Technical note about the monitoring of hydromorphological restoration/management of the Drau River (Carinthia, Austria)

BOKU

1. General presentation of the study site

The study site at the Austrian Drau River is located in the Upper Drau valley in the South of Austria in the region of Carinthia, mainly focussing on two restored reaches near the villages of Kleblach (Figure 1a) and Obergottesfeld. This area is part of the Austrian Alps; elevations reach from around 550 m up to more than 3000 m. The catchment basin drains around 2445 km² and covers parts of the southern limestone Alps as well as east alpine crystalline. The dominant sediment is gravel with a d_{50} diameter of 25 mm. Sediment input mainly results from upstream active torrents in the catchment. The channel slope at the study site is approximately 0.002. The mean discharge is about 74 m³/s; a one-year flood reaches 320m³/s. Floods mostly occur in spring when snowmelt – and also glacier melt - is released into the basin, or in summer after thunderstorms. The discharge regime can be described as strongly pronounced nivo-glacial with a maximum discharge in June (Mader, 1996). The mean annual rainfall in Sachsenburg (close to the study site) is around 982 mm/a (BMFLUW, 2014). Historically, the Drau River at the studied reach was a wandering river (Figure 1b), which results from a transition from a braided to a meandering morphology, before it was regulated and finally restored. At the study site the valley is unconfined with presence of an alluvial forest whereas most parts of the Drau River are straightened and narrowed with a narrow alluvial forest zone left.

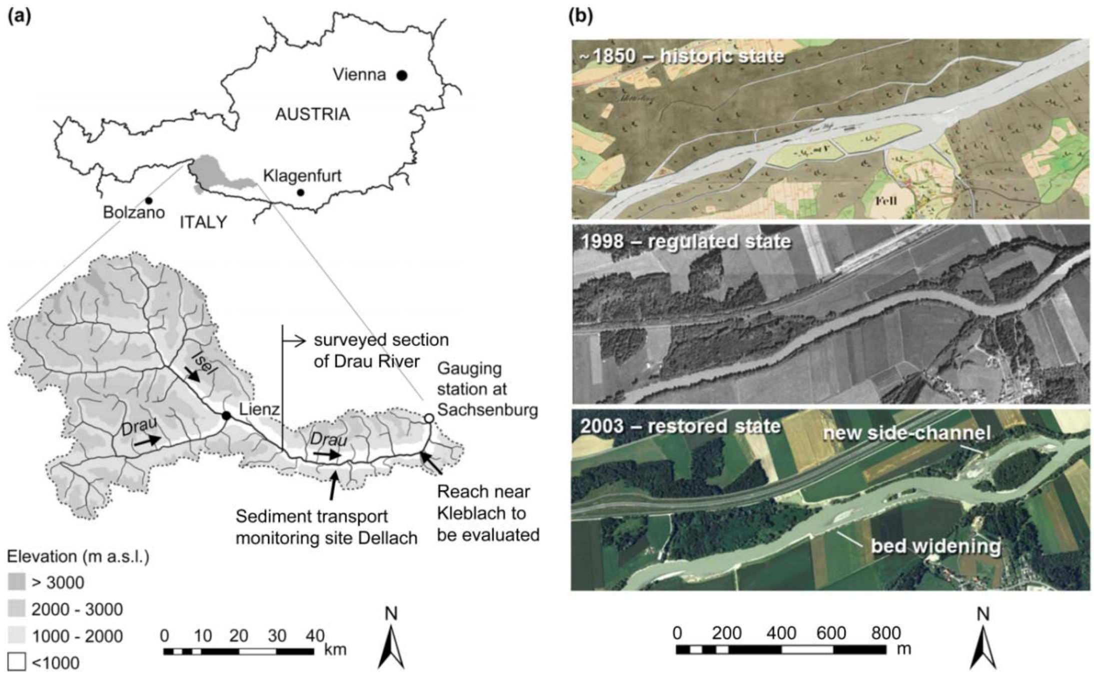


Figure 1: a) Location of the study site Kleblach-Lind at the Drau River, b) historic, regulated and restored state of the study site (Klösch and Habersack, 2017)

Table 1 contains an overview on the data of the study site.

Table 1: Main physical features of the pilot site

Pilot Site	Drau River
Drainage area at site (km²)*	2445
Location	Near the village of Kleblach
Length of the study reach (km)	1,8 km
Active channel width (m)	40-100
Channel slope (m/m)	0,002
Planform morphology	Currently: restored after regulation

Figure 2: Aerial image taken from a drone of the downstream part of the study site (2017)

2. Hydromorphological restoration/management

In the late 19th century as well as in the 1960s the Drau River was regulated in order to decrease flooding, aggradation and uncontrolled channel shifting. The systematic river regulation comprised river straightening, narrowing and protection of the riverbanks with riprap. This increased the bed shear stresses, which together with a reduction of sediment supply given check dams in the catchment, gravel mining and the construction of hydropower plants upstream resulted in continued channel incision (Figure 3) and accompanying problems such as alterations of aquatic and terrestrial habitats.

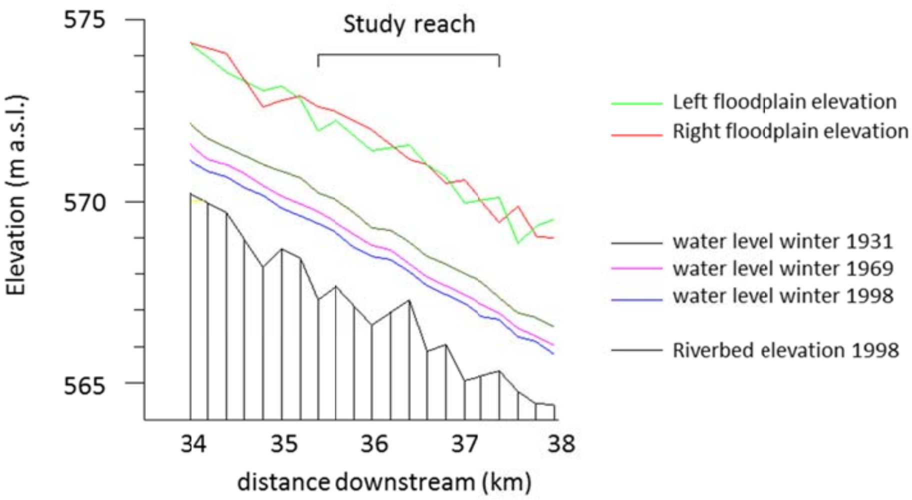
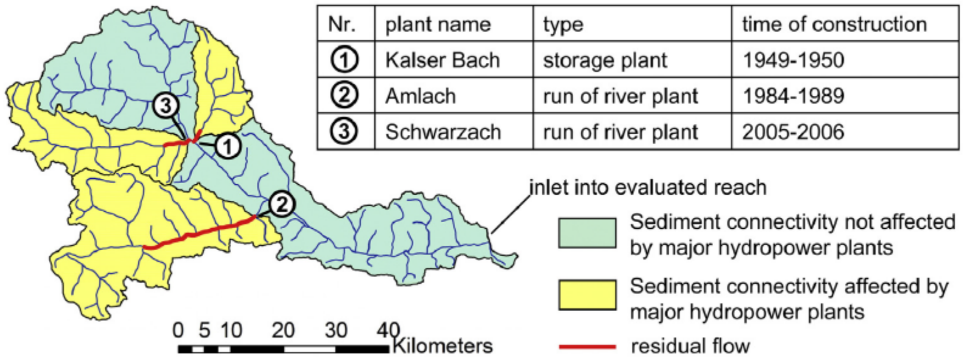


Figure 3. Decreasing low flow water levels measured in winter due to regulation and change of sediment supply

An overview of the major hydropower plants in the upper Drau catchment affecting the sediment transport is depicted in Figure 4.



Nr.	plant name	type	time of construction
①	Kalser Bach	storage plant	1949-1950
②	Amlach	run of river plant	1984-1989
③	Schwarzach	run of river plant	2005-2006

Figure 4: Location and types of hydropower plants in the upper Drau catchment (Klösch and Habersack, 2017)

To reverse the trend of ongoing riverbed incision countermeasures were implemented, starting in the 1990s. Several riverbed widenings were applied to stabilize the riverbed, improve flood protection with the new approach of providing an appropriate channel width and to re-establish the ecological integrity of the river.
Figure 5 shows the locations of the restoration measures along the Drau River as well as bedload and total load yields for the investigated area. The period between 1991 and 1998 was showing a degrading trend, analysis of the second (1998–2008) and third period (2008– 2013) exhibit aggrading trends, given a response to the implementation of major restoration measures such as the one near Kleblach-Lind.

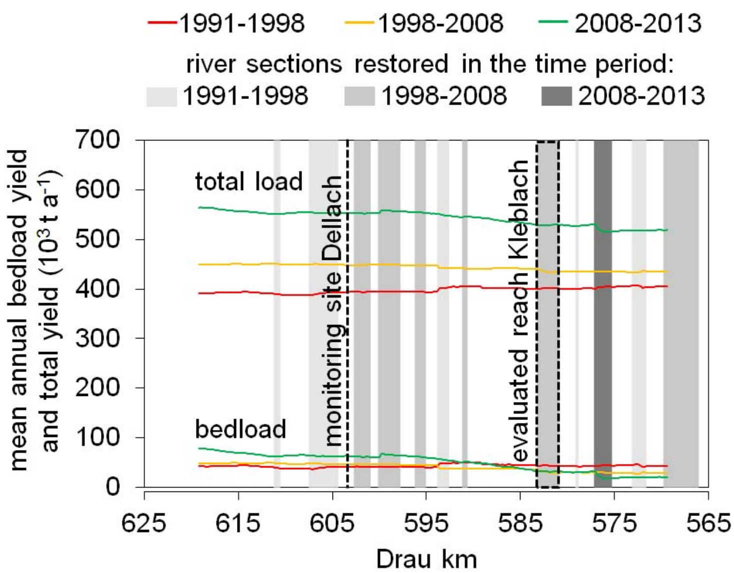


Figure 5: Annual bedload yield and total load along the Drau River related to restoration measures for the time periods 1991–1998, 1998–2008, and 2008–2013. The reduction of sediment loads with distance downstream reflects a shift from degradation to an aggrading trend as a consequence of restoration works (Klösch & Habersack, 2017)

The 1.8 km-long restoration measure at the study site in Kleblach-Lind was implemented in 2002. In the reach a riverbed widening was established via excavation, but restoration works also included a reconnection of a side-channel to provide space for self-dynamic widening. Groynes were embedded every 60 m to 110m in the hinterland of the outer bank to prevent uncontrolled bank retreat. Figure 6 shows the morphologic evolution of the site since the restoration measures in 2002 and 2003 (Figure 6).

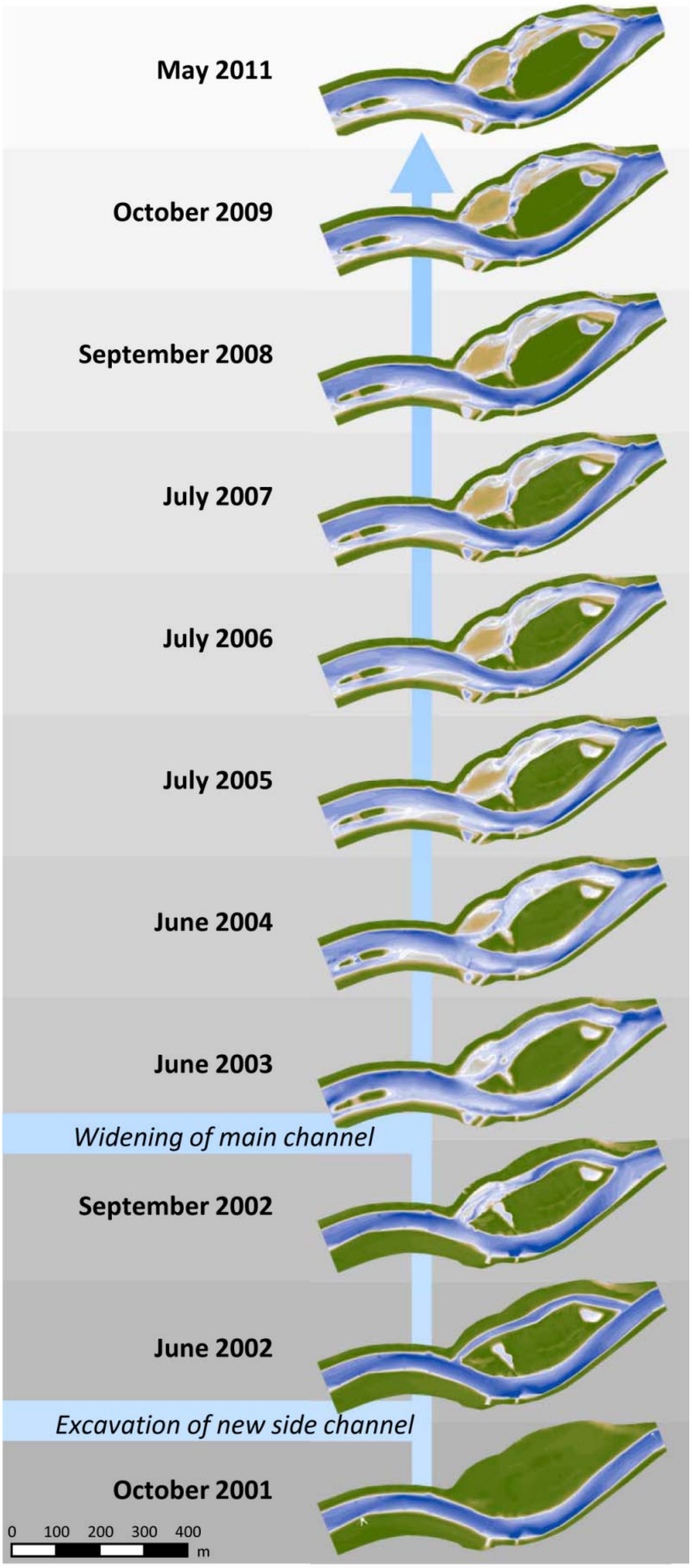


Figure 6. Change of morphology after the excavation of a new side channel in 2002 and the widening of the main channel in 2003 (Habersack et al., 2013). The elevation was detrended based on the valley slope, so that the colours approximately represent a relative elevation to the water surface. The white contours approximately represent the position of the water edge.

Kleblach - Side channel:
A small flood with a peak discharge of 286 m³/s in the first year after channel construction almost doubled the mean width of the side channel from 29 m to 55 m. Widening was largest upstream, where it was accompanied by the development of a large mid-channel bar. The groynes along the left bank were exposed quickly by bank erosion and have since then acted as constraints to the channel morphology. Due to aggradation the side-channel disconnected at low flow conditions, so that the inlet was modified in 2009 (the inlet structure - kind of a groyne - was set back a few meters), since then it is better connected.

Kleblach - Main channel:
The bed-levels rised after restoration (0.35m in the area of the former regulated bed between 2003 and 2011). More diverse flow patterns were established and habitats were successfully recreated. Big bars developed, but they are immobile given the remained channel constraints and continue aggrading.

Only 5 km downstream of the restored reach of Kleblach, near the village of Obergottesfeld, an even longer reach of the Drau River was restored. The restoration measures included the excavation of two side-channels, one side-channel 1 km in length, one 600 m in length, and were finalised in 2011. Again, groynes were embedded in the floodplain to prevent from erosion of private land. Especially the upstream side-channel quickly widened and triggered massive bank retreat, which required the installation of additional groynes.

Figure 7. Upstream part of the restored reach near Obergottesfeld in 2017. Massive riverbank erosion required the installation of additional bank protection (groynes) to prevent the erosion of private property. Flow is from right to left (image source: Carinthian government).

3. Monitoring activities

3.1. General objectives of the monitoring program

The restoration measures at the case study were already implemented in 2002 and 2003 and were already monitored in past projects, mainly in relation to the fulfilment of the restoration objectives defined prior to the restoration works:

- Improve the ecological integrity
- Mitigate channel incision
- Improve flood protection

The previous monitoring activities could already attest an improvement of ecological integrity (Unfer et al., 2004) and an increase of bed levels in the restored reach (Habersack et al., 2013). The effects on flood protection were not analysed but the more complex morphology of the site can be assumed to increase the retention of flood peak levels and improve flood situations downstream. Regarding the long time passed since measure implementation, and considering that the last survey of the case study reach near Kleblach was conducted in 2011, the case study site offers an opportunity to study the longer-term effects of restoration measures. The objectives of the surveys and related analyses are:

1. Assessing the longer term trajectory of a restored reach

First, one repeated survey of the entire reach will show the present state and hence carry forward the documentation of the morphologic evolution displayed in Figure 6. For that purpose, the same methodologies for surveys will be used as in the past surveys to ensure comparability. This repeated survey will allow analysing the latest developments and interpreting the longer-term dynamics of the restored reach (by calculating the elevation differences since the last survey), providing also information on the longer-term implications for ecosystem services. The focus of the analyses will be put on the development of the bed levels and on the sediment balance (Figure 8), finally allowing an analysis of the latest trajectory of the reach in response to the restoration works.

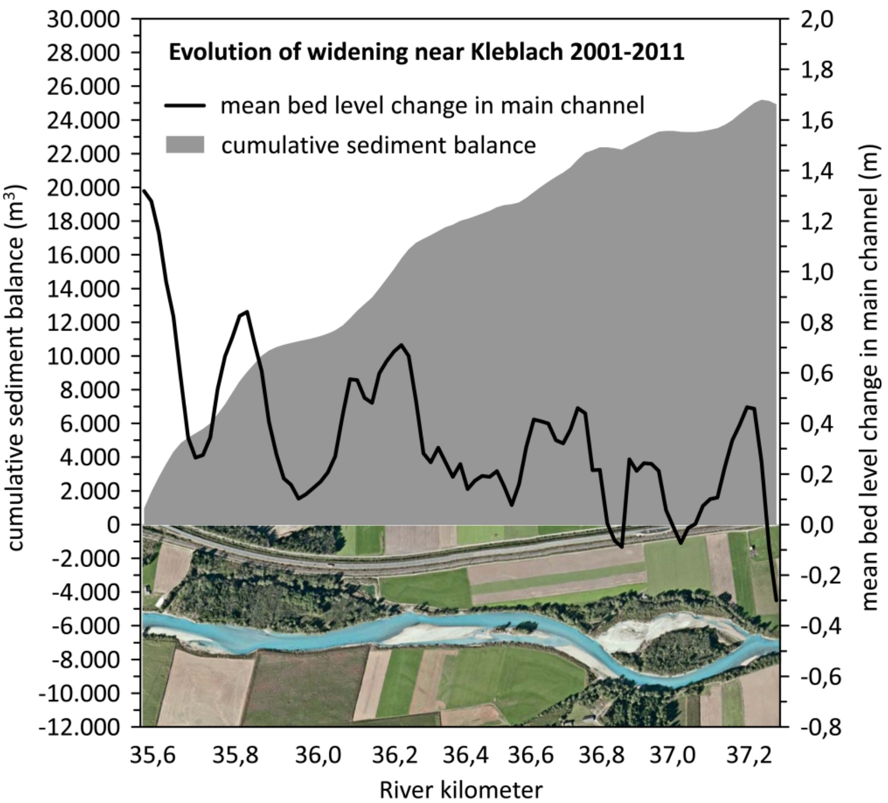


Figure 8. Change of sediment balance and bed levels after restoration, to be continued to the present state within HyMoCARES (translated into English language from Habersack et al., 2013).

2. Assessing the sustainability of the side channel in Kleblach

Second, the morphodynamics within a time interval of one year will be assessed more in detail for the side channel (using successive surveys in 2017 and 2018) to evaluate whether the evolution of this channel - after a longer period - approached a dynamic equilibrium, addressing the question of sustainability of such side channels regarding their morphology and related functions (finally to be evaluated for its relevance for ecosystem services). In the context of sustainability, the monitoring will address the question whether in the dynamic system of a restored channel the different morphodynamic processes (e.g. bank erosion, bar accretion) persist at a stable level. Accordingly, data will be obtained to see whether bank erosion is compensated by bank or bar accretion, or whether erosion of established vegetation is compensated by bare bars as habitats for pioneer vegetation. Additionally, the overall tendencies (narrowing, widening, degradation or aggradation tendencies) will be assessed.

3. Assessing the longer term effects of restoration at larger scale

Third, available data from riverbed surveys of the entire Upper Drau River section will be used to analyse also larger scale up- and downstream effects of the restored reach, and whether these effects approached an equilibrium condition.

4. Obtaining insights for developing and data for testing new HyMoCARES tools

Insights and data will be obtained to test the hydromorphological evaluation and the planning/design tools developed in WPT2 (see deliverables D.T2.2.1 and D.T2.3.1).

5. Derive recommendations for future planning.

3.2. Physical monitoring

Main channel survey

The riverbed of the main channel will be surveyed using echosounder measurements or tachymetric survey of the river bed in the main channel, both using a boat for the deeper part of the channel.

Side channel survey

UAV (unmanned aerial vehicle) surveys will be conducted in the side channel. For that purpose, a drone equipped with a camera is used within HyMoCARES to collect high-res spatial data in April 2017. Figure 9 shows a small part of a UAV based photogrammetric survey. The analysis of UAV-images is conducted with Agisoft photogrammetric software. Areas under water and areas covered by vegetation are additionally investigated by terrestrial surveying using a total station.
One of the drone surveys will be conducted simultaneously with the main channel survey, both data sets to be merged for obtaining one digital elevation model of the entire reach.

Figure 9: Example of a surface model computed with AgiSoft PhotoScan – side-channel Kleblach-Lind

Wolman pebble counts:

The grain sizes at the bed surface are repeatedly measured using the Wolman pebble count technique. We will relate the roughness detected with UAV-surveys to the pebble counts D_{50} to finally get information on all the area of the side channel and then analyse the change of surface sediment.

Figure 10: Sediment sampling for grain size analysis based on Wolman pebble counts

Radio tracer stone telemetry:

Around 20 km upstream of the study site Kleblach a sediment monitoring station of BOKU is located (Dellach im Drautal). 65 coded radio transmitters were used to create artificial stone tracers in 5 size classes using natural stones as templates (Figure 11 left). The stone tracers were put into the Drau River during low flow conditions (~ 35 m³/s) 5 km upstream of the sediment monitoring station, which is equipped with a permanent logging antenna to detect the tracers passing by at this cross-section. The monitoring of the tracer positions in the 5 km reach is performed by boat (Figure 11). The data serves as a basis for developing the SedRace tool in WPT2.

Figure 11: 65 coded radio tracer stones implemented in the Drau River (left) and the process of searching the tracers by boat

Bank erodibility measurements:

Jet tests are conducted at a characteristic riverbank of the Drau River to assess the erodibility of the cohesive sediment (Figure 12). We additionally assess the grain size distribution of the tested sediment as well as the bulk density.

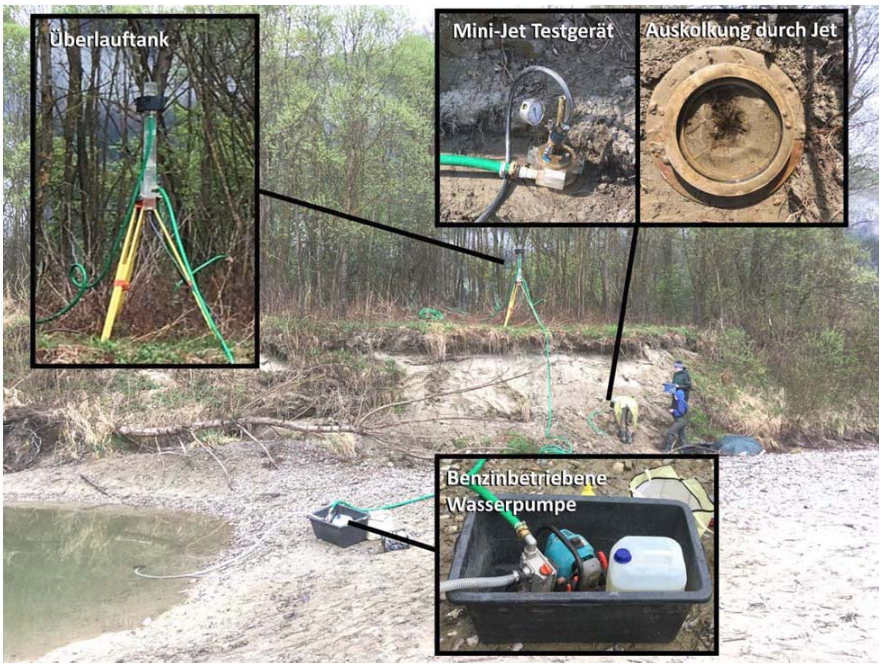


Figure 12: Experimental setup of the jet test

Assessment of artificiality along the water edges

In restored reaches, artificial constraints still co-determine the morphological evolution. At low flow condition, the artificiality along the water edges is measured as a proxy for the intensity of channelization to test a related tool developed in WPT2.

Time-lapse cameras

Two time-lapse cameras are installed, observing the riverbank next to a mid-channel bar in a widening reach of the Drau near Obergottesfeld. The images will allow determining the timing of bank erosion and will serve as a basis for developing the HyMoCARES WIDEST tool (WIDth ESTimator for alpine streams). The cameras take images of the same riverbank from two different positions, so that the images may be used for photogrammetric analysis, providing data on the riverbank geometry at high temporal resolution.

3.3. *Ecological monitoring*

From earlier projects (EU-LIFE ‘Auenverbund Obere Drau’ and EU-LIFE ‘Lebensader Obere Drau’) data on the development of aquatic and terrestric fauna and flora is available. Monitoring to assess fish and habitat conditions was conducted semi-quantitatively and quantitatively. The hydromorphological status was assessed according to a five-phase evaluation approach (Jungwirth et al., 2002) consistent with the EU Water Framework Directive. Reference conditions were deducted from (Roni et al., 2013): historic maps and reports, commercial fish catch, biological data on species distribution, as well as field data from comparable river reference sites and reference models. Additionally, amphibians and birds were monitored in the course of the EU-LIFE projects. Data on riparian vegetation derived from one ongoing project on the succession of vegetation since the implementation of restoration measures, with the most recent survey conducted in Mai 2018.

4. References

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