

## COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

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| <b>FOR CONSIDERATION UNDER: CHECK ONE</b><br><input checked="" type="checkbox"/> Topic A: Water and Watersheds    Subtopic # <u>2</u> <input type="checkbox"/> Topic B: Technology for a Sustainable Environment <input type="checkbox"/> Topic C: Valuation and Environmental Policy    Subtopic # _____                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                 |                                                                                                                                          |                                                                                                 | <b>FOR NSF USE ONLY</b><br><b>NSF PROPOSAL NUMBER</b>                                                   |  |
| <b>PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE</b><br>NSF/EPA Partnership for Environmental Research / NSF 95-48 / May 1, 1995                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                 |                                                                                                                                          |                                                                                                 |                                                                                                         |  |
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| TITLE OF PROPOSED PROJECT:<br>Investigations of Runoff and Sediment Yield from Pinyon-Juniper Watersheds, Northern New Mexico                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |                                                                                                                                          |                                                                                                 |                                                                                                         |  |
| REQUESTED AMOUNT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | PROPOSED DURATION (1-60 MONTHS) |                                                                                                                                          | REQUESTED STARTING DATE:                                                                        |                                                                                                         |  |
| \$ 151,218                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 36 months                       |                                                                                                                                          | October 1, 1995                                                                                 |                                                                                                         |  |
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| PVPD DEPARTMENT Department of Geography                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                 | PVPD POSTAL ADDRESS<br>University of Colorado<br>Campus Box 260<br>Boulder, CO 80309-0260                                                |                                                                                                 |                                                                                                         |  |
| PVPD FAX NUMBER<br>(303) 492-7501                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |                                                                                                                                          |                                                                                                 |                                                                                                         |  |
| NAMES (TYPED)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Social Security No.*            | High Degree, Yr                                                                                                                          | Telephone Number                                                                                | Electronic Mail Address                                                                                 |  |
| PVPD NAME<br>John Pitlick                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 571-78-8521                     | Ph.D.1988                                                                                                                                | (303) 492-5906                                                                                  | pitlick@spot.colorado.edu                                                                               |  |
| CO-PVPD<br>Bradford Wilcox                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 454-80-6364                     | Ph.D.1986                                                                                                                                | (505) 665-6044                                                                                  | bpw@ees15lan.lanl.gov                                                                                   |  |
| CO-PVPD<br>Steven Reaneau                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 572-23-5649                     | Ph.D.1988                                                                                                                                | (505) 665-3151                                                                                  | reneau@esslab.lanl.gov                                                                                  |  |
| CO-PVPD<br>Craig Allen                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 393-74-7888                     | Ph.D.1989                                                                                                                                | (505) 672-3861                                                                                  |                                                                                                         |  |
| CO-PVPD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                 |                                                                                                                                          |                                                                                                 |                                                                                                         |  |
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| *SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE NSF INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |                                                                                                                                          |                                                                                                 |                                                                                                         |  |

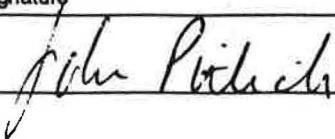
## CERTIFICATION PAGE

### Certification for Principal Investigators and Co-Principal Investigators:

I certify to the best of my knowledge that:

- (1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and  
 (2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this application.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is a criminal offense (U.S. Code, Title 18, Section 1001).

| Name (Typed)          | Signature                                                                         | Date    |
|-----------------------|-----------------------------------------------------------------------------------|---------|
| PI/PD<br>John Pitlick |  | 4-25-95 |
| CO-PI/PD              |                                                                                   |         |
| CO-PI/PD              |                                                                                   |         |
| Co-PI/PD              |                                                                                   |         |
| Co-PI/PD              |                                                                                   |         |

### Certification for Authorized Institutional Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding Federal debt status, debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in the Grant Proposal Guide (GPG), NSF 94-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

#### Debt and Debarment Certifications

(If answer "yes" to either, please provide explanation)

Is the organization delinquent on any Federal debt?

Yes \_\_\_\_\_ No   X  

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?

Yes \_\_\_\_\_ No   X  

#### Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding \$100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding \$150,000.

#### Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than \$10,000 and not more than \$100,000 for each such failure.

|                                                                                   |                         |                                                                                      |                              |
|-----------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------|------------------------------|
| AUTHORIZED INSTITUTIONAL REPRESENTATIVE                                           |                         | SIGNATURE                                                                            | DATE                         |
| NAME/TITLE (TYPED) Laurence D. Nelson, Director<br>Office of Contracts and Grants |                         |  | 4-28-95                      |
| TELEPHONE NUMBER<br>(303) 492-6221                                                | ELECTRONIC MAIL ADDRESS |                                                                                      | FAX NUMBER<br>(303) 492-6421 |

## PROJECT SUMMARY

This proposal seeks 3 years of funding to further develop a study of erosion and sediment transport in the pinyon-juniper woodlands of the Pajarito Plateau, northern New Mexico. The study will be conducted in Los Alamos National Laboratory and Bandelier National Monument in selected areas that are experiencing various levels of erosion from slight to severe. Results from a pilot project initiated 2 years ago suggest that in some areas the present-day rates of erosion are extreme and the sustainability of the pinyon-juniper ecosystem is at risk. The proposed study expands upon this work by addressing the following questions in greater detail:

- 1) when did the present cycle of erosion begin and why?
- 2) what are the present-day rates of erosion?
- 3) what do the present-day erosion rates signify about the sustainability of this ecosystem?
- 4) which among the factors of slope, precipitation, aspect and soils influence erosion the most?
- 5) how is sediment eroded from the mesa tops distributed and stored in the valley bottoms?

In the expanded study, many more plots will be established to measure surface erosion. These plots will be selected systematically to represent a wide range in environmental conditions. In addition, the pattern and volume of sediment stored in stream valleys will be measured. The final goal is to use existing high resolution digital elevation data and vegetation data to develop a GIS-based model of soil erosion. Specifically the GIS will be used to map the coincidence of factors that make an area susceptible to erosion.

The proposed study is a collaborative effort between scientists at the University of Colorado, Los Alamos National Laboratory and Bandelier National Monument. As such, several different areas of expertise are represented and many resources are available. The results of the project will have important implications for managing resources within Los Alamos National Laboratory and Bandelier National Monument. Specifically, there is concern that accelerated soil erosion has already had an impact on many archaeological sites and may represent a threat to some hazardous waste sites. Beyond the study area, there are several federal agencies (e.g. U.S. Forest Service, Bureau of Land Management and the National Park Service) that can utilize results from this project in developing their own strategies for managing pinyon-juniper woodlands.

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## PROJECT DESCRIPTION

### Introduction

Pinyon-juniper woodlands are extensive in the western US, covering 17-24 million ha (Miller and Wigland, 1994; West, 1988). In New Mexico, for example, woodland vegetation covers nearly 1/4 of the land area (Dick-Peddie, 1993). The range of these woodlands varies widely, but they generally occupy a distinct vegetation zone between the more arid grassland and desert shrub associations, and the more humid coniferous forests. There is clear evidence in many parts of the western US that pinyon-juniper woodlands have expanded in the last 100 years into what were savannah-like areas. Ecologists have argued that expansion is probably due to grazing and/or fire suppression- effects that simultaneously reduce herbaceous plant cover and allow stand density to increase (West, 1984). Whether the decline in understory vegetation is a cause or an effect of expansion is unclear, but once underway, the reduction in ground cover can lead to accelerated erosion (Carrara and Carrol, 1979), further reducing biological productivity.

There are extensive areas of pinyon-juniper woodlands on the Pajarito Plateau in northern New Mexico (Fig. 1). These woodlands are found between elevations of 1800 and 2400 m and their distribution is clearly related to local climatic gradients. We have become interested in pinyon-juniper woodlands in Bandelier National Monument (BNM) and Los Alamos National Laboratory (LANL) because many of these areas are eroding rapidly (Fig. 2). However, it is not obvious why this is occurring. Domestic livestock have been excluded from BNM and LANL for the past 50 yr, but we cannot discount grazing as a possible cause of erosion because earlier in this century the area was probably overgrazed and more recently wild burro and elk have had some impact. Fire suppression or the reduction in fire fuel may be factors because either would allow stand densities to increase, giving the pinyon and juniper an advantage over herbaceous plants in the competition for soil moisture. A final possibility is that the present cycle of erosion is associated with a drought in the 1950s (Betancourt et al., 1993) that caused the ponderosa pine and herbaceous ground cover to die off and allowed pinyon-juniper to become more established.

Whatever the cause, there is concern within BNM and LANL that accelerated soil erosion in pinyon-juniper woodlands will have undesirable impacts- not only on the ecosystem itself, but on the many archaeological sites in BNM and the many hazardous waste sites in LANL. When we began discussing this problem two years ago, we realized that very little was known about hillslope erosion and sediment yield in this area (exceptions being the work of Graf, 1994 and Leopold et al., 1966), and furthermore, few people had attempted an integrative study of the hydrology, geomorphology, and ecology of pinyon-juniper woodlands. With this in mind, we began an interdisciplinary study of two small (~1 ha) watersheds in BNM and LANL. The watershed in BNM is clearly eroding rapidly whereas the watershed in LANL is representative of a stable woodland. We installed extensive arrays of equipment and devices in both watersheds to

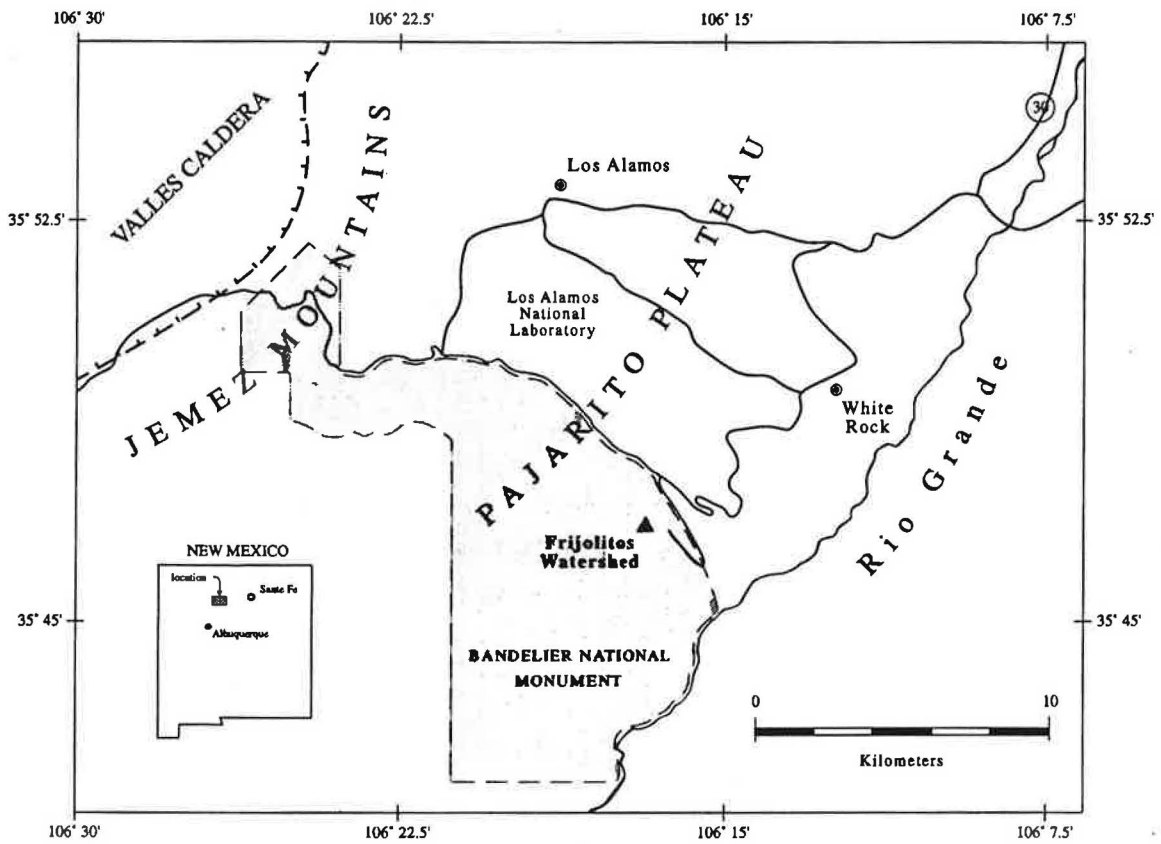


Figure 1. Location map of Los Alamos National Laboratory and Bandelier National Monument.



Figure 2. Eroded pinyon-juniper woodland in Bandelier National Monument

measure climate, soil characteristics, surface erosion, runoff, sediment yield, and changes in vegetation cover. The specific objectives of this on-going study are to:

- 1) determine when the current cycle of erosion in BNM began and why;
- 2) quantify rates of erosion and develop water and sediment budgets for both watersheds;
- 3) assess whether these woodland ecosystems are sustainable under present conditions.

Our preliminary results suggest that present-day erosion rates in the BNM watershed are probably well in excess of long-term rates (Wilcox et al., in press; Pitlick et al., 1993). Furthermore, although soils in the LANL watershed are not eroding at present, they are relatively thin (< 1m) suggesting that at some time in the past, this surface was stripped. Elsewhere in LANL there is evidence for at least one and maybe more periods of accelerated erosion (see attached letter from Steven Reneau). So, the issue at this point is not really one of sustainability-our observations suggest that erosion in BNM is not sustainable. Rather, the question is, what initiated this cycle of erosion, what are the dominant controls, and how widespread is it?

### **Objectives of the Present Proposal**

Our observations over the last 2 years have reinforced the opinion that pinyon-juniper woodlands are very dynamic. However, our work is somewhat limited in scope. For this research to be of broader value and interest, it must be extended for a longer period of time and it must cover a greater range in environments. The present proposal seeks funding to continue monitoring precipitation, runoff, erosion and vegetation change in the study watersheds, as per objectives 1-3 above, and to expand the scope of work to include the following elements:

- 4) extend the network of soil-erosion measurement plots to at least 7 additional sites;
- 5) map and measure sediment storage in higher order stream valleys and canyon floors; and
- 6) develop a GIS data base of vegetation cover, topography and severity of erosion.

Much of the previous work on the hydrology of pinyon-juniper woodlands focused on the question of whether vegetation removal or treatment would increase water yield (Wilcox, 1994). In general, these studies showed that treatment produced negligible increases in water yields. More recently, the emphasis of research in pinyon-juniper woodlands has shifted toward issues of ecosystem sustainability (Aldon and Shaw, 1993), effects of climate change, and changes in water quality (Schmidt, 1986). Even so, very little of this recent work has been aimed at understanding the link between physical processes and ecosystem sustainability. The work proposed herein is different in this and several other regards: we view the problem of soil erosion in pinyon-juniper woodlands as a complex association between the land-use history, soils, runoff, vegetation cover,

topography, and geomorphology. Furthermore, we view the problem in a long-term context; there is evidence that erosion may have been equally severe at other times in the Holocene. Finally, we intend to utilize some outstanding resources that were not available for any previous study. These resources include low altitude aerial photographs (1:7200 scale), high resolution digital elevation data, digitized vegetation maps, streamflow data from 18 U.S. Geological Survey gaging stations (see attached letter from Brad Wilcox) and climate data from National Weather Service stations.

Resource managers and scientists within BNM and LANL are particularly interested in this work for two important reasons. First, according to a recent inventory, 70% of the archaeological sites recorded in BNM were damaged by erosion (see letter from Roy Weaver, Superintendent BNM). If erosion continues, additional sites will be threatened and some may be ruined. Second, in LANL there are many areas where soils are contaminated because of weapons testing and surface disposal of radioactive waste. It is in everyone's interest to know how long it will take for these contaminated soils to move through and out of the system (see letter from Steve Reneau).

### **Study Area**

Los Alamos National Laboratory and Bandelier National Monument are located on the Pajarito Plateau east of the Jemez Mountains in northern New Mexico (Fig. 1). This plateau is formed by a series of volcanic units that were erupted from the Valles caldera over a 14 Ma period from the late-Tertiary through the Quaternary (Gardner and Goff, 1984). The most conspicuous of these units is the Bandelier Tuff, a 1.5 to 1.1 Ma ash-flow that caps the sequence and forms the surface of the plateau. The plateau is dissected by a series of steep-walled canyons- some up to 200 m deep- that have been cut by streams flowing east to the Rio Grande. Prominent knickpoints in the longitudinal profiles of these tributary streams provide evidence that they are still responding to base-level lowering along the Rio Grande (Dethier et al., 1988). These knickpoints also act as local baselevels that cause sediment to be stored in the canyon bottoms for long periods of time.

Mean annual precipitation on the Pajarito Plateau ranges from about 300 mm at lower elevations (~1,900 m) on the eastern edge of the plateau to more than 500 mm at higher elevations in the Jemez Mountains (Bowen, 1990). About half of the annual precipitation falls during intense thunderstorms from July through September. The remaining precipitation is associated with frontal storms that produce either snow or moderately intense rainfall.

The distribution of vegetation on the Pajarito Plateau is closely associated with elevation and precipitation (Allen, 1989). Sparsely vegetated pinyon-juniper woodlands are characteristic of the drier low-elevation mesa tops. In areas that are relatively stable, Blue grama is the dominant understory grass, bitterweed and fringed sagebrush are the common shrubs and forbes, and a cryptogamic crust may be present. Moderately dense stands of ponderosa pine are found on the tops of higher-elevation mesas and in valley bottoms (Tierney and Foxx, 1982).

## Discussion of Recent Work on Runoff and Soil Erosion on the Pajarito Plateau

*TA-51 Watershed:* The site in LANL is representative of a more stable pinyon-juniper woodland. The study site is located on a gently sloping ( $< 5\%$ ) east facing mesa-top at an elevation of 2140 m. Soils in this area are developed entirely on tuff residua. The site is extensively instrumented. A weather station continuously monitors precipitation, relative humidity, wind speed and direction, and air temperature. Continuous readings of soil moisture are taken at many locations using both neutron attenuation and time-domain reflectometry (TDR). Runoff and soil erosion data are collected at several different scales ranging from a 1 ha hillslope to six  $30\text{ m}^2$  plots to 15 small plots that range in size from 1 to  $8\text{ m}^2$ . The topography and vegetation of the TA-51 site have been mapped in great detail.

Results from 2 years of study in this watershed indicate that soils beneath the pinyon and juniper trees (canopy areas) have much higher infiltration capacities than soils between the trees (intercanopy areas), and thus, nearly all of the runoff and erosion are produced from intercanopy areas (Wilcox, 1994). Furthermore, both runoff and erosion tend to decrease as the measurement scale increases from small to large plots. This scale-dependent relation most certainly occurs because some of the water and sediment generated in intercanopy areas is lost due to infiltration in canopy-covered areas. Soil erosion rates at this site are probably several orders of magnitude lower than at the Bandelier site (see below).

*Frijolito Watershed:* This is a 1 ha watershed located in Bandelier National Monument (Fig. 1), south of the monument headquarters near the Frijolito ruins. The watershed lies on the south side of a moderately sloping ( $\sim 11\%$ ) mesa at an elevation of 1980 m. Mean annual precipitation in the area is about 360 mm (Bowen, 1990). Pinyon and juniper trees cover  $\sim 1/2$  of the watershed, but the presence of fallen ponderosa pine logs across the site suggests that these trees were once common. At present, there are no live ponderosa trees. Soils on the site are developed on tuff residua and volcanic pumice. Rills, patches of bare ground and soil pedestals provide evidence that the area is experiencing very rapid erosion.

This site is also extensively instrumented. A solar-powered weather station continuously measures solar radiation, air temperature, relative humidity, wind speed and direction, and precipitation. The discharge from individual runoff events is measured by means of a flume and stilling well installed at the outlet of the basin. We excavated a pit just upstream of the flume to capture sediment leaving the basin but soon realized that it was too small to trap all the sediment leaving the watershed. Thus, in 1994 we installed a series of smaller traps (capacity of  $1\text{ m}^3$ ) at the base of 4 tributary channels and four smaller ( $1\text{-m}^2$ ) plots to measure runoff and sediment from intercanopy areas.

intervals (we call this device an "erosion bridge"). To measure the topography, the erosion bridge is placed over the endpoints, a thin rod is slid through the holes to the ground surface, and the distance from the top of the rod to the level is measured. The erosion bridge is inexpensive, and the procedure is very straightforward. In terms of "bang-for-your-buck", this device has yielded perhaps the most useful information of all our instruments. In expanding the scope of work to other areas (see below), we propose to make further use of this method.

In the first 16 months of observation (from July 1993 to October 1994), a total of 640 mm of precipitation was measured in the Frijolito watershed. The 12 storms that produced measurable runoff were very different from each other in terms of precipitation duration and intensity (Table 1, from Wilcox et al., in press). Runoff generated by individual storms varied anywhere from 8 to 53% of the precipitation, and as a result, peak discharges measured at the basin outlet varied widely (Table 1). A total of 65 mm of runoff, or about 10% of the precipitation, was generated in this 16-month time period.

Measurements of the 20 erosion-bridge transects in 1993 indicated that several centimeters of soil were eroded from some areas (Fig. 3). The amount of surface erosion varied greatly among the 20 transects (Fig. 4), indicating there were some areas that were eroding much more rapidly than others. The average change in surface elevation, or depth of erosion, for all 20 transects was -0.34 cm (Fig. 4). Considering that half the watershed is canopy covered and isn't eroding, the average depth of erosion for the 20 transects converts to an areal (watershed) depth of erosion of about 0.17 cm/ha. Assuming a soil bulk density of  $1,500 \text{ kg/m}^3$ , this equates to a sediment yield of  $2,550 \text{ tons/km}^2/\text{yr}$ . For comparison, Leopold et al. (1966) reported an average surface erosion rate of 0.46 cm/yr in their calculation of a sediment budget for a small watershed near Santa Fe, NM. Our observations are certainly in line with this estimate, but we feel a rate of 0.17 cm/yr is probably well in excess of long term rates. We say this because if we assume an erosion rate of only 0.1 cm/yr, then it would take less than 5 centuries to erode most of the soil in the watershed. Earlier we noted that some soils contain an argillic horizon, which in this environment would take at least 10,000 yr to form. Thus we have come to the preliminary conclusion that present-day rates of erosion must be in excess of the long-term rates, otherwise there would be virtually no soil in the watershed.

Table 1. Precipitation, runoff, and erosion information for the Frijolito Watershed (July 1993 - October 1994).

| Date          | Precipitation |                    |               | Runoff    |                |                    |                                 | Erosion           |              |
|---------------|---------------|--------------------|---------------|-----------|----------------|--------------------|---------------------------------|-------------------|--------------|
|               | Amount (mm)   | Duration (min.)    | Peak (mm/min) | Plot (mm) | Catchment (mm) | Duration (min)     | Peak Flow (m <sup>3</sup> /sec) | Catchment (kg/ha) | Plot (kg/ha) |
| 1993          |               |                    |               |           |                |                    |                                 |                   |              |
| July 28, 1993 | 36            | 30+15 <sup>+</sup> | 1.8           |           | 9              | 33+20 <sup>+</sup> | 0.061                           | >600              |              |
| Aug 6, 1993   | 9             | 15                 | 0.7           |           | 1              | 12                 | 1.016                           | >600              |              |
| Aug 20, 1993  | 5             | 14                 | 0.5           |           | <1             | 8                  | 0.008                           | 600               |              |
| Aug 26, 1993  | 23            | 120                | 0.5           |           | 4              | 49+30              | 0.013                           | >600              |              |
| Aug 27, 1993  | 24            | 35                 | 2.0           |           | 12             | 35                 | 0.086                           | >600              |              |
| Aug 28, 1993  | 11            | 55+50 <sup>+</sup> |               |           | 3              | 30+60 <sup>+</sup> | 0.01                            | >600              |              |
| Sept 6, 1993  | 19            | 35                 | 2.0           |           | 6              | 28                 | 0.058                           | >600              |              |
| Sept 13, 1993 | 4             | 10                 | 1.0           |           | <1             | 15                 | 0.0095                          | 264               |              |
| 1994          |               |                    |               |           |                |                    |                                 |                   |              |
| Aug 2, 1994   | 6             | 21                 | 1.0           | 2         | 2              | 20                 | 0.03                            | 36                | no sample    |
| Aug 21, 1994  | 4             | 6                  | 1.5           | 2         | 1              | 10                 | 0.037                           | 144               | 164          |
| Sept 5, 1994  | 10            | 50                 | 0.7           | 1         | 5              | 34                 | 0.039                           | 216               | 30           |
| Oct 15, 1994  | 65            | 3 days             | 0.5           | 11        | 20             | 6 hr               | 0.026                           | >600              | 129          |

plus sign indicates that rainfall and runoff occurred in two distinct pulses

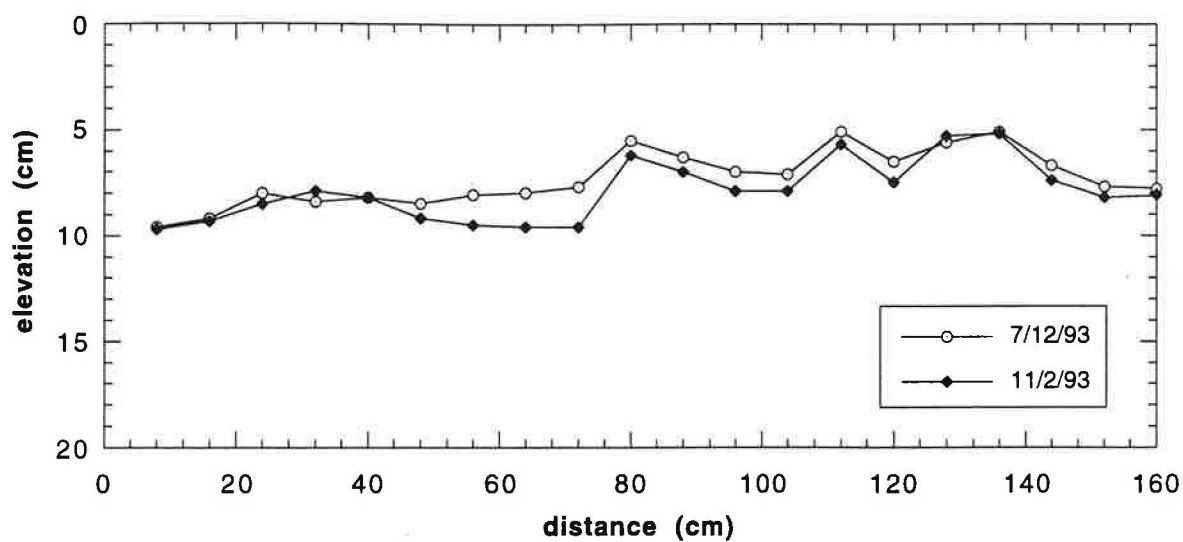


Figure 3. Example of changes in microtopography at one erosion-bridge transect.

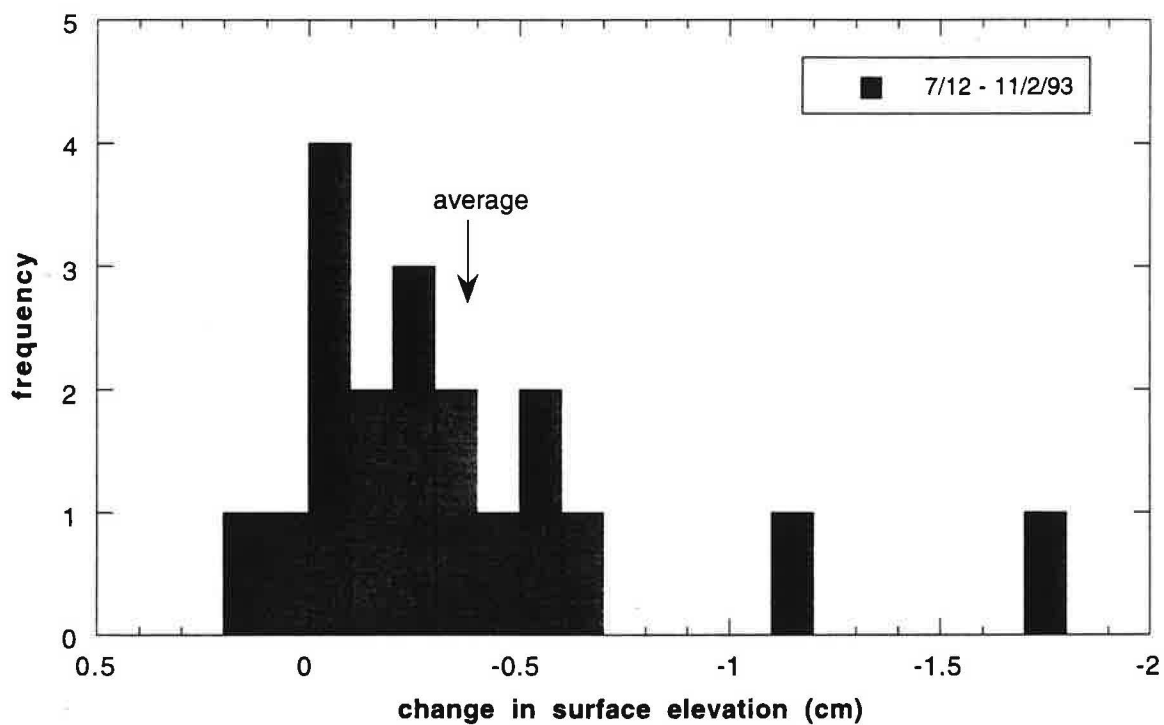


Figure 4. Changes in average ground elevation for 10 pairs of erosion bridges.

## Description of Proposed Work

The above observations indicate that accelerated erosion is clearly a problem at the BNM site, but not necessarily at the LANL site. However, we don't know how representative either of these sites really are, or how representative our two years of data are. As described below, we propose to expand the scope of work to include other sites and techniques that will allow us to place our results into a much broader context.

### 1. *Extend the network of soil-erosion measurement plots:*

We propose to install erosion-bridge transects at 7 additional sites covering about 1 ha each. In addition to being simple and effective, the erosion bridges have low aesthetic impact, which is important because some of the sites will be located in BNM or the neighboring Dome Wilderness Area. The new erosion bridge sites will be located in areas that differ from the present locations and allow us to look systematically at the factors that are most important for soil erosion, e.g. hillslope gradient, aspect (micro-climate), and average annual precipitation (macro-climate). The 7 sites will be selected to fill out the matrix of environmental conditions shown in Figure 5. The Frijolito watershed represents a south-facing high gradient site in an area of relatively low annual precipitation, hence it is shaded. Three other sites will be located nearby in areas with similar soils, but different hillslope gradient and aspect. To examine the effect of average precipitation, 4 other sites will be located at a higher elevation nearer the boundary between the pinyon-juniper and ponderosa pine forests (Fig. 5). Again, these sites will be distributed so as to examine the effects of different gradient and aspect.

| <u>LOWER ANNUAL PRECIPITATION</u> |                                | <u>HIGHER ANNUAL PRECIPITATION</u> |                               |
|-----------------------------------|--------------------------------|------------------------------------|-------------------------------|
| GRADIENT                          |                                | GRADIENT                           |                               |
| A<br>S<br>P<br>E<br>C<br>T        | south-facing,<br>high gradient | south-facing,<br>low gradient      | south-facing,<br>low gradient |
|                                   | north-facing,<br>high gradient | north-facing,<br>low gradient      | north-facing,<br>low gradient |

Figure 5. Proposed sampling scheme to measure hillslope erosion across a range of environmental conditions. The shaded box represents the Frijolito watershed, a site where data already exist.

The erosion-bridge transects will be laid out the same manner as in the Frijolito watershed. Ten pairs of erosion-bridge transects will be installed at each site in areas selected to cover a range in intercanopy conditions. Measurements will be taken at each site once every 4 weeks, either by visiting all the sites within the same week or by visiting them in a sequence of 1 or 2 sites per week. If a major regional storm occurs, all the sites will be measured. Because precipitation events tend to be localized, a nonrecording rain gauge will also be placed at each site. Precipitation collected in the rain gauges will be measured when the sites are visited, although we recognize that there could be a significant loss between storms due to evaporation.

In other areas of extreme erosion, the topographic relief between the canopy and intercanopy areas can exceed 1 m. For these cases, we propose selecting a few sites where we can use standard surveying techniques to measure the topography over longer transects. Based on our observations of the noneroding site at LANL (TA-51), we can assume that prior to erosion, the ground surface was nearly level, except under trees, and that the volume of material subsequently eroded can be estimated by measuring local relief along the transect. We can perhaps determine the onset of erosion at these sites by dating tree roots (Carrara and Carroll, 1979). Otherwise we may be able to determine when accelerated erosion began by reviewing aerial photographs.

## *2. Map and measure sediment storage in stream valleys:*

Many of the streams draining the Pajarito Plateau are ephemeral, and as a result, much of the sediment eroded from the mesa tops gets stored in the valley bottoms and never makes it to the Rio Grande. The depth of alluvium in storage exceeds 10 m in some canyons (Baldrige, 1992), but the ages are poorly constrained (see discussion of related work and letter by Steve Reneau). In any event, some knowledge of the pattern of alluvial storage in valley bottoms is needed if we are to estimate sediment budgets for individual areas. Furthermore, if the volume and age of the alluvium were known, we would have some constraint on the present-day erosion rates.

Mapping the pattern of alluvial storage in stream valleys is straightforward, but without subsurface data (wells or borings) or cross-section measurements, determining the actual volume of sediment in storage is more difficult, particularly in higher order streams (Madej, in press; Kelsey, 1980; Dietrich and Dunne, 1978; Leopold et al., 1966). In lower order tributaries, the task of estimating volume is easier because sediment is often stored in discrete places, such as discontinuous terraces or behind log jams (Pitlick, in press). The volume in storage in this case can be readily determined by measuring the length, breadth and height of such deposits. There has been some effort to map and characterize sediment in the valley bottoms in LANL (see letter by Reneau), but little of this type of work has been done in BNM, and there is still much more to do in the valleys and canyons in LANL.

We propose to measure the volume of alluvium in storage in approximately 20 lower order (< 3rd order) tributary streams in LANL and BNM. With this information, we will construct maps of the pattern of storage, noting in particular the valley or channel attributes (e.g. change in slope) where there are noticeable changes in storage. For the higher order (> 3rd order) stream channels, the surface area of the valley fill will be mapped, and where possible the depth of alluvium will be determined from available well data. There is increased interest in the subsurface distribution of contaminants and hazardous wastes at LANL, and as a result many wells and test borings have now been drilled in the valley bottoms. If well data are not available for a particular canyon, we will estimate the depth of alluvium based on data from other canyons. Baldrige (1992) indicates the depth of alluvium is generally less than 10m; this is small in comparison to the width and length of the valley fills. Thus, in this type of problem, the main source of error in estimating the volume of fill is in determining the surface area, which we can measure accurately. Other geologists at LANL have been investigating the Pleistocene and Holocene tectonic history of the area and they have begun to find organic materials in these valley-fill sediments that are suitable for C<sup>14</sup> dating. We will utilize these data as they become available.

### *3. Development of a GIS-based map of erosion potential:*

A set of high resolution (1:7200) color aerial photographs of BNM and LANL was flown in 1991. These photographs have been used to develop a digital elevation model (DEM) and 2-ft contour maps of all of LANL and some parts of BNM, and maps of vegetation cover and density in BNM. The advantage of having the elevation and vegetation data in digital form is that, with standard geographic information system (GIS) software, one can combine information from the separate data sets and look at interactive effects. For example, the GIS can be used to extract any number of measures of the surface topography such as the local hillslope gradient, the change in gradient (i.e. whether the slope is convergent or divergent), or the aspect, and these measures can then be compared with the amount or type of vegetation cover. Likewise, the DEM can be used to delineate the channel network and determine the area upslope of a given point. Along with gradient and vegetation cover, the area upslope of a point (contributing drainage area) is particularly relevant to the problem of hillslope erosion and channel initiation (Dietrich et al., 1993). Our goal in this phase of the project is to use existing high resolution data to begin to develop a GIS-based model of surface erosion that accounts for interactions among vegetation, hydrology and geomorphology. We don't intend to develop an entirely deterministic model of erosion, but rather one that explains the present situation in terms of simple parameters and variables, and that can be used to examine future scenarios where the climate or land use might change. In effect we are using the existing conditions as substitutes in space for what might occur in time, either past or future.

A second component of this work will involve image analysis of the aerial photographs to determine vegetation density and perhaps composition. ERDAS image processing software has the ability to distinguish between many levels of contrasting light and dark shades. We anticipate that trees will show as very dark areas and thus will be relatively easy to distinguish, and the woodland areas that are eroding most rapidly will have a characteristic brightness associated with bare soil. ERDAS works with a scanned image of an aerial photograph and can classify features on the image in either an unsupervised mode or in a supervised mode where a set of classification "rules" are written by the operator. Although this might sound straightforward, we foresee several problems with the procedure. First, the overall utility of the method depends highly on the quality of the original image. Second, the reliability of individual classifications varies with the complexity of the features. Third, there are significant data storage requirements. We are less concerned about the first 2 problems because a) these are low altitude color photographs and it is quite easy in a pinyon-juniper forest to distinguish trees from intercanopy areas, and b) the area is mostly a plateau so undesirable effects associated with rapidly changing topography (shadows, distortion, etc.) are not as apt to be a problem as in some other areas. The data storage problem, however, is of greater concern- it may require 10 to 30 megabytes of storage to process one color photograph. Add to this the time it takes to classify features on the image and we very soon reach a limit to the amount of area we can cover. Before we attempt to do this on a large scale, we will conduct a test of the image-analysis technique in a smaller area. If the results suggest the technique is not very accurate or it is too time consuming we will abandon it in favor of using the available vegetation maps. However, if the technique is successful, we will proceed and complete an image analysis for each of the areas where we propose to collect field data. In this way we can ground-truth the results. Although a vegetation map is available in this case, we want to test the utility of automated techniques because our overall goal is to develop a general approach that could be used to evaluate erosion in other areas where less data are available.

As a final step, we will combine results from the topographic analysis with the image analysis and begin to develop maps of erosion potential. To do this, the data sets will first be adjusted to the same scale to yield a common pixel size for topography and vegetation. We will then use the combined data set to test the hypothesis that the areas that are eroding most rapidly are the steeper, more xeric sites (perhaps south-facing slopes or areas at lower elevation). Areas will be broken into specific classes, and the percentage of the area in individual classes will be calculated. Visual inspection of the aerial photographs or observations on the ground will determine whether erosion was slight, moderate or severe. We will then determine if the severity of erosion is systematically related to micro-environmental variables (vegetation and topography) that can be calculated independently for each pixel in the GIS. If so, then we have some predictive ability to say how the potential for erosion might change given a change in the environment.

## **Available Resources**

Some of the resources available for this project have already been described. In addition to the recent aerial photographs, BNM and LANL maintain collections of older aerial photographs. Likewise there are dozens of LANL reports on the soils, hydrology and vegetation characteristics of the area. Climate data from several weather stations in the area are likewise available. Recently the U.S. Geological Survey, under contract with LANL, installed 18 gaging stations to evaluate hazards from storm-water runoff. Data from these gages will be utilized as they become available.

All the equipment needed to conduct topographic surveys for this project is available through the Department of Geography, University of Colorado. This equipment includes a total station (Topcon TDS-302), data logger and associated surveying software.

The development of the GIS data base and the image analysis will be done in the spatial data analysis laboratory in the Department of Geography, University of Colorado. This lab is outfitted with 16 IBM RS 6000 UNIX workstations and all the software (AutoCAD; Arc-Info; ERDAS) needed for this purpose.

## **Related Research**

The Principal Investigator (Pitlick) is a fluvial geomorphologist who has spent most of his professional career studying erosion and sediment transport in disturbed landscapes. This includes work in two of the most actively eroding areas in the United States- near Redwood National Park in northwestern California and Mount St. Helens in southern Washington. Publications resulting from this work are listed in the attached vitae. For the past 3 years he has been a consultant at Los Alamos, working primarily with Brad Wilcox on the problem of soil erosion described here.

The attached letters from Wilcox, Reneau and Allen describe some of their individual research efforts, and how the present project relates to their own work. Brad Wilcox has several other on-going research projects in LANL that are funded as part of the Environmental Restoration Program. The present project will provide data and information that are particularly important with respect to the surface transport and dispersal of contaminants, which in this area is a widespread environmental problem. Steven Reneau has been engaged in studies of the geomorphic and tectonic history of the area and he is beginning to pull together a wide range of data demonstrating the range in activity of surface processes through the Holocene. The present project complements Reneau's work because it provides a detailed view of modern-day processes. Craig Allen is an ecologist who has worked extensively on landscape-scale problems in BNM, LANL, the Jemez Mountains, and elsewhere in the region. His research looks at the effects of disturbance due to fire and land-use changes on forest structure and species composition. Results from the present project will assist Allen and others within BNM in their efforts to manage the pinyon-juniper woodlands more effectively.

## RESULTS FROM PRIOR NSF SUPPORT

**Award Number:** SBR-9305191

**Amount:** \$9,500

**Period of the Award:** 6/15/93 - 11/30/95

**Title:** Doctoral Dissertation Research: Changes in River Morphology and Endangered Fish Habitats of the Colorado River

### **Summary:**

This was a "Dissertation Improvement" award that went to one of my PhD students, Mark Van Steeter. This award funded part of an on-going study that focuses on changes in channel morphology and potential losses of fish habitat in reaches of the Colorado River near Grand Junction, Colorado. We have employed aerial photographs, discharge records, and field studies to evaluate the significance of historical changes in flow regime and the effects of more recent flow events. Our GIS analysis of aerial photographs indicated there have been measurable decreases in the amount of backwater habitat in the upper Colorado River, although this varies with the specific time period. A preliminary analysis of peak flow data from several gaging stations in the region indicated that there has been a 19% decrease in the average peak discharge of the upper Colorado River in the last 30 years. The reduction in peak flows began soon after most of the major reservoirs in the upper basin were constructed. Peak flows on unregulated tributary streams have remained stationary over the last 60 years. Field studies conducted in 1993 during a period of higher than average runoff revealed minor changes in channel morphology. Results from modeling to determine thresholds for coarse sediment transport were consistent with this observation: model results indicate that the peak flow in 1993 was just sufficient to cause significant movement of cobble and gravel bed material, but not high enough to cause significant changes in channel morphology.

### **Publications:**

Pitlick, J., and Van Steeter, 1994, Changes in Morphology and Endangered Fish Habitat of the Colorado River, Completion Report No. 188, *Colorado Water Resources Research Institute*, Fort Collins, Colorado, 24 pp.

Van Steeter, M. and Pitlick, J., 1994, Aerial Photograph/GIS Analysis and Field Studies of the 15 and 18 Mile Reach of the Colorado River, report to U.S. Fish and Wildlife Service, contract no. 60181-3-1224, 63 pp.

Van Steeter, M. and Pitlick, J., 1994. Analysis of changes in channel morphology of the upper Colorado River in relation to endangered fish habitats, *EOS Transactions of the American Geophysical Union*, Spring 1994 Meeting, p. 176.

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Regional Flood-Frequency Analysis for the Santa Ynez River Basin, California, U.S. Bureau of Reclamation, 1994 (\$2,495)  
Hydrology and Geomorphology of the Upper Mississippi River Basin, Literature Review for the Scientific Assessment and Strategy Team (SAST), 1994 (\$2,000)  
Runoff and Sediment Yield from Pinyon-Juniper Watersheds of the Pajarito Plateau, northern New Mexico, Los Alamos National Laboratory, 1994 (on-going consulting agreement)

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Channel Change in the Ruby-Horsethief Canyon Reaches of the Colorado River  
U.S. Fish and Wildlife Service, 1994 (\$20,000)  
Changes in Channel Morphology and Endangered Fish Habitats, Colorado River  
National Science Foundation Dissertation Improvement Award, 1993-94 (\$9,500)  
Colorado Water Resources Research Institute, 1993-94 (\$14,000)  
U.S. Fish and Wildlife Service, FY 1993 (\$14,500)

## 5 PUBLICATIONS RELATED TO THIS PROPOSAL:

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## 5 OTHER PUBLICATIONS:

- Pitlick, J., Levish, D.R. and Ostenaar, D. 1995. Flood-frequency analysis for the Santa Ynez River and adjacent regions, *Physical Geography* (in press)
- Pitlick, J., 1994. Relation between peak flows, precipitation, and physiography for five mountainous regions in the western USA, *J. Hydrol.*, v. 158, p. 219-240.
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- Pitlick, J. 1994. Coarse sediment transport and the maintenance of fish habitat in the upper Colorado River, *Special Session on Hydraulics of Mountain Rivers, 1994 A.S.C.E. Conf. Hydraul. Engr.*, Buffalo, NY, p. 855-859.
- Pitlick, J., 1992. Flow resistance under conditions of intense gravel transport, *Water Resour. Res.*, v. 28, p. 891-903.

## SCIENTISTS WITH WHOM THE PI HAS HAD A RESEARCH ASSOCIATION:

Dissertation advisors: Stanley Schumm and Michael Harvey (both at Colorado State University)  
Collaborators: Brad Wilcox (Los Alamos National Lab); Craig Allen (National Biological Service); Peter Wilcock (Johns Hopkins University); G. Mathias Kondolf (Univ. California, Berkeley); John Costa (U.S. Geological Survey, Vancouver, WA)

## GRADUATE STUDENTS ADVISED: (N=5)

PhD: Mark Schmееckle, Mark Van Steeter, and Gary Fleener  
MA: Bob Cress, Chris Johnston

**PROPOSED BUDGET DETAILS**

Institution: The Regents of the  
University of Colorado  
Campus Box 19  
Boulder, CO 80309-0019

Title: Investigations of Runoff and  
Sediment Yield from Pinyon-  
Juniper Watersheds,  
Northern New Mexico

Principal Investigator: John Pitlick

Duration: 10/1/95 - 9/30/98

|                                             | Year 1 | Year 2 | Year 3 |
|---------------------------------------------|--------|--------|--------|
| <b>A. Salaries and Wages</b>                |        |        |        |
| Principal Investigator: John Pitlick        |        |        |        |
| 100% time, 1 mo. summer                     | 4,482  | 4,706  | 4,941  |
| Graduate Research Assistant                 |        |        |        |
| 100% time, 3 mos. summer                    | 6,998  | 7,348  | 7,715  |
| 50% time, 9 mos. AY                         | 10,175 | 10,684 | 11,218 |
| Total Salaries and Wages                    | 21,655 | 22,738 | 23,874 |
| <b>B. Fringe Benefits</b>                   |        |        |        |
| PI: 19.29% + \$278/mo.                      | 1,143  | 1,186  | 1,231  |
| GRA: 3.36% + \$420/yr.                      | 997    | 1,026  | 1,056  |
| Total Fringe Benefits                       | 2,140  | 2,212  | 2,287  |
| <b>C. Permanent Equipment</b>               |        |        |        |
| 1, 2 Gigabyte hard drive                    | 2,000  | 0      | 0      |
| <b>D. Travel (domestic)</b>                 |        |        |        |
| PI travel:                                  |        |        |        |
| •to and from New Mexico                     | 500    | 500    | 500    |
| •subsistence for 1 month in New Mexico      | 500    | 500    | 500    |
| •to professional meeting (one/year)         | 500    | 500    | 500    |
| GRA travel:                                 |        |        |        |
| •to and from New Mexico + travel onsite     | 2,000  | 2,000  | 2,000  |
| •subsistence for 3 months in New Mexico     | 3,000  | 3,000  | 3,000  |
| •to professional meeting (one/year)         | 500    | 500    | 500    |
| Total Travel                                | 7,000  | 7,000  | 7,000  |
| <b>E. Other Direct Costs</b>                |        |        |        |
| 1) Materials and Supplies:                  |        |        |        |
| rain gauges, rebar, meas. tapes, etc.       | 1,000  | 1,000  | 1,000  |
| 2) Publication Costs                        | 0      | 1,000  | 1,000  |
| 3) Other:                                   |        |        |        |
| Communication costs (long distance, FAX)    | 200    | 200    | 200    |
| Tuition Remission (Yr. 1: non-resident GRA) | 13,840 | 0      | 0      |
| Tuition Remission (Yr. 2 & 3: resident GRA) | 0      | 3,562  | 3,918  |
| Total Other Direct Costs                    | 15,040 | 5,762  | 6,118  |

|                                       | Year 1       | Year 2       | Year 3       |
|---------------------------------------|--------------|--------------|--------------|
| <b>F. Total Direct Costs</b>          | 47,835       | 37,712       | 39,279       |
| <b>G. Indirect Costs</b>              |              |              |              |
| Off Campus: 26% of MTDC.              |              |              |              |
| Predetermined for the period 7/1/93 - |              |              |              |
| 6/30/96, provisional thereafter.      |              |              |              |
| Per HHS agreement dated 10/20/93.     | <u>8,319</u> | <u>8,879</u> | <u>9,194</u> |
| <b>H. Total Costs</b>                 | \$56,154     | \$46,591     | \$48,473     |

**Total requested from NSF for three years: \$151,218**

*This Institution will cost-share in compliance with NSF policy.*

## SUMMARY

Cumulative: 10/1/95 - 9/30/98

CU Proposal No. 0495.05.0555B

## PROPOSAL BUDGET

## FOR NSF USE ONLY

|                                                                                                                                            |  |  |  |                              |      |                                   |                                           |
|--------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|------------------------------|------|-----------------------------------|-------------------------------------------|
| ORGANIZATION<br>The Regents of the University of Colorado                                                                                  |  |  |  | PROPOSAL NO.                 |      | DURATION (MONTHS)                 |                                           |
| PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR<br>John Pitlick                                                                                    |  |  |  | AWARD NO.                    |      | Proposed                          | Granted                                   |
| A. SENIOR PERSONNEL: PI/PI, Co-PIs, Faculty and Other Senior Associates<br>(List each separately with title, A.7. show number in brackets) |  |  |  | NSF FUNDED<br>Person-mos.    |      | Funds<br>Requested by<br>Proposer | Funds<br>Granted by NSF<br>(If Different) |
|                                                                                                                                            |  |  |  | CAL                          | ACAD | SUMR                              |                                           |
| 1. PI: John Pitlick                                                                                                                        |  |  |  |                              |      | 3                                 | 14,129 \$                                 |
| 2.                                                                                                                                         |  |  |  |                              |      |                                   |                                           |
| 3.                                                                                                                                         |  |  |  |                              |      |                                   |                                           |
| 4.                                                                                                                                         |  |  |  |                              |      |                                   |                                           |
| 5.                                                                                                                                         |  |  |  |                              |      |                                   |                                           |
| 6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)                                                                               |  |  |  |                              |      |                                   |                                           |
| 7. ( 1 ) TOTAL SENIOR PERSONNEL (1-6)                                                                                                      |  |  |  |                              |      | 3                                 | 14,129                                    |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)                                                                                              |  |  |  |                              |      |                                   |                                           |
| 1. ( ) POST DOCTORAL ASSOCIATES                                                                                                            |  |  |  |                              |      |                                   |                                           |
| 2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)                                                                                  |  |  |  |                              |      |                                   |                                           |
| 3. ( 1 ) GRADUATE STUDENTS                                                                                                                 |  |  |  |                              |      |                                   | 54,138                                    |
| 4. ( ) UNDERGRADUATE STUDENTS                                                                                                              |  |  |  |                              |      |                                   |                                           |
| 5. ( ) SECRETARIAL - CLERICAL                                                                                                              |  |  |  |                              |      |                                   |                                           |
| 6. ( ) OTHER                                                                                                                               |  |  |  |                              |      |                                   |                                           |
| TOTAL SALARIES AND WAGES (A+B)                                                                                                             |  |  |  |                              |      |                                   | 68,267                                    |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)                                                                                            |  |  |  |                              |      |                                   | 6,639                                     |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)                                                                                          |  |  |  |                              |      |                                   | 74,906                                    |
| D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$1,000.)                                                      |  |  |  |                              |      |                                   |                                           |
| 1, 2 Gigabyte hard drive                                                                                                                   |  |  |  |                              |      |                                   |                                           |
| TOTAL PERMANENT EQUIPMENT                                                                                                                  |  |  |  |                              |      |                                   | 2,000                                     |
| E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)                                                                                  |  |  |  |                              |      |                                   | 21,000                                    |
| 2. FOREIGN                                                                                                                                 |  |  |  |                              |      |                                   |                                           |
| F. PARTICIPANT SUPPORT COSTS                                                                                                               |  |  |  |                              |      |                                   |                                           |
| 1. STIPENDS \$                                                                                                                             |  |  |  |                              |      |                                   |                                           |
| 2. TRAVEL                                                                                                                                  |  |  |  |                              |      |                                   |                                           |
| 3. SUBSISTENCE                                                                                                                             |  |  |  |                              |      |                                   |                                           |
| 4. OTHER                                                                                                                                   |  |  |  |                              |      |                                   |                                           |
| ( ) TOTAL PARTICIPANT SUPPORT COSTS                                                                                                        |  |  |  |                              |      |                                   |                                           |
| G. OTHER DIRECT COSTS                                                                                                                      |  |  |  |                              |      |                                   |                                           |
| 1. MATERIALS AND SUPPLIES                                                                                                                  |  |  |  |                              |      |                                   | 3,000                                     |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISEMINATION                                                                                            |  |  |  |                              |      |                                   | 2,000                                     |
| 3. CONSULTANT SERVICES                                                                                                                     |  |  |  |                              |      |                                   |                                           |
| 4. COMPUTER (ADPE) SERVICES                                                                                                                |  |  |  |                              |      |                                   |                                           |
| 5. SUBCONTRACTS                                                                                                                            |  |  |  |                              |      |                                   |                                           |
| 6. OTHER including tuition remission of \$21,320                                                                                           |  |  |  |                              |      |                                   | 21,920                                    |
| TOTAL OTHER DIRECT COSTS                                                                                                                   |  |  |  |                              |      |                                   | 26,920                                    |
| H. TOTAL DIRECT COSTS (A THROUGH G)                                                                                                        |  |  |  |                              |      |                                   | 124,826                                   |
| I. INDIRECT COSTS (SPECIFY RATE AND BASE)                                                                                                  |  |  |  |                              |      |                                   |                                           |
| OFF CAMPUS: 26% of MTDC (\$101,506)                                                                                                        |  |  |  |                              |      |                                   |                                           |
| TOTAL INDIRECT COSTS                                                                                                                       |  |  |  |                              |      |                                   | 26,392                                    |
| J. TOTAL DIRECT AND INDIRECT COSTS (H+I)                                                                                                   |  |  |  |                              |      |                                   | 151,218                                   |
| K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)                                                         |  |  |  |                              |      |                                   |                                           |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)                                                                                               |  |  |  |                              |      |                                   | \$151,218                                 |
| M. COST SHARING: PROPOSED LEVEL \$                                                                                                         |  |  |  | AGREED LEVEL IF DIFFERENT \$ |      |                                   |                                           |
| PI/PI TYPED NAME & SIGNATURE*                                                                                                              |  |  |  | DATE                         |      | FOR NSF USE ONLY                  |                                           |
| INST. REP. TYPED NAME & SIGNATURE*                                                                                                         |  |  |  | DATE                         |      | INDIRECT COST RATE VERIFICATION   |                                           |
|                                                                                                                                            |  |  |  |                              |      | Date checked                      | Date of rate sheet                        |
|                                                                                                                                            |  |  |  |                              |      | Initials-ORG                      |                                           |

NSF FORM 1030 (1/94) Supersedes All Previous Editions

\*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

## Current and Pending Support

|                                                                                                                                                                              |  |                                                                                   |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------------------------|--|
| The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal. |  |                                                                                   |  |
| Investigator: John Pitlick                                                                                                                                                   |  | Other agencies (including NSF) to which this proposal has been/will be submitted. |  |

|                                                                                                                        |                                  |                                               |                                                            |                                               |
|------------------------------------------------------------------------------------------------------------------------|----------------------------------|-----------------------------------------------|------------------------------------------------------------|-----------------------------------------------|
| Support:                                                                                                               | <input type="checkbox"/> Current | <input checked="" type="checkbox"/> Pending X | <input type="checkbox"/> Submission Planned in Near Future | <input type="checkbox"/> *Transfer of support |
| Project/Proposal Title: Investigation of Runoff and Sediment Yield from Pinyon-Juniper Watersheds, Northern New Mexico |                                  |                                               |                                                            |                                               |
| Source of Support: NSF (this proposal)                                                                                 |                                  |                                               |                                                            |                                               |
| Award Amount (or Annual Rate): \$ 151,000                                                                              |                                  | Period Covered: 10/95 - 9/98                  |                                                            |                                               |
| Location of Research: The University of Colorado at Boulder                                                            |                                  |                                               |                                                            |                                               |
| Person-Months Committed to the Project:                                                                                |                                  | Cal:                                          | Acad:                                                      | Summ: 1                                       |

|                                                                                                                            |                                    |                                  |                                                            |                                               |
|----------------------------------------------------------------------------------------------------------------------------|------------------------------------|----------------------------------|------------------------------------------------------------|-----------------------------------------------|
| Support:                                                                                                                   | <input type="checkbox"/> Current X | <input type="checkbox"/> Pending | <input type="checkbox"/> Submission Planned in Near Future | <input type="checkbox"/> *Transfer of support |
| Project/Proposal Title: Impact of Flows and Geomorphology on Food-Web Dynamics of the Colorado River Native Fish Community |                                    |                                  |                                                            |                                               |
| Source of Support: U.S. Fish and Wildlife Service                                                                          |                                    |                                  |                                                            |                                               |
| Award Amount (or Annual Rate): \$ 115,000                                                                                  |                                    | Period Covered: 4/94 - 9/96      |                                                            |                                               |
| Location of Research: The University of Colorado at Boulder                                                                |                                    |                                  |                                                            |                                               |
| Person-Months Committed to the Project:                                                                                    |                                    | Cal:                             | Acad:                                                      | Summ: 1                                       |

|                                                                                                    |                                    |                                  |                                                            |                                               |
|----------------------------------------------------------------------------------------------------|------------------------------------|----------------------------------|------------------------------------------------------------|-----------------------------------------------|
| Support:                                                                                           | <input type="checkbox"/> Current X | <input type="checkbox"/> Pending | <input type="checkbox"/> Submission Planned in Near Future | <input type="checkbox"/> *Transfer of support |
| Project/Proposal Title: Channel Change in the Ruby-Horsethief Canyon Reaches of the Colorado River |                                    |                                  |                                                            |                                               |
| Source of Support: U.S. Fish and Wildlife Service                                                  |                                    |                                  |                                                            |                                               |
| Award Amount (or Annual Rate): \$ 20,000                                                           |                                    | Period Covered: 1/94 - 6/95      |                                                            |                                               |
| Location of Research: The University of Colorado at Boulder                                        |                                    |                                  |                                                            |                                               |
| Person-Months Committed to the Project:                                                            |                                    | Cal:                             | Acad:                                                      | Summ: 1                                       |

|                                                                                                                                        |                                    |                                  |                                                            |                                               |
|----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|----------------------------------|------------------------------------------------------------|-----------------------------------------------|
| Support:                                                                                                                               | <input type="checkbox"/> Current X | <input type="checkbox"/> Pending | <input type="checkbox"/> Submission Planned in Near Future | <input type="checkbox"/> *Transfer of support |
| Project/Proposal Title: Doctoral Dissertation Research: Changes in River Morphology and Endangered Fish Habitats of the Colorado River |                                    |                                  |                                                            |                                               |
| Source of Support: NSF                                                                                                                 |                                    |                                  |                                                            |                                               |
| Award Amount (or Annual Rate): \$ 9,500                                                                                                |                                    | Period Covered: 6/93 - 11/95     |                                                            |                                               |
| Location of Research: The University of Colorado at Boulder                                                                            |                                    |                                  |                                                            |                                               |
| Person-Months Committed to the Project:                                                                                                |                                    | Cal:                             | Acad:                                                      | Summ: none                                    |

|                                                             |                                  |                                  |                                                            |                                               |
|-------------------------------------------------------------|----------------------------------|----------------------------------|------------------------------------------------------------|-----------------------------------------------|
| Support:                                                    | <input type="checkbox"/> Current | <input type="checkbox"/> Pending | <input type="checkbox"/> Submission Planned in Near Future | <input type="checkbox"/> *Transfer of support |
| Project/Proposal Title:                                     |                                  |                                  |                                                            |                                               |
| Source of Support:                                          |                                  |                                  |                                                            |                                               |
| Award Amount (or Annual Rate): \$                           |                                  | Period Covered:                  |                                                            |                                               |
| Location of Research: The University of Colorado at Boulder |                                  |                                  |                                                            |                                               |
| Person-Months Committed to the Project:                     |                                  | Cal:                             | Acad:                                                      | Summ:                                         |