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The Swedish network of sediment transport

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ABSTRACT The transport of suspended and dissolved material in some Swedish rivers is measured in a nationwide network of permanent stations. Data are available from 36 stations. Eleven of these stations have measured since 1966/67 and fourteen others have measured more than ten years. Today the network comprises nineteen stations. The stations of the network were chosen to constitute a representative picture of Swedish rivers. Most of the stations are situated near the mouths of large rivers, as one aim was also to calculate sediment transport to the seas around Sweden. Sampling frequencies have been changed due to the runoff situation for different stations in order to optimize the information. Attempts in estimating the transport of sediment in rivers without measurements have not been specially successful. Some studies of trends have been performed. New ideas of how to improve the information from the network are discussed.

INTRODUCTION

The purpose of the network is to collect physical base data from different Swedish water courses in order to determine the total transport of suspended material and dissolved matters. Other important issues are analysis of the variations of concentrations and transport and also to follow any possible long-term changes.

Erosion and sediment transport are not considered to be a serious problem in Sweden. Due to a relatively low rainfalls and snowmelt intensities and a dense vegetation cover, erosion is rather limited. In areas where the vegetation is removed or some work is done in a water course, erosion and sediment transport can cause a local problem.

The network for sediment transport was started in 1966 by The Department of Physical Geography at the University of Uppsala (Nilsson, 1971). In 1975, the responsibility for the network was handed over to SMHI. Data are available from 36 stations with varying time periods.

DESCRIPTION OF THE NETWORK

The network now includes 19 stations (Fig. 1). The stations were chosen to follow the situation in Sweden. Most of them are situated near the mouths of large rivers but some small basins are also represented. The sizes of the drainage area vary from 4 to 38 310 km^2. Many of the rivers are regulated. (Gotthardsson et al., 1992).

Field methods

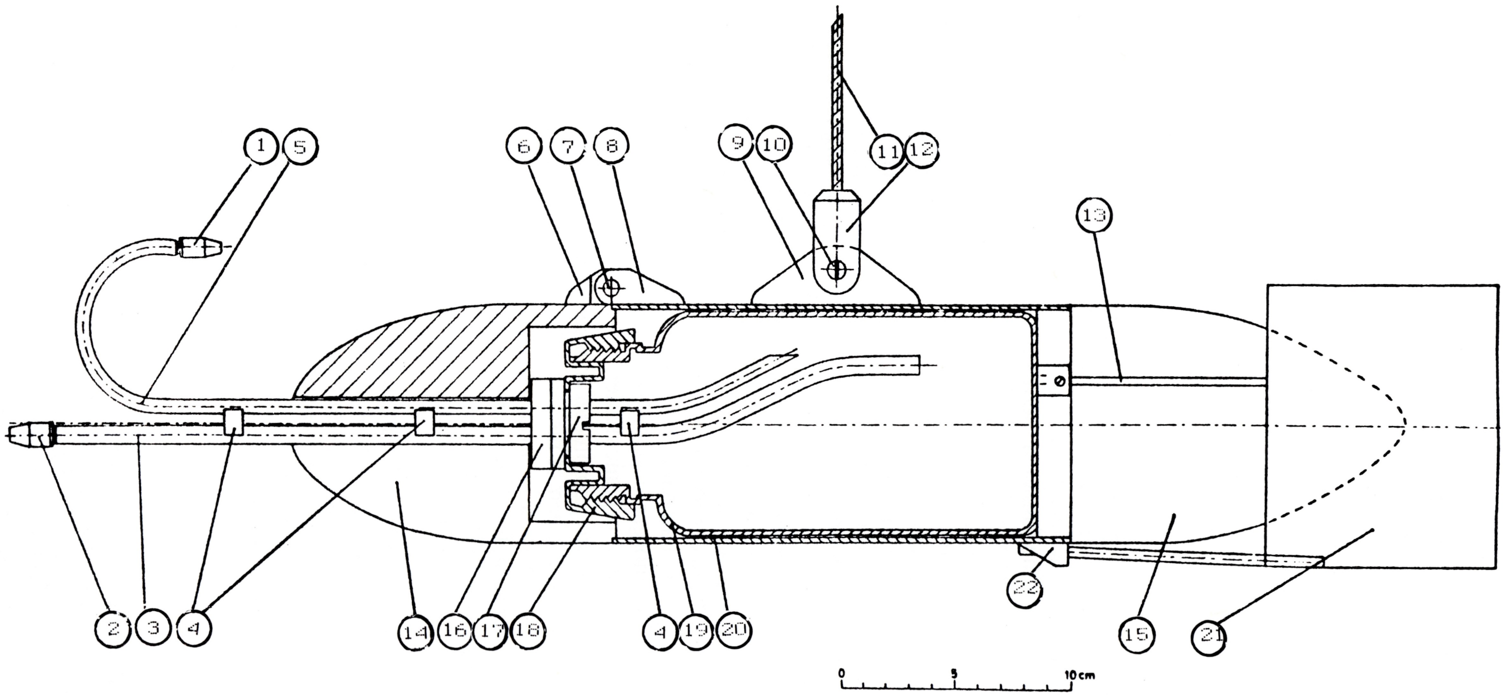
Usually a deep-intergrating sampler, developed at the University of Uppsala, is used (Fig. 2). The sampling is done in just one vertical that has been tested to give a mean value for the section. At many stations sampling is done from a bridge. In this case, a special attachment for a winch is put up. At some stations in small water courses, sampling is done at the jet of the weir.

FIG. 1 Location of sediment transport stations in Sweden.

Frequency of sampling

Samples are taken once a week during the year in the south of Sweden. In the north of Sweden, sampling is done once a week in the summer and twice a month in the winter

Sampling occasions have varied considerably during the past years, from once a month to about 100 times a year. In the beginning samples were taken daily during periods when runoff was rising. After some years, sampling was decreased as knowledge of the behaviour of the sediment transport increased.



1 Nozzle
2 Nozzle
3 Intake tube
4 Rest
5 Exhausting tube
6 Part of a hing
7 Axle
8 Part of a hing
9 Firmament
10 Axle
11 Wire
12 Schackle
13 Stay
14 Cone of lead
15 Cone of lead
16 Tube firmament
17 Nut
18 Lid
19 Container
20 Body
21 Stabilizer
22 Stay firmament

FIG. 2 Drawing of the depth-integrating sampler (Nilsson, 1969).

Analysis elements

The following analyses have been carried out:

- suspended inorganic and organic material
- dissolved inorganic and organic matters
- turbidity
- conductivity
- colour
- pH

Furthermore, water temperature is measured. Bed load is not measured.

Methods of analysis

In order to define the amount of suspended or dissolved material in a water sample, the solid particles must be separated from the water. This is done by filtration. The filtration receptical is a straight, glass cylinder clamped onto a funnel that leads down to a suction bottle. Between the cylinder and the funnel, a membrane filter is laid out over a strainer-plate. The membrane has a diameter of 100 mm and the size of the pores is 0.05 μm. The speed of filtration is 1.16 ml per minute and cm^2 with a vacuum of 700 Hg. The sample volume to be filtered is approximately one litre and is measured after filtration. Prior to this, 75 ml of filtered water is transferred by pipette to a pre-weighed beaker for evaporation in a hot cabinet for two days at a temperature of 105 °C. This sample is used to determine the amount of dissolved matter. The matter collected from the filter is then transferred by a brush as well as rinsing with distilled water to a pre-weighed beaker and placed in a hot cabinet for two days at a temperature of 105 °C for evaporation. This sample is used to determine the amount of suspended material. After two days, the beakers are allowed to cool for two hours in an exsiccator before they are weighed. In order to determine the amount of inorganic suspended material, the beakers are then heated to glowing hot for two hours at 550 °C. After cooling, the beakers are weighed again and the amount of inorganic material is calculated. The difference between the total amount of substance and that of inorganic matter (that was lost during heating the beakers to glowing hot) yields the amount of organic matter.

Turbidity is determined by micro photometer measurement. The water sample is illuminated in a beam of light and the part of the beam that reflects at a given angle (90 °C) yields the turbidity. The more the light is reflected, the more turbid the sample. The photometer is calibrated using samples with known turbidity.

Conductivity is measured with standard instruments that are calibrated with known solutions. Conductivity is dependant on temperature and the indicated value is always corrected to 25 °C.

Colour figures are measured by visual comparator against the colour on a colour disc that has been calibrated in a specified solution of platinum cobolt chloride. Determination is made from water that has been filtered through the membrane filter (see above).

pH is determined by potentiometric measurements with a pH-meter and a combination electrode. The sample is tempered to room-temperature before measuring.

Determination of particle size distribution is not performed.

Handling of data

All results of analyses and daily discharge values are stored on data media. Monthly and annual values of transport of suspended inorganic and organic material and dissolved matters are calculated as well as monthly mean concentrations of suspended inorganic and organic material and dissolved matter. In addition, monthly mean values of conductivity, turbidity, colour, pH and temperature are calculated. During periods between samplings, a sediment discharge rating curve is used. This curve is constructed from data compiled over the last three years by means of regression analysis between transport and discharge with least square method. Sediment transport for days lacking information is estimated with the aid of these curves and monthly and annual values of transport of suspended sediment can be calculated. The transport of dissolved solids is estimated by linear interpolation of concentrations between the sampling dates and multiplied by daily runoff values at the sites. The runoff values are based on the Swedish national network of discharge.

SOME RESULTS AND CONCLUSIONS

Results from the nationwide sediment transport network have been documented by Nilsson (1971) and Brandt (1982a and b, 1990).

The investigations have shown that the concentrations of suspended material and sometimes dissolved matter in the small research basins are often higher than in the larger rivers and thus not comparable. In the large basins there is deposition in lakes and reservoirs, on flood plains and in the river channel.

Generalizations from measurements in the different rivers have been tried, but have not been successful. In the early 1980's, attempts to estimate the sediment transport by regression analysis and also by a model were tested (Brandt, 1982a). The investigations did not show any clear relationships between sediment transport and various elements such as climate, relief, soil, vegetation, and land use. The snowmelt is the most critical factor for erosion losses and, therefore, we found it difficult to use any type of universal equation for Sweden.

Seasonal and interannual variations in sediment transport in larger basins in Sweden are mainly determined by the climate. This is exemplified in Figure 3 by the monthly sediment yields for 1986 (which was a quite normal climate year) for four representative, unregulated basins. The rivers are chosen to illustrate the most important differences in annual runoff regimes in Sweden. In the north of Sweden, the winter normally lasts several months, followed by snowmelt first in the lowlands and later in the mountains. Because of this, there is low runoff and transport in the winter and high runoff and transport in the spring, summer, and autumn in rivers from the mountains at Bölebyn. Torrböle station illustrates a forest river system, with high flow during both snowmelt in May and June and in the autumn due to precipitation. In summer, the runoff is low due to evapotranspiration. The annual runoff regime gradually changes from the north to the south of Sweden. In the south of Sweden, the winter is much shorter and is interrupted now and then by snowmelting. Thus, there is a quite different runoff regime, with the highest flows from November to May, but low runoff and transport in the summer during the growing season. Southwestern Sweden represented by Åsbro is much wetter than the southeastern area at Emsfors, due to weather systems coming mostly from the west. Åsbro and Emsfors are two mostly forested drainage areas.

Most rivers in the north and central part of Sweden are regulated for hydro power production. This effects the sediment transport. Figure 4 shows runoff and monthly sediment yields during 1975 in a regulated river (Skellefteälven) and an unregulated river (Vindelälven) in the north of Sweden. In both cases, the drainage areas are between 9 500 and 10 000 km^2 and the areas have about the same morphology, geology, and land use. The stations are situated inland, far from the mountains, and both streams have low concentrations of suspended matter. During the May and June spring flows in the period 1967-78 the yields in the unregulated Vindelälven were 50 - 75 % of the total annual sediment yield and in the regulated Skellefteälven only 15 - 35 %. During January and February the yields were only 5 % of the annual yields in Vindelälven and 15 % in Skellefteälven. This effect is mostly due to the change of runoff regime and not to silting in the reservoirs.

An increased transport of humus substances from forest rivers in northern and middle

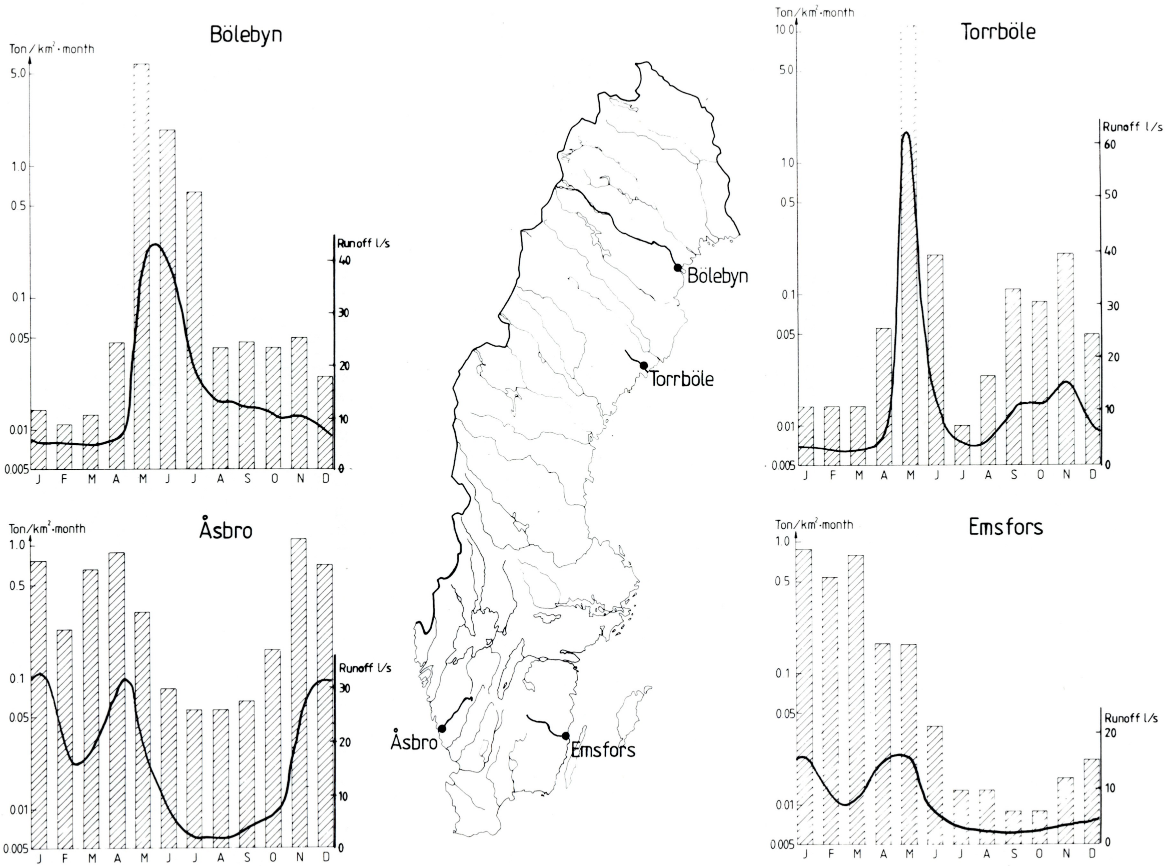


FIG. 3 Monthly sediment yields in 1986 (a normal climate year) at four stations in unregulated rivers in Sweden. (Notice that the scale of sediment yields is logarithmic). The curves are representative for different runoff regimes. (Brandt, 1990).

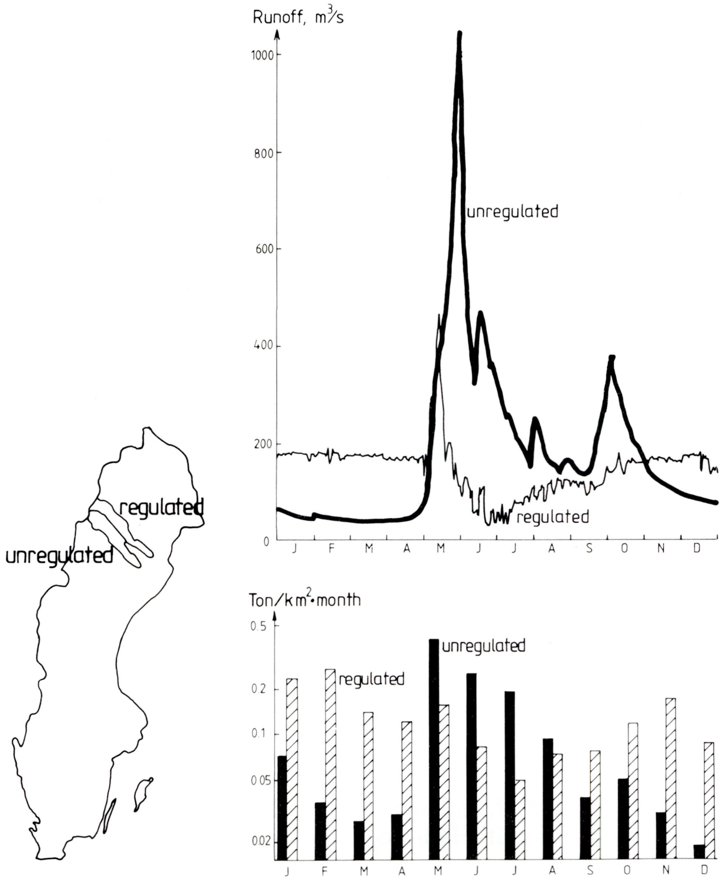


FIG. 4 Runoff and monthly sediment transport 1975 in an unregulated river, Maltbränna station on the river Vindelälven (thick line in the upper and black bars in the lower diagram), and in a regulated river, Skellefte-älven (Renströmsgruvan) (thin line in the upper and shaded bars on the lower diagram). (Brandt, 1990).

Sweden have been reported (Forsberg and Peterssen, 1990). Therefore the runoff, the concentration and the transport of dissolved material measured by the sediment transport network has been analyzed with respect to trends based on monthly mean values for the period 1967-87. The analysis does not confirm any increase in dissolved concentration, of which humus is a part (Brandt, 1990). However, the transport of dissolved matter seems to be increasing probably because of an increase in runoff over the last ten years, due to a tendency of higher precipitation (Alexandersson and Eriksson, 1989).

A simular result was found by Löfgren (1991) from a trend analysis of organic nitrogen and humus in the river Dalälven.

FUTURE PLAN

Physical base data are collected from different Swedish water courses which gives us the possibility to follow the variations in Sweden, fluctuations in transport between years at one place, site trends etc. Most stations are located in larger rivers which gives us information about integrated large-scale effects but not about processes.

Erosion and sediment loads in rivers have not been considered a serious environmental problem in Sweden except locally. Sediment derived from eroded land can, however, be a major pollutant and a carrier of polluting chemicals, such as nutrients (especially phosphorus), pesticides and contaminants such as heavy metals and complex organic components. In one of the small basins we have started coincident measurements of suspended material, total phosphorus, phosphate and particular phosphorus. As the adhesion of different materials depends on grain size distribution, discussions can ensue to start such analysis.

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