International workshop on “Erosion, Transport and Deposition of Sediments”

Introduction

The International Sediment Initiative (ISI) was founded by the UNESCO in September 2004 with the mission to organise and promote international information exchange on sediment related issues and provide links between scientific communities and political decision-makers. One of the tools used towards these ends is to organise and support workshops and conferences. The International Workshop Erosion, Transport and Deposition of Sediments was hosted by the ISI in April 2008 in Berne with the aim to bring together experts on topics related to sediment transport. The main focuses of the workshop were sediment management in the Rhine basin and global views on transport and sedimentation rates.

This report summarises the general findings and the results from the workshop. The aim is to disseminate ideas that emerged during discussion, to provide a coherent view on the current state of river sediment management and to identify major current problems in policy-making and research.

Rivers are complex systems, whose behaviour is tightly coupled for example with the catchment geology, the ground water system and the meteorology of the region. The sediment in the stream plays a key role: erosion and deposition shape the river bed, and sediment properties and distribution influence for instance fluid exchange with ground water or habitat availability. Managing the sediment in a stream amounts to finding the best solution to address the concerns of a variety of conflicting spheres of interest – amongst them economical and environmental constraints, water management and building issues and, not the least, the natural behaviour of the river itself. These conflicts manifest on a variety of levels and scales. The depth of temporal scales increases from the political scale (< 10 yrs) over the public perception (~ 10 yrs) and the engineering timescale (50-100 yrs) to the recurrence intervals of large natural hazard events (~ 100 yrs) and the dynamic timescale of the river (> 100 yrs). Likewise, spatial considerations range from local processes over reach and sub-catchment to national territories and to the whole catchment of large streams.

It seems unlikely that it is possible to find a solution that satisfies all constraints. For example, a river cross section suitable for navigation typically needs a depth larger than the one naturally adopted by the stream for a large fraction of the channel width. As a result, costly measures need to be undertaken to counteract the ensuing tendency of erosion or sedimentation. Moreover, an engineered cross section may not provide the most suitable environment for fish or water birds, and it may affect the interaction of the river with the ground water system.

Importance of scale and system behaviour

Any solution to a problem in river and sediment management needs to consider a variety of spatial scales. Local disturbances may not only affect reaches immediately upstream and downstream of the stretch in question, but the whole catchment, from the headwaters to the mouth, is a connected system. A manipulation in one part may have unanticipated effects in other parts, possibly after a considerable delay in time. The behaviour of many of the sub-systems of a catchment are more or less well understood. However, information on their coupling and their interaction is often missing.

Another problem related to scaling is extrapolation. Due to the mentioned difficulty in obtaining enough accurate data, especially during large floods, models often need to be used under conditions and in locations for which they have neither been developed nor tested. Small may behave differently to large – an example for this is bedload transport in steep streams, where physical effects, which can be neglected at larger drainage areas, may be dominant.

- River evolves naturally on a different time scale than what is of engineering interest
- Small behaves differently to large.
- Connections between upstream and downstream behaviour
- View of a catchment as a connected system
- Question of extrapolation

Sediment sourcing and transport

Due to anthropological influence such as logging, extensive farming and other land use, in many places soil erosion rates have increased over the past decades, especially in developing areas. Although a large number of conservation measures have been developed and applied in areas prone to erosion, few studies report on their effectiveness and which methods can be successfully applied in a catchment with given geological, meteorological and soil properties. Thus, no universal methodology for soil conversion and no general guidelines for catchment management exist.

Eroded sediment is transported to the ocean through the channel network. Due to its large physical complexity sediment transport is hard to model directly. Although many mostly semi-empirical models are available in the literature, each of which works well in some situations, none of them can be attributed general validity. As a result, one of the problems when making sediment transport calculations is to select an appropriate model for the situation. Existing data are too few and too inaccurate to test models in a wide range of conditions and to discriminate their performance. More reliable data would be needed to develop decision criteria for model selection and to identify and improve the most promising approaches. However, measuring sediment transport rates accurately in the field is difficult, costly and time-intensive. This is particularly the case for small headwater catchments.

- Few studies on effect of soil conservation measures
- No general guidelines for catchment management
- No universal method

Sediment transport

- Hard to model
- No established method that works under all conditions
- Little and inaccurate data

Importance of uncertainty and variability

The analysis of natural hazard risks is associated with large uncertainties, which are due to various sources. The most important of these are the natural variability of system properties or of the input, the reliability of data, the accuracy of the statistics based on the available data and the accuracy and precision of the models used. These sources of uncertainty will be discussed in more detail in the next few paragraphs.

Natural systems display a large intrinsic variability, both in time and in space, for example in rainfall patterns, soil properties and vegetation. Rare episodic events may dominate the dynamics of river catchments. This variability is often not or only partly evaluated in models. In systems where thresholds play an important role, which is often the case for geomorphic processes, an inclusion of the variability may change model predictions significantly.

Good statistics rely on long and accurate data series, which are only rarely available for discharge and suspended sediment load, and almost never for bedload transport. The situation is a little bit better for meteorological data; however, ground-based observations are typically made at a point and cannot map the large spatial variability of atmospheric processes. Their representative value may thus be inconsistent in time. On the contrary, data obtained by remote sensing can often give good information of the spatial variability of events, but local values should be used with great care. Hazard protection is often based on 100-year events, the size of which is typically estimated from rainfall or discharge data series with the length of just a few decades or even a few years. The extrapolation of such observations to longer timescales may feature large uncertainties. For example, the in- or exclusion of a rare event into the calculation of magnitude-frequency curves can considerably change statistics and hence may affect the prediction of the size of a 100-year event.

Catchment hydrology and sediment transport are complicated physical processes. Thus it is not surprising that models employ various degrees of simplification. Since models have been tested under limited conditions – typically not enough data is available to make a complete parameter study – the application to a new situation is an extrapolation and the validity of the model assumptions is not always clear. The use of a particular model itself thus introduces a certain degree of uncertainty, the size of which may be hard to assess.

- Natural variability (can it be included into models?)
- Episodic events may dominate catchment response
- Reliability and risk analysis (can it be automated?)
- Source of uncertainties (natural variability, accuracy of data, accuracy of statistics, accuracy and precision of models)
- Measurement methods

Importance of communication

Various communities work on river related problem: hydraulic engineers, geomorphologists, hydrologists, geographers, amongst others, think about different issues and often have very different perspectives on similar problems or use different tools. Here lies both an opportunity and a challenge. A challenge, as different communities employ a different style of thinking, they are interested in different problems and speak a different language. Moreover, workers may be busy with their own problems and may be unable to see the motivation in working across subject boundaries. An opportunity, as it offers the chance to share tools and experiences. One community may already have solved a problem another is struggling with, or it may at least possess the right tools to make solution possible. The knowledge of the natural behaviour of a river as studied in physical geography and geomorphology may help the engineer to plan a structure, and, vice versa, the experience of the engineer with the response of a river to a certain manipulation may help to understand its natural behaviour. Thus, since new results are of potential interest to workers with a wide range of backgrounds, it is essential to communicate them in a way that is useful to everybody. In particular, the assumptions underlying an approach and its applicability and limitations need to be clearly stated, and the terminology used needs to be defined.

Similar problems in sediment management are often encountered in different locations and there is a need to share experiences within communities as well. Working solutions to problems, but also failed attempts and new ideas should be easily accessible to any worker in research and practise. The basis for this is a generally known and widely used platform for knowledge exchange and an accessible database. These could also entail compilations on non-public data: what is available where, and how and under which conditions is it accessible?

Another problem arises from what has been discussed in the last two paragraphs: the problem of data comparability. For any scientific or engineering work two of the prime questions are these: what has been measured and how reliable is it? Different communities may use different methods to measure the same quantity and different conventions to describe it, moreover, the same item may refer to a different concept. This can, of course, lead to confusion and incorrect use of data and highlights the need for regular communication and tight networking across community boundaries.

River management does not only concern the communities directly involved in monitoring and managing the stream; the public is also affected. Therefore, not only scientific reasons may play a role, but also socio-economic and political aspects. This means that political representatives and administrative workers are involved in decision making, who may not be specialists in all matters of importance. Education of the general public and clear communication of the scientific basis of recommendations to decision-makers is thus essential. Here a particularly important aspect is the communication of uncertainty and risk.

- Networking (cross-community)
- Education and information of the general public / public awareness insufficient
- Education of researchers and practitioners (good understanding of limitations of results)
- Scientists often lack good communication skills (especially towards non-scientists)
- Knowledge exchange
- Accessible database
- Sharing experiences with specific issues and their solutions
- Need more information
- Need to make existing information accessible
- Data comparability?
- Comparability of language?

<u>Implications</u>

Although models and computing facilities develop fast, the processes occurring in a river catchment are complicated and highly heterogeneous. It seems certain that in the foreseeable future it will not be possible to completely map catchment processes and thus make accurate predictions without the need of simplified models. Rather, it may be more prudent to concentrate on evaluating the accuracy and reliability of predictions and to properly quantify the errors and uncertainties associated with model results. A major task lying ahead is thus to establish a culture of dealing with these uncertainties within the scientific communities and to educate the general public and political decision makers in how to interpret them.

This has direct implications for hazard management. As one accepts that available predictions have a finite accuracy, it seems clear that damage due to flooding and sediments cannot be avoided in all instances. Rather, the need is to plan for certain amounts of damage to property and, in hazard management and event intervention, aim to avoid loss of life and damage to people at all costs.

Sediment related issues in water management have not been explicitly addressed in the European Water Framework Directive (WFD). Thus, a tight and internationally consistent legal framework to deal with the problems discussed herein is currently lacking. The participants of the workshop recommend integrating a sustainable sediment management framework into the WFD, with the aim of achieving or maintaining a healthy ecology with only minimally disrupting economy.

- Prediction: realise that we can't model everything
- Hazard management: accept damage, avoid loss of life, communicate uncertainty of predictions and remaining risk
- Political: sediment issues overlooked in water framework directives

Research directions

For scientific understanding of the role of sediment in the catchment system and of transport processes to increase, more and more accurate data is needed. This is particularly true for the headwater catchments in mountainous regions and for bedload transport in general. Main focus of research investments in the near future should be to develop more accurate survey methods and to expand the network of observatories. Scientists and funding agencies should not be afraid to invest time and money into long-term projects, as long and accurate data series are needed for the evaluation and improvement of models both in research and in practise.

- Generally: more data
- Develop accurate survey methods
- Long-term projects
- Qualitative aspects of sediment transport (mainly important in densely populated areas)

Talk blocks:
Sediment management:
Martin Weiss, Stefan Vollmer, (Martin Keller), Emil Gölz, Hendrik Havinga
Reservoir sedimentation and management
Anton Schleiss, Gerrit Basson,
Changing sediment loads
Chunhong Hu, Des Walling
Sediment sourcing / headwaters
Dieter Rickenmann, Henrique Chaves
Ecology
Alfred Wüest
River morphology
Roy Frings
Methods
Thomas Udelhoven

Short characterisations of the presentations

Sediment management

Several presentations dealt with sediment management problems in Rhine valley, their current treatment and its effects, and remaining problems.

Martin Weiß gave an overview over sediment influx into Lake Constance and the problems introduced by two cut-offs of meanders, decreasing the channel length, and by the high settlement density in the flood plains south of the lake. The river bed near the mouth into the lake is unstable and flood protection considerations will make future drift management necessary.

Stefan Vollmer described sediment management activities in the upper Rhine catchment between Basel and Iffezheim. There, sedimentation in the impounded section of the Rhine causes rising bed and water levels, threatening navigability and flood protection measures. Necessary dredging is expensive and introduces the problem of what to do with the removed material.

Martin Keller investigated the resuspension risk of contaminated sediments. Due to strong spatial variations in sediment contamination, it is difficult to map their distribution and to identify high risk areas. Open questions are in what way historic polluted sediments influence sediment and water quality, how they are affected by current sediment management such as dredging and relocation, and if contaminated material in the upper Rhine needs to be a source of concern for downstream regions.

The presentation of **Emil Goelz** dealt with sediment management and bed stabilisation in the free flowing Rhine, concentrating on the region downstream of the Iffezheim weir, where the channel is characterised by a bedload deficit. Bed degradation or aggradation in many reaches requires extensive artificial bedload supply or removal to keep a navigable channel. Although this presents large effort and cost, experiences are overall positive.

Hendrik Havinga considered the navigation aspects and sediment management of the Dutch Rhine. There, current regulation works are mainly driven by needs of flood protection and ecological objectives. The aim is to create a more sustainable approach to the inland water transport potentials of the river. This calls for a dynamic control of water and sediment and plans to accommodate long-term changes.

Reservoir sedimentation and management

Reservoirs are built to provide water for irrigation, drinking and hydropower generation and their sedimentation is both an economical and an engineering problem. As basins fill with material supplied from upstream, usage efficiency may decline and eventually the structure needs to be abandoned.

Anton Schleiss explained the methods used to counteract sedimentation, such as dredging and flushing. Newer techniques include the resuspension of older fine material, the heightening of the dam or water release structures and cone flushing. A second topic of the presentation was protection measures against turbidity currents that might damage the dam or other structures. Working techniques include shielding with geo-textiles, air bubbles or a water jet, or the construction of an obstacle.

Gerrit Basson gave an overview on global sedimentation rates and loss of storage volume. The predicted average global sedimentation rate lies at 0.8 % and by the year 2050 a large number of countries could reach critical sedimentation volumes, such that reservoirs cannot fulfil their function anymore.

Changing suspended sediment loads in time

Many factors affect the sediment yield of rivers and some of them are only incompletely understood. A wide range of problems could result from changing sediment loads of rivers, related for example to nutrient availability and the biogeochemical cycle, soil erosion and agriculture, or simply river management and engineering.

Chunhong Hu described changing sediment loads in ten major Chinese rivers. All of the studied streams show declining sediment loads due to dam construction, land use changes and soil conservation measures.

Des Walling presented a global view on changing sediment loads. There is increasing evidence of change. Human activity, chiefly through reservoir construction and land use changes, often affects the sediment yield of catchments of all sizes and seems to be more important than the effects of climate change.

Sediment sourcing and transport in headwaters

Soil erosion and sediment transport in small headwater streams determines sediment availability for larger rivers. Many aspects of the processes happening there remain poorly understood.

Henrique Chavez described the problems in Brazil due to large soil erosion rates. There is an increasing need to employ advances farming and soil conservation methods. New cropping systems have been shown to decrease erosion rates significantly.

Dieter Rickenmann discussed the problem of sediment transport in steep headwater catchment. Dominant processes are bedload transport and debris flows, for both of which many models have been proposed, although none is adequate to explain available observations.

Miscellaneous

Several presentations focused on topics that do not fit into the categories discussed above.

Alfred Wüest studied the influence of damming on particle transport and ecology of Lake Brienz (Switzerland). There, total whitefish yield declined over the course of several years and finally collapsed in 1999. The collapse could be traced to a large flood in spring of the same year, while upstream damming only minimally affects total fish stocks.

Roy Frings investigated the morphological processes at bifurcations of the lower Rhine River. Sediment sorting in channel bends and bed armouring play a large role in the stability of bifurcations. Sediment dynamics in the bifurcation seem to be dependent on discharge, where deposition is dominant during floods and erosion during medium flows.

Thomas Udelhoven presented a new fingerprinting technique to trace sediment sources based on colour. If possible source regions and their soils are known, the colour of suspended sediment can be analysed using a chromatic mixing model, and the relative supply from the different source regions can be worked out.