ORGANIZING NEW METHODS FOR EROSION AND SEDIMENTATION MONITORING AND CONTROL

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ABSTRACT

Historic and continuing land uses at the U.S. Army's Fort Carson and the Pinon Canyon Maneuver Site (PCMS) may degrade training lands and cause erosion and increased sediment loading of local waters. A team of experts from the US Geological Survey, the USDA Agricultural Research Service's Southwest Watershed Research Center, and two offices of the USDA Natural Resources Conservation Service is identifying methods and projects that can be used by Army land managers to evaluate the Army's potential contribution to the regional sediment pollution problem. Projects include site reclamation to control erosion and sediment transport; monitoring of stream flow, climate, and sediment concentrations; prediction of soil erosion; and assessment of rangeland health. Although the team has coordinated several agency projects and improved the overall approach to erosion and sedimentation monitoring and control, new research and technology will ensure additional progress in the future. This will include quantifying the impacts of military land use and training activities and maintaining this information in databases to enable the development of measurement techniques and indicators of ecosystem status, change and damage. Integrated information systems are required to combine the power of modern databases, simulation modeling, and expert judgment in designing and evaluating erosion control measures in terms of erosion and sediment transport processes. Because environmental concerns do not conform to political or administrative boundaries, the Army/ARS/USGS/NRCS team shares ideas and resources to provide both the Army and the regional community with responsible environmental management. Fort Carson's multidisciplinary team adopts the challenge of change, demonstrates new directions in managing highly complex challenges, and validates the federal government's effectiveness and ability to be efficient.

Keywords: erosion, sedimentation, military lands

INTRODUCTION

Historic and continuing land uses at the U.S. Army's Fort Carson and the Pinon Canyon Maneuver Site (PCMS) may degrade training lands and cause erosion and increased sediment loading of local waters. Fort Carson is identifying its potential contribution to the regional sediment pollution problem through a team of experts from the US Geological Survey, the USDA Agricultural Research Service's Southwest Watershed Research Center, and two offices of the USDA Natural Resources Conservation Service. Because

environmental concerns do not conform to political or administrative boundaries, the team shares ideas and resources to provide both the Army and the regional community with sound environmental management. The team has identified methods and projects that can be implemented by the Army for improved land management.

Background

Fort Carson includes 67 firing ranges, 56 training areas, Butts Army Airfield, 12 drop zones, and an Air Force live fire range that supports over 3,000 sorties each year. The general population at Fort Carson is 15,000 active duty military, and 3,500 civilian employees. Pinon Canyon is a satellite facility of Fort Carson and is staffed with Fort Carson personnel. Combined acreage for Fort Carson and the PCMS is more than 373,000 acres.

The primary missions of Fort Carson and the PCMS are training, housing and support of the 7th Infantry Division, 3rd Armored Cavalry Regiment, the 43rd Area Support Group, the 3rd Brigade Combat Team of the 4th Infantry Division (mechanized), and the 10th Special Forces. The posts also support the US Army Reserve, the National Guard, the Reserve Officers Training Corps, the US Air Force Reserve, the US Naval Reserve and the US Marine Corps Reserve. Soldiers are high-profile Department of Defense assets that include the Green Berets, and armored units who defeated Iraq's elite Republican Guard during Operation Desert Storm.

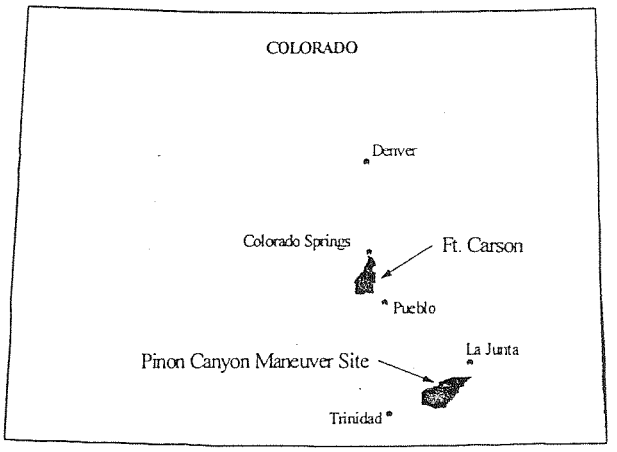

Figure 1. Location map of Fort Carson and the Pinon Canyon Maneuver Site

Army lands have been degraded by human activities beginning with the introduction of livestock in the 1860's, and continuing with the advent of military uses in the 1940's at Fort Carson and 1980's at the PCMS. The historic destruction of vegetation has increased erosion and sediment yield to streams, damaging both public and private lands, and creating a complex community problem. Army land managers are striving to identify its contribution to the regional problem, and are implementing practices to control sediment production on Fort Carson and PCMS lands.

Understanding how land use activities and associated environmental conditions influence sediment production is an extremely difficult undertaking. To gain this understanding, and to develop an approach for sediment prevention, Army land managers assembled a team of experts from other federal agencies. The Directorate of Environmental Compliance and Management (DECAM) at Fort Carson brought

together experts from the US Geological Survey (USGS), the USDA Agricultural Research Service's (ARS) Southwest Watershed Research Center (SWRC), and two offices of the USDA Natural Resources Conservation Service (NRCS). The multi-agency partnership is gaining an understanding of how military activities affect erosion processes, and is developing best management practices and appropriate remediation strategies.

This approach has resulted in numerous projects that characterize, monitor, and control erosion and sediment transport, while increasing available military training land resources without expanding physical Army land boundaries. This paper presents projects addressing reclamation for control of erosion and sediment transport; monitoring of stream flow, climate, and sediment concentrations; prediction of soil erosion; and assessment of rangeland condition.

METHODS AND PROCEDURES

Team Organization and Function

The ARS applies its knowledge from the intensely studied semi-arid watershed at Walnut Gulch, Arizona, to design Fort Carson and Pinon Canyon monitoring needs. Monitoring devices vary from continuous sediment samplers and water-level recorders to a network of 17 remotely monitored weather stations that record meteorological data. The USGS is responsible for system maintenance, data collection, storage, and dissemination. The NRCS from Arizona is coordinating with the Colorado NRCS and the ARS to develop a system of vegetation and rangeland health assessment that relates to a long-term vegetation data base the Army has developed on Fort Carson and PCMS lands.

Other Fort Carson cooperators have been brought into the process as well. The University of Wyoming's selenium (Se) assessment study of Fort Carson identified guidelines that are being integrated into the multi-agency team's best management practices and decisions. Army land managers describe military activities for the team, and implement team developed strategies that are practical and economically feasible. On a regional basis, Fort Carson and the NRCS are part of the Fountain Creek Watershed Management Working Group of the Pikes Peak area Council of Governments. This relationship ensures that Army actions are sensitive to private and local government concerns.

Programs and Projects

US Army

At Fort Carson and the PCMS, historical land use has caused degradation of the vegetation that normally traps, uptakes, and transpires rainfall and snowmelt (US Army Corps of Engineers, 1997). Reduction in plant cover results in soil loss by the processes of sheet and rill erosion, headcutting, and the formation of large gulleys. Montmorillonite clays in the soils allow the sides of erosion courses to remain steep instead of collapsing to a shallower angle of repose, and form deep gullies that interfere with training activities. The team identified the need to repair steep-

wall erosion as one of its first projects. Bank sloping was selected as the preferred method to stabilize and repair the gulleys.

Remediative bank sloping is the process of contouring the banks of gulleys to an angle where vegetation can be successfully established, helping to stabilize and bring an area into hydraulic balance. Army land managers have identified bank sloping as the most effective method for correcting the imbalance in a manner that will provide full benefit to Army operations and concurrently solve soil and water degradation problems.

Bank sloping using various methods has been conducted on a modest scale for years at Fort Carson and the PCMS. The first tests of bank sloping were conducted in 1997, and included vegetation components that provide decision support data for long term re-vegetation.

Large-scale bank sloping began in 1998 at Fort Carson and the PCMS when more than 816,000 cubic yards of soil were moved. Once vegetation is fully re-established, this will result in the stabilization of miles of stream channels and protection of down stream waterways from excessive sediment yield. Storm runoff will be retained in vegetation on the bank sloped areas. Bank sloping projects will continue in 1999 beginning at the PCMS with 120,000 cubic yards of soil to be moved.

Bank sloping is used in conjunction with other hydraulic controls such as erosion control dams, an aggressive plant material management and augmentation program, and regulatory controls of military land users. Fort Carson and the PCMS have more than 800 erosion control dams to curtail erosion, but some isolated conditions persist in causing bank failures and excessive sediment production.

Bank sloping efforts show immediate success by removing barriers to military traffic and controlling erosion. However, scientifically based monitoring for long-term performance assessment is currently lacking as are written plans to document performance assessment and life cycle operational characteristics (Lane et. al, 1998).

Another team product is the reclamation of an area where selenium is found in high concentrations, and where a Se environmental pathway through vegetation and Se attachment to eroding soil particles occurs. Fort Carson constructed its first selenium remediation project in 1998 during which 136,000 cubic yards of Se contaminated soil were buried and stabilized. Selenium is potentially toxic to wildlife and Fort Carson/PCMS lands have some of the highest naturally occurring levels in the United States. A Se Reception Study, conducted in conjunction with the University of Wyoming, has been completed to define Se environmental reception mechanisms. The study was an Army initiative, as no current government standards or regulations exist for terrestrial and non-point source Se. Results of the Selenium study provide Army land managers with knowledge to insure that land user activities do not create a Selenium environmental reception hazard. Army land managers combined concepts from the Se study with knowledge from the

multi-agency team to drive reclamation design.

ARS

Identification of the link between sediment transport mechanisms and historic land degradation is an important team goal. To better understand and characterize erosion and sediment transport processes at Fort Carson, the ARS conducted a study to estimate sediment discharge from Fort Carson streams and develop a Prototype Sediment Monitoring System. The objectives of the study were to investigate and quantify water and sediment discharges in selected stream channels entering and leaving Fort Carson; to develop, install, and evaluate a prototype sediment monitoring system on two drainage areas above erosion control dam (ponds with less than two ac-ft storage capacity); and to document the methods, data, and technology in internal reports and in the scientific literature to facilitate technology transfer to Fort Carson personnel and their cooperators.

Water level recorders and associated meteorological instruments were installed at erosion control (EC) Pond 46.212 and at the Red Creek monitoring site at Red Devil Bridge. In addition, a sediment pump sampler was installed and operated at the Red Creek monitoring site.

Sediment accumulation data in Pond 46.212 were obtained by surveying the pond storage capacity and determining sediment deposition behind the EC dam and the inlet stream channels above the pond area. The watershed draining into Pond 46.212 was characterized in terms of topography, vegetation, and particle size distribution of sediment collected from channel alluvium samples along the main channel in the watershed. An example of DECAM, NRCS, and ARS efforts to assess the performance of erosion control at Pond 46.212 includes an analysis of DECAM sponsored sediment yield monitoring from 1960 through the present. Over a 25 year period Pond 46.212 trapped about 1 ton/acre/yr (2.2 t/ha/y) which prevented some 5000 tons (4500 metric tons) of sediment from leaving Fort Carson. In addition to this benefit, construction of the erosion control dam and the reservoir behind it stopped the advance of the gully headcut and significantly reduced erosion and sediment yield downstream from the dam.

Structures such as dams, and the associated reservoirs and spillways are designed to control gully advance and prevent sediment from reaching downstream points. Quantification of changes in the rate of gully headcut advancement and volume of accumulated sediment can provide measures of the performance of these structures. Similar performance measures should be derived as part of a comprehensive monitoring and performance assessment program for erosion control programs at Fort Carson and PCMS.

Red Creek channel geometry was measured using surveying techniques and the channel bed sediments were quantified by sampling and subsequent sediment particle size analyses. Suspended sediment concentration samples collected at the Red Devil monitoring site on Red Creek were used

to quantify sediment discharge rates during a stream flow event. Suspended sediment concentration from depth integrated samples (DIS) obtained by wading the creek during a low flow period were compared with suspended sediment concentrations from the fixed-stage pump sampler for runoff during June 1997. The DIS concentration data are assumed as the standard since they are integrated with depth of flow and across the entire flow cross-section. A total load sediment transport calculation procedure (the APOINT model; Lane and Nichols, 1997) was applied to data from the June 1997 runoff event at the Red Creek monitoring site and was found to be in fairly good agreement with suspended sediment concentration data from the DIS samples.

The ARS also applied modern erosion prediction technology along hillslope profiles that were linked to existing Army vegetation transects. Field data were collected to parameterize a hillslope erosion model developed at ARS. Three hillslope profiles at each of 20 sites were measured for length and slope steepness, and sampled for vegetative cover and ground surface cover. These data were taken along the hillslope profile in segments determined by topography, vegetation community, and vegetation density. The compass bearings for each segment were used to develop layouts of the hillslope profiles in a geographic information system (GIS). The ARS cooperated with the DECAM at Fort Carson on the field data collection and GIS work.

The hillslope erosion model was applied to all 20 sites to evaluate soil erosion potential. The Army's existing vegetation database (Land Condition-Trend Analysis Report, 1989) was also evaluated using the model to determine the value of that data in soil erosion prediction, and potential use in reconstructing the hillslope profile data over time. In addition, the portions of Fort Carson characterized as rangeland, based on soil type and vegetation cover, were identified and mapped in a GIS database. These data will be used to guide future management decisions at Fort Carson.

USGS

Since the 1980's the USGS has operated meteorologic, streamflow, water-quality, sediment, and ground-water data-collection sites at Fort Carson and the PCMS in support of DECAM operations. The USGS also published separate reports on the hydrology of Fort Carson and PCMS during this period (von Guerard et. al, 1993). Recent interest in avoiding duplication of efforts, increasing cooperation between the various agencies, and evaluating monitoring networks has prompted the USGS to develop data-collection and analysis strategies that provide more information for assessment of military activities on streamflow and sediment discharge from Fort Carson and PCMS. In addition, methods are being developed to collect water-resource data in support of other agencies, analyze hydrologic and meteorologic data, and provide a basis for the future development of tools that can be used to manage land under military training.

During 1999 the USGS began the operation of a network of 17 radio-telemetry meteorologic data-collection sites at Fort Carson and PCMS.

Precipitation, air temperature, relative humidity, wind speed, soil moisture, and barometric pressure data are collected. In addition to this network, six rain gages are operated at streamflow-gaging stations on PCMS. All of these data eventually will be accessible over the Internet. Computation, analysis, maintenance of historical data bases, and computer access of selected climatological information will result in a coordinated, efficient meteorologic data-collection effort that will benefit DECAM training-area management, Land Condition Trend Analysis (LCTA), ARS hillslope-erosion evaluations, NRCS rangeland health assessment, and USGS streamflow-sediment runoff investigations, and verification of National Weather Service (NWS) radar information. Investigation of methods to determine the areal distribution of precipitation and soil moisture is planned.

The USGS also operates a network of streamflow-gaging stations in support of DECAM and other cooperating agencies, primarily in support of water rights issues. In addition, the USGS operates streamflow/sediment concentration data collection sites previously operated by ARS on Red Creek and Pond 46.212 at Fort Carson. The streamflow data-collection network at PCMS is used to quantify streamflow and sediment loads from various training areas on the maneuver site and to determine the effects of training maneuvers on streamflow and sediment loads. The network includes 9 streamflow-gaging stations, four of which include pumping-sediment samplers. Most of the sites are operated seasonally from April through October when the majority of flow occurs as a result of intense thunderstorm activity

A network of about 60 erosion-control reservoirs is being monitored on Fort Carson and PCMS to evaluate sediment yields. Reservoir surveys are being conducted as needed to document sediment deposition and evaluate basin sediment yield for use with LCTA vegetation plots and ARS hillslope-erosion modeling. A network of four selected erosion-control reservoirs with dataloggers and rain gages is being operated at PCMS to quantify military effects on the hydrology of small watersheds. The data will be used to extend interpretations of the rainfall-runoff responses of small watersheds to the larger training-area scale. The progression of data from small watershed to training-area to maneuver-site scales would ultimately give land managers more accurate information to evaluate the effects of changes in training activities and remediation techniques. Operation guidelines will be established between Fort Carson and the USGS (with technical assistance from ARS) to help ensure that accepted uniform surveying procedures are used in future data collection at erosion-control reservoirs.

The USGS is exploring the use of classified satellite imagery for possible use in determining the effects of military training on hydrologically-related characteristics of the PCMS training areas.

NRCS

The NRCS in Arizona and Colorado are cooperating with ARS to conduct

rangeland health assessments at Fort Carson and PCMS. Soil health or quality is recognized as a key indicator of overall ecosystem status on rangelands, and is an important component of the NRCS's new rangeland health assessment concept. Rangeland health is defined as "the degree to which the integrity of the soil and the ecological processes of rangeland ecosystems are sustained." A system to evaluate the condition of Army lands will aid in the long-term sustainable use of Fort Carson and PCMS.

Ecological site descriptions are being evaluated for a subset of the existing Army LCTA vegetation transect locations to represent the major rangeland ecological sites at Fort Carson and to represent a range of army training activities. Rangeland health assessments have been performed at each location. To expand the qualitative rangeland health assessment, each site was assigned the appropriate Ecological Site name as determined by vegetation and soils within the sample area. Approximate vegetation production was determined at the time of sampling using NRCS vegetation sampling procedures.

The rangeland health rating system is currently being evaluated by the NRCS to better quantify rangeland status. Future assessments at Fort Carson and PCMS will be conducted using the most current system.

SELECTED RESEARCH AND TECHNOLOGY NEEDS

Although the new organization described herein has coordinated several agency efforts and improved the overall approach to erosion and sedimentation monitoring and control, new research and technology will enable additional progress in the future.

Military activities and maneuvers have the potential to cause significant damage to soil and vegetation resources and exacerbate erosion and sedimentation problems. Research is needed to understand and quantify these impacts and to develop new technology to monitor them. Included in this need are the development of direct measurement techniques and the development of indicators of ecosystem status, change and damage. Continued meteorological, streamflow, water quality, and sediment yield monitoring will also be required. In addition, the impact of military land use and training activities must be quantified and maintained in databases to enable the development of the measurement techniques and indicators.

Future erosion control procedures should be designed using a systems or life cycle approach wherein monitoring and performance assessment are planned and conducted throughout the life of the procedures. These monitoring and performance assessment technologies should be documented and scientifically defensible.

Integrated information systems are required to combine the power of modern databases, simulation modeling, and expert judgment in designing and evaluating erosion control measures in terms of erosion and sediment transport processes. By improving the monitoring and evaluation phases of the erosion control programs, these integrated

information systems have the potential to become important decision tools.

CONCLUSION

Federal agencies frequently collaborate, but less often work together as a succinct team. The Army/ARS/USGS/NRCS team is unique in this respect. Because environmental concerns do not conform to political or administrative boundaries, the team shares ideas and resources to provide both the Army and the regional community with responsible environmental management. This approach has led to numerous reclamation projects that effectively control erosion and sediment transport, and simultaneously increase military training area land resources without expanding physical Army land boundaries. The team is a good example of government reengineering where the government helps itself instead of creating redundant and expensive efforts. The multidisciplinary team adopts the challenge of change, demonstrates new directions in managing highly complex challenges, and validates the federal government's effectiveness and ability to be efficient. This current work will help define future research and land management programs at both Fort Carson and the PCMS.

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