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Physical Model Study: Rill Erosion Morphology and Flow Conditions

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Using common catchment size erosion model software either lack of knowledge or lack in process ability of watershed characteristics leads to increasing simplifications in model assumptions. Referring to open channel hydraulics, erosion model equations are prevalently based on stepwise uniform flow condition requirements. Approaching balance of gravitational and frictional resistance forces, channel roughness is fundamental model input. The fusion of simplified model assumptions and the use of lumped roughness determination cause ambivalence in model calibration.

By means of a physical model experiment at the National Soil Erosion Laboratory (NSERL), West Lafayette, USA, channel roughness was itemized into skin friction and channel shape friction due to rill morphology. Particularly the Manning-Strickler equation was analyzed concerning the applicability of constant and holistic factors describing boundary friction impacts. The insufficiency in using the Manning-Strickler equation for non-uniform flow conditions is widely advised, whereas lack in predictability in rill erosion development inhibits proper model adoptions. The aim of the present study is to determine the impact of channel morphology on roughness assessment in rill erosion scale.

Therefore a 1.9 meter long, 0.6 meter wide and 0.3 meter deep flume with an inclination of 10 % was filled with a loamy soil representing a section of a hill slope. The soil was prepared and saturated by simulated rainfall before each model run. A single erosion channel was enforced to develop by means of steady state runoff. Two different erosion channel types were initiated and observed: I.) a Straight Constrained Rill (SCR) shape by concentration of the runoff into a prepared straight initial rill and II.) a Free Developing Rill (FDR) by back-cut erosion through the plain soil body. Discharge of the outflow was measured in 5 minute interval and outflow sediment concentration was measured every minute. A top view stereo camera setup was installed to detect the channel topography whereas additional channel width and knick point depth measurements were undertaken manually. Flow velocity was measured at different channel development stages using colour tracer.

Based on the measurements the comparison of flow conditions of different channel types was enabled. Assuming the flow conditions are described by the Manning-Strickler equation adequately, the extracted roughness factor for the SCR is influenced by skin friction only, whereas the FDR holistic roughness factor consists of both - skin and shape friction.

By means of the rill erosion study a significant dependency of Manning-Strickler roughness factors and the developed rill morphology was observed. The experimentally extracted roughness values related to skin friction only (SCR) are up to 30 % higher than the roughness values out of the FDR experiment.

Disregarding criticism about common channel flow equations used in erosion models, experimental studies may provide fractional explain-ability of holistic constants and diminish uncertainty in parameter estimations. The present study shows rill roughness characteristics under specific conditions – varying the experimental conditions reasonable predictions for estimating the rill morphological impact may result.