RECLAMATION
Managing Water in the West

Developing tool to assess model uncertainty in sediment simulation

Research and Development Office
Science and Technology Program
Final Report ST-2017-8680-1

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

February 27, 2018

Mission Statements

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The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

REPORT DOCUMENTATION PAGE		*Form Approved* *OMB No. 0704-0188*
T1. REPORT DATE: 02/2018	**T2. REPORT TYPE:** RESEARCH	**T3. DATES COVERED** 10-01-2017 to 2-28-2018

T4. TITLE AND SUBTITLE Developing tool to assess model uncertainty in sediment simulation	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER R12AC80251
	5c. PROGRAM ELEMENT NUMBER 8680 (S&T)
6. AUTHOR(S) Youngjai Jung, Jeff Niemann, and Blair Greimann	**5d. PROJECT NUMBER** ST-2017-8680-01
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER 86-68240
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Colorado State University, Department of Civil Engineering Campus Delivery 1372, Fort Collins, CO 80523-1372	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Research and Development Office U.S. Department of the Interior, Bureau of Reclamation, PO Box 25007, Denver CO 80225-0007	**10. SPONSOR/MONITOR'S ACRONYM(S): R&D:** Research and Development Office, **BOR/USBR:** Bureau of Reclamation, DOI: Department of the Interior
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) ST-2017-8680-01

12. DISTRIBUTION / AVAILABILITY STATEMENT
Final report can be downloaded from Reclamation's website: https://www.usbr.gov/research/

13. SUPPLEMENTARY NOTES

14. ABSTRACT ***(Maximum 200 words)***
The uncertainty in numerical model predictions can result from simplifications in the model's representations of the physical systems (model structure uncertainty), errors in the values assigned to model parameters (parameter uncertainty), and errors in the model inputs (forcing or input uncertainty). The long-term objective of this research is to develop a formal and efficient framework to evaluate uncertainty in predictions from hydrologic, hydraulic, and sediment-transport models. This project aims to assess the uncertainty associated with parameter, forcing, and model structure using Bayesian uncertainty methods, and reduce the computational cost of the Bayesian method substantially while still providing reliable uncertainty estimates. The new approach for uncertainty reduces the required number of simulations to be applied to complex model applications, and retains enough formality to reliably evaluate data collection and model calibration strategies. To constrain the scope, this research focuses on applying the framework to a sediment transport model called Sedimentation and River Hydraulics – One Dimension (SRH-1D).

15. SUBJECT TERMS Uncertainty Analysis, Sediment Transport Modeling, Bayesian

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT** U	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U			**19b. TELEPHONE NUMBER** 303-445-2673

S Standard Form 298 (Rev. 8/98)
P Prescribed by ANSI Std. 239-18

BUREAU OF RECLAMATION

Research and Development Office
Science and Technology Program

Sedimentation and River Hydraulics, Technical Service Center, 86-68240

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2-28-2018

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Executive Summary

Colorado State University has been working with Reclamation to develop a framework to evaluate the uncertainty associated with numerical models developed at the U.S. Bureau of Reclamation (Reclamation). A variety of hydrologic and hydraulic numerical models has been developed and widely used by the Reclamation to predict impacts of potential river restoration activities. Recently, assessing the uncertainty in predictions from such models has been underscored in the field of hydraulic and sediment transport modeling. Those uncertainties can result from the simplifications and assumptions used in the model's mathematical structure, errors in the model parameter values, and errors in the data used for the model inputs. Several methods using a Bayesian uncertainty framework have been suggested to quantify the uncertainty in the predictions specifically from the Sedimentation and River Hydraulics – One Dimension (SRH-1D) model. GSA-GLUE (Global sensitivity analysis – Generalized likelihood uncertainty estimation) method was developed to assess uncertainty of individual model parameters. The combination of the MSU (Multivariate shuffled complex evolution Metropolis) and BMA (Bayesian model averaging) methods was suggested to evaluate the uncertainty of model parameters and the uncertainty associated with the selection of a transport equation in SRH-1D simulations.

The purpose of this research project was to develop and test a formal and efficient framework to assess the uncertainty in the predictions from hydrologic, hydraulic, and sediment transport models. Through this research, we aimed to develop improved methodologies that: (1) require few model simulations and (2) retain enough formality so that data collection and model calibration strategies can be simplified to reduce the uncertainty in the model predictions. To constrain the immediate scope, the new methods focused on quantifying how the uncertainties originating from model parameter values, input data, and the model's mathematical structure affect the predictions from the SRH-1D model, but those methods are transferrable to other types of models. The chapters in the final report address three specific objectives that have been accomplished to achieve the primary purpose of this research. Those chapters are summarized below:

1. Simple error models are developed for the input data of a sediment transport model and integrated into an existing Bayesian method in order to determine whether uncertain inputs contribute substantially to the overall uncertainty in the predictions. Input errors are modeled using Gaussian distributions separately for various input data such as discharges, sediment rating curves, and cross section elevations. The means and standard deviations of those distributions are treated as uncertain parameters, and they are estimated within the Bayesian framework for parameter uncertainty. This approach enables a modeler to identify the contribution of each uncertain input to the overall uncertainty, which can suggest strategies to reduce the uncertainty and improve reliability in the model predictions.

2. A new algorithm is developed to improve the efficiency of the uncertainty estimation process for sediment transport model parameters. In order to reduce the computational cost, the new method is designed to use repeated parameter sets in the sample when specifying the probability distributions of parameters instead of generating new but similar parameter sets that require new model simulations, which is the typical approach of existing Markov chain Monte Carlo methods. This new approach can save large numbers of model simulations when evaluating the uncertainty in model predictions due to uncertainty in the parameter values.

3. A multivariate version of the BMA method is developed to assess the uncertainty associated with the selection and application of a transport equation in sediment transport models. The existing BMA method is modified to enable consideration of multiple model output variables and allow the uncertainty associated with each equation to vary with the magnitude of the variables if needed. This methodology can reduce the effects of imperfections in a single model prediction and provide a forecast along with its credible interval to characterize the uncertainty through combining the predictions from a set of competing transport equations.

The Final Report for this project is submitted in the form of a project report from Colorado State University and is found in Appendix A.

Contents

Appendix A – Final Report From Colorado State University