RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Research and Development of Watershed-Scale Model/Tool

Simulating the Effects of Wildfires on Mercury Contamination of Land and Water

Research Bulletin
Science and Technology Program

S&T Project 7112

Wildfires may significantly increase surface runoff, erosion, and transport of sediment, mercury and methylmercury. An integrated modeling package was created to simulate and study wildfire effects on runoff, sediment erosion, and mercury and methylmercury loads at a watershed scale. The modeling package was applied to the upper Cache Creek watershed, CA and obtained satisfactory results.

Mission Issue

Wildfire could seriously impact water quality and decrease the capacity of Reclamation's reservoirs.

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More Information

https://www.usbr.gov/research/projects/detail.cfm?id=7112

Problem

Large, high-severity wildfires can significantly increase runoff and erosion that negatively impact water quality in streams, rivers, and lakes. Post-fire storm events may carry large sediment loads which could decrease reservoir capacity significantly, mobilizing and transporting contaminants, such as heavy metals. Of particular concern is potential movement of mercury (Hg) into downstream waters, and formation of methylmercury (MeHg), a potent neurotoxin with a strong tendency to bio-magnify within the food chain. However, few data exist on the impacts of wildfire on Hg-soil behavior, and no models exist that can be used to predict the effects of wildfire on transport of sediment, Hg, and MeHg in surface waters. Previous studies have shown increases in MeHg concentrations in surface waters and biota after wildfire and that suspended sediment concentration remains a controlling factor in Hg flux in disturbed watersheds, especially those impacted by wildfire.

Solution

Project goals were achieved by constructing a relatively simple watershed-scale model to simulate wildfire effects on runoff, and loads of sediment, mercury (Hg) and methylmercury (MeHg) at the watershed outlet. Runoff increases after wildfires that burn vegetation and create a condition of soil-water repellence (SWR). A new post-fire watershed hydrological model, PFHydro, was created to simulate vegetation interception and SWR effects for four burn-severity categories: high, medium, and low burn severity and unburned. The model was applied successfully to the upper Cache Creek watershed in California by simulating one year pre-fire (water year (WY) 2015) and two years post-fire (WYs 2016-17). The PFHydro-WQ model was created and applied successfully in the Cache Creek watershed for WYs 2015-2017 by simulating daily sediment erosion and load using input of surface runoff from PFHydro. A one-dimensional soil-heating model was used to estimate fire-related Hg loss from soils as a function of burn severity and vegetation. Land use/land cover data were used to estimate post-fire soil Hg concentrations. Daily sediment loads were used to make reasonable estimates of Hg and MeHg loads, which were dominantly particulate.

Application and Results

PFHydro was applied to simulate hourly runoff post-fire from the Upper Cache Creek Watershed in California, USA. Nash–Sutcliffe modeling efficiency (NSE) was used to assess model performance. The modeling NSE was 0.88 and 0.93 for WYs 2016 (first year post-fire) and 2017 respectively. The value 1.0 of NSE means 100% match between simulation and observation. The PFHydro model provides reliable way to simulate post-fire watershed-scale hydrological process and precipitation-induced runoff. The PFHydro-WQ model was created to simulate daily sediment load post-fire with input of surface runoff obtained from the PFHydro model. The PFHydro-WQ model was successfully applied to the upper Cache Creek watershed. The modeling NSE was 0.60 and 0.79 for WYs 2016 and 2017, respectively. The modeling of post-fire daily mercury (Hg) and methyl mercury (MeHg) load in the Cache Creek watershed assumes that Hg and MeHg loads are associated with soil Hg and MeHg concentrations and associated sediment loads from the watershed. The soil Hg concentration was obtained from a one-dimensional soil-heating model with inputs of burn severity, vegetation, land use/land cover data. The Hg and MeHg modeling obtained good results for the largest storm event in WY 2017 and a similarly sized, pre-fire storm event in WY 2015. The Hg and MeHg modeling results are also considered satisfactory with regard to annual loads based on comparison with observed values from detailed monitoring.

Future Plans

Future research includes the following:

- Extend modeling of Cache Creek watershed through Water Year 2020 to characterize effects of 2018 fires.
- Gather hydrologic and soils data to support modeling.
- Perform process-oriented biogeochemical studies to improve knowledge of fire effects on Hg methylation and transport.
- Initiate or expand data collection for water flow, suspended sediment, total mercury, and methylmercury in watersheds of interest to Reclamation, especially in the context of the pending state-wide mercury control program on reservoirs.
- Update PFHydro and PFHydro-WQ algorithms for the model to be applied in a heterogeneous watershed and simulate SWR effects and Hg/MeHg load more effectively.
- Construct a user-friendly interface for PFHydro and PFHydro-WQ and publish documentation so that these models may be readily used by land and water managers and their staff.