

Historical and On-Going Hydrologic and Sediment Transport Research at Little Granite Creek near Bondurant, Wyoming

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Abstract

Measurements of sediment flux and flow were made during the course of 13 runoff seasons in a small watershed near Bondurant, Wyoming. Begun in 1982 through the combined efforts of the U.S. Geological Survey and U.S. Forest Service, the database from Little Granite Creek represents one of the most comprehensive sources of information on stream transport processes available for an individual site. In August 2000 a wildfire burned portions of the watershed, creating an opportunity to monitor the impacts of fire on stream processes and water quality. Scientists from the U.S. Forest Service, Rocky Mountain Research Station initiated studies in 2001 to assess the magnitude of increased runoff and sedimentation generated by spring snowmelt and summer thunderstorms following wildfire. Additional work was initiated in 2002 on the post-fire dynamics of organic matter (dissolved, fine, and coarse), the status of aquatic macroinvertebrates and fish, and the re-establishment of vegetation in the riparian corridor. In this paper, we describe the monitoring effort in the Little Granite watershed and present preliminary results from the first year after burning. Such data are useful for planning future Burned Area Emergency Rehabilitation (BAER) efforts, validating erosion models (such as WEPP), and evaluating long-term sensitivity of aquatic systems to wildfire.

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Introduction

In August 2000, a fire in the Gros Ventre Wilderness Area on the Bridger-Teton National Forest in northwestern Wyoming burned most of the forest vegetation in the Boulder Creek watershed. This watershed constitutes nearly 40% of the area of Little Granite Creek where researchers from the U.S. Geological Survey [USGS] and U.S. Forest Service [USFS] collected data on sediment transport processes (bedload and suspended sediment) during 13 runoff seasons between 1982 and 1997 (Ryan and Emmett 2002). Other data collected include a flow record of several years, channel surveys, and data on dissolved loads and aquatic communities. Hence, the Boulder Creek Fire within the Little Granite Creek watershed presents a unique opportunity for evaluating the local and downstream effects of fire-related sedimentation relative to established baselines, as well as interactions among physical processes, recovery of riparian vegetation, and water quantity and quality. Further, most of the burn was contained within one sub-watershed whereas an adjacent sub-watershed remained largely unburned. The sub-watersheds are similar in size, aspect, and geology and enable a paired-watershed comparison of disturbance and recovery processes.

Watershed Description

Little Granite Creek, an upland contributor to the Snake River system, drains 21.1 mi² (54.6 km²) of the Gros Ventre range near Bondurant, Wyoming, south of Jackson, Wyoming. The area is administered by the USFS, Bridger-Teton National Forest, Jackson Ranger District. Over half of the basin is in the Gros Ventre Wilderness Area. The two main tributaries of Little Granite Creek are Boulder Creek (8.0 mi²/20.7 km²)

and the upper basin of Little Granite Creek (7.6 mi²/19.7 km²). Approximately 80% of the forested area in Boulder Creek and less than 5% of that in upper Little Granite Creek burned in 2000 (Figure 1). Both basins face south and had similar pre-fire forest cover (Engelmann spruce, subalpine fir, and lodgepole pine). In the broader valley bottoms, riparian vegetation is dominated by willow species (*Salix* spp.), with an extensive herbaceous understory (Youngblood et al. 1985). In more confined portions, the floodplain overstory is dominated by conifers, with riparian shrubs occurring along the streambanks (Youngblood et al. 1985). Flow and rates of sediment transport are monitored at (1) the mouth of Boulder Creek (burned), (2) upper Little Granite Creek (unburned), and (3) Little Granite Creek above the confluence with Granite Creek (site of previous work) (Figure 1). Site 3 is approximately 2.5 river miles (4 km) downstream of the burned area. The elevations of the monitoring sites are around 6500 feet.

Runoff in the watershed is generated primarily by snowmelt and flows peak between mid-May and mid-June. While small to moderate thunderstorms are common in summer, they produce only minimal rises in the hydrograph. Mean annual temperature is 33.3°F (1.0°C) and mean annual precipitation is 20.53 inches (52.15 cm) at a nearby climate station in the vicinity of Bondurant, Wyoming (elevation 6,504 ft) (Western Regional Climate Center [WRCC]; National Climate Data Center [NCDC] Normals, 1961-90). Most of the precipitation falls as snow from November through March. Average annual snowfall measured at Bondurant between 1948 and 1999 is 134 inches (standard deviation ± 48.9 inches) (WRCC Monthly Total Snowfall).

The geology underlying the basin consists primarily of sedimentary formations (sandstone and claystone) of marine origin (Love and Christiansen 1985). Areas are prone to mass wasting from slow-moving earthflows, smaller-scale slumping, and soil creep. Upland resource uses include grazing and dispersed recreation (camping, hiking, horseback riding, and hunting). One USFS road parallels the stream for about 1.5 miles in the lower end of the watershed. Former land uses include coal extraction and a mining camp near the main stem above the confluence with Boulder Creek (Figure 1). These former and present uses are small in scale and their influence on sediment delivered to the channel is currently nominal.

Little Granite Creek near Bondurant, Wyoming

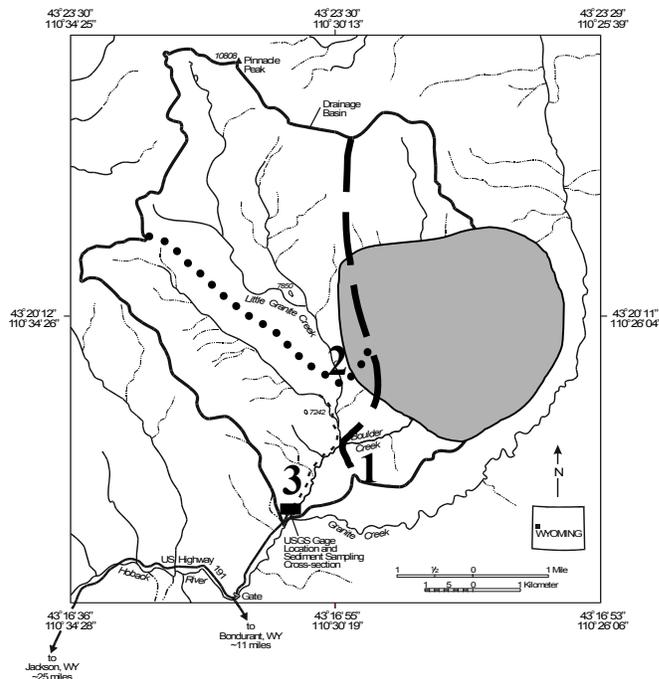


Figure 1. Map of Little Granite Creek watershed. Stipple pattern approximates the area burned by the Boulder Creek fire in 2000. An estimated 75% of the area burned with moderate to high intensity. The dark dashed line delineates the Boulder Creek watershed and the dotted line indicates the limits of the unburned watershed (upper Little Granite Creek). Numbers are described in text. The light dashed line represents an unimproved forest road.

The channel of Little Granite Creek ranges from step-pool in confined valley bottoms to pools and riffles in wider floodplains. Bed material ranges from gravel to small boulders, with less than 10% sand-sized grains located primarily at the channel margins and in small patches in the lee of larger particles. Banks are composed of sand, gravel, and cobbles overlain by fine sand and organic matter. The primary sources of sediment are scour from the channel bed and banks. External sources of sediment come from mass wasting, including active earthflows from unstable hillslopes, and slumping from undercut terraces and road cuts. Baseline concentrations of suspended sediment transport at high flows are relatively high (between 100 and 1000 mg L⁻¹) because of the underlying marine sedimentary formations. By comparison, similar measurements in streams in forested areas draining granitic terrain are rarely greater than about 100 mg L⁻¹ (Andrews 1984, USDA Forest Service unpublished data).

Experimental Plan

Our basic approach in this watershed study is comparative, contrasting sedimentation processes, water quality, and riparian condition in burned and unburned drainages of the same watershed over time and against baseline data. The overall objectives of the Little Granite Creek study are listed below. However, we address only the first four objectives in this paper.

- Document changes in runoff patterns following wildfire.
- Compare pre-and post-fire rates of sediment flux at the historical site to determine the magnitude of increases in sedimentation following wildfire.
- Determine the relationships between temperature, snowmelt runoff, precipitation, stormflow response, and rates of suspended sediment transport in burned and unburned watersheds.
- Describe the fate and movement of large wood in the channels and floodplains in burned and unburned areas.
- Document changes in sediment storage, bed particle size, and embeddedness in burned watersheds.
- Quantify the transport and retention of organic matter (dissolved, fine particulate, and coarse particulate) in burned and unburned watersheds.
- Determine the relationships between sediment movement and post-fire recovery of riparian plant communities.

Monitoring methods

Flow stage is monitored at the three sites using automated stage recorders from April to November (or until the sites are no longer accessible). Frequent discharge measurements (>30 per season) are made at each site so that well-defined stage-discharge relationships are established (Nolan and Shields 2000). Precipitation and temperature are monitored at five

locations in the watershed, both near the gaged sites and at higher elevations. There is also a SNOTEL (snow telemetry) site near the confluence between Little Granite and Granite creeks from which longer-term trends in temperature and precipitation data may be extrapolated.

Samples of transported bedload were collected at the three sites using a thick-walled Helley-Smith bedload sampler with a 3 x 3" (0.076 x 0.076 m) opening (Helley and Smith 1971). Typically, measurements were taken once per day at each site during the snowmelt runoff season. Samples of stream water were collected at each site using an ISCOTM automated sampler. The samplers were programmed to collect water once every 4 hours between May and October in the first 2 years post-fire, producing a very detailed record of sedimentation patterns from over 2000 samples per site. Suspended sediment concentration [SSC], fine particulate organic matter [FPOM], and a "sand-silt split" (at 63- μ m) are obtained from these samples. Additional water grab samples were collected for analysis of dissolved organic matter [DOM] (USEPA 1987). Samples of coarse particulate organic matter [CPOM] were acquired for a range of flows from drift nets.

In an effort to improve and simplify methods for monitoring SSC, we deployed an Optical Backscatter Sensor [OBS-5] at the lower site in 2002 to measure turbidity for comparison with our measured concentrations. Turbidity is also used as a qualitative indicator of water quality and light penetration for aquatic studies.

Several stream reaches were selected for long-term monitoring of changes in sediment storage. Fourteen reaches (10 in Boulder Creek and 4 in upper Little Granite Creek), each 100 m (330 ft) in length, were monumented and surveyed in 2001-02. Within these reaches, equally spaced channel cross-sections and the longitudinal profile were surveyed using a total station surveying instrument. Pebble counts (Wolman 1954) using 200 grains were used to characterize the grain size distribution of the channel surface. Embeddedness, or the extent to which bed particles are covered by silt and sand, was estimated using a "view bucket" whereby the percentage of particles covered with fines is determined using a gridded template (Wayne Minshall, Professor of Ecology, Idaho State University, personal communication). The redistribution and recruitment of

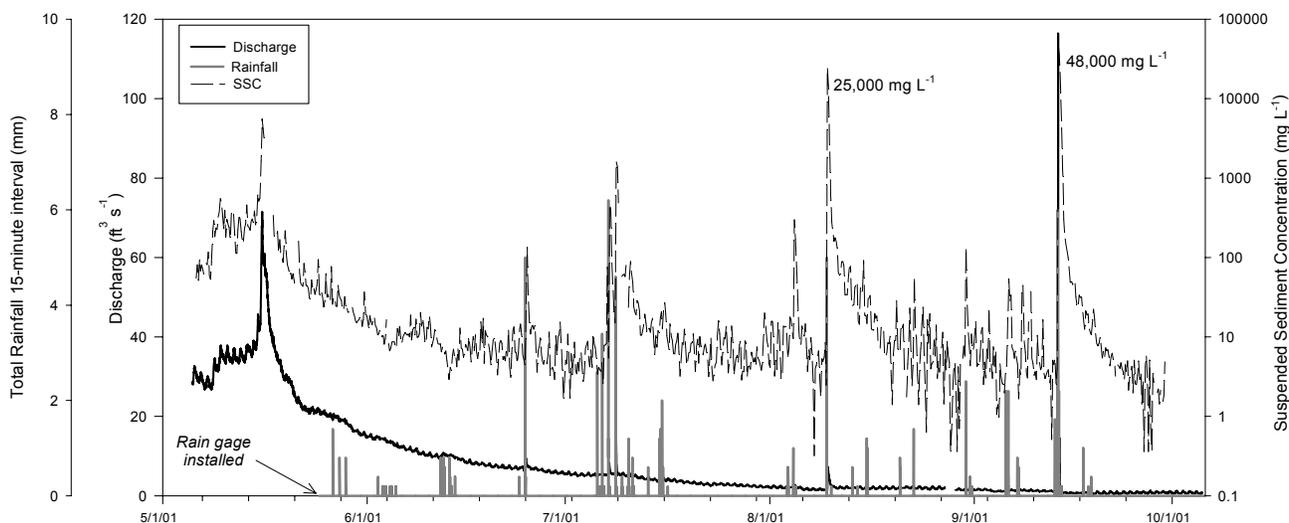


Figure 2. Boulder Creek rainfall intensity (at high elevation station), discharge, and SSC measured in 2001. Note that SSC is on a log scale, so differences in low concentrations appear exaggerated while higher concentrations appear muted.

large wood (tree trunks) within the channel and on the floodplains is monitored through repeat surveys. About 600 pieces of large wood were tagged, surveyed, and classified for stability during 2001 and re-surveyed in 2002. The stream survey work is repeated annually to monitor gross changes in channel morphology and movement of large wood over time. Vegetation (overstory, shrubs, seedlings, and vascular plants) growth and re-growth in burned riparian areas are monitored using permanent transects and quadrats within several of the reaches.

Results

The results described here are primarily from 2001 because, as of this writing, analyses of 2002 data are largely in progress. Similar to areas throughout the western United States, flows in Little Granite Creek were relatively low in water year 2001. Discharge on the main stem exceeded bankfull for only a few hours during a prolonged rainstorm during snowmelt runoff in May. Measured rates of suspended sediment transport were about 5x higher on the rising limb of the snowmelt hydrograph relative to pre-burn values, while there were no substantial differences observed for the falling limb. Rates of bedload transport during snowmelt runoff were similar to those measured before the fire.

During mid-summer, there were a few low to moderate-intensity thunderstorms that raised the

Boulder Creek hydrograph by a small amount (Figure 2), similar to runoff patterns prior to burning. However, there were often large increases in suspended sediment associated with these storms. Rainfall rates of 1-6 mm in 15 minutes produced increases in SSC between 1-2 orders of magnitude (Figure 2). Concentrations returned to baseline values with a few hours or days during these smaller “blackwater” events. By contrast, no measurable increase in SSC was observed in the unburned watershed during these periods.

Two larger rainstorms in late summer produced the highest SSC measured at Little Granite to date. A brief (<15 minutes) but intense rainfall (~2 inches hr⁻¹ or 50 mm hr⁻¹) on August 9 generated a few fine-grained mudflows from gullies within the burned area (Figure 3). Suspended sediment concentration was about 3 orders of magnitude greater than baseline values and it took over a week for these values to return to baseline (Figure 2). By contrast, SSC increased by 1 order of magnitude in the control watershed, returning to baseline within 8 hours. A second series of storms on September 13 produced a substantial spike in flow and SSC in streams below the burned areas (note: bedload was not measured during either storm). Flows on Boulder Creek exceeded bankfull and were greater than those measured during snowmelt runoff (Figure 2). Suspended sediment concentration peaked at about 48,000 mg L⁻¹ which is about 4 orders of magnitude greater than baseline values whereas SSC in the control watershed was 1,300 mg L⁻¹, or about the same peak



Figure 3. Photograph of the track of a fine-grained mudflow emanating from a gully in an area burned by the Boulder Creek wildfire (taken in August 2001). The channel upstream of this location plugged with debris causing the mudflow to move on to the floodplain and rejoin the channel downstream of this location. Similar tracks were observed after rainstorms on August 9 and September 13, 2001.

concentration observed during snowmelt runoff. The event in Boulder Creek was witnessed by several hunters camping nearby who later reported thunderous noises, numerous “gully washers,” and rapid increases in flow. During reconnaissance, we noted areas with shallow (~6 inches or 0.15 m) soil slips, scoured gullies, fresh mudflow tracks, and out-of-bank flow marks. Additionally, several wood jams that had been tagged for monitoring earlier in the summer had been dismantled and large tree trunks could be traced up to 0.5 km (0.3 miles) from the site where they were originally surveyed. Channel cross-sections within the burned area showed localized zones of deposition and scour which were frequently associated with the rearrangement of large wood (Figure 4).

With each storm and subsequent blackwater event, the bed of Boulder Creek and Little Granite Creek below the burned area became increasingly infused with fines, consisting of a mixture of burned organic matter and inorganic materials. Measurements taken in 2002 indicated that the degree of embeddedness in Boulder Creek ($92\% \pm 4\%$, $\bar{x} \pm 1 \text{ s.e.}$) was

substantially greater than that observed in the control watershed ($59\% \pm 2\%$).

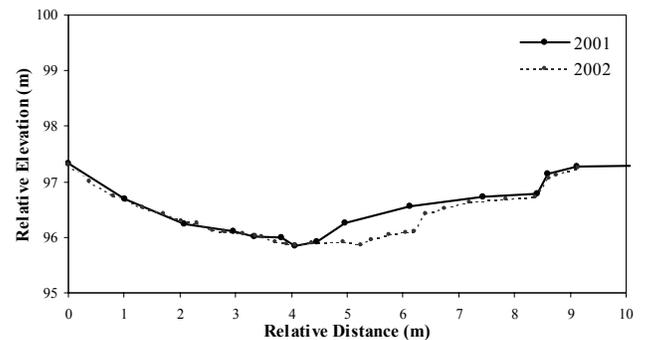


Figure 4. Example of change in cross-section observed between summer of 2001 and 2002. This particular cross-section is located downstream from a wood jam and the scour likely occurred during the rearrangement of wood during the September 13 storm. Vertical exaggeration is approximately 1:1.

Future Work

We plan to continue monitoring runoff, stream sedimentation, and morphologic changes at Little Granite Creek, in addition to following the re-growth

of vegetation and recovery of riparian areas over time. Such results are useful to forest managers from several disciplines for addressing critical issues concerning resource fragility and system recovery following wildfire. Hydrologists and vegetation managers need information on hydrologic changes following wildfire and their expected impacts in different parts of the watershed in order to define areas where rehabilitation efforts may be most effective. Downstream users (municipal and agricultural) need information on local and off-site impacts of wildfire on stream water quality and quantity. Ecologists need to identify areas most prone to heavy sedimentation or scour and how such changes may affect aquatic communities. Over longer time frames, managers must consider the overall fragility of the watershed in order to prescribe adequate protection for burned areas. Through integrated monitoring of recovery in streams, such as that demonstrated by the long-term project in Little Granite Creek, we can begin to address these concerns and project how far into the future the effects of wildfire may be sustained by an aquatic system.

Acknowledgments

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