Fine-Grained Channel Margin Deposits Form by Recirculating Flow Downstream of Woody Debris in a Laboratory Flume

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Introduction

Fine-grained channel margin (FGCM) deposits appear in the lees of large woody debris (LWD) in the gravel-bed South River in Virginia. These deposits represent significant reservoirs of fine-grained sediment and adsorbed pollutants. We used a recirculating flume to determine the factors influencing FGCM formation. A more complete understanding of FGCM deposit formation will improve predictions of location and residence time of fine-grained sediment and adsorbed pollutants in the river system.

Aerial photograph of FGCM deposit in a field setting next to illustrated diagram

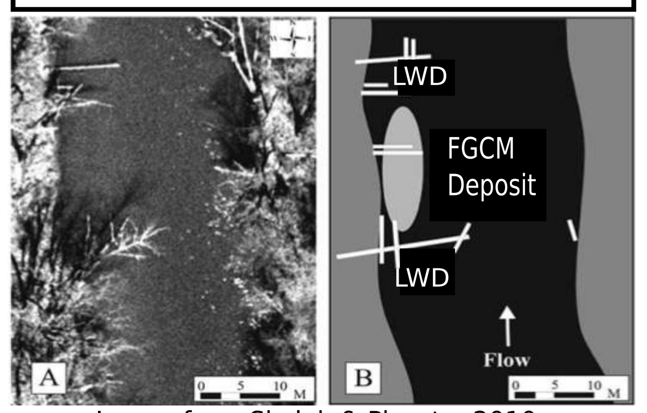
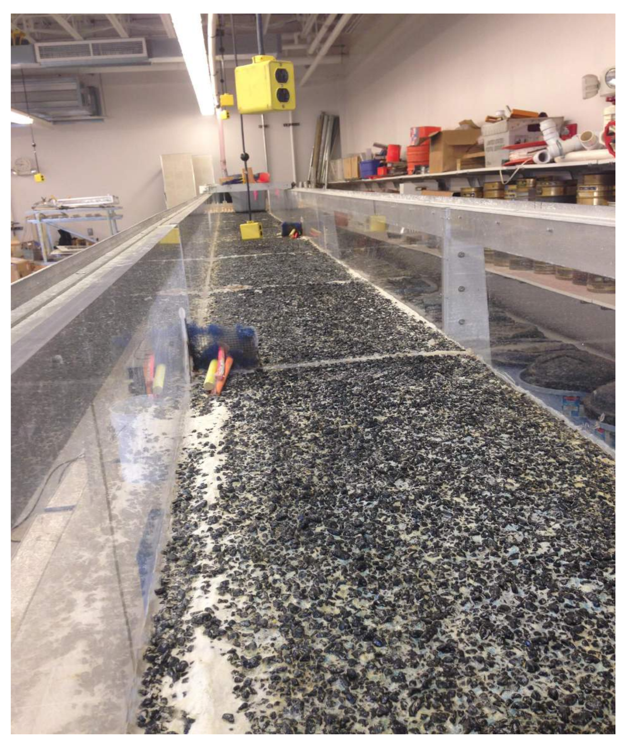


Image from Skalak & Pizzuto, 2010

Experimental setup and methods

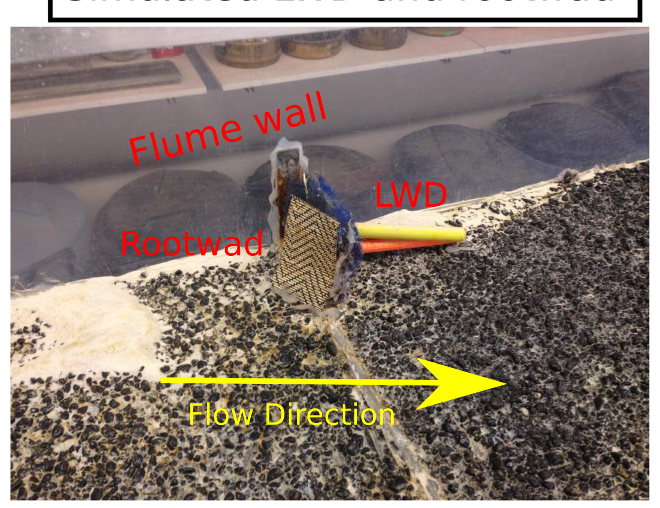
Overview

We used a 15 by .6 meter, adjustable slope, recirculating flume with a fixed pebble bed in these experiments. Two LWD obstructions were placed along opposite walls 3.7 meters apart. LWD was simulated using wooden dowels with wire-mesh bases to simulate upstream facing rootwads.
We documented the effects of LWD on flow using Vectrino velocimeters before adding 31 kg of very fine-grained (.125 mm) sand; the run continued until FGCM deposits were fully formed.



15 by .6 meter flume. Flow direction is towards camera

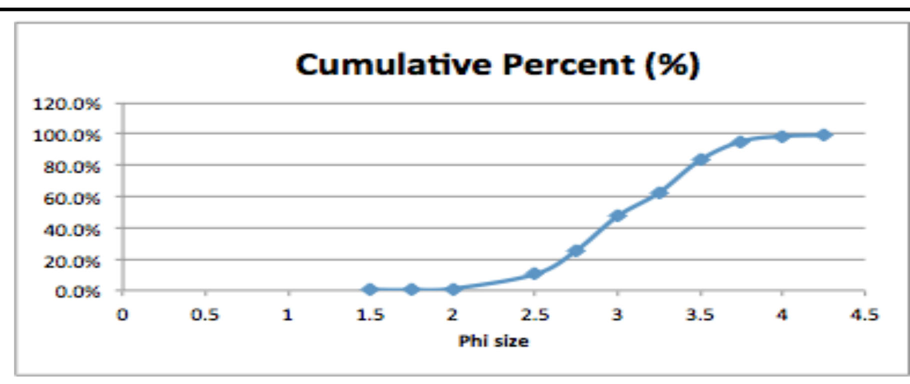
Simulated LWD and rootwad



Flow characteristics

The Froude, Shields, and Rouse numbers, metrics of sediment transport characteristics and flow regime in the flume (.51, .059, and 6.39, respectively), resemble those in gravel-bed rivers. As such, sediment transport and deposition in the flume should resemble a gravel-bed field environment.

Grain Size Distribution of Added Sediment



Grains averaged 3.1 phi (about .125 mm in diameter with a sorting of .45 phi.

Acknowledgements

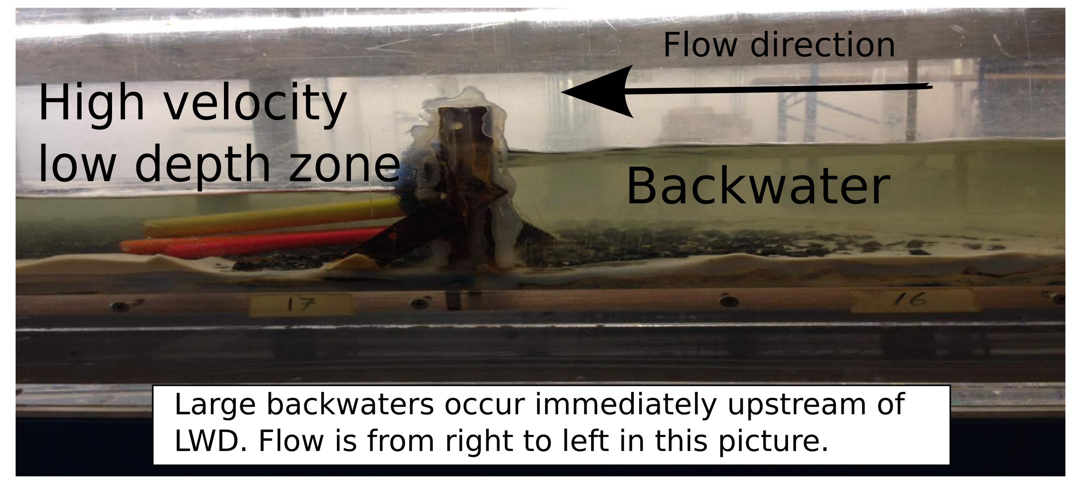
We would like to thank the University of Delaware, the Stroud Water Research Center, and Johns Hopkins University for supporting this research.

The authors acknowledge financial support from NSF EAR 1263212, a project entitled "Collaborative Research: REU/RET site - Introducing Critical Zone Observatory science to students and teachers".

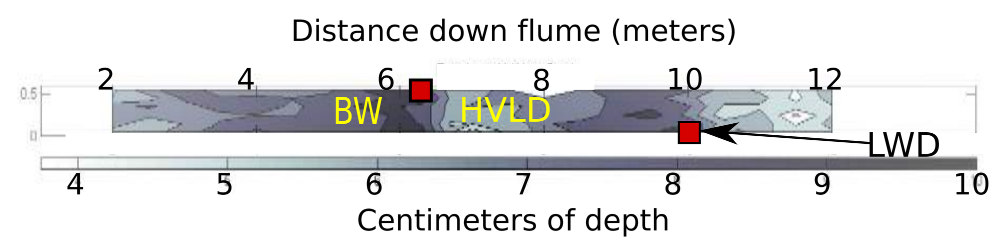
Experimental Results

Hydraulics

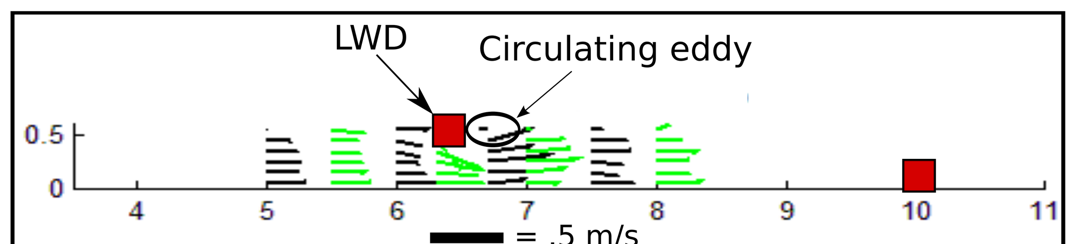
LWD imposes several critical alterations on flow in the flume. Large **backwaters** form immediately upstream of LWD. Flow towards the center of the flume accelerates from about .2 meters per second to about .4 meters per second in a **high velocity, low depth zone**. Some flow, however, is deflected upstream by the LWD in a **circulating eddy**.



Large backwaters occur immediately upstream of LWD. Flow is from right to left in this picture.



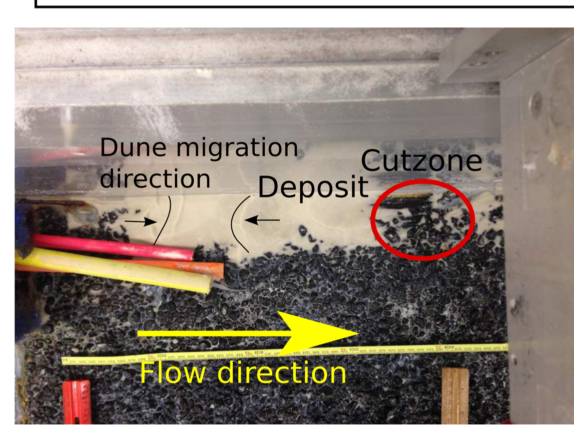
Map view of flow depth. Red squares represent LWD. BW indicates a backwater, while HVLD indicates a high velocity, low depth zone.



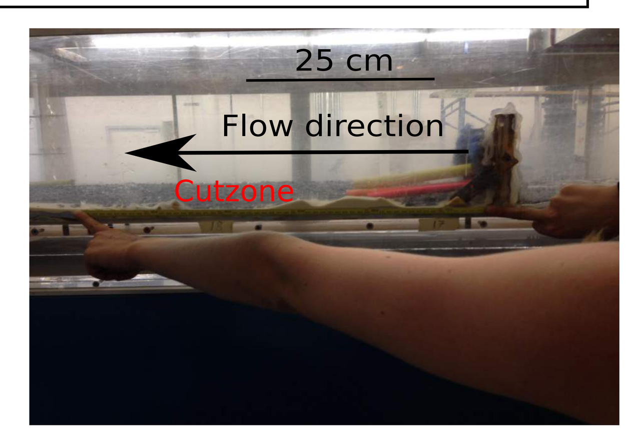
Flow vectors in flume (map view).

Deposits

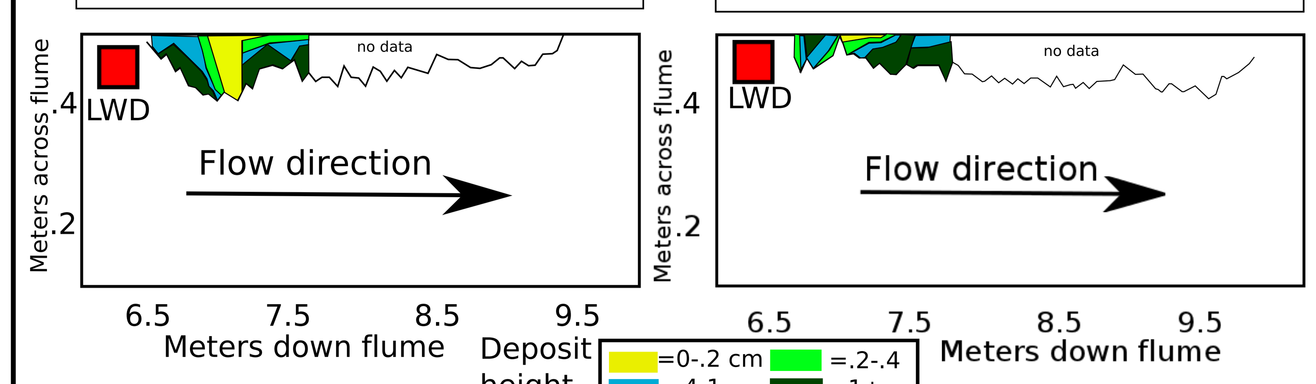
FGCM deposits created in the flume contained both upstream and downstream migrating duneforms. Immediately behind the LWD, a single downstream migrating dune precedes tall, upstream migrating dunes. Downstream of these dunes, a "**cutzone**" area showed no deposition. On the other side of the cutzone, dunes migrated downstream, generally standing shorter than those migrating upstream.



FGCM deposit with **cutzone** visible on right. The dune closest to the LWD migrates downstream, while the others move downstream.



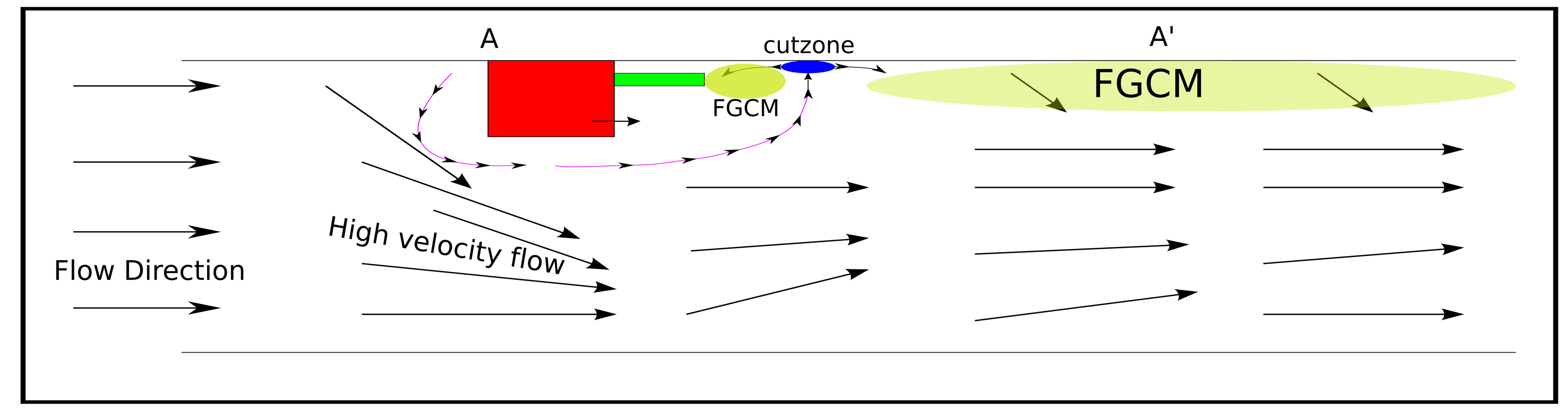
FGCM deposit in profile. Cutzone is visible above "18", where no sediment is present. Flow is from right to left in this picture.



FGCM deposit width and height before (left diagram) and after (right diagram) the addition of sediment.

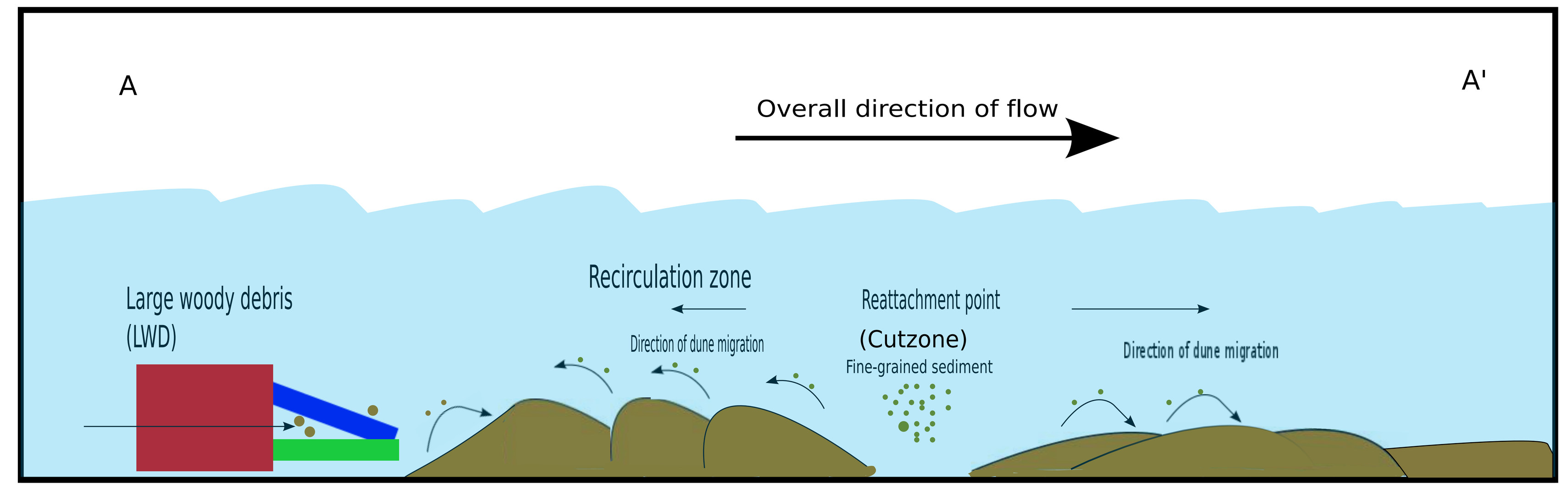
Conceptual Model of FGCM Formation

Hydraulic Model



Map view of flow paths of water in the flume. The size and direction of the arrows indicates the magnitude and direction of flow. As water approaches the LWD, a large backwater forms. Flow towards the center of the flume accelerates rapidly past the LWD as the backwater is released. Some flow deflects around the LWD and recirculates towards the left wall of the flume (pink arrows). As this recirculation current approaches the wall, some water reattaches with the primary direction of flow while some recirculates upstream towards the LWD. The reattachment bar/cutzone is indicated by the blue oval. The recirculation current slows flow enough to allow sediment to fall out of suspension. Yellow ovals represent areas in which FGCM deposits form.

Sediment Transport Model



While some sand is washed through gaps in the rootwad, recirculation currents transport large amounts of fine-grained sediment into the lee of the LWD. The current diverges at the reattachment point, with some rejoining the overall direction of flow and some recirculating upstream towards the LWD. Both of the currents stemming from the reattachment point are significantly slower than elsewhere in the flume. Lower current velocities allow particles to fall out of suspension, leading to the creation of FGCM deposits. Particles in saltation move with the direction of flow, causing dunes to migrate towards the LWD in the recirculation zone. Current rejoining the overall direction of flow at the reattachment point is also slow enough to allow deposition to occur. These duneforms migrate downstream and tend to be shallower in thickness than those occurring in the immediate lee of the LWD.

Conclusions

The fine-grained channel margin deposits in this experiment formed as a result of recirculation currents imposed by large woody debris. Recirculation slows current enough to allow particles to fall out of suspension, leading to the formation of FGCM deposits. Similar processes occur in bedrock canyon rivers, where debouching debris flows create current recirculation and deposition of sediments previously carried in suspension (Schmidt, 1990).

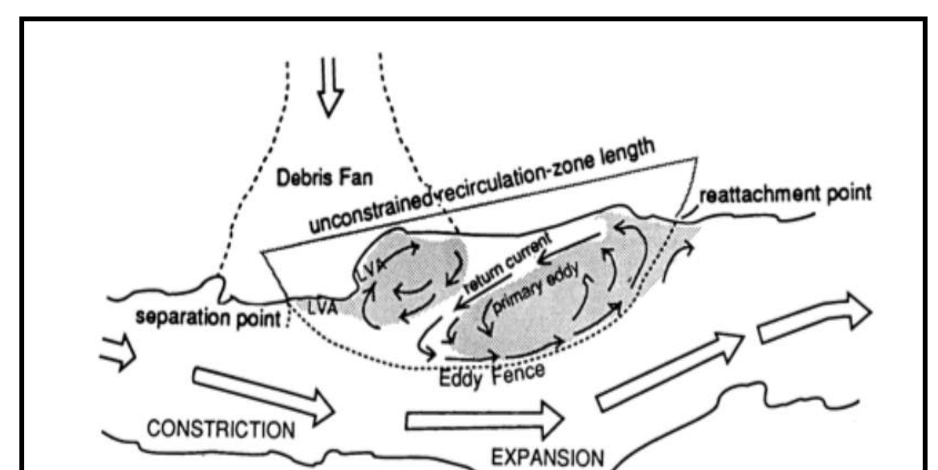


Image from Schmidt (1990)

Reattachment and separation bars forming near a debouching debris flow fan in the Grand Canyon.

References

Skalak, K; Pizzuto, J. The distribution and residence time of suspended sediment stored within the channel margins of a gravel-bed bedrock river. *Earth Surface Processes and Landforms*. **2010**, 35(4), 435-446. DOI: 10.1002/esp.1926

Schmidt, J. Recirculating flow and sedimentation in the Colorado River in Grand Canyon, Arizona. *The Journal of Geology*.**1990**, 98(5) 709-724.

Skalak, K. Fine-grained channel margin deposits in a typical gravel bed river: spatial and temporal controls on the distribution, quantity, and residence time and implications for centennial-scale mercury cycling. **2009**. U. of Del. PhD thesis, 437 pp.