AASHTO
TECHNICAL COMMITTEE ON HYDROLOGY AND HYDRAULICS

Hydraulics Newsletter

November 2016 | Issue 14

Letter from the Technical Committee on Hydrology & Hydraulics Chair

Nick Wark, Vermont Agency of Transportation and TCHH Chair

Greetings and welcome to the 2016 fall edition of Hydrolink. Prior to my involvement in AASHTO, newsletters like this were my main source of information on technical innovations, large projects and national issues. One of the primary missions of the Technical Committee on Hydrology and Hydraulics (TCHH) is to connect the small group of scattered professionals that specialize in hydrology and hydraulics. Formal publications such as the AASHTO Drainage Manual contain a wealth of information, but they are a huge task to publish and update. Hydrolink provides the TCHH with a forum for more timely and informal knowledge sharing. I hope you find the articles as interesting and informative as I do.

In This Issue

Speaking of connecting with other professionals in the field, the National Hydraulic Engineering Conference was held this year along the shores of the Columbia River in Portland, Oregon.

Figure 1. View of Portland, OR

A special thanks to ODOT for hosting a great conference. In Vermont, there are less than 10 people who know what SRH-2D is. At the NHEC you might sit down at lunch with someone who has created dozens of models, an instructor of the SRH-2D NHI training, or maybe even the programmer of the software! That is

just one example of the many opportunities at the NHEC. If you have never been, I would highly recommend attending in 2018 (location TBD, any east coast volunteers?).
If you have any questions, new topics you would like covered, or would like to write an article, please contact me (nick.wark@vermont.gov) or any member of the TCHH (http://design.transportation.org/Pages/HydrologyandHydraulics.aspx). Chances are you know at least one of us.

Sincerely
Nick Wark, Vermont Agency of Transportation and TCHH Chair

Figure 2. VT 108 (Mountain Rd) in Stowe, Vermont

index

2016 National Hydraulic Engineering Conference

The National Hydraulic Engineering Conference (NHEC) was held August 9-12, 2016 in Portland Oregon. The Oregon Department of Transportation and NHEC planning committee out-did themselves with two field trips (Bonneville Dam and Stormwater Treatment Test Center), three workshops (Sediment Transport Modeling with SRH-2D, Design Hydrology for Stream Restoration and Channel Stability and Stream Crossings, and SRH2D Bridge Hydraulic Modeling and Scour Analysis) along with over 60 presentations. ort period of time the presentations from the conference. Some of the presentations are available online: http://www.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/docs/Conference/2016_NHEC-Agenda.pdf

Several attendees have agreed to share with you some of the highlights of the conference.

Figure 3. Aerial View of Bonneville Dam

What is new in Hydrology **Andrea Hendrickson, Minnesota DOT &TCHH**

The session that really stood out for me was the one on hydrology. The speakers in this session did not just go over how we have been doing hydrology in the past (for many, many years) but presented new information on the future of hydrology, and how things are changing. The talk on StreamStats that Amanullah Mommandi (Colorado DOT) gave had fascinating information on Paleo flood studies and using pressure transducers for crest gages.

Stacy Archfield studied changes in floods, looking at four parameters: frequency, volume, duration, and peak streamflow. Local regional trends were identified but data lacked spatial patterns that would confirm climate change influence on a large scale. In the future, we may need the help of a hydro-climatologist to predict what the flow rates will be over the life of our hydraulic infrastructure. David Baker (CH2M) discussed the reasons climate models such as SIMCLIM might not be appropriate when developing IDF curves.

Roger Kilgore went over FHWA's new HEC-17 which incorporates climate change, risk and resilience into hydrologic design. Some key take-aways for me were: that the level of effort and analysis will differ depending on the project, climate modeling is very dynamic and we should expect models, downscaling processes and methodologies continue to improve over time, and that for the first time in a very long time hydrologic design is poised for some major changes. For those of us that have been using Rational Methodology, NRCS Equations, Regression Equations and TP-40 (recently replaced by Atlas 14) for the last 30 years this is both a daunting and exciting time to be in the field of hydrology and hydraulic design.

Bridge scour in cohesive soils **Matt O'Connor, Illinois DOT & TCHH**

Bart Bergendahl's presentation on the FHWA's In-situ Scour Testing Device (ISTD) was a very informative update on the FHWA's continuing effort to provide tools for estimating scour in cohesive soils. The ISTD represents another step towards quantifying scour utilizing common soils parameters or actual in-situ testing results. In 2013, 5th Ed. HEC-18 included ultimate scour equations for cohesive soils. In 2015, FHWA Report HRT-15-033 Scour in Cohesive Soils by the Turner Fairbank Research Center team produced quantitative tools for determining the key soils-related variables in the HEC-18 equations. The ISTD promises to produce the testing necessary to estimate critical shear of fine-grained cohesive soils. It has long been the perception of bridge and hydraulic engineers in Illinois that HEC-18 scour estimates very safely over-predict scour conditions for structures founded in cohesive soils. Bart's update highlights what we feel is another welcome step on the part of FHWA Hydraulics toward more accurate and cost-effective methodologies.

Lawyers, 2D, and Modeling **Dave Hedstrom, Montana DOT & TCHH**

Lawyers, Floods, and Money was a standout presentation for me. Hearing the Washington perspective from Joe Krolak on the implications of Executive Order 13690 was entertaining and informative. I learned that all federal agencies are responsible for implementing their standard and Joe explained that both USDOT and FHWA must update their regulations before the new Federal Flood Risk Management Standard (FFRMS) can be applied to FHWA projects. This process is expected to take several years. In the meantime, we should continue to follow 23 CFR 650 Subpart A.

I also found *Transient Mixed Flow Modeling Capability in SRH-2D for Culverts and Bridges* interesting. Dr. Lai did an excellent job of explaining how SRH-2D calculates both pressure and open channel flow with the same equation using the Preissmann Slot. The Preissmann Slot allows the program to utilize open channel equations by assuming that a small vertical slot extends to the surface above closed structures. This is how SRH-2D can model pressure flow through and over bridges.

The final presentation that stood out for me was Scott Hogan's *Hydraulic Modeling: Selecting the Right Tool for the Job*. Scott outlined the software that FHWA supports, provided an update on the latest releases, and identified available resources. Scott pointed out that the FHWA Hydraulic Tool Box has a beta version that has an enhanced scour calculator that imports data from HEC-RAS and produces a scour plot. The new HY8 added the HEC 26 procedure and a low flow calculator. WMS and SMS now have free community versions available.   In addition, the difference between HY8 and HEC-RAS for culvert calculations is that HY8 assumes a still pool at the inlet and outlet while HEC-RAS incorporates the velocity head.

Why attend the NHEC: National Updates and State's Lessons Learned

Rachel Westerfield, Mississippi DOT & TCHH

If you want to know the future of the hydraulic engineering field as it relates to transportation, this conference never disappoints. So many knowledgeable and driven individuals in our field put together great presentations, and share their passion for the projects they have undertaken. Attending the conference gives you an opportunity to not only learn best practices from other states, but also hear updates from FHWA, AASHTO, TRB, NCHRP, and Western Federal Lands. If you have a question, you can always shake a hand and talk in person.   It is the perfect opportunity to learn something new and take what you can from the conference then you can work on moving your state forward.

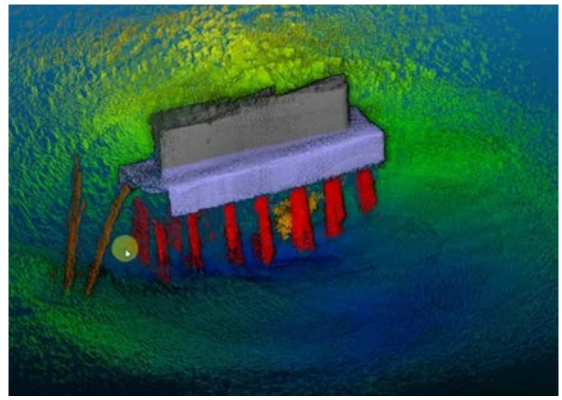

Figure 4. Visual from 3D Scan

I enjoyed so many presentations, but I would like to share Minnesota's presentation on *Lessons Learned While Implementing 3D Sonar Scanning Equipment* by Petra DeWall. Minnesota acquired the scanning equipment through research funds, and the scans provide accurate 3D representation of conditions underwater. You can import the data into CAD software and color code the points. The scans are also great to convey information to concerned stakeholders since a picture is worth a thousand words. Minnesota's take away was that 3D scanning is "extremely useful but there is a steep learning curve." If you are interested in learning more check out their YouTube channel: https://www.youtube.com/watch?v=KKP3qKvPlQA

index

Following Up...   EDC4 CHANGE Innovation to Support 2D Hydraulic Modeling

Matt O'Connor, Illinois DOT & TCHH

In Issue 13, Moving Forward with Advanced Hydraulic Modeling (by Scott Hogan, FHWA Hydraulics) described the current state of 2D modeling practice, examined factors involved in selecting a model, and profiled the two primary, Federal agency-supported models; SRH-2D and HEC-RAS 2D. Scott concluded the article with:
"In fact, beginning in late 2016, an Advanced Hydraulic Modeling Tools initiative will be promoted nationwide by FHWA as part of Phase 4 of our Every Day Counts (EDC-4) program to promote the use of 2D modeling and graphical analysis tools to a wider audience. Stay tuned!"

The EDC-4 innovation (e.g. initiative) Scott alluded to is called CHANGE- Collaborative Hydraulics: Advancing to the Next Generation of Engineering. He is the designated point of contact for CHANGE, which is just 1 of the 11 different EDC-4 innovations. Per FHWA, the primary goal of CHANGE is to advance the state of the practice in each state.   Potential assistance to participating state DOT's includes:

- free access to FHWA-supported 2D software
- training & technical guidance resources on best-practice modeling techniques
- user forums and peer exchange for modelers & reviewers
- communication with DOT's & other agencies on the benefits of 2D/3D graphical visualization tools
- technical modeling assistance on a limited basis

EDC-4 \ CHANGE background & contact information: http://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/

FHWA has scheduled seven 2-day summit meetings around the country to introduce the 11 innovations on the EDC-4 menu. PR, DC and all 50 states have been invited to a summit meeting. From the information presented by FHWA, including a Sep 28 webinar, CHANGE is a golden opportunity for state DOT's to ramp up their 2D modeling capabilities. **HOWEVER**, it is important for state DOT hydraulic staff- and for the H&H community in general- to understand this: **state DOT's must select the CHANGE innovation from the EDC4 menu in order to participate and benefit from this innovation**. State DOT's that do not select CHANGE will have limited opportunity- best case- to participate. The EDC-4 innovations will kick-off Jan 1, 2017, and run through the end of 2018. Interested TCHH members (and non-TCHH state hydraulic engineers!) should be working with their upper management ASAP to select CHANGE before Jan 1.

index

Welcome New TCHH Members!

Carlton D. Spirio, Jr.
Florida DOT

Carlton (Carl) has nearly 29-years of experience, consisting of 15-years with the Florida Department of Transportation (FDOT) and 14-years in the Private Industry. Recently, he became the State Drainage Engineer after serving eight (8) years as a District Drainage Engineer and overseeing all drainage and environmental permitting services within a twelve County region. Carl has a passion for learning new fields and his work experience includes, but is not limited to, roadway reconstruction, coastal design, bridge hydraulics and scour analysis, stormwater conveyance and management, riverine and floodplain modeling and environmental permitting through Florida's Water Management Districts, the Florida Department of Environmental Protection, U.S. Army Corps of Engineers, Coast Guard, and various local municipalities. Carl is currently serving on an NCHRP Project 24-42 that is studying the effects of "Underwater installation of Filter Systems for Scour and other Erosion Control Countermeasures."

Carl has been a passionate statewide leader in producing innovative strategies to assess regional stormwater management and watershed initiatives throughout Florida. He has given numerous presentations on these ever-changing and aggressive stormwater management strategies that the Department is pursuing. Similarly, he has developed solid working relationships with various regulatory agencies and local municipalities throughout Florida, which have resulted in diverse partnerships to forecast and balance water budgets, promote wetland restoration, wildlife habitat creation and other regional watershed initiatives such as stormwater re-use and aquifer recharge.

Carl graduated from the University of South Florida in December, 1987, with a BSCE. He has been a registered Professional Engineer in Florida since January, 1994.

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Peter VanKampen, P.E.
New York State Department of Transportation

Peter has been with the New York Department of Transportation since 1998. He is a Graduate of the SUNY Institute of Technology in Utica, NY and earned is Professional Engineer License in 2005.
Peter has 18 years of experience in Highway Design while specializing in storm system and culvert analysis and design. He currently manages several design squads and has served several committees with in the agency. INTERACT was an interagency group with the purpose of improving aquatic organism passage and stream connectivity within new culverts. Ongoing activity includes NYSDOT's committee on climate change and workgroup developing climate change criteria for the future design of culverts and bridges.

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index

Rick Renna Retires

Andrea Hendrickson, Minnesota DOT & TCHH

Rick has been a tireless advocate for hydraulics and hydrology issues both at a state and national level. He has served nearly 42 years at the Florida Department of Transportation (FDOT) where he championed improvements to the scour equations, pipe inspections, practical storm water management solutions and his latest challenge, climate change. His co-workers at FDOT thought highly of Rick, nominating him for the FDOT *Exceptional Service Award*.

But Rick's influence didn't stop at the Florida border. He participated as a panel member in many nationwide research projects and was a member of the AASHTO Technical Committee on Hydrology and Hydraulics. Rick first joined the AASHTO Technical Committee on Hydrology and Hydraulics in 2001, serving on the committee for 15 years. His work was recently recognized at the National Hydraulic Engineering Conference when he was awarded the 2016 Mark Miles Award. The *Mark Miles Award* begins with a nomination of a person who has a career marked by:

- Constant service to the motoring public, colleagues and
- The advancement of the transportation hydraulic engineering profession

An excerpt from the Mark Miles Award Presentation speech given by Joe Krolak who is the Principal Hydraulic Engineer in Federal Highway's Office of Bridges and Structures in Washington D.C., sums up Ricks national service: *"He has helped improve all aspects of hydraulic program and project delivery, including research, deployment, and guidance. His vision supporting highway hydraulics research will always be remarkable. We appreciate his contributions and practical input for proposed research studies. His participation on NCHRP project panels has been extremely significant; contributing excellent input and ideas; keeping projects on track; and Ensuring outcomes represented actionable and useful products.*

His passionate advocacy for improving scour analyses and procedures advanced the state of the art; leading to better designs, reduced costs, and adoption of procedures into national scour guidance. He essentially introduced coastal engineering as a much needed transportation consideration; foresight that served us well in responding to hurricanes Ivan, Katrina, and Sandy. He always served diligently to lead or support efforts to improve national guidance and practice. He served as a member and chair of the AASHTO technical committee on hydrology and hydraulics; He helped develop and create several versions of AASHTO hydraulic publications; most recently, the 2014 AASHTO Drainage Manual.

In fact, regardless of the subject matter, FHWA would often reach out for his expertise and insights in formulating, developing, and deploying technical guidance and outreach efforts. He would often call me up and say something like: 'Joe, I respectfully disagree with FHWA …' and then tell me why were we wrong. And most often than not, he was right. So I would be remiss if I didn't also recognize his professional, but personable manner. He is well known as a mentor and supporter of his national colleagues. His pleasant, good nature helped lead even potentially contentious discussions into understanding, consensus, and progress. In May 2016, he retired after 41 years at the Florida Department of Transportation. And while he continues his service to the transportation community through his new role in the consulting arena, we wanted to recognize and commend his outstanding efforts in advancing the national practice in all aspects of hydrologic, hydraulic, scour, and coastal engineering."

Figure 5. Joe Krolak, Rick Renna and Karuna Pujara at Mark Miles Award presentation.

The AASHTO Technical Committee on Hydraulics and Hydrology wants to second Joe's comments and to give Rick a heartfelt thanks for his many years of service, we are all better off from knowing you.

index

Illinois Updates Urban Regional Regression Equations

Tom Over, U.S. Geological Survey (USGS) and Matt O'Connor, Illinois DOT & TCHH

Illinois is home to the third-largest city in the U.S. and land development in its metropolitan area continues to expand, so for the design of roadway-stream crossings in the region, there is an ongoing need for estimating design discharges in urbanized and urbanizing watersheds. However, as of 2012, for estimating these discharges by the regional regression method, the only available equations were developed in 1979 with streamflow data through 1976, and no automated method of computing the underlying basin properties, such as with USGS StreamStats (http://water.usgs.gov/osw/streamstats/), was available. To address this need, the Illinois DOT partnered with the USGS Illinois-Iowa Water Science Center through the Illinois Center for Transportation (ict.illinois.edu) to conduct a three-year study that was finished in July, 2016. The study team comprised hydrologists, geographers, and statisticians from the USGS Illinois-Iowa Water Science Center, with review, regional skew computation, and StreamStats implementation by the USGS Office of Surface Water. Overseeing the project was a technical review panel with personnel from IDOT's Central Bridge Office; the Illinois Department of Natural Resources; the U.S. Army Corps of Engineers, Chicago District; and IDOT districts.

For this study, annual peak discharge records from 1940 to 2009 from 117 stream gages from both urban and rural watersheds within and near northeast Illinois were used to develop two sets of regression equations. For the first set of equations, the longitudinal effects of urbanization were diagnosed and combined over the watersheds as a function of exceedance probability (p) by combining longitudinal and quantile regression (figure 6). The urbanization variable used in this first analysis was based on the housing density dataset developed by Theobald (2005; http://www.ecologyandsociety.org/vol10/iss1/art32/) from U.S. Census data.

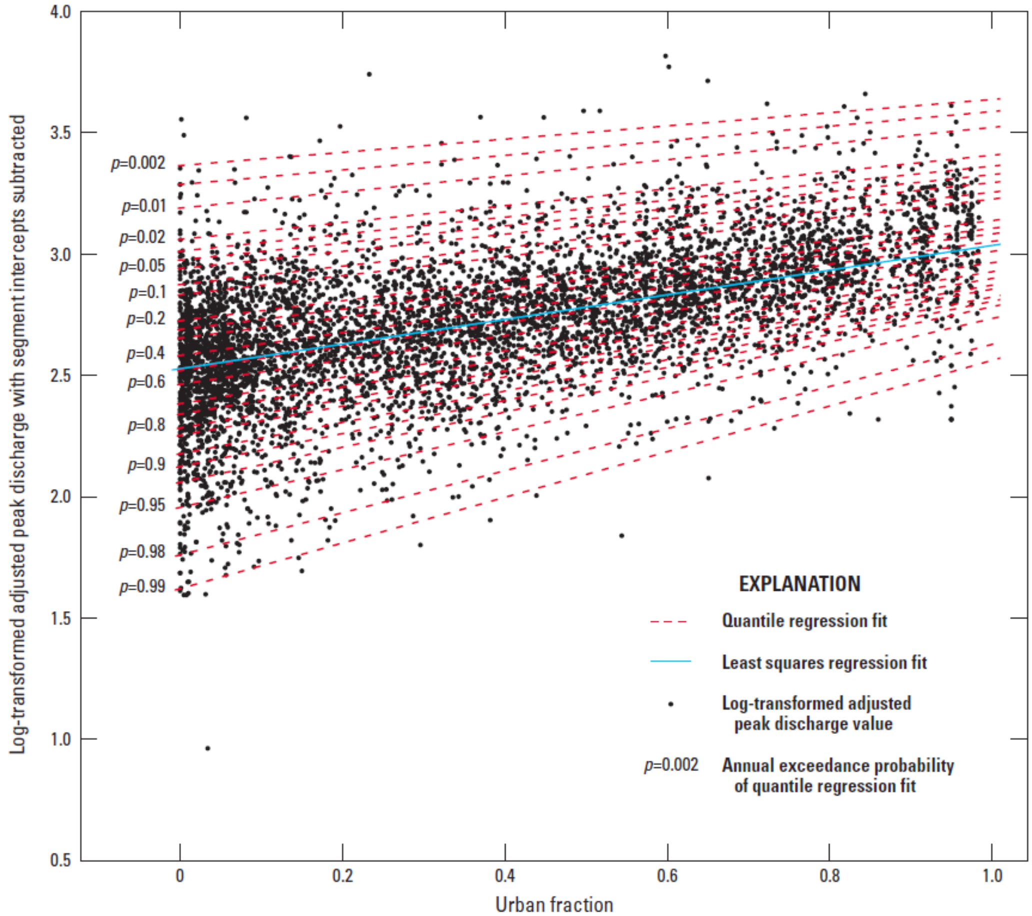

Figure 6: Plot of the longitudinal-quantile regression analysis used to diagnose exceedance probability-dependent effects of urbanization in this study in northeastern Illinois (from ICT 16-014 / USGS SIR 2016-5050).

The first set of equations was used to adjust the peak discharge records from the study watersheds to 2010 land use conditions, which was necessary in order to use records from watersheds that had experienced large changes in urbanization over their period of record. Because the equations in the first set were developed with urbanization as the only predictor, they are also appropriate for adjusting existing rural regression equations for the effects of urbanization and were implemented in StreamStats for this purpose for watersheds outside the northeast Illinois region.

Following the urbanization adjustment, at-site peak discharge quantiles from 2 years (p=0.5) to 500 years (p=0.002) were computed with PeakFQ (http://water.usgs.gov/software/PeakFQ/), which includes the updates of Bulletin17B to handle historic and censored peaks by the expected moments analysis and the use of the multiple Grubbs-Beck test to identify influential low peaks (http://acwi.gov/hydrology/Frequency/b17c/). An urbanization-dependent regional skew equation was also estimated.

The at-site peak-discharge quantiles were then fit by multiple generalized least squares regression to create the second set of equations, with drainage area, 2011 National Land Cover Database (NLCD) (http://www.mrlc.gov/nlcd2011.php) developed area fraction, slope, and water and wetlands variables as predictors. The urbanization variable was switched from Theobald (2005) to NLCD developed area in these equations to enable use of the regular five-yearly updates of the NLCD product. The second set of regression equations was implemented in StreamStats for use in the northeast Illinois study region.
Further details can be found in the study report, which is available at https://apps.ict.illinois.edu/projects/getfile.asp?id=4974 and https://pubs.er.usgs.gov/publication/sir20165050.

index

Introduction

The Technical Committee on Hydrology and Hydraulics (TCHH) is the steward of technical aspects of hydrology and hydraulics for AASHTO. Accordingly, this committee report is intended to discuss the areas of hydrology and hydraulics engineering practices that may be impacted by extreme weather and climate change. This report also identifies efforts that are needed in other disciplines in supporting hydraulics engineers to adopt necessary changes. Hydraulic engineers will be the lead players in the following areas of hydraulic engineering practice:

- Update of drainage design standards
- Use of precipitation, stream gauge and sea level data
- Modification of infrastructure hydraulic design processes, based on latest predictions of hydrologic change
- Dialogue between climate change scientists and design engineers on hydraulic methodology to translate climate change information to be useful to hydraulic practice.
- Public Education on hydraulic design approaches involved in response to extreme events and climate change. For example, we should make it clear to the public that floods can be due to many more things besides changes in precipitation patterns.

The terms extreme events and climate change have not been well defined for engineering purposes. Hydraulic Engineers have used extreme events in hydraulic design for many years. There are multiple definitions of extreme event which vary by the audience and context. Highway drainage design has been using 10, 25, 50, 100 and 500-year events for the design and review of hydraulic structures. Extreme events are often considered by hydraulic engineers to be events that exceed the design event. Events larger than the design event may be associated with negative impacts on drainage structures, adjacent lands or buildings. Extreme events have occurred in all climate conditions. If the climate is significantly changing there may be an increase or decrease in the frequency of extreme events.

The proposed engineering definition of extreme event is "any event equal to or larger than the event used to design the structure". This definition then shows that design is based on an extreme event. The design should be reviewed for events exceeding the design event in a risk assessment or analysis. The return period of the extreme event should be specified whether it is based on climate adjusted data or unadjusted (pre climate change conditions).

To properly steward public resources, hydraulic policy should be based on valid science and available information. This document focuses on identifying the path to ascertain appropriate changes to hydrologic and hydraulic design methods to account for expected climate changes.

Anticipated impacts from climate change should be treated like any other future impact to our designs. They are only unique in that they have not previously been a consideration because we lived in what we perceived to be a stationary age. Climate impacts should, therefore, be folded into the decision process associated with asset management which includes things that may have more significance than climate such as physical condition, age of infrastructure, available funds to provide adaptation, shifting needs for service, etc.

Interdisciplinary Collaborative Approach

Global climate change, as a standalone topic, is outside the expertise of hydraulic engineers. The areas of extreme weather and climate change that are of most interest to hydraulic engineers include: regional changes in sea level; changes to wave energy; changing groundwater levels; changing rainfall amounts, flood peaks and patterns; changes in sediment discharge and size distribution, and vegetation changes. Hydraulics engineers, and more specifically hydrologists, have traditionally developed statistical, risk-based design approaches, at a regional scale, from historical rainfall and stream flow records. Hydraulic design often employs future assumptions for watersheds that the engineer expects to develop, and future runoff rates are based on these predicted land use changes. In addition, hydraulic engineering has methodologies (independent of climate change) to account for uncertainties in future conditions. However, in general, water resources engineers do not have the expertise to determine which of the myriad of climate change models and scenarios should be used in estimating future needs. Collaborative efforts are needed to communicate these concepts and produce datasets that are useful to the appropriate disciplines. Ultimately, decisions to maintain, preserve, and/or replace highway drainage infrastructure need to be made in a larger context of asset management which would include an analysis of potential climate impacts in the mix of traditional asset-level and system-level decision inputs (such as age, condition, available budget, etc.). Some of the experts to consult when making these decisions, along with hydraulic engineers and climate scientists, are asset managers, statisticians, hydrologists, economists, land use planners, regulators, and policy writers. Similarly, coastal engineers are skilled in the examination of historical sea level data and coastal storm data (from hurricanes, nor'easters, tsunamis, etc.) to craft statistical risk-based design conditions for infrastructure subject to coastal storm attack.

Collaboration with the regulatory community is critical to pre-empting the promulgation of premature rulemaking that is out of step with the maturity of the undergirding science. Policy making that is not founded on sound science and thorough communication with practitioners may be impractical and of little value to the intended beneficiaries of the policy. Thus, key federal and state regulators should be at the table with climate scientists and hydraulic engineers as climate change design needs are resolved.
Engineers typically rely on historic and statistical data for their procedures; climate scientists rely on models to predict future climates. The integration of these two approaches is challenging and requires a measured and comprehensive, interdisciplinary dialog. Hydraulic and coastal engineers have extensive knowledge and experience with local conditions and data to ground truth and ultimately verify climate change predictions. They also are uniquely familiar with the significant destructive forces and damage mechanisms that climate events may unleash on highway infrastructure and the existing resiliency of highway infrastructure in the face of these forces. Collaborative dialogue between the aforementioned disciplinary groups is essential to the formulation of risk-based design that accounts for impacts from climate change.

Undoubtedly, as climate science becomes more refined and critical to the evolution of methods to better implement the science, regular interdisciplinary re-examination of policy is important.

Actions Needed to Engage Collaboration

Workshops that gather leading climate scientists with hydraulic engineers and coastal engineers could provide a venue for the valuable contributions from all three disciplines. These workshops would focus on elevating the data requirements and analytical capabilities of the hydraulic and coastal engineers, and on the fundamental tenets of climate science. Hydraulic and coastal engineers should be able to assist in determining how model results should be presented to allow professionals to make informed decisions. Additionally, identifying gaps and proposing research to fill those gaps are best produced by interdisciplinary teams.

Upon reaching an appropriate level of consensus between climate scientists and hydraulic design engineers, further collaboration among engineers, policy makers, administrators, and planners is necessary to transform the science and concepts into funded and implementable activities.

Interim Design Policy and Methodology

Until the development and adoption of hydrologic methodologies that move beyond stationarity assumptions, hydrologists are limited in how they can address climate trends in precipitation analyses. In this interim period, our approach will be one of pursuing the most current data and state of the practice methodologies in order to provide credible and defensible designs.

Current practice includes resiliency and redundancy, a result of a conservative philosophy common to all engineering practice. Thus, climate change impacts that might increase the severity of extreme events may already be accounted for, in varying degrees, in the design of drainage infrastructures through the following:

- Existing resilience due to conservative methods of design and calculations
- Existing resilience due to current factors of safety in current design standards- such as freeboard, curve number prediction, provision for wave action or protection.

- Incorporating extreme events into the data used in design through regular updates - data that are commonly utilized such as stream gage data, sea level data, tidal information – mean high tide, mean higher high tide elevation

Action Needed to Close Gaps of Uncertainty

The first step toward effective implementation of climate change science into hydraulics is to close the communication gap between the two disciplines to create confidence, within the engineering community, in climate change predictions. In addition, the format of results obtained from climate change models may not be suitable for designs where daily data is not adequate. For example, the duration of precipitation predictions from a climate change model, under a specific scenario, have little correlation to extreme events impacting IDF curves or results from flow rate regression equations.

A recent FHWA publication, "Assessment of Key Gaps in the Integration of Climate Change Considerations into Transportation Engineering", listed the following key gaps. Further discussion of these points may be found in the publication:

- Translation of climate data to terms that resonate with transportation practitioners
- Guidance on engineering solutions for incorporating information for climate change
- Methods for evaluating efficacy and Costs/Benefits of Implementing Adaptation Measures
- Organizational Processes/Decision Making ability of public agencies to implement the adaptation strategies and create non-engineering solutions such as emergency response plans

From the hydraulic and coastal engineering disciplines, more frequent updates to hydrologic and sea level statistics can serve as an interim measure to keep pace with changing climate. Statistical analysis of stationarity in rainfall/stream flow records will provide a helpful near term validation of climate change conclusions.

Vision & Strategy for Research

Immediate research needs are listed below; likely, additional research needs will become evident as climate change scientists and hydraulic engineers engage in dialogue on this topic:

- Statistical examination of climate data for non-stationarity
- Identification of adaptation measures that allow existing infrastructure to continue to function to the end of their service life in spite of not having been designed for climate change
- Outreach and literature search for peer reviewed research by other entities, both national and international
- Development of methodology for characterizing rainfall associated with hurricanes
- Some applicable FHWA-sponsored research includes the following (details are provided in Appendix B):
    - Investigation by National Weather Service (NWS) into identifiable trends in precipitation patterns and intensities across the spectrum of design events (return periods and durations)
    - Investigation by Federal Lands and Highways (FLH) into sensitivity of various types of drainage structures to increased flow scenarios (i.e. inherent resiliency)
    - Investigation of relationship of watershed characteristics (size, slope, cover, etc.) and storm characteristics (duration, speed, size, direction, etc.) in the conversion of precipitation to flow at a point of interest (touched on by Iowa pilot project)
    - Investigation of secondary effects influencing floods not related to precipitation changes (e.g. fire hydrology, pests, vegetative changes, antecedent moisture changes, etc.) (TEACR project)
    - Investigation into historical costs and damages including loss of service costs resulting from extreme events (Sandy and TEACR projects)
    - Technical guidance on climate impacts in the coastal environment (HEC-25 Volume 2), impacts in the riverine/floodplain environment (HEC-17 2nd ed.), conducting initial vulnerability assessments (Gulf Coast 2 and Climate Pilots), culvert management systems[1]

Summary and Directions for Moving Forward

The decision to adopt the results of climate change models, before they have been adequately examined and incorporated into the hydraulic design process, can have very large cost implication for future infrastructure projects. Over estimation of climate prediction can result in costly over sizing of drainage infrastructure, while under estimating the impacts may leave some infrastructures vulnerable and the resulting impacts on surrounding lands and structures inadequately addressed.

Hydrologic and hydraulics engineers should work in collaboration with climate scientists, coastal engineers, and regulators to prepare for the possible impacts of climate change, which may affect hydraulic engineering practices. Proper engineering policy is implicitly cost prudent, founded on the concept of acceptable predicted risk. Hydraulic engineers are accustomed to checking their designs for extreme events such as 100 year or 500 year event for certain practices. In the interest of accountability for public resources and reasonable acceptable risks, practitioners must understand and evaluate the appropriateness of current levels of acceptable risk before considering changing those levels of acceptable risk based on related to climate change predictions. To that end, the TCHH recommends the following directions forward:

- Undertake regular, collaborative workshops between hydraulic engineers, coastal engineers, and climate change experts
- Perform more frequent updates to statistical measures of potential climate change, including statistical examination of stationarity:
    - sea level statistics, including tide and wave generation
    - hurricane statistics, including storm surge and probabilities of impact along coastal points
    - precipitation data, including expected changes to precipitation type, durations, intensities
    - stream gage data
- Promote the adoption the more frequent updates to statistical measures of potential climate change in design
- Support research (see Appendix A for in progress NCHRP research project)
- Support and participate in collaborative policy workshops and task forces on engineering standards and operational practice. Recent such example is the 1st International Conference on Surface Transportation and Climate Change[2] and AASHTO's Climate Change Exchange. TCHH is also interested in working through interdisciplinary efforts lead by TRB or ASCE.
- Identify suitable adaptive measures that would allow the utilization of exiting drainage infrastructure to the end of their design service life.

TCHH commits itself to participation in the above types of efforts to further the public interest serving transportation needs. Climate change will be added to its business agenda in order to provide technical guidance to hydrologists and hydraulic engineers within the transportation arena. Over time, it plans to incorporate peer reviewed scientific and engineering findings in its drainage design manuals, policies and guidelines.

[1]Culvert Management Case Studies: Vermont, Oregon, Ohio and Los Angeles County, FHWA-HIF-14-008, 2014 http://www.fhwa.dot.gov/asset/pubs/hif14008.pdf

[2] First International Conference on Surface Transportation System Resilience to Climate Change and Extreme Weather Events, September 16–18, 2015, Washington, DC, http://onlinepubs.trb.org/onlinepubs/conferences/2015/ClimateChange/Program.pdf

index

	AASHTO **This newsletter is published biannually by the AASHTO Technical Committee on Hydrology and Hydraulics. Please send suggestions for articles and comments to:** Andrea.Hendrickson@dot.state.mn.us**, 651-366-4466 or Westerfield, Rachel rwesterfield@mdot.ms.gov, 601-359-7914**

index