Sources, Sinks, and Transport of Organic Matter with Fine Sediment along an Urban Stream

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Abstract

Fanno Creek, in northwest Oregon, was historically forested with wetlands throughout, but now is dominated by urban land cover. Abundant organic matter in the watershed decomposes instream, leading to periods of low dissolved oxygen that can threaten the health of aquatic organisms. This study was designed to investigate fine sediment dynamics associated with organic matter along Fanno Creek. Geomorphic mapping identified spatial extents of sediment sources and sinks and linked them to field measurements of erosion and deposition. Approximately 70% of the banks along the creek are eroding. The main mechanisms of fine sediment input are fluvial erosion and mass wasting. Average bank erosion rates (4.2 cm/year) and deposition rates (4.8 cm/year), applied to the mapped source and sink areas and evaluated for total organic carbon content reveal that 49–116 tonnes (metric tons, t) of organic matter from bank sediment are exported from Fanno Creek annually. When compared to measurements of litterfall biomass sources of organic matter (136–991 t), it is evident that bank material is an important, but not dominant, source of organic matter to Fanno Creek.

Fanno Creek Watershed

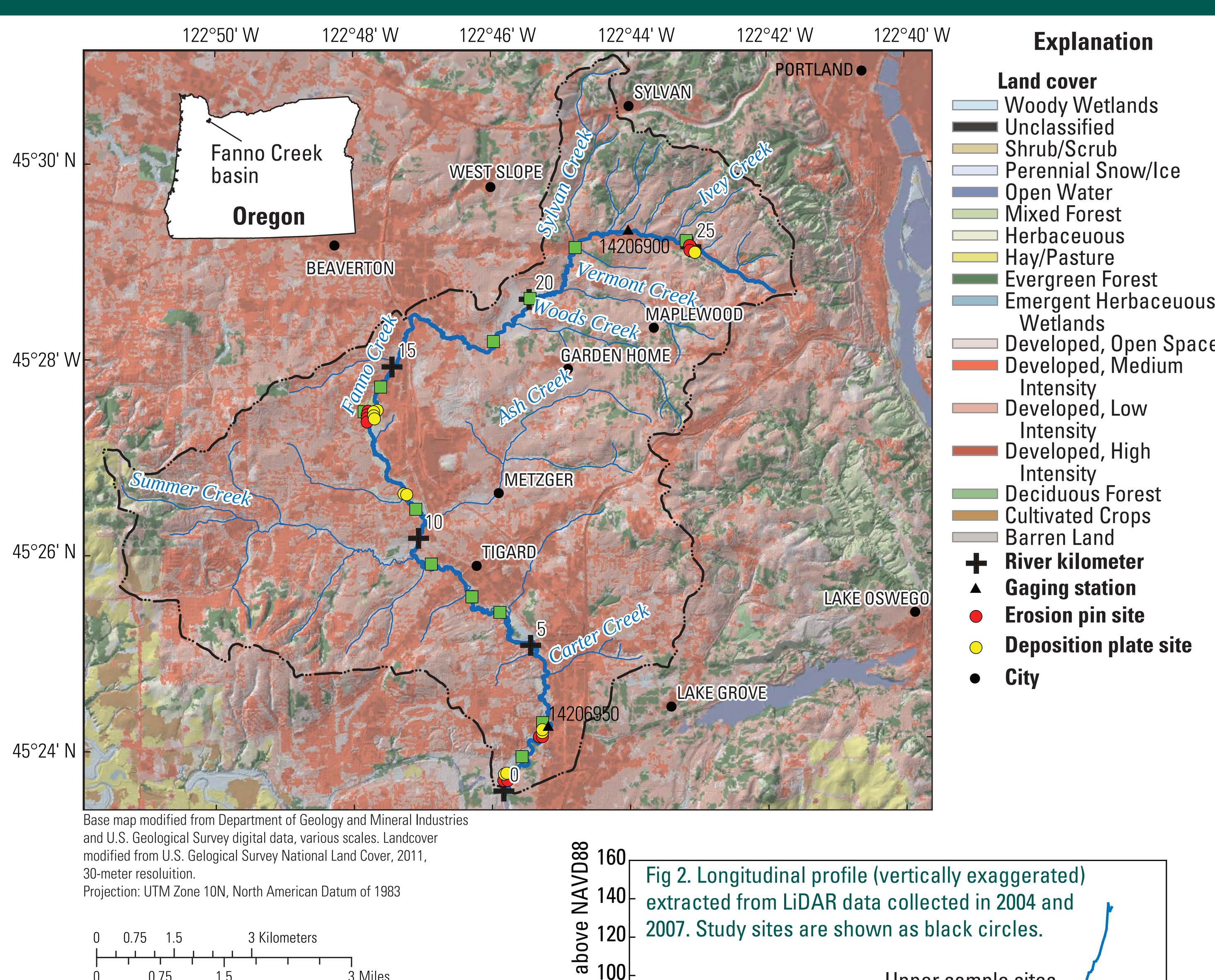


Fig 1. Map of the Fanno Creek basin, Oregon, with locations of erosion pin and deposition plates.

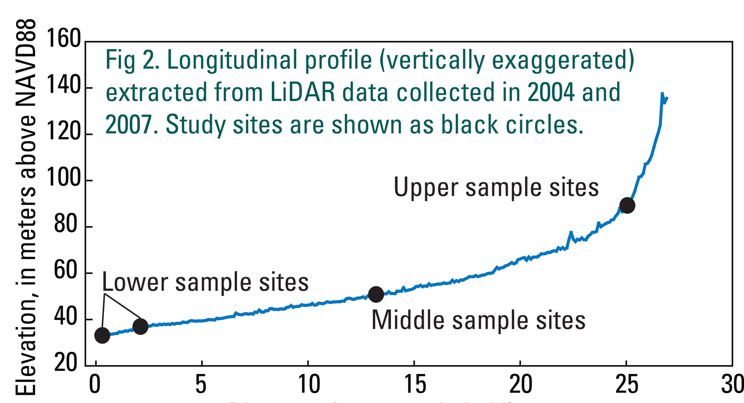
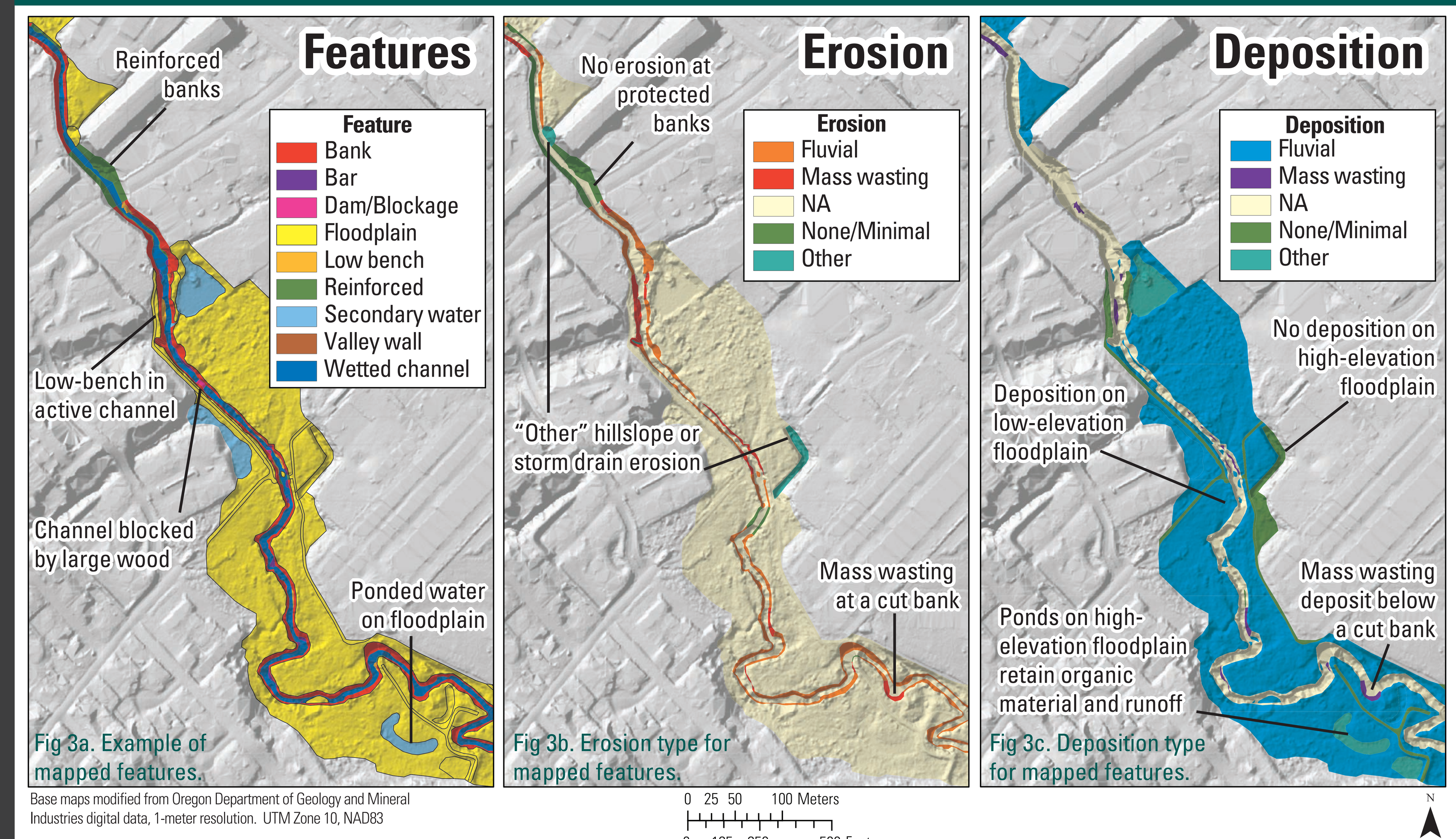


Fig 2. Longitudinal profile (vertically exaggerated) extracted from LiDAR data collected in 2004 and 2007. Study sites are shown as black circles.

Fanno Creek is a 27-km long tributary to the Tualatin River draining 82.4 km² near Portland, Oregon. The Fanno Creek watershed was historically forested with wetlands throughout but now is dominated by urban land use (89% developed). The channel flows through moderately forested riparian corridors, open wetland zones, and dense residential or industrial areas. Channel banks have been stabilized at numerous locations, especially where the channel is adjacent to business and residential zones.

Bed-material varies between silt-clay muds mixed with organic detritus and more resistant hardpan clay (dense, low permeability soil). Natural accumulations of sand and gravel are present only in the uppermost and lowermost segments, but local accumulations of gravel to boulder-sized rock, either intentionally placed in the channel or mobilized from bank armoring, are found throughout Fanno Creek. Soils are silty with slow infiltration rates. A high density of impervious areas within the urban setting, combined with poorly drained soils along much of Fanno Creek, creates a hydrologically flashy environment where discharge and stage rise and fall quickly with precipitation.

Identifying Sources and Sinks



Sediment sources and sinks were mapped in the field and with LiDAR and aerial photographs. Approximately 70% of the banks along Fanno Creek are eroding or have a high potential for eroding. In-channel sinks, such as bars, are most abundant in the lower watershed and minimal elsewhere except as slumped bank material, at beaver dams, or where other large wood blocks the channel.

Quantifying Erosion and Deposition

Short term: erosion pins and deposition plates

Erosion pin arrays were placed on the left and right bank at straight and meander segments in the upper, middle, and lower watershed to measure bank erosion, while deposition plates were placed on the floodplain and low benches within the active channel near pin sites to measure deposition (Figs 1 and 2). High flow events (>2-year flow) deposited substantial amounts of sediment on the the plates; however, greater amounts of sediment can be deposited from moderate but more frequent flows. Measurements from pins showed both erosion and deposition (typically from mass wasting or soil movement) with greater changes following higher flow periods.

Erosion pin array

Deposition plate

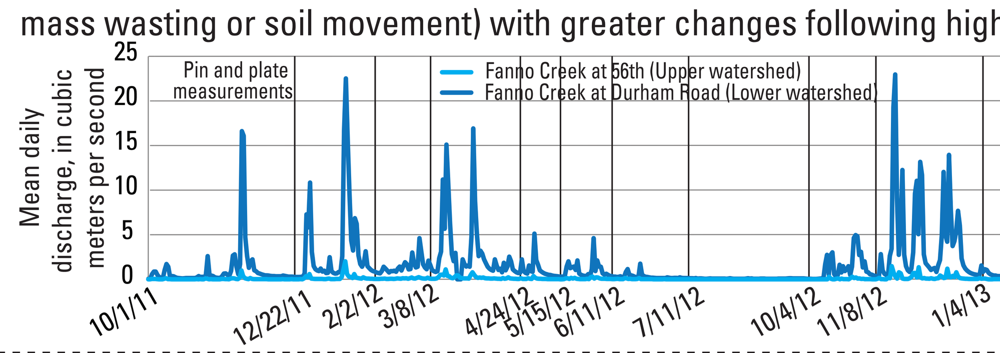


Fig 4. Mean daily discharge over the sampling period with sampling dates.

Long term: dendrogeomorphic measurements

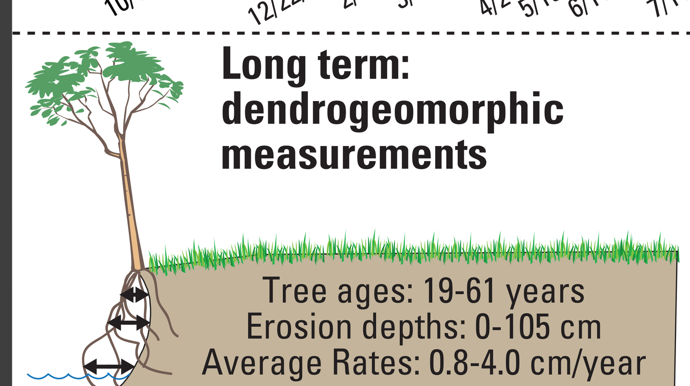


Fig 5. Illustration of undercut tree measurements.

Several trees along Fanno Creek have been undercut. Twelve trees throughout the basin were cored. Tree age and the degree of undercutting were used to calculate long-term erosion rates. A maximum erosion rate of 5.08 cm/yr was measured in a narrow stretch of the channel with steep, bare banks. There is no apparent trend in rates with tree age or basin position for the small sample size.

Net Sediment

Average annual reach erosion rates range from 2.8 to 6.2 cm/year while deposition rates ranged from 1.8 to 5.7 cm/year. These rates were applied to field mapped zones of erosion and deposition. Scaling deposition to a size fraction <2 mm and applying a single bulk density to erosion (1.7 g/cm³), the net change in sediment storage ranges from ~1,770 t of erosion in the lowermost watershed to ~1,250 t in the middle watershed.

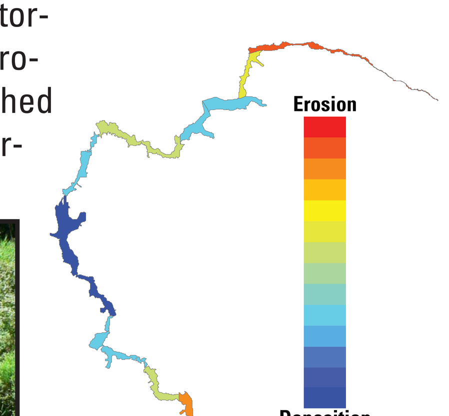


Fig 6. Net erosion or deposition by reach.

Suspended Sediment Loads

A regression between suspended sediment concentrations and continuously monitored turbidity was used to estimate suspended sediment loads. Suspended sediment loads varied with discharge and turbidity values. Loads were greatest for the high-flow period between 11/8/12–1/4/13 (900 t), accounting for 34 % of the total suspended sediment load estimated for the sampling period. Approximately, 2,650 t of suspended sediment was exported from Fanno Creek during the sampling period (~1,870 t for water year 2012). Bank sediment from the main-stem Fanno Creek could account for up to 80% of the total annual suspended sediment load.

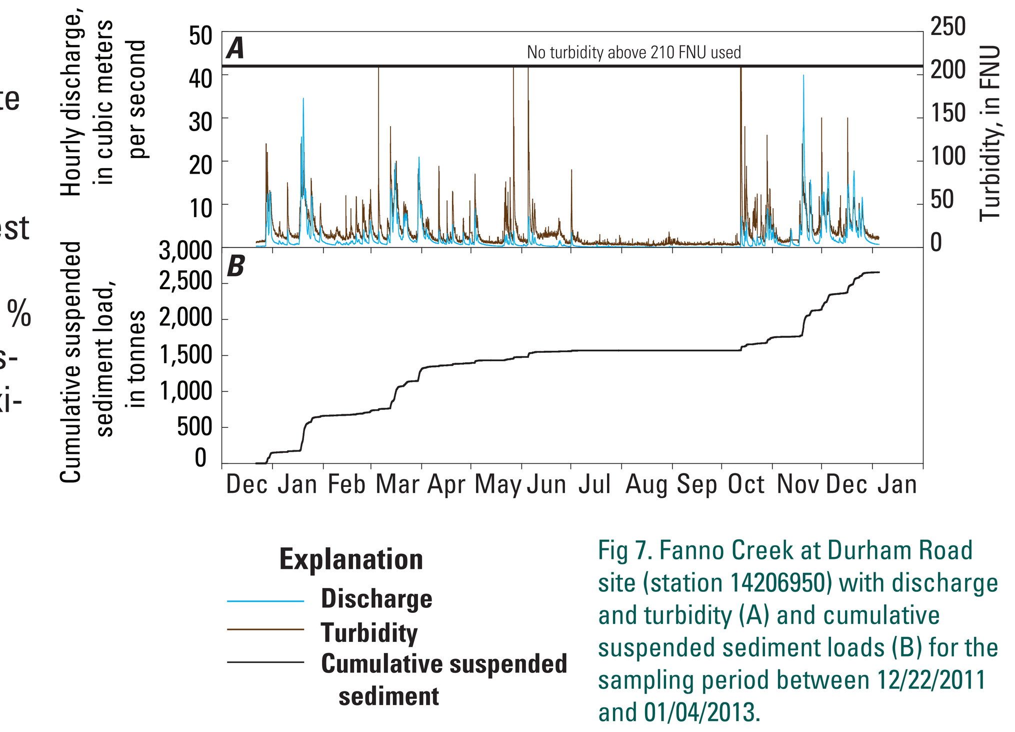


Fig 7. Fanno Creek at Durham Road site (station 14206950) with discharge and turbidity (A) and cumulative suspended sediment loads (B) for the sampling period between 12/22/2011 and 01/04/2013.

Organic Matter

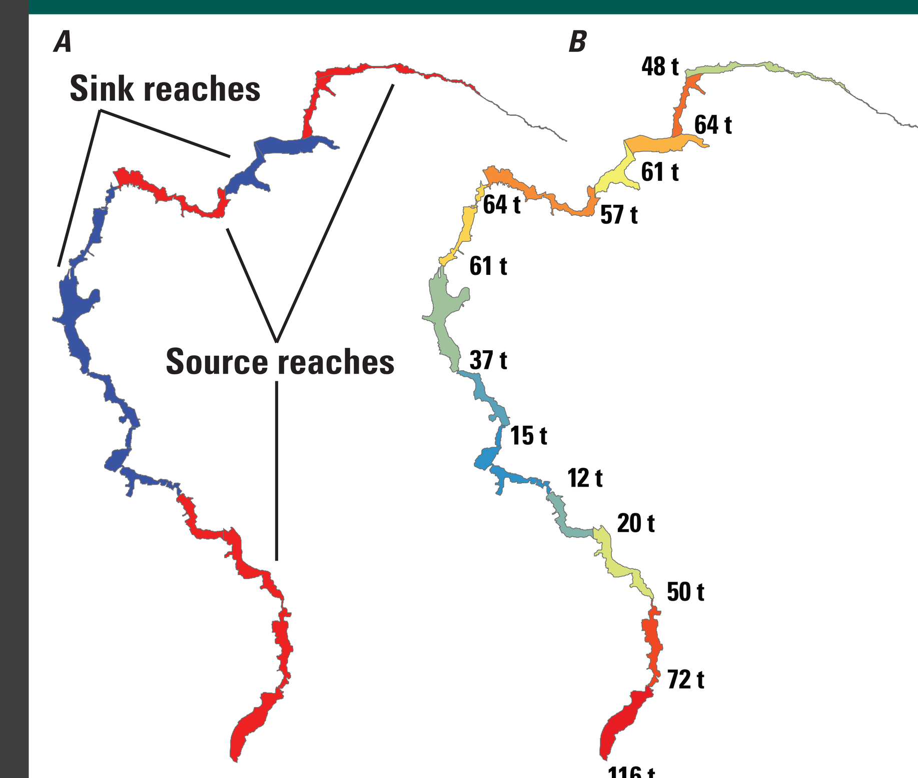


Fig 8. Organic matter sources and sinks by reach (A) and upper range for cumulative downstream values of organic matter in tonnes (B) for Fanno Creek.

Total organic carbon (TOC) contents were measured at the pin and plate sites. TOC ranged from 2.5% to more than 40% in floodplain deposits, but was less than 4% for all bank material. Bank TOC content was applied to net sediment estimates and converted to organic matter (OM). The uppermost and lowermost reaches are the largest source zones for OM associated with bank material, producing between 31–48 t annually. In the middle watershed, the contribution of OM from bank material is much lower, or there is loss to the floodplain from upstream sources. In the alternative, ther may be up to 24 t net deposition of OM from the channel to the floodplain in a single reach.

Conclusions

The dominant sources of OM are not from the distal floodplain. The majority of OM comes from other sources in riparian areas that lack bank-stabilizing vegetation, or from wetland areas in the lower, wider floodplain where more sediment and OM is reworked at moderate flows.

In all reaches, large wood, beaver dams, or other blockages retain fine sediment and OM, at least temporarily.

Most of the banks along Fanno Creek are eroding, possibly as a result of the enhanced peak flows associated with urbanization. Results indicate that the largest source of OM associated with fine sediment from bank erosion is from the uppermost and lowermost reaches. Much of the OM eroded in the upper reaches is subsequently deposited on the floodplain in the middle watershed. In constrast, there are fewer sinks in the lower watershed, making downstream reaches the key contributors of bank sediment to the Tualatin River.

Bank sediment makes up a greater amount of the total OM load at different times of the year. A better understanding of OM transport as a function of season and flow would elucidate how climate change and continuing urbanization will affect OM loading in the Tualatin River.

Acknowledgements

We thank Clean Water Services for providing funding and Sarah Schanz (University of Washington) for field assistance.