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Development and evaluation of the microbial fate and transport module for the Agricultural Policy/Environmental eXtender (APEX) model

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Pathogenic microorganisms in recreational and irrigation waters remain the subject of concern. Water quality models are used to estimate microbial quality of water sources, to evaluate microbial contamination-related risks, to guide the microbial water quality monitoring, and to evaluate the effect of agricultural management on the microbial water quality. The Agricultural Policy/Environmental eXtender (APEX) is the watershed-scale water quality model that includes highly detailed representation of agricultural management. The APEX currently does not have microbial fate and transport simulation capabilities. The objective of this work was to develop the first APEX microbial fate and transport module that could use the APEX conceptual model of manure removal together with recently introduced conceptualizations of the in-stream microbial fate and transport. The module utilizes manure erosion rates found in the APEX. The total number of removed bacteria was set to the concentrations of bacteria in soil-manure mixing layer and eroded manure amount. Bacteria survival in soil-manure mixing layer was simulated with the two-stage survival model. Individual survival patterns were simulated for each manure application date. Simulated in-stream microbial fate and transport processes included the reach-scale passive release of bacteria with resuspended bottom sediment during high flow events, the transport of bacteria from bottom sediment due to the hyporheic exchange during low flow periods, the deposition with settling sediment, and the two-stage survival. Default parameter values were available from recently published databases. The APEX model with the newly developed microbial fate and transport module was applied to simulate seven years of monitoring data for the Toenepi watershed in New Zealand. The stream network of the watershed ran through grazing lands with the daily bovine waste deposition. Based on calibration and testing results, the APEX with the microbe module reproduced well the monitored pattern of E. coli concentrations at the watershed outlet. The APEX with the microbial fate and transport module will be utilized for predicting microbial quality of water under various agricultural practices (grazing, cropping, and manure application), evaluating monitoring protocols, and supporting the selection of management practices based on regulations that rely on fecal indicator bacteria concentrations. Future development should include modeling contributions of wildlife, manure weathering, and weather effects on manure-borne microorganism survival and release.