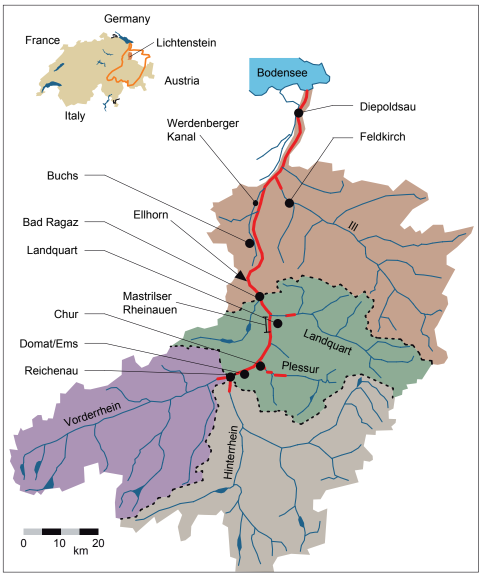
Sediment Management of the Alpine Rhine



Alpine Rhine with the tributaries Ill, Landquart, Plessur, Hinterrhein and Vorderrhein

In the middle of the 19th century the first comprehensive training of the Alpine Rhine River took place. Two further milestones in the training of the Alpine Rhine were set at the turn of the century with the construction of the canal in Fussach and two decades later with the one in Diepoldsau. At the Laboratory for Hydraulic Research and Soil Mechanics at the Swiss Federal Institute of Technology, Zurich, Meyer-Peter and his colleagues carried out the first comprehensive investigation on the bed load transport of the Alpine Rhine in the thirties and forties. Until 1970 all construction measures undertaken on, and gravel withdrawal from, this mountain river were aimed at lowering the river bed or at least preventing further gravel deposition. An increase in the discharge capacity was desired for flood protection reasons. With time the initially desired, but unfortunately further continued lowering of the river bed took on such an extent that the stability of bank protection measures, dams or bridges were endangered. Because of these artificial measures along different sections of the Alpine Rhine a transition took place: reaches with sediment deposition turned into reaches with erosion.

Until 1988 all gravel withdrawal except for at three locations, in the Alpine Rhine was stopped to prevent or at least to slow down the undesired erosion. Gravel withdrawal at the confluence of the Upper and Lower Rhine Rivers and at the mouth of the tributaries Plessur and Landquart still take place. Additionally several boulder ramps were built to stabilise the river bed, for instance at Felsberg, at Chur, at the Ellhorn and at Buchs.

The interests of the various parties in the Alpine Rhine are diverse. It serves for example as a source of gravel for building material and the electricity industry is interested in it as a source of water power. In the light of these two interests the bed load budget of the Alpine Rhine between Domat/Ems (km 4.2) and its mouth into Lake Constance (km 90) was investigated with the numerical model MORMO. The numerical model first had to be calibrated with effective discharges and with the river bed alterations observed. The period between 1-1-1974 and 12-31-1988 was chosen for the calibration. With this calibration procedure a range for the characteristic grain diameters of the bed load and a corresponding range for the bed load inputs into the Alpine Rhine for the calibration period could be determined. The resulting mean annual bed load inputs were: from very little to 15’000 m3 at Domat/Ems, 35’000 to 65’000 m3 from the tributary Plessur, 60’000 to 80’000 m3 from the tributary Landquart and 20’000 to 30’000 m3 from the tributary Ill. Additional calculations in the area of the confluence of the Vorder- and Hinterrhein and the tributaries mentioned above confirmed the magnitudes of these bed load inputs.

The calibration procedure enabled the bed load budget to be analysed. It showed clearly that the Alpine Rhine is not in equilibrium. Reaches with aggradation are followed by reaches with degradation, in which the river bed is partly stabilised by fixed points. Between Domat/Ems and the boulder ramp in Buchs reaches with degradation are dominant. Only in the Mastrilser Rheinauen and along a short reach upstream of the boulder ramps at Ellhorn and Buchs deposition can be recorded. Between Buchs and Lake Constance aggradation is dominant except for the reach down- stream of the mouth of the River Ill. In the reaches with degradation the bed load transport increases considerably, decreasing again in reaches with aggradation.

The calibration procedure shows clearly the importance which has to be attached on the downstream fining of the bed load. It was found that the mass reduction of the bed load due to fluvial abrasion must be significantly less than previously assumed. In a special research project focusing on this topic, it was shown that the reduction value due to fluvial abrasion is dependent on the transport distance, and that for the Alpine Rhine a medium value of magnitude 0.01 km-1 would be more accurate than the traditionally used value of 0.046 km-1.

Meyer-Peter and Lichtenhahn (1963) state values for the mean annual bed load transport volumes between the mouths of the tributaries Landquart and Ill of 1.3 Mio. m3 to 0.25 Mio. m3. This study, however, shows that the effective bed load transport during the calibration period was significantly lower. At km 44.5 (bridge Sevelen-Vaduz) a maximum transport volume occurs for the calibration period, which is of the order of 75’000 m3 per year. These different values arise from the different methods of calculation. An analysis of the calculations of Meyer-Peter shows that for the so called decisive cross section of a test reach, the strip method, the assumption of an equilibrium longitudinal profile between Ellhorn and the mouth of the tributary Ill and a reduction value due to fluvial abrasion of 0.046 km-1 result in too large values for the bed load transport.

Prognoses for a period of 45 years show that with bed load inputs remaining the same, equal processes occur over long reaches as those during the calibration period. The degradation and aggradation processes do, however, decrease with time. A large proportion of the erosion takes place at flood discharges greater than 1000 m3/s. For scenarios without bed load input into the Alpine Rhine erosion is intensified. Even for scenarios with extremely high bed load inputs along the reach of the Canton Graubünden erosion remains dominant. Between the boulder ramp at Buchs and Lake Constance extensive deposition has to be expected except for the scenario without bed load input. The bed load input from the Alpine Rhine into the international reach below the mouth of the tributary Ill is independent of the bed load transport at the boulder ramp at Ellhorn. This is because the local bed load transport capacity in the deposition reach upstream of the mouth of the tributary Ill acts as a control.

With this diagnosis of the bed load budget and the prediction of the development of the river bed an important basis for the planning of future river training measures is available. Planned measures can be optimised and their effects analysed with the help of the numerical model of the Alpine Rhine.

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