



## The sediment budget of Norwegian rivers and the flux of particle bound chemical elements

Jim Bogen

Norwegian Water Resources and Energy Directorate, Oslo, Norway (jbo@nve.no)

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*Jim Bogen<sup>1</sup>, Truls E. Bønsnes<sup>1</sup>, Patricia Kennie<sup>1</sup>, Rolf Tore Ottesen<sup>2</sup> and Ola Anfin Eggen<sup>2</sup>*

<sup>1</sup>Norwegian Water Resources and Energy Directorate, e-mail jbo@nve.no

<sup>2</sup>Geological Survey of Norway,

#### Abstract

The river basins of Norway are of extremely varying character and conditions differ greatly between regions and from high to low latitudes. Sediment transport monitoring programmes have revealed that there are five important sediment-source areas. These are the gullied marine clay areas, the forest areas, the glacier areas, the mountain areas outside the glacier covered areas and the cultivated areas.

The mean value of measured sediment yield supplied from the areas classified as "forest" is  $2.88 \text{ t km}^{-2}$ , giving a total annual suspended sediment yield of  $0.427 * 10^6 \text{ t y}^{-1}$ . This includes a very large part of the country, also marshland and areas with sparse vegetation are included in this category. A mean sediment yield of  $5.0 \text{ t km}^{-2} \text{ y}^{-1}$  was found for the mountain areas in mainland Norway outside the glacier areas. Their total area is  $152\,819 \text{ km}^2$ , giving a total sediment supply of  $0.764 * 10^6 \text{ t y}^{-1}$ .

The soil loss from agricultural areas of the entire country has been estimated as  $1.874 * 10^6 \text{ t y}^{-1}$  corresponding to a mean sediment yield of  $37 \text{ t km}^{-2} \text{ y}^{-1}$ . The sediment yield of gullies incised in clay areas outside agricultural land has been estimated as  $155 \text{ t km}^{-2} \text{ y}^{-1}$  and the corresponding erosion activity is  $0.155 * 10^6 \text{ t y}^{-1}$ . Different sediment yields have been calculated for different groups of glaciers varying from  $116 \text{ t km}^{-2} \text{ y}^{-1}$  for smaller cirques and plateau glaciers to a mean value of  $528 \text{ t km}^{-2} \text{ y}^{-1}$  for larger valley glaciers and outlet glaciers from ice caps. The total estimate of sediment derived from glacial erosion was found to be  $1.052 * 10^6 \text{ t y}^{-1}$ . The sum of the sediment supplied from all the different areas in mainland Norway amounts to a total of  $4.272 * 10^6 \text{ t y}^{-1}$ . In Svalbard, the temperature regime is also important. One third of the area of Svalbard is occupied by small glaciers believed to be cold and frozen to the bed and hence do not erode. An erosion rate of  $586 \text{ t km}^{-2} \text{ y}^{-1}$  has been regarded as representative for the polythermal type of glaciers. A yield of  $82.5 \text{ t km}^{-2} \text{ y}^{-1}$  is assigned to the non-glacial area giving rise to an estimated annual flux of sediment from Svalbard in the order of  $16 * 10^6 \text{ t yr}^{-1}$ .

Eight river basins have been selected for further study of sediment budget and calculation of the flux of the particle bound chemical elements Al, As, Cd, Cr, Cu, Hg, Ni, Pb and Zn based on the analysis of overbank sediments on floodplains. The range of the inorganic sediment flux and the percentage of organic material in the total load amounts to  $95 - 141\,000 \text{ t y}^{-1}$  and  $4 - 14 \%$  in Glomma,  $23 - 143\,000 \text{ t y}^{-1}$  and  $4-20 \%$  in Numedalslågen,  $195 - 1319 \text{ t y}^{-1}$  and  $32 - 56 \%$  in Vikedalselv,  $45 - 127\,000 \text{ t y}^{-1}$  and  $0.9 - 3.2 \%$  in Jostedøla,  $46 - 155\,000 \text{ t y}^{-1}$  and  $1.5 - 3.2 \%$  in Blakkåga,  $1500 \text{ t y}^{-1} - 90\,000 \text{ t y}^{-1}$  and  $0.9-25 \%$  in Beiarelva and  $5 - 23\,000 \text{ t y}^{-1}$  and  $1.5 - 5.1 \%$  in Bayelva. Higher concentrations of arsenic were found in the rivers of Svalbard in comparison to mainland Norway. Sediment storage on floodplains has been observed at 35% of the total suspended load, but construction of flood protection walls and bed level lowering have prevented the sediment load from being deposited and decreased overbank sedimentation in later years. In some of the rivers the diversions associated with hydropower development have caused an increase in sediment delivery to the sea. It is also assessed that climate change will lead to a substantial increase in sediment delivery due to the predicted meltdown of glaciers, the increase in precipitation and the increase in the number of flash floods of extreme magnitude.