
1 km resolution of the INCA – CH model output (in grey) and the forecast downscaled to 100 m (resolution of the hydrological model PREVAH). Black contour lines indicate the elevation zones. The downscaling is done by fitting Thin Plate Splines (TSP) to the surface taking the elevation as co-variate.



PREVAH Model

Study Area

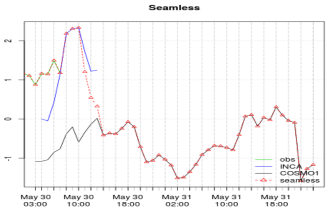
Gletsch catchment:
Area: 39.8 km^2 ;Glaciation: 52%; Mean elevation: 2719 m a.s.l.



Seamless stream-flow forecast

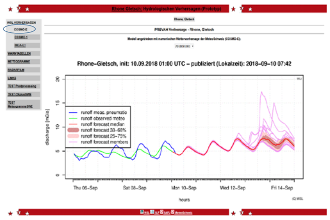
The INCA – CH system is a forecast bridging the information gap between the latest available observations in real-time (e.g. CombiPrecip) and COSMO 1 forecasts. However, because of different times of initialization and data, resp. forecast availability at WSL, the resulting stream-flow forecasts show jumps between the different data sets. Therefore a simple weighting schema is applied to create seamless stream-flow forecasts without abrupt junctions.

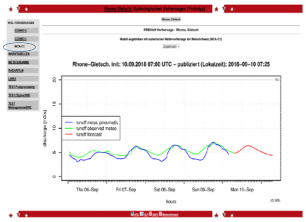
Example of a temperature forecast showing the latest available observations (green), INCA –CH forecast (blue), the COSMO 1 forecast (black) and the seamless forecast (red)

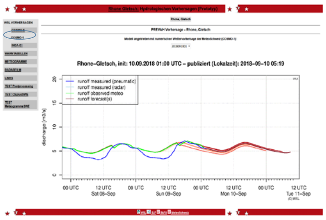


Operational implementation

The results of these different forecast systems are available now operationally for Gletsch on the web showing the 5 days forecasts driven by COSMO-E, the INCA forecast for the first 6 hours and the seamless forecast combining the INCA and COSMO-1 for the next 33 hours



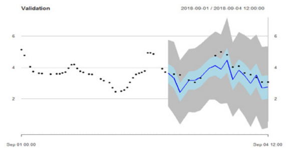




COSMO-E – Ensemble forecast for the next 5 days (top left)
INCA – CH 6 hourly forecast (top right)
Seamless INCA – CH + COSMO 1 forecast for the next 33 hours (bottom left)

Outlook

- Collection of longer forecast data sets in order to train Machine Learning techniques for post-processing the stream-flow forecasts.
- Implementing a Nowcast Ensemble Prediction System*
- Deriving the predictive uncertainty



Example of a post-processing test applying MARS (Multivariate Adaptive Regression Splines)

* Ongoing research at MeteoSwiss
D. Nerini, et al, 2017: A non-stationary stochastic ensemble generator for radar rainfall fields based on the short-space Fourier transform, Hydrology and Earth System Sciences 21(6), http://doi.org/10.5194/hess-21-2777-2017

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Supported by:

Investigation of transient mixed flow at hydropower plant intake

A. Gaspoz[1], V. Hasmatuchi[1], C. Nicolet[2], C. Munch-Alligné[1]

[1]HES-SO Valais, School of Engineering, Hydroelectricity Group, CH-1950 Sion, Switzerland, anthony.gaspoz@hevs.ch
[2]Power Vision engineering Sàrl, Chemin des Champs Courbes 1, CH-1024 Ecublens, Switzerland

This study is performed in the framework of the **SmallFlex** project which aims to show that small-hydropower plants can provide winter peak energy and ancillary services, whilst remaining eco-compatible.

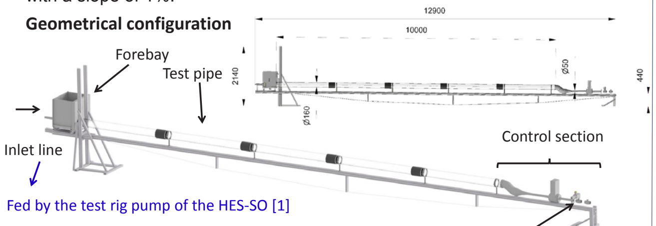
Objectives of this study

- Development, design and building of a reduced-scale test bench as well as its control to reproduce transient behaviour developing at hydropower plant intake and its penstock.
- Numerical modelling and simulations of those phenomena with Simsen.
- Analysis and comparison of numerical and experimental results for two test cases.

Laboratory reduced-scale test bench

The test bench is mainly manufactured with transparent parts to allow flow visualisation and contains a forebay, a test pipe and a control section. The whole test section is mounted on a inclinable support allowing slope setting. A return pipe, a free-surface tank and a pump completes the closed-loop hydraulic circuit. A high speed closing ball valve has been specially developed to obstruct the flow in less than 10 milliseconds. This obstruction speed generates a direct water hammer in case of a full filled pipe. The principal test case is a fast valve closure at the downstream of a mixed flow with a slope of 1%.

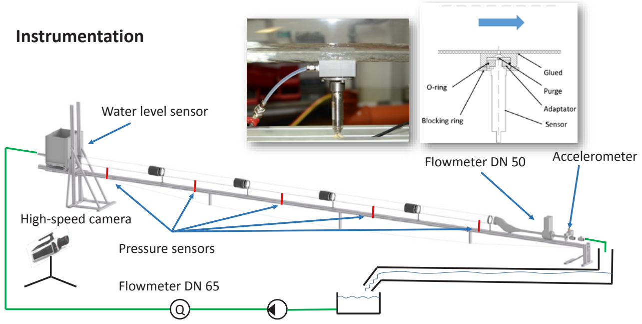
Geometrical configuration



Fed by the test rig pump of the HES-SO [1]

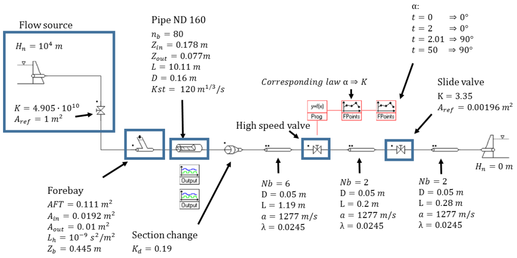
Rapid obstruction of the downstream flow (1x high-speed ball valve)
Adjustment of the free surface height, to ensure a **Fr <1** (1x slide valve**)**

Instrumentation



Numerical approach

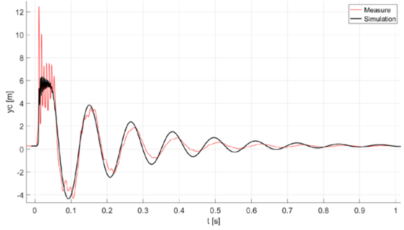
A compressible numerical approach was considered using a 1D software called Simsen [2]. This software allows to compute both transient electrical and hydraulic schemes. The Preissmann model [3], specially developed for the computation of transient compressible mixed flow, was used. The considered Simsen model is the following:



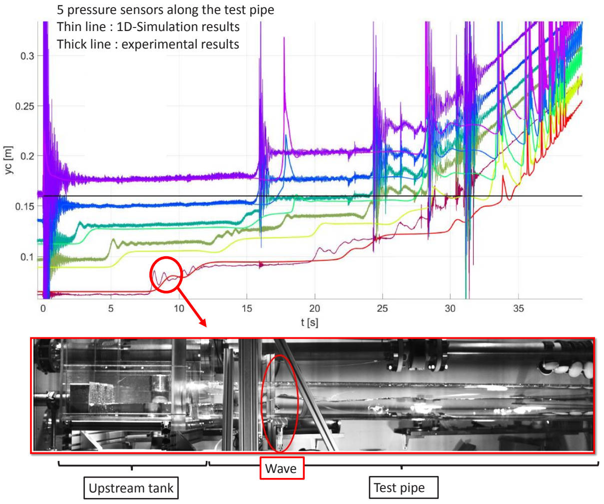
Results

Experimental and the numerical results have been compared in the case of a fast closure using the high speed valve. A good agreement is observed for both considered flow initial conditions, the fluid structure interactions being discarded.

1) Full pipe with a quasi-stationary flow:



2) Mixed flow in the test pipe, free surface mainly parallel to the pipe bottom, the end of the test pipe being completely filled. The flow was quasi-stationary and the Froude number was everywhere below 1.



Conclusions and perspectives

These investigations have shown that:

- The developed test bench allows to reproduce transient flow observed at the intake of hydropower plant.
- The transient behaviour of the flow, either monophasic or mixed, is globally well predict with Simsen 1D-Simulation with a correct calibration of some parameters.
- Ongoing work: development and implementation of a model able to simulate flows with a Froude number > 1 and its validation on this test bench.

Acknowledgements

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Confederaziun svizra
Office fédéral de l'énergie OFEN

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Assessment of a pressurized flushing event in a deep alpine reservoir

Maria Ponce, Samuel L. Vorlet, Azin Amini, Pedro Manso*

Platform of Hydraulic Construction (PL-LCH), École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
**Corresponding author: maria.ponceguzman@epfl.ch*

Framework

Mountainous reservoirs face a serious problem with sediment management. The retention of sediments through time reduces the water storage capacity and can lead to the blockage of bottom outlets and power intakes. In case of blockage, drastic emergency maneuvers at the dam maybe will be required to control the harmful impacts on the downstream river system. Therefore, regulating or removal of the deposited sediments must be anticipated, planned and properly implemented.

Grimsel reservoir in the Swiss Alps is affected by high glacier erosion and periodically uses the pressurized flushing to evacuate fine sediment.

The objective of this study is simulate a pressurized flushing event in order to estimate the amount of sediment removed and identify the morphologic evolution of the flushing channel bed with reasonable computational resources.

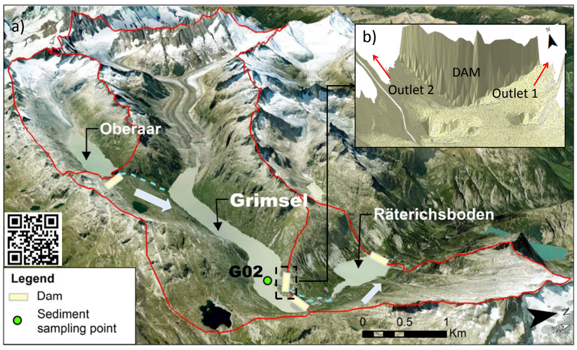
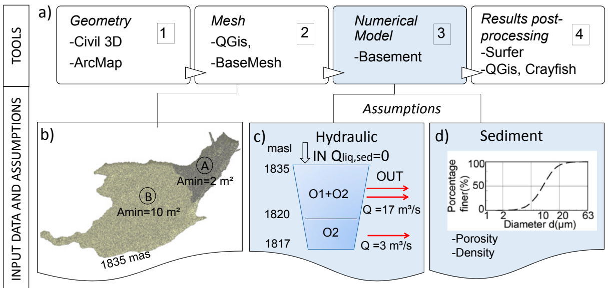


Figure 1: a) Upper view to west of the Grimsel Lake as a part of the cascade hydropower scheme, and b) Sketch of the generated mesh close to the outlets (galleries).

Methods

- The numerical model was built in Basement 2.8, using a 2D depth-averaged formulation.
- The scenario modeled is a future planned event based on the second stage of the 2000 flushing event during the winter season characterized by a partial reservoir drawdown lasting 5 hours.



MODELS

e)

1: Hydraulic	2D Shallow water		
2:Sediment transport	Capacity	Bed load	Engelund Hansen equation
		Suspended load	Advection-Difussion equation
	Bed evolution	Exner eq. + Gravity transport	

Figure 2: Model construction framework: a) Tools, b) Mesh was done with the bathymetry of 2016 (triangular elements with two areas of refinement), c) Boundary conditions, d) Granulometry curve (G02 sample, ETH-VAW, 2017), and e) Mathematical models for water and sediment transport.

Preliminary results and discussion

The computational time for a full simulation has been for 10 hours, with a CPU with 28 cores, which is considered a reasonable duration for a scenario assessment.

The volume of the bed load removed through the outlets is 3200 m³ which corresponds to the volume of the flushing cone estimated by EPFL in 2009. This low volume can also be validated with the bathymetries of 2000 and 2016 that show a loss of 90% of storage capacity below the elevation 1834 masl.

The suspended concentration at outlet 2 was only taken into account during the first 15 min during which it reached 960 ml/l after 10 min then reduced to 260 ml/l.

It can been noticed small bed changes on the border of the contours, some re-deposition areas close to the dam and significant erosion close to the outlets due to the higher velocities (figure 3d).

The channels formed by flushing did not show any significant bed change during the simulation. However, the bed width of the existed incised channel agreed with the results of the empirical equation derived by Tsinghua University reported in White (2001) showing that the flushing discharge is the key factor for the channel formation in this reservoir, and therefore highlight the necessity to improve the normal flushing operation to change the depositional areas.

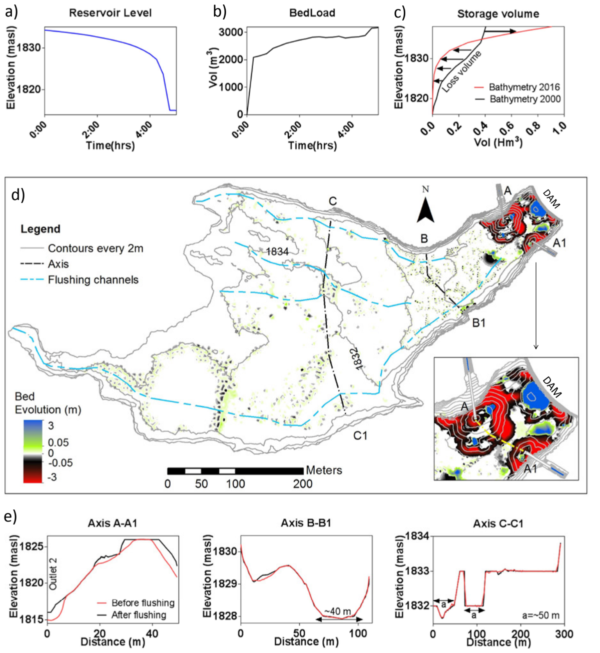


Figure 3: Main results of 5-hour flushing event from partial drawdown level of El. 1835: a) Reservoir level and b) Removed bedload volume reached during the simulation, c) Storage water lost between 2000 and 2016, d) Bed evolution after the flushing event, and e) Bed change at the respective cross section at the beginning and at the end of the modeled event.

Conclusion and Perspectives

The preliminary results provide only limited deposit close to the outlets, and show that the flushing event is ineffective to remove the deposited sediment away from the dam, and is ineffective to form new flushing channels across the reservoir.

To optimize the flushing operation (remove sediments at an adequate rate and minimize downstream impacts), two possible scenarios will be considered:

1) Adding a constant input discharge from Oberaar (coordinated operation) and changing the duration and the discharge of the outlets.

2) Modifying the bed topography of the reservoir, enlarging the section and increasing the longitudinal slope of the flushing channel immediately upstream of the dam in order to increase the movement of the sediment in the subsequent flushing operation.

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Scaling up and specifying a stirring device (SEDMIX) from laboratory to prototype

Chraibi, A., Amini, A., Manso, P., Schleiss, A.J.*
*Platform of Hydraulic Constructions (PL-LCH), EPFL; *corresponding author: anass.chraibi@epfl.ch*

Introduction

Sedimentation is a key challenge in reservoir management. A recent PhD study at EPFL (Jenzer-Althaus, 2011) proposed an innovative system (called SEDMIX, Figure 1) allowing to keep in suspension or re-suspend the fine particles near the dam. The current project's aim is to develop a real-sized prototype of SEDMIX device. It is equipped with 4-nozzle pressurized water jets inducing sufficient upwind turbulence to maintain fin sediments in suspension.

The work encamps the following aspects:

- Hydraulic and structural design as well as technical specification of the device.
- Installation procedure.

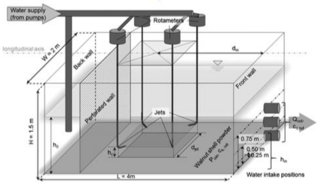

***Figure 1**: SEDMIX experimental model*
(Jenzer-Althaus, 2011)

Up-Scaling

- To guaranty a similar efficiency as in the hydraulic model, the scaling factor (λ_L) used to design a real-sized SEDMIX should satisfy two conditions:
    - Froude similarity, expressed by a relationship between the jet discharges used in the test and those of the real case.
    - the circulation velocity compared to the settling velocity should at least be the same as in test conditions.
- SEDMIX would be supplied either with a pump or directly connected to a water conveying tunnel which transfers water from a neighbouring catchment.
- For the presented prototype, a total jet discharge of $5\ m^3/s$ is considered. This leads to a scaling factor of $\lambda_L = 38$.

Design

- The design of SEDMIX prototype has been performed to fulfil the following objectives:
    - Minimise head losses and consequently the required power during operation.
    - Minimize fabrication and installation costs, specially for the manifold pipe diameter (Figure 2).
    - Optimal structural stability and strength according to the relevant design standards (ANSI/ASME …) (Figure 3).
    - Figure 4 illustrates the manifold specifications

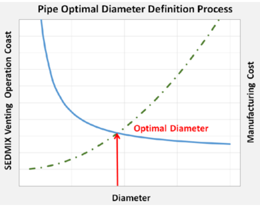

***Figure 2:** Pipe diameter optimization*

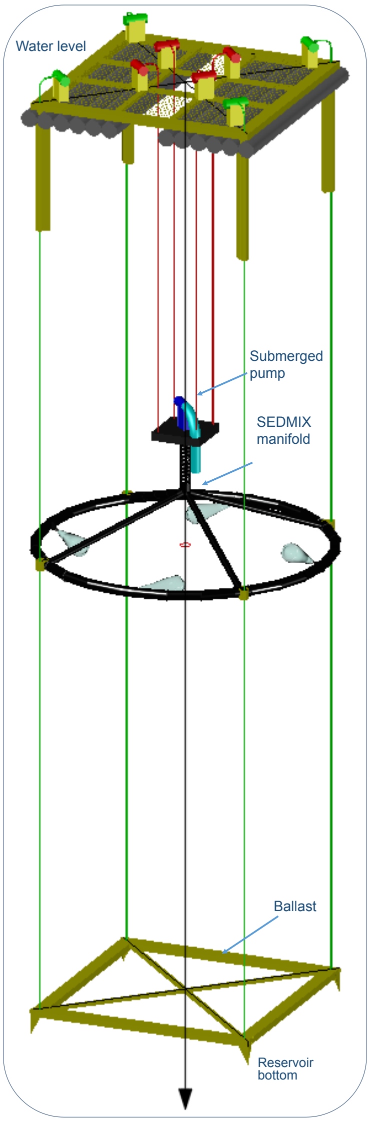

***Figure 5:** SEDMIX device*

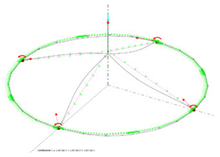

***Figure 3:** Typical SEDMIX structural analysis.*

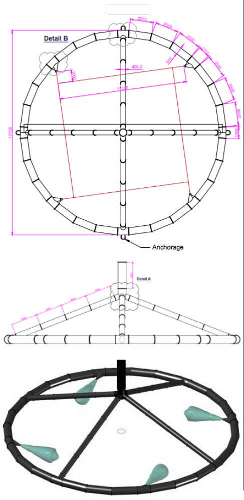

***Figure 4:** SEDMIX manifold specification*

***Figure 7**: SEDMIX installation steps*

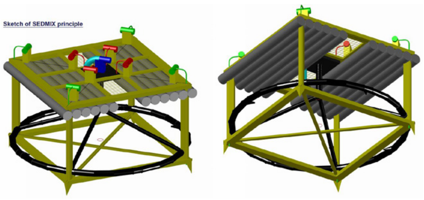

***Figure 6:** Floating platform details*

Installation method

- The multi-nozzle manifold frame is kept in place using a floating platform at water surface elevation and a ballast at the reservoirs' bottom (Figure 5 & Figure 6).
- The manifold is mobile along the vertical chains which allows to locate it at its optimal position, derived from numerical simulations, and even change the position during the same operation (Figure 5).
- The device can be assembled and installed in a given dam reservoir then dissembled and moved to another.
- All the system components can be displaced by moving the floating platform which is anchored onshore (Figure 7).

Reference

- Jenzer Althaus, J., 2011, Sediment evacuation from reservoirs through by jet induced flow, LCH EPFL, DOI : 10.5075/epfl-thesis-4927.

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Supported by:

Detection of harsh operating conditions on a Francis prototype based on in-situ onboard and non-intrusive measurements

V. Hasmatuchi, J. Decaix, M. Titzschkau, L. Rapillard, P. Manso, F. Avellan, C. Münch-Allígné

Motivation

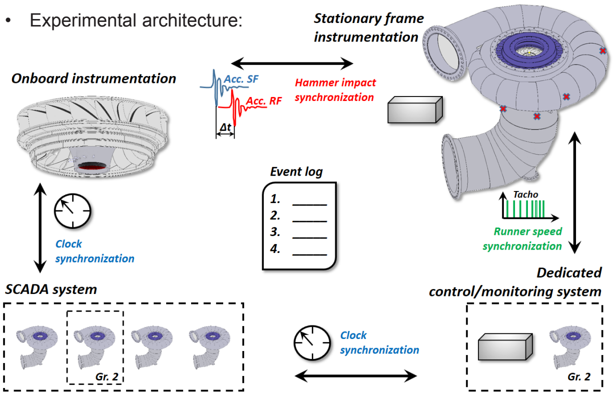
- Pumped-storage power plants: key components of a successful integration of renewable energy sources into electrical grid.
- Hydraulic turbines and pump-turbines:
  - operation in a wide range to offer power regulation flexibility;
  - subject to frequent start-up and/or stand-by operating regimes;
  - facing harsh structural loadings with impact on their lifetime.

Objectives:

- Establishment of a hydrodynamic instability level hill-chart of the machine based on several experimental monitoring parameters;
- Proposal of an alternative less-harmful start-up path and stand-by position with direct effect on the long-term maintenance costs;
- Elaboration of a diagnosis protocol to redraw hydrodynamic instability level hill-charts on different hydropower units, using only a simplified instrumentation set.

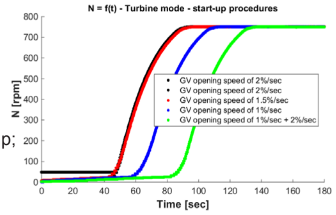
Experimental instrumentation architecture

- Case study: a 100 MW Francis turbine prototype, part of one of the four horizontal ternary groups of Grimsel 2 pumped-storage power plant.
- Experimental architecture:



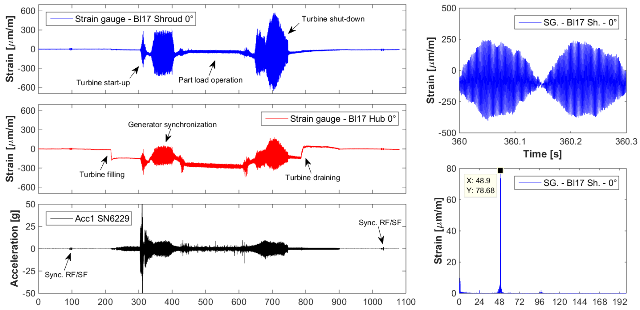
Experimental results

- Conducted tests focused on:
  - Turbine full operating range;
  - Turbine deep part-load;
  - Turbine normal start-up;
  - Modified slower turbine start-up;
  - Pump start-up.



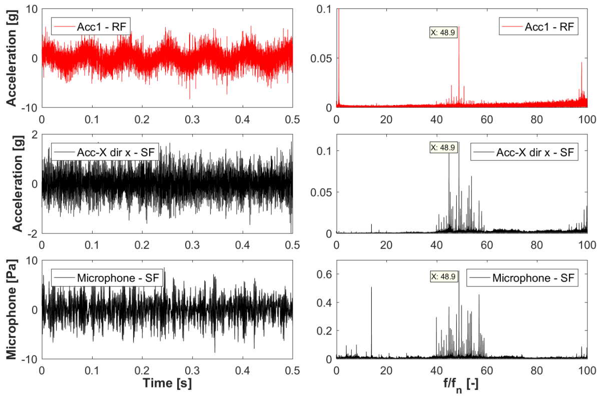
Evidence of harsh turbine start-up and shut down procedures

- Evidence of harmful structural loading of the turbine runner blades during the normal start-up and shut down procedures – signals recorded with the onboard instrumentation.



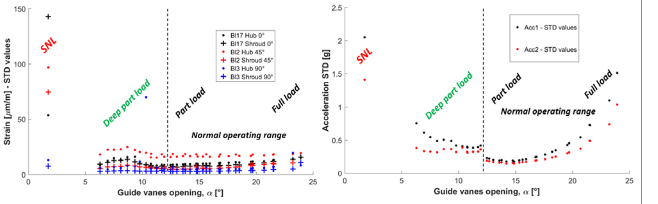
Non-intrusive instrumentation detection capabilities

- Identification of the harmful structural loading fluctuation of the runner blades at SNL condition using the non-intrusive instruments.



Strain and vibration fluctuations charts

- Fluctuations STD of the runner blades strain and the runner vibrations at SNL, deep part load, and the full normal operating range.



Conclusions & Perspectives

- Two successful experimental measurements campaigns conducted on a 100 MW high-head Francis turbine prototype;
- A 3rd experimental campaign based only on non-instrumentation successfully driven in 2018 on a different machine.
- Still seeking for a feasible simple technical solution to avoid harsh turbine runner blades loading during start-up and shut down;
- Final analysis of results ongoing;
- Diagnosis protocol based on a simplified instrumentation set to identify harsh operating conditions on a different hydropower unit ongoing.

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Acknowledgements

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Mise à profit hivernale d'un dessableur souterrain en milieu alpin pour l'exploitation hydroélectrique flexible

Jessica Zordan[1], Pedro Manso[1], Cécile Münch-Alligné[2]

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

[1] Plateforme en Constructions Hydrauliques (PL-LCH), École Polytechnique Fédérale de Lausanne(EPFL),
[2] HES-So Valais/Wallis, School of Engineering Hydroelectricity Group, Sion
corresponding authors: jessica.zordan@epfl.ch; pedro.manso@epfl.ch

1. Introduction

Le projet de recherche SmallFlex a pour objectif de démontrer la capacité des petites centrales hydroélectriques à fournir de l'énergie de pointe et des services systèmes malgré l'absence d'un lac d'accumulation d'eau en amont, tout en mesurant l'impact de ce nouveau fonctionnement sur l'environnement, le productible et les revenus. L'aménagement hydroélectrique de **Gletsch-Oberwald** a été sélectionné par les partenaires comme site pilote pour une telle démonstration d'exploitation flexible en milieu alpin. Il a été mis en service début 2018.

Parmi les méthodes visant à augmenter les possibilités d'exploitation, nous pouvons citer l'ajout de stockage intra-journalier, les prévisions à court terme des apports en eau et en sédiments ou encore l'exploitation adaptée des turbines Pelton à jets multiples.

La présenté étude se concentre sur l'utilisation «intelligente» du **dessableur souterrain** pour le **stockage d'eau**, en particulier dans la période hivernale de faibles débits. Ceci , à turbiner dans les moments de pointe de demande et à débit le plus possible proche au débit équipé des turbines pour en augmenter leur rendement.

2. Disponibilités hydrologiques

Le régime hydrologique du basin versant du site pilote est fortement influencé par **la fonte glaciaire**, avec des débits très importants en été, et de débits très faibles en fin d'automne, hiver et début du printemps.

Pour le cas d'étude, le débits horaires d'apports, turbinés, résiduels, module et débit équipé basé sur les données horaires de 1974 à 2016 à ont été analisés (Figure 1).

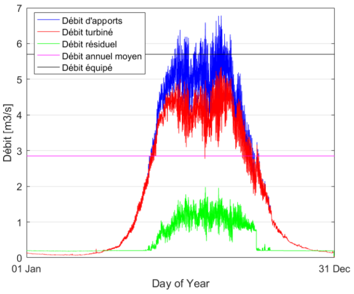

Figure 1. Débits horaires d'apports, turbinés, résiduels, module et débit équipé basé sur les données horaires de 1974 à 2016 à la station hydrométrique de Gletsch N°2268 (OFEV).

On remarque que souvent pendant l'hiver l'eau, même si elle pouvait est captée parce que le débit est supérieur au débit de dotation, elle n'est pas turbinée vu que le débit est inférieur au débit plancher de la turbine (Figure 2).

Afin de **réduire les volumes d'eau perdus** (zone jaune dans la Figure 2) une solution est de ajouter un moyen de stocker ces volumes captés, pour le turbiner plus tard dans la journée. Les cavernes existantes ou des excroissances à réaliser peuvent être mises à profit moyennant des modifications d'usage et des adaptations du système de pilotage de l'aménagement.

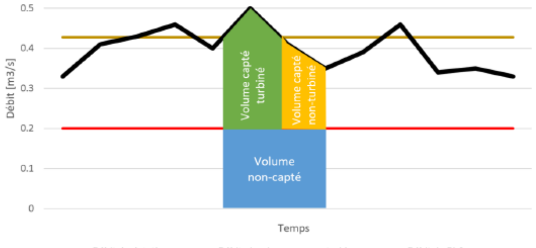

Figure 2. Illustration des volumes d'eau captés et turbinés dans l'aménagement au fil de l'eau en hiver.

Références

- Morand G. (2017) Augmentation de la flexibilité d'exploitation d'aménagements hydroélectriques de haute-chute au fil de l'eau en Valais, Projet de diplôme Master, LCH, EPFL.

3. Concept d'un volume de stockage «flexible»

A Gletsch le dessableur (Figure 3) a un volume de stockage disponible pour être utilisés en mode flexible, qui est défini entre les niveau de submergence minimal et du seuil trop-plein:

Volume utile pour mode flexible	(V_{flex})	2050 m^3
Niveau d'eau maximal	(N_{MAX})	1747.45 masl
Niveau d'eau minimal	(N_{MIN})	1742.70 masl

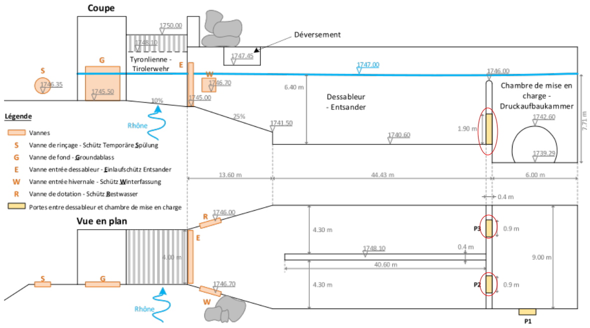

Figure 3. Prise d'eau et dessableur (schème opérationnel de l'exploitant, à l'état printemps 2018).

Suite à l'étude préliminaire (Morand et al., 2017), la géométrie du **dessableur a été adapté sur chantier** afin de créer deux ouvertures de fond (cercles rouges en Figure 3) qui permettent une connexion avec la chambre de mise en charge et donc d'utiliser le volume d'eau stocké. Ces ouvertures sont obturés pendant le fonctionnement en mode dessableur. Le fonctionnement s'articule dans les phases suivantes:

1. Le dessableur se remplit jusqu'au niveau du trop plein N_{MAX}.
2. Quand N_{MAX} est atteint :
   - Soit le trop plein du dessableur évacue l'excès d'eau (V_{OUT});
   - Soit l'eau est utilisé pour alimenter une des turbines, vidant progressivement le dessableur jusqu'au niveau d'eau minimal qui déclenche la fermeture des vannes-injecteurs.
3. Un nouveau cycle de remplissage s'initie.

3. Campagne d'essaies sur prototype

Un campagne de tests sur site est prévue pour **novembre 2018.** Différents modes d'exploitation flexible de l'aménagement hydroélectrique de Gletsch-Oberwald seront testés. Tous les partenaires seront actifs pour la campagne des tests sur le terrain. L'EPFL-LCH se concentrera particulièrement sur le fonctionnement de la prise d'eau, du dessableur et de la chambre de mise en charge, à l'aide du système de mesures actuel et de nouveau instruments à installer dans le but de mesurer:

- Les débits prélevés, déversés et retournés;
- Les niveaux d'eau dans les différents ouvrages;
- Les apports en sédiments (quantité, granulométrie, densité);
- Les temps de passage entre modes d'exploitation;
- La fréquence d'utilisation du dessableur et des vannes de purge. La présence de neige ou glace.

4. Conclusions

Des solutions innovatrices simples ont déjà été implémentés dans le site pilot permettant de nouveaux modes d'exploitation flexibles, notamment **en période hivernale**. Des essais sur site sont la prochaine étape pour valider le concept des points de vue énergétique, environnemental et économique, et mesurer son réel potentiel. Ce projet s'inscrit parfaitement dans la stratégie énergétique suisse et dans le marché d'un futur proche sans RPC où **l'énergie de pointe** sera fortement valorisée.

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Subsurface Fluid Pressure and Rock Deformation Monitoring using Seismic Velocity Observations

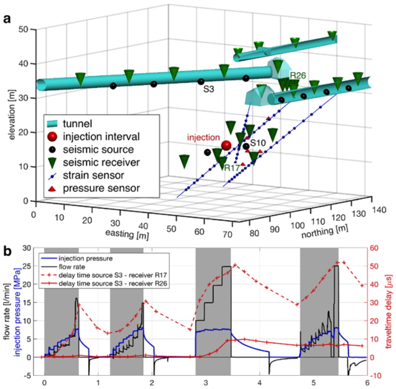
Joseph Doetsch, V. Gischig, L. Villiger, H. Krietsch, M. Nejati, F. Amann, M. Jalali, C. Madonna, H. Maurer, S. Wiemer, T. Driesner, D. Giardini

Abstract

The pressure of fluids in the subsurface is generally a function of depth as well as the regional geological history. Changes to the subsurface fluid pressure – be it natural or human-induced – disturb the stress field and are known to drive volcanic eruptions, as well as to trigger earthquakes. For example, pressure increase by fluid injection for hydraulic stimulation and wastewater disposal has been linked to earthquake activity. Unfortunately, pressure measurements need direct access through boreholes, so that pressure data is only available for few locations. A method for estimating the spatial distribution of fluid pressure remotely would thus be highly beneficial. From measurements in a 20-m-scale experiment in granite, we find that fluid pressure propagation can be predicted from observed seismic velocity variations, based on a strong correlation between observed changes in seismic velocities and fluid pressure measured within the rock.

Setup and data acquisition

- Hydraulic stimulation with injection volume of 1.25 m³
- Deformation monitoring using 60 fibre-bragg grating strain sensors
- In-situ pressure monitoring using 10 pressure sensors
- Active seismic monitoring using 8 hammers, 2 piezo-sources 26 piezo-receivers



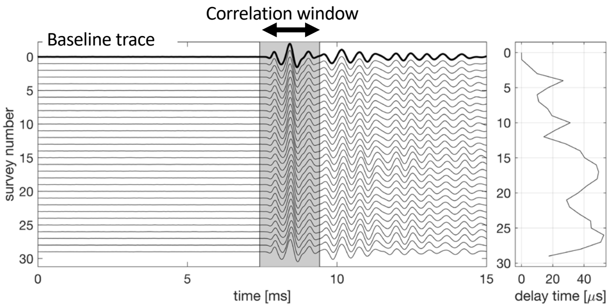
Setup and injection protocol.

Active seismic monitoring

- Repeated surveys (every ~10 min) using 10 sources
- Highly repeatable signals
- Correlation analysis to extract variation in first arrivals


Hammer source

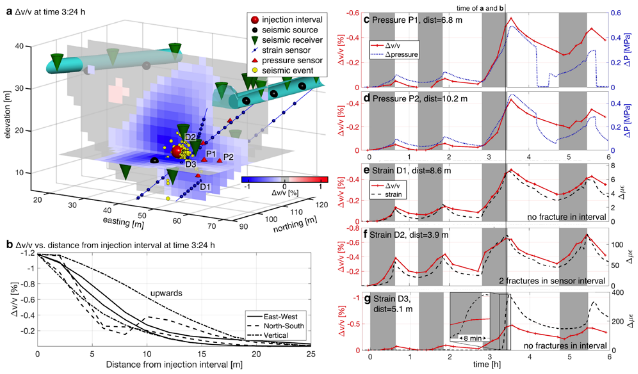

Borehole sensor



Highly repeatable seismic signal. The delay time is determined using correlation analysis.

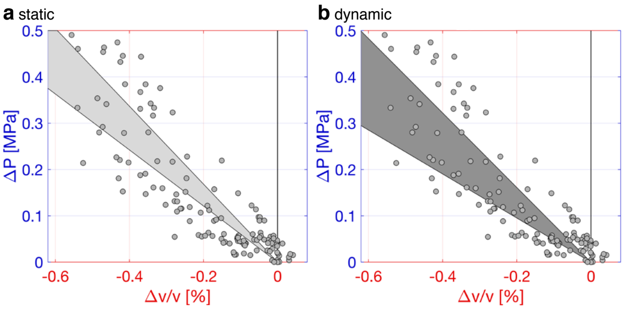
Inversion results

- Transient 3D traveltime inversion in order to determine seismic velocity variation over time
- Comparison with in-situ pressure and strain measurements shows strong correlation



Discussion and validation

Comparison with laboratory measurements shows the same linear relationship between seismic velocities and stress changes. This implies that seismic monitoring can be used to remotely measure the in-situ pressure evolution.



Field measurements (dots) and laboratory predictions show the same relationship between pressure change (ΔP) and relative velocity vatiaion (Δv/v).

Conclusions

Active seismic transmission data recorded during a 1.25 m³ water injection experiment show a direct response to the high-pressure fluid injection cycles. Inversion of these data yield a transient 3D seismic velocity model of the injection volume. Comparison with fluid pressure measured within the rock volume reveals a strong correlation, which enables prediction of subsurface fluid pressure based on the seismic velocity variations. The link between seismic velocity variations and rock deformation is more complex, with a clear link existing for reversible deformation driven by the fluid-pressure related stress change. We conclude that seismic velocity changes measure volumetric strain resulting from effective stress changes, while shear dislocation does not affect seismic velocity.

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Doetsch et al. (2018), *Geophysical Research Letters.*
https://doi.org/10.1002/2018GL079009

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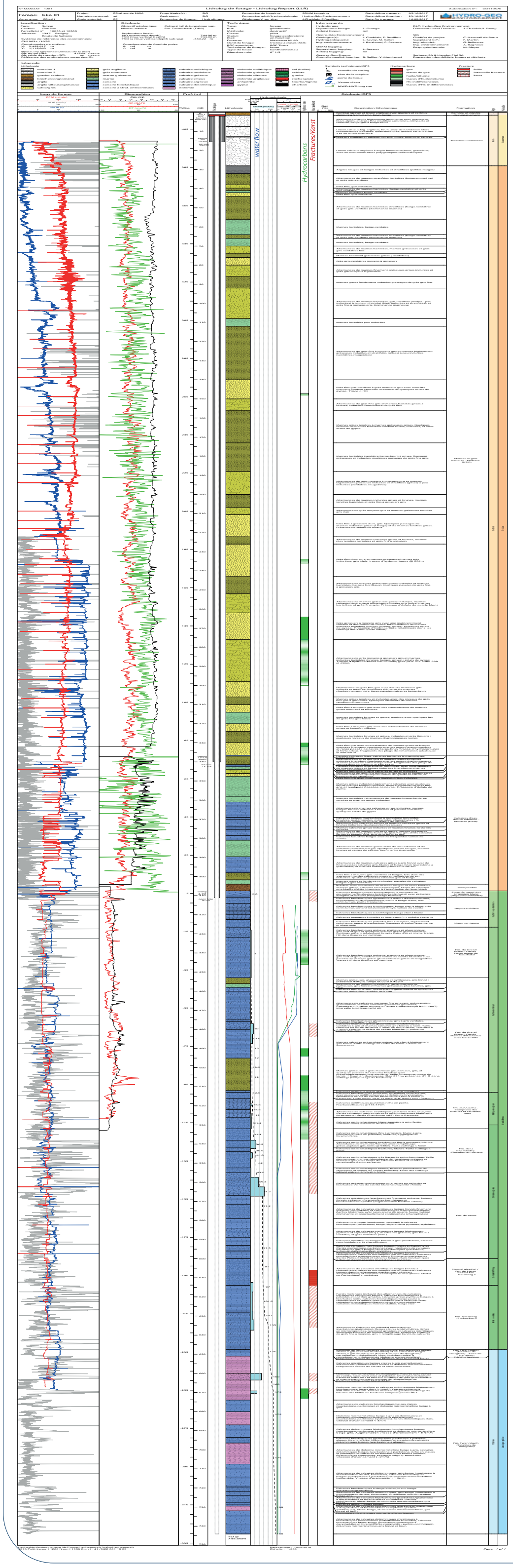
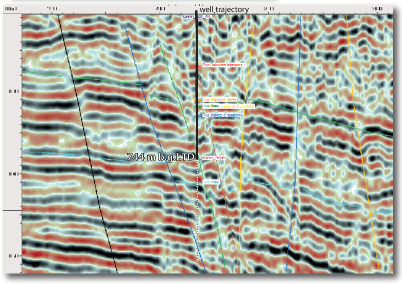
GEo-01 : The first GEothermie 2020 P&D well in the Canton of Geneva - Preliminary results.

SIG Services Industriels de Genève - Canton of Geneva, Service de géologie, sols et déchets,
Hydro-geo Environment Sarl - Geneva Geo-Energy Sarl - University of Geneva, Department of Earth Sciences
Project coordinator: Dr. Carole Nawratil De Bono, SIG



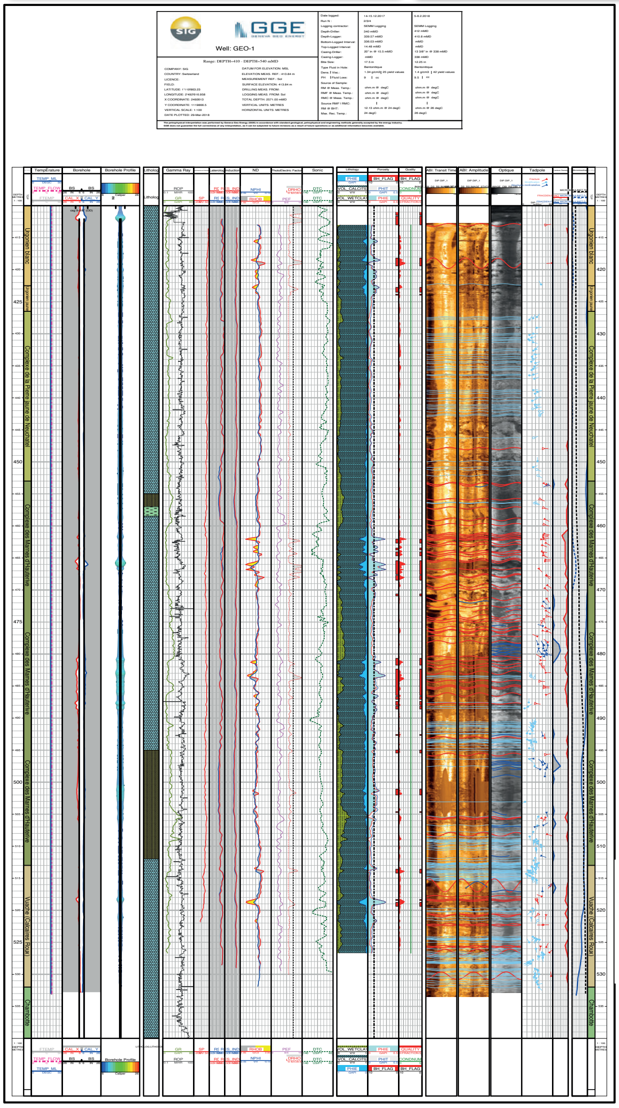
Location map of the first two P&D wells.

The GEothermie 2020 program, consisting of three main phases i.e. prospection, exploration and exploitation, has recently entered into the exploration phase with the drilling of a series of shallow boreholes i.e. ca 600 -1000 m deep below ground level (b.g.l.). The first exploration well GEo-01 has been successfully drilled in 2018 in Satigny, North-West of the city of Geneva, fiding artesian water flowing at 50 l/s and 34°C from faulted lower Cretaceous carbonate units at various depth intervals ranging between 460 and 670 m b.g.l.



2D sesimic line passing near the GEo-01 well location

Aerial view of the GEo-01 Drilling side



Long-duration hydraulic tests on the artesian flow will be conducted for the next 6 months. During this phase, continuous measurements of temperature, pressure, flow rate, turbidity and hydro-chemical and isotopic analysis will be performed.

The second exploration well GEo-02 will be spud in January 2019. The overall goals of this well are similar to the GEo-01 well: test the faulted lower Cretaceous and Upper Jurassic limestones, reach the Kimmeridgian reef complex at 950m as well as improve our knowledge of performing successful geothermal drilling projects. The expected total depth of the well GEo-02 is 1130 m b.g.l.

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CO_2 sequestration: progress in the ELEGANCY-ACT project

Alba Zappone [a-b*], *Melchior Grab* [d], *Antonio Rinaldi* [b], *Claudio Madonna* [c], *Anne Obermann* [b], *Stefan Wiemer* [b]
[a]Institute of Process Engineering, [b]Swiss Seismological Survey, [c]Geology Institute, [d]Institute of Geophysics, ETH Zurich, Switzerland
* alba.zappone@sed.ethz.ch

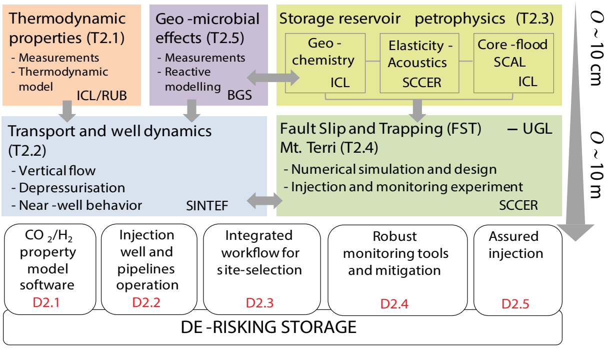
The European project

ELEGANCY (Enabling a Low-Carbon Economy via Hydrogen and CCS) is an European project within the ACT (Accelerating CCS Technologies) initiative, aiming at fast-track the decarbonization of Europe's energy system by exploiting the synergies between two key low-carbon technologies: CCS and H_2.

Main objectives of ELEGANCY are:

- Develop and demonstrate CCS technologies with high industrial relevance
- Validate key elements of the CCS chain by frontier pilot and laboratory scale experiments
- Optimize combined systems for H_2 production and H_2-CO_2 separation
- De-risk storage of CO_2 from H_2 production by providing experimental data and validated models
- Develop simulators enabling safe, cost-efficient design and operation of key elements of the CCS chain
- Assess societal support of key elements of CCS

The Work package on CO_2 injection and storage (WP2)



Thermodynamic properties (T2.1)
- Measurements
- Thermodynamic model
ICL/RUB

Geo-microbial effects (T2.5)
- Measurements
- Reactive modelling
BGS

Storage reservoir petrophysics (T2.3)
Geo-chemistry ICL
Elasticity - Acoustics SCCER
Core-flood SCAL ICL

Transport and well dynamics (T2.2)
- Vertical flow
- Depressurisation
- Near-well behavior
SINTEF

Fault Slip and Trapping (FST) – UGL Mt. Terri (T2.4)
- Numerical simulation and design
- Injection and monitoring experiment
SCCER

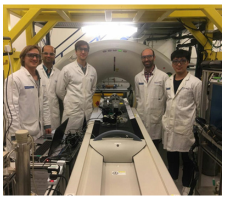
O ~ 10 cm
O ~ 10 m

CO_2/H_2 property model software D2.1
Injection well and pipelines operation D2.2
Integrated workflow for site-selection D2.3
Robust monitoring tools and mitigation D2.4
Assured injection D2.5

DE-RISKING STORAGE

The geological storage of CO_2 is an essential component for enabling the efficient generation of H_2 as a transport fuel. The large volumes of CO_2 produced in the natural gas reforming H_2 manifacture require a coupling with direct CO_2 separation techniques, and safe geological storage. The contribution of SCCER_SoE is at centimeter and decameter lab scales scales: Laboratory and pilot scale.

The laboratory scale



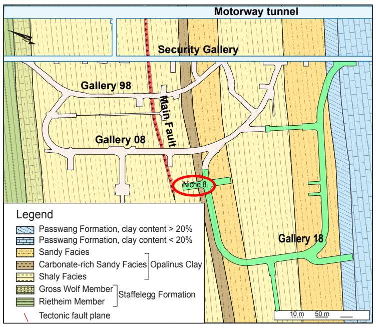
First joint experimental campaign at ICL on March 20-28 2018 in collaboration with colleagues from ETH/SCCER to investigate and image fluid transport in a fractured rock using the new core-holder and X-ray tomography. The first experiment was conducted on fracture aperture characterization on Westerly Granite and Carrara Marble with and without shearing

Laboratory experiments are performed by ETH Zurich, EPF Lausanne, Imperial College London and McGill University. The focus of the experiments is the characterization of the elastic, mechanical and transport properties of intact and fractured rock samples. The majority of the experiments will be done on samples extracted from the borehole campaign in the underground laboratory at the Mt. Terri, which has started at the end of August 2018.

The following activities have been completed:

- First samples selection for petrophysical studies (elastic mechanic and transport properties).
- Characterization of the pore and gas sorption properties of Opalinus Clay
- First experimental campaign on the observation of tracer transport through fractured cores by X-ray Computed Tomography .

The field scale: Mont Terri CS-D experiment



Partners in CS-D:

swisstopo
Chevron
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TOTAL

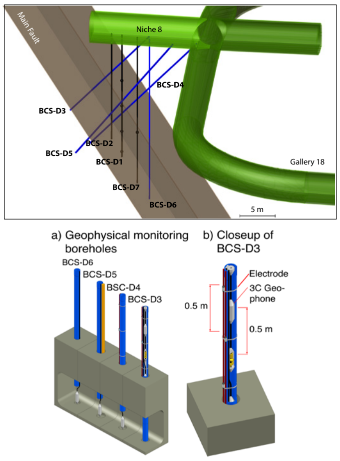
A new niche has been drilled and equipped by Swisstopo to host the CS-D experiment.

The CS-D experiment aims to investigate the sealing capability and caprock integrity by determining CO_2-rich brine mobility in a fault zone hosted in a clay rich formation (Opalinus Clay).

In Particular we investigate:

- the migration of CO_2-rich brine through the core of the Main Fault (MF, scaly clay fabric),
- the interaction of the CO_2 with the neighboring intact rocks, and damaged zone
- the impact of long time exposure to CO_2 on the rocks permeability in the

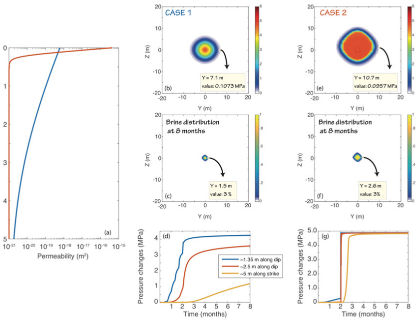
The experimental layout



The borehole setup of the CS-D experiment comprises three vertical boreholes for fluid injection, pressure monitoring, displacement monitoring, and fluid sampling. For geophysical monitoring, boreholes BCS-D3 and D4 will be drilled inclined in order to enable the tomographic planes being parallel to the symmetry axis of the anisotropy (normal to the bedding). The boreholes BCS-D5 and -D6 will be equipped with sensors to locate microseismic events in 3-D. All boreholes will be equipped with fiber optics for deformation and temperature measurements.

Modeling for CS-D experiment

We investigate the possible distribution of pressure and brine in the Mont Terri fault with the continuum hydro-mechanical code TOUGH-FLAC. We limited the injection pressure to be below the reactivation threshold observed previously. The fault plane is simulated with a finite width (1 m) and we model it as a fracture zone accounting for possible elastic opening. We analysed two cases: (i) a constant increase of permeability with decreasing normal effective stress (elastic behavior) and (ii) assuming that the fracture jack opens after reaching small value in effective normal stress (opening). For both cases both pressure and brine should reach a distance at which the monitoring should be possible (i.e. around 2 m).



ACT ELEGANCY, Project No 271498, has received funding from DETEC (CH), BMWi (DE), RVO (NL), Gassnova (NO), BEIS (UK), Gassco, Equinor and Total, and is cofunded by the European Commission under the Horizon 2020 programme, ACT Grant Agreement No 691712.

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Computational Modelling of an Innovative Water Stirring Device for Fine Sediment Release: The test case of the Future Trift Reservoir

Chraibi, A.[1], Vorlet, S.L, Amini, A.[2], Manso, P.
Platform of Hydraulic Constructions (PL-LCH), EPFL; [1]corresponding author: anass.chraibi@epfl.ch, [2] azin.amini@epfl.ch

Introduction

- This work is part of a development project which aims to carry out an innovative system (SEDMIX) allowing to keep in suspension or re-suspend fine particles near the dam. With its 4-nozzle pressurized water jets, SEDMIX is expected to induce sufficient upwind vortex flow to maintain fin sediments in suspension.
- The aim of this part is to analyse the performance of a real-sized SEDMIX operating in the future Trift reservoir (Figure 1) via numerical analyses. This study allows to validate or to improve SEDMIX optimal configuration experimentally determined in a recent PhD study at EPFL (Jenzer-Althaus, 2011).


1948 2008 202?

Figure 1: Trift Glacier over time

Methodology

The numerical simulations were performed with ANSYS-CFX v.18 on five different positions for the SEDMIX device (Figure 4). Steady state simulations as well as transient simulations were computed for the same boundary conditions, namely, the mass flow rate for the inlet ($M_{in} = 21002.7\ kg/s$), the relative pressure for the outlet ($P_{outlet} = 0\ Pa$) and 4 Source points (SEDMIX jets) with specific discharge and directions + 1 source point with negative discharge (submerged SEDMIX supplier pump) (Figure 3). All the simulations are multiphase since they include sediment ($D_s = 0.1mm,\ \rho_s = 2600kg/m^3, C_s = 0.7g/L$). The chosen turbulence model was the $k-\varepsilon$ model combined with inhomogeneous Eulerian model.

The performance of SEDMIX in each position has been evaluated and tested for different jet discharges.

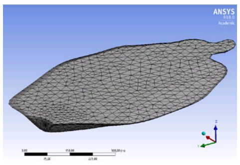

Figure 2: Computational model and mesh

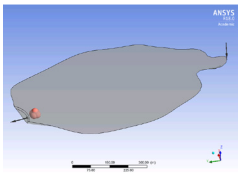

Figure 3: Numerical model geometry with the boundary conditions

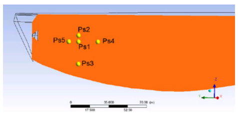

Figure 4: SEDMIX tested positions

Results

Analysis of the numerical simulation results has shown:

- the presence of SEDMIX does create a vortex flow pattern and sediment movement upward (Figure 5).
- The sediment volume fraction in the higher layouts of the reservoir increases with time (Figure 5)
- The transient simulation with SEDMIX does reach a Steady State S_i (at a $t \simeq 3\tau_j$ with $\tau_j = V/\Sigma Q_j$) (Figure 6 & 7). 43% increase in sediment release.
- the supplementary sediment evacuation ratio, defined as follow (reference case: without SEDMIX), has confirmed the increase of the sediment release with SEDMIX (Figure 8):
$$\eta(t) = M_{s,out,j}(t)/M_{s,out,ref}(t)$$
- The performance of SEDMIX in each position (Ps1, Ps2…) has been compared and evaluated according to the evacuated sediment ratio γ_s (Figure 9):
$$\gamma_s = \lim_{t\to\infty} \frac{M_{s,out}(t)}{M_{s,in}(t)} = \lim_{t\to\infty} \frac{\dot{M}_{s,out}(t)}{\dot{M}_{s,in}(t)} \quad \text{(L'Hôpital rule)}$$

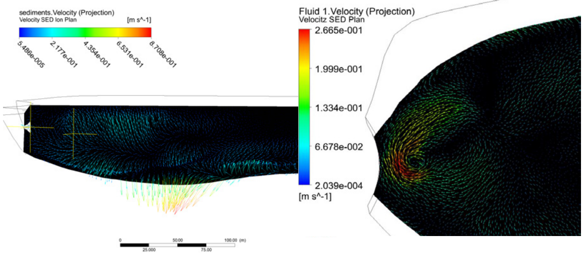

Figure 5: (a) appearance of a vortex flow generated by SEDMIX (b) Sediment velocity showing movement upward

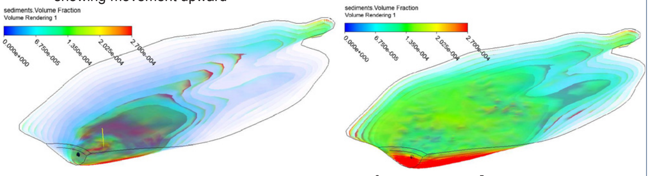

Figure 6: Sediment volume fraction (a) at t = 8x10^{6}s (b) at t = 5x10^{5}s

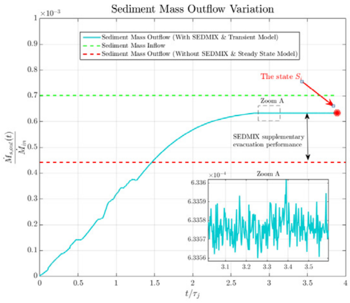

Figure 7: Sediment Mass Outflow: Steady and transient models, with and without SEDMIX

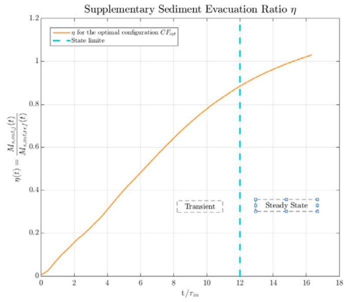

Figure 8: SEDMIX supplementary sediment evacuation compared to the reference case

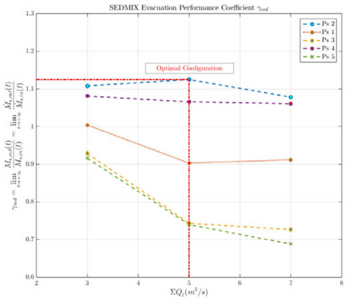

Figure 9: SEDMIX performance in each position

Conclusions

- The optimal discharge corresponds, as expected, to the SEDMIX geometric up-scaling discharge (5 m^3/s) (Jenzer Althaus, 2011).
- The optimum position is P2, where the SEDMIX device is located in front of the water intake.

References

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