Report for 2004AK25B: Monitoring Thermokarst Evolution at Caribou-Poker Creeks Research Watershed

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    - Kodial, P. Toniolo, H., Hinzman, L. & Yoshikawa, K. 2005. Thermokarst evolution in sub-arctic Alaska: A study case. In Proceedings: World Water & Environmental Resources Congress, May 15-20, 2005, Anchorage, AK. 11 pps.
    - Toniolo, H. Kodial, P., Bolton, W., Hinzman, L., and Yoshikawa, K. 2005. Effects of Climatic Change in a Sub-Artic Watershed in Alaska, US. In Proceedings: CONAGUA 2005. XX National Water Congress and III Symposium on Water Resources of the Southern Cone (on CD), 11 pp.

Report Follows

Monitoring thermokarst evolution at
Caribou-Poker Creeks Research Watershed

Introduction

In recent years, many researchers have estimated or reported the effects of climate warming in cold regions. The degradation of discontinuous permafrost in sub-artic Alaska has been already reported (Osterkamp and Romanovsky, 1999). The Permafrost Task Force's report, 2003; Hinzman *et al.*, 2004 have pointed out the increasing development of thermokarsts in sub-artic settings. Extensive work on thermokarst has been conducted on the thermal aspects (i.e.: Yoshikawa and Hinzman, 2003; Fraver, 2003, among others). However, detailed studies on morphologic and sediment transport processes on thermokarsts have not been performed. This study focused on the role of sediment transport processes in the spatial and temporal evolutions of a thermokarst located in the Caribou-Poker Creeks Research Watershed (CPCRW). The study was conducted in a thermokarst which development increased markedly after a very high precipitation event in July 2003. According to Burn (1992), thermokarsting process is indicated by slumping along the banks and drunken trees (trees inclined to the ground depressions). These characteristics are clearly visible in the area. This report presents some initial findings and observations on thermokarst evolution and sediment transport. It also explores the possible effects of the accelerated growth of the thermokarst on the local topography.

Study Area and Methods

The thermokarst is located in the CPCRW, which is a tributary to the Chatanika River (Slaughter and Lotspeich, 1977). The area is underlain by discontinuous permafrost. The watershed is reserved to conduct research in sub-artic environments. It was established as research site in 1969. Human activity in the area is restricted to research work. Thus, processes studied there are representative of natural settings. Soil type in the thermokarst area is predominantly silt loam. Vegetation is typically spruce and an organic mat consisting of moss and low growing shrubs (Rieger, et al., 1972). Terrain slope in the area is mild.

Field work in the study site started in March and was carried out to September 2004. Two locations were selected along the thermokarst for discharge measurements and water sampling. One of them was located at the thermokarst water input, namely, "upstream". The other one was located in the central portion of the thermokarst, here defined as "downstream".

The discharge was measured using the volume-by-time method. Water samples were collected in 1000 ml plastic bottles for suspended sediment concentration and grain size distribution analyses. An autosampler, ISCO model 3700, was installed in the downstream site. The autosampler was programmed to take a sample every 6 hs. The same bottle in the instrument was used to collect four consecutive samples. Thus, an integrated daily sample was obtained from each bottle in the autosampler. The instrument was working during the entire period of its deployment in the field to allow the water sampling during sudden rainfalls which are common in the watershed.

The collected water samples were analyzed in laboratories at the Water and Environmental Research Center (WERC), UAF to determine the suspended sediment concentration and grain size distributions.

Topographical surveys were conducted at the beginning and end of summer of 2004. The first field survey was performed in May after breakup. The second field survey was conducted in the first week of October. Field measurements were taken to determine the lateral and inward thermokarst expansions. The sedimentation of a natural depression, pond-like feature, in the downstream site was monitored over the summer.

Results and Discussion

Figure 1 shows the measured discharges at the upstream and downstream study locations as well as recorded precipitation. Precipitation values plotted on the secondary axis were obtained from the *National Atmospheric Deposition Program (NADP)* rain gauge installed close to the thermokarst site. Measurable discharge into the thermokarst was first observed on April 24, 2004. In general, peak flows were observed the day after a rainfall event indicating a delayed response time at the thermokarst.

During the early part of spring and summer the water supply to the thermokarst was by snow melt and precipitation. By mid summer there was significant discharge even though there was no rainfall. In addition, the discharge at the downstream site was typically lower than the upstream discharge. Both of these factors suggest that groundwater flow is important in the thermokarst area.

The suspended sediment concentration plots for the same locations are shown in Figure 2. High values of suspended sediment concentration were calculated after rainfall events, especially during late May and early June. Available data show that suspended sediment concentration after snowmelt was very small. Maximum sediment concentration, close to 40 mg/g, was measured towards the end of May when the flow path changed from surface water to groundwater. The eroded material from the soil matrix was moved in suspension and deposited in the pond due to the reduction in the sediment transport capacity (i.e.: reduction of flow velocity). Bed sediment deposit thickness in the pond was around 60 cm. At the end of summer, after consolidation and drying, the thickness was approximately 55 cm.

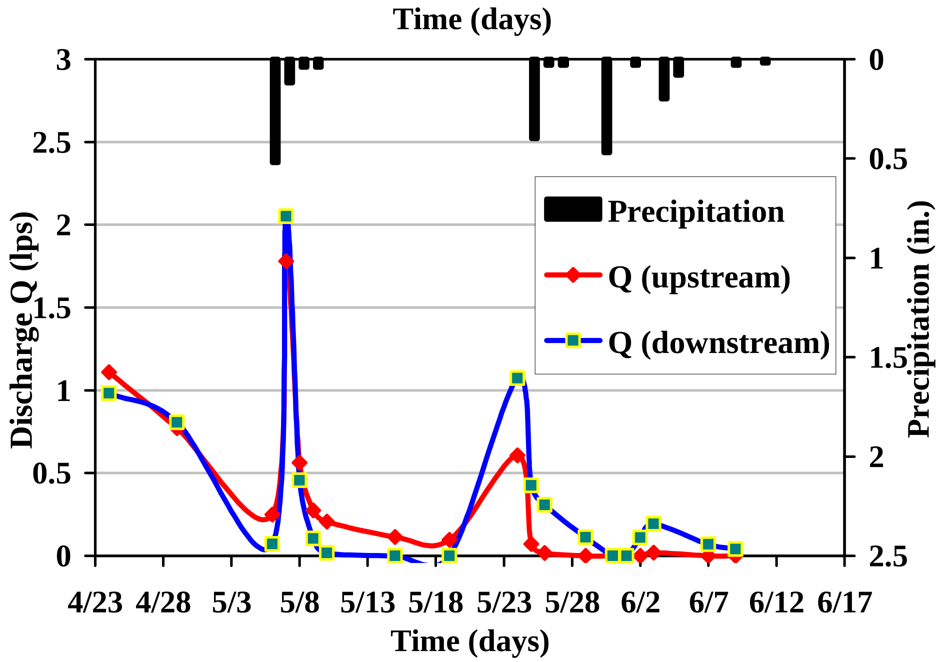

Figure 1. 2004 discharge measurement plots for the upstream and downstream study locations. Discharge ceased towards end of June due to the unusual dry summer. Precipitation data is indicated on the secondary axis.

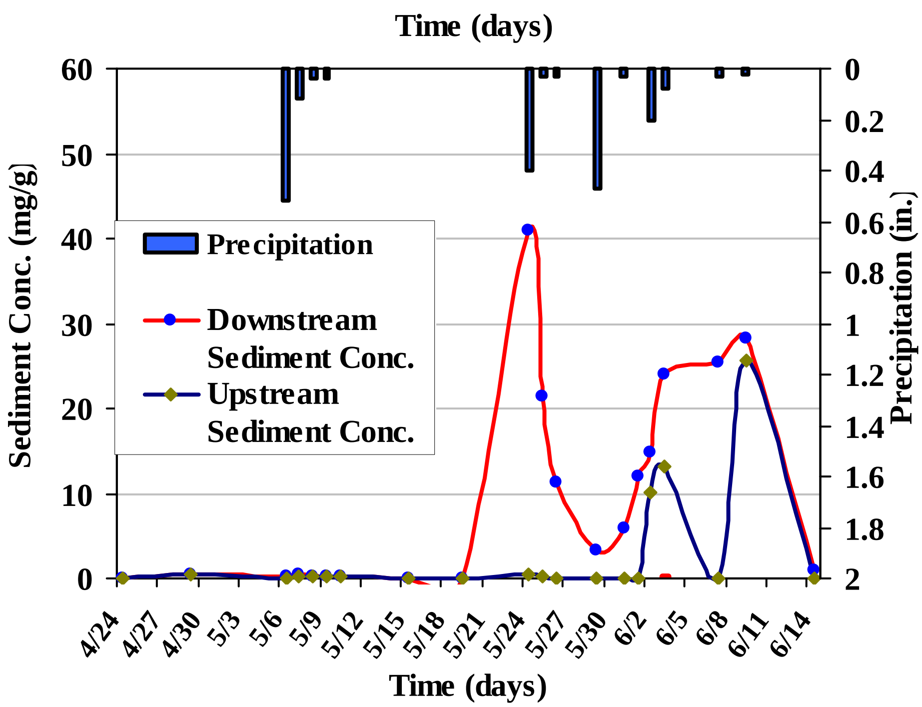

Figure 2. 2004 sediment concentration plots for the upstream and downstream sites. Precipitation data is indicated on the secondary axis.

One of the main factors for the high rate of lateral erosion detected at the upstream site during the field season was due to the combined erosive effects of flowing water and permafrost thawing. This type of erosion along lake and river banks is known as fluvio-thermal erosion (French, 1996).

Drastic morphologic changes were detected in the entire study area. As an example, Figure 3 shows the evolution at the downstream location. Specifically, the figure indicates the sequence of events that were observed at the downstream site. There was significant discharge after breakup (Figure 3(a)) followed by erosion along the banks (Figure 3(b)). Muddy water is clearly noticeable in Figure 3(c). Pond completely filled at the end of summer is shown in Figure 3(d).

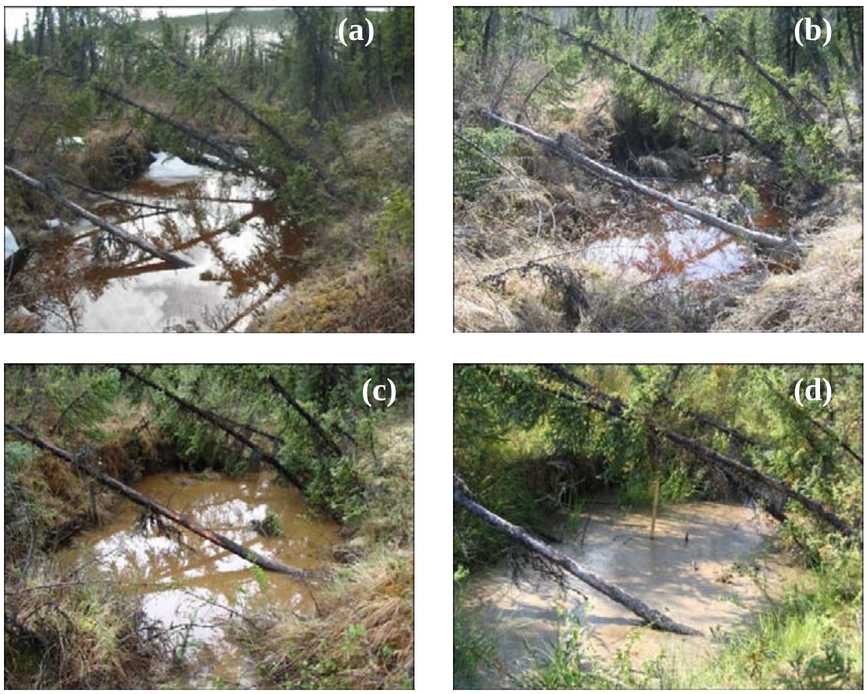

Figure 3. Thermokarst evolution at the downstream site. (a) 4/29/2004 photo after snowmelt; (b) 5/15/2004 photo showing erosion; (c) 5/24/2004 photo showing sediment laden flow; (d) 8/13/2004 photo of the sediment bed. Flow direction in all the photographs is from bottom to top.

Results from the particle size analyses are presented in Figure 4. The data indicate that during snowmelt the sediment sizes in suspension were very small compared to sediment in suspension during following periods. The curves progressively shift towards the right, thus suggesting a general increase in the particle size with time. However, mid summer the curve again shifts to the left due to lower flows (i.e.: reduction in sediment transport capacity).

Morphologic changes were calculated through the comparison of topographic surveys. Specifically, the upstream point moved about 2.5 m. Lateral erosion at the downstream site was approximately 0.5 m on both banks.

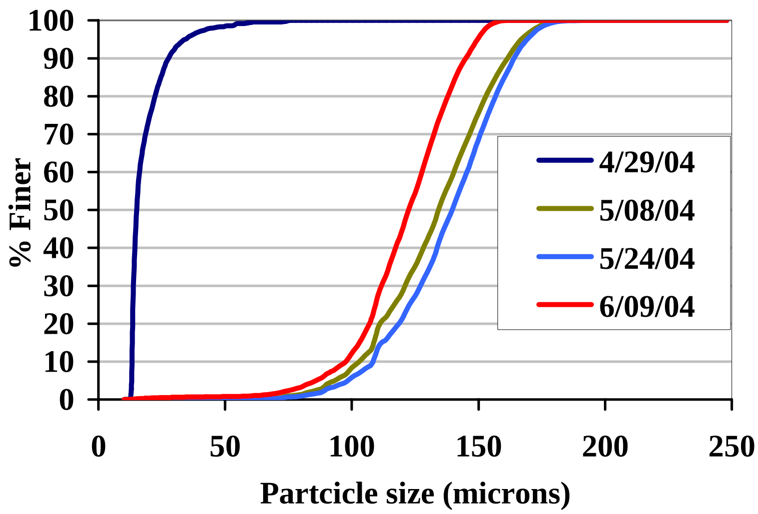

Figure 4. Particle size distribution analyses curves of suspended sediment samples.

Conclusions

The thermokarst site at CPCRW has markedly evolved in the past summer. Main changes are related to lateral and upward bank erosion. Active sedimentation processes in the downstream location allowed a significant volume reduction in the existing pond. Sediment concentration and sediment sizes during the early breakup indicated that in spite of high water discharge, practically no sediment was in suspension. It may be an indication that no sediment is available to be moved during snow melt (i.e.: all sediment is frozen). Climate warming in interior Alaska may lead to additional thermokarsts developing in CPCRW. The thermokarst under study is not likely to develop into a thermokarst lake due to the absence of special conditions like flat topography and high ground-ice content (Kääb and Haeberli, 2001). If there are more warm summers such as during 2004, and sufficient ground ice present in the vicinity, very rapid thermokarst activity may lead to more slumping and undercutting of the banks. Additionally, one can hypothesize that a small stream will form in time, which in turn may ultimately discharge sediment and water into the Caribou creek.

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