CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: U.S. Geological Survey training course entitled "Sediment Data-Collection Techniques" (SW1091TC)
(AI 06002.01.362.530)

DATE/PLACE: March 13–18, 2005
Castle Rock, Washington

AUTHOR: Donald Hooper, Research Scientist
Center for Nuclear Waste Regulatory Analyses (CNWRA) at
Southwest Research Institute® (SwRI®)

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PERSONS PRESENT:

One staff member from the Center for Nuclear Waste Regulatory Analyses attended the training course. A total of 32 scientists enrolled in the course, which was taught by a team of U.S. Geological Survey staff members with John Gray as course leader and coordinator.

BACKGROUND AND PURPOSE OF TRIP:

This training course in Castle Rock, Washington, near Mount St. Helens, provided instruction in basic sediment data-collection techniques with principal emphasis on the following: (i) basic sediment concepts; (ii) sampler characteristics; (iii) field techniques; (iv) direct sampling with suspended sediment, bed material, and bedload samplers; (v) computation of sediment discharge records; (vi) quality-assurance procedures; and (vii) estimating sediment properties from surrogate technologies based on bulk optic, digital optic, laser, acoustic, and pressure-differential principles. The final two days of the course featured trips to Mount St. Helens and the Cascades Volcano Observatory Sediment Laboratory in Vancouver, Washington.

Castle Rock, Washington, is less than 35 driving miles west of Mount St. Helens. Field exercises and sediment sampling were held at the South Fork Toutle River gage and a reach of the North Fork Toutle River. These rivers contain volcaniclastic material derived from the 1980 Mount St. Helens eruption. A small explosive event occurred at the volcano on March 8, 2005, sending a steam-and-ash plume to an altitude of 36,000 feet above sea level and drifting to the east-northeast. No noteworthy activity occurred during the week of the field class.

SUMMARY OF PERTINENT POINTS:

After an introduction and discussion of safety, the first day (Monday) of the course began with a review of basic fluvial sediment concepts and physical properties of fluvial sediment. The training then focused on the design and function of suspended-sediment samplers and sampling techniques. In the afternoon, participants traveled to the South Fork Toutle River bridge and were divided into groups that rotated through five different activities (stations):

(i) sampling suspended sediment in a partial cross-section using the DH-59 sampler and an equal-discharge increment technique, (ii) sampling suspended-sediment in a partial cross-section using the DH-95 sampler and an equal-width increment technique, (iii) sampling suspended sediment at a single vertical from a bridge box using the D-74 sampler with an A-reel, (iv) sampling with a D-96 bag sampler at a single vertical, and (v) sampling suspended sediment at a single vertical using the P-61 sampler and an E-reel. The suspended sediment load is in most instances dominated by clay- and silt-sized particles, and is generally easier to measure than bedload. Sediment concentrations were low (below normal for March) because of the recent lack of precipitation.

The samplers used in these exercises have been developed by the Federal Inter-Agency Sedimentation Project (FISP) and use the following codes: D, depth sampling; H, hand-held by rod or line; P, point integrating; BM, bed material; and BL, bedload sampler. The two digits represent the year in which the sampler was developed. When a suspended-sediment sampler is submerged with the nozzle pointing directly into the flow, a part of the streamflow enters the sampler container through the nozzle as air in the container exhausts under the combined effect of three forces: (i) the positive dynamic head at the nozzle entrance, due to the flow; (ii) a negative head at the end of the air-exhaust tube, due to flow separation; and (iii) a positive pressure due to a difference in elevation between the nozzle entrance and the air-exhaust tube. Most samplers are designed to operate isokinetically and serve as a tool for obtaining a representative sample. A representative suspended-sediment sample will have a sediment concentration and size distribution equal (or similar) to that averaged over the stream cross-section when the sample was collected. The first evening concluded with a discussion of the day's activities and a video on flow in alluvial channels.

The second morning featured lectures on the following: (i) U.S. Geological Survey National Sediment Laboratory Quality Assurance Program, (ii) computation of suspended-sediment records, (iii) Graphical Constituent Load Analysis System (GCLAS), (iv) bed-material samplers and sampling techniques, and (v) bedload samplers and sampling techniques. Bedload is best defined as sediment that moves by sliding, rolling, or bouncing along on or near the streambed. Bed material is the sediment mixture of which the bed is composed. Noncohesive bed particles enter motion as soon as the shear stress applied on the bed material exceeds the critical shear stress.

After a working lunch viewing an IMAX film of the 1980 eruption of Mount St. Helens volcano, the course participants returned to the same Toutle River bridge. Participants rotated through four stations: (i) sampling bed material using the BM-54 sampler, (ii) sampling with the BL-84 bedload sampler, (iii) pumped samples, and (iv) measuring suspended-sediment concentrations and particles-size distributions with an experimental isokinetic laser profiler. The collection and analysis of material larger than coarse gravel are more difficult and costly because other techniques are required to handle heavy samples. The evening featured a discussion of sediment-surrogate technologies and a video on debris flows, mudflows, and hyperconcentrated flows.

The third day of the training course began with lectures on the measurement and use of turbidity data, research in sediment-surrogate technologies (e.g., laser, digital optic, acoustic, and pressure difference), and sediment-sampling techniques. The group then traveled to a reach of the North Fork Toutle River to conduct the wading exercise. Participants rotated through five stations: (i) equal-discharge increment method sampling, (ii) equal-width increment method sampling, (iii) bed-material particle counts, (iv) discharge measurement techniques, and (v) turbidity measurements. Both the equal-discharge increment and equal-width increment methods were used widely during this training. The equal-discharge increment (or EDI) method involves stream discharge divided into 4 to 9 equal increments of discharge, the collection of velocity- and discharge-weighted samples from the centroid vertical of each discharge increment, a variation of the transit rate among verticals to obtain equal sample volumes, and the analysis of samples individually or as a composite. Similarly, the equal-width increment (or EWI) method involves a stream cross-section divided into 8 to 20 equal-width increments, a sampling transit rate for all sample verticals determined at the deepest/fastest vertical, the collection of velocity-weighted sub-samples from the mid-point vertical in each width increment, and the composite of all sub-samples for analysis.

Because of the rain that began in the early morning, both stream turbidity and suspended-sediment concentration increased during the wading exercise. Water temperature remained roughly constant at 8°C [46°F]. The evening discussion focused on special topics in sediment transport.

The fourth day began with the usual routine of morning lectures. Topics included the design of sediment data-collection programs, stream classification, and a partial summary of analyses from sediment samples collected during the week. In the afternoon, course participants departed for the Coldwater Ridge Visitor Center at Mount St. Helens. From this viewpoint the crater was visible, but the lava dome was mostly shrouded in clouds. Coldwater Lake contains a large debris fan or delta of mostly volcanic material deposited over the past 25 years. Due to schedule changes, weather, and time constraints, the group did not visit the Sediment Retention Structure. The same constraints prevented a hike to the 1980 avalanche and lahar deposits. No sampling was done in the boundaries of the Mount St. Helens National Volcanic Monument. Evening discussions focused on the 1980 and 2004–2005 volcanic activity.

The final day (Friday) of the course was spent at the Cascades Volcano Observatory Sediment Laboratory. This portion of the training focused on the Laboratory Data Management System, data retrieval, laboratory quality assurance and quality control, standardization, and an overview of laboratory sediment analyses.

DISCUSSION:

Continuous monitoring of streamflow and suspended-sediment discharges from disturbed basins following the catastrophic 1980 eruption of Mount St. Helens reveals when, and under what conditions, sediment redistribution occurs following a major landscape disturbance. The redistributed sediment includes material deposited by the 1980 eruption, as well as older sediment that has been remobilized from storage. Watersheds proximally north of the volcano (those most affected by the directed blast) underwent the most severe disturbance because of the large debris avalanche. This primarily comprises the upper North Fork Toutle River valley. Suspended-sediment yields from two lahar-affected basins (South Fork Toutle River and Muddy River) are substantially less than from the avalanche deposit. The Green River, affected solely by the blast current, transported the least suspended sediment (Major, 2004).

Sediment yields in the aftermath of explosive volcanic eruptions typically decline nonlinearly as physical and vegetative processes reduce sediment yield. Twenty years after the catastrophic eruption at Mount St. Helens, suspended-sediment yields remain high (1 to 2 orders of magnitude above background levels) in basins where mass-flow sediments were deposited in channels (Major, 2004). In basins where the geomorphic impact was dominantly hillslope disturbance (e.g., Green River basin), suspended-sediment yields returned to background levels within five years. Therefore, Major (2004) concludes that persistent extraordinary suspended-sediment yields from severely disturbed channels indicate that mobile supplies of sediment remain accessible, and those supplies likely will not be exhausted for many more years or possibly decades.

A process-level model is being developed as part of the Redistribution of Radionuclides in Soil Integrated Subissue to evaluate the long-term redistribution of tephra following a scoria-cone (or violent strombolian) eruption. A sediment budget approach is incorporated to model sediment erosion, storage, and transport processes in fluvial systems. Initial modeling efforts have concentrated on the deposits from three scoria cones with different sediment yields: (i) Parícutin, Mexico, with a high sediment yield; (ii) Sunset Crater, Arizona, with an intermediate sediment yield; and (iii) Lathrop Wells, Nevada, with a low sediment yield. Scoria cones such as Sunset Crater show that substantial tephra deposits can persist for 1,000 years, even with a period of accelerated erosion immediately following the eruption. The extent and character of erosion at each location is a complex function of site-specific processes and characteristics. The Cascade volcanoes, such as Mount St. Helens, differ in both climatological setting and volcano type from what occurs in the Yucca Mountain region of Nevada. However, the Mount St. Helens watershed has had a controlled, rigorous sediment-sampling program for more than 20 years.

This course provided valuable insights into the sedimentary and fluvial characteristics of the Fortymile Wash drainage system at Yucca Mountain. Direct methods of quantifying fluvial sediment discharge include suspended-sediment sampling, bed material sampling, and bedload sampling. Without direct sampling, however, equations based on incipient motion or energy are typically used. Unfortunately, these formulations require discharge measurements and knowledge of size distributions and depth-integrated sediment concentrations. Fortymile Wash is an ephemeral system with minimal sediment discharge and stream-flow information. Appropriate model parameters are being substantiated for expected dryland conditions following a modeled eruption at Yucca Mountain. Therefore, the simplified sediment budget approach employed by CNWRA staff appears to be a viable methodology for estimating sediment yield and long-term fluvial redistribution from the Fortymile Wash drainage system. This investigation presents a new and innovative approach for evaluating tephra remobilization and redistribution processes.

Discussion of sediment yields and fluvial data with members of the U.S. Geological Survey provided useful feedback. Dr. Jon Major noted that he observed a decline in the erosion rate of tephra at Mount St. Helens due to the development of a stable rill network. Dr. Kurt Spicer noted that he could not recall any bedforms indicating hyperconcentrated flow in reworked deposits along the Green River north of Mount St. Helens. Insights gained from these discussions and the training lectures help staff prepare a technical basis to review DOE models that address volcanological and redistribution issues.

CONCLUSIONS:

Participation in training courses provides staff with an opportunity to remain current with relevant technical developments. The goal of this U.S. Geological Survey training course (Sediment

Data-Collection Techniques, SW1091TC) was to acquire the requisite understanding of fluvial-sediment theory, supported with field training, to enable development of a useful sediment data-collection program, and collect and interpret reliable, quality-assured fluvial-sediment data. Widespread landscape disturbance by the catastrophic 1980 eruption of Mount St. Helens, Washington, abruptly increased sediment supply in surrounding watersheds. Locating the training in and around Castle Rock , Washington, offers an opportunity to examine the long-term impacts of volcanically disturbed watersheds, including perturbed runoff hydrology and channel hydraulics, impulsively loaded channels with easily eroded sediment, and greatly increased sediment yields. The magnitude and duration of the redistribution of volcanic material deposited by the eruption varied according to the nature of the original disturbance. Twenty years after the eruption, suspended-sediment yields remain high (1 to 2 orders of magnitude above background levels) in basins where mass-flow sediments were deposited in channels (Major, 2004). In basins where the geomorphic impact was dominantly hillslope disturbance (e.g., Green River), suspended-sediment yields returned to background levels within five years. Therefore, Major (2004) concludes that persistent extraordinary suspended-sediment yields from severely disturbed channels indicate that mobile supplies of sediment remain accessible, and those supplies likely will not be exhausted for many more years or possibly decades.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

It is recommended that a related U.S. Geological Survey course entitled "Geomorphic Analysis of Fluvial Systems" (QW1169TC) be taken in the future.

REFERENCES:

Major, J.J. "Posteruption Suspended Sediment Transport at Mount St. Helens: Decadal-Scale Relationships with Landscape Adjustments and River Discharges." *Journal of Geophysical Research.* Vol. 109. F01002, doi:10.1029/2002JF000010. 2004.

SIGNATURES:

Donald M. Hooper
Research Scientist

March 29, 2005
Date

CONCURRENCE:

Sitakanta Mohanty, Manager
Performance Assessment

March 31, 2005
Date

Larry McKague, Manager
Geology and Geophysics

3/31/05
Date

Budhi Sagar
Technical Director

3/31/05
Date