

USGS-WATER QUALITY PARTNERSHIP, FIXED STATION

Hydrologic response to woodland restoration treatment (IMR-BAND #110113)

Abstract

Overland runoff and associated sediment production at Bandelier National Monument threaten the integrity of both a wilderness landscape and the thousands of pre-historic cultural resources it contains. Restoration studies conducted at multiple scales at Bandelier since 1992 have demonstrated the potential of slash-mulching restoration treatments in degraded woodland areas to promote herbaceous growth and stabilize eroding soils; in 1996 a paired, 40 ha watershed restoration study area was established to evaluate landscape scale effects of restoration treatment. Subsequently, two separate hydrologic assessments were initiated within the watershed study area to quantify and monitor the long term effects of the restoration treatment on runoff and sediment production. The first (2000-2001) was designed to quantify differences between the treated and untreated watersheds for bed-sediment production as measured in six 0.1 ha catchment areas in each 40 ha watershed. The second (2002-2004) was designed to quantify differences in runoff and suspended-sediment production between treated and untreated watersheds by instrumenting a 0.38 ha catchment in each watershed. The bed-sediment production study documented a two order magnitude difference between the two watersheds for the two years sampled; the runoff/ suspended sediment study however, has suffered from a relative absence of significant precipitation events since it was initiated in 2002. The current proposal is a request for funding to continue fixed station monitoring of runoff and suspended sediment for an additional three years, given the initial investment to instrument the two 0.38 ha catchment areas and the absence of significant results to date. Continued operation of the two stations would provide an opportunity to sample a sufficient number and range of runoff events necessary to properly quantify differences in hydrologic response between treated and untreated areas.

Problem

Bandelier National Monument (BAND), a mountain wilderness and cultural landscape of abandoned pre-historic settlements, was established to preserve the unique ancestral remains of Puebloan Indian peoples. Rapid soil loss in degraded woodlands, where most of the cultural resources are located, is unsustainable and threatens the integrity of thousands of pre-historic cultural sites. Without concerted management action to stabilize soils, significant and irreversible losses of natural and cultural resources will likely occur within the next 100 years. In addition, accelerated soil erosion and the loading of streams with sediment can contribute to the degradation of watershed values including water quality. Restoration studies conducted at multiple scales at Bandelier have demonstrated the potential for the slash-mulching treatment to promote herbaceous growth and stabilize eroding soils. In 1996, a paired, 40 ha watershed restoration study area was established to evaluate the effects of restoration treatment at landscape scales. Subsequently, two separate hydrologic assessments were initiated within the watershed study area to quantify and monitor the effects of landscape scale restoration treatments on runoff and sediment production. The first study, during 2000-2001, was designed to quantify differences in bed-sediment

production between the treated and untreated watersheds as measured in six 0.1 ha catchments in each 40 ha watershed. The second study, during 2002-2004, was designed to quantify differences in runoff and suspended-sediment production between the treated and untreated watersheds as measured in 0.38 ha catchments located within each of the 40 ha watersheds (fig. 1). The 0.38 ha catchment study was a cooperative effort between the U.S. Geological Survey New Mexico Water-Science Center (USGS) and Bandelier National Monument and was funded through the USGS-NPS Water Quality Partnership Program (Partnership Program).

The final year of Partnership Program funding for the 0.38 ha catchment study was 2004. During the two planned field seasons (2002-2003), data-collection efforts suffered from a lack of significant precipitation events due to regional drought. Sampling and data analysis plans were predicated on an antecedent historic frequency of 6 measurable runoff events per monsoon season (generally July-September). However, because of severe drought conditions, there were few measured and sampled runoff events (see the following "Previous Work" section for details). Given the absence of measurable events during the two planned field seasons, final year (2004) funding originally slated for data analysis and report preparation was instead used to support a third year of data collection.

Preliminary results for the runoff and sampled events suggest that slash-mulching treatment is effective at decreasing runoff and sediment transport. However, the data are insufficient to quantitatively demonstrate the effects of the restoration treatment on runoff and sediment transport or validate the effectiveness of slash-mulching as the preferred management alternative for protecting natural and cultural resources. While future precipitation patterns cannot be reliably predicted, it is anticipated that three additional years of monitoring should capture sufficient runoff events to enable proper quantification of treatment differences.

Previous Work

The proposed study is a continuation of the previously funded (2002-2004) USGS-NPS Partnership Program work (BAND #47466). Two comparable 0.38 ha catchment areas (i.e. similar size, aspect, and topographic position) were selected to provide a basis for runoff and suspended-sediment transport comparisons between the treated and untreated watersheds. Both of the 0.38 ha catchments are west facing, with an axial length of about 90 meters and slope of greater than 45 percent. Soils in both 0.38 ha catchments are primarily weathered tuffs, although the untreated 0.38 ha catchment contains weathered pumice soils at the lower end. Pre-restoration treatment vegetative cover data were comparable between the two catchments.

During the 2002 monsoon season there were only 2 measurable runoff events. The first occurred in June prior to flume and autosampler installation. The second occurred in September, but the autosamplers did not activate because the conductivity of the runoff was less than the autosamplers' conductivity sensor trigger threshold of 20 microsiemens per centimeter. In June 2002 the autosamplers at the monitoring sites were retrofitted with relay switches that are turned on by datalogger software when flow in the flume equals or exceeds a depth of 0.05 feet. Also in 2002, an autosampler was added to existing flow-

measurement instrumentation at the nearby Frijolito Watershed Study area to collect runoff samples and determine suspended-sediment concentrations. Because of low runoff conductivity, as noted above, the Frijolito Watershed autosampler did not collect any samples during 2002. This autosampler was retrofitted with a float switch to activate the autosampler.

The 2003 monsoon season began much later than usual and again produced only two measurable runoff events. Rainfall on August 25, 2003 and September 9, 2003 was of sufficient amount and intensity to produce runoff in both 0.38 ha catchments (figs. 2 and 3). The amount of rainfall in the treated catchment was essentially the same as in the untreated catchment for both the August 25 and September 9 events (fig. 2 and 3). However, only the runoff in the untreated catchment was of sufficient magnitude to initiate the datalogger's 5-second recording mode (5-second recording initiates if the water level in the flume equals or exceeds 0.05 feet). The August 25 event did not produce a sufficient depth of flow in either the treated or untreated catchment flume for successful suspended-sediment sampling. Even though the amount of rainfall on September 9 (0.37 in) was about half of the amount of August 25 rainfall (0.67 in) the intensity of the September 9 rainfall produced peak flow large enough for successful sampling in the untreated catchment. Flow recording and sample analysis indicate that about 63 cubic feet of water and about 22.5 kilograms of suspended-sediment passed through the untreated catchment flume on September 9 for an average suspended-sediment concentration of 12.6 milligrams per liter (fig 4).

The 2004 monsoon season was an improvement over the previous two years and produced several events that were both measurable and that activated the samplers. At the untreated catchment, runoff events were recorded and sampled on July 27, August 6, August 10, August 18, and October 5. At the treated catchment the very first set of samples was obtained on October 5. Data for the 2004 monsoon season have not yet been analyzed.

During FY2002-04 funding for this project was spend on gauging supplies and equipment, installation of equipment in the 0.38 ha catchments, sampling supplies, sample analyses, salary for equipment operation, maintenance, and upgrades, and salary to administer the project. Operation and maintenance of the electronic equipment and autosamplers at the remote 0.38 ha catchments requires a significant investment of time to ensure that all systems are working properly and that capture of data for the rare runoff events is optimized. Due to the paucity of data, the final year of funding that would have been used to generate and publish a final report was instead used to operate the stations for an additional year. Annual investigator reports were provided to NPS.

Objectives

The core objectives of this proposal, as a continuation of the "Hydrologic Response to a Watershed Restoration Treatment" study, are very similar to those of the original proposal. That is, to quantify the effects of the slash-mulching restoration treatment on runoff and suspended-sediment production from two 0.38 ha catchments located in treated and untreated 40 ha watersheds.

Specific objectives of this proposal are to:

- 1) Characterize runoff thresholds for storms of varying size and duration within and between treatments;
- 2) Quantify runoff and suspended-sediment production for a range of precipitation events, and as an indicator of treatment effect; and
- 3) Obtain a larger and more representative baseline monitoring data set by extending the sample collection period beyond that of the first study and by modifying equipment at the sampling sites to insure that smaller-magnitude events (lower flows) can be sampled.

Methods

Monitored rainfall amount and intensity, runoff rate and duration in each of the 0.38 ha catchments will be used to determine what storm magnitudes and intensities initiate runoff in the treated and untreated catchments. Rainfall amount and intensity will be recorded in each 0.38 ha catchments using tipping bucket rain gages with data loggers that have been installed near the center of the each catchment. The rain gages, installed and operated by Bandelier personnel, record precipitation with a resolution of 0.01 inch. A soil-moisture probe will be installed in each catchment and the data will be recorded on CR10X data loggers.

Runoff and suspended-sediment production will be measured in each 0.38 ha catchment using the hydrologic monitoring equipment installed in 2001 at the base of each 0.38 ha catchment area. Each monitoring station currently (2004) consists of a critical-flow flume, water depth (stage) pressure sensor, and automated sediment sampler (autosampler). The critical-flow flume is designed to accommodate sediment transport through the flume at the expected ranges of discharge. Equipment at each monitoring station is powered with a solar panel/battery system of sufficient capacity to run the data logger and autosampler for typical storm events. Stage readings are recorded on a CR10X data logger at 5-second intervals when water height in the flume exceeds 0.05 feet and are recorded at hourly intervals when water height is less than 0.05 feet. Stage data are converted to discharge using rating data developed by the manufacturer for the flumes. Stage data are downloaded from the CR10X data loggers using a laptop or hand-held computer and are transferred to the USGS Automated Data-Processing System (ADAPS) database where the flume rating data is used to convert stage values to discharge values. Stage data will be downloaded and the equipment serviced on approximately a monthly basis during the summer monsoon season and after each significant rainfall event.

Because of problems encountered in sampling low flows in the flumes (air is sucked into the autosampler tube for water depths of less than about 0.1 feet) a flow-concentrating trough will be added to the downstream end of each flume. The troughs will have a v-shaped cross section to concentrate flow into a width that is narrower than the flumes. The troughs will be positioned such that water exiting the flume

will free fall about 2 inches before entering the trough so as not to impede flow in the flume. The narrower width of the trough will increase the water depth as compared to the flume and enable the autosampler to sample lower flow events without sucking air.

Snowmelt runoff will not be measured, because it has been observed that most sediment movement occurs in association with the more intense summer precipitation events. The monitoring equipment will be operated during the normal monsoon season (late June -September) with operation extended from May through October as funding allows. Runoff during all precipitation events during the operational time will be sampled using an autosampler. Sediment sampling intervals, currently set at the shortest possible interval (1 minute), may be adjusted to span the expected duration of streamflow events as data is collected. Events recorded thus far have lasted 15 minutes or less. The autosampler intake tubes will be positioned at similar depths in the flow-concentrating troughs at both the treated and untreated sites to obtain comparable samples.

Discharge and suspended-sediment concentration data will be used to compute the load (i.e. kilograms per year) of suspended-sediment being transported out of the 0.38 ha catchments. If samples are obtained for enough rainfall events an estimate of the average suspended-sediment yield from treated and untreated catchments will be calculated for the magnitude and intensity ranges of the storms that were sampled.

Data from a climatological station in the nearby Frijolito Watershed can be accessed remotely from Bandelier park headquarters to provide current information on storm magnitude and intensity. After storms of sufficient magnitude and intensity, Bandelier personnel will notify USGS personnel of the event and the possibility that runoff and sampling occurred. If storm events are of such duration and frequency that sample bottles in an autosampler are full and USGS personnel cannot respond quickly, Bandelier personnel will replace the full bottles with empty bottles. Full sample bottles will be stored at Bandelier offices until retrieved by USGS personnel. Samples from the 0.38 ha catchments will be analyzed for suspended-sediment concentration either at a USGS sediment lab in Albuquerque, New Mexico or Des Moines, Iowa.

Suspended-sediment measurements in the Frijolito Watershed Study area will be supported using an autosampler at a flume located at the downstream end of the study area. The autosampler intake tube is positioned at the upstream end of the flume about 1 inch above the streambed such that only suspended sediment should be drawn into the autosampler. The flume is equipped with a pressure transducer that measures the stage in the flume. Stage is converted to discharge using rating curves developed for the flume. Samples from the Frijolito Watershed will be analyzed by Bandelier personnel using methodology presented by Guy (1969).

Discussion

Bandelier National Monument is a unique wilderness landscape, harboring abandoned pre-historic settlements that are increasingly threatened by accelerated and unsustainable soil erosion. Davenport and others (1998) and Allen and Breshears (1998) have estimated that at current estimated erosion rates (1 cm per year) intercanopy areas would completely lose soil cover in about 200 years. Cultural sites at Bandelier are national treasures that should be preserved to the best of our ability. To this end, natural- and cultural-resource managers need reliable information about the effectiveness of preferred management restoration treatments for controlling runoff and soil erosion, across a range of precipitation intensities and relative to time since treatment.

Data from this study will support EIS level planning and implementation of proposed woodland restoration at Bandelier by quantifying hydrologic response to preferred treatment options and providing defensible baseline monitoring data across a range of precipitation events. These baseline data will also be used as the foundation of long term monitoring efforts associated with the planned large scale restoration at the monument. Methods and findings from this study should also be applicable to other culturally significant, semi-arid landscapes experiencing accelerated soil erosion.

Quality Assurance

Stream stage, sediment, and precipitation data obtained during the proposed work will be collected and processed in accordance with procedures described in the USGS New Mexico District's quality assurance plan (U.S. Geological Survey, 1997). The critical-flow flumes were installed in accordance with procedures described by Rantz (1982). Instream discharge will be measured with a graduated 1000 ml beaker and stop watch if USGS personnel are present during a runoff event. Park personnel have been trained by USGS personnel in the use, care, and maintenance of the autosamplers. Samples will be analyzed using procedures described by Guy (1969).

Data Management

Both streamflow and sediment-concentration data will be stored in the National Water Information System (NWIS) database. Streamflow data will be retrievable through the ADAPS program, whereas sediment-concentration data will be retrievable through the QWDATA program. Stream stage and precipitation data will be downloaded monthly from data loggers during the field season. Stream stage and sampling times will be downloaded in the field using laptop or handheld computers and subsequently transferred to the USGS ADAPS database. The ADAPS database is backed up daily. Suspended-sediment samples will be retrieved from the autosampler on an event basis by USGS or Bandelier personnel. Samples retrieved by Bandelier personnel are stored in a secure location for later pickup by USGS staff.

Products

A USGS Fact Sheet that describes in general terms the long-term implications of sediment erosion and the potential loss of cultural history and degradation of watershed and water-quality conditions at Bandelier will be written during the first year of the study. The Fact Sheet will be useful as a tool to raise the awareness of the general public as to the consequences of soil erosion on cultural resources and the potential for slash-mulching restoration treatments to significantly slow soil erosion.

The specific results of the study will be documented in a USGS Scientific Investigations Report to be written during the last year of study. The runoff, suspended sediment, and precipitation datasets will be provided to Bandelier on CD in excel format.

Safety

Appropriate safety procedures will be followed at all times and all personnel will read and become familiar with the Job Hazard Analyses developed for this project. All personnel present at the study sites during construction activities shall wear clothing as appropriate for work and weather conditions. All personnel should be cognizant of weather conditions and take appropriate action if the weather deteriorates. Lightning strikes occur frequently during the summer monsoon season.

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Budget

Federal Fiscal Year (Oct. – Sept.)			
Budget Item	FY2006	FY2007	FY2008
Labor	20,700	13,280	26,070
Travel and transportation	1,000	1050	1,200
Supplies	500	410	370
Equipment repair/replacement	2,000	2100	0
Vehicle fuel and maintenance	500	520	250
Laboratory sediment analyses	5,250	5,250	0
Preparation of figures for publication	600	0	1,200
Printing (published reports)	500	0	800
Distributed Direct Science Surcharge ¹	8,610	5,790	9,960
Total Net Cost	39,660	28,400	39,850
Facilities ²	0	0	0
Common Services ³	6,880	4,630	7,970
TOTAL COST	46,540	33,030	47,820

¹The Distributed Direct Science Surcharge line item is a net cost to every project in the USGS New Mexico Water Science Center. This cost primarily pays for salaries of project supervisors, publication staff salaries, ground-water specialist, surface-water specialist, and water-quality specialist salaries, and program development.

²The Common Services line item is primarily an assessment for the local office's administrative staff salary, District Chief salary, computer supplies and services, and general office supplies, but also includes assessments for Regional and Headquarters staff and science-support programs.

³The Facilities line item pays for local office and warehouse space. The facilities assessment is zero for this project because the facilities costs are not assessed on USGS direct funding.

Workplan

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Personnel:

[illegible]

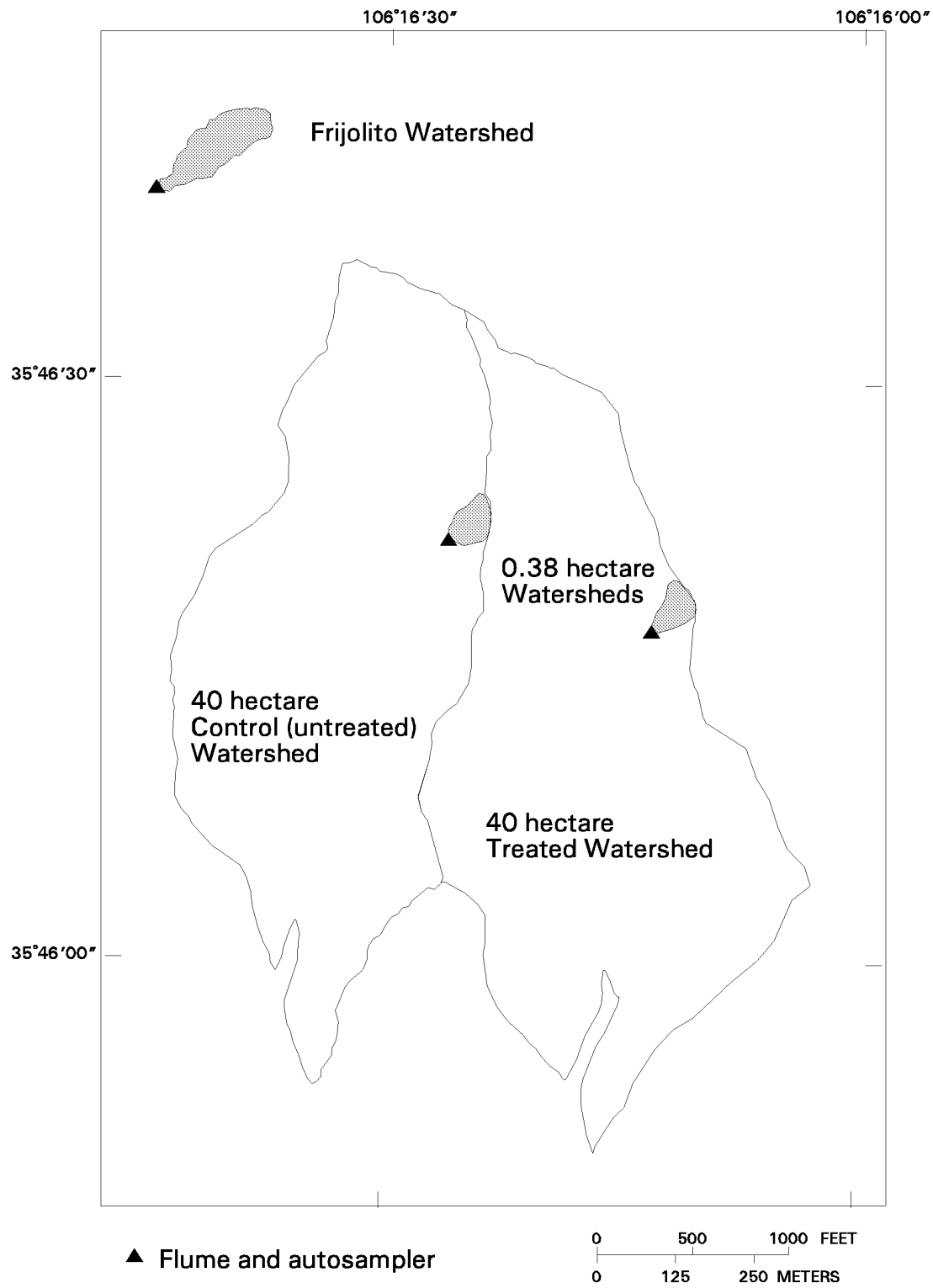


Figure 1. Location of watersheds

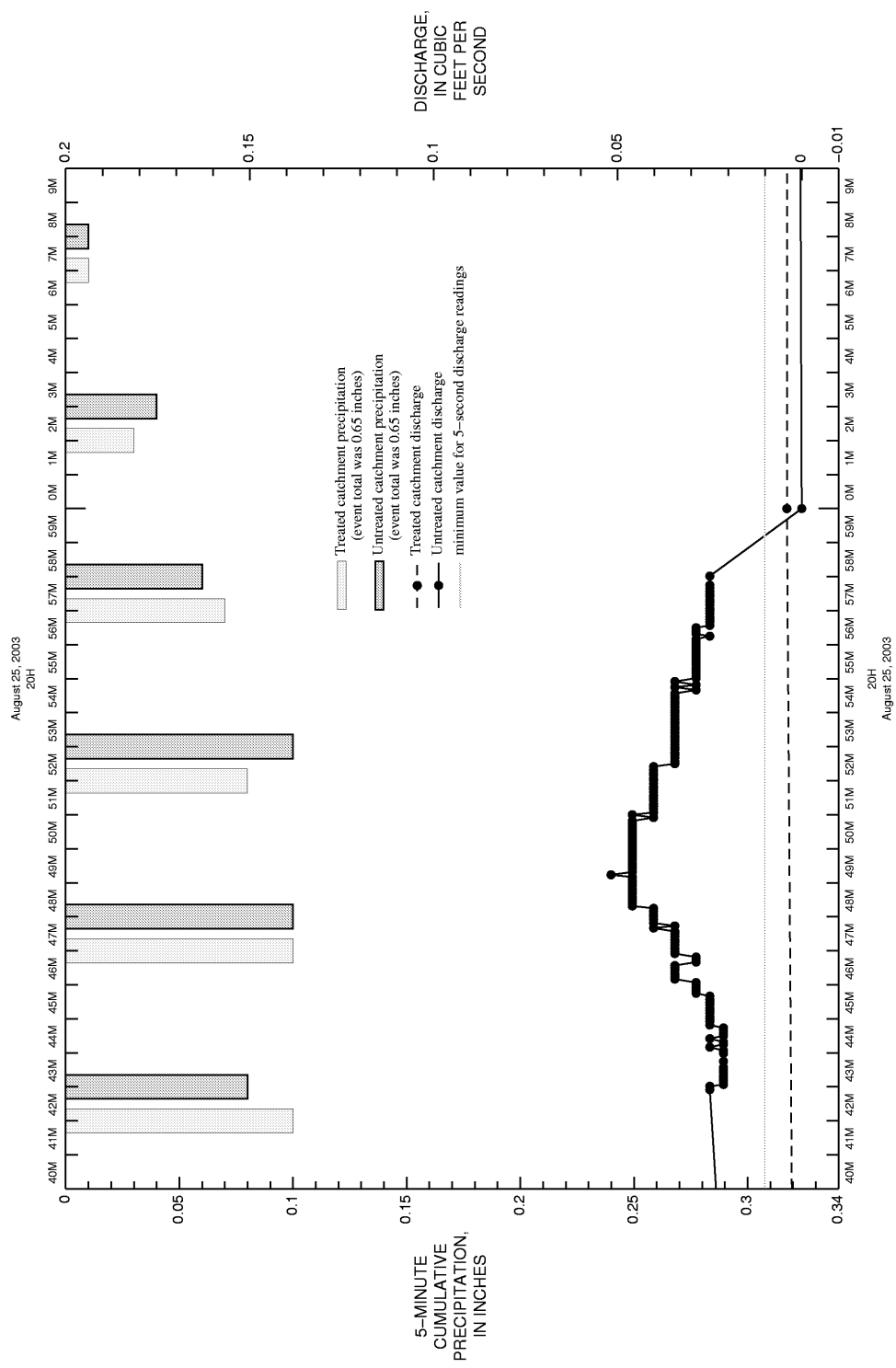


Figure 2. August 25, 2003 precipitation and runoff.

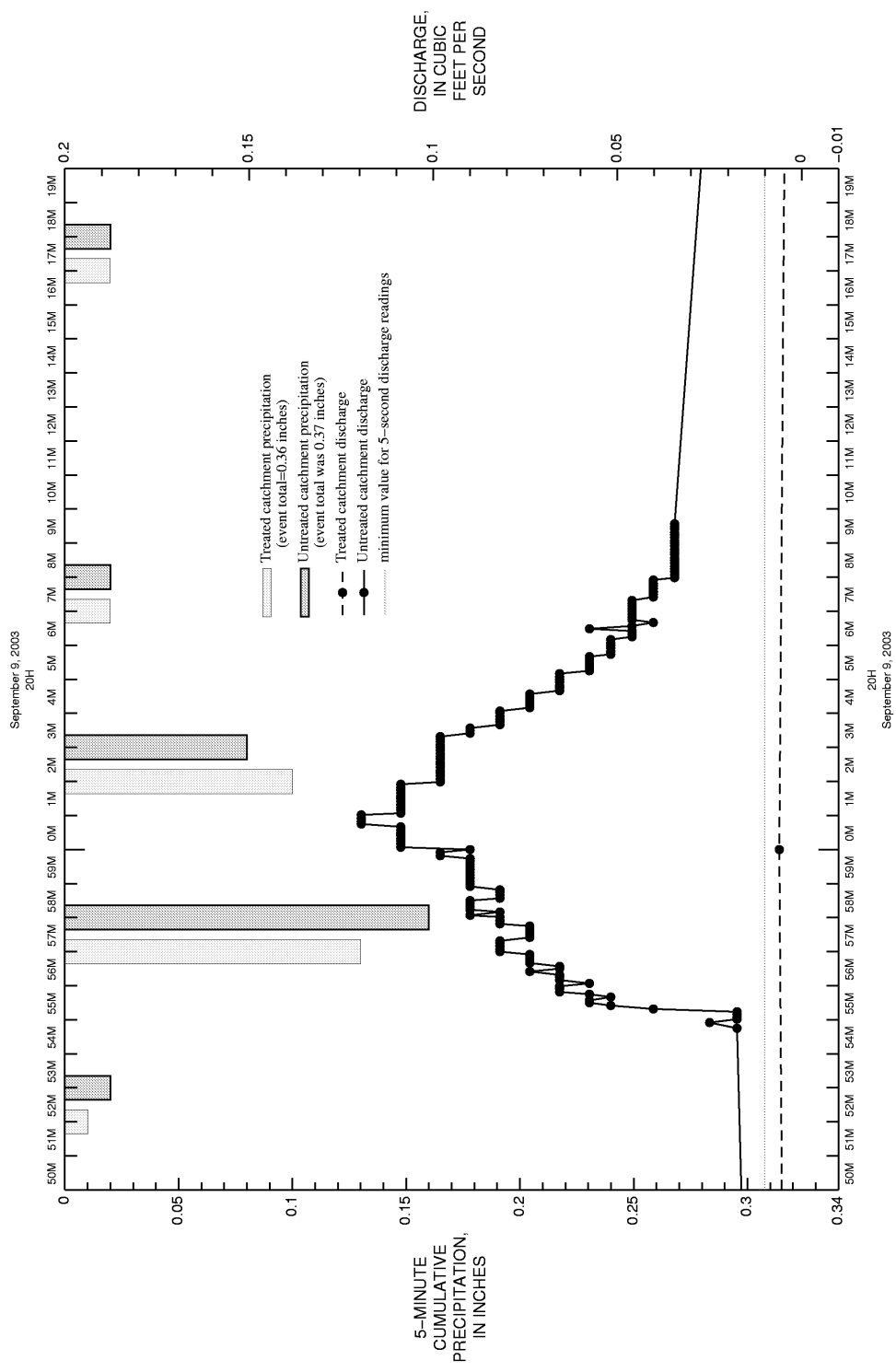


Figure 3. September 9, 2003 precipitation and runoff.

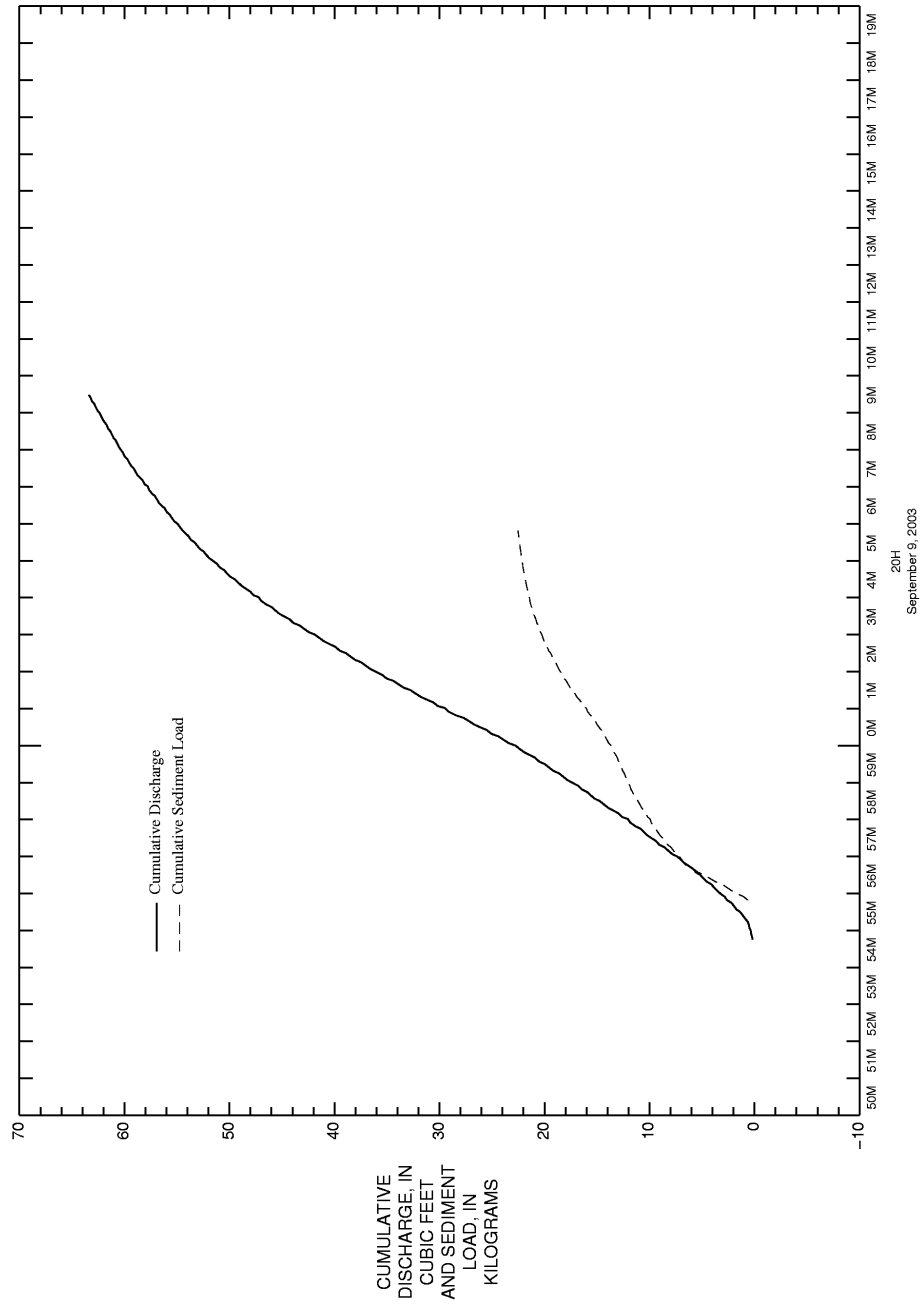


Figure 4. September 9, 2003 cumulative discharge and sediment load.

