Establishing a Suspended Sediment Flux Model for the Lower Big Creek Drainage: What role do fires play?

Student name: Eric James Carlson

Sponsor name: Dr. Benjamin T. Crosby

Sponsor Title: Assistant Professor

Department of Geosciences

Student address:

Schubert Heights, Apt: 404

Pocatello, ID 83209

Student phone: 209-603-6162

Campus phone of sponsor: 208-282-2949

Campus Box of sponsor: 8072

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The DeVlieg Foundation

Research Selection Committee

Cc: Dr. Colden Baxter:

Idaho State University

Department of Biological Sciences

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Abstract

The purpose of this project is to quantify and analyze the spatial and temporal patterns of suspended sediment delivery to Big Creek and its tributaries. Furthermore, this study will explore the affect of fire, both recent and historic, on suspended sediment delivery. The overall goal is to create a suite of suspended sediment rating curves which describes the relation between sediment flux and water discharge as a function of time since last burn and burn severity. This will be accomplished using two methods: First, automated pump samplers will collect stream water samples for suspended sediment concentration analysis. Second, on Big Creek, at the Taylor Ranch bridge, a tethered hand sampler will be used to collect suspended sediment samples from the larger river. I anticipate that catchments that have been recently burned will produce more sediment than those that have not burned. This study will provide a measure of how much sediment is moving out of the Big Creek drainage at any giving time based on stream discharge. This will be useful in measuring stream health, water quality, and the affect of sedimentation on riparian and aquatic ecosystems.

Introduction

In recent years global climate change has become a major concern. These changes directly affect the rate, frequency and magnitude of many earth surface processes including wildfire, mass movements and flooding. These changes have serious repercussions not only on the human populace, but on the natural world as well. Taylor Ranch Field Station and its wilderness setting provide an ideal laboratory examine how these change in climate influence natural processes in the absence of human influence. Recent studies demonstrate that the rise in temperature due to global warming appears to be, "increasing the duration and intensity of the wildfire season in the western United States" [*Running*, 2006; *Westerling et al.*, 2006]. One of the major reasons for this increased length in the fire season is spring snow melt is occurring, "1 to 4 weeks earlier than [it] did 50 years ago, and stream flows thus also peak earlier" [*Running*, 2006]. A longer and more intense fire season carries many negative consequences, but one in particular is the temporary loss of vegetation due to wildfire. Root networks of trees, shrubs and grass provide significant soil cohesion and aid in slope stability [*Montgomery et al.*, 2000]. Furthermore, increased runoff leads to "decreased interception, decreased infiltration, and decreased evapotranspiration" [*Kunze and Stednick*, 2006]. As fire frequency increases, slope stability decreases; hence, causing more erosion on fire scared landscapes in the form of sheet runoff, rills, gulling, and mass movements. This increase in erosion will lead to a temporary increase of the suspended sediment delivery from affected streams [*Reneau et al.*, 2007].

Motivation

In the Big Creek watershed catchments provide a diverse range of wildfire histories ranging from the unburned regions of upper Cliff Creek to the Dunce Creek fire of 2006. These catchments provided a perfect opportunity to test how much sediment is reaching the stream, and its tributaries, due to fire and loss of vegetation. Along with loss of vegetation and increased runoff, burned catchments can lead to, "increased discharge and peakflow, channel changes and substantially increased hillslope soil redistribution and catchment sediment yields" [*Shakesby and Doerr*, 2006]. Serious morphological consequences arise from sediment invasion of a stream; it would be advantageous to explore these changes in stream channel geometry and stability. A change in the physical attributes of a stream, such as Big Creek and its tributaries, can incite a change in aquatic and riparian species diversity and distribution. Linked studies that examine the interaction of wildfire, biological, hydrological and sedimentalogical factors have been conducted in other locations, but never at Taylor Ranch or in the Big Creek watershed (or even in the Salmon River?). This is an ideal location due to the fact there are several ongoing (The Minshall Sites, The Big Onion) and past (Rachel's Project) studies on stream ecology. Also, this project will be done in direct partnership with Neil Olson (shared field sites) who is studying the temporal and spatial patterns of stream discharge on Big Creek and its tributaries.

Research Objectives and Hypotheses

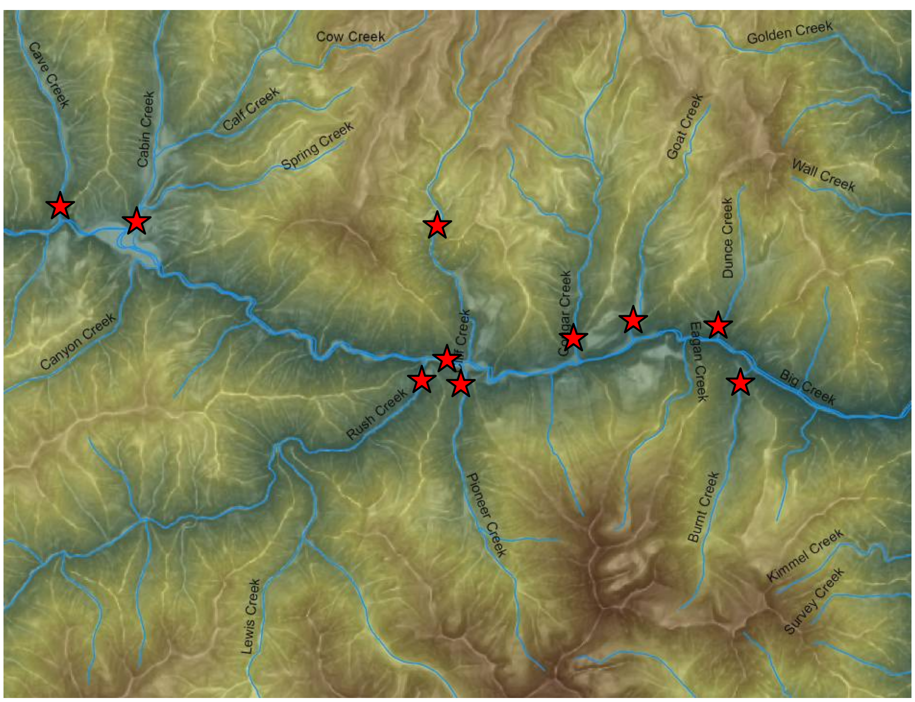
During this summer's field season and in the subsequent Fall and Spring semesters I plan to accomplish three main research objectives. First, I wish to quantify the suspended sediment load in Big Creek and its tributaries during peak and low flow conditions. Second, I will explore if a correlation exists between the concentration of suspended sediment observed in tributaries and the time since last burn. Third, I wish to construct a suite of sediment rating curves (based on time since last burn or burn severity) that relate sediment flux to water discharge for Big Creek and its tributaries. These three objectives will allow me to examine three testable hypotheses:

- H1: Suspended sediment concentrations are demonstrably higher in catchments with more recent or severe burns.
- H2: Suspended Sediment concentrations from Big Creek are, on average, lower than in the tributaries because they integrate both recently and historically burned regions.
- H3: Stream assemblages reflect the time since last burn.

Methods

Sampling sites

I wish to measure suspended in Big Creek at the Taylor Ranch bridge as well as from several tributaries near their junctions with Big Creek. All these sites will correlate with the sites where Neil Olson will be gaging water discharge. The tributaries may include Pioneer Creek, Cliff Creek, Cougar Creek, Goat Creek, Rush Creek, Cabin Creek and Burnt Creek. These locations are chosen because they represent a diverse range of fire histories and possess a previous stream ecology studies. Samples will be collected at Big Creek in order to calibrate the existing turbidity sensor operated by NOAA. This allows their long term observational data to provide a rough measure of the annual sediment flux from the mainstem of Big Creek. There are preliminary plans to collect hand samples of stream water from the mainstem of Big Creek between jut above Monumental Creek and the junction with the Middle Fork. This temporally limited sample collection campaign will assess downstream changes in sediment concentration and the relative contributions of many different tributaries. This will also allow us to recognize catchments that release high amounts of sediment because they are easily erodible rather than because they were recently burned.



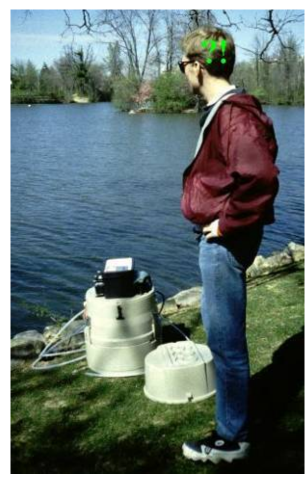
Potential locations for time-series monitoring of suspended sediment marked by red stars.

Sample Collection

Water samples will be collected by three methods. The most basic is the "grab sample," in which I will just use a 1 liter bottle to collect a representative sample of what is flowing down the creek. This method will only be used in the most time-pressed situations such as along-stream sampling campaigns. The second method is the use of an automated pump sampler [Thomas, 1985]. This sampler sucks a volume of water (~250ml) from the center of the stream at fixed intervals (2-12 hours) and stores the sample in an array of up to 24 bottles. The sampler can also be programmed to increase sampling frequency during high discharge events or during and after rainfall events. It stands to reason that during such an event as a rain storm that erosion will take place at higher rates. Under these conditions, it will be necessary to sample at a higher temporal frequency to capture the character of the sediment delivery associated with the storm. The third sampler is a depth-integrating isokinetic water sampler [F.I.S.P., 2008] which is just a fancy name for a bottle with a specialized inlet nozzle. These isokinetic samplers are like the "grab samples" but are more systematically used to collect a representative sample from the stream or river. They are either manually dipped in and out of the flow or lowered off a bridge by a simple tether.


Collecting a grab sample


An isokinetic hand sampler

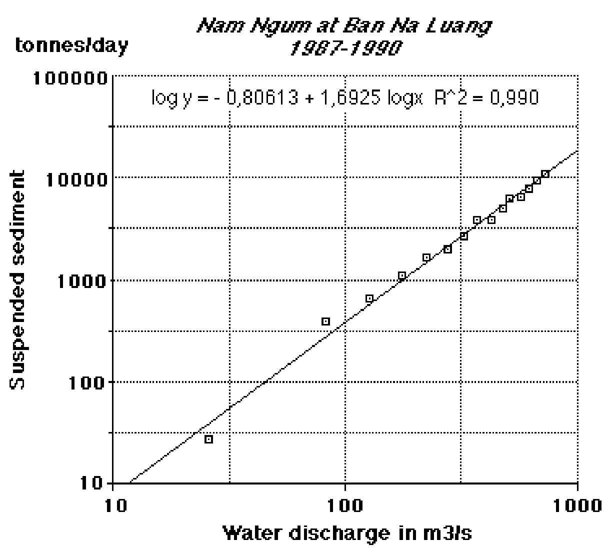

Automated pump sampler

Sample Analysis

All water samples collected will be returned to Taylor Ranch where their sediment concentration will be analyzed using a standard gravimetric technique. In this technique, each sample volume is determined using a graduated cylinder and then the sample is vacuum filtered through paper, dried and weighed. If an accurate scale (+/- 0.001g), wet filter papers will be placed in vials and returned to ISU where the measurements will be made during the fall semester in a laboratory setting. This technique returns the suspended sediment concentration in the sample, measured as mass of sediment (in grams) per volume of sample (in liters). Because the pump samplers and turbidity sensors do not always collect samples that are representative of the depth-integrated flow (sediment concentration increases with depth), it is necessary to calibrate these proxy sample results to the hand-collected isokinetic sampler results. This correlation (usually linear) assures that the pump or turbidity data accurately represent the sediment concentration in the whole channel.

Analysis and Dissemination of Results

Sediment concentration data, collected at a particular point in time, will then be correlated with water discharge data as collected at these paired sites by Neil Olson. Then a sediment rating curve will be created to relate the discharge of the stream to the suspended sediment at any given time. This rating curve will provide an approximation of how much sediment is flowing in the stream at any given time based on the present discharge. Since discharge can be remotely, inexpensively and continuously monitored, as sediment rating curve provides significant value to the existing hydrology project.



An example of a sediment rating curve that relates measurements of suspended sediment discharge to water discharge.

(From *Axelsson 1992 (Sedimentation in the Nam Ngum reservoir, Lao PDR. AB Hydroconsult, Uppsala)*

Once all my data has been collected and interpreted, I shall relate my findings with previous and ongoing studies being conducted in the Big Creek watershed. This will be done in attempt to show a correlation between sediment and the influence on biological processes in riparian and aquatic ecosystems, whether detrimental or beneficial to stream health. Sample site locations and data results will be stored in a Geographic Information System (GIS) database and made available to future workers at Big Creek or within the Salmon River drainage in general. All correlation figures, rating curves and associated data will be made available in electronic format and published online. Dr. Crosby has confirmed that this project would make an ideal senior thesis. It would be great for the final write up of this project to function as both a report to Taylor Ranch a thesis and the start of a professional publication! Along the way, I plan to discuss my results at local, regional and national meetings.

Timetable

a. March, 08
    i. Background reading on:
        1. Regional fire history
        2. Existing aquatic and riparian research
        3. Suspended sediment sampling and analysis techniques
    ii. Prepare application for Undergraduate Research Committee funding to assist in equipment and salary (Due March 20th)
b. April, 08
    i. Purchase and preparation of field equipment
    ii. Trial runs on Portneuf River
c. May, 08
    i. Fly in equipment and personnel to Big Creek
    ii. Installation of sediment samplers in tributaries
    iii. Preparation of lab facilities at Taylor Ranch
    iv. Begin sampling campaign in collaboration with Neil Olson's water discharge measurements
d. June, 08
    i. Continue sampling through hydrograph peak
e. July, 08
    i. Continue sampling through decreasing summer flows.
f. August, 08
    i. Continue sampling through decreasing summer flows.
    ii. Remove all sampling equipment and break down lab set-up at Taylor Ranch, Fly out equipment
g. Fall, 2008
    i. Enroll in geomorphology course to build context for study

ii. Compile and analyze all collated data.
iii. Build sediment rating curves and assess statistical strength of findings
iv. Presentation of research results at professional meetings (Geological Society of America (GSA) or American Geophysical Union)

h. Spring, 2009
   i. Report completed March 15, 2009
   ii. Presentation of results at GSA regional meeting (mid-March)
   iii. Presentation at ISU Undergraduate Research Symposium (mid-April)

Additional Support

My faculty supervisor on this project is Dr. Ben Crosby, Assistant Professor of Geosciences, Idaho State University. Professor Crosby has assisted in gathering the proper research materials, providing background information, and aiding in the construction of the proposal. Furthermore, he will help acquire all the proper materials needed to conduct this study, as well as showing me how they are operated, and field testing them before being implemented at Big Creek. Professor Crosby plans to visit Big Creek at least twice during the duration of my research project at Taylor Ranch. If additional materials are necessary for this project, Crosby will try to purchase from existing start-up funds.

Educational and Career Goals

As a Current ISU student enrolled in the Geosciences program, this research opportunity would provide me with excellent learning experiences, which will only further my knowledge in earth processes. As an aspiring Geologist, it is not only my goal to have a better understanding of the natural world, but this is also a passionate obsession in which I wish to explore for many years to come. This would be a great leaping station that would prepare me for my life's ambition, as well as an opportunity to conduct research that will aid the scientific community. This is the perfect setting to apply the knowledge I have gained thus far in the classroom; and, in turn, allowing me to expand my comprehension of the hydrologic system and its various components. Furthermore, conducting my own research at the undergraduate level will only prepare me for entering the graduate program. Once I have obtained Bachelor of Science degree from ISU, I plan to continue on to acquire a Master of Sciences here at the university as well. Upon my completion of my educational career, I plan to enter the scientific field in which I wish to perform, experiment, and research topics such as the one presented in this proposal. With my knowledge, and my degree, I wish to pursue a career in the scientific realm; in an effort to improve our understanding of the environment, protect the needs of the natural world and to share my insight and experience.

Budget

The budget for this project will be divided between (1) travel expenses required for student and advisor, (2) the cost of purchasing sampling and laboratory equipment and materials, (3) summer salary for undergraduate student. From preliminary calculations, we anticipate roughly half the budget will be used for travel and equipment and the other half will be dedicated to student compensation.

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