MODELING HEADCUT DEVELOPMENT AND MIGRATION IN UPLAND CONCENTRATED FLOWS

Sean J. BENNETT and Carlos V. ALONSO

ABSTRACT

On hillslopes and agricultural fields, discrete areas of intense, localized soil erosion commonly take place in the form of migrating headcuts. These erosional features significantly increase soil loss and landscape degradation, yet the unsteady, transient, and migratory habits of headcuts complicate their phenomenological and erosional characterization. Here a unique experimental facility was constructed to examine actively migrating headcuts typical of upland concentrated flows. Essential components of the facility include a deep soil cavity with external drainage, rainfall simulator, capacity for overland flow, and a video recording technique for data collection. Results from these experiments show that: (1) after a short period of adjustment, headcut migration attained a steady-state condition, where the rate of migration, scour hole geometry, and sediment discharge remain constant with time; (2) boundary conditions of higher rates of overland flow, steeper bed slopes, and larger initial headcut heights produced systematically larger scour holes with higher rates of soil erosion; and (3) during migration, the turbulent flow structure within the scour hole remained unchanged, consisting of an overfall nappe at the brink transitioning into a reattached wall jet with two recirculation eddies within the plunge pool. The systematic behavior of headcut development and migration enabled the application of modified jet impingement theory to predict with good success the characteristics of the impinging jet, the depth of maximum scour, the rate of headcut migration, and the rate of sediment erosion. These laboratory data and the analytical formulation can be used in conjunction with soil erosion prediction technology to improve the management of agricultural areas impacted by headcut development and ephemeral gully erosion.

Key Words: Soil erosion, Headcuts, Rills, Gullies, Jet impingement

EVALUATION OF TOPOGRAPHIC INDICES FOR EPHEMERAL-GULLY EROSION ASSESSMENT

J. CASALÍ, L. M. De SANTISTEBAN,J. J. LÓPEZ, J. V. GIRALDEZ, J. POESEN,
J. NACHTERGAELE, M. GOÑI, J. LOIZU and M. A. CAMPO

ABSTRACT

Soil erosion by concentrated flows in agricultural areas is an important process affecting soil losses and landscape degradation. The main factors controlling concentrated flow erosion include the erodibility of materials, soil use and management, climate, and watershed topography. In this paper, two topographic indices, closely related with mathematical expressions suggested by different authors, are used to characterize the influence of watershed topography on gully erosion. The *AS1* index is defined as the product of the watershed area and the partial area-weighted average slope. The *AS2* index is the product of the watershed area and the length-weighted average swale slope. Using different ephemeral gully erosion databases, a high correlation was found between the topographic indices and the volume of eroded soil. The accuracy of different methods for field measurement of ephemeral gullies was evaluated to ensure that the relation between erosion and topographic indices is not affected by assessment errors. The resulting relation are useful to assess soil losses from gully erosion, to identify the most susceptible watersheds within large areas, and to compare the susceptibility to gully erosion among different catchments. This information also can be important to study the response of natural drainage network systems to different rainfall inputs.

Key Words: Concentrated flow erosion, Ephemeral gully erosion, Erosion prediction, Watershed topography

KINETIC MODELING OF CONSTITUTIVE RELATIONS FOR PARTICLE MOTION IN LOW TO MODERATELY CONCENTRATED FLOWS

Guangqian WANG, Xudong FU and Xingkui WANG

ABSTRACT

Formulating underlying mechanisms of concentrated solid-liquid flows is essential for simulation of various industrial processes and natural phenomena. A generalized constitutive model for particle motion in flows with low to moderate solids concentrations is developed. This generalized model facilitates characterization of inelastic collisions, particle-fluid interactions, and shearing effects. Moderately concentrated simple shear flows of a sand-water mixture are analyzed, and comparisons of model predictions and experimental data are in good agreement. This model exhibits sound performance in characterizing particle motion for wide ranges of concentration and shear rate, and may supply a reasonable and competent alternative to previous models developed for dilute and rapid-granular flows when applied to moderately concentrated situations. The concentration approaches zero ($C \rightarrow 0$) asymptote is observed at a relatively high shear rate in model predictions. Assumption of low collisional dissipation of the particle phase as $C \rightarrow 0$ is more reasonable for this observation, compared to that without the interstitial fluid effect. Accurately modeling energy dissipation is important for characterizing the stability of dilute simple shear flows of solid-liquid mixtures. Incorporating friction forces will also facilitate improvement of the applicability of this generalized model to flows at extremely high concentrations.

Key Words: Constitutive relations, Kinetic model, Two-phase flow, Turbulent diffusion, Collisions, Stress, Concentration, Shear rate

CONTROL OF GULLY EROSION USING STIFF GRASSES

F. D. SHIELDS, Jr., S. M. DABNEY, E. J. LANGENDOEN and D. M. TEMPLE

ABSTRACT

Concentrated flow can cause gully formation on sloping lands and in riparian zones. Current practice for riparian gully erosion control involves blocking the gully with a structure comprised of an earthen embankment and a metal or plastic pipe. Measures involving native vegetation would be more attractive for habitat recovery and economic reasons. To test the hypothesis that switchgrass (*Panicum virgatum* L.) hedges planted at 0.5-m vertical intervals within a gully would control erosion, a series of hedges was established in four concentrated flow channels. Two of the channels were previously eroded trapezoidal channels cut into compacted fill in an outdoor laboratory. The other two channels were natural gullies located at the edge of floodplain fields adjacent to an incised stream. While vegetation was dormant, artificial runoff events were created in the two laboratory gullies and one of the natural gullies using synthetic trapezoidal-shaped hydrographs with peak discharge rates of approximately 0.03, 0.07, and 0.16 m^3/s. During these tests flow depth, velocity, turbidity, and soil pore water pressures were monitored. The fourth gully was subjected to a series of natural runoff events over a five-month period with peaks up to 0.09 m^3/s. Flow depths in all tests were generally < 0.3 m, and flow velocities varied spatially and exceeded 2.0 m/s at the steepest points of the gullies. Erosion rates were negligible for controlled flow experiments, but natural flows in the fourth gully resulted in 1 m of thalweg degradation, destroying the central portions of the grass hedges, most likely due to the highly erodible nature of the soils at this site. Geotechnical modeling of soil steps reinforced with switchgrass roots showed factors of safety > 1 for step heights < 0.5 m, but instability was indicated for step heights >1 m, consistent with the experimental observations.

Key Words: Erosion, Gully, Grass hedges, Buffers

2D NUMERICAL SIMULATION OF FLOOD AND FLUVIAL PROCESS IN THE MEANDERING AND ISLAND-BRAIDED MIDDLE YANGTZE RIVER

Yong-jun LU, Zhao-yin WANG, Li-qin ZUO, and Li-jun ZHU

ABSTRACT

The characteristics of water flow and sediment transport in a typical meandering and island-braided reach of the middle Yangtze River is investigated using a two-dimensional (2D) mathematical model. The major problems studied in the paper include the carrying capacity for suspended load, the incipient velocity and transport formula of non-uniform sediment, the thickness of the mixed layer on the riverbed, and the partitioning of bed load and suspended load. The model parameters are calibrated using extensive field data. Water surface profiles, distribution of flow velocities, riverbed deformation are verified with site measurements. The model is applied to a meandering and island-braided section of the Wakouzi-Majiazui reach in the middle Yangtze River, which is about 200 km downstream from the Three Gorges Dam, to study the training scheme of the navigation channels. The model predicts the processes of sediment deposition and river bed erosion, changes of flow stage and navigation conditions for the first 20 years of impoundment of the Three Gorges Project.

Key Words: Yangtze River, 2D mathematical model, Meandering and braided channel, Flow velocity, Sediment transport

SOIL EROSION PROCESS RESEARCH AND ITS POTENTIAL IMPACT ON EROSION PREDICTION MODEL DEVELOPMENT

Chi-hua HUANG and Fenli ZHENG

ABSTRACT

This paper highlights past efforts in developing erosion process concepts that lead to the development of the current process-based erosion prediction model, i.e., WEPP. Recent progress includes the development of a multiple-box system that can simulate hillslope hydrologic conditions. Laboratory procedures enable the quantification of near-surface hydrologic effects, i.e., artesian seepage vs. drainage, on the soil erosion process and sediment regime, flow hydraulics, and sediment transport and deposition processes. These recent findings improve soil erosion science and provide new erosion control strategies that may have additional environmental benefits relative to the traditional erosion control practices. The paper also discusses the potential impacts of the erosion process on erosion model development and future research directions of soil erosion process research and model development.

Key Words: Soil erosion process, Erosion prediction model, Surface condition, Spatial and temporal variability, Transport capacity

NUMERICAL SIMULATION OF SEDIMENT TRANSPORT IN DYNAMIC FLOW CONDITIONS

Farhad YAZDANDOOST

ABSTRACT

The results of mathematical modelling of unsteady flow conditions coupled with specific sediment transport relations are presented here. Simultaneous solutions of the de Saint Venant equations with three different transport relations, namely the Engelund-Hansen equation, Graf equation, and an empirical equation are presented. The results obtained were compared with those from the Fluvial-12 program under the same input conditions and reasonable correlation was observed. The advantages of the coupled method for simultaneous solution of the equations comprise a higher degree of accuracy, the possibility of introduction of any desired transport equation into the model and the possibility of introducing any boundary conditions into the model alongside a complete unsteady flow modelling.

Key Words: Unsteady flow, Numerical modelling, Sediment transport simulation, Open channel flow