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# ANN Model for Maximum Scour Depth Prediction Beneath and Downstream a Hydraulic Structure

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**Abstract**

***Recently, neural network appears as powerful tool for scientist and engineers' applications, a wide range of phenomenon are simulated using this approach successfully. The basic concept of this approach depended on the human brain and how a huge number of neurons transmit the information to result the output activities. This approach has the ability to work with the lack in information by storing the phenomenon behavior in the entire network. In this study, the capacity of NN model to foresee the most extreme scour profundity information downstream of (DS) abrupt extending stilling bowls (SESB) is examined. The information utilized for preparing the system are gathered utilizing a lab flume 30 cm wide, 30 cm deep and 17.5 m working segment long. Distinctive stream conditions and diverse extension are utilized through the test program. 80% of the information are utilized for preparing the system while the remainder of the information are utilized for approving and testing the created ANN model. (80, 15, 5) % of data are taken for training, testing and holdout respectively to build the model, from the result, ANN technique is the best method to predict the maximum scour depth due to high correlation where $R^2$ is found to be 0.98 in that proposed model in this study.***

**Keywords**: *Scour, stilling basins, hydraulic structures, ANN.*

# 1 Introduction

The generation of scour problem beneath and downstream the hydraulic structures is a serious problem that threatens the stability of such structures, which in turn weakens the foundation. Therefore, it is very important for designers of hydraulic structures such as sluice gate and stilling basin to consider the geometric properties of the scour itself. Stilling basin downstream scouring can bit by bit degrade channel bed ensuing to a distinction in level with concrete of the basin floor. Hence, downstream of basin and therefore the whole structure is often at risk of scouring and therefore the potential threats caused by scouring.

Stilling bowls (SB) are utilized primarily to guarantee the security of water powered structures against the erosive intensity of the giving high speed stream. One of such SB is the unexpected extending SB. The related examinations to the abrupt growing stilling bowl were investigated in (A. Negm, Abdelaal, Saleh, Sauida, & Technology, 2002; A. M. Negm, Abdel-Aal, Saleh, & Sauida, 2002). (BREMEN, Hager, & Energy, 1994) in their examination on SESB, performed two investigations utilizing versatile bed of uniform boulder of 15 mm have a 160 mm thick, at F1=7 and B/b=4.0 (F1 is the moving toward stream Froude num The generation of scour problem beneath and downstream the hydraulic structures is a serious problem that threatens the stability of such structures, which in turn weakens the foundation. Therefore, it is very important for designers of hydraulic structures such as sluice gate and stilling basin to consider the geometric properties of the scour itself. Stilling basin downstream scouring can bit by bit degrade channel bed ensuing to a distinction in level with concrete of the basin floor. Hence, downstream of basin and therefore the whole structure is often at risk of scouring and therefore the potential threats caused by scouring.

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Eldin, & Ahmad, 2003) examined of SESB without ledge, nearness of focal ledge and when an end ledge is utilized individually. They utilized the relapse investigation to create factual expectation models to foresee the greatest profundity of scour DS of SESB as far as stream, soil and bowl parameters. (Nagy, Watanabe, & Hirano, 2002) applied the ANN technique to predict the stream sediment discharge represented by sediment concentration. A different data collected from many rivers are collected to judge the artificial neural network model that gave a good result compared with previous works dealt with estimating sediment discharge. (Bakshi & Bhar, 2020; Lin & Namin, 2005) used associate integrated numerical and artificial neural network technique to estimate sediment loads distribution, under different flow conditions (uniform and nonuniform). (Lin & Namin, 2005) used the benefits of mathematical and ANN gained which showed acceptable result. To the extent the creators know, practically no examinations exist on utilizing the artificial neural network to foresee the most extreme scour profundity DS of the SESB under the impact of supercritical stream with or without a focal ledge. (A. Negm et al., 2002; A. M. Negm et al., 2002) also studied the consequences of utilizing the ANN to fabricate a forecast model to foresee the greatest scour profundity DS of the SESB regarding the fundamental included parameters as in the recently evolved relapse models, the performance of existing empirical and new optimized equations as well as. (Mahtabi, Mehrkian, & Taran, 2019) evaluated two intelligent models of M5 model tree and K nearest neighbors (KNN) to estimate the hydraulic characteristics of hydraulic jump over both lined and unlined beds. The results revealed that the two models have nearly an equivalent performance. Also, the results of the sensible situations of M5 for estimating sequent depth, energy loss and shear force constant showed that Froude number is the major parameter in calculation of hydraulic jump characteristics and the relative roughness parameter has negligible effect.ber, B is the width of the wide channel and b is the width of the tight channel). (Champagne, Barkdoll, González-Castro, & Deaton, 2011) conducted an experiment to understand the scouring pattern at the downstream of stilling basin and that they found that the first scour hole was shaped due to water jet impact that exits from stilling basin causing channel bed erosion. Scour geometry was affected by the first downward roller together with the counter rotating vortices. Consequently, varied eddies caused by flow separation within the plan-view conjointly contributed to the scouring formation. (Nashta, Garde, & Swa Mee, 1987) explored the impact of subcritical stream (F1=0.48 to 0.73) in unexpected extension (B/b=1.5 to 3.5) on mobile bed geography (residue size was 0.25 mm). As of late, (A. Negm et al., 2002; A. M. Negm et al., 2002; Saleh, Negm, Waheed-Eldin, & Ahmad, 2003) examined of SESB without ledge, nearness of focal ledge and when an end ledge is utilized individually. They utilized the relapse investigation to create factual expectation models to foresee the greatest profundity of scour DS of SESB as far as stream, soil and bowl parameters. (Nagy, Watanabe, & Hirano, 2002) applied the ANN technique to predict the stream sediment discharge represented by sediment concentration. A different data collected from many rivers are collected to judge the artificial neural network model that gave a good result compared with previous works dealt with estimating sediment discharge.

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# 2 Material and Method

## 2.1 Experimental setup

The training data was collected by experimental work was disbursed employing a rectangular flume made from Perspex. The flume and simulated system characteristics can be summarized as in Table 1.

Table1. Simulation system dimensions.

| No. | Property | value |
|---|---|---|
| 1 | Flume length | 17.5m |
| 2 | Flume width | 0.3m |
| 3 | Water depth | 0.3m |
| 4 | Bed slope | 1:6 |
| 5 | Spillway height | 0.355m |

A point gauge of 0.1mm accuracy was used to measure water and scour depths. The area and length of the scour gap were exactly measured employing a scale put in on the interior wall of the flume. A tailgate was accustomed control the downstream water depth. set up and placement of flume baffle is shown in Figure.1.

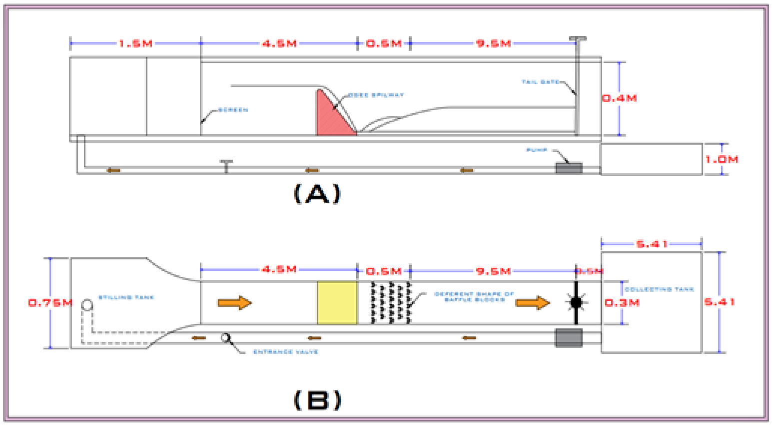


**Figure 1.** Definition sketch for the studied stilling Basin, after (A. M. Negm et al., 2002)

The influential parameters on the scour depth ($D_{max}$) downstream of degraded stilling basin will be summarized in Equ.1:

$$D_{max} = f\,(\mathrm{L},\ \mathrm{v},\ D_{50},\ y_1,\ \mathrm{H},\ \mathrm{B},\ \mathrm{b},\ \rho,\ \rho_s,\ X_s,\ h_s,\ \mathrm{g},\ \mathrm{n}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

L: stilling basin length.

v: average velocity.

$D_{50}$: the diameter of particles that 50% of the particles are finer than.

$y_1$: water depth upstream the stilling basin.

H: opening height.

B and b:

upstream

and downstream canal width, respectively.

$\rho$ and $\rho_s$: water and movable soil mass density, respectively.

$X_s$ and $h_s$: sill distance and height, respectively.

g: gravitational acceleration.

n: Manning coefficient.

Some parameters in equation 1 are eliminated due to either they maintained constant during experimental work or their effect are found to be negligible according to previous work in literature, the studied parameter are summarized in equation 2 as:

$$D_{max} = f\,(\mathrm{L}, \mathrm{v}, y_1, \mathrm{H}, X_s, h_s) \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

### 2.2 Modeling of Scour Depth Using NN

Artificial neural networks (ANN) are simply software execution of the biological neuron network processing, depending on the flexibility of those systems to simulate the studied behavior by analyzing the input and output data. ANN model is consisting of input layer, hidden layer, and output layer, that ought to be managed during a correct processing formula. ANNs are an application of nonlinear mathematics modeling, the complicated relation between and output layers are analyzed to produce the output for the relation under completely different conditions. Throughout the present study, many trials are experienced to seek out the succeeded pattern, a hyperbolic tangent is adopted for hidden layer of activation function and identity function for output layer to simulate the studied phenomenon (Figure 2).

The output from the generated model is the downstream scour depth ($D_{max}$), the input layer contains $\mathrm{L}, \mathrm{v}, y_1, \mathrm{H}, X_s$ and $h_s$ according to equation (2). The input and output datasets were normalized considering the maximum values of the data, and therefore the data will be reduced to be between zero and one to avoid the saturation impact, is also attainable by victimization sigmoid activation function.

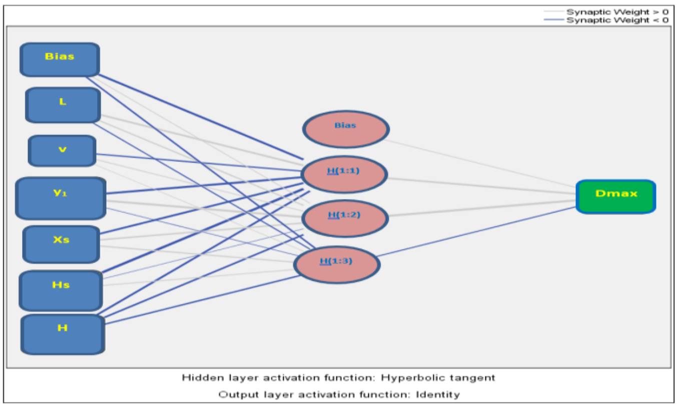


**Figure 2**. Proposed ANN Model

# 3 Results and Discussion

Many computer trials were tested to find the best initial network weights connections. The activation function, neurons number of hidden layer and optimum iterations were optimized. The network stability also checked during this stage. The output of all experiments was checked with predicted of output model as the square of the correlation coefficient, $R^2$. Higher $R^2$ means better performance of the network. The succeeded network gives $R^2$ equal to 0.9822 as shown in Fig. 3, the figure shows a symmetrical distribution of data around the zero-error line indicating the randomness nature of the residuals. While the high scatter of these residual indicates that they are uncorrelated with the predicted values proving the validity of using the succeeded ANN model in prediction of the maximum scour downstream the stilling basin

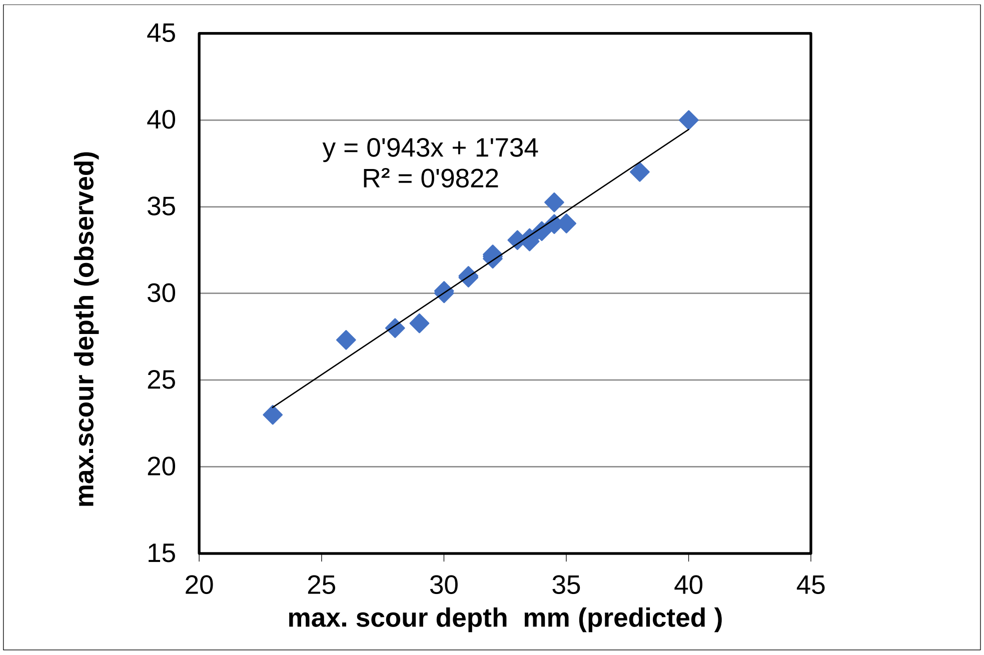


**Figure 3.** The predicted versus observed data.

Table 2 shows the summary of the statistical indicators of the proposed model. The elative error was 0.730 for training and 0.503 for testing data. Table 3 explains the estimated parameters weights among all layers to reach the specified values of output layer. Fig.4 shows the sensitivity analysis of this model which declare that $y_1$ is more important factor affected on predicted maximum scour depth. On the other hand, lesser effect is indicated for the average velocity compared with stilling basin geometric parameters. This behavior is justified where as it known stilling basin geometry is used to dissipate flow energy.

Table 2. Model Summary

| | | |
|---|---|---|
| Training | Sum of Squares Error | 5.478 |
| | Relative Error | 0.730 |
| | Stopping Rule Used | 1 consecutive step(s) with no decrease in error |
| | Training Time | 00:00:00.015 |
| Testing | Sum of Squares Error | 0.089 |
| | Relative Error | 0.503 |

**Table 3.** Parameter Estimates

| Predictor | | Predicted | | | |
|---|---|---|---|---|---|
| | | Hidden Layer 1 | | | Output Layer |
| | | H(1:1) | H(1:2) | H(1:3) | Dmax |
| Input Layer | (Bias) | -1.126- | .153 | -.437- | |
| | L | .969 | .375 | -.210- | |
| | V | -.443- | .207 | .090 | |
| | Y1 | -1.204- | 1.131 | -.135- | |
| | XS | -1.017- | .622 | .392 | |
| | HS | -1.481- | -.024- | .209 | |
| | H | -.766- | -.762- | -.481- | |
| Hidden Layer 1 | (Bias) | | | | .198 |
| | H(1:1) | | | | 1.005 |
| | H(1:2) | | | | 1.292 |
| | H(1:3) | | | | -.274- |

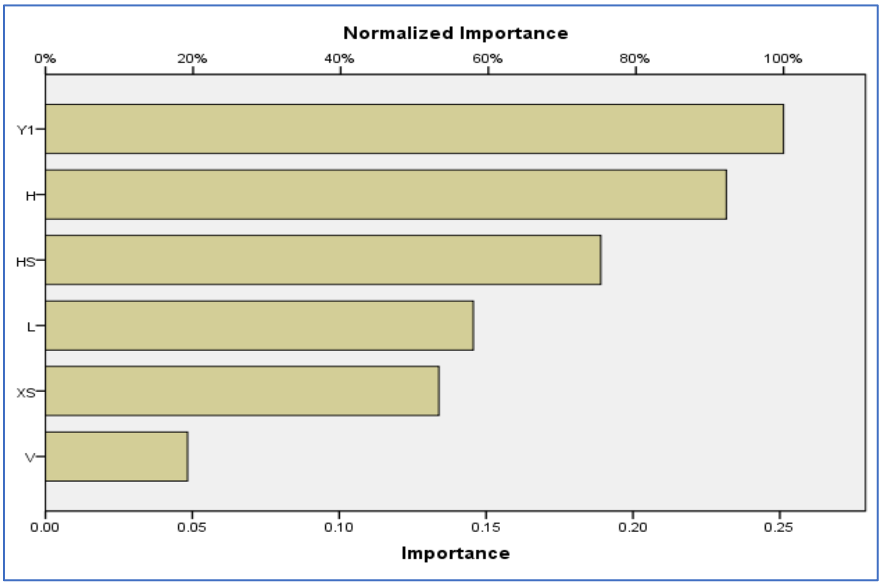


**Figure 4.** Sensitivity analysis

# 4 Conclusions

The ANNs Model used to simulate the scouring phenomenon downstream a stilling basin. Firstly, the suitable neural network is examined, the generated model was divided data to three data groups (80, 15, 5) % of the data for training, testing and verified, respectively. The model gives an encouraged result where it coincides the experimental results with a correlation of 98%. The water depth upstream the stilling basin have the heaviest weight in model output while stilling basin geometry and sill properties affects the studied phenomenon in descending weight order. As a conclusion, artificial neural network is a powerful tool in predicting scour depth where it saves time and effort especially if it uses for preliminary investigations of hydraulic structures.

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