The effect of controlled floods on decadal-scale changes in channel morphology and fine sediment storage in debris fan-affected river canyons

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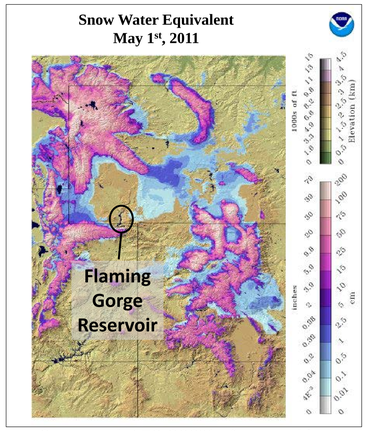
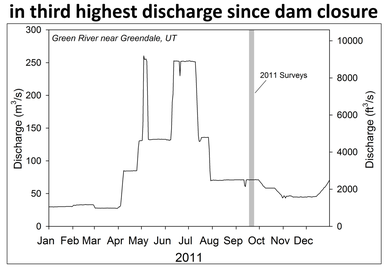
INTRODUCTION

In 2011, a large magnitude flow release from Flaming Gorge Reservoir resulted in the third highest recorded discharge of the Green River downstream from Flaming Gorge Dam subsequent to its closure in 1963. Following this event, we made measurements of channel geometry, tracer gravel displacement, and sandbar sedimentology at four long-term monitoring reaches within the Canyon of Lodore in Dinosaur National Monument, Colorado. Here we integrate these data with nearly two decades of channel monitoring at these sites, encompassing five controlled floods of varying magnitude and duration, providing a coarse resolution, but coherent, picture of channel response and changes in fine sediment storage in a canyon-bound river. We discuss these results in the context of long-term monitoring along the Colorado River in Marble and Grand Canyons.



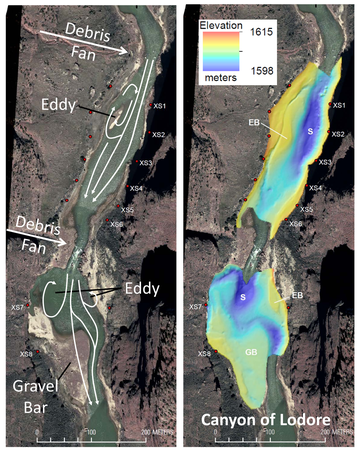
Snowpack 150-300% of normal in much of the Rockies

Bypass flows from Flaming Gorge Dam result in third highest discharge since dam closure

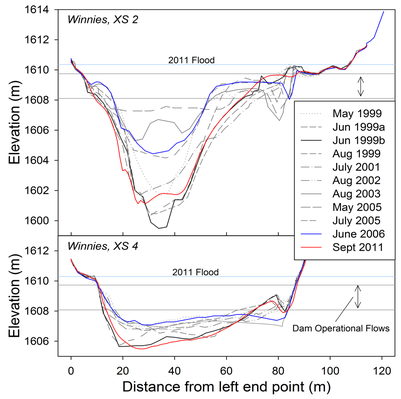


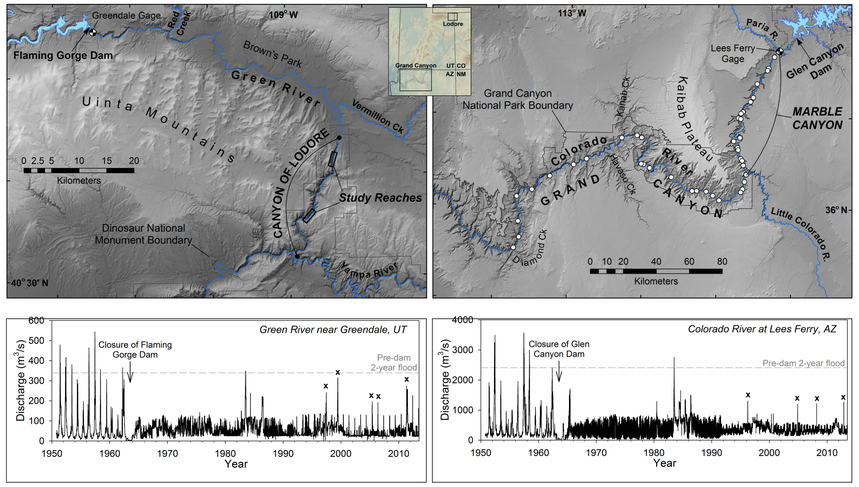
Controlled floods such as in 2011 occur periodically from large dams in the west, and are more frequently becoming used to rehabilitate downstream river ecology and geomorphology. Here we present long-term monitoring of the effects of controlled floods on fine sediment storage along the Green River in Canyon of Lodore, Dinosaur National Monument, Colorado. We then compare these results to long-term monitoring of controlled floods along the Colorado River in Marble and Grand Canyons, Arizona.

Fan-Eddy Complex



Hydraulic interactions with debris fans control reach-scale channel geometry. In the post-dam system, geomorphic response is focused on fine sediment on the bed and in lateral recirculation eddies

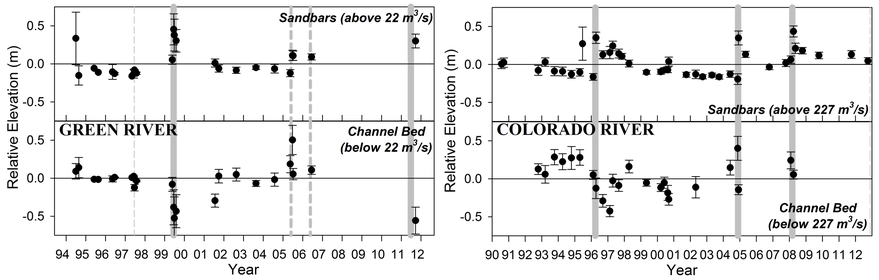




Canyon of Lodore **Grand Canyon**

The Green River in Canyon of Lodore is a small-scale version of the Colorado River in Marble and Grand Canyons. In both systems, the influence of controlled floods on sandbars and fine sediment storage has been monitored through cross-sectional and three-dimensional topographic surveys.

RESULTS

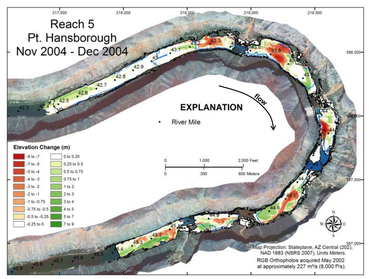


Time series of sandbar and channel bed elevation

(gray lines: controlled floods; error bars: standard error of mean)

- Eddy sandbars aggrade during controlled floods, but the effect is transient, as bars erode to pre-flood conditions within several years. Thus, increasing bar persistence requires more frequent floods.
- The channel bed in pools scours during controlled floods. In Canyon of Lodore, the bed as at its most deeply scoured following larger floods, and then aggrades within several years. But in Marble and Grand Canyons the bed may be more scoured during inter-flood periods, and shows more variability.
- Controlled floods generally result in net sediment evacuation because bars occupy a smaller area than the channel bed, but the sediment budget for a given reach may be positive or negative.
- While both rivers have undergone geomorphic change since dam completion, decadal changes in fine sediment storage have been relatively modest since the mid-1990s when controlled floods began.

Provisional Data – do not cite

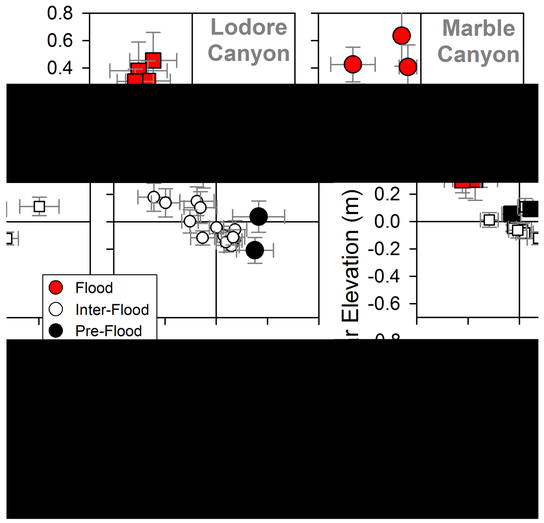


Pre-flood Post-flood Inter-flood

Progression from pre-flood to immediately post-flood to inter-flood sandbar conditions for an eddy sandbar in Marble Canyon due to controlled floods

DISCUSSION

- Differences in flood and inter-flood response between canyons is tied to sediment supply and reach-scale hydraulics during floods and dam operational flows
- A long sand-bedded reach in Browns Park buffers sediment supply to Canyon of Lodore.
- Stochastic inputs from downstream tributaries, such as the Paria River, dominate in Marble and Grand Canyons.
- Other factors such as distance from dam and flood duration and magnitude are likely also important.



Suspended sediment monitoring programs are now active in both systems (gcmrc.gov)

CONCLUSIONS

- **Controlled floods effectively rebuild sandbars**
- **Persistence of these features depends on flood frequency**
- **Changes in fine sediment storage since the 1990s are modest**
- **Understanding sediment supply will be key to long-term success**

Acknowledgements

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