Forum

Debris-fan reworking during low-magnitude floods in the Green River canyons of the eastern Uinta Mountains, Colorado and Utah

COMMENT

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The recent paper by Larsen et al. (2004) provides interesting new data that extend concepts developed for the Grand Canyon's Colorado River to the Green River, Utah. However, previous work is misrepresented and an internal inconsistency causes confusion about the conclusions.

In Larsen et al. (2004, p. 309 and 312) it is stated that: (1) "According to Kieffer (1985), reworking takes place only during very large discharges," and (2) "Our data [that of Larsen et al.] do not support the conceptual model of Kieffer (1985) who suggested that large floods are required for reworking." To the contrary, in discussion of their Figure 12 (reproduced here as Fig. 1), Kieffer stated (1985, p. 402 and 403): "Floods of differing sizes and frequency erode the channel to progressively greater widths, as shown in Figures 12C, 12D, and 12E [here 1C, 1D, 1E]. Small floods (Fig. 12C) enlarge the channel somewhat. Moderate floods (Fig. 12D) enlarge the channel further…Rare large floods (Fig. 12E) carry this process further…The shape of the main stream at a debris fan at any instant of geologic time therefore reflects the contouring that occurred at the maximum discharge of the river since the last emplacement episode in the history of that debris fan, unless sedimentation of the finer-grained, more transient material partially mask the larger scale erosion." It was never stated or implied in Kieffer (1985) that "large floods are required for reworking, or that "reworking takes place only at large discharges" (Larsen et al., 2004).

In defining constriction ratios "as the ratio of the upstream width to the channel width at the constriction (Kieffer, 1985)," Larsen et al. (2004, p. 311) have misquoted Kieffer. The Kieffer definition was in fact the *inverse* of the Larsen et al. definition. Kieffer (1985, p. 397) states, "The ratio of the width at a cross section taken through the constriction to upstream width in region 0 (w_2/w_0) will be called the constriction of the river." Thus, the statement in the abstract of Larsen et al., "Peak discharges…decreased fan constrictions," is inconsistent with the text (p. 311) where Larsen stated that "there was 10 m of lateral bank retreat that widened the constriction ratio from 0.25 to 0.33."

In spite of the confusion caused by the wrong definition of a constriction ratio, several statements in Larsen et al. (2004, p. 309, 311, and 312) directly support the Kieffer (1985) concept: (1) "Fans whose surfaces had been aggraded decades earlier and had already been inundated by prior floods were not significantly reworked in 1996," (2) "No reworking [of the Wild Mountain Debris fan] occurred during subsequent smaller floods," and (3) "These results indicate that lateral bank erosion is an important process in reworking. Once significant reworking has occurred, subsequent smaller floods accomplish little geomorphic work."

These statements support the conclusion by Kieffer (1985, p. 385) that "each new level of record high discharges caused the river to erode a channel of sufficient width to reduce flow velocities below a threshold value required for movement of the larger boulders of the debris fan, thus contouring the fan toward a configuration more in equilibrium with the high discharges." This is precisely the picture given in Figure 1.

REFERENCES CITED

Kieffer, S.W., 1985, The 1983 hydraulic jump in Crystal Rapid: Implications for river-running and geomorphic evolution in the Grand Canyon: Journal of Geology, v. 93, p. 385–406.

Larsen, I.J., Schmidt, J.C., and Martin, J.A., 2004, Debris-fan reworking during low-magnitude floods in the Green River canyons of the eastern Uinta Mountains, Colorado and Utah: Geology, v. 32, p. 309–312, doi: 10.1130/G20235.1.

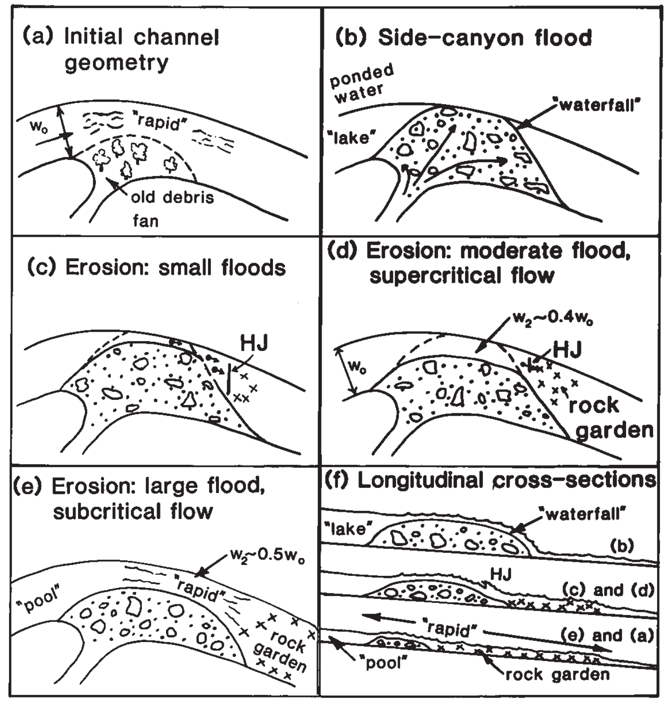

Figure 1. Emplacement and modification of debris fans on the Colorado River in the Grand Canyon. This model was based on geology and hydraulics at Crystal Creek, but generalized by Kieffer and others to interpret debris fan morphology in the Grand Canyon. Reprinted with permission of *Journal of Geology*.

REPLY

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Larsen et al. (2004) presented data on debris fan reworking in the Green River canyons of Dinosaur National Monument and concluded that discharges that do not exceed the pre-dam 2 yr flood data cause significant fan reworking and mainstem channel adjustment. Kieffer (2004) has two main comments: (1) we did not define the term "constriction ratio" correctly, and (2) we misrepresented the findings of Kieffer (1985) that debis fan reworking *only* takes places during very large floods.

First, Kieffer (2004) is correct in pointing out our mistake concerning definition of the constriction ratio term. Although we computed constriction ratio in the same way as Kieffer (1985), we described in words the inverse of this ratio, and we thank Kieffer (2004) for pointing this out. The values reported in Larsen et al. (2004) were computed in the same way as those of Kieffer (1985). Channel width at the constriction widened during our study period at both sites.

Second, we agree with Kieffer's (2004) recognition of the role of low and high magnitude floods in reshaping debris fan constrictions. Kieffer

(1985) primarily studied the effects of the unprecedented 2700 m^3s^{-1} flood of 1983 on Crystal Creek debris fan that widened the constriction from 0.25 to 0.4. She also estimated the discharge necessary to further widen the constriction to 0.5 and estimated that this discharge is ~11,320 m^3s^{-1}. This is a very large discharge; the paleoflood record indicates that one flood exceeding 14,000 m^3s^{-1} occurred 1600–1200 years ago, and 10 floods exceeding 6800 m^3s^{-1} occurred during the past 2000–2300 years (O'Conner et al., 1994). Kieffer (1985) acknowledged conceptually that small floods cause some reworking (Kieffer, 1985, their Fig. 12), but the relative magnitude of reworking by small, moderate, and large floods was not estimated.

Thus, interpretations of Kieffer's (1985) work typically focus on the essential role of large floods in reworking debris fan deposits. For example, the final environmental impact statement for Glen Canyon Dam operations stated, "riverflows within the operational range of [the] Glen Canyon Dam Powerplant will remove some of the new material [from debris flows]. However, floods of 100,000 to 200,000 cfs [2700 to 5400 m^3s^{-1}] or more probably would be necessary to remove the largest boulders from some debris fans, to increase the constriction ratio, and to decrease the elevation drop (Kieffer, 1985)" (U.S. Department of the Interior, 1995).

Subsequent studies of debris fan reworking have shown that significant increases in constriction ratio and decreases in elevation drop occur during small and moderate floods, especially if those floods occur soon after debris flow emplacement (Webb et al., 1999). Dam managers may misinterpret Kieffer's (1985) results as a demonstration that significant channel widening can *only* occur during floods that constitute true hydrologic emergencies. If significant reworking only occurs during emergencies, debris flow reworking need not be considered part of the objectives of regular dam operations. Our work, and that of Webb et al. (1999), demonstrates by field measurement that significant reworking occurs at flows much lower than those at which Kieffer (1985) estimated were necessary to widen constriction ratios to 0.5.

REFERENCES CITED

Kieffer, S.W., 1985, The 1983 hydraulic jump in Crystal Rapid: Implications for river-running and geomorphic evolution in the Grand Canyon: Journal of Geology, v. 93, p. 385–406.

Kieffer, S.W, 2004, Debris-fan reworking during low-magnitude floods in the Green River canyons of the eastern Uinta Mountains, Colorado and Utah: Comment: Geology, v. 32, p. e62, doi: 10.1130/0091-7613(2004)31<e62:DRDLFI>2.0.CO;2

Larsen, I.J., Schmidt, J.C., and Martin, J.A., 2004, Debris-fan reworking during low-magnitude floods in the Green River canyons of the eastern Uinta Mountains, Colorado and Utah: Geology, v. 32, p. 309–312.

O'Conner, J.E., Ely, L.L., Wohl, E.E., Stevens, L.E., Melis, T.S., Kale, V.S., and Baker, V.R., 1994, A 4500-year record of large floods on the Colorado River in the Grand Canyon, Arizona: Journal of Geology, v. 102, p. 1–9.

U.S. Department of the Interior, 1995, Operation of Glen Canyon Dam, final environmental impact statement: Salt Lake City, Bureau of Reclamation.

Webb, R.H., Melis, T.S., Griffiths, P.G., and Elliot, J.G., 1999, Reworking of aggraded debris fans, *in* Webb, R.H., et al., eds., The controlled flood in Grand Canyon: American Geophysical Union Geophysical Monograph 110, p. 37–51.