Channel Response to the 2021 Spring Disturbance Flow in Western Grand Canyon

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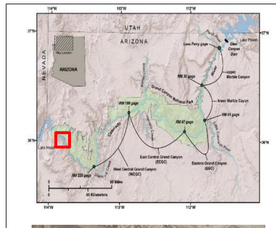
Abstract

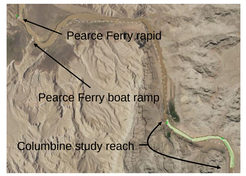
The Colorado River in Western Grand Canyon is very different than the debris fan-dominated segments upstream. We informally refer to the Western Grand Canyon as the segment between approximately Spencer Canyon at river mile 246 to Pearce Ferry Rapids at river mile 280. In this segment the Colorado River has incised through fine-grained lake and delta deposits. Erosion of these tall banks delivers additional sediment to the river and results in a shallow, sand-bedded river with ever-shifting sandbars. This project aims to examine the relation between dam releases, sediment inputs, and channel elevation changes in Western Grand Canyon.

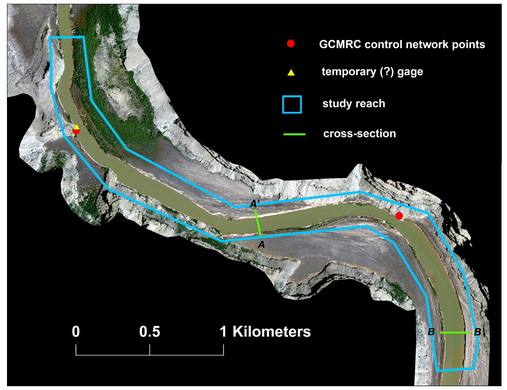
Data were collected in 2021 to test the hypothesis that the high-flow component of the Spring Disturbance Flow (SDF) would cause significant changes to channel bed elevation in this segment. We evaluated this hypothesis by collecting repeat topographic and bathymetric surveys in a 3.2 km reach beginning at River Mile 273 (Figure 1). Five surveys were conducted before, during and after the SDF and reveal, not surprisingly, that the reach is dynamic. Preliminary results show large changes, both erosion and deposition, between all surveys. Over the course of the observations, there was a loss of sediment in the reach, with significant dune movement and erosion of the steep, fine-grained banks by as much as 5 meters. Comparison of surveys before and after the SDF record an overall loss of sediment from the reach, but no significant change in overall bed elevation.

The results of this project will be finalized in FY2023. This includes finalizing the analysis of the changes in sediment volume within the reach. A sediment budget will be developed for Western Grand Canyon be based on sediment transport measurements (from CR at Diamond Creek), estimates of sediment input from channel banks, and revised bedload transport estimates from repeat surveys within the study reach. In addition, a numerical flow model will be developed and calibrated for the study reach that can be used to predict response to different dam operations.

Columbine Study Reach



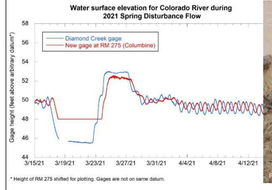




Data Collection

Before surveys were collected, geodetic control benchmarks were found and occupied to collect additional GPS observations that will bolster the solutions for these infrequently visited points.

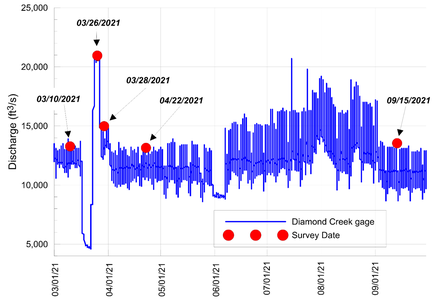
A temporary gage was installed to measure water surface elevation and travel-time between Diamond Creek and study reach.



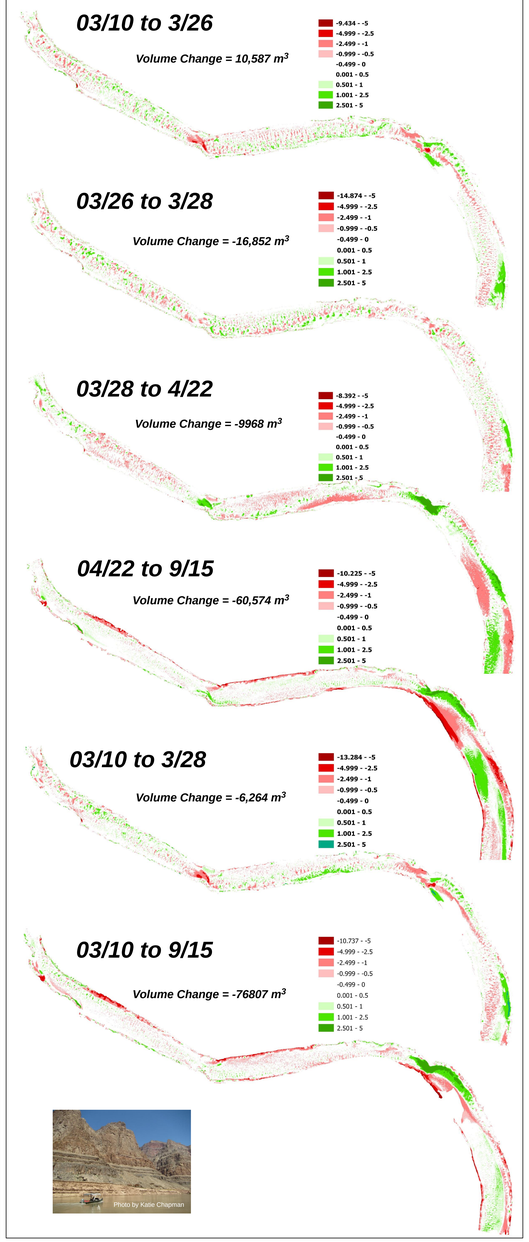
Each survey included measurements of riverbed elevation with multibeam sonar, measurements of bank topography by boat-mounted lidar, and measurements of water-surface profile using real-time kinematic (RTK) global-positioning system (GPS) receivers. Sonar and Lidar measurements were collected using the R.V. Ryan Seumptewa, a 5 meter "John" style boat with 70 Hp outboard motor. Bathymetric surveys were collected using a 400 kHz Norbit iWBMS sonar system. Navigation and motion were collected using GNSS signals and post processed to static GNSS observations at a geodetic control point. Above water topography was collected at the same time, using a Velodyne Lidar scanner. Each site visit included a full survey of the study reach, plus at least one hour of repeat surveys over a 200 m section of the reach for bed transport estimates.

Photographs of surveys being conducted in study reach: A) R.V. Ryan Seumptewa preparing to survey, photo by Matt Kaplinski; B) R.V. Ryan Seumptewa conducting bathymetric and lidar survey within study reach, photo by Katie Chapman; C) Katie Chapman conducting RTK GNSS surveys of subaerially-exposed sandbar within study reach, photo by Matt Kaplinski; D) Sonar/lidar operaters station on deck of R.V. Ryan Seumptewa, photo by Matt Kaplinski; E) Paul Grams operating the sonar/lidar system while conducting surveys within study reach, photo by Matt Kaplinski.

Surveys

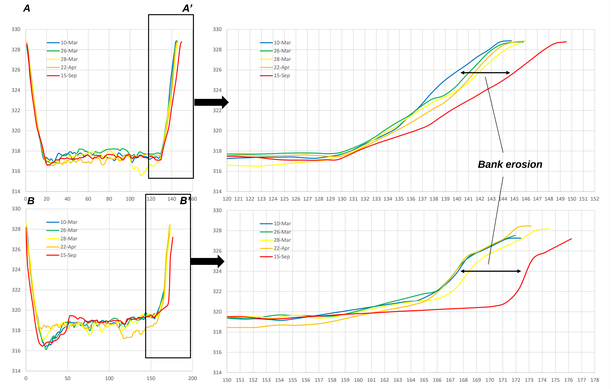


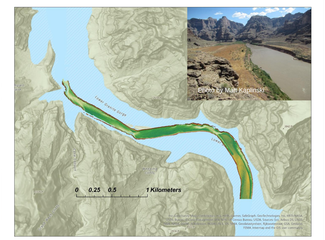
DEMs of Difference



Bank erosion

We used the repeat surveys of the steep, fine-grained banks within the study reach to investigate the rate of bank erosion. Preliminary analysis shows that in two places, the subaerial part of the river channel eroded by a total of about 5 m laterally. Along the two cross sections, erosion rates surrounding the SDF (3/10 to 3/28) are estimated to be 0.1m/day. Erosion rates following the SDF (3/28 to 9/15) are about 0.02m/day. A full analysis of volume changes along the exposed fine-grained banks should provide an estimate of how much sediment is added by bank erosion.





conclusions

- **Bed is dynamic and conveying a large sediment load with changes in bed elevation of 5+ m**
- **Analysis of the repeat bathymetric surveys:**
  - **Bars in the reach were active and aggraded slightly during the disturbance flow**
  - **Pools in the reach scoured during the disturbance flow**
  - **Following summer operations, bars eroded and pools filled**
- **Repeat lidar scans of banks show up to 5 m of lateral bank retreat**
  - **Although erosion rates were greater during the spring disturbance flow, the amount of bank retreat during that event was less than occurred during the remainder of the year**
- **Repeat with different/higher flow pulse would be informative**

Future work

- **Complete analysis of changes in Columbine study reach.**
- **Develop sediment budget for Western Grand Canyon based on transport measurements (CR at Diamond Creek) and estimates of sediment input from banks.**
- **Develop and calibrate numerical flow model for study reach.**
- **Use model to predict response to different dam operations.**
- **Prepare draft report to be finalized in FY2023.**

The authors would like to thank the Hualapai tribe and National Park Service for their support, cooperation, and shared interest in the sediment dynamics of the western Grand Canyon.