Formation of a Bedload Research International Cooperative

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Summary

The state of the science in bedload research and monitoring in the last quarter century has progressed at a much slower rate than that for suspended sediment. Some new instruments and measuring techniques are available, but they are functionally similar to earlier methods in that they require routine manual collection and subsequent analyses of physical samples. Many of the old problems related to bedload measurement remain, including sampler limitations, vagaries associated with manual deployment, and a lack of temporal continuity in measurements. Acceptably and quantifiably accurate measurement of bedload discharge at discrete time intervals, let alone as a time series, is often an unattainable goal. The accuracy of equations for estimating bedload transport, predicated on accurate bedload calibration and verification data, remains unquantifiable.

On-going research on bedload-measurement instruments and measuring techniques has been taking place on an ad hoc basis within and between various countries, with little coordination among researchers. Bedload studies typically are underfunded and often lack adequate local or institutional scientific support. Some bedload and ancillary data are available, albeit in piecemeal fashion. These issues are exacerbated by the fact that the bedload-transport process is complex and characterized by large temporal and spatial variability. The authors are convinced that progress in bedload research and monitoring could be enhanced and that more accurate measurements of bedload transport, including time-series data, could be obtained as a consequence of better communication and coordination among the world's bedload-research and monitoring community.

To this end, we propose establishing a Bedload Research International Cooperative (BRIC). The BRIC will be by, for, and responsive to the international bedload research community. It will provide an international focal point for bedload research, methods development, and data sharing. Membership will be free, as will be acquisition of BRIC data. Information compiled and disseminated as part of the BRIC would enable coordination of research to fill critical gaps in our understanding of bedload processes and measurement techniques. The concept of the BRIC is evolving, and suggestions of potential collaborators are sought as the concept matures.

Introduction

World-wide needs for fluvial sediment data continue to increase with the realization of the ubiquitous influence that sediment has on the environment. "Clean sediment" – sediment without consideration for sorbed chemical or biological constituents – is listed as one of the most prevalent impairments of streams in the United States (U.S. Environmental Protection Agency, 2004). Osterkamp et al. (1998) estimated that annual sediment damages in North America totalled $16 billion. Sediment damages and data needs are well documented in many other countries.

Of the following four categories—suspended sediment, bed material, bed topography, and bedload—considerable technical progress in providing data more accurately, inexpensively, and in a safer manner, has been achieved in all but the bedload category.

Bedload is the most complex fluvial-sediment transport process requiring quantification. This is due to a combination of factors related to the spatially and temporally variable nature of the bedload-transport process, and limitations in the samplers, sampling techniques, and resources available to collect accurate bedload data. Progress in knowledge about bedload-transport processes appears to be sluggish for wont of more reliable and accurate bedload data.

There are many factors and obstacles that impinge on our ability to accurately monitor bedload discharge. These arise as a consequence of needs to determine:

(1) bedload discharge under unstable bed conditions (aggradation or degradation), but also under equilibrium conditions;
(2) bedload discharge under supply- or transport-limited conditions;
(3) bedload discharge in sand-bed, gravel-bed, and mixed-bed systems;
(4) bedload fluxes entering reservoirs, lakes, floodplains and coastal outlets;
(5) scour characteristics at bridge piers, abutments, and other in-stream structures;
(6) the extent of variation of bedload discharge and particle-size distribution due to varying land use;
(7) reliable relations between bedload discharge and explanatory variables, such as water discharge; and lastly,
(8) the nature of bedload processes and bed activity.

Bedload monitoring in essentially all environmental settings, but especially in gravel and mixed gravel/sand bedded streams, is complicated by the nature of the bedload-transport processes. Bedload occurs close to and in contact with the river bed, and the channel is typically the principal source of sediment available for transport as bedload. Almost without exception, the nature of bedload movement has necessitated deployment of samplers that contact the bed, or slot samplers arrayed in the bed. Both types of devices suffer from an assortment of monitoring difficulties and errors. For direct monitoring devices, these include but are not limited to:

(1) the need to have personnel present at the site during bedload transport;
(2) the use of measuring techniques that are laborious, time consuming, relatively expensive, potentially dependent on the skill and knowledge of the operator, and in some cases potentially hazardous;
(3) the presence of a physical sampler on the bed, which may alter the very process that is intended to be measured; and
(4) a variety of sampling errors (representativeness, repeatability, bias, precision) dependent on hydraulic and sampling efficiency, bedload size and shape, sampler stability issues, and issues related to sampler deployment – all exacerbated by typically large spatial and temporal variations of bedload discharge.

In the case of indirect monitoring devices, they have yet to be evaluated by acceptable calibration procedures, although evaluation has begun recently or is about to take place at several locations.

Determination of bedload discharge is a task facing researchers and government organizations in most countries. For example, in the United States these include agencies in charge of hydrometry (e.g., the U.S. Geological Survey); agriculture and drainage (e.g., the Agricultural Research Service and the Natural Resource Conservation Service of the

U.S. Department of Agriculture); forestry (e.g., U.S. Forest Service); environment (e.g., U.S. Environmental Protection Agency); navigation and flood protection (e.g., U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers); highway (e.g., Federal Highway Administration and U.S. Department of Transportation). Organizations in other countries with bedload-monitoring responsibilities include Norway's Water Resources and Energy Directorate, China's Ministry of Water Resources, and New Zealand's National Institute of Water & Atmospheric Research.

Progress in bedload measurement would benefit from a concerted and collaborative effort among the world's bedload-research and monitoring community. Advances in technologies based on acoustic and optic techniques show promise for applications in continuous monitoring of bedload. Instruments based on these and other surrogate technologies do not require routine collection of a physical sample and provide a time series of data heretofore unavailable, except perhaps for data provided by slot samplers. Additionally, these techniques may enable derivation of reliable estimates of uncertainties associated with the bedload-measurement process. Such experimental instruments need to be brought to maturation and calibrated against both "ground truth," and traditional-type samplers. These endeavors would be best accomplished through national and international partnerships.

Developing capabilities to monitor bedload discharge more economically and accurately, and with a substantially higher data density, should encourage additional scientists to work in this field. The authors have met and (or) have corresponded with individuals active in bedload monitoring in Austria, China, Germany, Israel, Italy, Japan, New Zealand, Norway, Poland, Spain, Switzerland, United Kingdom and the United States, who have shown interest in the formation of a Bedload Research International Cooperative. We surmise that researchers in other countries also will show such an interest toward international collaboration.

Concept of a Bedload Research International Cooperative (BRIC)

We have independently conceived and jointly developed the concept for a BRIC, opting to combine our views toward the formation of a world-wide organization for research that will provide a better understanding of bedload processes and improved means for estimating bedload discharge.

The BRIC is to be a non-profit group of researchers, practitioners, resource managers and others interested in acquisition and use of bedload data for research and for application in studies or management of river systems. The BRIC will be by, for, and responsive to the international research community. We envision that members of the BRIC will come from a wide range of disciplines with expertise in one or more of the following fields: fluvial geomorphology, hydraulic engineering, forestry, agriculture, clastic sedimentology, aquatic ecology, and fisheries services. Membership will be open to scientists from other disciplines that traditionally have not been associated with bedload processes, such as remote sensing, physics, geophysics, fluid mechanics, and mechanical engineering. Other than possession of the requisite interest and expertise, there will be no limits on BRIC membership. Although making bedload data available for use by others is not a prerequisite for BRIC membership, such data sharing will be one of the fundamental strengths of the BRIC.

The BRIC will represent a focal point for this varied expertise and a central source of information of common interest to its members and the scientific community at large. Members will be encouraged to share information on advances in bedload sampling methods, bedload databases and findings once these have been published.

A fundamental component of the BRIC will be establishment of a permanent clearinghouse for bedload and ancillary data relevant to, or developed as part of the BRIC. The data clearinghouse and some other aspects of the BRIC are dependent on the availability of appropriate operational funds. Initial organization and oversight of the BRIC, including development of the template for the data clearinghouse, will be provided by the authors without the need for external financial compensation. Suggestions on funding mechanisms for the clearinghouse and other BRIC requirements beyond the financial resources of the authors are sought.

Objectives

The objective of the BRIC is to provide an organizational forum and framework for the international community to address issues of bedload transport, which will be defined by the membership. Topics that seem to be of considerable interest and immediate urgency include:

(1) Determining *bedload-monitoring needs* under varying fluvial environments. This includes accuracy criteria for bedload samplers. A range of criteria based on bed type and flow condition may be necessary. These needs could reconsider manual sampling methodologies by comparing commonly used methods for deploying bedload samplers, including use of staylines and tetherlines. These needs could also address temporal and spatial aspects of bedload-transport monitoring, as well as those related to sediment supply with respect to the monitored cross section or reach.
(2) Aiding in the *development of novel (surrogate) devices for the monitoring of bedload*. These include samplers, traps, and especially indirect monitoring techniques using sensors, be they in situ or remote sensing, as well as *calibration of devices* in flumes and under prototype conditions. A key goal is to provide continuous (time-series) measurements of bedload.
(3) Aiding in the *dissemination of information* on the design, deployment, and use of bedload-monitoring devices through the data clearinghouse and other less formal mechanisms. As a first stage, the BRIC will seek to gather this information to be published as an up-to-date and on-line manual that may be updated periodically. Members will be invited to contribute as coauthors to this manual (see item 2: 'Historical Information');
(4) Compiling a bedload-discharge *database* (central or distributed) of rivers in various hydrologic and sedimentologic regimes. The database will be available publicly at no cost, and will set standards of storage criteria and data quality; and
(5) Providing a *vision* of bedload-data needs and comparing that vision to worldwide on-going efforts in bedload research and monitoring; identifying gaps between the vision and on-going efforts, and encouraging research to fill those gaps.

Approach

To attain these objectives, the BRIC will encompass the following activities:

(1) **Communication**: Aid in the interaction among active developers of bedload-monitoring devices by:
    (a) establishing a webpage;
    (b) publishing the names and email addresses of all its members;
    (c) establishing an email list maintained by a coordinator; and
    (d) organizing periodic conferences or workshops.

(2) **Historical Information**: Publish a document that summarizes available bedload-monitoring techniques, and addresses topics including design, construction, cost of construction or purchase, cost of deployment, method of deployment, fluvial settings, and groups that have used such devices, difficulties in the use of such devices, accuracy and suggested conditions that may best suit them. This document will also include the most current information available on novel bedload-monitoring techniques that are at various stages of testing and calibration.

(3) **Bedload and Ancillary Data Sharing**: A fundamental component of the BRIC will be establishment of a permanent clearinghouse for bedload and ancillary data relevant to, or developed as part of the BRIC. A template for storage of bedload data will be developed as part of the BRIC and placed on-line. Access to and acquisition of databases through the clearinghouse will be free. However, publication rights of authors regarding access to their data will be respected, and contributor data will be made public only after receipt of the contributor's consent.

(4) **Seek Funding:** Attempt to obtain funds[3] for the following specific objectives:
    (a) develop novel monitoring techniques and their calibration;
    (b) publish the historical information document;
    (c) aid young scientists as well as scientists from less developed countries to take part in actively operating bedload-monitoring research groups and to participate in conferences and workshops;
    (d) stimulate private-sector development of instruments and methods needed, and
    (e) fund projects for graduate and post doctoral fellows as resources permit. The projects may involve theoretical developments, but will likely concentrate on flume and field experimentation under diverse fluvial settings.

[3] Funding, collaboration, and interaction between BRIC members may be national or international. We shall provisionally contact one individual to be a national representative in matters that require national, rather than international, communication or activity.

Individuals interested in joining the BRIC will be asked to fill in a web-based form, indicating their experience with bedload monitoring. This form or one other will include questions regarding the availability of bedload data for the clearinghouse. The database of these forms will be available publicly upon entry to the database. Information that will be sought on the form will include:

(1) name, institution, physical address, and email address;
(2) type(s) of monitoring device, and for each type, the availability of narrative and visual documentation, particularly if on-line;
(3) method of deployment (e.g., in situ, wading, cable, from boat);
(4) name and location (cross-section, reach) of river, including latitude-longitude;
(5) type of river according to one or more specified classification systems;
(6) drainage area, reach channel slope, width of channel at low and high flow, and other hydrologic variables;
(7) description of channel bed including texture, bedforms, single or multiple channel, d_{50}, and d_{90} grain sizes, as well as the entire grain-size distribution, and other sedimentologic variables;
(8) hydraulic conditions under which monitoring was undertaken (range of depth and average vertical velocity, average cross-sectional shear stress).
(9) hydrologic regime such as flood, normal flow, low flow, rising phase, falling phase, etc.;
(10) general climate such as semi-arid, humid, etc.;
(11) range of monitored bedload discharge (kg/sm = kg per second per meter) ;
(12) detailed grain-size distribution of sampled bedload;
(13) range of sampling time for individual samples; for continuous monitoring, maximum duration during which device was operated and whether or not this encompassed the duration of bedload movement; cross-sectional location(s) where sampling was undertaken;
(14) protocols by which the data were collected;
(15) measurement errors and extent of uncertainty, if available, either quantified or qualified; and
(16) methods used to assess uncertainty.

All information related to measurements will be in metric units.

Until the BRIC membership form is developed and placed on-line, we invite prospective BRIC members to write to us with suggestions regarding the form, realizing that the form is intended in part to publicize experience with bedload research and monitoring. Additionally, suggestions on requisite data types and formats for the international bedload database are sought, as well as insights regarding the evolving BRIC concept, its formation and implementation, and potential collaborators.

An international meeting and/or a cyberspace meeting of the BRIC is planned for 2004 or 2005. Until then, communication will be administered by Jonathan B. Laronne in an active e-mail listing.

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References Cited

Osterkamp, W.R., Heilman, P., and Lane, L.J., 1998, Economic Considerations of a Continental Sediment-Monitoring Program: International Journal of Sediment Research, Vol. 13, Nov. 4, pp. 12-24.

U.S. Environmental Protection Agency, 2004, Total Maximum Daily Loads, 100 Top Impairments of Waters Listed in the United States: Accessed January 28, 2004, at http://oaspub.epa.gov/waters/national_rept.control#TOP_IMP .