Report for 2002AK2B: Hydrological and Geomorphological Controls on Sediment Transport Processes in the Alaskan Arctic

- Conference Proceedings:
  - J. A. Oatley, L. D. Hinzman, D. L. Kane and J. P. McNamara. 2003. Case study of a large summer flood on the North Slope of Alaska: bedload transport. Proceedings 14th Northern Research Basins Symposium and workshop. Kangerlussuaq, Greenland. In Press.
- Articles in Refereed Scientific Journals:
  - J. A. Oatley, L. D. Hinzman, D. L. Kane and J. P. McNamara. In Prep. Suppression of bedload transport by bedfast ice. Geomorphology.
- Dissertations:
  - Oatley, J.A. 2002. Masters thesis: Ice, bedload transport, and channel morphology on the Upper Kuparuk River, University of Alaska Fairbanks, 92 pp.

Report Follows:

Problem and Research Objectives

The objective of this research is to develop a better understanding of watershed morphology and to elucidate how a basin structure may evolve with the onset of climatic warming. Over the past several years, river morphology studies performed in the Kuparuk River have documented some of the changes that have occurred as a result of bedload transport. This study will provide insight into the nature of the bedload transport process. The study is being conducted in the upper Kuparuk River, near the intersection of the river and the Dalton Highway.

Objective

There are three primary goals for this study:

1) Use predictive methods to determine the total sediment load in the river for a given flow rate.
2) Compare the bedload material movement that occurs during the spring snowmelt to that which occurs in response to significant rainfall events during the summer.
3) Compare features of three arctic rivers to identify characteristics that may be symptomatic of the role of ice in arctic river morphology.

Methodology

Several field measurement methods have been, and will continue to be used to quantify the total amount of sediment transport.

Suspended sediment is being measured directly by using an auto-sampler to collect 1-liter samples at regular time intervals during the summer months. These samples will be filtered and weighed to determine the mass of solid material in each sample.

Bedload material movement is being monitored by two different methods. One method is tracer rocks; the other method is sediment traps. Scour chains, located throughout the study reach are also being used.

A total of 400 Tracer rocks are being used to study the movement of specific pieces of cobble. Both active and passive tracer rocks have been placed in the channel. The passive tracers are painted rocks. The active tracers are rocks that have a small radio transmitter implanted in them. These transmitters emit a different pulse rate at rest than during movement. This feature allows knowledge incipient motion.

Sediment traps are being used to capture particles (greater than 3mm diameter) during motion. These traps will be fixed to the riverbed and the current will carry particles into the traps.

Principal Findings and Significance

During the summer of 2001 the study reach was fully surveyed and field measurements of the channel material grain size distribution were made in the form of Wohlman pebble counts. This information has been used to perform the modeling task of predicting the bedload rating curve for the study reach. The bedload rating curve analysis showed that the competent flow threshold for this channel is approximately 20 m^3/s. Since this study began the peak flow volume has been 16.4 m^3/s, so there has not been a significant amount of bedload movement to this point. Of the 201 tracers that were in place during the snowmelt period of 2001, 14 tracers moved a measurable distance and another 12 tracers were not recovered.

During the snowmelt period of 2002 the discharge, channel cross section, and water surface slope were monitored on the Upper Kuparuk River, in the Alaskan Arctic, to determine how the Manning's roughness coefficient varied during this dynamic event.
The results show that at the onset of runoff on May 20th, while the ice was still fresh, the calculated roughness value of 0.025 was similar to that of a sand-bed stream. As the ice began to erode and large blocks of ice broke free and became entrained in the flow, the roughness value increased to a maximum value 0.051. This maximum value corresponded in time with the peak discharge value on May 24th. Over the next week, as considerable ice remained in the channel, but less was entrained in the flow, the discharge dropped to a baseflow level and the roughness value stayed near 0.040. On June 14th the ice-free Manning's roughness value, during low flow, was calculated to be 0.050.

An August 2002 precipitation event on the Upper Kuparuk River resulted in the largest discharge level (snowmelt or rainfall) over the ten-year period of monitoring at this site. During the second largest runoff event, in July 1999, channel cross section survey data and scour chains were used to study the effects of the flood on reach-scale channel morphology. In addition to channel cross sections and scour chain data, this study incorporated bed material grain size distributions and tracer rocks to monitor bedload transport during snowmelt runoff, as well as during summer rainfall events. All of these methods were utilized to study the bedload transport and morphological impact of the 2002 storm on the study reach of the Upper Kuparuk River research watershed. This flood mobilized virtually the entire bed, with the exception of random boulders greater than 0.5m. The channel cross-section and water edge survey data illustrate the considerable morphologic response generated by the flood. The magnitude of this response resulted in only a 13% tracer rock recovery rate. Using the virtual velocity method the total bedload transport was estimated to be 870 m^3 of bed material.

Arctic rivers differ from those of more moderate climates in that ice is present in the channels for eight or more months a year. Also, due to the continuous permafrost presence, there is little or no baseflow during these winter months and the headwaters and shallow reaches of these river channels freeze solidly to the riverbed. This condition is referred to as bottom ice.

In this region, all precipitation from approximately October through May is stored as snow and then released over a 6-20 day snowmelt runoff period. This snowmelt runoff is often the major hydrologic event of the year, frequently of channel-forming competence. However, in the headwater and shallow reaches of these rivers, where most of the sediment in the river system would originate, the bottom ice armors the riverbed and banks, protecting them from sedimentation processes.

The study of bedload transport initiated with the objective of quantifying the impact of bottom ice on sedimentation processes. The approach taken was to use the Meyer-Peter and Mueller (1948) and Parker (1990) equations to estimate the bedload rating curve, and to apply the rating curve to the ten year flow history of the study site to determine the total potential bedload transport that was suppressed during snowmelt runoff. The results suggest that the potential bedload transport suppressed (500 m^3) over the ten-year flow history is comparable to the amount of transport that occurred during the extreme event of August 2002 (870 m^3), and that the suppression of bedload transport, due to an ice covered bed surface, affects the morphology and sediment supply of the river.