College of Arts and Sciences Poster Presentations

2011 Undergraduate Research and Scholarship Conference

4-11-2011

Modeling Fire-Related Debris Flow Volumes in MATLAB Using Surveyed Data Collected from the Middle-Fork Salmon River, Idaho to Determine Contribution of Episodic Fire-Related Debris Flows on Long Term (10^3 – 10^4) Sediment Yield

Austin Hopkins
Department of Geosciences, Boise State University

Jen Pierce
Department of Geosciences, Boise State University

Kerry Riley
Department of Geosciences, Boise State University

Modeling fire-related debris flow volumes in MATLAB using surveyed data collected from the Middle-Fork Salmon River, Idaho to determine contribution of episodic fire-related debris flows on long term (10^3 – 10^4) sediment yield

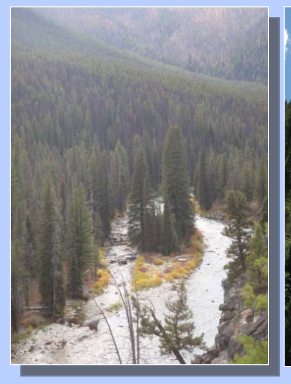
Austin Hopkins (austinhopkins@u.boisestate.edu), Jen Pierce, Kerry Riley - Boise State University

Introduction

Fire-related debris flows play a significant role on the long term sediment yield of the Salmon River Basin. Previous studies (Kirchner et al., 2001) quantified the total long term sediment yield of the Salmon Basin at 261 □36 tkm/yr. This study aims to quantify the Middle Fork's contribution of sediment from fire-related debris flows to the long term sediment yield. Multiple debris flow deposits were surveyed on the Middle Fork and the Kotch Creek deposit was analyzed using the program MATLAB to find the volume of deposition. Using charcoal found in stratigraphic profiles of the deposits and C^{14} dating, the timing and occurrence of periods of deposition were found. Volume calculations coupled with timing data from carbon dating allows for the reconstruction of the long term sediment yield contribution of fire-related debris flows on the Middle Fork Salmon River. Calculated volumes will be compared with estimated volumes from empirical formulas based on remotely sensed spatial data (burn severity and slope), measured geometric data (longitudinal profile, cross sectional area, flow banking angle), and precipitation records (Cannon et al.,2010).

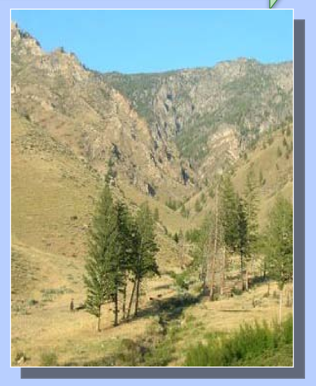
Study Location

Ecosystem gradient produces range in fire regimes



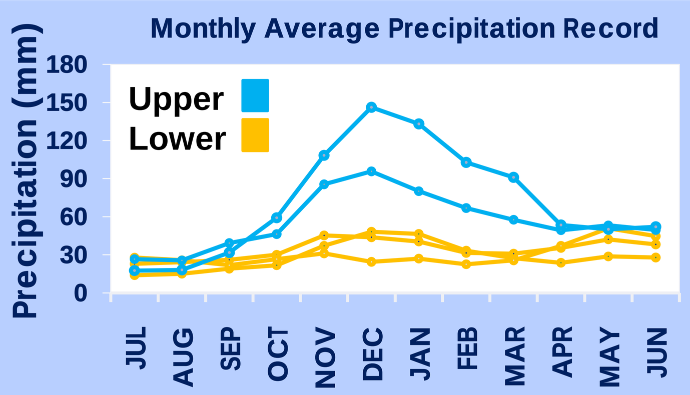
Subalpine

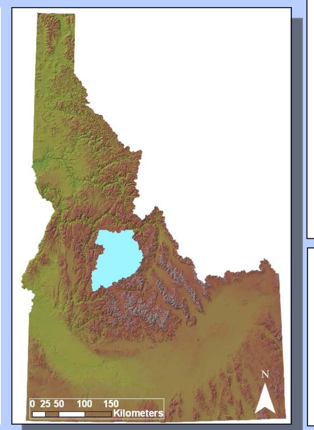
Montane



Sagebrush Steppe

All study sites are primarily Granodiroite





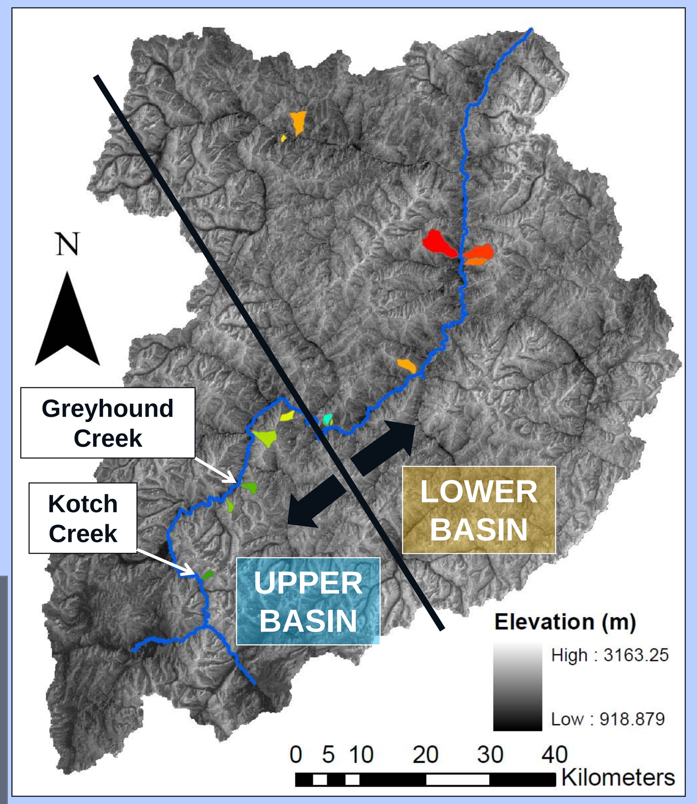


Figure 1 – Delineated sub-basins with colored polygons are study sites with preserved alluvial fans. Sub-basins are classified by vegetation and grouped into upper basin (cool wet vegetated) and lower basin(dry sagebrush steppe)

Methods

Approach

- Upload surveyed data into MATLAB and separate fan and levee points
- Using surveyed points, construct triangulated surface connecting all data points and create interpolation of fan and levee surface
- Assuming sediment is deposited on horizontal surface, create arbitrary horizontal datum at base of deposit
- Integrate from datum to surface for every point
- Sum integrations to find total volume of deposit

Sediment Yield Calculation

Total eroded mass = Event volume * sediment bulk density (assuming bulk density =1500 kg/m^3)

Sediment Yield = mass/area/time

Holocene fire-related debris flow sediment yield = (# events * measured fire-related sediment yield) / time

Assumption - All fire-related debris flows produce the same sediment yield.

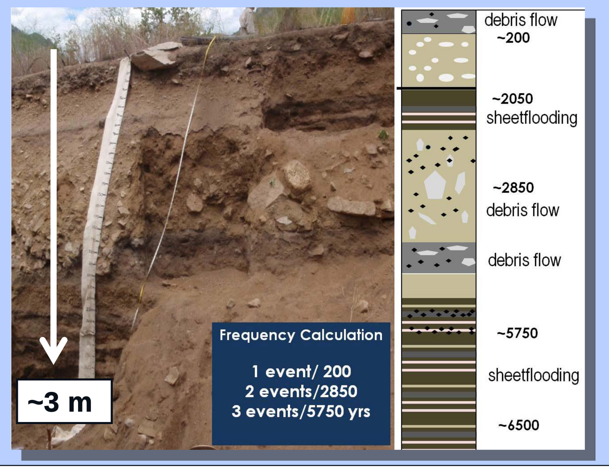


Figure 2- Profile of incised alluvial fan surface with debris flow frequency calculation shown in blue box.

Fire-Related Debris Flow Volume

Measured Volume

Total volume **= 15,928 ± 2500 m^3**

Sediment lost directly to river
≈ 560 m^3

Fan deposit = **14,393 ± 1330 m^3**

Levees deposit
≈ 975 ± 1170 m^3

Estimated Volumes

$$\ln V = 7.2 + .6(\ln A) + .7(B)^{1/2} + .2(T)^{1/2} + .3$$

(where A is area with slopes ≥ 30% (km^2), B is moderately to severely burned area (km^2), T is precipitation depth (mm) (Cannon et al. 2010))

Kotch Creek estimated volume = 11,000 m^3

$$v = (g * r_c (\cos\alpha) * (\tan\beta))^{1/2}$$

(flow super elevation formula where v is mean flow velocity, g is gravity, r_c is radius of curvature, α is longitudinal slope, β is flow banking angle)

Qmax = Amax * v (Amax is the maximum flow cross sectional area)

Greyhound Creek estimated volume **= 22,500 m^3**

Figure 3 – Aerial photograph of recent deposition from fire-related debris flow at Kotch Creek.

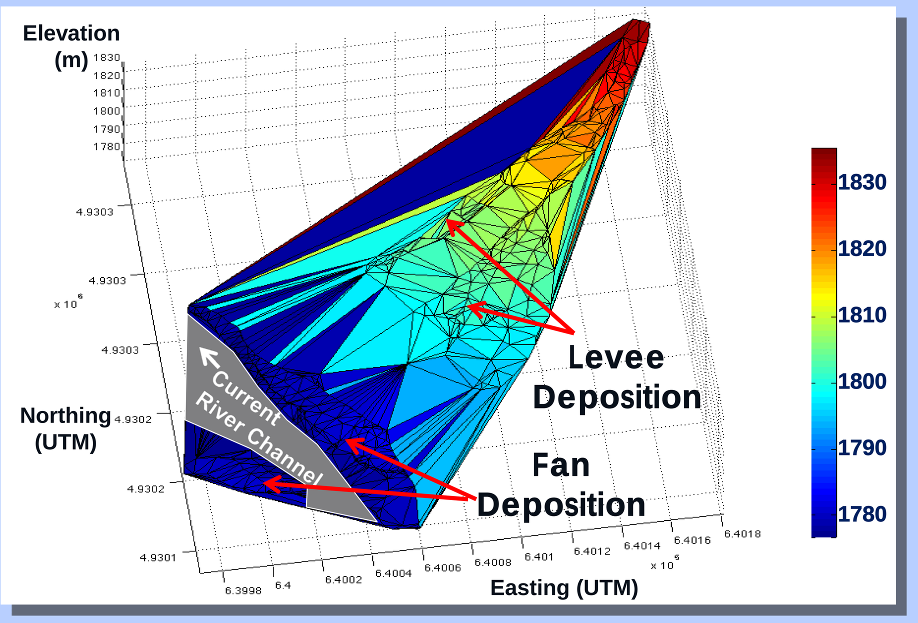


Figure 4 – MATLAB-generated image of entire Kotch Creek fire-related debris flow deposit.

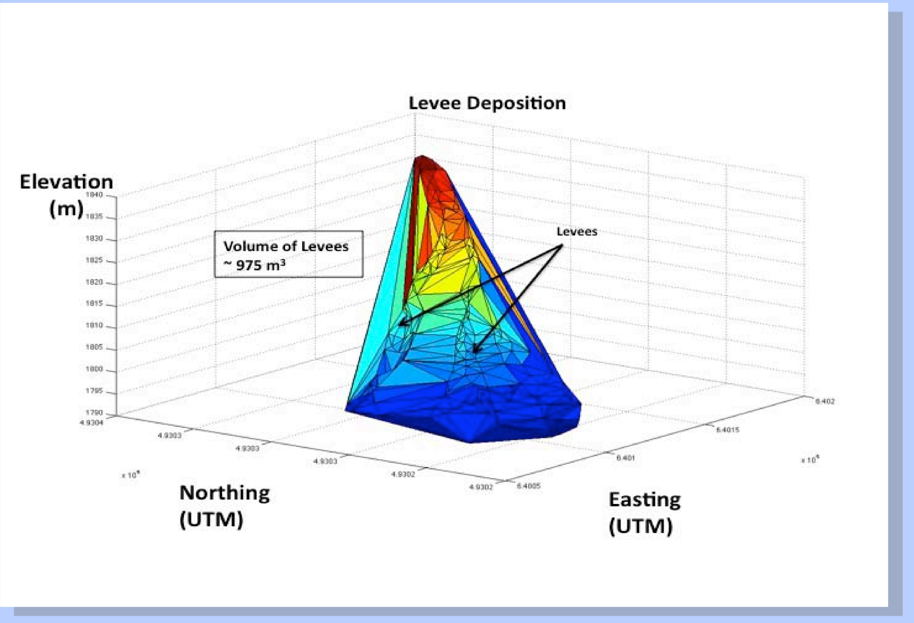


Figure 5 – MATLAB image of isolated Kotch Creek levee deposits.

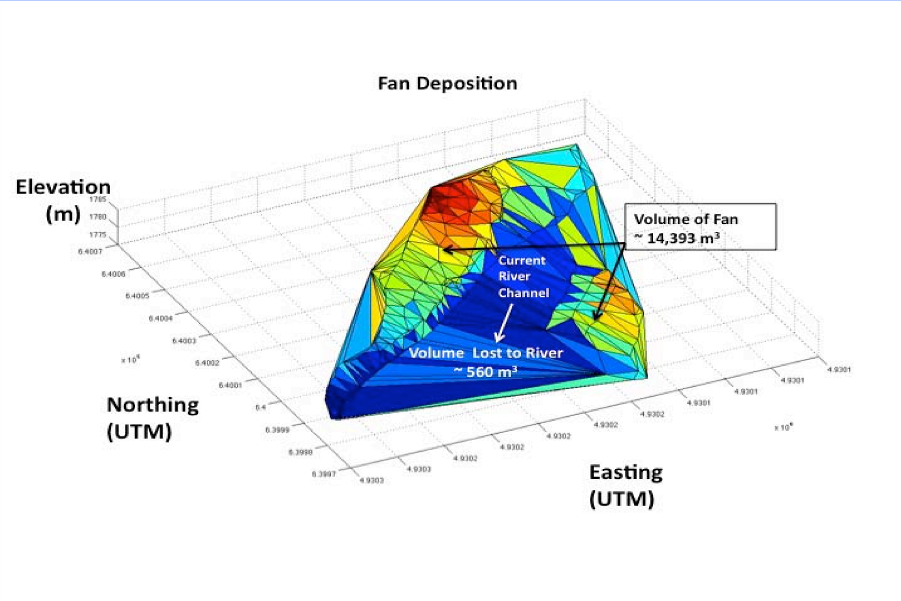


Figure 6 – MATLAB image of isolated Kotch Creek fan deposit with current river channel.

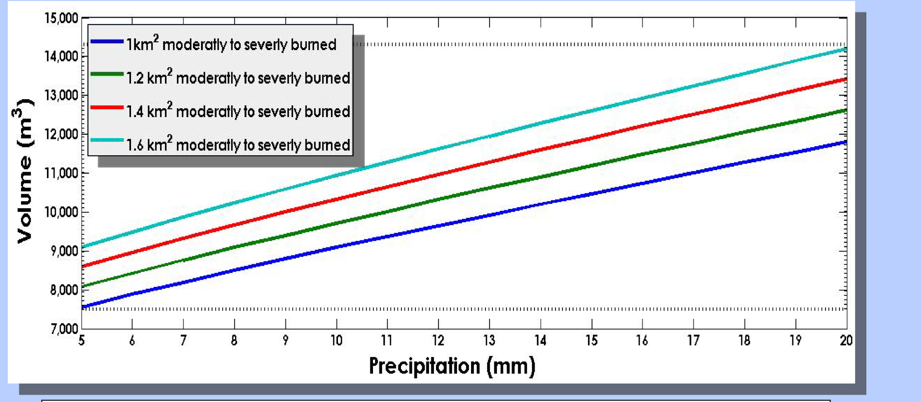


Figure 7 – Sensitivity analysis of Cannon et al., 2010 fire-related debris flow equation. (Area with slopes ≥ 30% = 1.6 km^2)
(figure by Kerry Riley, 2010)

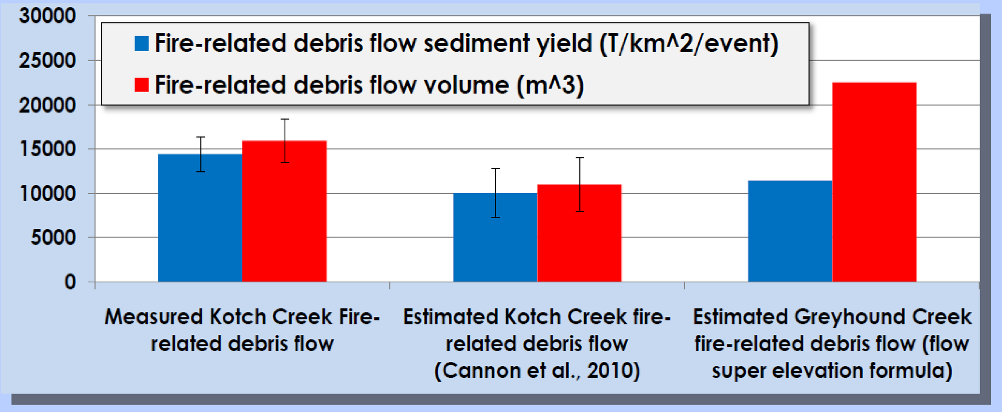
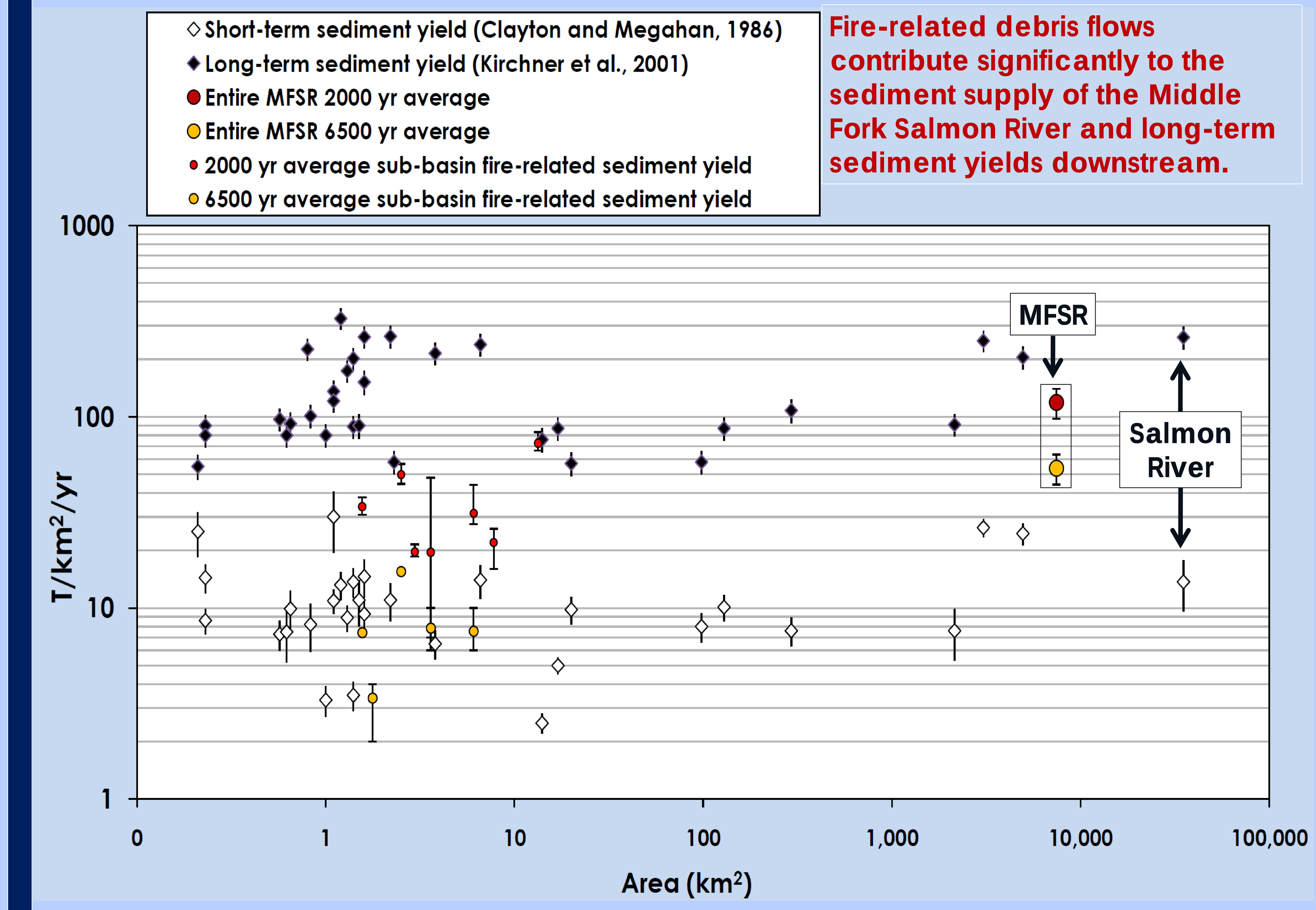


Figure 8 – Fire-related debris flow volume and sediment yield. Comparison of measured and estimated.
(figure by Kerry Riley, 2010)

Long-term Fire-Related Sediment Yield



Fire-related debris flows contribute significantly to the sediment supply of the Middle Fork Salmon River and long-term sediment yields downstream.

Figure 9 – Idaho sediment yields - Short-term data (Clayton and Megahan, 1986) measured using conventional sediment trapping and long-term data (Kirchner et al., 2001) was measured using cosmogonic ^{10}Be.
(figure by Kerry Riley, 2010)

Conclusions

1. Estimated volumes using empirical formulas produce values within error bars of calculated values found using surveyed data points and MATLAB.
2. More than 50% of total sediment yield for Salmon River Basin over the past 2000 years is accounted for in estimates of fire-related debris flows from the Middle Fork Salmon River.

References

- Cannon, S. H., J. E. Gartner, et al. (2010). "Predicting the probability and volume of postwildfire debris flows in the intermountain western United States." Geological Society of America Bulletin 122(1-2): 127-144.
- Kirchner, J. W., R. C. Finkel, et al. (2001). "Mountain erosion over 10 yr, 10 k.y., and 10 m.y. time scales." Geology 29(7): 591-594.

Special Thanks

- Dr. Jen Pierce for the opportunity to work with her graduate students and helping me develop my own research project.
- Kerry Riley for research assistance and getting me down the Middle Fork in one piece.
- Dr. Alejandro Flores research advising and assistance with MATLAB