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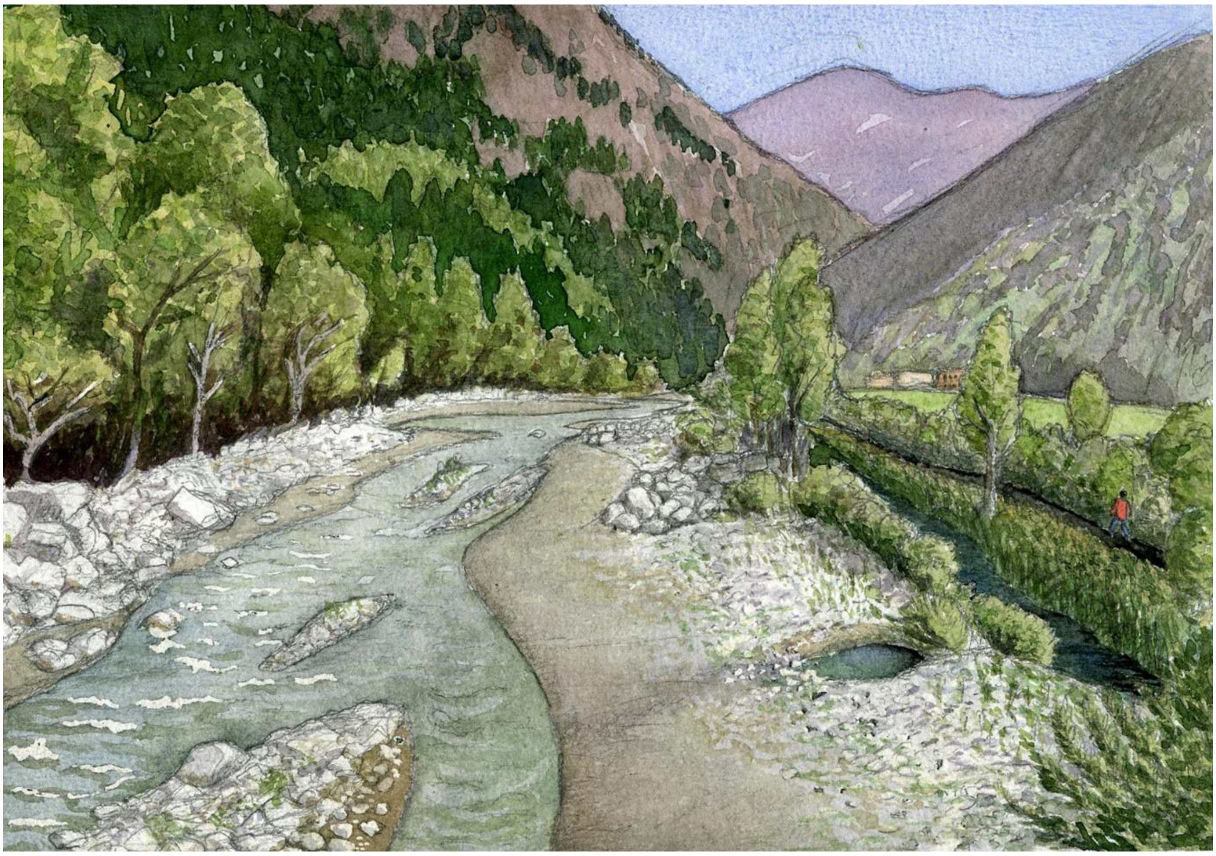
Revitalization of the Dranse river and flood protection in Sembrancher-Vollèges



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Sediment management measures for the revitalization of the Dranse river and flood protection in Sembrancher-Vollèges

Summary

Sediment transport plays a key role in the morphological and ecological value of river ecosystems in the Alpine valleys. The river training projet of the Dranse in Sembrancher-Vollèges is heavily submitted to this constraint, requiring management measures both for the flood control and revitalization. The project was initiated after the October 2000 flood and it stands out for its extent, with a total reach longer than 4 km.

The effects of the channel modification on the bedload transport capacity have been simulated with the a numerical hydraulic and sediment transport model, requiring several iterations to address both environmental and flood protection constraints. The expected outcomes are the restoration of the river bed dynamics with the formation of alternate bars and an improvement of the longitudinal and lateral connectivity.

The project includes the implementation of sediment control measures that stabilize the morphological regime and allow the fish migration in the river, while ensuring the flood protection. It involves extracting gravel in some key locations, to replace weirs by rock ramps and to use lateral deflectors to protect and structure the river banks.

In addition, particular revitalization measures are applied to enhance the biological and landscape grades of the river. Studies continue on several fronts, in particular on the management control of transported sediments, on biological and landscape monitoring, as well as on soft mobility and recreation in connection with the watercourse.

Introduction

The Dranse is one of the main tributaries of the Rhône river upstream of the Lake Geneva, their junction occurs at the elbow of Martigny. This region is currently the subject of many projects of improvement and enhancement of watercourses, the most important of which are the third correction of the Rhone river, the crossing of Martigny city and the crossing of the communes of Sembrancher and Vollèges (Fig. 1). The last mentioned is subject of this visit document.

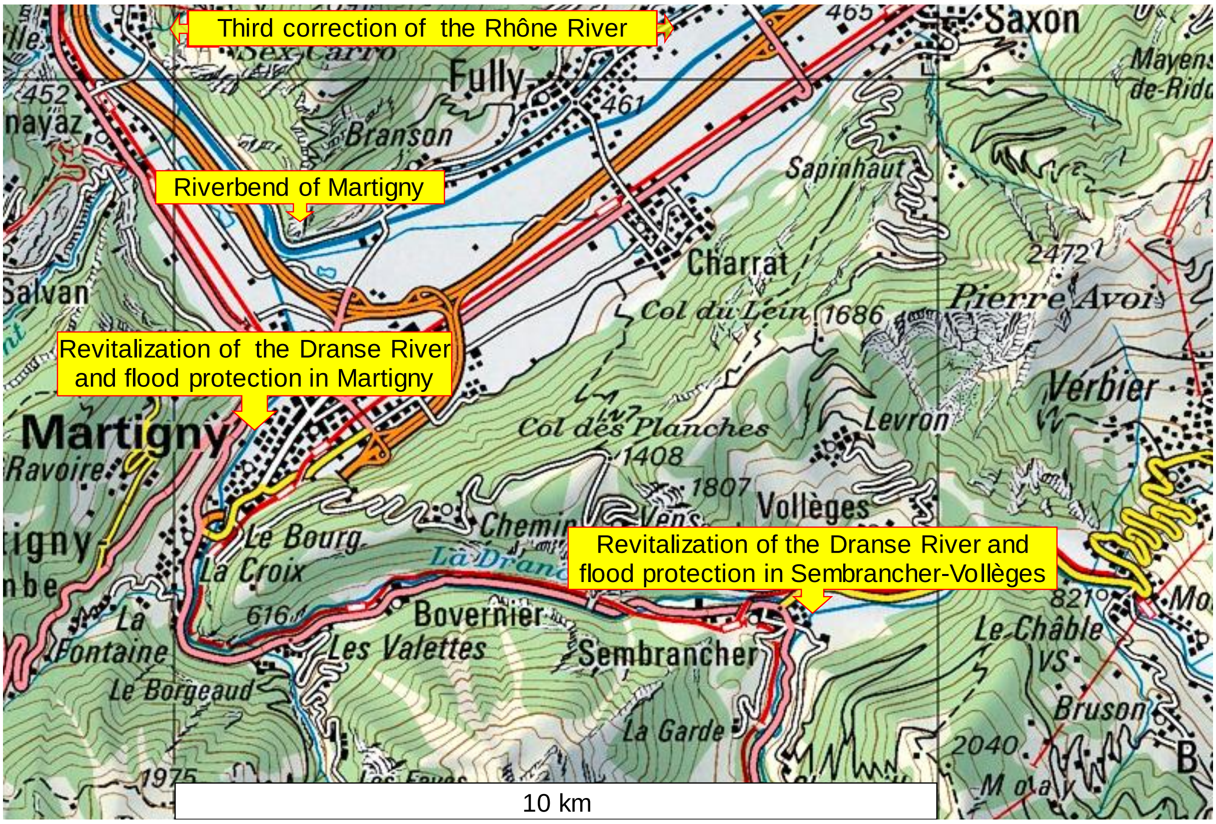

Figure 1. Main watercourses development projects in the Martigny region

The project at Sembrancher-Vollèges concerns the flood protection and revitalization of the Dranse river. The river reach is located in a watershed where about half of the runoff is harnessed for hydroelectricity production (Fig. 2). The hydrological and sedimentary regimes are therefore significantly altered by the hydropower schemes. The river flow and the bedload transport capacity are considerably reduced as well. However, the villages of Sembrancher and Vollèges were still exposed to flood risk, as evidenced by the major event of October 2000. The process of sediment deposition during floods is at the heart of the problem.

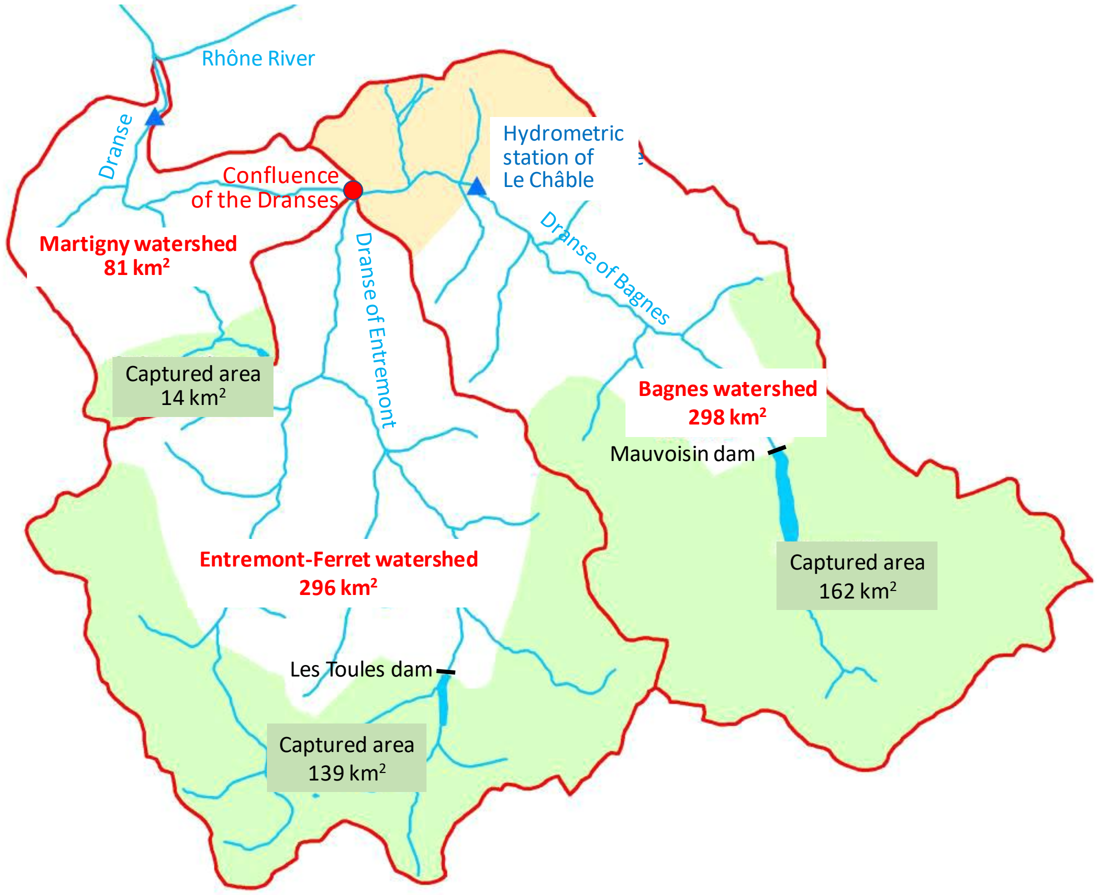

Figure 2. Watershed of the Dranse river in Martigny.

The total extent of the project, higher than 4 km, was subdivided in three sectors for its realization (Fig. 3). The work was initiated from downstream, allowing the completion of the two firsts sectors in June 2016, respectively March 2018. The third sector at Contô, currently at planning stage, is part of the strategic concept for watercourses renaturation in the Canton of Valais.

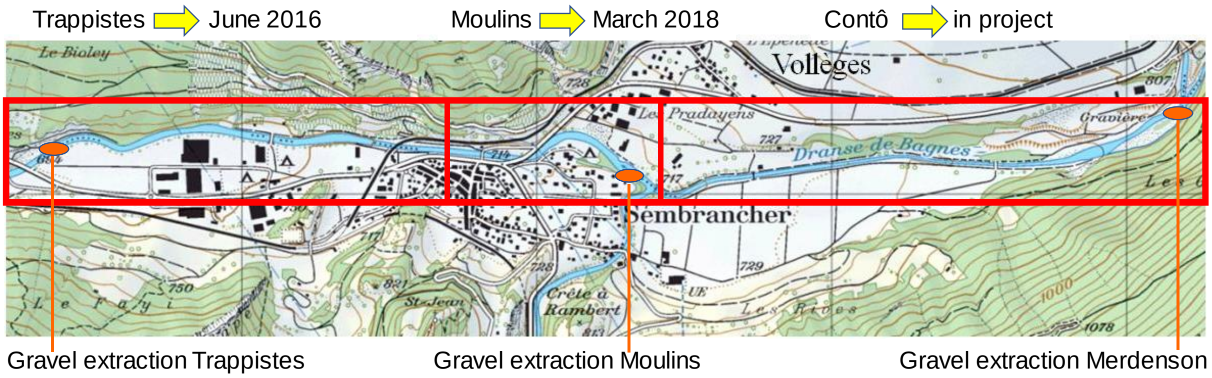

Figure 3. Scope of the Dranse project at Sembrancher-Vollèges and realization stages.

Flood protection

On the Trappistes sector, the flood protection objective is associated with 100 years return period. At this place, located after the junction of the Dranses of Bagnes and Entremont, the peak discharges amount to the values presented in Table 1.

Table 1. Peak discharges at Sembrancher for 100 and 300 years return periods and for extreme flood (EHQ).

Watershed	Area [km^2]	Q100 [m^3/s]	Q300 [m^3/s]	EHQ [m^3/s]
Dranse of Bagnes	298	132	172	198
Dranse of Entremont	296	131	171	198
Dranse at Sembrancher	594	210	274	316

In order to evaluate the inundation risk, hydraulic and sediment transport simulations have been performed with the software DuPiro (Dubois & Roquier, 2013). DuPiro simulates the sediment transport and bed evolution based on the bed-load transport formula of Smart & Jäggi (1983), considering a simplified geometry based on trapezoidal cross sections.

Before the simulation of major events, DuPiro was first calibrated in the original river geometry for series of common floods (between 2 and 10 years return periods) until reproducing the measured volumes of sediment carried by the Dranse River, as described in Figure 6 which synthetizes the sediment extractions.

The width, length and bank slopes of the river reaches have been defined according to the photogrammetry of the area. 10-minutes flow time series were extrapolated from downstream and upstream gauging stations.

The measured grain sizes in situ revealed not satisfactory to reproduce the current sediment transport and bed stability. As an alternative, the calibration was therefore performed by determining the mean grain size (D_m) able to reproduce the estimated annual sediment load. This calibration was based on the flow series and sediment extractions of the Dranse River between 2001 and 2010.

The hydrograph of October 2000 has then been processed to validate the model. The simulation results confirmed the deposits of material and overflows observed during and after the flood event. After this calibration/validation process, the 100 years return period flood was computed, revealing the protection deficit visible on Figure 4.

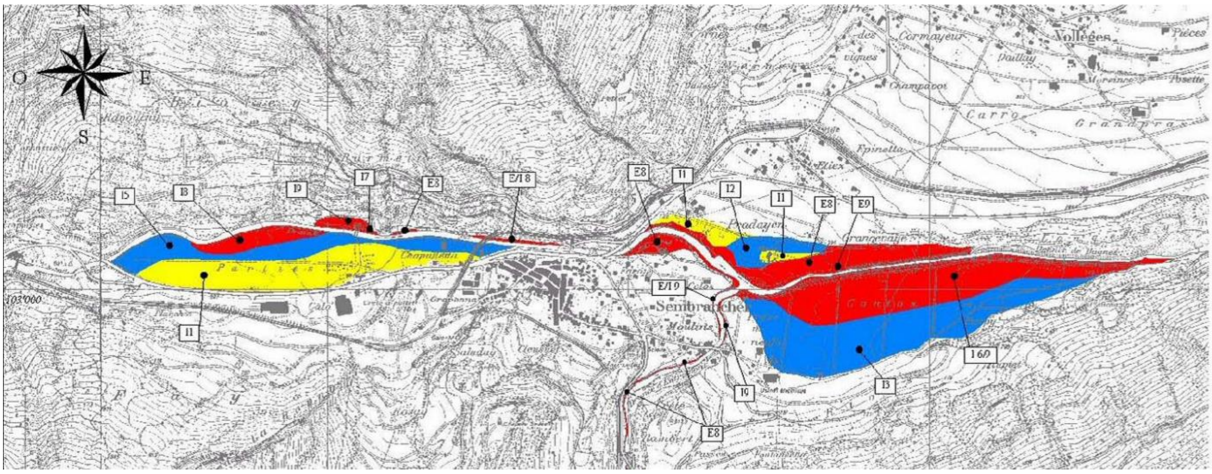

Figure 4. Flood hazards map on the Sembrancher-Vollèges sector for 100 years return period, demarcating high (red), medium (blue) and low (yellow) intensities.

At the end of an iterative process, a widened design of the river reach providing a long-term "controlled" sedimentary equilibrium was obtained (see next paragraph). This equilibrium is maintained by the gravel extraction that regulates the excess of sediment. A sediment transport capacity almost identical to the original was required to preserve the morphological dynamics of the river.

The model of the widened river was then tested to simulate flood events. Figure 5 shows bedload and hydraulic results for a 100 years return period flood. These values have been used to design the protection levees, considering a safety margin as defined in the recommendation of the Swiss Commission on Flood Protection (KOHS, 2013).

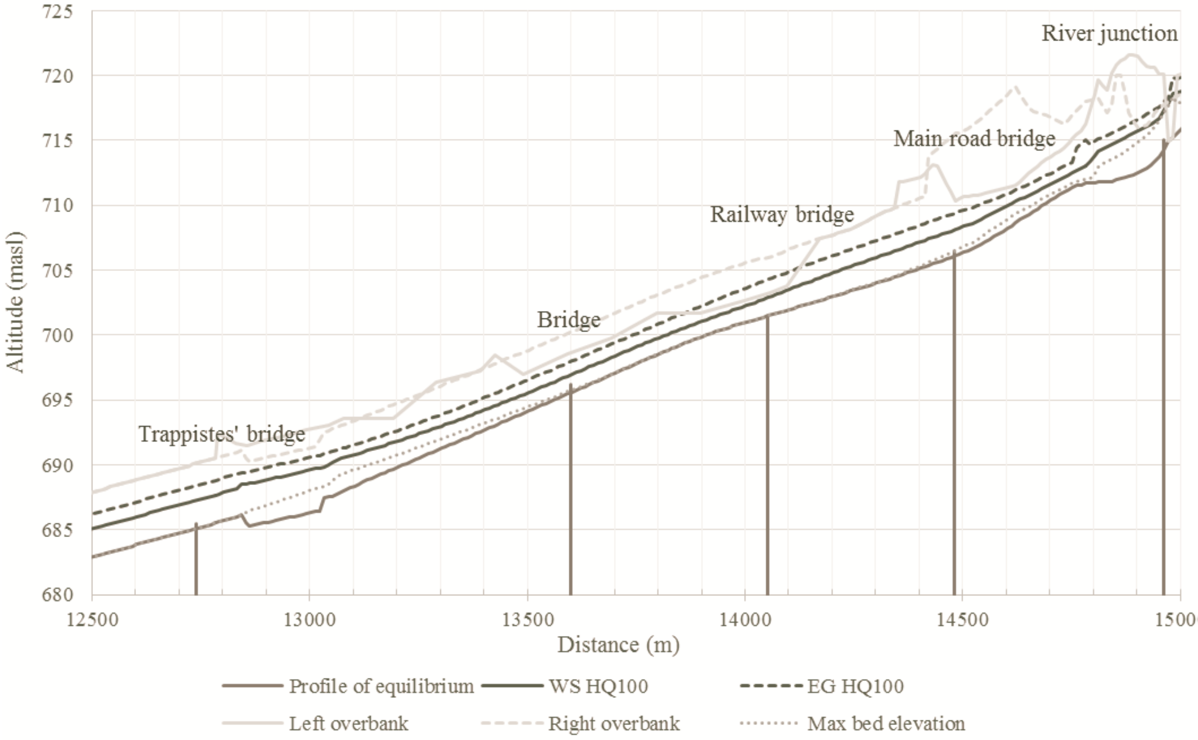

Figure 5. Results of numerical simulation of the widened design for a 100 years return period flood.

Finally, the widened design was submitted to extreme flood conditions (EHQ), corresponding to 500 years return period (Tab. 1). This simulation was conducted in order to evaluate the incurred residual risk. It is intended to define additional useful measures for the protection of singular objects.

In order to ensure their sustainability with regard to stability and scouring, the protection measures of the water course itself, like ramps or lateral deflectors, were designed to resist under extreme flood conditions.

In the project, rock deflectors have been implemented instead of conventional perpendicular spur dikes (Pereira et al., 2008). These works are positioned to prevent bank erosion as well as to induce some stream sinuosity, in adequacy with alternate bars formation. They also globally reduce the width of the channel and consequently increase the sediment transport capacity.

Sediment management

Due to the topographical local conditions, the bed load has a natural tendency to deposit on the Trappistes reach. As a control measure, the longitudinal profile of the river is maintained at its current level by sediment extractions in several key locations, upstream, downstream and across Sembrancher village (Figs. 3 and 6). These extractions are essential to maintain the river bed elevation. As a result, the challenge of the Trappistes project is to manage the few 57’000 m^3/year of sediment entering the river reach by maintaining the sediment transport capacity and managing the gravel extraction.

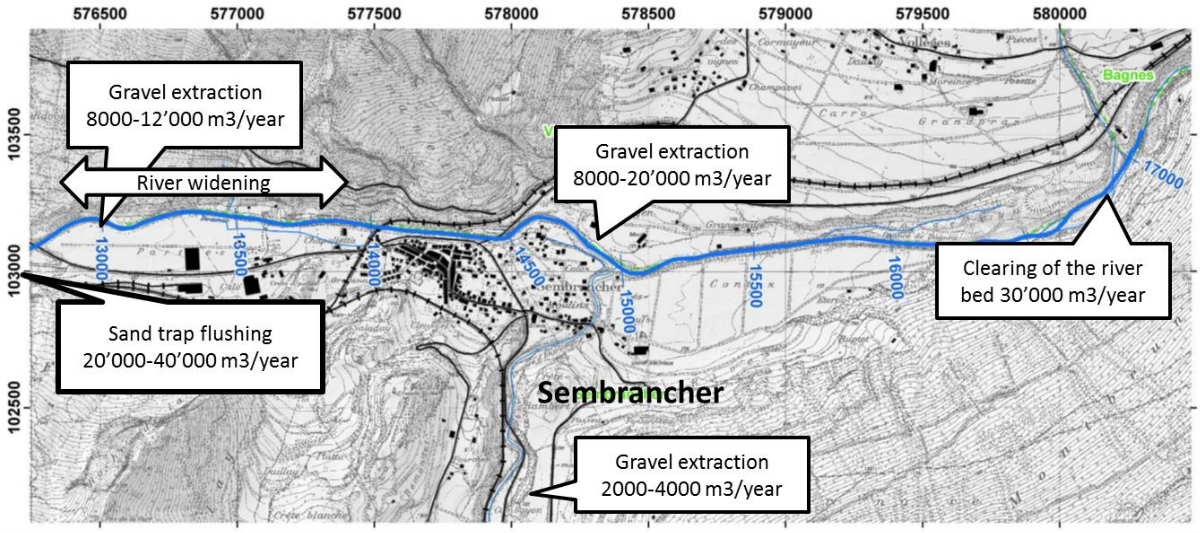

Figure 6. Gravel extractions on the Dranse river near Sembrancher-Vollèges

The initial width of the river reach was about 15 m, which lies clearly below the regime width. The available historical data are however not sufficient to determine an observed “natural width” of the river. A theoretical regime width was so estimated based on the theoretical methods of Yalin & da Silva (2001) as well as Parker-Günter (Jäggi et al., 2011), using flood events related to return periods between two and five years (respectively 50.9 m^3/s and 74.5 m^3/s). Due to their high frequency, these floods are considered to be significantly formative of the river morphology.

The discharge values are based on statistics considering the hydrological regime affected by the large storage reservoirs located in the upstream part of the watershed. This means that the current flood intensity for such return periods is significantly reduced by comparison to the original natural floods.

Considering a characteristic sediment diameter of 57 mm, the method of Yalin and da Silva (2001) leads to a regime width comprised between 19 m and 24 m but assumes a longitudinal equilibrium slope much lower than the one of the Dranse River in Sembrancher.

The second method of Parker and Günter (Jäggi et al., 2011) assumes that the formative flow to consider is the one that is able to break the pavement layer. The method is based on an iterative determination of the regime width, using the formula of Günter (1971) to assess the critical stability of the armored bed. The calculation was based on a mean sediment diameter D_m = 57 mm, as used for the sediment transport simulation, and D_{90} = 200 mm corresponding to 3.5 times D_m for the armoring layer.

Based on these estimations, a widening to 26 m was adopted. According to Yalin & da Silva (2001), the channel widening to 26 m was expected to modify the current straight channel morphology of the Dranse towards an alternate bars' regime, improving the ecological potential of the river (Roquier et al., 2014).

Once the hydraulic-sediment transport model calibrated for the original state, iterative scenarios with a widening of 26 m have been performed to finally obtain a project configuration that almost keeps the current sediment transport capacity, and therefore limit the risk of sediment deposition.

As illustrated in Figure 7, the original situation assumes a stable longitudinal profile between the two gravel pits (a). If a widening of the river section is performed, an elevation of several meters is expected along the reach (b). The removal of the downstream weir improves the situation but is not sufficient to counterpart the effect of the new equilibrium slope. The final solution is obtained by lowering the downstream control point at the upstream limit of a gravel pit and a rock ramp to ensure the bed stability (c).

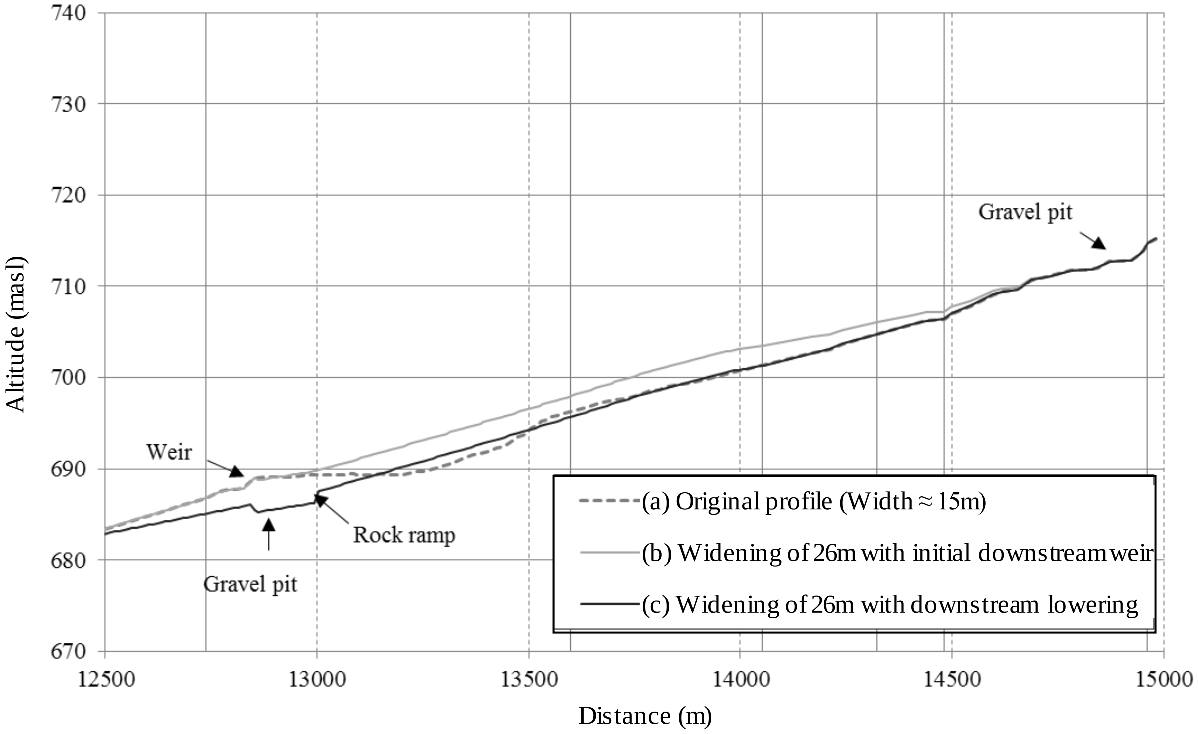

Figure 7. Profile of equilibrium of the Dranse depending on downstream elevation and river width.

A program of sedimentary monitoring of the project has been initiated. A detailed annual survey of the Dranse bed by drone flight, as well as a survey after each major flood are planned.

The results can be compared with the survey carried out after the completion of the work to detect possible areas of erosion or aggradation. The analysis of the survey conducted in spring 2017, one year after the completion of the work, showed that the Dranse bed remained very stable.

Revitalization

Longitudinal connectivity

Dams, weirs and falls are barriers to fish migration and limit the sediment transport. Therefore, their removal is required as a positive effect on fish populations, sediment balance and river morphology.

On the considered river reach, weirs are built to intercept sediments for gravel exploitation and thus to control the bed profile and reduce the risk of overtopping during floods. Given that gravel extraction is necessary to regulate the bed elevation, it was chosen to replace the weirs by rock ramps. With a maximal slope of 6.5 %, these works do not prevent the fish migration.

Based on Studer (2010) experimental study, the ramp is structured with a meandering channel in order to improve the swimming easiness of fish under low flow conditions.

Structuring the river banks

The habitats diversity in the transition zone between aquatic and terrestrial environment depends mainly on the structure of the banks. Improvement and diversification of the lateral structure is obtained through following measures:

- Flattening of riverbanks to better connect the river to the shore and thereby enhance the lateral connectivity between aquatic and terrestrial ecosystems.
- Diversification of substrates such as topsoil, wood structures and riprap.
- Creation of stagnant water branches connected to the main stream to create new ecosystems.
- Implementation of deflectors (Fig. 8) to vary the nature and geometry of the banks. The top of these deflectors reveals also useful to favor the vegetation diversification.

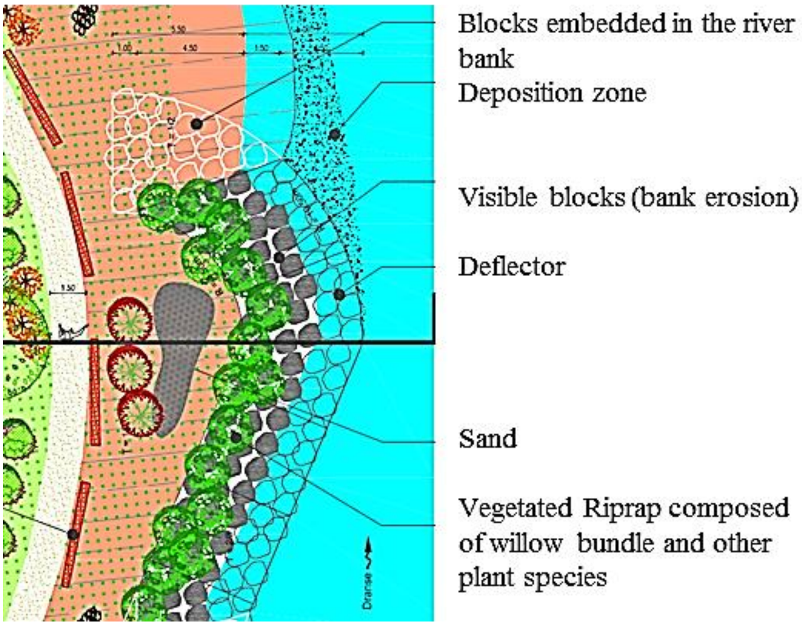

Figure 8. Schematic representation of bank protection and vegetative diversification by a lateral deflector.

In addition to the river bank protection, the deflectors have additional functions, aiming to induce the formation of gravel and sand bars and to expand the variability of water depth and flow velocity.

Particular works

The bloc ramps (Fig. 9) have a preferential channel to concentrate the flux at low-flow periods. An energy dissipation pool is stabilized at the downstream end of the ramps and rest areas are arranged every 5-7 meters along the profile. These constructive elements intend to facilitate fish migration.

In order to provide calmer water and diversify aquatic habitats, several dead arms have been constructed on the left bank of the Dranse (Fig. 10). The latter are fed from downstream and allow the development of lentic environments, particularly favourable to the amphibians. These dead arms are separated from the stream by a longitudinal dike, submersible from downstream and designed for Q5 at its lowest point. After such events, the dead arms will purge automatically.

Figure 9. Bloc ramp for fish migration.

Figure 10. Dead arm to diversify aquatic habitats.

Several specific arrangements have been made to maximize the diversity of both aquatic and terrestrial habitats (Zanini et al., 2018) including:

- Shoals, providing an area conducive to shorebirds, among others.
- Blocks at the foot of banks and in the river bed, in favour of varied flows and granulometry.
- Scree on the banks, at least 3x3m in size and 1 m in depth, guaranteeing frost-free habitats especially for reptiles.
- Sand deposits, at least 2x2m and 50 cm thick, for enthomofauna, especially hymenoptera.
- Piles of deadwood and stumps, for beetles and other insects (Fig. 11).
- Clusters of spiny and various plantations, offering shelter for avifauna (Fig. 12).

Figure 11. Piles of deadwood and stumps for insects.

Figure 12. Clusters of spiny for avifauna.

Biological monitoring

A follow-up of the vegetative evolution and colonization by the fauna of the shores and water of the Dranse is underway. This monitoring has already revealed the appearance of Cyperus fuscus and Myricaria Germanica. This plant species (Fig. 13) which appeared on 2 separate stations had been no longer observed in the area for more than 50 years (Zanini et al., 2018). Currently, the reproduction of the river trout has been attested on at least 2 sites, after only one year since the end of the works. Reproduction had not been recorded for years. Redheaded frog clutches were also observed in a dead arm (Fig. 14).

Figure 13. Reappearance of Myricaria Germanica.

Figure 14. Redheaded frog clutches in a dead arm.

Soft mobility, recreation and awareness

From the beginning of the project, the relaxation and leisure aspects were taken into account, in the form of a pedestrian didactic path, which runs along the Dranse on the left bank on more than 1,200 meters. This trail connects the centre of the village of Sembrancher with the river and is accessible to people with reduced mobility.

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