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# Net local removal of floodplain sediment by river meander migration

J. Wesley Lauer [a,*], Gary Parker [b]

[a] Seattle University, Department of Civil and Environmental Engineering, 901 12th Avenue, Seattle, WA 98122, USA
[b] University of Illinois, Department of Civil Engineering and Department of Geology, Urbana, IL, USA

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**Abstract**

Erosion from the banks of meandering rivers causes a local influx of sediment to the river channel. Most of the eroded volume is usually replaced in nearby point bars. However, the typical geometry of river bends precludes the local replacement of all eroded material because (i) point bars tend to be built to a lower elevation than cutbanks and (ii) point bars tend to be shorter than the eroding portion of cutbanks because of channel curvature. In a floodplain that is in equilibrium (i.e., neither increasing nor decreasing in volume), sediment eroded from cut banks must be replaced elsewhere on the floodplain. The local imbalance caused by differences in bank height should be balanced primarily by overbank deposition, while the local imbalance caused by curvature should be balanced primarily by deposition in abandoned stream courses or oxbow lakes. Estimates of these local imbalances based on remotely sensed measurements of bank geometry and channel migration have been made on four systems in the United States: a 91-km reach of the Pearl River in Louisiana and Mississippi, a 62-km reach of the Bogue Chitto River in Louisiana, a 35-km reach of the Neuse River in North Carolina, and a 2.7-km reach of the Vermillion River in Minnesota. For these systems, the total local imbalance, integrated over many bends, ranged from 0.36 to 2.27 $m^3$/yr/m of valley length (0.15 to 1.32 $m^3$/yr/m of channel length), or 7 to 45% of gross cutbank erosion, with a typical value of about 17%. When compared with gauged suspended sediment data, the measurements provide estimates of the relative importance of floodplains for storing material transported by a river system. The data suggest that even if the studied systems are near long-term mass balance equilibrium (as opposed to undergoing net deposition or erosion), almost all of the sand and in some cases much of the silt and clay in transit through these systems is likely to have spent some time stored in an upstream floodplain.
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## 1. Introduction

Geomorphologists often assume that river channels tend toward an equilibrium (graded) condition in which the rate at which sediment leaves a particular reach is roughly equal to the rate at which sediment enters that reach (Gilbert, 1877; Mackin, 1948). The concept of a tendency toward an equilibrium state (in the statistical rather than deterministic sense) remains a useful one for understanding river behavior, even though external forcing can prevent many or most river reaches from actually achieving the perfect, equilibrium grade. Steady changes to external parameters (such as base level, climate, or sediment supply), if sustained long enough,

* Corresponding author. Tel.: +1 206 296 5523; fax: +1 206 296 2173.
*E-mail addresses:* lauerj@seattleu.edu (J.W. Lauer), parkerg@uiuc.edu (G. Parker).

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simply lead to a geomorphic steady state that is usually close to but not precisely equal to the perfectly graded state.

Meandering alluvial rivers are inseparable from their floodplains, so it is an oversimplification to define grade simply in terms of the sediment balance of the channel alone. In a truly graded river – i.e., one in perfect mass-balance equilibrium (see Thorn and Welford, 1994) – not only does the long-term sediment input need to be equal to the long-term output, but the net exchange of sediment between channel and floodplain must average in the long term to zero. If rivers continually move sediment to near-channel overbank regions during floods, and if there is any possibility of a long-term mass balance equilibrium, there must be mechanisms for removing the deposited sediment.

In a classic paper, Wolman and Leopold (1957) framed the problem as follows. If vertical accretion on a floodplain were to continue unabated without the removal of any sediment, channel banks would tend to grow in elevation until they eventually became so high that the channel would rarely flood. They offered a hypothetical model describing this process (Fig. 64 therein), while at the same time arguing that the bankfull depth predicted by such a model would be considerably larger than the depth they observed in the field. Their model and the large body of data on flood-related sediment deposition collected since then (e.g., Pizzuto, 1987; Mertes, 1994; Walling et al., 1996; Dietrich et al., 1999; and others) highlight the importance of describing processes that can result in a net return of sediment from the floodplain to the channel and thereby limit the vertical growth of the floodplain.

Such transfer can potentially occur several ways. Cases of the removal of an entire floodplain by a severe flood have been documented (Schumm and Lichty, 1963; Matthai, 1969; Nanson, 1986; Nanson and Croke, 1992; Moody and Troutman, 2000). These occurrences are, however, most often observed in arid/semiarid environments with significant flow variability or on floodplains confined by mountain gorges. They are not universal. Small channels are present on some floodplains (Fagan and Nanson, 2004) and, to the extent that they form erosively, could be responsible for net export of material from floodplains. However, once again, floodplain channels are not obviously present on all river floodplains. On some highly cohesive systems, sediment that was recently deposited on river banks can slump back directly into the channel and thereby recycle material in the absence of channel migration (Pickup, 1984; Brooks, 2005). This process, however, is localized to a narrow band on either side of the channel and cannot serve to remove sediment from more distal locations on the floodplain.

One mechanism for the removal of floodplain deposits is, however, likely to be common to all actively shifting meandering rivers, i.e., the process of migration itself. As meandering rivers migrate, they tend to remove material from cutbanks and deposit material on point bars and floodplains. If the process of migration were biased so as to remove slightly more material from cutbanks (eroding banks) than is deposited laterally on point bars, the difference between the two could serve to balance floodplain deposition. [For simplicity we refer to all laterally accreted sediment as point bar sediment, even though we acknowledge that there are configurations where channel migration can result in lateral accretion on convex banks.] More specifically, in a graded system, the net rate of removal of floodplain sediment by channel migration would balance the rate of floodplain deposition, thereby bringing the (long-term, reach-averaged) net transfer of sediment between the channel and floodplain to zero. In addition, channel migration, as opposed to the other mechanisms for floodplain removal cited above, has the potential to remove overbank material over the entire width of the floodplain. This is the process that Wolman and Leopold (1957) postulated prevents floodplains that undergo active overbank deposition from continuing to grow vertically without limit.

In the present study, we consider two related geometric consequences of channel migration, each of which can result in a net local transfer of floodplain sediment to the channel. The first occurs when the migrating channel rebuilds a floodplain that is somewhat lower than the floodplain being removed adjacent to the outer cut bank (Fig. 1A; see also Fig. 62 of Wolman and Leopold, 1957). The net effect is to remove the upper portion of the floodplain in a process we term *floodplain shaving*. This process clearly occurs on floodplains that are reworking thick overbank deposits originally laid down during periods extremely high watershed sediment production (Trimble, 1993; Lecce, 1997). However, we propose here that a relative difference in bank height is expected even on systems at or near grade whose floodplains experience active overbank deposition. One of the purposes of the present study is to document the floodplain shaving imbalance across long reaches of several meandering rivers.

The second consequence of channel migration we consider here is related to evolution of planform geometry. As rivers migrate laterally, they tend to increase their sinuosity over time (Brice, 1974; Hooke and Harvey, 1983; Larsen, 1995; Stølum, 2002;

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