

**NEW ENGLAND TRANSPORTATION CONSORTIUM  
RESEARCH PROBLEM STATEMENT**

DUE to [netc@uvm.edu](mailto:netc@uvm.edu)

By January 15, 2018

**I. PROBLEM TITLE**

Transportation network management for extreme hydrologic events

**II. RESEARCH PROBLEM STATEMENT**

During extreme weather events such as hurricane Irene, high flow rates in and flooding of the stream/river network caused extensive and expensive damage to the road transportation network. Currently, state and federal authorities have limited ability to predict and assess the impact of storm induced flooding of inland waterways on the transportation network, meaning that their ability to prepare for and manage the transportation infrastructure during such events is limited. This negatively affects society by exacerbating the effects of such events and extending the timeline for recovery.

In order to better be able to predict and assess the effect of inland flooding on the transportation network, research should be conducted to couple hydrologic models with models for transportation network robustness. Two particular areas of need are streamside roadway embankments and bridges, each of which were heavily impacted by Hurricane Irene. Because the hydrologic and transportation networks effectively link large geographic areas, only a coupled system model will be able to provide the kind of information that regional planning and emergency response communities need to improve preparedness and recovery.

**III. RESEARCH OBJECTIVES**

1. Select an example of a coupled waterway/transportation network relevant to the NETC participating agencies. This should be an inland area that has been subject to historical flooding caused by large rainfall events and in which such flooding has severely impacted the road network by causing failure of streamside embankments and bridges. A candidate location consists of Western Massachusetts and Southern Vermont in light of impacts of Hurricane Irene.
2. Collect, organize, and map (GIS) data on the hydrologic and road networks. Key features of the region that must be included in such a data collection effort include topography, waterway locations and connectivity, and soil type, and roadway geometry, connectivity, capacity, and embankment/bridge locations.
3. Enhance existing hydrologic models to include stream elevation and velocity beyond existing flow volume
4. Gather and synthesize from the literature existing models for embankment and bridge fragility relative to stream elevation and velocity. For bridges, the two failure modes of deck overtopping and pier/abutment scour will be addressed.
5. Generate an example case study for a particular real or synthesized storm that shows probabilistic predictions of impact on the transportation network

6. Generate an example case study demonstrating how different strategies for staging response equipment and personnel can affect recovery time and how different staging strategies could be affected by information provided by the coupled hydrologic/transportation models.

#### IV. ESTIMATE OF FUNDING NEEDED

\$300k primarily for grad student/postdoc support and faculty summer salary:

#### V. RESEARCH PERIOD

24 months.

#### VI. URGENCY AND PAYOFF POTENTIAL

Hurricane Irene demonstrated the vulnerability of rural infrastructure to flooding caused by heavy rainfall events. Hurricanes Sandy, Harvey, Irma, and Maria present a pattern of increasing storm severity that will lead to more frequent impacts on New England as were experienced during Irene. Increasing availability of data and advances in modeling present a timely opportunity to advance the state of the art and state of practice in emergency management related to inland flooding and transportation networks. The payoff potential includes the possibility of reducing loss of life, direct economic impacts due to transportation network failure, and reduced cost of recovery by better planning and preparedness.

#### VII. PRELIMINARY LITERATURE SEARCH

*To avoid duplicating research already published or in progress, the submitter of the Problem Statement will perform a quick literature search prior to submitting the Problem Statement and attach a summary of the results of the literature search to the Problem Statement. This literature search can be conducted by accessing the Transportation Research Board's TRID database available at <https://trid.trb.org/>. The TRID database contains information on completed research as well as research in progress.*

Source of preliminary literature search (check as appropriate):  TRID  RIP

Other (describe): \_\_\_\_\_

Summary of preliminary literature search (how the subject of this Research Problem Statement would differ from or add to, existing Studies): \_\_\_\_\_

\_\_\_\_\_ (attach additional pages if necessary)

#### VIII. KEY WORDS TO BE USED FOR ADDITIONAL LITERATURE SEARCH

*Provide the key words that can be used to conduct a search of the Transportation Research Board's electronic database (TRID) for completed,*

*related research. To the maximum extent possible key words should be selected from the National Transportation Library's Transportation Research Thesaurus. The Thesaurus can be found at <http://trt.trb.org/trt.asp>.*

hydrology  
flooding  
stream  
embankment  
bridge  
scour  
staging

stream flood scour

Analysis of bridge and stream conditions of over 300 Vermont bridges damaged in Tropical Storm Irene  
Structure and Infrastructure Engineering, Volume 13, Issue 11, 2017, pp 1437-1450  
<http://dx.doi.org/10.1080/15732479.2017.1285329>

Local Scour Calculation around Bridge Pier during Flood Event  
KSCE Journal of Civil Engineering, Volume 21, Issue 4, 2017, pp 1462-1472  
<http://dx.doi.org/10.1007/s12205-016-0986-3>

Vulnerability Evaluation of Scoured Bridges under Floods  
Engineering Structures, Volume 132, Issue 0, 2017, pp 288-299  
<http://dx.doi.org/10.1016/j.engstruct.2016.11.044>

Climate Change Impact on Highway Bridges: Flood-Induced Bridge Scour  
Transportation Research Board 96th Annual Meeting, 2017, 15p

Real-Time Flood Forecasting and Monitoring System for Highway Overtopping in Iowa,  
TR-699 Iowa Department of Transportation, \$229425, 2015, Active

Scour Damage to Vermont Bridges and Scour Monitoring UVM report  
[http://www.uvm.edu/~transctr/research/trc\\_reports/UVM-TRC-15-002.pdf](http://www.uvm.edu/~transctr/research/trc_reports/UVM-TRC-15-002.pdf)

Scour Related Vermont Bridge Damage from Tropical Storm Irene  
Structures Congress 2014, 2014, pp 505-515  
<http://dx.doi.org/10.1061/9780784413357.046>

Combining Individual Scour Components to Determine Total Scour  
Transportation Research Board, \$600000.00, 2012, Active  
<http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3187>

Taking a Key Role in Reducing Disaster Risks  
Public Roads, Volume 73, Issue 6, 2010, pp 20-25  
<http://www.fhwa.dot.gov/publications/publicroads/10mayjun/04.cfm>

Risk-Based Approach for Bridge Scour Prediction

---

National Cooperative Highway Research Program, \$500000.00, 2010, Completed  
<http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=2736>

Iowa's Proactive Approach to Bridge Scour Monitoring  
Bridges, Volume 9, Issue 3, 2006, pp 22-24

A CASE STUDY OF THE POSSIBLE EFFECTS OF LONG-TERM CLIMATE CHANGE ON  
BRIDGE SCOUR  
First International Conference on Scour of Foundations, 2002, p. 842-853

Irene bridge

Stream Power Application for Bridge-Damage Probability Mapping Based on Empirical  
Evidence from Tropical Storm Irene  
Journal of Bridge Engineering, Volume 22, Issue 5, 2017, Content ID 05017001  
[http://dx.doi.org/10.1061/\(ASCE\)BE.1943-5592.0001022](http://dx.doi.org/10.1061/(ASCE)BE.1943-5592.0001022)

Prediction and mitigation of scour and scour damage to Vermont bridges  
, 2017, 141p  
<http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/VTrans%20Scour%20Project%20731%20Anderson%20Et%20al%20%28FinalReport%2003-10-17%29.pdf>

Scour Damage to Vermont Bridges and Scour Monitoring  
, 2015, 52p  
[http://www.uvm.edu/~transctr/research/trc\\_reports/UVM-TRC-15-002.pdf](http://www.uvm.edu/~transctr/research/trc_reports/UVM-TRC-15-002.pdf)

Disaster Protection of Transport Infrastructure and Mobility Using Flood Risk  
Modeling and Geospatial Visualization  
, 2015, 161p  
<http://www.ncitec.msstate.edu/wp-content/uploads/2012-25FR.pdf>

Scour Related Vermont Bridge Damage from Tropical Storm Irene  
Structures Congress 2014, 2014, pp 505-515  
<http://dx.doi.org/10.1061/9780784413357.046>

Risk-Based Transportation Asset Management: Building Resilience into Transportation  
Assets: Report 5: Managing External Threats Through Risk-Based Asset Management  
, 2013  
<http://www.fhwa.dot.gov/asset/pubs/hif13018.pdf>

Prediction and Mitigation of Scour for Vermont Bridges  
UVM Transportation Center, \$37012.00, 2012, Completed  
<http://www.uvm.edu/trc/university-transportation-center/utc-current-project-list/>

1.

---

**TWO DOT ENDORSEMENTS ARE REQUIRED**

**IX. ENDORSEMENT BY THE SPONSORING DOT** *(To be signed by the DOT representative to the NETC Advisory Committee through whom the Problem Statement is submitted).*

*By signing the endorsement, the DOT representative is certifying that:*

- 1. The Problem Statement follows the required format*
- 2. The required literature search has been conducted*
- 3. The Problem Statement addresses a transportation issue of relevance to NETC and does not duplicate another Problem Statement being submitted at this time.*

  
\_\_\_\_\_  
(Name)

MASSDOT  
\_\_\_\_\_  
(DOT)

1/16/18  
\_\_\_\_\_  
(Date)

**X. ENDORSEMENT BY A DOT SPONSOR TO LEAD THE TAC** *(To be signed by a DOT lead with technical knowledge and commitment to the research outcome).*

DOT Technical Endorsement: *I agree to chair the NETC Technical Committee if this problem statement is selected.*

\_\_\_\_\_  
(Name)

\_\_\_\_\_  
(DOT)

\_\_\_\_\_  
(Date)

NOTE: To expedite the processing of Research Problem Statements,  
NETC requires submittal by E-mail ([netc@uvm.edu](mailto:netc@uvm.edu)) by January 15, 2018.

**NETC LITERATURE SEARCH**

**RPS Title:** Transportation Network Management for Extreme Hydrologic Events

**Summary of Relevance of Literature Search Retrievals to the Problem Statement:**

Number of Relevant TRID Transport Retrievals: [High – 17, Medium – 10]

Number of Relevant Internet Retrievals: [High – 5, Medium – 0]

Total Number of Relevant Retrievals: [High – 22, Medium – 10]

- **Search Terms Provided by RPS:** hydrology, flooding, stream, embankment, bridge, scour, staging, stream flood scour
- **Additional Search Terms used by Coordinator:** transportation network, GIS, Irene, Sandy, Harvey, Irma, Maria

**TRID RETRIVALS with HIGH RELEVANCE:**

**Title:** Post-Extreme Event Damage Assessment and Response for Highway Bridges

**Author(s):** Alipour, Alice

**Abstract:** This report reviews the procedures that state departments of transportation and two local authorities, New York City and Los Angeles County, use to assess the damage in bridges in response to extreme events and conduct the emergency response activities. Extreme events include those with geological sources (such as earthquakes and landslides), of hydro-meteorological sources (such as hurricanes and floods), or those of man-made origin, either accidental (such as truck crashes) or malicious (such as terrorist attacks). The study found that collision (mostly over-height vehicles) is the number one source of failures in bridges followed by those caused by hydraulic sources such as scour and flood and debris flow. Visual inspection is the first tool for assessing damage to bridges. Bridge engineers use other techniques for assessing damage, such as non-destructive testing and sonar surveys. Most states have emergency response plans for extreme events. Follow-up interviews, however, found that not all of the response plans are tailored for response to bridge damage.

**Record Type:** Publication

**Record URL:** <http://www.trb.org/Main/Blurbs/175479.aspx>

**ISBN:** 9780309389785

**Serial:** NCHRP Synthesis of Highway Practice

**Publisher:** Transportation Research Board

**ISSN:** 0547-5570

**Issue:** 497

**Pagination:** 379p

**Publication Date:** 2016-00-00

**Language:** English

**Media Info**

**Media Type:** Digital/other

**Features:** Appendices; Figures; Glossary; References; Tables

**Subjects/Keywords**

**Subject Areas:** Bridges and other structures; Highways; Safety and Human Factors; Security and Emergencies

**Keywords:** Crashes; Disasters and emergency operations; Flood damage; Highway bridges; Inspection; Structural health monitoring

**Accession Number:** 01629555

**Report/Paper Numbers:** Project 20-05, Topic 46-11

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/isbn/9780309389785>

**Files:** TRIS; TRB; ATRI

**Created Date:** 3/20/2017 11:24 AM

**Title:** Resiliency Analysis of Storm Surge for Interstate 95 Right-of-Way at Long Wharf / New Haven, CT

**Author(s):** Anagnostou, Emmanouil; Zhang, Wei

**Abstract:** This report focuses on the transportation resiliency of the Long Wharf area in the City of New Haven, CT, with the aim of identifying resiliency strategies for these transportation assets. The report begins with reviewing the important transportation assets in Long Wharf area, which includes highways, bridges and railways. Subsequently, a statistical analysis is carried out to regress the extreme water levels to atmospheric forcing in the region. In order to simulate the potential total water level, a simulation scheme that combines a high-resolution atmosphere model, a land-surface model and a parametric wind-wave model is devised, considering both the actual Superstorm Sandy and simulated future scenarios. The derived total water levels from actual and future Sandy simulation scenarios are used to generate GIS-based flood inundation maps for the study area, followed by the evaluation of resiliency of the transportation assets due to flood hazards during hurricanes. Finally, based on a comprehensive review of the resiliency options utilized across US coastal regions, potential resiliency options are made for the study area

**Record Type:** Publication

**Record URL:** <http://www.ct.gov/dot/lib/dot/documents/dresearch/CT-2299-F-17-3.pdf>; <http://common/images/covers/large/1473186.png>; <https://rosap.ntl.bts.gov/view/dot/32462>

**Edition:** Final Report

**Corporate Authors:**

University of Connecticut, Storrs

Department of Civil and Environmental Engineering, 261 Glenbrook Road

Storrs, CT 06269-2037 United States

Connecticut Department of Transportation

2800 Berlin Turnpike

Newington, CT 06131 United States

Federal Highway Administration

1200 New Jersey Avenue, SE

Washington, DC 20590 United States

**Pagination:** 50p

**Publication Date:** 2017-03-23

**Language:** English

**Media Type:** Digital/other

**Period Covered:** February 2016 to November 2016

**Features:** Figures; References; Tables

**Subject Areas:** Environment; Highways; Planning and Forecasting

**Keywords:** Floods; Interstate 95; New Haven (Connecticut); Resilience (Adaptability); Right of way (Traffic); Simulation; Storm surges

**Accession Number:** 01641111

**Report/Paper Numbers:** CT-2299-F-17-3

**Availability:**

National Technical Information Service

5301 Shawnee Road

Alexandria, VA 22312 United States

**Files:** NTL; TRIS; ATRI; USDOT; STATEDOT

**Created Date:** 7/5/2017 12:50 PM

**Title:** NCHRP Practice-Ready Solutions for Bank Erosion and Bridge Scour

**Author(s):** N/A

**Abstract:** The most common cause of bridge failure is scour. Consequently, one of the most important elements of bridge design is the ability to predict the effects of scour so that foundations can be designed to withstand these effects over the life of the bridge. Such predictions require the use of complex hydraulic equations, which are set out in Federal Highway Administration's (FHWA's) Hydraulic Engineering Circular No. 18 (HEC-18), the go-to resource for designing bridges to withstand bridge scour. A second circular, HEC-20, addresses channel migration and stream stability. A third, HEC-23, details the design and use of countermeasures to prevent scour and stream instability. After a series of scour-related bridge failures during floods in the 1980s, the Transportation Research Board's National Cooperative Highway Research Program (NCHRP) embarked on several research projects to better quantify and model the mechanisms of bridge scour and to develop effective, efficient countermeasures to its occurrence. This research led to a wealth of new knowledge about scour, followed by major updates to HEC-23 in 2009 and to HEC-18 and HEC-20 in 2012. The projects described here are selected from that research. Also presented are recent and ongoing efforts that will lead to further improvements of scour estimates—along with updates to FHWA's circulars—in the coming years. The sections of the report highlight: bank erosion countermeasures, bridge scour countermeasures, predictive equations for scour, and scour special cases.

**Record Type:** Publication

**Record URL:** <http://www.trb.org/Main/Blurbs/176359.aspx>

**Serial:** NCHRP Research Topic Highlights

**Publisher:** Transportation Research Board

**Pagination:** 8p

**Publication Date:** 2017-07-00

**Language:** English

**Media Type:** Digital/other

**Features:** Photos

**Subject Areas:** Bridges and other structures; Design; Highways; Hydraulics and Hydrology

**Keywords:** Banks (Waterways); Bridge design; Bridge foundations; Countermeasures; Equations; Erosion; Hydraulic properties; Scour

**Accession Number:** 01643946

**Files:** TRIS; TRB; ATRI

**Created Date:** 8/23/2017 1:52 PM

**Title:** FloodCast: A Framework for Enhanced Flood Event Decision Making for Transportation Resilience

**Author(s):** N/A

**Abstract:** Flooding, and the effects and impacts of flooding along transportation corridors, has caused billions of dollars of damage and countless deaths. Technology currently exists to accurately pinpoint those areas along a transportation corridor that are susceptible to flooding. Many state departments of transportation (DOTs) have a bridge flood monitoring program for structures that are susceptible to bridge scour. Additionally, most state DOTs have inundation mapping and use inundation modeling in the design of their transportation infrastructure. Although there are weather and climate tools and systems available for predicting changes in the weather and climate conditions, they have not yet been integrated to provide sufficient planning and prediction information required by state DOTs to carry out flood planning, risk management, mitigation, operations, and emergency response activities. Research is needed to translate the available technologies into a suite of tools and methods for use by decision makers at DOTs. Such research is intended to support DOTs in their efforts to develop and deploy emergency management early warning systems that can be applied to flood prediction and warning for enhanced flood event decision making and situational awareness for transportation resilience by harnessing available processes, tools, and hydrometeorology network capabilities. The objectives of this research are to develop a strategic framework and a prototype tool for enhanced flood event decision making. The framework and tool should help state DOTs plan, manage risks, mitigate hazards, and respond to flood and flash flood events. The framework and tool should address not only immediate flood impacts, but also cascading, escalating impacts. Given the large amount and diversity of applicable data and tools, the framework design should be flexible and scalable to accommodate the available data sets and allow users to easily share both data and products with other users, thereby fostering collaboration across government organizations and the private sector.

**Record Type:** Project

**Record URL:** <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3725>

**Language:** English

**Contract Numbers:** Project 20-59(53)

**Status:** Active

**Funding Amount:** 248236.00

**Sponsor Organizations:**

Federal Highway Administration

1200 New Jersey Avenue, SE

Washington, DC 20590 United States

American Association of State Highway & Transportation Officials

444 North Capitol Street, NW, Suite 225  
Washington, DC 20001 United States  
National Cooperative Highway Research Program  
Transportation Research Board  
500 Fifth Street, NW  
Washington, DC 20001 United States

**Project Managers:**

Parker, Stephan A.  
(202) 334-2554

**Performing Organizations:**

Dewberry Consultants LLC

**Principal Investigators:**

Mampara, Mat

**Notice Date:** --

**Start Date:** 2014-09-02

**Expected Completion Date:** --

**Actual Completion Date:** 2016-03-01

**Source Data:** RiP Project 37656

**Subject Areas:** Bridges and other structures; Highways; Hydraulics and Hydrology

**Keywords:** Bridges; Decision making; Floods; Monitoring; Risk management; Scour; State departments of transportation; Transportation corridors

**Accession Number:** 01543630

**Source Agency:** Transportation Research Board

500 Fifth Street, NW

Washington, DC 20001 United States

**Files:** TRB; RiP

**Created Date:** 11/19/2014 1:03 AM

**Title:** Developing a Bridge Scour Warning System

**Author(s):** Young, Bryan C.

**Abstract:** Flooding and scour can be major threats to the integrity of bridges. During flood events, scour at bridge piers and abutments can undermine the foundations of the bridge, causing significant damage or even total structure loss. Because scour occurs below the water level during a large flood event, it can be difficult to detect and may go unnoticed unless a targeted inspection is performed. The Kansas Department of Transportation (KDOT) is required by federal mandate to establish and maintain a bridge scour plan of action for all scour-critical bridges in the state. A plan of action can include the implementation of scour countermeasures to protect and stabilize a bridge and/or scour monitoring. Bridge scour monitoring presents multiple challenges for bridge owners, including state Departments of Transportation (DOTs). This research project surveyed in situ and ex situ monitoring options with particular attention on warning system options in the public domain. In situ monitoring can include portable and/or fixed devices for detecting bridge scour. Ex situ monitoring implies a statewide system that issues scour alerts to trigger bridge closures and/or inspections based on hydrologic conditions (rainfall and/or streamflow). A systematic statewide system would be preferable for monitoring

scour-capable events at bridges across the state. KDOT could leverage existing United States Geological Survey (USGS) and National Weather Service (NWS) tools to monitor scour-critical bridges or pursue a vendor to offer a turn-key solution. For critical locations, additional measures could be implemented at specific sites to offer more information or a higher level of monitoring.

**Record Type:** Publication

**Record URL:**

<http://dmsweb.ksdot.org/AppNetProd/docpop/docpop.aspx?clienttype=html&docid=9671303>;

<http://dmsweb.ksdot.org/AppNetProd/docpop/docpop.aspx?clienttype=html&docid=9671304>

**Edition:** Final Report

**Corporate Authors:**

University of Kansas, Lawrence

Department of Civil, Environmental and Architectural Engineering

1530 West 15th Street

Lawrence, KS 66045-7609 United States

Kansas Department of Transportation

Bureau of Research, 2300 SW Van Buren Street

Topeka, KS 66611-1195 United States

**Pagination:** 50p

**Publication Date:** 2016-09-00

**Language:** English

**Media Type:** Digital/other

**Period Covered:** 10/2013-3/2016

**Features:** Figures; Maps; References; Tables

**Subject Areas:** Bridges and other structures; Highways; Maintenance and Preservation

**Keywords:** Bridges; Floods; Kansas; Real time information; Scour; Structural health monitoring; Warning systems

**Accession Number:** 01611956

**Report/Paper Numbers:** K-TRAN: KU-14-1

**Files:** TRIS; ATRI; STATEDOT

**Created Date:** 9/19/2016 11:55 AM

**Title:** Prediction and Mitigation of Scour for Vermont Bridges

**Author(s):** N/A

**Abstract:** The majority of bridge failures in the United States and elsewhere are caused by scour, which was also observed in Vermont following the tropical storm Irene. Successfully mitigating such scour related problems associated with bridges is dependent on engineers' ability to reliably estimate scour potential, design effective scour prevention and countermeasures, design safe and economical foundation elements accounting for scour potential, and design reliable and economically feasible monitoring systems. The outcomes of this research project will enable the Agency of Transportation to holistically address the scour problem - predict the anticipated scour at a given site using modern numerical techniques such as artificial neural networks that employ the stream geomorphic data assembled by the Agency of Natural Resources; develop design and/or countermeasures techniques for bridge

abutments that are appropriate for Vermont; and develop relatively low-cost passive sensors that will actively yet remotely communicate excessive scour.

**Record Type:** Project

**Record URL:** <http://www.uvm.edu/trc/university-transportation-center/utc-current-project-list/>

**Supplemental Notes:** [http://www.uvm.edu/~transctr/research/trc\\_reports/UVM-TRC-15-002.pdf](http://www.uvm.edu/~transctr/research/trc_reports/UVM-TRC-15-002.pdf)

**Language:** English

**Contract Numbers:** DTRT06-G-0018; 027398

**Status:** Completed

**Funding Amount:** 37012.00

**Sponsor Organizations:**

Research and Innovative Technology Administration  
University Transportation Centers Program  
1200 New Jersey Avenue  
Washington, DC 20590 United States

**Project Managers:**

Troy, Austin  
austin.troy@uvm.edu  
Aultman-Hall, Lisa  
(802) 656-1245  
laultman@uvm.edu

**Performing Organizations:**

UVM Transportation Center  
University of Vermont  
210 Colchester Avenue  
Burlington, VT 05405 United States

**Principal Investigators:**

Frolik, Jeff  
jeff.frolik@uvm.edu  
Huston, Dryver R  
(802) 656-1922  
huston@emba.uvm.edu  
Rizzo, Donna  
drizzo@cems.uvm.edu  
Dewoolkar, Mandar  
(802) 656-1942  
Mandar.Dewoolkar@uvm.edu2

**Notice Date:** --

**Start Date:** 2012-06-01

**Expected Completion Date:** --

**Actual Completion Date:** 2014-12-31

**Source Data:** RiP Project 32172

**Subject Areas:** Bridges and other structures; Design; Highways; Maintenance and Preservation

**Keywords:** Bridge abutments; Bridges; Design; Maintenance; Remote sensing; Scour; Vermont

**Accession Number:** 01566188

**Source Agency:** UVM Transportation Center

University of Vermont

210 Colchester Avenue

Burlington, VT 05405 United States

**Files:** UTC; RiP

**Created Date:** 6/12/2015 1:01 AM

**Title:** Risk-Based Transportation Asset Management: Building Resilience into Transportation Assets: Report 5: Managing External Threats Through Risk-Based Asset Management

**Author(s):** N/A

**Abstract:** This is the fifth of five reports examining how risk management complements asset management. This last report examines how physical, climatic, seismic and other external threats can be addressed in risk-based asset management programs. The first four reports and the literature review emphasized the definition of risk as the positive or negative effect of uncertainty or variability upon agency objectives. Those reports emphasized that risks could be positive in that some types of uncertainty can create opportunities. However, this report will focus more on negative risks, or threats. These risks generally are external, and while highly probable over a long period of time, are difficult to predict in the short term. Randomness and variability complicate planning for them. In August 2011, Hurricane Irene reached one of the nation's most northern states, Vermont, and damaged 480 bridges out of a total network of 2717 bridges. In one day, more bridge deterioration occurred than normally would occur over many years. Accurate prediction of such events is nearly impossible. Such a significant storm had not struck Vermont for 83 years. In managing risks to assets from external threats, this report emphasizes the Three Rs, which are Redundancy, Robustness and Resiliency. These will be defined, described and illustrated through several agency examples. Asset management plays a critical role in each, particularly Robustness and Resiliency. Including the Three Rs in asset planning efforts can better prepare agencies to cope with an increasingly unpredictable world.

**Record Type:** Publication

**Record URL:** <http://www.fhwa.dot.gov/asset/pubs/hif13018.pdf>;  
[/common/images/covers/large/1265582.png](#)

**Corporate Authors:**

Federal Highway Administration

Office of Asset Management, 1200 New Jersey Avenue, SE

Washington, DC 20590 United States

**Publication Date:** 2013-03-00

**Language:** English

**Media Type:** Digital/other

**Features:** Figures; Maps; Photos; Tables

**Subject Areas:** Economics; Highways; Planning and Forecasting; Security and Emergencies; I10: Economics and Administration; I72: Traffic and Transport Planning

**Keywords:** Asset management; Redundancy; Resilience (Adaptability); Risk management; Robustness; Transportation planning

**Accession Number:** 01495865

**Report/Paper Numbers:** FHWA-HIF-13-018; Report 5

**Files:** TRIS; ATRI; USDOT

**Created Date:** 10/18/2013 10:55 AM

**Title:** Disaster Protection of Transport Infrastructure and Mobility Using Flood Risk Modeling and Geospatial Visualization

**Author(s):** Uddin, Waheed; Altinakar, Mustafa

**Abstract:** This project addresses the goal of using flood simulations to assess the flood risk and impacts on the built infrastructure. The primary objectives of this project are to: select a test site in Mississippi on the downstream of a river, extract river centerline and infrastructure features on a geospatial map, simulate extreme flood scenarios, and evaluate the structural integrity of bridges. Traditionally, flood simulation and risk mapping relied on one-dimensional flood models. In this project, two-dimensional flood propagation modeling is simulated over large areas using the DSS-WISE software, developed by the National Center for Computational Hydroscience and Engineering. It combines a state-of-the-art two-dimensional numerical model, CCHE2D-FLOOD, with a digital elevation model (DEM) of the study area and geospatial visualization. The numerical model solves full dynamic shallow water equations over the DEM of natural topography that can handle mixed flow regimes, wetting/drying, and disconnected flow domains. The extreme flood simulation results for the pilot study Sardis site considering 10-m square computation cells of the bare ground indicate a total area of 31 mi<sup>2</sup> (80 km<sup>2</sup>) inundated. The floodwater reached up to 39 ft (12 m) above the ground level and 13–16 ft (4 – 4.9 m) over the top of the two highways and rail infrastructure bridges. The local scour around the 10 ft.-diameter bridge piers in the main channel is estimated as 17.30 ft (5.3 m), which is severe. A detailed structural integrity analysis of the US-51 bridge model shows the most critical condition as the factor of safety approaches 1.0. This happens when the floodwater level is at the top of the concrete girders, which destabilizes the girder-bearing areas. Field evidence and failure analysis of post-flood images show the washing away and destruction of bridges over streams and other bodies of water when the floodwater reaches the deck level, as observed for bridge destruction cases during both 2005 Katrina and 2011 Irene hurricane disasters. This important finding of optimum clearance of bridge superstructure above the channel bed is recommended to implement in state bridge management systems for flagging such vulnerable bridges and prioritizing for mitigation.

**Record Type:** Publication

**Record URL:** <http://www.ncitec.msstate.edu/wp-content/uploads/2012-25FR.pdf>;  
[/common/images/covers/large/1363642.png](#)

**Edition:** Final Report

**Corporate Authors:**

University of Mississippi, University

Center for Advanced Infrastructure Technology

University, MS 38677-1848 United States

National Center for Intermodal Transportation for Economic Competitiveness

Mississippi State University  
479-2 Hardy Road 260 McCain Hall  
Mississippi State, MS 39762 United States  
Research and Innovative Technology Administration  
1200 New Jersey Avenue, SE  
Washington, DC 20590 United States

**Pagination:** 161p

**Publication Date:** 2015-05-00

**Language:** English

**Media Type:** Digital/other

**Features:** Figures; Maps; Photos; References; Tables

**Subject Areas:** Bridges and other structures; Highways; Planning and Forecasting; Security and Emergencies; I72: Traffic and Transport Planning

**Keywords:** Bridge management systems; Bridges; Disaster preparedness; Floods; Geospatial analysis; Infrastructure; Mississippi; Risk analysis; Simulation; Structural analysis; Visualization

**Accession Number:** 01574115

**Report/Paper Numbers:** UM-CAIT/2015-01

**Files:** UTC; TRIS; RITA; ATRI; USDOT

**Created Date:** 7/31/2015 1:50 PM

**Title:** Prediction and mitigation of scour and scour damage to Vermont bridges

**Author(s):** Anderson, Ian A.; Dewoolkar, Mandar M.; Rizzo, Donna M.; Huston, Dryver R.; Frolik, Jeff; Brand, Matthew; Howard, Lucas

**Abstract:** Over 300 Vermont bridges were damaged in the 2011 Tropical Storm Irene and many experienced significant scour. Successfully mitigating bridge scour in future flooding events depends on the ability to reliably estimate scour potential, design safe and economical foundation elements accounting for scour potential, design effective scour prevention and countermeasures, and design reliable and economically feasible monitoring systems, which served as the motivation for this study. This project sought to leverage data on existing Vermont bridges and case studies of bridge scour damage, and integrate available information from stream geomorphology to aid in prediction of bridge scour vulnerability. Tropical Storm Irene's impact on Vermont bridges was used as a case study, providing damage information on a wide range of bridges throughout the State. Multiple data sources were combined in an effort to include data, which represents the complex, interconnected processes of stream stability and bridge scour, then identify and incorporate features that would be useful in a probabilistic model to predict bridge susceptibility to scour damage. The research also sought to identify features that could be included in inspections and into a scour rating system that are capable of assessing network-level scour vulnerability of bridges more holistically. This research also sought to review existing scour countermeasures and scour monitoring technologies available in the literature and examine efficacy of new, indirect scour countermeasures and passive scour monitoring techniques. The specific objectives of this research were to: (1) review the literature and identify methods/technologies that are adaptable to Vermont; (2) analyze Tropical Storm Irene bridge damage information and observations by collecting and geo-referencing all available bridge records and stream geomorphic assessment data into a comprehensive

database for identifying features that best represent bridge scour damage; (3) conduct watershed analysis on all bridges, including creation of stream power data to assess if watershed stream power improves the prediction of bridge scour damage; and (4) investigate new scour countermeasures and monitoring technologies, and provide recommendations on implementations.

**Record Type:** Publication

**Record URL:**

[http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/complete\\_dprojects/VTrans%20Scour%20Project%20731%20Anderson%20Et%20al%20%28FinalReport%2003-10-17%29.pdf](http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/complete_dprojects/VTrans%20Scour%20Project%20731%20Anderson%20Et%20al%20%28FinalReport%2003-10-17%29.pdf); /common/images/covers/large/1460935.png

**Edition:** Final Report

**Corporate Authors:**

University of Vermont, Burlington  
School of Engineering, 33 Colchester Avenue  
Burlington, VT 05405 United States  
Vermont Agency of Transportation  
Materials and Research Section  
1 National Life Drive, Drawer 33  
Montpelier, VT 05633 United States  
Department of Transportation  
Washington, DC United States

**Pagination:** 141p

**Publication Date:** 2017-02-20

**Language:** English

**Media Type:** Digital/other

**Period Covered:** 2012-2016

**Features:** Figures; Maps; Photos; References; Tables

**Subject Areas:** Bridges and other structures; Highways; Hydraulics and Hydrology; Maintenance and Preservation

**Keywords:** Bridges; Case studies; Countermeasures; Hurricane Irene, 2011; Literature reviews; Probability; Recommendations; Scour; Sensors; Streamflow; Structural health monitoring; Vermont

**Accession Number:** 01633297

**Files:** TRIS; ATRI; USDOT; STATEDOT

**Created Date:** 3/24/2017 4:20 PM

**Title:** Stream Power Application for Bridge-Damage Probability Mapping Based on Empirical Evidence from Tropical Storm Irene

**Author(s):** Anderson, Ian; Rizzo, Donna M.; Huston, Dryver R.; Dewoolkar, Mandar M.

**Abstract:** On August 28, 2011, Tropical Storm Irene hit the state of Vermont with a severity that deposited 100–200 mm (4–8 in.) of rain across the state and resulted in damage or failure of over 300 bridges. The analysis of available data sets helped identify a set of 313 bridges (with a span greater than 6 m) damaged in a single state from a single extreme flood event that caused a 12-h rainfall recurrence interval that exceeded 500 years in some areas and 100 years

throughout most of the affected areas. Based on available damage reports and photographs, the observed bridge damage was grouped into four levels of severity. This paper links watershed stream power to the observed bridge damage, develops a process for quantifying the hazard at bridges both as a case study and for future storms, and uses stream power as a hazard metric to produce probabilistic predictions of bridge vulnerability. The analysis also offers a comparison between damaged bridges and bridges that were not damaged in Tropical Storm Irene. Specific stream power (SSP) and the event-based Irene-specific stream power (ISSP) were computed and found to be both statistically significant at discriminating between damaged and non-damaged bridges, as well as between damage levels. The application of the empirical fragility curve analysis for SSP and ISSP produces a probability of damage generated from the results collected from Tropical Storm Irene. Spatially mapping the bridge-damage probability from an extreme event like Tropical Storm Irene enables the hazard to be effectively displayed over a broad range of scales (e.g., stream reaches, select watershed, statewide). The methodology presented here can be applied to other geographic settings and storm events of interest, and to the best of the authors' knowledge, this is the first investigation comparing site-specific stream power to observed bridge damage at a network level.

**Record Type:** Publication

**Record URL:** [http://dx.doi.org/10.1061/\(ASCE\)BE.1943-5592.0001022](http://dx.doi.org/10.1061/(ASCE)BE.1943-5592.0001022)

**Supplemental Notes:** © 2017 American Society of Civil Engineers.

**Serial:** Journal of Bridge Engineering

**Publisher:** American Society of Civil Engineers

**ISSN:** 1084-0702

**OCLC:** 32947845

**URL:** <http://ojps.aip.org/beo>

**Volume:** 22

**Issue:** 5

**Pagination:** Content ID 05017001

**Publication Date:** 2017-05-00

**Language:** English

**Media Type:** Web

**Subject Areas:** Bridges and other structures; Highways; Hydraulics and Hydrology; Security and Emergencies

**Keywords:** Floods; Hurricane Irene, 2011; Mathematical models; Rainfall; Streams; Structural health monitoring; Vermont; Watersheds

**Accession Number:** 01644167

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/oclc/32947845>

**Files:** TRIS; ASCE

**Created Date:** 3/31/2017 3:03 PM

**Title:** A Case Study of the Possible Effects of Long-Term Climate Change on Bridge Scour

**Author(s):** Kirshen, P.; Edgers, L.; Edlmann, J.; Percher, M.; Bettencourt, B.; Lewandowski, E.

**Abstract:** Long-term climate change due to global warming is expected to produce increased frequency of storms and precipitation in the northeastern United States. Consequently, there

may be an increase in peak streamflows and thus an increase in the scour of bridge foundations. A case study of possible impacts was performed in eastern Massachusetts for an important highway bridge with two concrete piers on reinforced concrete spread footings. The bridge selected for this study was classified as close to scour critical by Federal Highway Administration/Massachusetts Highway Department criteria under present climate conditions. The authors evaluated the possible effects due to 10 to 30% increases in the 100 year flood discharge caused by climate change and then possible footing remediation and bridge replacement strategies. They found that riprap was the most cost effective footing protection method. If the superstructure of the bridge was in poor condition, a single span superstructure was found to be preferred because it was least expensive compared to multiple span alternatives and scour protection was needed only at the abutments.

**Record Type:** Publication

**Supplemental Notes:** The proceedings are available on CD-ROM.

**Corporate Authors:**

Texas Transportation Institute  
Texas A&M University System, 1600 E Lamar Boulevard  
Arlington, TX 76011 United States

**Editors:** H-C Chen, J-L Briaud

**Pagination:** p. 842-853

**Conference:** First International Conference on Scour of Foundations

Location: College Station, Texas

Date: 2002-11-17 to 2002-11-20

**Publication Date:** 2002-00-00

**Language:** English

**Features:** Figures; References; Tables

**Subject Areas:** Bridges and other structures; Design; Environment; Highways; Hydraulics and Hydrology; Marine Transportation; Safety and Human Factors; I24: Design of Bridges and Retaining Walls

**Keywords:** Bridge piers; Bridges; Case studies; Climate change; Cost effectiveness; Countermeasures; Global warming; Highway bridges; Impacts; Massachusetts; Northeastern United States; Precipitation (Meteorology); Riprap; Scour; Spread footings; Storms

**Accession Number:** 00977064

**Availability:**

Texas Transportation Institute  
Texas A&M University System, 1600 E Lamar Boulevard  
Arlington, TX 76011 United States

**Files:** TRIS

**Created Date:** 8/6/2004 12:00 AM

**Title:** Iowa's Proactive Approach to Bridge Scour Monitoring

**Author(s):** Claman, David; Gray-Fisher, Dena M.

**Abstract:** Scour, which is the result of the erosive action of flowing water excavating and carrying away material from the bed and banks of streams and from around the piers and abutments of bridges, is the most common cause of bridge failure. The structural instability and

undermining caused by scouring are affected by factors such as channel and bridge geometry, floodplain characteristics, flow hydraulics, bed material, channel protection and stability, riprap placement, and ice formation and debris. Directing its attention to the scour problem, the Federal Highway Administration issued a Technical Advisory in 1988 and again in 1991, revisiting the National Bridge Inspection Standards to require evaluation of all bridges for susceptibility to damage resulting from scour. Of special concern were scour-critical bridges, or those bridges that could experience catastrophic failure or become structurally unstable as a result of excessive scour caused by a destructive flood event. Over the past 4 years, the Iowa Department of Transportation has devoted significant time to evaluating the bridges under its jurisdiction and assigning scour-classification codes to them. This article discusses the scour evaluation of Iowa's 2,100 waterway bridges, 180 of which have been classified as scour-critical, and the scheduled hydraulic and structural construction countermeasures being taken to prevent their catastrophic failure.

**Record Type:** Publication

**Serial:** Bridges

**Publisher:** ZweigWhite

**Volume:** 9

**Issue:** 3

**Pagination:** pp 22-24

**Publication Date:** 2006-05-00

**Language:** English

**Media Type:** Print

**Features:** Photos

**Subject Areas:** Bridges and other structures; Design; Highways; I24: Design of Bridges and Retaining Walls

**Keywords:** Bridge abutments; Bridge failure; Bridge foundations; Highway bridges; Iowa; National Bridge Inspection Standards; Scour; State departments of transportation; Strengthening (Maintenance); Structural deterioration and defects; U.S. Federal Highway Administration

**Accession Number:** 01026259

**Files:** TRIS

**Created Date:** 6/4/2006 10:00 PM

**Title:** Taking a Key Role in Reducing Disaster Risks

**Author(s):** Duwadi, Sheila Rimal

**Abstract:** Natural and human-induced hazardous events can have significant impacts on transportation infrastructure. Certain links in the highway network – especially bridges on essential routes -- are critical in that their incapacitation would cause great physical and economic disruption. Recognizing that most hazards cannot be prevented, the White House's National Science and Technology Council established the Subcommittee on Disaster Reduction (SDR), charged with prioritizing Federal investments in science and technology to enhance disaster resilience. To accomplish this goal, the subcommittee crafted a 10-year strategy identifying six "grand challenges" to enhance community resilience and thus create a more disaster-resilient Nation. The U.S. Department of Transportation (USDOT) and Federal Highway

Administration (FHWA) are carrying out research and development (R&D) to address the six grand challenges for the transportation sector. The FHWA's Turner-Fairbank Highway Research Center (TFHRC) is researching solutions to reduce the impacts of extreme events. This overview of FHWA's hazard mitigation R&D program describes the threats to highway bridges and their vulnerabilities, and demonstrates how the program is reducing risks for the Nation's transportation infrastructure. The focus of the current R&D effort is on addressing the grand challenges for the following hazards as they affect bridges: flooding and scour; coastal inundation; wind, including hurricanes; earthquakes; and technological hazards, including terrorism. The emphasis is on the engineering aspects of building disaster resiliency into the transportation infrastructure for ease in response and recovery. Each event imparts loads on a structure of different magnitude, direction, and location, so one solution will not always satisfy all hazard requirements. The R&D effort underway focuses on single hazards, develops solutions, and then ensures the solutions are compatible with other hazards before implementation. Research conducted at TFHRC is helping build a resilient transportation system that continues to function during and after hazard events.

**Record Type:** Publication

**Record URL:** <http://www.fhwa.dot.gov/publications/publicroads/10mayjun/04.cfm>

**Serial:** Public Roads

**Publisher:** Federal Highway Administration

**ISSN:** 0033-3735

**OCLC:** 1586080

**URL:** <https://www.fhwa.dot.gov/publications/publicroads/>

**Volume:** 73

**Issue:** 6

**Pagination:** pp 20-25

**Publication Date:** 2010-05-00

**Language:** English

**Media Type:** Print

**Features:** Photos

**Subject Areas:** Bridges and other structures; Highways; Security and Emergencies; I24: Design of Bridges and Retaining Walls

**Keywords:** Bridge engineering; Coast and river protective works; Disaster preparedness; Disaster relief; Disasters; Earthquake resistant design; Flood protection; Highway bridges; Product development; Research; Scour; Terrorism; U.S. Federal Highway Administration; Wind resistant design

**Accession Number:** 01159945

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/oclc/1586080>

**Files:** TRIS; ATRI

**Created Date:** 6/29/2010 2:19 PM

**Title:** Scour Related Vermont Bridge Damage from Tropical Storm Irene

**Author(s):** Anderson, Ian A.; Dewoolkar, Mandar M.; Rizzo, Donna M.; Huston, Dryver R.

**Abstract:** Tropical Storm Irene swept through Vermont with 100-200 mm (4-8 inches) of rain, causing intensive flooding in the Southern and Central regions. Over 300 bridges suffered damage or failed as a result of heavy rains. Resources from the Vermont Agency of Transportation, Vermont Agency of Natural Resources, and Vermont Regional Planning Commission were joined to create a comprehensive bridge database. The database combines the stream characteristics and Irene damage along with the bridge attributes into a common resource that can be used for analysis. The examination of affected bridges showed scour as the dominant mode of damage from Irene. Bridges damaged tended to have floodplain contraction, and spans incapable of passing flood flows. Flow constriction and floodplain blockage were key indications of poor performance.

**Record Type:** Publication

**Record URL:** <http://dx.doi.org/10.1061/9780784413357.046>

**Supplemental Notes:** © 2014 American Society of Civil Engineers.

**Monograph Title:** Structures Congress 2014

**Corporate Authors:**

American Society of Civil Engineers  
1801 Alexander Bell Drive  
Reston, VA 20191-4400 United States

**Editors:** Glenn R Bell, Matt A Card

**ISBN:** 9780784413357

**Pagination:** pp 505-515

**Conference:** Structures Congress 2014

Location: Boston Massachusetts, United States

Date: 2014-04-03 to 2014-04-05

**Publication Date:** 2014-04-00

**Language:** English

**Media Type:** Web

**Features:** References

**Subject Areas:** Bridges and other structures; Data and Information Technology; Highways; Maintenance and Preservation; I60: Maintenance

**Keywords:** Bridges; Columns; Databases; Flood damage; Flood plains; Floods; Hurricane Irene, 2011; Scour; Vermont

**Accession Number:** 01522424

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/isbn/9780784413357>

**Files:** TRIS; ASCE

**Created Date:** 4/9/2014 3:01 PM

**Title:** Real-Time Flood Forecasting and Monitoring System for Highway Overtopping in Iowa, TR-699

**Author(s):** N/A

**Abstract:** The Iowa Department of Transportation (DOT) has utilized the BridgeWatch program since 2006 to provide alerts when rainfall events or stream gages indicate the potential for significant flooding at scour critical bridges. The Iowa DOT would like to use this real-time

warning program to provide alerts when a highway is about to overtop due to flooding. To this end the project proposed a project to interface the information of sonic-sensors developed by the Iowa Flood Center and the prediction of their hydrologic model with BridgeWatch and perform a study to determine the impact of merging these technologies in improving response to situation of road flooding, and flash flooding. In order to better predict the potential for flood waters to overtop a highway, the University of Iowa's hydrologic model CUENCAS will be used to provide flood forecasting at various sites where the highway infrastructure is most vulnerable to flooding. The Iowa Flood Center has created a hydrologic model for the entire state which can incorporate real-time rainfall events and forecast resultant peak flows along any basin in the state of Iowa. The hydrologic model can provide a predicted flood discharge that can be integrated with a stage/discharge relationship in the BridgeWatch program so that real-time warnings can be provided to maintenance staff before a highway overtops thereby enhancing public safety. In addition to the CUENCAS hydrologic model, the Flood Center has developed sensors that can provide real-time stage/discharge information at bridge sites. For smaller sized basins, these sensors can provide real-time warning of highway overtopping by integration into the BridgeWatch program. As part of the research, the project will involve interviewing maintenance staff to assess and documenting their current responses to significant rainfall/highway overtopping events. The research project will determine the time and costs associated with monitoring sites before they overtop and the issues associated with closing a road while floodwaters are overtopping the highway. Once the project has been implemented over several seasons, follow-up interviews will be performed to determine the accuracy of the warnings and if the system provided a better allocation of resources and an enhancement of public safety. The Iowa DOT would like to monitor 26 of the most vulnerable infrastructure sites that overtop due to flooding. The project will provide real-time warning by merging the University of Iowa's real-time hydrologic flood forecasting model (CUENCAS) and stage sensors with the assessment and alert notification capabilities of the BridgeWatch program. The proposed research will assess the predictability and potential cost savings of a system that will provide better information for maintenance staff to protect the traveling public during flood events.

**Record Type:** Project

**Language:** English

**Contract Numbers:** TR-699

**Status:** Active

**Funding Amount:** 229425

**Sponsor Organizations:**

Iowa Department of Transportation

800 Lincoln Way

Ames, IA 50010 United States

Iowa Highway Research Board

Iowa Department of Transportation

800 Lincoln Way

Ames, IA 50010 United States

**Project Managers:**

Goetz, Vanessa

(515) 239-1382

vanessa.goetz@dot.iowa.gov

**Performing Organizations:**

University of Iowa, Iowa City

IIHR- Hydroscience & Engineering

307 C. Maxwell Stanley Hydraulics Lab

Iowa City, Iowa 52242 United States

University of Iowa

Iowa Flood Center

207 C. Maxwell Stanley Hydraulics Laboratory

Iowa City, Iowa 52242 United States

**Principal Investigators:**

Mantilla, Ricardo

(319) 335-5941

ricardo-mantilla@uiowa.edu

Krajewski, Witold F.

(319) 335-5231

witold-krajewski@uiowa.edu

**Notice Date:** --

**Start Date:** 2015-10-15

**Expected Completion Date:** 2018-09-30

**Actual Completion Date:** --

**Subject Areas:** Bridges and other structures; Data and Information Technology; Environment; Highways; Hydraulics and Hydrology; Maintenance and Preservation; Planning and Forecasting

**Keywords:** Benefit cost analysis; Bridge management systems; Bridges; Detours; Flood damage; Floods; Forecasting; Hydrology; Iowa; Overtopping; Sensors; Stream gages

**Accession Number:** 01580314

**Source Agency:** Iowa Department of Transportation

800 Lincoln Way

Ames, IA 50010 United States

**Files:** RiP; STATEDOT

**Created Date:** 11/2/2015 10:04 AM

**Title:** Climate Change Impact on Highway Bridges: Flood-Induced Bridge Scour

**Author(s):** Fioklou, Ameh; Alipour, Alice

**Abstract:** Research in climate change trends has shown with certainty a future increase in the frequency and duration of extreme precipitation events across the U.S. with the Midwest and the Northeast projected to experience the largest increase. These changes could result in higher flow depth and flow speed. With respect to scouring of the foundation the higher flow speed and frequency of its occurrence would result in an increased likelihood of damage due to the bridge. With the understanding of increased risk to the bridges due to scour, transportation agencies are developing strategies to adapt the transportation infrastructure to the ever changing climate. This study benefits from a previously conducted pilot climate change study in the state of Iowa and applies the proposed procedure on the US 30 bridge over South Skunk

River in Iowa as a case study. The paper presents five different countermeasures to reduce the risk of failure of the bridge due to increased scour and compares the cost to benefit ratio of each method.

**Record Type:** Publication

**Record URL:** <http://amonline.trb.org/>

**Supplemental Notes:** This paper was sponsored by TRB committee A0020T Special Task Force on Climate Change and Energy.

**Monograph Title:** TRB 96th Annual Meeting Compendium of Papers

**Corporate Authors:**

Transportation Research Board

500 Fifth Street, NW

Washington, DC 20001 United States

**Pagination:** 15p

**Conference:** Transportation Research Board 96th Annual Meeting

Location: Washington DC, United States

Date: 2017-01-08 to 2017-01-12

**Publication Date:** 2017-00-00

**Language:** English

**Media Type:** Digital/other

**Features:** Figures; Maps; Photos; References; Tables

**Subject Areas:** Bridges and other structures; Environment; Highways; Maintenance and Preservation

**Keywords:** Benefit cost analysis; Case studies; Climate change; Coast and river protective works; Countermeasures; Failure; Flood damage; Highway bridges; Iowa; Scour

**Accession Number:** 01626644

**Report/Paper Numbers:** 17-04559

**Files:** TRIS; TRB; ATRI

**Created Date:** 12/8/2016 11:44 AM

**Title:** Analysis of bridge and stream conditions of over 300 Vermont bridges damaged in Tropical Storm Irene

**Author(s):** Anderson, Ian; Rizzo, Donna M.; Huston, Dryver R.; Dewoolkar, Mandar M.

**Abstract:** The 2011 Tropical Storm Irene deposited 100–200 mm of rain in Vermont with a rainfall recurrence interval for a 12-hour storm exceeding 500 years in some areas. This single hurricane-related event damaged over 300 bridges. The wide range of damage prompted a network-wide analysis of flood, scour, stream and structural conditions. A first step was the assembly of a unique data set containing information on 326 damaged bridges, 1936 undamaged bridges and the surrounding stream conditions. Descriptions of the damage appear as case studies that include pre-storm bridge and stream geomorphology conditions. The assembled and georeferenced data include rainfall, damage type and extent, estimated and actual repair costs, bridge characteristics, bridge ratings and stream geomorphic assessments from a number of sources. The analyses identified significant features of bridge vulnerability under extreme floods. The bridge age and rating assessment characteristics, such as substructure, channel and structural adequacy ratings, followed by scour, waterway adequacy

and sufficiency ratings, correlated strongly to damage. The stream geomorphic features have promise to supplement future bridge rating systems and in identifying hydraulic vulnerability of bridges. Empirical fragility curves relating probability of meeting or exceeding different bridge damage levels based on channel and waterway adequacy ratings are also presented.

**Record Type:** Publication

**Record URL:** <http://dx.doi.org/10.1080/15732479.2017.1285329>

**Supplemental Notes:** Abstract reprinted with permission of Taylor & Francis.

**Serial:** Structure and Infrastructure Engineering

**Publisher:** Taylor & Francis

**ISSN:** 1573-2479

**EISSN:** 1744-8980

**URL:** <http://www.tandfonline.com/loi/nsie20>

**Volume:** 13

**Issue:** 11

**Pagination:** pp 1437-1450

**Publication Date:** 2017-11-00

**Language:** English

**Media Type:** Web

**Features:** Figures; References

**Subject Areas:** Bridges and other structures; Highways; Hydraulics and Hydrology; Maintenance and Preservation

**Keywords:** Analysis; Bridges; Case studies; Condition surveys; Costs; Floods; Geomorphology; Hurricane Irene, 2011; Rainfall; Ratings; Risk assessment; Scour; Streams; Vermont

**Accession Number:** 01644130

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/issn/15732479>

**Files:** TRIS

**Created Date:** 8/18/2017 3:00 PM

#### **TRID RETRIVALS with MEDIUM RELEVANCE:**

**Title:** Protecting Bridges from Scour

**Author(s):** Horne, William A.

**Abstract:** Scour is the primary cause of bridge failures in the United States. Unlike most forms of deterioration that occur gradually, scour can destroy bridges quickly, especially during floods. After several bridge scour failures in the 1980s, the Federal Highway Administration (FHWA) and the engineering community changed the way bridges are evaluated for vulnerability. Bridges now undergo regular underwater inspections, evaluations to predict performance during floods and monitoring of streambed elevations. Corrective Plans of Action (POAs) are developed for vulnerable bridges. Today, National Bridge Inspection Program Metric No. 18 (Scour Critical Bridges) and Inspection Item 113 (Scour Rating) quantify scour conditions, inspection requirements, and designate compliance. To comply with FHWA scour directives, bridge owners must prioritize evaluations and implement POAs for scour-critical bridges. In

April 2012, the FHWA provided another in a series of formal scour memoranda to all 50 states that clarified the expectations for implementing POAs, provided strategies for prioritizing various categories of bridges, and reinforced a 2008 directive that scour-critical ratings must be assigned to bridges with unknown foundations by 2010. If a bridge is rated scour critical, a POA must be developed and corrective action implemented. The Maine Department of Transportation's scour management plan is highlighted as an example of how a state can meet the FHWA expectations. Although rating bridges for scour is part of the challenge, the ultimate goal is to protect them. One countermeasure that is commonly used in Europe and shows promise in the United States is partially grouted riprap (PGR). PGR construction involves placing riprap on top of a gravel filter base and/or geotextile fabric. The voids between stones are partially filled by a flowable cement-based grout, interlocking the armoring stones. This increases both the mass of the repair and its hydraulic stability. Compared to traditional countermeasures, PGR requires less material, reduces the need for channel excavation, and improves performance during floods.

**Record Type:** Publication

**Record URL:** [http://www.cenews.com/magazine-article-cenews.com-7-2012-protecting\\_bridges\\_from\\_scour-8899.html](http://www.cenews.com/magazine-article-cenews.com-7-2012-protecting_bridges_from_scour-8899.html)

**Serial:** CE News

**Publisher:** Zweig White Information Services

**Editor:** Sharon Fauerbach

**ISSN:** 1051-9629

**URL:** <http://www.cenews.com>

**Volume:** 24

**Issue:** 6

**Pagination:** pp 36-39

**Publication Date:** 2012-07-00

**Language:** English

#### **Media Info**

**Media Type:** Print

**Features:** Photos

#### **Subjects/Keywords**

**Subject Areas:** Bridges and other structures; Highways; Maintenance and Preservation; I24:

Design of Bridges and Retaining Walls; I60: Maintenance

**Keywords:** Bridges; Countermeasures; Flood damage; Floods; Inspection; Maine Department of Transportation; Ratings; Riprap; Scour; U.S. Federal Highway Administration

**Accession Number:** 01443805

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/issn/10519629>

**Files:** TRIS

**Created Date:** 8/26/2012 11:52 PM

**Title:** NYSDOT and Hurricane Sandy: Operational Impacts and Lessons Learned

**Author(s):** Mark, Edward L.

**Abstract:** Hurricane Sandy hit the New York City metropolitan area on October 29, 2012, resulting in flooding and widespread damage which closed or partially obstructed transportation facilities throughout the region. Damaged transit systems and highways crippled commutes for roughly 10 million commuters for weeks after the Storm. The New York State Department of Transportation (NYSDOT) manages “511NY”, a statewide multi-modal travel and incident information service which serves New York via its 511NY.org website and phone number. TDM (transport demand management) outreach and rideshare support is provided by NYSDOT through 511NYRideshare as an Integral element of 511NY. During Hurricane Sandy, 511NYRideshare provided information support and outreach to commuters and employers, especially to medical staff in area hospitals, since access to several hospitals was heavily impacted by the storm. This paper details the range of traveler information services provided by NYSDOT and 511NYRideshare and outlines the level of emergency preparedness planning and response for providing travel information services. It also highlights the need for traditional TDM operations, including multi-modal travel information services and employer outreach, to be integrated into larger multi-agency emergency preparation and response efforts. Furthermore, this paper showcases outcomes of employer involvement in emergency response, which further emphasizes the benefits of integrated TDM programs. A commuter survey and employer interviews were conducted to analyze the change of commute behavior and impact of employer involvement in encouraging alternatives for long term commuter travel behavior. The paper also outlines lessons learned and recommendations for further integration of TDM and emergency preparation and response services.

**Record Type:** Publication

**Record URL:** <http://docs.trb.org/prp/14-2752.pdf>;  
[/common/images/covers/large/1288449.png](http://common/images/covers/large/1288449.png); <http://amonline.trb.org/>

**Supplemental Notes:** This paper was sponsored by TRB committee ABE50 Transportation Demand Management.

**Monograph Title:** TRB 93rd Annual Meeting Compendium of Papers

**Corporate Authors:**

Transportation Research Board  
500 Fifth Street, NW  
Washington, DC 20001 United States

**Pagination:** 22p

**Conference:** Transportation Research Board 93rd Annual Meeting

Location: Washington DC

Date: 2014-01-12 to 2014-01-16

**Publication Date:** 2014-00-00

**Language:** English

**Media Type:** Digital/other

**Features:** Figures; Maps; References

**Subject Areas:** Operations and Traffic Management; Planning and Forecasting; Public Transportation; Security and Emergencies; I72: Traffic and Transport Planning

**Keywords:** Commuters; Disaster preparedness; Emergency management; Employers; Flood damage; Hurricane Sandy, 2012; Hurricanes; Information dissemination; New York

Metropolitan Area; New York State Department of Transportation; Public transit; Ridesharing; Travel demand management; Traveler information and communication systems

**Accession Number:** 01520095

**Report/Paper Numbers:** 14-2752

**Availability:**

Transportation Research Board Business Office

500 Fifth Street, NW

Washington, DC 20001 United States

**Files:** PRP; TRIS; TRB; ATRI

**Created Date:** 1/27/2014 2:56 PM

**Title:** Use of Mobile Lidar Data to Assess Hurricane Damage and Visualize Community Vulnerability

**Author(s):** Gong, Jie; Maher, Ali

**Abstract:** Hurricane Sandy, the worst storm of its type to hit U.S. New York City and the state of New Jersey in generations, caused devastating damage to the region's infrastructure, properties, and businesses. Various technologies for the acquisition of geospatial information have been used since the landing of Hurricane Sandy to support critical decision making related to search and rescue, damage assessment, environmental risk analysis, debris removal, and rebuilding processes. The challenge is to match the best sensing method with the desired post-disaster applications. A large-scale application of mobile terrestrial laser scanning technology to post-hurricane situations is described for the support of disaster recovery operations in the United States. Several innovative data analysis approaches for supporting damage assessment and flood resilience analysis are presented. Opportunities for and challenges presented by the use of mobile terrestrial laser scanning to support post-disaster recovery operations are discussed to highlight future research directions.

**Record Type:** Publication

**Record URL:** <http://dx.doi.org/10.3141/2459-14>

**Monograph Title:** Critical Infrastructure, Emergency Evacuation, and Logistics of Disaster Recovery 2014

**ISBN:** 9780309295512

**Serial:** Transportation Research Record: Journal of the Transportation Research Board

**Publisher:** Transportation Research Board

**ISSN:** 0361-1981

**Issue:** 2459

**Pagination:** pp 119-126

**Publication Date:** 2014-00-00

**Language:** English

**Media Type:** Print

**Features:** Figures; Photos; References; Tables

**Subject Areas:** Highways; Planning and Forecasting; Security and Emergencies; I72: Traffic and Transport Planning

**Keywords:** Data analysis; Disasters and emergency operations; Floods; Hurricane Sandy, 2012; Hurricanes; Laser radar; Risk assessment

**Accession Number:** 01552183

**Report/Paper Numbers:** 14-4592

**Availability:**

Transportation Research Board Business Office

500 Fifth Street, NW

Washington, DC 20001 United States

Find a library where document is available

Order URL: <http://worldcat.org/isbn/9780309295512>

**Files:** TRIS; TRB; ATRI

**Created Date:** 1/30/2015 9:58 AM

**Title:** Peak Discharge, Flood Frequency, and Peak Stage of Floods on Big Cottonwood Creek at U.S. Highway 50 near Coaldale, Colorado, and Fountain Creek below U.S. Highway 24 in Colorado Springs, Colorado, 2016

**Author(s):** Kohn, Michael S.; Stevens, Michael R.; Mommandi, Amanullah; Khan, Aziz R.

**Abstract:** The U.S. Geological Survey (USGS), in cooperation with the Colorado Department of Transportation, determined the peak discharge, annual exceedance probability (flood frequency), and peak stage of two floods that took place on Big Cottonwood Creek at U.S. Highway 50 near Coaldale, Colorado (hereafter referred to as “Big Cottonwood Creek site”), on August 23, 2016, and on Fountain Creek below U.S. Highway 24 in Colorado Springs, Colorado (hereafter referred to as “Fountain Creek site”), on August 29, 2016. A one-dimensional hydraulic model was used to estimate the peak discharge. To define the flood frequency of each flood, peak-streamflow regional-regression equations or statistical analyses of USGS streamgauge records were used to estimate annual exceedance probability of the peak discharge. A survey of the high-water mark profile was used to determine the peak stage, and the limitations and accuracy of each component also are presented in this report. Collection and computation of flood data, such as peak discharge, annual exceedance probability, and peak stage at structures critical to Colorado’s infrastructure are an important addition to the flood data collected annually by the USGS. The peak discharge of the August 23, 2016, flood at the Big Cottonwood Creek site was 917 cubic feet per second (ft<sup>3</sup>/s) with a measurement quality of poor (uncertainty plus or minus 25 percent or greater). The peak discharge of the August 29, 2016, flood at the Fountain Creek site was 5,970 ft<sup>3</sup>/s with a measurement quality of poor (uncertainty plus or minus 25 percent or greater). The August 23, 2016, flood at the Big Cottonwood Creek site had an annual exceedance probability of less than 0.01 (return period greater than the 100-year flood) and had an annual exceedance probability of greater than 0.005 (return period less than the 200-year flood). The August 23, 2016, flood event was caused by a precipitation event having an annual exceedance probability of 1.0 (return period of 1 year, or the 1-year storm), which is a statistically common (high probability) storm. The Big Cottonwood Creek site is downstream from the Hayden Pass Fire burn area, which dramatically altered the hydrology of the watershed and caused this statistically rare (low probability) flood from a statistically common (high probability) storm. The peak flood stage at the cross section closest to the U.S. Highway 50 culvert was 6,438.32 feet (ft.) above the North American Datum of 1988 (NAVD 88). The August 29, 2016, flood at the Fountain Creek site had an estimated annual exceedance probability of 0.5505 (return period equal to the 1.8-year flood). The August

29, 2016, flood event was caused by a precipitation event having an annual exceedance probability of 1.0 (return period of 1 year, or the 1-year storm). The peak stage during this flood at the cross section closest to the U.S. Highway 24 bridge was 5,832.89 ft. (NAVD 88). Slope-area indirect discharge measurements were carried out at the Big Cottonwood Creek and Fountain Creek sites to estimate peak discharge of the August 23, 2016, flood and August 29, 2016, flood, respectively. The USGS computer program Slope-Area Computation Graphical User Interface was used to compute the peak discharge by adding the surveyed cross sections with Manning roughness coefficient assignments to the high-water marks. The Manning roughness coefficients for each cross section were estimated in the field using the Cowan method.

**Record Type:** Publication

**Record URL:** <https://www.codot.gov/programs/research/pdfs/2017-research-reports/usgs-peak-discharge/view>

**Edition:** Final Report

**Corporate Authors:**

U.S. Geological Survey

Colorado Water Science Center

Denver, CO United States

Colorado Department of Transportation

Denver, CO 80222 United States

Federal Highway Administration

1200 New Jersey Avenue, SE

Washington, DC 20590 United States

**Pagination:** 74p

**Publication Date:** 2017-12-14

**Language:** English

**Media Type:** Digital/other

**Features:** Appendices; Figures; Maps; Photos; References; Tables

**Subject Areas:** Highways; Hydraulics and Hydrology

**Keywords:** Coaldale (Colorado); Colorado Springs (Colorado); Floods; Peak discharge; Probability; Regression analysis; Stream gages; Streamflow

**Accession Number:** 01656887

**Report/Paper Numbers:** CDOT-2017-13; Scientific Investigations Report 2017-5107

**Files:** TRIS; ATRI; USDOT; STATEDOT

**Created Date:** 1/3/2018 2:31 PM

**Title:** Estimating Foundation Scour for Extreme Hydrologic Events at Scour-Critical Bridges

**Author(s):** Sturm, Terry W.; Stoesser, Thorsten; Hong, Seungho; Kara, Sibel; Wang, Yung-Chieh  
Becky

**Abstract:** During extreme hydrologic events, bridges may be subjected to submerged orifice flow and overtopping because they were not designed for such large flows. As a result, such bridges are vulnerable to excessive scour of the foundations and possible failure. The objective of this research is to examine both the hydrodynamics of the flow and the scour resistance of fine sediments to improve prediction of scour depths under extreme flooding conditions. The research approach is three-pronged: (1) experimental measurement of the scour depths and

flow field in a large compound channel flume; (2) application of computational fluid dynamics to predict the turbulence properties of the flow field; and (3) testing of laboratory mixtures of fine sediments to develop a relationship for critical shear stress at the threshold of scour. Results of these three tasks are combined to form a procedure for scour prediction that considers both the causative and resistive factors in the complex process of bridge scour.

**Record Type:** Publication

**Record URL:** [http://g92018.eos-intl.net/eLibSQL14\\_G92018\\_Documents/09-08.pdf;/common/images/covers/large/1398321.png](http://g92018.eos-intl.net/eLibSQL14_G92018_Documents/09-08.pdf;/common/images/covers/large/1398321.png)

**Edition:** Final Report

**Corporate Authors:**

Georgia Department of Transportation  
Office of Research, 15 Kennedy Drive  
Forest Park, GA 30297-2534 United States  
Georgia Institute of Technology  
Civil & Environmental Engineering  
790 Atlantic Drive NW  
Atlanta, Georgia 30332 United States

**Pagination:** 99p

**Publication Date:** 2016-02-00

**Language:** English

**Media Type:** Digital/other

**Period Covered:** Feb. 2010 – March 2013

**Features:** Figures; References; Tables

**Subject Areas:** Bridges and other structures; Highways; I24: Design of Bridges and Retaining Walls

**Keywords:** Bridge foundations; Floods; Fluid dynamics; Forecasting; Methodology; Overtopping; Scour; Sediments

**Accession Number:** 01592076

**Availability:**

Georgia Department of Transportation  
Office of Research, 15 Kennedy Drive  
Forest Park, GA 30297-2534 United States

**Files:** TRIS; ATRI; STATEDOT

**Created Date:** 2/17/2016 11:01 AM

**Title:** Risk-Based Approach for Bridge Scour Prediction

**Author(s):** N/A

**Abstract:** Current practice for the prediction of scour depth at bridge piers and abutments uses empirical equations developed primarily from laboratory-scale studies, supplemented by limited data from field measurements. Equations for contraction scour (both clear-water and live-bed conditions) are based on an approach that combines both empirical and deterministic relationships. Additionally, the statistical analysis that was performed on the data collected from the laboratory studies and was used to create these relationships employs various statistical approaches that possibly provide more conservative results than necessary. When

you also take into account the uncertainty associated with the development of key parameters used in the empirical relationships, the room for error is significant. In contrast, because of numerous advantages, bridge structural engineers, and more recently geotechnical engineers, have adopted Load and Resistance Factor Design (LRFD) which is a probabilistic approach to design. LRFD considers a probabilistic approach and allows for the possibility of assessing the level of risk associated with a given design. There is a need for the bridge scour engineer to have the option of performing scour calculations using probabilistic methods so that risk can be more appropriately assessed and the option of something other than the most conservative design considered. Current practice for determining the total scour prism at a bridge crossing involves the calculation of various scour components (e.g., pier scour, abutment scour, contraction scour, and long-term channel changes). Using the principle of superposition, the components are considered additive and the scour prism then is drawn as a single line for each frequency flood event (e.g., 50-year, 100-year and 500-year flood events). This approach does not provide an indication of the uncertainty involved in the computation of any of the additive components. Uncertainties in hydrologic and hydraulic models and the resulting uncertainty of relevant inputs (e.g., design discharge, flow duration, velocity, depth, flow direction, etc.) to the scour calculations will have a significant influence on scour prediction. To develop an overall estimate of confidence in the estimated scour magnitude, one must examine the level of confidence associated with the results of the hydrologic analysis (design discharges, flow duration, etc.), the level of confidence associated with the hydraulic analysis (depths, velocities, flow direction, etc.), and the level of confidence associated with the scour estimates (pier, abutment, contraction, long-term channel changes, etc.). Scour reliability analysis involves quantification of the uncertainties in each of these steps and then combines them in such a way that the overall estimate of confidence is known for the final prediction of scour. For the hydrologic analysis component, the desired end product could result in a probability density function (PDF) of the peak discharge. This can be done by examination of the flood flow frequency curve developed from gage records. If no gage records are available and regional regression equations are used, levels of confidence based on the results of the statistical analysis used to develop the regression equations can be used. If a single or lumped-parameter hydrologic model is used, important parameters could be identified, a PDF developed for these parameters, and a Monte Carlo simulation of these parameters could be performed to obtain the PDF of the peak discharge. The same can be performed for the hydraulic model except that the PDFs of the relevant hydraulic parameters would be developed using Monte Carlo simulations. Current practice provides an estimate of scour based on the hydrologic and hydraulic conditions associated with a specified design event (a 100- or 500-year flood, for example). The scour equations are generally understood to be conservative in nature, and have been developed as "envelope" curves for use in design. The research objective is to develop a methodology that can be used in calculating bridge scour so that the scour estimate can be linked to a probability; for example, there is a 95.0% probability that the maximum scour will be 8.3 feet or less over the life of the bridge. To achieve this objective, at a minimum the following tasks must be performed: (1) Review of existing knowledge: Some work along these lines has already been done in the area of hydrologic and hydraulic analysis. Relating the uncertainty associated with the hydrologic and hydraulic analysis to the uncertainty associated with the scour estimation techniques needs to be performed. Other disciplines where risk and reliability

approaches are being integrated into engineering design also should be explored and documented by the research team (2) Identify uncertainties: This task will consist of identifying and evaluating the parameters associated with each of the various components (hydrology, hydraulics, and scour). (3) Formulate the methodology. This task will consist of combining the uncertainty associated with each of the various components (hydrology, hydraulics, and scour) into a procedure to use for scour prediction. The results of this task will ultimately lead to a probabilistic method to compute and evaluate bridge scour that will be consistent with LRFD approaches used by structural and geotechnical engineers. (4) Proof of concept: This task will consist of validating the methodology against data sets where variability in measured scour has been quantified. The new methodology must be demonstrated to be consistent with probabilistic approaches currently used by bridge structural and geotechnical engineers. >Final Report: The final report will be written in two parts. The first part will document the research performed to arrive at the methodology. The second part will be written in the form of a manual that provides design guidelines for practitioners in the field of bridge scour calculation. Currently scour estimates at bridge foundations use the best available technology, but are still roundly criticized as being overly conservative. The most common complaint is that the equations that were developed under laboratory conditions don't fit conditions at the site. Often this results in deeper foundations than necessary which leads to more costly bridge designs, which can stress already overloaded state department of Transportation budgets for bridge replacement and repair. Bridge designers and engineers are in need of a tool to make cost versus reliability tradeoff decisions with respect to scour and foundation design. A reliability-based design procedure for estimating scour at bridges will provide a consistent methodology for making decisions on design scour depth based on calculated risk instead of estimates which can be overly conservative. The pay-off is a scour estimate that will be more reliable in that it will be tied to a selected level of reliability that can be effectively communicated to the public. This type of approach will help alleviate over-conservatism in bridge design inconsistent with accepted target risk levels.</div>

**Record Type:** Project

**Record URL:** <http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=2736>

**Language:** English

**Contract Numbers:** Project 24-34

**Status:** Completed

**Funding Amount:** 500000.00

**Sponsor Organizations:**

Federal Highway Administration

1200 New Jersey Avenue, SE

Washington, DC 20590 United States

American Association of State Highway and Transportation Officials (AASHTO)

444 North Capitol Street, NW

Washington, DC 20001 United States

National Cooperative Highway Research Program

Transportation Research Board

500 Fifth Street, NW

Washington, DC 20001 United States

**Project Managers:** Dekelbab, Waseem

**Performing Organizations:** Ayres Associates, Incorporated

**Principal Investigators:**

Lagasse, Peter F.

(970) 223-5556

**Notice Date:** --

**Start Date:** 2010-04-21

**Expected Completion Date:** --

**Actual Completion Date:** 2013-06-28

**Source Data:** RiP Project 22374

**Subject Areas:** Bridges and other structures; History; Hydraulics and Hydrology; Planning and Forecasting

**Keywords:** Best practices; Bridge abutments; Bridge design; Bridge piers; Geotechnical engineering; Laboratory tests; Load and resistance factor design; Peak discharge; Probability density functions; Risk analysis; Scour

**Accession Number:** 01464179

**Source Agency:** National Cooperative Highway Research Program

Transportation Research Board

500 Fifth Street, NW

Washington, DC 20001 United States

**Files:** TRB; RiP; USDOT

**Created Date:** 1/3/2013 2:37 PM

**Title:** Combining Individual Scour Components to Determine Total Scour

**Author(s):** N/A

**Abstract:** Current guidance in the Federal Highway Administration's Hydraulic Engineering Circular No. 18 (HEC-18), "Evaluating Scour at Bridges," recommends that estimates of total scour at new or existing bridges consist of computing the individual components of scour separately and combining them as a simple summation. Individual scour components at a particular bridge may include any or all of the following: contraction (general) scour, local scour at piers, local scour at abutments, and pressure scour (sometimes referred to as "vertical contraction scour"). These scour processes are considered on an event-based time scale, and during a single flood event all four scour processes, if present, are generally recognized to occur simultaneously. While long-term degradation is not considered to be a local bridge scour phenomenon, its effects are recognized as a system-wide response driven by an imbalance between water and sediment transport and/or a decrease in elevation of a base-level control. Typically, long-term degradation occurring over the life of the structure is estimated and is added to the local scour components as well. The assumption that the calculated scour depths for each individual scour component can simply be superposed to provide an estimate of total scour has been challenged for many years by bridge engineers as being excessively conservative. Specifically, the interaction between scour types remains an unanswered question. The objective of this research was to determine the relationship between combined, independent estimates of the individual scour components and total scour actually observed for the same event. This objective will require researchers to identify, compile, and assess

existing, appropriate laboratory and field data sets where scour processes occurring simultaneously have been observed and quantified. For the purposes of this project, total scour is defined as the combination of contraction (general) scour, local scour at piers, local scour at abutments, and pressure scour (sometimes referred to as “vertical contraction scour”). Long-term degradation/aggradation is not to be considered an element in total scour, but may need to be recognized and accounted for in the field data sets.

**Record Type:** Project

**Record URL:** <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3187>

**Language:** English

**Contract Numbers:** Project 24-37

**Status:** Completed

**Funding Amount:** 600000

**Sponsor Organizations:**

Federal Highway Administration

1200 New Jersey Avenue, SE

Washington, DC 20590 United States

American Association of State Highway & Transportation Officials

444 North Capitol Street, NW, Suite 225

Washington, DC 20001 United States

National Cooperative Highway Research Program

Transportation Research Board

500 Fifth Street, NW

Washington, DC 20001 United States

**Project Managers:** Reynaud, David A

**Performing Organizations:**

Georgia Institute of Technology, Atlanta

Georgia Tech Research Corporation

505 10th Street, Suite 213

Atlanta, GA 30332 United States

**Principal Investigators:** Strum, Terry W.

**Notice Date:** --

**Start Date:** 2012-10-01

**Expected Completion Date:** --

**Actual Completion Date:** 2017-05-31

**Source Data:** RiP Project 37902

**Subject Areas:** Bridges and other structures; Highways; Hydraulics and Hydrology

**Keywords:** Bridge abutments; Bridge piers; Data collection; Field studies; Floods; Laboratory studies; Scour; Sediments

**Accession Number:** 01545235

**Source Agency:** Transportation Research Board

500 Fifth Street, NW

Washington, DC 20001 United States

**Files:** TRB; RiP

**Created Date:** 11/26/2014 1:00 AM

**Title:** Scour Damage to Vermont Bridges and Scour Monitoring

**Author(s):** Anderson, Ian; Dewoolkar, Mandar M.; Rizzo, Donna M.; Huston, Dryver R.; Frolik, Jeff

**Abstract:** Scour is by far the primary cause of bridge failures in the United States. Regionally, the vulnerability of bridges to flood damage became evident from the damage seen to Vermont bridges in the 2011 Tropical Storm Irene. Successfully mitigating scour-related problems associated with bridges depends on the ability to reliably estimate scour potential, design effective scour prevention and countermeasures, design safe and economical foundation elements accounting for scour potential, and design reliable and economically feasible monitoring systems. This report presents research on two particular aspects related to bridge scour – 1) System-level analysis of damage observed at Vermont bridges from Tropical Storm Irene. Example case studies are presented including description of the bridge damage, as well as the pre-storm condition of the bridges. Statistical comparison to non-damaged bridges is included to identify significant factors that determine bridge vulnerability to storm damage; and 2) Development of a low-cost scour sensor suitable for monitoring scour and redeposition continuously and communicating the readings wirelessly in real time to stake holders.

**Record Type:** Publication

**Record URL:** [http://www.uvm.edu/~transctr/research/trc\\_reports/UVM-TRC-15-002.pdf](http://www.uvm.edu/~transctr/research/trc_reports/UVM-TRC-15-002.pdf);  
[/common/images/covers/large/1357875.png](http://www.uvm.edu/~transctr/research/trc_reports/UVM-TRC-15-002.pdf)

**Supplemental Notes:** This document was sponsored by the U.S. Department of Transportation, University Transportation Centers Program.

**Corporate Authors:**

University of Vermont, Burlington  
Transportation Research Center  
210 Colchester Avenue  
Burlington, VT 05405-1757 United States  
Vermont Agency of Transportation  
1 National Life Drive  
Drawer 33  
Montpelier, VT 05633 United States  
Research and Innovative Technology Administration  
1200 New Jersey Avenue, SE  
Washington, DC 20590 United States

**Pagination:** 52p

**Publication Date:** 2015-06-10

**Language:** English

**Media Type:** Digital/other

**Features:** Figures; Photos; References; Tables

**Subject Areas:** Bridges and other structures; Highways; Maintenance and Preservation; I24: Design of Bridges and Retaining Walls; I61: Equipment and Maintenance Methods

**Keywords:** Bridges; Case studies; Countermeasures; Hurricane Irene, 2011; Scour; Sensors; Structural health monitoring; Vermont

**Accession Number:** 01567333

**Report/Paper Numbers:** 15-002

**Files:** UTC; TRIS; RITA; ATRI; USDOT; STATEDOT

**Created Date:** 6/18/2015 8:02 AM

**Title:** Vulnerability Evaluation of Scoured Bridges under Floods

**Author(s):** Hung, Chung-Chan; Yau, Wen-Gi

**Abstract:** The erosion or removal of soil from around bridge foundations due to scour can significantly increase the vulnerability of bridges under flood conditions. It has been reported that scour at bridge foundations due to flooding is a major cause of bridge failure. While retrofitting bridge foundations with additional piles is a common approach to improve the resilience of scour-critical pile-supported bridges, its effectiveness remains to be explored. The objective of the study is to develop a rational vulnerability evaluation method for scoured pile-supported bridges under flood conditions. In addition, the effects of scour depths and foundation retrofitting work on the failure mechanism and vulnerability of bridges subjected to flood-induced loading are quantitatively investigated. The investigation is conducted using a complex nonlinear three-dimensional finite element model that accounts for the interactions between bridge structures, soils, water flow, and pile foundations. The validity of the developed vulnerability evaluation method is demonstrated using the Shuang-Yuan Bridge that collapsed during a flood event in 2009. Finally, a safety management procedure for scour-critical bridges is suggested.

**Record Type:** Publication

**Record URL:** <http://dx.doi.org/10.1016/j.engstruct.2016.11.044>;

<http://www.sciencedirect.com/science/article/pii/S0141029616313232>

**Supplemental Notes:** Abstract reprinted with permission from Elsevier.

**Serial:** Engineering Structures

**Publisher:** Elsevier

**ISSN:** 0141-0296

**URL:** <http://www.sciencedirect.com/science/journal/01410296>

**Volume:** 132

**Issue:** 0

**Pagination:** pp 288-299

**Publication Date:** 2017-02-01

**Language:** English

**Media Type:** Web

**Features:** Appendices; Figures; References; Tables

**Subject Areas:** Bridges and other structures; Environment; Highways

**Keywords:** Bridge foundations; China; Collapse; Failure; Finite element method; Floods; Pile foundations; Piles (Supports); Risk assessment; Scour

**Accession Number:** 01631024

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/issn/01410296>

**Files:** TRIS

**Created Date:** 3/15/2017 3:34 PM

**Title:** Local Scour Calculation around Bridge Pier during Flood Event

**Author(s):** Tabarestani, Mojtaba Karimaee; Zarrati, Amir Reza

**Abstract:** In the present study, local scour around bridge pier during flood event especially in flashy hydrographs is investigated, experimentally. The duration of tested hydrographs were deduced from different ephemeral rivers in nature using physical modeling concepts. Final scour depth as well as scour hole width and time development of scour depth were recorded by high resolution cameras. The effects of flood hydrograph rising as well as falling limb and peak discharge on local scour were studied. Results showed that, for hydrographs with similar duration and peak discharge, the influence of time for hydrograph rising limb ( $T_r$ ) on final scour depth is not of great importance. On the other hand, the scour depth slightly decreased after the hydrograph peak due to the slide of the scour hole slopes and deposition of some of suspended sediments. The maximum decrease was about 5% of the pier diameter. In addition, it is shown that the effect of time for hydrograph falling limb ( $T_f$ ) on scour depth and width is closely related to parameter  $T_f/T_r$ . For example, final scour depth for a typical hydrograph with  $T_f/T_r = 9.25$  is about 42% larger than similar hydrograph with only a rising limb. Overall, experimental results revealed that hydrograph peak discharge plays a much more important role than other parameters in affecting the development of scour hole. Based on the present as well as the previous experimental results, a new modification factor is added to HEC-18 empirical equation to calculate final scour depth during a hydrograph event. Finally, by using stepped-hydrograph model, time development of scour depth was calculated for the present tested flashy hydrographs which showed acceptable accuracy of this method.

**Record Type:** Publication

**Record URL:** <http://dx.doi.org/10.1007/s12205-016-0986-3>

**Supplemental Notes:** © Korean Society of Civil Engineers and Springer-Verlag Berlin Heidelberg 2017.

**Serial:** KSCE Journal of Civil Engineering

**Publisher:** Korean Society of Civil Engineers

**ISSN:** 1226-7988

**EISSN:** 1976-3808

**URL:** <http://link.springer.com/journal/12205>

**Volume:** 21

**Issue:** 4

**Pagination:** pp 1462-1472

**Publication Date:** 2017-05-00

**Language:** English

**Media Type:** Web

**Features:** References

**Subject Areas:** Bridges and other structures; Highways; Hydraulics and Hydrology; Maintenance and Preservation

**Keywords:** Bridge piers; Flood hydrographs; Floods; Hydrographs; Peak discharge; Scour

**Accession Number:** 01633165

**Availability:** Find a library where document is available

**Order URL:** <http://worldcat.org/issn/12267988>

**Files:** TRIS

**Created Date:** 4/20/2017 2:58 PM

**INTERNET RETRIVALS with HIGH RELEVANCE:**

**Title:** Adapting bridge infrastructure to climate change: institutionalizing resilience in intergovernmental transportation planning processes in the Northeastern USA

**Author(s):** Schulz, Anna; Zia, Asim; Koliba, Christopher

**Abstract:** Multi-level governance networks provide both opportunities and challenges to mainstream climate change adaptation due to their routine decision-making and coordination processes. This paper explores institutionalizing resilience and adaptation to climate change in the intergovernmental transportation planning processes that address bridge infrastructure in the Northeastern United States (USA), specifically in Vermont and Maine. The research presented here relies on nine interviews with policy-makers and planners, a survey of transportation project prioritization criteria, development of a longitudinal bridge funding database, and its integration with publicly available geospatial data. It presents a novel spatial analysis methodology, a modified version of which could be adopted by transportation agencies for prioritizing scarce adaptation funds. Although transportation agencies are undertaking a variety of mitigation activities to address business-as-usual needs, climate change adaptation and resilience efforts remain under prioritized. Adaptation is a global concern, but impacts vary dramatically between regions and require localized solutions. Bridges and culverts, which are especially vulnerable to climate-induced flooding impacts, have complex maintenance and design processes and are subject to convoluted adaptation planning procedures. Critical gaps in resources and knowledge are barriers to improved adaptation planning. Restructuring the transportation project prioritization procedures used by planning organizations to explicitly include adaptation may provide a novel strategy to institutionalize resilience in transportation. These procedures must be considered in the context of the intergovernmental networks that exist to support transportation infrastructure. Although these networks will likely vary across countries, the approaches introduced here to study and address transportation infrastructure adaptation may be applied to many settings.

**Key Words:** Adaptation, Bridge infrastructure, Climate change, Geospatial analysis, Multi-level governance, Transportation planning, Resilience to extreme events, Institutional design

**Full Citation:** Schulz, A., Zia, A., & Koliba, C. (2017). Adapting bridge infrastructure to climate change: institutionalizing resilience in intergovernmental transportation planning processes in the Northeastern USA. *Mitigation and Adaptation Strategies for Global Change*, 22(1), 175-198.

**DOI:** <https://doi.org/10.1007/s11027-015-9672-x>

**Print ISSN:** 1381-2386

**Online ISSN:** 1573-1596

**Publisher:** Springer Netherlands

**Title:** Integrating Extreme Weather into Transportation Asset Management Plans

**Author(s):** Meyer, Michael D.; Flood, Michael

**Introduction:** Over the past five years, the transportation community has become increasingly more concerned about the impact of climate change and extreme weather events on

transportation infrastructure and services. Partly in response to major natural disasters such as Hurricanes Katrina and Irene, Superstorm Sandy, massive flooding in the Midwest and large forest fires in the west, and in part due to a growing awareness of the potential threats described in research and policy studies many transportation agencies are interested in understanding the risks associated with a changing climate. At the same time, the continuing development and use of asset management systems and performance-based decision-making in state departments of transportation (DOTs) raises questions about how such systems and decision making processes could be linked to the risks associated with climate change and extreme weather events. The objective of this study was to develop a process for DOTs to incorporate climate change and extreme weather consideration into Transportation Asset Management Plans (TAMPS). The study investigated the limited number of examples that have done so for a variety of weather conditions (e.g., sea level rise, shoreline retreat, freeze/thawing cycles, extreme rainfall), and examined the linkage between extreme weather and climate change given a proposed FHWA rulemaking on risk-based TAMPs in response to the Moving Ahead for Progress in the 21st Century (MAP-21) legislation. In particular, the results of recent Federal Highway Administration (FHWA) pilot studies on climate change and extreme weather asset vulnerabilities were assessed for their contribution to TAMP development. The result of this study is a suggested process and template that can be used by DOT officials for considering extreme weather events and climate change (hereafter referred to as extreme weather/climate change) when developing or updating the TAMP.

**Full Citation:** Meyer, M. D., & Flood, M. (2015). INTEGRATING EXTREME WEATHER INTO TRANSPORTATION ASSET MANAGEMENT PLANS.

**Title:** Modeling sediment mobilization using a distributed hydrological model coupled with a bank stability model

**Author(s):** Stryker, J.; Wemple, B.; Bomblies, A.

**Abstract:** In addition to surface erosion, stream bank erosion and failure contributes significant sediment and sediment-bound nutrients to receiving waters during high flow events. However, distributed and mechanistic simulation of stream bank sediment contribution to sediment loads in a watershed has not been achieved. Here we present a full coupling of existing distributed watershed and bank stability models and apply the resulting model to the Mad River in central Vermont. We fully coupled the Bank Stability and Toe Erosion Model (BSTEM) with the Distributed Hydrology Soil Vegetation Model (DHSVM) to allow the simulation of stream bank erosion and potential failure in a spatially explicit environment. We demonstrate the model's ability to simulate the impacts of unstable streams on sediment mobilization and transport within a watershed and discuss the model's capability to simulate watershed sediment loading under climate change. The calibrated model simulates total suspended sediment loads and reproduces variability in suspended sediment concentrations at watershed and subbasin outlets. In addition, characteristics such as land use and road-to-stream ratio of subbasins are shown to impact the relative proportions of sediment mobilized by overland erosion, erosion of roads, and stream bank erosion and failure in the subbasins and watershed. This coupled model will advance mechanistic simulation of suspended sediment mobilization and transport from watersheds, which will be particularly valuable for investigating the potential impacts of climate and land use changes, as well as extreme events.

**Key Words:** suspended sediment, DHSVM, BSTEM, stream bank erosion model, watershed sediment load, unstable channels

**Full Citation:** Stryker, J., Wemple, B., & Bomblies, A. (2017). Modeling sediment mobilization using a distributed hydrological model coupled with a bank stability model. *Water Resources Research*, 53(3), 2051-2073.

**DOI:** 10.1002/2016WR019143

**Title:** Estimated Effects of Climate Change on Flood Vulnerability of U.S. Bridges

**Author(s):** Wright, Len; Chinowsky, Paul; Strzepek, Kenneth; Jones, Russell; Streeter, Richard; Smith, Joel B.; Mayotte, Jean-Marc; Powell, Anthony; Jantarasami, Lesley; Perkins, William

**Abstract:** We assessed the potential impacts of increased river flooding from climate change on bridges in the continental United States. Daily precipitation statistics from four climate models and three greenhouse gas (GHG) emissions scenarios (A2, A1B, and B1) were used to capture a range of potential changes in climate. Using changes in maximum daily precipitation, we estimated changes to the peak flow rates for the 100-year return period for 2,097 watersheds. These estimates were then combined with information from the National Bridge Inventory database to estimate changes to bridge scour vulnerability. The results indicate that there may be significant potential risks to bridges in the United States from increased precipitation intensities. Approximately 129,000 bridges were found to be currently deficient. Tens of thousands to more than 100,000 bridges could be vulnerable to increased river flows. Results by region vary considerably. In general, more bridges in eastern areas are vulnerable than those in western areas. The highest GHG emissions scenarios result in the largest number of bridges being at risk. The costs of adapting vulnerable bridges to avoid increased damage associated with climate change vary from approximately \$140 to \$250 billion through the 21st century. If these costs were spread out evenly over the century, the annual costs would be several billion dollars. The costs of protecting the bridges against climate change risks could be reduced by approximately 30% if existing deficient bridges are improved with riprap.

**Key Words:** adaption costs, bridges, climate change, flooding

**Full Citation:** Wright, L., Chinowsky, P., Strzepek, K., Jones, R., Streeter, R., Smith, J. B., ... & Perkins, W. (2012). Estimated effects of climate change on flood vulnerability of US bridges. *Mitigation and Adaptation Strategies for Global Change*, 17(8), 939-955.

**DOI:** <https://doi.org/10.1007/s11027-011-9354-2>

**Print ISSN:** 1381-2386

**Online ISSN:** 1573-1596

**Publisher:** Springer Netherlands

**Title:** Field Study of Scour Critical Bridges in Rhode Island

**Author(s):** Laurent, Wendy K.

**Abstract:** All bridges in the United States are required to complete a detailed scour analysis in accordance with the Federal Highway Administration's (FHWA) Hydraulic Engineering Circular Number 18 (HEC-18) standards using predetermined design flood events. Proper scour depth predictions are essential, as over conservative estimates may lead to a bridge being classified as scour critical, leading to a required plan of action and possible costly remediation efforts.

Conversely, under conservative estimates could lead to reduced performance of a bridge or even complete failure (Arneson et al. 2012).

In Rhode Island there are 127 bridges that are classified as scour critical, requiring the Rhode Island Department of Transportation (RIDOT) to create a detailed plan of action for each bridge and regularly monitor them. Following historic floods in 2010, an evaluation of the scour critical bridges throughout the state was performed, and this study suggested that the current HEC-18 methodology to evaluate scour is over conservative (AECOM 2013). The experiments used to develop the current scour equations found in HEC-18 do not include detailed site characteristics such as complex hydrology, vegetation, cobbles, or soil cohesion which are all common features in Rhode Island.

The objective of this study is to evaluate the current scour methodology on selected scour critical bridges in Rhode Island. Four bridges were selected: Three riverine bridges and one bridge crossing a tidal inlet. To estimate information such as flow, velocity, and depth, each bridge site must be modeled using the US Army Corps of Engineer's Hydraulic Engineering Center's River Analysis System (HEC-RAS). Conditions from the 2010 flooding event were used to model the riverine bridges and Hurricane Sandy in 2012 was used to model the marine bridge. Scour at each site was predicted using the equations presented in HEC-18 and compared with both past and present scour observations. Finally, the sensitivity of multiple parameters within the HEC-18 equations were evaluated to create an upper and lower bound for the scour prediction during the event of interest.

To support the modeling effort, a detailed field testing program was conducted. At each bridge, the local bathymetry and topography was obtained using a combination of interferometric sonar, real-time kinematic, and total station surveying. Information about the bed conditions and existing scour features was obtained from analysis of grab samples, side scan sonar images, and CHIRP sub-bottom profiler. From this data, any existing scour features were noted. Minor scour was present at one of the riverine bridges. Prominent scour features were observed at the tidal bridge. Both features observed in this study have occurred in the past and have been slightly in-filled according to documentation.

Cross sections were created from the survey information to accurately model the bridge sites. Steady, one-dimensional HEC-RAS models of the 2010 flooding event were created at the three riverine sites and the associated scour was estimated. For the tidal site, complex unsteady one-dimensional models were created for Hurricane Sandy and the resulting scour was predicted. Predicted and observed values of scour were compared and it was concluded that the scour prediction equations over estimated scour at all four sites where scour analyses were completed.

A sensitivity analysis identified variations in the predicted scour depths, providing an upper and lower limit with regards to grain size, angle of attack, Froehlich's length of active flow, and the Manning friction coefficient. It was determined that the selected median grain size plays a significant role on the prediction of scour, varying the estimates by about five feet. The angle of attack significantly affected pier scour, but had minimal effects on abutment scour. Froehlich's length of active flow had an average change of 2.4 feet on abutment scour at the four bridge sites. Finally, the Manning friction coefficient had the smallest changes with an average change in scour of 1.1 feet. It was easily seen that the scour predictions over-predicted

the depth of scour as compared to the observed, indicating that the scour prediction equations over-estimate scour features in Rhode Island.

**Key Words:** applied sciences, bridge, field study, flood, Hec-18, Hec-ras, scour

**Full Citation:** Laurent, W. K. (2017). Field study of scour critical bridges in Rhode Island (Doctoral dissertation, University of Rhode Island).

**INTERNET RETRIVALS with MEDIUM RELEVANCE:**

None.