Research papers

Physical and numerical modeling of performance of detention dams

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Abstract

In this study, the trap efficiency ($T_E$) of detention dams was investigated using a laboratory study. To express the mathematical relationship between dependent and independent parameters, nonlinear regression and soft computing techniques including multivariate adaptive regression splines (MARS), gene expression programming (GEP) and group method of data handling (GMDH) were utilized. To find out the most effective parameters on TE, analyzing the Gamma Test (GT) and reviewing the structures of GMDH, MARS and GEP were performed. The accuracy of empirical formula derived based on the nonlinear regression with ($R^2 = 0.65$ and RMSE = 15.17) was inappropriate. Evaluating the performances of GMDH, GP and MARS with regarding calculation of standard error indices such as ($R^2$ and RMSE) indicated that all of them with minimum value of $R^2 = 0.95$ and maximum value of RMSE = 5.79 have suitable accuracy for modeling and predicting the TE. However, the MARS model is a bit more accurate than the others. Results of GT and reviewing the structure of prepared models (GMDH, MARS and GP) declared that ratio of volume of flood to volume of sediments ($V_F/V_S$), ratio of mean diameter of sediment size to the volume of flood ($D_{50}/V_F$) and specific gravity ($G_s = \gamma_d/\gamma_w$) are the most effective parameters on $T_E$.

1. Introduction

Constructing high dams are virtually the most expensive project among water resource projects; therefore, in designing stages some strategies should be considered to increase their efficiency and lifetime. Control of sediment load (bed and suspended loads) before reservoirs is one of the most important approaches to this purpose (Ab. Ghani and Azamathulla, 2014). Several studies with the aim of experimental and numerical methods have been conducted on the mechanism of sediment transport in rivers and reservoirs of dams (Ab. Ghani et al., 2011; Grenouille, 2015; Heininger and Cullmann, 2015; Mohammadzadeh-Habili et al., 2009). Entracing the sediments into dam reservoirs causes to decrease the usable volume of dam reservoirs and sometimes it causes the distortion of hydraulic installations. Therefore, estimating the volume of sediments, these distributions and the percentage of deposited sediments are important parameters in reservoir management (Hassan-Esfahani and Banihabib, 2016; Kiat et al., 2008; Sinnakaudan et al., 2006). Measuring sediment load in rivers and dam reservoirs is based on measuring flow discharge and suspended load sediment. Nowadays, advanced mathematical approaches (Dehdar-behbahani and Parsaie, 2016) such as image processing (Radice et al., 2006) and soft computing approaches including Artificial Neural Network (ANN) (Nourani and Andalib, 2015), adaptive neuro-fuzzy inference system (Mianaei and Keshavarzi, 2009; Parsaie et al., 2016b, 2016c; Vafakhah, 2012), genetic programing (Guven and Kişi, 2010), group method of data handling (GMDH) and wavelet (Olyaie et al., 2015; Parsaie et al., 2016a) have been proposed for predicting the suspended load in rivers and dam reservoirs (Azamathulla et al., 2013). During dam designing process, usually a dead volume is considered for sedimentation. Estimating dead volume has a significant effect on the cost of dam projects. If the volume of this area is estimated to be more than real volume, it increases the cost of dams; on the other hand, underestimating the real volume causes the reduction of dam operation period. To increase the lifetime of hydro-system projects, specifically high dams, construction of detention dams is conducted at the upstream. Detention dams attempt to deposit sediment loads. Performance of detention dams is evaluated using a parameter called trap efficiency ($T_E$). $T_E$ is defined as the ratio of outlet load sediments from detention dam to the total sediment load entered the reservoir of detention dams. Predicting sediment $T_E$ is necessary to provide an accurate estimate of this volume (Jansen, 1989). Using detention dams at the upstream of big dams is a reliable approach to reduce sediment transport load into reservoirs and using detention dams for reducing bank erosion in rivers,