Instituting a Geotechnical Focus for FHWA's Scour Program

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ABSTRACT

The FHWA Scour Program (Scour Program) came into existence as a result of the 1987 scour induced failure of the I-90 Schoharie Creek bridge, subsequent scour related bridge failures and Federal oversight findings. FHWA rapidly established the Scour Program to assess and evaluate scour hazards potential, relying mainly on hydraulics approaches, with little or no contribution of the insights offered by the geotechnical discipline. To illustrate, Scour Program research based equations for estimating scour depth equations on simplified soil assumptions; assuming a uniform layer of soil, characterized by bed material based on the D50 properties. Over the last several years, the FHWA has initiated a Scour Program re-evaluation with a goal to improve scour design and account for the hydraulic and geotechnical factors that impact scour assessment. The Scour Program re-evaluation is called Next Generation Scour Program (NextScour) that considers both hydraulic and geotechnical aspects of the scour design process. NextScour geotechnical conducts research into soil types, index and strength properties, and variability relation to soil erosion resistance. New developed methods for soil erosion evaluation include field in-situ scour testing device and laboratory erosion tests and Erosion Indexing to correlate erosion to geotechnical soil properties. The research will consider the incorporation of artificial intelligence/machine learning (AI/ML) techniques for evaluation of soil properties' correlation to the scour design.

INTRODUCTION

The FHWA established a Scour Program as the result of the 1987 scour induced failure of the I-90 Schoharie Creek bridge (NTSB HAR-88/02), subsequent scour related bridge failures and Federal oversight findings. To address public safety, FHWA rapidly instituted Scour Program development and deployment. The compelling need to assess potential scour hazards necessitated the use of existing approaches (nearly all hydraulic) and applying incremental advances to those approaches; rather than grounding and balancing hydraulic and geotechnical fundamentals, science, and engineering. Thus, in hindsight, the Scour Program focused on the hydraulic components; did not incorporate contributions and insights potentially offered by the geotechnical discipline. To illustrate, current scour practice assumes a uniform layer of soil, characterized by using D50 for properties (Figure 1).

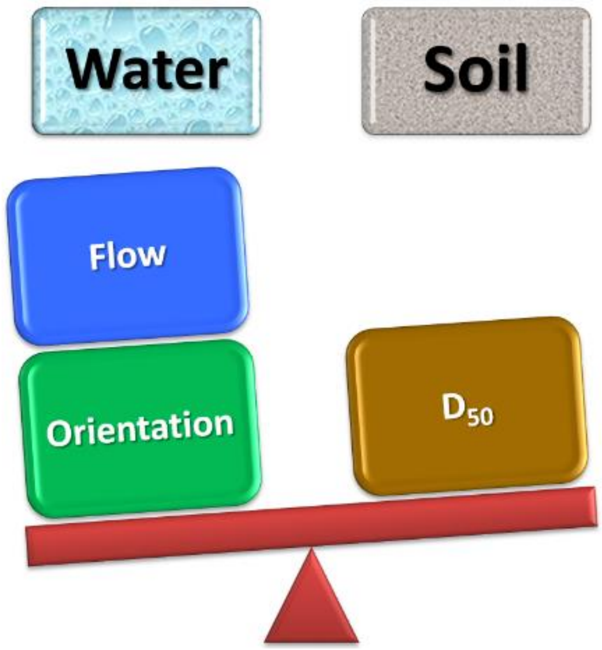

Figure 1. Unbalanced historic considerations for scour (FHWA).

Recently, FHWA initiated a Program re-evaluation; called the Next Generation Scour Program (NextScour). NextScour recognizes that erosion resistance of soils is primarily a geotechnical issue, related to soil strengths and characterization. In this context, hydraulics mostly provides information of the forces or loads affecting that geotechnical system. Therefore, NextScour institutes a geotechnical focus to scour; addresses geotechnical system, and properly establishes a balanced and co-equal aspect between geotechnical and hydraulic considerations for scour. NextScour includes programmatic, research, guidance, development, and deployment activities.

NEXTSCOUR PROGRAM

Historical Background.

The scour-induced failure of the I-90 Schoharie Creek Bridge and recommendations from the Federal oversight findings resulted in establishing FHWA Scour Program. The FHWA formalized the Scour Program in 1988; issuing the FHWA Technical Advisory (TA) T5140.20 "Interim Guidelines for Evaluating Bridge for Scour" to address public safety. The 1989 scour-related bridge failure at US 51 Hatchie River in Tennessee emphasized the need for updating the guidelines. As a result, in 1991 the FHWA released TA 5140.23 "Scour at Bridges." This 1991 TA defined five components of the Scour Program. The components included recommendations for an interdisciplinary team to evaluate each bridge for scour . The TA's first and second components included the geotechnical discipline in the scour evaluation process:

I. Evaluation by Interdisciplinary Team
    - Hydraulic
    - Geotechnical
    - Structural

II. New Bridges
    - Hydraulic Analysis
        - Withstand 100-year flood
        - Not fail during a superflood (>100 year)
    - Geotechnical Analysis
        - Assume scour prism removed

To rapidly respond to the need for assessment of potential scour hazard and to meet the Scour Program goals for public safety, the FHWA instituted an approach relying mainly on existing hydraulic components; adopting simplified and limited geotechnical assumptions. Thus, the scour design relied on empirical simplified 1D design equations in Hydraulics Engineering Circular-18 (HEC-18) "Scour at Bridges" for predicting scour for individual foundation components. The scour design also assumed a uniform soil layer; characterized by the D50 (Diameter of soil particles at 50% passing) (Figure 2). However, at most bridge locations, the soil system consists of several layers, of different thicknesses; types, properties and strengths.

These assumptions resulted in over estimation of scour depth and in some cases overdesign of foundations installed in certain types of riverbed material.

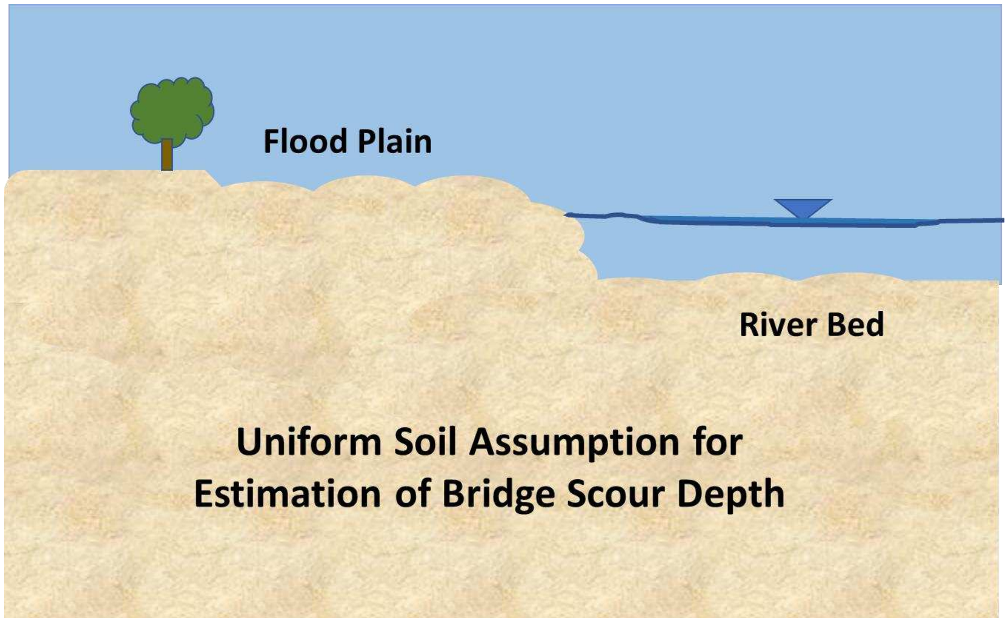

Figure 2. Uniform Soil Assumption for Estimation of Bridge Scour Depth (FHWA).

This was a notable inconsistency between intent and practice as the FHWA defines scour in the Code of Federal Regulations (CFR), National Bridge Inspection Standards 23 CFR 650, subpart C §650.305 (Definitions) as "Erosion of streambed or bank material due to flowing water; often considered as being localized around piers and abutments of bridges". The definition captures the contribution of hydraulics and geotechnical factors on scour. The practice did not adequately address the geotechnical contribution.

This began to change in 2011, when the FHWA announced a new bridge safety initiative in 2011 that implements a risk-based, data-driven approach to all aspects of the FHWA bridge program, including scour (Krolak, 2016). To meet this requirement, FHWA initiated improvements to the scour program and labeled it Next Generation Scour Program (NextScour).

NextScour Program Components.

The NextScour program recognizes that the phenomenon of scour consists of two major aspects or components, (a) consideration of water and hydraulic forces (loads) causing (b) erosion resistance of soils, and their associated geotechnical effects (resistance) (Figure 3).

Correspondingly, NextScour instituted two focus areas: “NextScour: Hydraulics” (NS:H) and “NextScour: Geotechnical.” (NS:G).

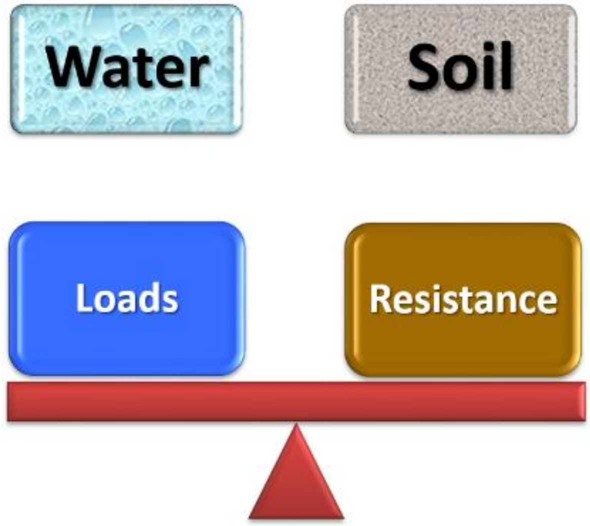

Figure 3. The two components of scour (FHWA).

NextScour Program Direction.

The FHWA intends these two focus areas NS:H and NS:G meet the agency’s strategic goals for safe, efficient and economical transportation infrastructure. The NextScour seeks to accomplish this through successful planning and implementation of the program using research innovations and findings, developing technical materials, deployment efforts and outreach. While the NS:H will focus on water and hydraulic forces and their effects based on quantity, ranges, orientation and time causing erosion, NS:G will focus on foundation and soil erosion resistance through consideration of soil types, index and strength properties, layering, depths and spatial variability (Figure 4).

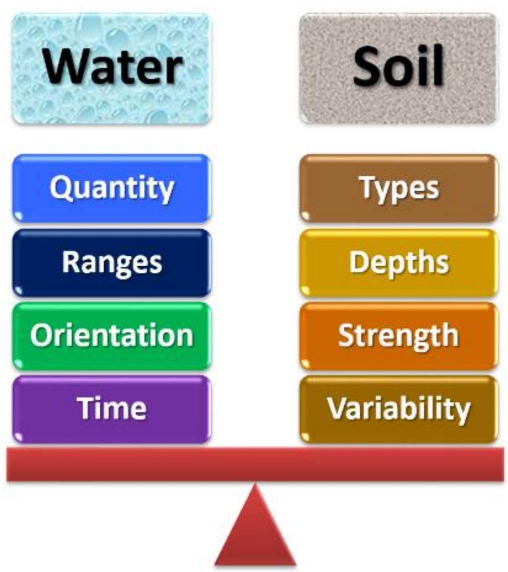

Figure 4. NextScour Program Direction (FHWA).

NextScour: Geotechnical Efforts & Directions

The NS:G team is conducting research into soil types, index properties, strengths, depths, and variability to help in determining the erosion resistance of soil layers. Recently, NextScour research efforts resulted in the development of the In-Situ Scour Testing Device (ISTD) for field testing of soil's erosion resistance and laboratory erosion tests. These research and deployment efforts also identified the important needfor NS:G to understand the correlation of Geotechnical properties to erosion resistance of soils.

The NS:G plan include performing research to investigation the correlation of geotechnical soil properties to erosion resistance of soils. The research will benefit from the results of Erosion Testing (ET) using in-situ scour testing (e.g. In-Situ Scour Testing Device (ISTD)) and laboratory erosion tests, Erosion Indexing (EI) to determine correlation of soil erosion to geotechnical properties. The research will also consider developing Erosion Maps (EM) that will retain erosion testing and soil indexing data and link it to subsurface stratigraphy. NS:G program will support NS:H program in developing 3-D subsurface erosion maps/stratigraphy to describe soil layer's spatial variability within and near a waterway.

When coupling these models with NextScour's hydraulic models (that computes dynamic and spatial hydraulic loads across the bathymetric domain), Next Scour anticipates the ability to compute 3D scour bathymetries for all bridge foundation elements.

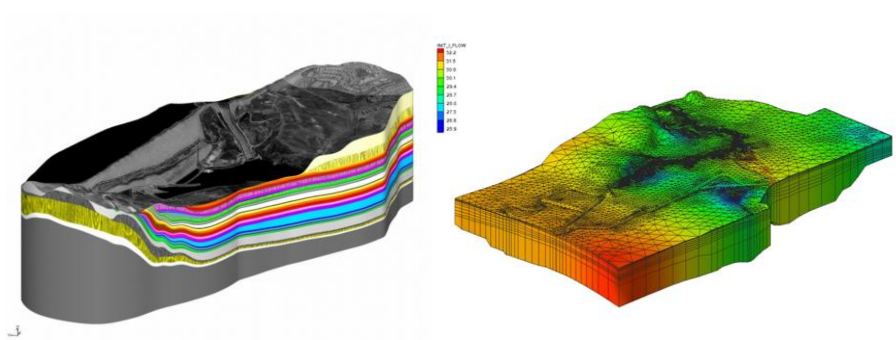

Figure 5. Stratigraphy development and subsurface erosion maps (FHWA).

DEVELOPMENT OF ARTIFICIAL INTELLIGENCE/MACHINE LEARNING GEOTECHNICAL MODELS FOR SCOUR

The NS:G program plan includes performing research to investigate the use of Artificial Intelligence/Machine Learning (AI/ML) methods for analyzing geotechnical soils properties correlations to erosion. The soil properties and erosion data generated from field and laboratory testing can be used for training of AI/ML models. This will take advantage of AI/ML models that learn from data input and output to determine the structure and parameters that govern the system without making assumptions about the physical behavior of the system (Shahin 2014)

With the emerging use of AI/ML for problem-solving, it has been successfully implemented in recent years for the evaluation of several geotechnical engineering problems. An example is the application of Artificial Neural Network (ANN) for creating geotechnical models to predict soil-related responses to settlement of shallow foundations, liquefaction potential, swelling pressure of expansive soil, and load settlement behavior of pile foundations (Shahin et al.; 2002, 2009). Developing ANN models require the collection and organization of the data for training (calibrate), testing (verify) and validating the neural network models. Therefore, AI/ML techniques for solving engineering problems is data-driven based on learning about the functional relationships among the data by examples of data inputs and outputs (Shahin 2014).

NEXTSCOUR PROGRAM FUTURE DEVELOPMENT PLAN

The NextScour program research efforts that began in 2012 resulted in the development of ISTD for collecting soil erosion resistance data, while NS:H research efforts focused on using Computational Fluid Dynamics (CFD) to improve the accuracy of predicting hydraulic forces.

NextScour: Geotechnical Development Plan

The future plan for the development of NS:G includes erosion testing in the field (ISTD) and laboratory, erosion indexing to correlate geotechnical properties to erosion data and to develop a data base for erosion data in a 3D subsurface map format. . NS:G program involves the following components to achieve its goal:

- Erosion Testing (ET): ET is expected to increase during coming years to build-up soil erosion database. The need for ET is expected to decrease thereafter and would only be performed on as needed basis for specific sites.
- Erosion Indexing (EI): Research will be performed on the collected ET and geotechnical soil properties (EI) data to determine the governing correlation between the two. Once a dominant geotechnical parameter that governs the correlation between ET and EI is determined, additional field and laboratory testing will be performed to build a database. The research will consider using collected erosion and soil properties data and develop AI/ML models to help with determining the correlation between ET and EI. This effort will require partnering with State DOTs, other transportation agencies and academia to build erosion rate vs. soil index properties database. An example is the recent National Cooperative Highway Program (NCHRP) research report 915 on relationship between erodiblity and properties of soils (Briaud, 2019)
- Erosion Subsurface Maps (EM): The collected ET and EI data will be linked to subsurface stratigraphy using coordinates based on geographic information system (GIS) for future use. Erosion subsurface maps will continue to improve in the future as more data is added. The intent is for the erosion/indexing data be associated with

the mapping (via GIS) and be used by designers where data exists in the vicinity of the designer's project.

Figure 6 depicts FHWA's expectation for the progression of development of the key components of NS:G.

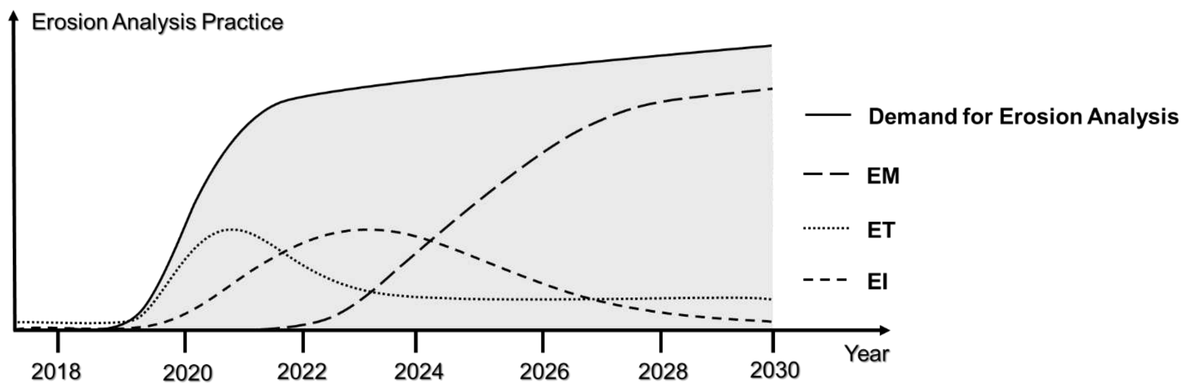

Figure 6. Progression of the development of key components of NS:G (FHWA).

CONCLUSION

FHWA initiated a Scour Program re-evaluation; called the Next Generation Scour Program (NextScour). One of the goals of the NextScour Program is to balance the focus of the scour program that was established in 1988 following scour induced failure of the I-90 Schoharie Creek Bridge in 1987. The early program development focused on hydraulic components with limited consideration of geotechnical aspects of the scour. One of the consequences for the program was over prediction of scour in cohesive soils. NextScour established two focus areas to better improve scour design and consequently provide cost effective bridge foundations design. NextScour include "NextScour: Hydraulics" (NS:H) to account for hydraulic forces (load) and "NextScour Geotechnical" (NS:G) to account for soil erosion (resistance).

NextScour focuses NS:H on water and the effect of hydraulic forces based on quantity, ranges, orientation and time causing erosion. While NS:G focuses on erosion resistance of soil and factors that impact the erosion process including soil types, index and strength properties, soil layering and spatial variability. NextScour includes programmatic, research, guidance, development, and deployment activities. The initial efforts resulted in the development of field and laboratory erosion testing including the ISTD. NS:G future research efforts includes investigating the correlation between erosion resistance and geotechnical index properties using

ET and EI including using AI/ML models. The data collected from ET and EI will be linked to subsurface stratigraphy to generate erosion surface maps (EM) that can be used in scour analysis.

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