River Morphology and Countermeasures

A Century on the Wolf River: Urbanization and Migration in Memphis, TN
Presenters: Wesley Peck and DJ Wiseman

The Wolf River watershed encompasses a substantial portion of southwest Tennessee. The lower watershed includes a highly urbanized, historically densely developed portion of the city of Memphis. The lower Wolf River also experiences significant backwater from the Mississippi River during major events. Due to these factors, the lower river is historically a dynamic channel and that tendency has been exacerbated since it was straightened and channelized and Interstate 40 was built on the floodplain fringe in the 1960's.

This presentation will use historic aerial photography and USGS quad maps dating back to the late 19th century to trace the migration of the Wolf over the last 100 years with some introductory material on migration of the Mississippi River in the vicinity of Memphis as well.

Real-Time Bridge Scour Monitoring in South Carolina
Presenter: Tim Lanier

Scour and depositional responses to hydrologic events have been shown to be a major threat to bridge infrastructure and thus a leading cause of bridge failure. Following the Federal Highway Administration's (FHWA) guidelines for evaluating scour critical sites, the South Carolina Department of Transportation (SCDOT) has identified 3,246 bridge structures in South Carolina as being scour critical. These scour critical structures are required by the FHWA to have a Plan of Action that should include countermeasures for managing scour. One potential countermeasure is real-time scour monitoring to assess the integrity of the bridge structures. The U.S. Geological Survey in cooperation with the SCDOT has implemented a sonar-based realtime scour monitoring system at 10 bridges in South Carolina. The sonar-based scour sensors were installed at locations on each bridge as determined by the SCDOT based on their internal scour monitoring records. This system continuously monitors the channel bottom to measure scour at piers or abutments during hydrologic events. The sonar derived measurements are periodically verified with manual measurements to the streambed from the water surface near the pier. Real-time stage gages and cameras also are installed at each site to measure water levels and monitor for debris, respectively. Data from monitoring programs such as this are vital to the State's transportation system where bridge failure can have not only an economic impact, but one of health and public safety as well if evacuation routes from coastal communities are disrupted during extreme weather conditions or other natural disasters.

Scour and Stream Stability at U.S. 98 over the Pearl River
Presenters: Katie Wimberly and Blake Palmer

In February 2020, a major flood event occurred on the Pearl River that caused significant bridge scour, bank erosion, and the failure of existing streambank stabilization countermeasures at U.S. Highway 98 (US 98) near Columbia, MS. The Mississippi Department of Transportation (MDOT) maintains US 98, and in 2015 began planning and designing a new structure over the Pearl River to replace the 90-year-old eastbound bridge that was constructed in 1933. The US 98 westbound bridge was built in 1970 and was not originally scheduled to be replaced. The Pearl River is significantly meandering, and in 1986 MDOT constructed a series of five (5) jetties along the left descending channel bank to stabilize the lateral channel migration that was occurring immediately upstream of US 98. The 2020 flood caused up to twenty feet of scour along the jetty system, causing failure of one of the structures and severe bank erosion at a second structure. The scour along the jetties contributed to additional local scour of up to fifteen feet at the US 98 bridge opening which led MDOT to implement a real time scour monitoring plan of action, and accelerated plans to replace the US 98 westbound bridge. This presentation will provide background for the US 98 bridge replacement project, lateral stream migration, and will discuss how technologies such as multi-beam bathymetric surveying, two-dimensional (2D) hydraulic modeling, and underwater acoustic imaging lead to a more informed and accurate decision-making process for MDOT. This will include both short-term and long-term plans to address stream and scour issues at the US 98 crossing over the Pearl River.

Exciting Components of The New Edition of HEC-23
Presenter: Laura Girard
The next edition of HEC-23 *Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance* is out. This presentation will highlight the new Design Guides on Engineered Log Jams, Rockeries, and Vegetated Riprap. You will hear about FHWA's abutment scour design philosophy, including new layout details, determining the scour design datum, and when an abutment scour countermeasure is unnecessary. Additionally, all Design Guides now include 2D modeling examples.

Advanced Stormwater Modeling

Evaluation of Screen Performance for Filtering Debris from Stormwater Inlets
Presenter: Troy Lyons

Trash and debris can clog stormwater inlets and pond water on roadways, creating hazardous conditions for motorists. The size, type, and amount of trash and debris can vary widely from urban to rural settings, and currently there is not a good understanding of the best means to prevent trash and debris from entering and clogging these systems. In urban settings, concrete barriers are commonly used to divide highways and stormwater inlets are spaced along the barriers periodically to receive stormwater runoff from roadways. Barrier inlets typically consist of a long narrow opening at the base of the concrete barrier and sometimes a grated inlet in the roadway adjacent to the inlet. During dry periods trash and debris accumulate along the roadway and become mobilized during storms and flow with the stormwater to the inlets where clogging can occur.

The evaluation of inlet screens to effectively filter trash and debris from on-grade Inlet No. 3 Single Slope Barrier, a drainage structure used by Ohio DOT, was performed on a full-scale experimental test channel at IIHR – Hydroscience and Engineering, the University of Iowa. The test channel modeled a range of flows and longitudinal and cross slopes to simulate typical hydraulic conditions encountered on Ohio highways. In the channel, a series of tests was performed to evaluate the hydraulic efficiency of the inlet with and without screens for various roadway slopes and flow conditions, and the potential reduction in hydraulic efficiency with inlet screens installed. Several commercially available and custom screens were evaluated for their ability to filter and resist clogging when subjected to various types and sizes of trash and debris. This presentation will cover the description of the experimental testing approach, the performance factors used to evaluate the screens, the results on a representative subset of the performed tests. A complimentary study was performed at Argonne National Labs that utilized three-dimensional computational fluid dynamics (CFD) simulations to evaluate hydraulic efficiency of the barrier inlet without screens. The synergies of utilizing numerical and physical model approaches will also be discussed.

Computational Modeling and Analysis of the Inlet No. 3 Single Slope Barrier Hydraulic Efficiency.
Presenter: Marta Sitek

Stormwater runoff from streets and highways is typically captured by drainage structures strategically placed when roadways use curb or curb and gutter systems. These structures include catch basins with grates, inlets, or combination inlets that collect and discharge storm water runoff to buried pipe conveyance systems. The performance of these drainage structures is measured in terms of hydraulic efficiency, which is defined as the percentage of flow captured by the basin as compared to the total flow draining to the structure. Understanding the performance of these drainage structures allows for a safe and economical design which prevents flooding along Ohio roadways.

The hydraulic efficiency for an on-grade Inlet No. 3 Single Slope Barrier, a drainage structure used by Ohio DOT, was analyzed with the use of physical and computational modeling. The full-scale physical model of a section of the pavement with the barrier inlet and grate was built at the Iowa Institute of Hydraulic Research. The three-dimensional computational fluid dynamics (CFD) simulations of the tests were performed at Argonne National Laboratory with the use of Siemens' Simcenter STAR-CCM+ software on a high-performance computing cluster. The study covered a range of longitudinal and cross slopes of the pavement and varying discharge to represent the typical hydraulic conditions encountered on Ohio highways. The presentation will cover the description of the modeling approaches, the results of the comparative analysis on a representative subset of the performed tests, and lessons learned from this comparative study.

Computational Modeling of Infiltration from Ditches into Roadway Embankments
Presenter: Marta Sitek

Road ditches are built along roadways to capture and convey runoff from roadways and offsite drainage. This allows for safer travel and protects the pavement from water infiltration. South Carolina DOT expressed interest in studying infiltration of water from ditches into roadway embankments. As part of the current design criteria, it is recommended that the road subgrades are one foot above the design water surface elevation to protect the pavement subbase from water infiltration. With changes in roadway design standards, larger shoulders and flatter cross-slopes have moved ditches further away from the pavement. The additional embankment width may warrant a smaller freeboard without risking negative effects to the subbase. Computational fluid dynamics (CFD) modeling was selected as a method of evaluation of the water infiltration from the ditch into the embankment with the goal to assess if the design requirements can be modified. The full-scale three-dimensional computational fluid dynamics (CFD) simulations were performed at Argonne National Laboratory with the use of Simcenter STAR-CCM+ software on a high-performance computing cluster. The test case matrix includes a combination of several parameters related to the hydraulic conditions, soil properties, and geometry of the cross-section. The presentation will cover the modeling approaches and main findings of the ongoing study.

Storm Sewer Geysering – An Exercise in Risk and Resiliency with Stormwater Infrastructure in Urban Environments
Presenters: Erik Carlson, Jose Vasconcelos, Marta Sitek

The Michigan Department of Transportation (MDOT) is in the process of constructing and planning for future construction projects involving modernization of I-75 and I-94 and out of the City of Detroit. The stormwater infrastructure for the City of Detroit and several surrounding communities consists of Combined Sewer Overflows (CSOs) that are enclosed and limited on capacity. In some cases, the Hydraulic Grade Line for the downstream CSO has been above the plan grade of the interstate, which has led to overflows on the highway during large flood events. Given the restricted outfalls, the limited ability for above ground storage in an urban environment, and the design criteria for interstates, the decision was made to design and construct deep underground storage tunnels.

The concept of a deep underground storage tunnel has been utilized for multiple CSO systems across the United States but was a relative new concept for MDOT. A Consultant with experience with design of these systems was brought on board to assist with the design. They highlighted the importance of designing these systems to reduce the risk of Adverse Multiphase Flow Interactions (AMFI), often described as “storm sewer geysering.” A similar phenomenon was observed on I-35W in Minnesota in the 1990s and in the Chicago area in 2022, and MDOT has concerns about public safety.

AMFI phenomena has been detected in stormwater systems across the US and are observed often when such systems undergo rapid filling during intense rain events. Rather than gradual filling, rapid filling leads to the entrapment of large air pockets through different mechanisms that have been identified in laboratory studies. Due to the large compressibility of air and the much larger water density, air surging can be severe, worsening issues linked to surging in vertical structures. Also, the uncontrolled release of air pockets through water-filled vertical structures can lead to air pressurization in shafts, geysering, manhole cover displacements, and the return of conveyed water to grade. Ongoing investigations are still providing insights on these events, as well as means to attenuate or avoid such occurrences. Due to the rapid inflow concentration and drainage in roadways and the prospect of more intense rains with climate change, the understanding of how to avoid AMFI in stormwater systems has become increasingly relevant.

Preliminary computational modeling of air-water interaction in a pipe system was performed with the use of Computational Fluid Dynamics (CFD) software which has the capability to model open-channel and pressurized flow, multiphase flows and complex geometries in full scale, time and space-dependent inflow conditions and other variables, etc. CFD simulations may allow for including many details of the geometry and physics and therefore give more accurate results, but at the same time, may require more time and computational resources than simplified 1D methods. Nevertheless, the information from 1D models regarding the location of air entrapment is indispensable to inform the 3D models.

Results from example CFD models which represent a laboratory-scale physical model of a pipe system, with varying number and size of ventilation pipes, will be presented at the conference. In the selected scenarios, the flow and geometry conditions lead to formation of water surges, layering of water and air, and pockets of water and air being pushed out through the ventilation shaft forming geysers.

Advanced Hydraulic Modeling

Determination of Shear Amplification between Approach Flow and Bridge Foundation Obstructions using CFD and a 5000 Case Matrix
Presenter: Hubert Ley
A new procedure for estimating scour that accounts for the material resistance of sediments, such as clay, is planned for the 6th edition of HEC 18. This new shear decay method requires information on the material properties and thicknesses of the subsurface layers of sediment at bridge foundations including the critical shear stress, roughness, and D50 for granular materials. It relies on a shear decay function that correlates the reduction of nominal shear stress in a developing scour hole with scour depth. The decay function requires an amplification factor that accounts for the increase in shear stress compared to upstream conditions caused by flow obstructions due to flow acceleration around the obstruction at bridge foundation structures, such as piers and abutments.

Argonne National Laboratory analyzed a case matrix of about 5000 cases with varying channel, floodplain, pier and abutment flow conditions and geometry to determine the amplification of nominal shear stress at piers and abutments compared to approach flow conditions affecting local scour at bridge foundation structures. The OpenFOAM CFD software was used to run the case matrix, with spot checks against Siemens' STAR-CCM+ CFD software for verification. Results were also compared with the SRH2D hydraulic flow software, which is used to obtain 2D flow conditions. Completing such a large case matrix would be impossible without automating the process with scripting software to generate the case geometries and case condition parameter files. An automated procedure to submit cases to Argonne's HPC computer cluster and monitor their progress was also developed.

The presentation will cover the development of procedures and analysis of the results in determining amplification factors for shear stress at piers and abutments

Selection and Application of Manning's Roughness Values in Two-Dimensional Hydraulic Models: Results from NCHRP 24-49
Presenter: Xiofeng Liu

Manning's roughness coefficient, often called Manning's n for short, is the single most important parameter in hydraulic models. Manning's n is often the only tuning parameter during model calibration. While hydraulic engineers have enjoyed the simplicity of a single parameter, Manning's n sometime is abused in practice. There are many aspects of Manning's n that a hydraulic engineering should be aware of when determining its values. For example, how should one change the Manning's n value from 1D to 2D models, what flow resistance factors should be considered and excluded in Manning's n, what is the impact of turbulence model, and is it reasonable that for a same simulation case the Manning's n values are different in different hydraulic models? This talk will present the main findings in the completed NCHRP 24-49 project and the resulted NCHRP Research Report 1077. The talk will start from the fundamentals of flow resistance and what exactly is Manning's n. Then, we will present answers to some of above questions. A general guideline and some best practices will also be briefly presented.

Automated Meshing and 3D Visualizations for 2D Bridges and Culverts in SMS/SRH-2D
Presenter: Scott Hogan

As 2D hydraulic modeling use and application becomes more widespread amongst State Departments of Transportation (DOTs) and others, FHWA strives to continue to improve the accuracy and efficiency of transportation hydraulic analyses and bridge scour evaluations. One area of significant advancement is the representation of bridges and culverts more accurately in SMS/SRH-2D. Although 2D bridge pressure flow analysis features have been in SRH-2D for several years, the assumption of a horizontal bridge deck and need to construct a high quality mesh with skewed pier or bridge configurations often presented challenges.

Several new tools in the SMS interface have overcome these limitations and added new capabilities in the process. The tools can be used to automatically generate meshes for bridges and piers with various configurations, as well as a 3D representation of the structure that defines a variable pressure ceiling. Two-dimensional culvert meshing and analysis has also been added as a new feature in SMS/SRH-2D. This presentation provides an overview of these new features with a few sample cases studies.

Understanding the role of bank vegetation in hydraulic modeling and scour – insights gleaned from CFD simulations for a bridge over the American River
Presenter: Kevin Flora

Bankline vegetation is known to have a significant influence on the hydrodynamics of rivers and plays an important role in meander migration and bank vegetation. This study demonstrates how inclusion of trees in computational fluid dynamic (CFD) models greatly affects the model results. Specifically, a case study of a scour critical bridge crossing over the American River in California is used to evaluate how vegetation along the banks of a channel can impact the velocity magnitude, turbulence, kinetic energy and shear stress in the river both near the banks and throughout the channel. Failing to reproduce these effects will provide inaccurate results in the flow characteristics and prediction of scour potential at a bridge site where vegetation is a dominant feature. However, including trees in a CFD model is problematic due to the complexity and spatial irregularity of the vegetation. For this study, two approaches were tested to incorporate trees into large-eddy simulations and the results were compared. Additionally, the scour potential at the sites was evaluated with and without bankline vegetation. Lastly, the hydrodynamic results from the 3-dimensional CFD model were compared to both 1 and 2-dimensional numerical models at this site.

Lightening Session #1

Future River Analysis & Management Evaluation (FRAME): A new forecasting tool for long-term morphological response in river channels
Presenters: Charlie Little and Blake Mendrop

Long-term forecasting of river channel evolution and morphological response is critical for ensuring that river management successfully mitigates against undesirable future outcomes. However, delivering such foresight competency against a range of plausible river futures with computational expedience remains largely beyond the capabilities of conventional river engineering models that tend to focus investigations on targeted reaches of interest over project-design time-scales. A new type of one-dimensional model is currently in development, overseen by the US Army Corps Engineer Research and Development Center (ERDC), with the aim of exploring uncertainty-bounded trends in sediment transport and channel morphology over decadal and centennial time-scales. The FRAME (Future River Analysis & Management Evaluation) tool is being designed with river managers and planners in mind where outputs will offer indicative insights into the evolutionary response of rivers to future changes in flow, variations in boundary conditions and, critically, hypothetical management scenarios.

FRAME employs historical and probabilistic annual flow duration curves to facilitate hydroclimatic simulation of future flow years, making it possible to investigate morphological sensitivity to periods of wetter- or drier-than-average years associated with climate change scenarios. The tool uses reachaverage cross sections with simplistic geometries to ensure computational efficiency. Sediment transport is calculated by grain size fraction with a simple hiding-exposure factor and active layer mixing facilitating fining or coarsening of bed material in response to erosion and deposition. However, unlike models that calculate sediment transport and channel change in response to time-stepping through hydrographs, FRAME performs its hydraulic and sediment transport calculations for discharge classes pertaining to each flow duration curve, with channel morphology adjusting in response to the imbalance in flow frequency-weighted sediment yield between consecutive cross sections. Sub-annual time-steps ensure model stability and smooth convergence towards sediment transport equilibrium.

A unique attribute of FRAME is its hybrid interfacing of traditional one-dimensional hydraulic and sediment transport modelling with geomorphic rules for representing the operation and performance of management interventions and characterizing the nature of morphological response (see related presentation by Downs et al.2023). Thus, in addition to simulating future flow regimes, FRAME currently includes functionality to simulate bed erosion control, dikes, diversions, tributary inputs, bed material variation and adjustment of sediment input. FRAME's ongoing development has been aided by two testbed models: a 200-mile reach of the Mississippi River upstream of Vicksburg, MS, and; Sabougla Creek, a tributary of the Yalobusha River, MS. Near-term priorities for advancing FRAME to a fullyoperational tool include capabilities for lateral channel adjustment (and bank erosion control) and reach lengthening to simulate the changing nature of river meandering and a beta testing program involving a working group of end users. On release, the ability to rapidly forecast river channel evolution over multiple decades and with easy-to-test management options will provide part of a broader program of foresight competency that generates the evidence base necessary for making strategic decisions to maximize the functioning and ecosystem benefits of future rivers.

Impact to infrastructure of the January and March 2023 Flooding
Presenter: Cathy Avila

California experienced significant flooding and many counties were declared local, state and federal disaster areas in 2023. The damage in many communities was so widespread that the Internal Revenue Service (IRS) delayed tax filing deadlines in California. This presentation will focus on January and March Storm events in Tulare, Sonoma, and San Luis Obispo Counties where transportation infrastructure was damaged or destroyed. Such infrastructure includes bridges, culverts and roadways adjacent to rivers. We will illustrate several bridge failure case studies including (1) a Tulare County where a four-span bridge lost a pier due to pier scour and (2) an undersized San Luis Obispo County bridge that failed due to channel migration.

We will also analyze case studies of undersized-culvert washouts due to debris blockage and/or roadway overtopping. Such case studies include a temporary "Acrow" type bridge (replacing an undersized culvert which failed in a 2020 flood) which failed in the 2023 floods.

Finally, we will showcase an analytical lens of flood hazard hydraulic modeling (velocity times depth) to emphasize the importance of "turn around, don't drown". We will demonstrate the importance of modeling human instability factors by reviewing the work of Jonkman and Penning-Rowsell [1]in the context of a San Luis Obispo County tragedy which resulted in the loss of a young child at a low water crossing.

Scour calculations using HEC-RAS 2D: Comparison of Modeling and Parameterization Alternatives for Bridges
Presenter: Shams Al-Amin

Currently there are different modeling approaches to include bridges in HEC-RAS 2D. Bridges are modeled using SA-2D connections, terrain modifications or a combination of both. Each of these modeling approaches include a set of assumptions and parameterization techniques. Sensitivity of the bridge hydraulics under different hydrologic boundary conditions for these approaches are unknown. This study compares bridge hydraulics for three approaches: (i) SA-2D connections, (ii) terrain modifications, (iii) combinations of both, and compares the abutment scours, contraction scours and pier scours following the HEC-18 5th Edition (FHWA-HIF-12-003, 2012) guideline. This study will provide insights into the sensitivity of theoretical scours under modeling and parameterization assumptions for different hydrologic and overtopping conditions.

Two Dimensional Modeling of the Lower Wolf River in Memphis, TN
Presenters: Amanda Whitlock

The lower Wolf River watershed is highly urbanized and has a long history of migration. The lower Wolf experiences significant backwater effects during major floods on the Mississippi River. It was channelized in the 1960's and I-40 was built on the floodplain during the same time period. This has resulted in a very dynamic river experiencing significant bend migration and head cuts in some areas. Recent bridge replacement projects on the lower Wolf River have resulted on extra attention in this area. This presentation will present the results of the modeling showing velocity patterns through the migrating reaches and the reaches that have remained straight since the 1960's.

Bridge Scour Mitigation using Concrete Armor Units - 25-years of Performance
Presenter: Daniel Priest

Scour at culverts and bridge abutments/piers is a problem confronting transportation authorities across virtually every jurisdiction. Mitigation techniques developed over many years are compiled in HEC-23. Among the methods described is the use of concrete armor units, which disrupt flows so that scouring dynamics do not develop. In the United States, concrete armor units known as AJacks have proven to be an effective, durable, and permanent scour mitigation system.

Designers must evaluate the multiple mitigation alternatives outlined in HEC-23 and select a solution that will provide effective, long-term protection against site specific scour conditions. This presentation will review four diverse applications where transportation authorities used A-Jacks to address their scour problems. Research, design methods, and environmental impacts will be reviewed. These applications include bridge abutments, bridge piers in a flowing river, a culvert outfall onto a steep embankment, and bridge piers in intermittent streams subject to large flood flows where riprap had proven to be an inadequate solution.

Flood Monitoring for South Carolina Bridges
Presenters: Beatrice Hunt and Ellen Newman

The South Carolina Department of Transportation (SCDOT) recently documented scour and foundation risks for approximately 8,000 bridges over waterways. This included the preparation of risk-based scour Plans of Action (POAs) for scour critical and unknown foundation bridges and the implementation of BridgeWatch, a web-based, bridge monitoring software application. To comply with FHWA requirements and improve operational resilience in flood monitoring, SCDOT developed and implemented requirements and documented the current state of the practice. These are described in SCDOT's new Flood Monitoring Guidance Manual and training for the monitoring personnel.

Flood monitoring consists of checking flood and scour conditions at a bridge when the critical threshold is exceeded, or following observation of flood conditions by SCDOT employees. The SCDOT Flood Monitoring protocol and documents were developed to allow flexibility in the monitoring response with consideration to prioritization by risk category, the history of the structure, the severity of the flood event, and available resources and staff. These are used to determine the proper level of response for each bridge before, during and after flood events. The three types of flood monitoring – visual monitoring and portable and fixed instrumentation– are detailed in the guidance. A useful new tool is the Flood Monitoring Form for SC monitoring personnel to assist in the uniform and efficient documentation of their site visits. This form includes "items to watch" to ensure the important items are checked during often difficult site conditions, and to streamline the process.

During the development of these materials discussions and interviews were held with several groups in SCDOT including the Districts, various other State DOTs, and the consultants developing SC POAs and BridgeWatch. The bridge owners discussed their successes and challenges in flood monitoring and explored innovative new procedures to facilitate and improve their monitoring. The protocol includes an Adaptive Management strategy so the experiences and data obtained from flood events can be used to maintain and improve flood monitoring. The team effort and the resulting SCDOT Flood Monitoring Guidance Manual

Taking on River Woes: The Whitewater Bridge's Battle with Bed Degradation in California's High Desert Amid Climate Challenges
Presenters: Oscar Suaznabar and Kevin Flora

Wildfires and debris flow resulting from extreme weather events have become increasingly common in California due to climate change. These events can lead to bridge scour and severe bed degradation, compromising transportation infrastructure stability and safety. In response, Caltrans has implemented various scour mitigation strategies aimed at protecting bridges from the adverse effects of these phenomena.

The case study conducted in the high desert region highlights the importance of understanding the unique challenges posed by climate change and geographical features such as wildfires and debris flow in California's high desert. This study contributes to the body of knowledge on scour mitigation strategies in regions prone to wildfires, debris flow, and severe bed degradation. By identifying effective solutions and best practices, Caltrans can enhance the resilience of transportation infrastructure and mitigate the impacts of climate change on bridge safety and functionality.

Bedform Evolution in Aquatic Organism Passage Culverts
Presenter: Haoyin Shan
Culvert design and operation significantly impact river ecosystem health and hydraulic efficiency. The need for environmentally optimal practices in civil engineering has become increasingly recognized, especially in the context of culvert installations. This study integrates riverbed analysis and computational fluid dynamics (CFD) to propose a novel framework for designing and assessing culvert bedforms in AOP culverts. Our research focuses on understanding the interactions between culvert structures, riverbed materials, and aquatic habitats, with the ultimate goal of enhancing ecological connectivity and minimizing hydraulic disruptions.

The first phase of our study involved testing common bedform configurations that may be present in current AOP culverts to see how they evolved in a laboratory setting. The main case we investigated was an AOP culvert with banks. Before and after running a low and high flow condition in our laboratory setup, we took 3D-LiDAR scans of the bed topography with high resolution in the flume. These time-dependent scans were then used to investigate the evolution of bedforms due to flow as well as their effects on the subsequent flow events. After processing the point clouds into adaptable meshes, we implemented CFD simulations to model water flow through these bathymetries in order to better understand and predict the flow conditions. A joint YouTube/Tech-note release will be available in order to visualize the process and results of our CFD/AOP investigations.

The CFD results are then used to analyze the hydraulic conditions (flow velocity, depth etc.) in order to check the viability of passage based on specific criteria necessary for the species of interest. The fish path model developed by our cooperators at Argonne National Laboratories treats the simulation domain as individual cells that may or may not be a potential path for the organisms. Through the usage of this technology, we can not only investigate the AOP viability of current conditions in a culvert but also what bedforms and structures may aid in the resilience of the AOP systems.

We also partially conducted a second phase of the study where we utilize LiDAR-scanned bathymetry in the field for full scale simulations. A YouTube video is also being produced for these experiments with similar CFD and AOP simulations in order to showcase the as-built application of these evaluation methods.

The results from this study contribute significantly to the field of ecohydraulics and culvert design. By providing a comprehensive framework that combines empirical riverbed analysis with advanced CFD simulations, our research aids in the development of AOP culvert installations. The experiments not only investigate ecological and hydraulic concerns but also offer a method to evaluate and create practical solutions for civil engineers and environmental managers. The implementation of these designs could lead to improved river ecosystem health, increased biodiversity, and enhanced flood management strategies.

This study presents a groundbreaking approach to AOP culvert design, bridging the gap between hydraulic engineering and environmental conservation. The integration of riverbed analysis, CFD and fish and AOP modeling into the design process represents a significant advancement in achieving sustainable water resource management and protecting aquatic ecosystems. Future research should focus on long-term monitoring of implemented and existing bedform designs and exploring their applicability and resiliency in diverse environmental settings.

The US Coastal Research Program and How it Can Help Our Coastal Roads
Presenter: Daniel Sharar-Salgado

The goal of the U.S. Coastal Research Program (USCRP) is to build a community of practice to address societal needs along the coast. USCRP is a collaboration of Federal agencies, academics, and stakeholders that aims to identify research priorities, enhance funding for academic programs, foster collaboration, and promote science translation. This presentation will discuss some of the accomplishments of the USCRP to date, some of their plans moving forward, and how hydraulic engineers in the transportation community can collaborate with and learn from the USCRP.

Scour

A New Scour Tool: NextScour Shear Decay Method
Presenter: Kornel Kerenyi and James Pagenkopf

The Federal Highway Administration (FHWA) is advancing NextScour, an innovative research initiative aimed at enhancing scour evaluation and delivering more accurate estimates of scour depths for the design of bridge foundations. NextScour addresses the two principal elements of scour: the hydraulic forces at play and the ability of soils to resist erosion (Figure 1). To calculate scour depths near bridges more accurately, shear decay functions for contraction, pier, and abutment scour have been developed. These functions are the result of comprehensive research that integrates flume scour testing, computational fluid dynamics (CFD) simulations, and probabilistic analysis. They assess the soil's erosional resistance across different layers, as identified by geotechnical engineers, enabling a more accurate determination of scour depths.

This presentation will guide you through the detailed process of applying FHWA's new shear decay method for accurately estimating the depths of contraction, pier, and abutment scour. The shear decay method treats contraction scour distinctly from pier or abutment scour. It employs grain size roughness and flow conditions to determine the shear stress in the bridge opening specifically for clear-water contraction scenarios. Additionally, adjustments are made for shear decay across different soil layers by considering changes in roughness. For clear-water contraction, the scour depth is considered to reach an equilibrium when the reduced shear stress becomes equal to or less than the critical shear stress of the soil. Furthermore, the method uses the velocity ratio to calculate shear for live-bed contraction scour at the scour depth determined during live-bed conditions.

The shear stress associated with the equilibrium depth of contraction scour was subsequently increased to calculate the maximum shear stress at the piers and abutments. For pier and abutment scour, shear decay functions are utilized to identify the diminished shear stress at incremental assumed scour depths. Adjustments for changes in roughness between soil layers to shear stress are omitted because of the limited exposure of different soil layers within the local scour hole. The equilibrium depth for pier or abutment scour is determined at the first point where the shear decay function intersects with the resistances offered by the soil layers.

Data-drive Shear Decay Design Analysis
Presenters: Kornel Kerenyi and Haoyin Shan

The Federal Highway Administration (FHWA) is developing NextScour, a forward-looking research initiative focused on advancing the study of scour to enhance analysis methods and offer more precise predictions of scour depths for bridge foundation designs. NextScour tackles the dual aspects of scour: the hydraulic forces acting upon structures and the capacity of soils to resist erosion. As the scour hole deepens, the water flow cross-section widens, leading to a reduction in flow velocity and the hydraulic pressure exerted on the riverbed. This decrease in hydraulic load persists until it aligns with the critical shear stress of the soil, indicating that the scour hole has stabilized at its equilibrium depth.

This presentation explores the development of the shear stress decay functions for analyzing contraction, pier, and abutment scour. The majority of pier and abutment scour tests in flumes were conducted under clear-water conditions, deliberately isolating contraction scour from pier or abutment scour. Consequently, the NextScour shear decay method initially addresses the reduction in shear stress due to contraction scour. By modifying equations found in HEC-18 (5th Edition), we formulated a shear stress decay function that determines the equilibrium depth of contraction scour under both clear-water and live-bed scenarios. The shear stress corresponding to this equilibrium depth was then increased to calculate the peak shear stress needed for estimating pier and abutment scour. To enhance our analysis, we gathered over sixty sets of pier and abutment temporal scour data from literature. A four-parameter function was selected to fit each temporal data set, from which the scour rate was calculated. This scour rate was then transformed into shear stress values using a sediment pick-up function. The calculated shear stress decay, alongside scour depth for all data sets, facilitated the creation of shear stress amplification and decay factors. Additionally, the shear amplification factor was refined with data from over 6,000 computational fluid dynamics (CFD) simulations. A probabilistic analysis was performed to incorporate the uncertainties presented in the temporal scour data, leading to the determination of the design shear stress decay factor.

This presentation summarizes the creation of the NextScour shear decay functions, designed for analyzing contraction, pier, and abutment scour. It emphasizes the function's role in improving the accuracy of scour depth predictions by considering the reduction of hydraulic forces and the differential erosional resistances of soil strata adjacent to bridge foundations.

Enhancing Bridge Resilience: Hydrodynamic Modeling for Scour Evaluation
Presenter: Donald Lynn Hendon

MassDOT is embarking on a critical infrastructure project—the replacement of the Dennis-Yarmouth Bridge over the Bass River along Route 28. This bridge serves as a vital link connecting Cape Cod to the mainland. However, the existing structure has succumbed to the relentless forces of time and nature, necessitating urgent replacement.

To ensure that the new bridge stands resilient against the elements and endures for its intended lifespan, HDR collaborated with MassDOT. Leveraging cutting-edge hydrodynamic models, we predicted water surface elevations, velocities, and shear stresses. Our innovative approach involved utilizing data from coastal surge models (specifically, MIKE21 HD and MIKE21SW) as input for the Federal Highway Administration's preferred hydraulic model for scour evaluations—SRH-2D. By estimating scour depths around the proposed bridge substructure, we aimed to safeguard against the worst possible scour scenarios.

Our assessments considered both rain-induced and surge-driven events, recognizing that the bridge's resilience becomes even more critical during times of heightened usage. Moreover, we factored in projected sea-level rise and the increasing intensity of storms due to climate change. Armed with this comprehensive understanding, the new bridge will be better equipped to withstand the challenges posed by our ever-evolving environment.

Join us in this endeavor to build a bridge that not only connects communities but also stands as a testament to resilience in the face of nature's forces.

Lake Superior Water Level Impacts on Bridge Scour
Presenter: Steve Neary

In August 2021 a routine underwater inspection revealed deep pier scour at B-4-57, a three-span girder bridge located west of Ashland WI on USH 2. This bridge spans the mouth of Fish Creek as it empties into Lake Superior. Structural analysis of the bridge determined that additional scour would affect pile capacity and increase potential for pile instability.

A 2D hydraulic model was created to determine total scour potential and guide decision making related to scour countermeasures. Pier scour protection was installed in late 2022 using innovative techniques for deep water and low bridge clearance. Sonar depth sensors were installed in May 2023 to provide real time streambed elevations.

2D modeling revealed the greatest scour potential when Lake Superior levels are low and angle of attack on bridge piers is most severe. Recent fluctuations in Lake Superior water levels – including multiple lows since 2007 – provide an interesting perspective for resilient structure design along Great Lakes coastal areas given uncertain future climate conditions and resulting impacts to water surface elevations.

Hydrology

Introduction to Hydrologic Modeling with SRH-W and SMS
Presenter: Alan Zundel

This presentation will cover an introduction to the hydrologic modeling capabilities with SRH-W and SMS. The presentation will include demonstration of key input variable and the workflow of computing hydrologic output in SMS-SRH2D.

Neptune Close Upon Vulcan's Heels: Post-Wildfire Bulked Runoff Analysis of a Burned Watershed Using Multiple First-Response Methods
Presenter: Steve Griffin

Analysis of potential post-wildfire runoff has become a critical component of Emergency Action Plans and first response risk planning for transportation agencies throughout the Western US and Canada. Increased peak flows, reduced hydrologic transit times, and sediment bulking in the first few years after a fire's containment are all proven risks to downslope transportation infrastructure as well as to the life and safety of the traveling public. Post-fire flow analyses can inform the immediate public safety response as well as inform potential upgrades to the transportation infrastructure to better accommodate bulked sediment-laden flows. In many cases, these quick, first-blush analyses can be completed with relatively little site-specific information.

A variety of new tools are now available to assist the practitioner in these post-fire determinations. Both HEC-RAS and HEC-HMS (USACE) have incorporated hydrologic and hydraulic-based workflows specific to post-wildfire analysis. Here, our aim is to compare and contrast a number of these tools alongside other methods and tools, by selecting known debris flow paths along CO State Highway 125 in the East Troublesome burn scar.

We begin with a pre-fire hydrologic analysis of the Denver Creek basin, a 3.6 mi2 basin which was 100% burned in the 2020 E. Troublesome Fire. We shall then compare and contrast the post-fire "bulked" flows via a number of methods currently incorporated into HEC-HMS. We shall also compare and contrast these results with two other common methods: a HEC-HMS analysis using modified NRCS Curve Numbers for the post-fire flow rates, and the USGS post-wildfire peak discharge analytical methods as presented in Moody (2011).

After highlighting the similarities and data requirements of these hydrologic methods, we conclude by highlighting the significance of these estimates in terms of hydraulic variables and the true-to-life site observations from the Denver Creek and CO Highway 125 post-fire debris flows from the past three years. As the road crossing has experienced significant sedimentation and debris accumulation post-fire, we reconcile the observed sedimentation with the information gained from these tools to extract a strategy of culvert retrofit or replacement at this location.

Drainage Area Limitations for NRCS Methods
Presenter: Rollin H. Hotchkiss

NRCS (SCS) methods to predict runoff volume and peak discharge from rainfall have been in use for 70 years. Despite the fact that 45 out of 50 state DOTs are still using NRCS methods to design highway drainage infrastructure, there is no clearly identified limitation on drainage area size for single, homogeneous watersheds. This lack of consensus is demonstrated in the literature, with disparate sources restricting NRCS methods to drainage areas between 0.1 and 100 square miles. The strongest statements limit application to less than 20 square miles, but there is no analytic method to firmly establish a drainage area limitation. This study, requested by the Nebraska Department of Transportation, will therefore compare flow frequency calculated from more than 100 small watershed stream gages in Nebraska to estimates using TR-20, results from regression equations, and the National Water Model and GEOGLOWS. Statistical analysis will follow. Although subject to regional variability, the methods we develop for finding drainage area limitations will be reproducible and can be applied in other states. Ongoing work and findings will be shared at the meeting.

Watershed Surface and Channel Runoff Coefficient Assessment with Unified Runoff Time Implications
Presenter: Ken Kagy

This presentation offers insight to T_c calculations and T_c analogies in small watersheds for the following: (i) four types of surface runoff coefficients are evaluated and compared to impervious surface, (ii) NRCS's segmental equations are calculated and graphically displayed by watershed attributes, (iii) four different T_c empirical equations are compared to NRCS's segmental calculations.

Water Quality Analysis and Stormwater Design

Uncertainty in stormflow-quality estimates at unmonitored sites can confound efforts to determine if infrastructure projects will have an adverse effect on water quality.
Presenter: Gregory E. Granato

Governments agencies need to consider the potential adverse effects of transportation on receiving waters and these agencies also are expending resources to participate in Total Maximum Daily Load (TMDL) analyses and to address resulting municipal separate storm sewer system (MS4) mitigation requirements. The potential for adverse effects of stormwater discharge on receiving waters depends, in part, on the receiving-water quality. Recent research indicates that stormwater treatment will not have a measurable effect on downstream water quality when upstream water quality approaches the quality of highway or urban runoff. The number of sites where information may be needed is vastly greater than the number of sites where sufficient water-quality data are available. For example, a recent runoff-quality study in southern New England resulted in the delineation of more that 48,000 road-stream crossings and fewer than 100 water-quality monitoring sites with 10 or more paired values of measured flow and total-phosphorus concentration. Unlike widely available mean-daily streamflow, data water-quality data is sparse in time and space and is more difficult to compare from place to place. This is, in part, because available water quality samples were collected over different time periods, or on different days in the same period, or on different points on the hydrograph if collected on any given day. Because water quality at any given location can vary widely with time, flow, and other variables sampling at any given site of interests is resource intensive and must be carried out over extended time periods. Therefore, methods are needed to estimate water quality at unmonitored sites over a wide range of conditions so that decisions about the potential effects of runoff on receiving waters and the potential effectiveness of mitigation measures can be made. A numerical experiment was done to assess the potential uncertainty in stormflow-quality estimates at unmonitored sites to address these information needs. Water-quality transport curves, which are regression equations developed to estimate concentrations from normalized streamflows, were developed by using paired concentration and flow data measured at 60 monitoring sites in and around southern New England without upstream municipal wastewater inputs. The Stochastic Empirical loading and Dilution Model was used to produce a standardized long-term hydrologic record from which standardized populations of concentrations could be calculated by using the transport curves. The similarities in basin properties among sampling sites, which included location, drainage area, imperviousness, selected land-cover percentages, and the lag-time index were used with several measures of goodness of fit including the Nash Sutcliff index, correlation, and percent bias to assess uncertainty in methods for estimating stormwater quality at unmonitored sites. Because of it's clear meaning and intuitive value the absolute percent bias was selected for comparison. Among variables tested, the median absolute percent bias ranged from about 46 to 63 percent and the maximum bias for individual stations ranged up to about 18000 percent. The best predictor based on the median value was great-circle distance between sampling points, followed by drainage area, basin lag factor, and percent imperviousness; the worst predictor was percent forest. The median absolute percent bias was only 2.2 percent when the best predictor stations were used, but this study indicates that it is difficult to identify the best predictor station a-priori by using commonly available basin characteristics. Therefore, operational definitions rather than specific upstream water-quality estimates may best guide decisions about the need for mitigation measures at unmonitored road-stream crossings.

Updates to the USGS-FHWA Highway-Runoff Database to support highway-stormwater practitioners
Presenter: Alana B. Spaetzel

The U.S. Geological Survey, in cooperation with the Federal Highway Administration, developed the Highway-Runoff Database (HRDB) and the Stochastic Empirical Loading and Dilution Model (SELDM) to provide planning-level information for decision makers, planners, and highway engineers to assess and mitigate possible adverse effects of highway runoff on receiving waters. The latest version of the HRDB (2024) has been updated with new monitoring datasets and statistical output options to facilitate data interpretation and provide input statistics for SELDM. This presentation will describe the latest updates to the HRDB and demonstrate how the HRDB and SELDM may be used by stormwater practitioners to simulate the effects of runoff on receiving waters and support stormwater management decisions.

Effects of impoundments on selected flood-frequency and daily mean streamflow characteristics in Georgia, South Carolina, and North Carolina
Presenter: Toby D. Feaster

The U.S. Geological Survey (USGS) has a long history of working cooperatively with the Georgia, South Carolina, and North Carolina Departments of Transportation (DOT) developing methods for estimating the magnitude and frequency of floods. In 2023, the USGS, in cooperation with the DOT in GA, SC, and NC, updated flood-frequency statistics for rural streams at gaged locations and developed regional regression equations that can be used to estimate those statistics at ungaged locations. As part of that study, flood-frequency statistics were computed at 72 regulated streamgages across the three States. In a companion study with the SCDOT, the USGS assessed the effects of impoundments on flood-frequency characteristics by comparing annual exceedance probability (AEP) streamflows from pre- and post-regulated (before and after impoundment) periods at 18 USGS long-term streamgages (30 or more years of record). For an assessment of how differences in such statistics can be influenced by period of record and hydrologic conditions captured in those records, which could be considered as natural variability, AEP streamflows at an additional 18 long-term USGS streamgages that represent unregulated conditions in those three states were computed and compared for the first and last half of those records. A subset of the 72 regulated streamgages that are located predominately above the Fall Line, also were used to develop regional regression equations that can be used to estimate flood-frequency statistics at ungaged regulated locations in GA, SC, and NC. This presentation will provide an overview of the results of this cooperative investigation.

FDOT Water Quality BMP Research Updates
Presenter: Jennifer Johnson

This presentation will provide an update to FDOT’s water quality BMP research projects. Several projects have been completed the past few years, with interesting results, particularly with Bio-Activated Media (BAM) in a variety of applications. The presentation will include a preview of upcoming research projects.

Hydraulic Modeling Case Studies

Aquatic Algorithms: A Comparative Analysis of 2D Modeling Methods
Presenter: Abigail Richardson

For hydraulic engineers, it is imperative to understand what software is appropriate to use for each scenario. This presentation outlines three different 2-Dimensional software programs (PCSWMM, SRH-2D, and HEC-RAS 2D) and compares how they perform when modeling a series of bridges in pressure flow. The same inputs are used across all three models, and the results are compared. Moreover, the ease of use, limitations, and reasons for any variations are discussed. The results reveal that HEC-RAS 2D and SRH-2D produce very similar results for velocity and water surface elevation. PCSWMM, however, reveals many limitations when modeling open channels and bridges, and its results are not consistent with the HEC-RAS 2D and SRH-2D model results. This presentation concludes that PCSWMM is recommended for subsurface drainage, while HEC-RAS 2D and SRH-2D perform equally well for large scale bridge hydraulics. However, if detailed bridge scour is necessary, SRH-2D is recommended, as it reveals detailed hydraulics under the bridge and has built-in scour tools available that helps the user calculate scour with ease.

A Comparison of Complex Hydraulic Modeling along Crabtree Creek using HEC-RAS 2D and SRH-2D
Presenter: Emma Bones and Matt Lauffer

As part of STIP Project I-5870, NCDOT is proposing a set of improvements in the vicinity of Crabtree Valley Mall located in northwest Raleigh that will impact Crabtree Creek and its tributaries. The scope of project I-5870 is expected to include improvements at the I-440/U.S. 1 interchange at U.S. 70 (Glenwood Avenue), the intersection of Glenwood Avenue and Blue Ridge Road/Lead Mine Road, a possible new connection to Crabtree Valley Avenue, and other revisions to the road network within the project area. The project site includes multiple bridges, culverts, stream confluences, and Crabtree Mall, which is completely contained within the floodplain. Given the complex hydraulics of the project site, NCDOT elected to complete the preliminary modeling in a 2D modeling software to provide the most accurate results to support decision-making for future improvements. There are numerous sources that provide guidance on when to select a 1D or 2D model, but there is much less guidance to support proper selection of a 2D model, such as HEC-RAS 2D or SRH-2D, based on the particular hydraulic features to be modeled. Given this lack of information, NCDOT elected to create both a HEC-RAS 2D model and an SRH-2D model of the existing conditions and compare the results to support future decision making when selecting 2D models. This presentation will compare the results of each of the 2D models as well as the 1D HEC-RAS model. Further, the presentation will provide suggestions on when each 2D model may be most applicable for these particular modeling needs.

Improving West Memphis Port Hydraulics
Presenter: Andy McCoy

The City of West Memphis, Arkansas owns a port located along the Mississippi River designed to support industrial transport and commerce in the region (oil and gas, fertilizer, construction, and agriculture). The City is in the process of thinking through their long term strategy with respect to the port.

Due to site specific hydrodynamics, conditions become very difficult for barge operators to navigate into and out of the port safely above a river flow of 1,000,000 cfs (less than a 2-year flood). Conditions were described and documented by barge operators in stakeholder workshop meetings.

During the years 2020 and 2021 the port was closed more than six months each year causing significant amount of lost revenue at the port.

A planning study was performed to investigate the underlying cause of the un-safe conditions, recommend short and long-term solutions, and tested the efficacy of the solutions.

This abstract describes the development and results of modeling tools to a computational fluid dynamics (CFD) model that considered the unique conditions that exist due to the natural river channel bathymetry and site features.

Port improvements were conceptualized and evaluated.

This following were documented:

- The riverine context for bank improvements
- The use of the 2D model to screen potential hydraulic alternatives and to inform the CFD boundary conditions
- Confirmation that the 2D model and the CFD model were reasonably reproducing known velocity conditions by comparing acoustic doppler current profiler (ADCP) information
- Existing conditions, velocities, and flow patterns near the docking area
- The results of design alternatives to improve flow patterns near the docking area

Salt Creek Boardwalk: Water and Life in Death Valley National Park
Presenter: Amanda Peters

Death Valley National Park (DEVA), an area often thought of as being defined by extreme drought and heat, was impacted by extreme flood events in August 2022 and August 2023. Each of these storm events equaled seventy-five to one hundred percent of the average annual rainfall, causing severe damage to many transportation facilities and interpretive sites throughout DEVA. One of the destroyed interpretive sites is the Salt Creek Boardwalk Trail. The boardwalk is a pedestrian interpretive trail that, since 1976, has provided visitors an intimate experience in a unique area of DEVA that is teeming with life. Salt Creek is one of the few perennial streams in DEVA and supports a fragile desert ecosystem that provides the only habitat for the Salt Creek pupfish. This species of pupfish is endemic to the park and has adapted to live in the very high salt concentrations found in Salt Creek.

As part of the Emergency Relief for Federally Owned Roads (ERFO) program, the Central Federal Lands Highway Division, in partnership with DEVA, was given the opportunity to design a replacement structure. The goals of the project are to construct a new, more resilient boardwalk to replace what was lost in the extreme storm events and reestablish the visitor experience. The most recent boardwalk, constructed in 1997, was a raised wooden structure built on shallow concrete foundations without consideration for hydraulics and scour.

An approximately 1,500 square mile basin drains to the boardwalk location and ultimately has an outfall at Badwater Basin, the lowest point in North America at 282 feet below sea level. Salt Creek lies in a wide alluvial valley and has a high potential for erosion and lateral migration. The design of the new boardwalk alignment had many factors that needed to be balanced, including avoiding impacts to sensitive paleontological resources, providing visitors an intimate experience with the pupfish and vegetation, and creating a resilient design to ensure longevity of the structure. As a part of the hydraulic design, extensive modeling and sediment transport analyses were conducted using SRH-2D within the Surface-water Modeling System (SMS) interface to evaluate sediment movement throughout this sandy, desert system. To conduct this analysis, LiDAR data was initially collected after the 2022 event and again after the 2023 event, providing an opportunity to compare topographic changes between storm events. This information, in conjunction with local scour analyses at piers, was used to determine appropriate scour values for the boardwalk. The results of the scour analyses and the potential for future lateral migration were used to develop various scour zones (areas of similar expected scour) along the length of the proposed boardwalk to be used in design and construction of the over 500 micropiles being installed as the boardwalk foundation. Scour zones were developed to account for channel movement in the highly mobile system, knowing portions of the boardwalk that currently would not be impacted during a storm event could be in future events. In addition to the scour analysis, a hydraulic capacity analysis of the boardwalk was completed, balancing the need to keep the boardwalk close to the creek for the visitor experience while ensuring the boardwalk would not be inundated during frequent storm events. This sustainable design provided a unique opportunity to analyze sediment movement in Salt Creek and provide the National Park Service with a boardwalk with increased resiliency to future storm events.

Lightening Session #2

Comparison of 1D and 2D Hydraulic Models Applications for Maryland SHA Stream Crossings
Presenter: Pawel Mizgalewicz

Maryland State Highway Administration (SHA) Office of Structures, Structure Hydrology and Hydraulics Division (SHHD) has been evaluating various modeling approaches in the process of designing bridges and analyzing flooding conditions at the stream crossings for 400-acre and larger watersheds, and for floods ranging from 2-yr or bankfull to 100-yr and larger floods. The purpose of this presentation is to share our experience and comparison of one-dimensional (1-D) and two-dimensional (2-D) hydraulic models, identify advantages and disadvantages depending on the purpose for the model, location, length and slope of the system, available data, and other factors.

For most bridge and small structures replacement projects, the 1-D applications have been the primary approach as it has been standardized in detailed procedures, perfected through detailed reviews by experienced users. Nevertheless, some projects presented challenges that were best addressed using 2-D models. Currently 2-D models are typically used to verify the stability of proposed stream improvements, such as stream reconstruction, floodplain grading and/or stream relocation when they are related to designing a bridge or culvert replacement. Simplistic 2-D models are also used for preliminary analysis to determine river flow paths and correct location and alignment of stream cross sections for field survey data collection.

The 2-D model development requires a detailed digital elevation model or digital terrain model; however, our experience is that in some instances this data significantly deviates from the topographic survey and field collected cross sections. Another major difference between the two modeling approaches is how the stream channel and floodplain roughness are defined. Verification of the data and input parameters, including roughness coefficients is more complicated for 2-D models and requires an experienced and well-trained hydraulic engineer.

To investigate the advantages and disadvantages of HEC-RAS 1-D and 2-D models for river crossings analysis and design process, a set of projects was selected. The selected sites include crossings with channel bends, sites that were modeled by split flow technique to represent stream flow separation (different hydraulic conditions in two or more flow tubes), and a crossing with a large upstream storage. However, as the technology progresses and the regulatory agencies are also exploring new innovative approaches and new technology implementation, hydraulic engineers need to better understand applicability and data requirements to properly apply the advanced modeling tools.

The purpose of this his study is to evaluate applicability of two-dimensional modeling in comparison with the one-dimensional models for analysis and design at Maryland waterway crossings, to evaluate the costs and benefits and discuss various limiting factors users need to consider before selecting the proper modeling approach. The presentation is going to discuss the study results, summarize comparisons of 1-D and 2-D approaches used on selected projects. The study is intended to help develop a plan for implementing 2D modeling into SHA bridge and culvert crossings design process.

The KISS Method – Keep It Simple and Sustainable – for Hydraulic Engineers
Presenter: Rachel Westerfield

Do you know about the KISS method? KISS – Keep It Simple and Sustainable

Hydraulic designs shouldn't be overly complex and the infrastructure we recommend shouldn't be difficult to maintain. Ingenuity doesn't equate to writing a thesis for your design. Sometimes ingenuity is simply learning to follow a new path, a more efficient path, or the latest and greatest path (aka tools at our fingertips provided by some of the brightest minds in our field of study).

KISS – Keep It Simple and Sustainable – the key to developing accurate and reliable hydraulic designs for our transportation network

- Too Much of a Good Thing: Level of Detail on your HECRAS Cross Sections Could be Detrimental to the Accuracy of your Model
    - Did you know that allowing your cross section in HECRAS to contain 500 points thanks to the LiDAR now available could actually affect conveyance calculations. Too many points could affect the accuracy of HECRAS computations of the water surface elevations. You only need enough points to adequately represent the shape of the cross section. Engineering judgement should be used to accurately describe the channel and floodplain geometry. HECRAS has to compute areas between each point. In this case, more data doesn't equal better results. Could having too many points increase computed water surface elevations? Probably. HECRAS adding this tool allows engineers to properly filter points and evaluate results. Finding balance between the old HEC-2 data of having 10 to 15 points for your cross section and the over abundance of 500 points is key. ~KISS

"Manning's roughness values, along with channel and floodplain geometry (i.e., topographic and hydrographic surface data), are recognized to be the two most important components for developing and calibrating hydraulic models." – NCHRP Research Report 1077

- Sharpen your Pencils – Use Information that is Already at Your Fingertips: Advancements in Selecting Manning's Roughness Values
    - Did you know that there is an NCHRP report out that helps identify feasible, cost-effective, and consistent guidelines to improve the state of the practice in selecting roughness values for hydraulic modeling? ~KISS

- The Ultimate KISS: SMS/SRH2D Hydraulic Modeling Compared to 1D HECRAS Hydraulic Modeling
    - Did you know someone that has had equal training for HECRAS and SMS/SRH2D can actually complete the 2D model faster and get more accurate results? It takes years of experience to accurately model a site in HECRAS. KISS with SMS/SRH2D

"2D modeling does not take longer than 1D modeling. Recent advances in software have automated many tasks, making 2D modeling very efficient; in fact, in many cases, 2D models take less effort." Dusty Robinson

Other KISS methods will be presented as “Did you Know...” based on over 20 years of hydraulic design experience and lessons learned.

KISS – Keep It Simple and Sustainable

Navigating CLOMR Complexity: Moving a Project with Over a Mile of Natural Stream Design & 9 New Structures Through FEMA’s CLOMR Process
Presenters: David Spinks

In 2018 the Tennessee Department of Transportation (TDOT) Hydraulics group began planning the drainage for a large roadway project that would relocate approximately 4 miles of SR-115 (Alcoa Highway) including a new interchange with SR-162 (Pellissippi Parkway) near the McGhee Tyson Airport in Blount County, TN. This area also contains Russell Branch and its Zone AE Special Flood Hazard Area.

It became clear in the project's early stages that regardless of the design choices made, the roadway fill and nine new structures impacting Russell Branch's FEMA Floodway were going to necessitate a Conditional Letter of Map Revision (CLOMR), so the decision was made to relocate over one mile of stream channel using Natural Stream Design (NSD) in order to generate stream mitigation credits. As the greater project was being designed, the group was also tasked with incorporating a "temporary" crossing for an Amazon distribution center access road that would eventually have to fit into the final design. During the lengthy design and review process TDOT developed and refined a 2D Hydraulic Model using Aquaveo's SMS SRH-2D to help check the 1D CLOMR submittal accuracy (this is being updated with the new SMS 3D structures functionality introduced in v13.3.9).

Attendees will hear from TDOT Hydraulics staff members Wesley Peck, David Spinks and Jimmy Scales as they discuss this project, the 1D and 2D modeling choices and challenges that were encountered while developing the Russell Branch hydraulic models, as well as the lessons learned during our 28 month CLOMR application process.

Reliability-based Lower-bound Critical Shear Stress Prediction for Cohesive Soils
Presenter: Haoyin Shan

In 2015, the Federal Highway Administration (FHWA) published a critical shear stress equation for cohesive soils based on soil index properties, including water content, fraction of fines, plasticity index, and unconfined compressive strength. This equation was developed from tests of engineered soils with limited properties, but FHWA received feedback from practitioners asking if the equation was applicable to a wider range of field cohesive soils. The Hydraulics Laboratory at Turner Fairbank Highway Research Center (TFHRC) reviewed erosion and soil indexing data of clay specimens collected from 11 states, and determined the equation gave reasonable estimates of critical shear stresses. Additional literature data was collected, resulting in a total of 178 data points. The measured and computed τ_c were compared, and more comprehensive analyses were conducted considering the variation of the soil index properties. Following the framework of the National Cooperative Highway Research Program (NCHRP) 24-34 report, the mean of the ratios between the measured and computed τ_c, i.e. the bias, was calculated. The distribution of the ratios follows the lognormal distribution. A design equation to predict the critical shear stress was proposed based on the bias and COV of the lognormal distribution. The design equation allows a range of estimation of τ_c from 0 to 32 Pa for clay with varied index properties.

Beyond the FEMA Model: Innovations in Flood Assessment

Presenter: Colin McKernan

In September 2013, Boulder, Colorado experienced an unprecedented deluge, with over 18 inches of rain falling in less than a week. The devastating impact included the loss of four lives and the destruction of nearly 300 homes. Boulder Creek, typically a tranquil stream, transformed into a raging river, wreaking havoc on its surroundings.

The Colorado Department of Transportation (CDOT) recognized the urgency of addressing flood risks in the heart of Boulder. CDOT commissioned HDR, a leading engineering firm, to analyze two critical structures along CO-7 that spanned Boulder Creek. The primary objective was to mitigate or eliminate the Special Flood Hazard Area and floodway.

During the assessment process, several challenges emerged while evaluating the existing FEMA model:

- Misassigned Manning's 'n' Roughness Values: Inaccurate parameters affected flow predictions.
- Improperly Implemented Junctions: Flow paths were compromised due to flawed junction modeling.
- Overlapping Cross Sections: The model failed to account for intersecting flow paths.
- Missed Flow Paths: Some critical flow routes were overlooked.
- Improperly Implemented Lateral Flow Structures: Lateral inflows were not adequately represented.
- Missing Flow Between Cross Sections: Connectivity gaps hindered accurate simulations.

To address these issues, HDR developed an SRH-2D model, which meticulously assessed flow paths and rates in the vicinity of the project. These results informed the creation of a truncated version of the effective HEC-RAS 1D model. Additionally, a RAS2D model was specifically tailored for this project.

In this presentation, we will delve into the project's context, challenges, and the three hydraulic models developed. We will compare and contrast their strengths, limitations, and applicability. By leveraging advanced modeling techniques, we aim to enhance flood hazard assessment and contribute to resilient infrastructure planning.

Coastal Strategies for Drainage Resilience and Permitting in Florida
Presenter: Carl Spirio

This presentation will focus on the emerging issues impacting Florida's coastlines and highlight the research needs and design guidance required to address more comprehensive solutions that promote better resiliency and long-term sustainability. Similarly, this session will focus on the environmental permitting and Stakeholder engagement required to produce successful regional projects involving coastline protection and water quality initiatives throughout Florida.

Although Florida has always been vulnerable to coastal flooding associated with tropical systems, new strategies and guidance is needed to address Sea Level Rise (SLR) and other types of nuisance flooding impacting coastal areas throughout the State. The presenter has been involved with several Peer Exchange Workshops, hosted by the Federal Highway Administration (FHWA) to discuss all types of coastal concerns, as well as identify innovative strategies to better adapt to these events. As a result of these Workshops, additional coordination has been initiated with various local municipalities, several Water Management Districts (WMDs) and with the Florida Department of Environmental Protection (FDEP) to gain more insight into their efforts related to overcoming recurring coastal flooding issues and the strategic measures needed to improve water quality to inlets, bays and estuaries Likewise, there are numerous regulatory hurdles that must be addressed to ensure regional projects satisfy the environmental permitting constraints related to sovereign submerged lands and critical species habitat. Due to the competing interests amongst the various Stakeholders within the coastal watershed, additional planning and coordination is critical in identifying solutions that are tailored to specifically protect and preserve communities and critical infra-structure given the site-specific environmental conditions involving the particular coastal region in Florida.

Developing a New Generation of Hydraulic Engineers
Presenter: Megan Frye

Many organizations are faced with continued turnover and attrition in the hydraulic discipline through retirements and reassignments. The development of the new generation of hydraulic engineers adds to an already full plate for many managers. This presentation will look to provide some training resources, development opportunities, and employee development considerations with the hope of taking some of the burden off managers.

The Mississippi River Basin Model – A Triumph in Hydraulic Engineering
Presenter: Donald Lynn Hendon and Sarah McEwen

The Mississippi River Basin Model (MRBM) stands as a remarkable testament to human ingenuity and engineering prowess. Born out of necessity and shaped by historical events, this colossal physical model represents one of the most successful experiments in hydraulic engineering ever constructed.
<u>Background</u>
In 1927, the Mississippi River unleashed a devastating flood, submerging over 23,000 square miles of land, displacing countless people, and claiming approximately 250 lives. In response, the U.S. Congress passed the Flood Control Act of 1928, empowering the U.S. Army Corps of Engineers (USACE) to design and construct flood control projects along the Mississippi River and its tributaries. This legislation not only increased public awareness of flood control but also sparked discussions about evaluating river systems comprehensively.
<u>The Birth of the MRBM</u>
The original purpose of the MRBM was to research and understand the intricate interactions of all reservoirs within the Mississippi River Valley. Constructing such a large-scale model required innovative planning, especially given the constraints of World War II. The ideal location near Clinton, MS, facilitated labor accessibility, as the land for Camp Clinton was purchased in 1942, followed by the adjacent land for the MRBM.
<u>POWs and Precision Sculpting</u>
Prisoners of War (POWs) played a pivotal role in moving earth, installing underground cisterns, and laying the groundwork for the model's panels. Engineers meticulously poured and sculpted concrete in 10-foot sections, starting with the Missouri River Valley. As they worked their way down, a concrete portrait of the country emerged, including roadways, levees, flow obstructions, rail lines, and existing flood control structures.
<u>Legacy and Significance</u>
The MRBM remains historically significant due to several factors:

- POW Contributions: World War II POWs contributed significantly to its construction.

- Hydraulic Engineering Advancements: The MRBM led to discoveries and advancements in hydraulic engineering.
- Impact on Flood Control: Its influence stretched from the Dakotas in the north to Louisiana in the south.

Rediscovering the MRBM

In 2015, a group of engineers visited the MRBM, witnessing its sculptural magnificence. Although weathered and obscured by vegetation in a forgotten park in southwest Jackson, the MRBM holds fascinating clues about how engineers learned to predict and respond to flooding and other hydraulic disasters.

Endless Opportunities

The MRBM's potential for cross-programming between history preservation, STEM education, and recreational opportunities is boundless. Let us recognize and preserve this monumental achievement—a scaled replica of the Mississippi River basin that forever shaped flood control strategies and our understanding of hydraulic systems.

Friends of the MRBM

It was these possibilities that in 2016 led to the creation of a non-profit organization with the goal of preserving this engineering masterpiece. Friends of the Mississippi River Basin Model not only seek to preserve, but to educate. Our goals are to preserve the site for future generations, increase recreational access, increase SEM education with the construction of a STEM Center on the site, restore and preserve artifacts found, and even have a portion of the model to flow again for demonstration purposes!

In this presentation, we will cover the past, present, and future of this amazing hydraulic engineering wonder.

FHWA's Development of a Scour Assessment Template
Presenters: Laura Girard and Paul Sharp

The Federal Highway Administration (FHWA) intends to develop a Scour Assessment template for owners' use in satisfying the National Bridge Inspection Standards (NBIS) (2022) regulations and would like to gather perspectives regarding the template documentation and processes. Representatives from FHWA Headquarters and Resource Center Hydraulics Teams will facilitate an interactive discussion with hydraulic engineers on how a new Scour Assessment and Appraisal approach can assist their bridge inspection programs by providing the basis for Coding Guide Item 113/SNBI Item B-AP-03, and ensuring each bridge is not vulnerable to scour.

This effort is informed by the NBIS (2022) regulations, in 23 CFR 650.313(o)(1) , which requires owners to *Perform a scour appraisal for all bridges over water, and document the process and results in the bridge file. Re-appraise when necessary to reflect changing scour conditions. Scour appraisal procedures should be consistent with Hydraulic Engineering Circulars (HEC) 18 and 20. Guidance for scour evaluations is located in HEC 18 and 20, and guidance for scour assessment is located in HEC 20.*

Additionally, FHWA's April 9, 2012, memo on 'Guidance on Applying Risk-Based, Data-Driven Decision-Making Process to the FHWA Scour Program' encourages owners to consider the use of risk-based and data-driven National Bridge Inspection Program (NBIP) oversight processes to manage their limited resources more efficiently. Within this memo, FHWA notes that a risk and data strategy enables the priority and level of analysis required for scour appraisals and provides examples of when a Scour Assessment may be appropriate rather than a full HEC-18 and HEC-20 Scour Evaluation.

Innovation

TPF 5(461) Research Study Updates
Presenter: James Pagenkopf

In 2020 the Federal Highway Administration (FHWA) initiated a Transportation Pooled Fund (TPF) study allowing it to partner with State departments of transportation (DOTs) to provide soil and erosion testing services to improve bridge scour evaluations. This effort is part of FHWA's NextScour Research Initiative, which is an interdisciplinary effort between hydraulics and geotechnical engineers to address knowledge gaps surrounding traditional methods of scour analysis, especially for bridge sites that contain subsurface layers of cohesive soils.

Since the TPF study was initiated, FHWA has participated in two major case studies with Michigan DOT on the Lafayette Avenue Bridge replacement project and North Carolina DOT I-95 bridge replacement project in Lumberton, NC. Numerous soil samples were collected from each site and tested in the Ex-situ Scour Testing Device (ESTD) to determine the critical shear stress of the clay layers. The case studies also included a reanalysis of the hydraulic modeling using 2D and computational fluid dynamics (CFD) modeling to verify the flow conditions and determine bed shear stresses at the bridge site. Another case study involved conducting soil erosion testing of Yazoo clay layers for Mississippi DOT near I-20 and Lynch Creek in Jackson MS. A fourth project used physical flume testing and CFD modeling to analyze a reduced countermeasure design for Florida DOT for a scour-critical bridge. This presentation will provide an overview of these projects and how the FHWA Hydraulics Research Laboratory provides technical assistance to States for their hydraulic analyses and scour calculations.

Development of the New Highway Drainage Manual
Presenter: Jim Schall and Casey Kramer

This presentation outlines the results of NCHRP Project 24-50 which updated the 2014 AASHTO Drainage Manual (ADM). The objective of this project was to produce a new, up-to-date ADM informed by the 2014 ADM and the results of NCHRP Project 20-07 (417) that provides state DOTs and local transportation agencies with design policy and guidance and the technical background to support them. Since 1991 the ADM has set a high standard of technical excellence and practical value for many state and local agencies completing highway drainage design.

The updated ADM will be published as a single volume in 7 downloadable PDF files that will enable faster implementation and future updates to incorporate research findings, emerging issues and technologies, and new design responsibilities. Formatting the ADM this way will allow updating a portion of the ADM without having to republish the entire ADM. This aspect will be increasingly important and valuable as the speed of technological change continues to increase.

The presentation will provide an overview of the technical content that was updated throughout the ADM and the development of three new chapters: Resilience, Aquatic Organism Passage (AOP), and Stormwater Best Management Practices (BMPs). A secondary result from the project was the person-to-person survey completed. The survey was conducted to identify specific changes needed to make the document more relevant to the end user. However, it will also provide valuable information and insight for the transportation industry and future NCHRP and AASHTO projects.

The project successfully completed the project objective by providing a significantly updated ADM based on the latest technology and design practices.

Alaska DOT&PF: New tools to support rapid assessment and response in remote areas
Presenter: Michael Knapp, P.E., Statewide Hydraulics Engineer

The Alaska Department of Transportation & Public Facilities is deploying new tools during field work that allow inspectors to engage subject matter experts in real-time from remote locations to address critical findings and emergencies. Mr. Knapp will present typical logistical challenges of working in remote Alaska, and discuss some of the new tools being deployed, including Unmanned Aerial Systems (drones), Starlink backpacks (internet connections), laptops with Teams connections, and more. The presentation will highlight how these tools have been used successfully to inspect a pier following the discovery of severe damage by maintenance personnel.

A Tidal Wave of Innovation – Washington State Department of Transportation Hydraulics Office Updates
Presenters: Julie Heilman and Casey Kramer

This presentation provides an overview of numerous innovations and updates being performed by the Washington State Department of Transportation (WSDOT) Hydraulics Office and their augmentation staff.

Innovations and updates that will be covered in the presentation include but are not limited to:
Training and Certification

- WSDOT Scour Training and Certification
- WSDOT Fish Passage and Stream Restoration Design Training and Certification
- WSDOT Highway Runoff Manual Training and Certification

Collaboration with Public and Private Sectors

- WSDOT Fish Passage and Stream Restoration Design Workshop Series
- WSDOT and FEMA monthly coordination meetings
- WSDOT design academies with virtual reality, stream table, and research demonstration tables
- Coordination, collaboration, and partnerships with resource agencies and Tribes

Policy Updates and Templates

- Scour policy updates: Hydraulics, Bridge, Roadside, and Design manuals
- WSDOT Flood Risk Assessment and No-Rise Templates
- Preliminary and Final Hydraulic Design Report and other Templates
- Scour review checklist
- 2D model review checklist

Development and Implementation of Virtual Site Visits

Many of these innovations and updates are available through the WSDOT Hydraulics Office website and their training website. These innovations and updates have assisted WSDOT in delivering the largest fish passage program in the world and to continue to improve the state of practice for transportation hydraulics.

Aquatic Organism Passage

Design and Resilience of Waterway Crossing for Aquatic Organism Passage in the Coastal Plains of Maryland
Presenter: Arthur Parola

Maryland State Highway Administration (SHA) developed a research project to evaluate aquatic organism passage (AOP) practices implemented on projects over the past three decades. The purpose of the research project was to understand AOP challenges, the potential for improving AOP solutions for implementation at culvert replacement and rehabilitation projects, and the verification of the long-term sustainability of AOP solutions.

Current Maryland regulatory guidance related to AOP is limited. The Code of Maryland Regulations (COMAR) section concerning construction on nontidal water and floodplains states, "Culverts shall have at least one cell placed at least 1 foot below the invert of the stream. In the case of bedrock foundations, culverts shall be designed without a concrete invert unless measures are incorporated into the design to ensure that fish habitat or migration patterns are not adversely affected" (26.17.04.06). SHA replacement and rehabilitation projects must comply with this regulation. SHA realizes that this requirement is often inappropriate or inadequate in ensuring that all objectives of the crossing are met, including those associated with floodwater elevations and channel stability.

A selection process led to the evaluation of 21 stream crossings from over 70 sites in Maryland's Eastern and Western coastal plains. A primary concern of AOP in Maryland is the migration of anadromous and catadromous fish that use streams and wetlands of the coastal plain to spawn. The site selection was based on information from USFWS fish migration studies and structure inventories conducted by SHA. Each crossing was evaluated 1) to identify AOP barriers, 2) to assess morphological changes to the channel and crossing, and 3) to assess the potential repercussions on upstream and downstream flooding. The evaluation yielded valuable insights, culminating in recommendations for resilient culvert design and effective AOP implementation in Maryland's Coastal Plains.

Reconnecting the Bayou Darter: A One of its Kind Partnership in the Southeast
Presenter: Sarah McEwen

The Mississippi Department of Transportation (MDOT) selected the State Route 18 stream crossing of White Oak Tributary 1 for replacement based on the need to widen the road to support requirements for evacuation routes and the future Average Daily Traffic count. The site is north of Port Gibson, and north of the Bayou Pierre crossing along SR 18. The existing crossing was a double box culvert design that was installed in 1935 with a drainage area of roughly 2 square miles. At first glance this seems to be a simple alternative analysis to determine if widening the culverts or a bridge is required; however, the environmental investigation led to a unique partnership with the United States Fish and Wildlife because the crossing sits in the Bayou Pierre Watershed, the only place on earth you find the threatened Bayou Darter (Etheostoma rubrum).

Erosion and high water for larger recurrence events created headcuts and steep riverbanks within the Bayou Pierre watershed which damaged Bayou Darter spawning habitat. These problems were compounded by decades of poor management decisions related to gravel mining and livestock raising along the river. This site, because of an existing ten-foot headcut at the outfall of the culvert, was selected for redesign and replacement including aquatic organism passage due to it being critical habitat for a threatened species and the individual needs of the species.

The project included several alternatives, but each had to meet clear design standards, pass the design recurrence events for MDOT with respect to required freeboard, resolve the head cut, and allow passage of the Bayou Darter during low flow events with respect to its biological limitations.

In this presentation we will walk through the partnership of the state and federal agencies, the design process and evaluation of the site, and show the final design with finished construction of the first step-pool fish passage in the Southeast.

Challenges in Meeting Local Community Floodplain Management Requirements for Fish Passage and Stream Restoration Projects
Presenters: Henry Hu and Julie Heilman

In 2013, a federal court injunction required Washington State to correct complete or partial fish barriers in Western Washington by removing state owned culverts that block access to spawning and rearing habitat for salmon and steelhead by 2030. There are approximately 1,000 culverts under state highways that are subject to the injunction. WSDOT must correct approximately 400 barriers by the year 2030 by replacing existing culverts with new crossings that restore access to habitat, allow for natural stream processes and to aid in the protection and restoration of fish populations.

In this presentation, we will present challenges and opportunities on the flood risk management aspect. WSDOT's fish passage and stream restoration projects essentially eliminate significant backwater under existing conditions due to undersized culverts. Another critical project component is to install channel complexity features to provide fish habitat. As a result, in some cases, flood inundation depths and extents increase in the vicinity of the project area even though the project does not alter the natural water course. The flood risk in these potentially affected areas is defined at a range of levels from unmapped by Federal Emergency Management Agency (FEMA) to a mapped floodway. Floodplain management requirements for local jurisdictions vary significantly, some of which are significantly beyond the typical FEMA National Flood Insurance Program requirements. We will present case studies to demonstrate challenges in obtaining local floodplain permits.

A GIS-based hydraulic modeling tool for Massachusetts stream crossing replacement projects in USGS StreamStats
Presenter: Gardner Bent

The U.S. Geological Survey (USGS), in cooperation with the Massachusetts Department of Environmental Protection and the University of Massachusetts at Amherst (UMass Amherst), have developed a GIS-based hydraulic modeling tool for Massachusetts stream crossing replacement projects. Many of the over 25,000 roadway stream crossings in Massachusetts are currently undersized, which can result in substantial impacts to aquatic organism passage, habitat connectivity, and the capacity to withstand floods. The USGS StreamStats web application provides preliminary culvert designs for conveying the 10-, 4-, 2-, and 1-percent annual exceedance probability (AEP) flood flows and to meet the Massachusetts Stream Crossing Standards (SCS) for a box, arch, and pipe culvert types.

The GIS-based hydraulic modeling tool uses automated scripts to create input data files for the U.S. Army Corps of Engineers HEC-RAS hydraulic modeling program. The automated scripts create the required cross-sections and stream profiles for HEC-RAS using elevations derived from lidar data. The elevations for the stream channel are determined using estimated bankfull channel geometry from regional regression equations. The cross-sections are cut using algorithms that determine inflection points in the stream channel elevation profile upstream and downstream of the existing culvert. The 10-, 4-, 2-, and 1-percent AEP flood flows are estimated using regional regression equations in StreamStats.

The StreamStats web application for the GIS-based hydraulic modeling tool allows the user to generate a report with information on the stream crossing location, North Atlantic Aquatic Connectivity Collaborative stream assessment data, Massachusetts Department of Transportation roadway classification and associated hydraulic design flow, UMass Amherst aquatic habitat quality and stream connectivity restoration potential, flood flows, bankfull channel geometry, elevations, preliminary culvert dimensions, and SCS data. Additionally, the user can download the HEC-RAS input and output files from StreamStats, which allows the user to customize data such as field survey data, flood flows, etc. and re-run the hydraulic model outside of StreamStats. This web application provides municipalities, engineers, water managers, and others a stream crossing planning tool that addresses improving flood resiliency and aquatic organism passage for replacement projects.

Coastal

A framework for evaluating pavement vulnerability to shallow groundwater rise in coastal Alabama.
Presenter: Bruno J.O. Sousa

Coastal areas are particularly vulnerable to sea level rise, which is the case of Fort Morgan Peninsula, AL. That coupled with the possibility of higher frequency of extreme rainfall events may overwhelm infrastructure such as roads and stormwater conveyance. Such is the case of AL-180, a road that crosses this peninsula in its full extension, connecting it via Ferry to Dolphin Island and serving as an evacuation route. However, most studies look at surface flooding or demand complex groundwater evaluations. High water tables may also impact pavements by saturating the subbase and subgrade and reducing their loading capacity. This research intends to produce an intuitive framework to evaluate the resilience of AL-180's pavement to elevated shallow groundwater levels (SGWL). The framework is based on accumulated rainfall, proximity to water bodies, tidal level fluctuations, drawdown characteristics, and the presence of nearby roadway drainage. The framework is supported by SGWL data monitored every 15 minutes in 3 locations from February 2023 to February 2024 with HOBO water level loggers with 1-centimeter accuracy. Then we separated the rainfall events in this period and investigated the relationship between rainfall depth and the rise in the SGWL. Preliminary findings show that there is a good fitting relationship between the depth of rainfall and the increase in the SGWL (R^2=0.89), explained by the high conductivity of sandy soils in the area. In addition to the proposed framework, data-derived SGWL exceedance probability curves from the whole period help to indicate the fraction of the time that SGWL can be damaging. The prevalence of such conditions will increase with a sea level rise, particularly for low-lying roads. This research can help guide policies and decision-making regarding coastal roadway management and the application of nature and nature-based features (NNBF) to control SGWL in other US coastal roads.

Innovative Culvert Hydraulics for Coastal Climate Resilience
Presenters: Timothy S. Mallette and Charlie Hebson

NH DOT collaborated with Maine DOT and experts from the Advanced Structures and Composites Center at the University of Maine for design, manufacture and rehabilitation of a failing culvert located on tidal fringe floodplain in Exeter NH. Alex Mann, C.G., President of Culvert Diffuser Systems (See TR 14-17 Outlet Diffusers to Increase Culvert Capacity) helped design the system, constructed in 2023. Alex Mann designed the diffuser based on proven geometry and low head performance testing of smaller diffusers constructed for Maine DOT. The 3D printing engineering project was led by Roberto Lopez-Anido, Ph.D., P.E. and Sunil Bhandari, Ph.D. from the Advanced Structures and Composites Center at the University of Maine. Material samples were placed on-site, both in submerged locations and exposed to direct sunlight at the time of construction. Testing and evaluation of the samples is planned in a few years.

Tim Mallette will present system hydraulics, why this site was selected, and permitting challenges specific to New Hampshire. Alex Mann will discuss the application of diffusers in general (how, when, where, why). Suitable site characteristics for diffuserswill be reviewed (slope, backwater, Right-of-Way space and outlet length). The geometry and intended upper size limit of Alex Mann's diffuser design will be discussed. Fiberglass vs. 3d printed material choices will be briefly reviewed.

Don LeBlanc, President of DL VEWS, Inc. based in Maine helped the team prior to design and during construction by CLH & Son, of Turner Maine. Don is a culvert rehabilitation expert who services the Northeast states and parts of Canada. Rumor has it he will make a cameo appearance for the Q&A period.

The design of the culvert diffuser model for additive manufacturing using a large format 3D printer including the thermoplastic composite material selection criteria, segmental manufacturing, postprocessing steps for cutting, finishing, and joining the 3D printed segments, and cost analysis will be presented. This information will be prepared by Dr. Lopez-Anido and Dr. Sunil Bhandari from UMaine.

Funding for the 3D printing engineering project was provided by the Transportation Infrastructure Durability Center (TIDC) at the University of Maine under grant 69A3551847101 from the U.S. Department of Transportation's University Transportation Centers Program.

This presentation will review the site characteristics, an overview of the culvert diffuser system design (including 3d manufacturing and design) as well as review of the environmental concerns and adaptations made to accommodate those concerns.

Sea Level Rise Adaption in SCDOT's Coastal Design
Presenters: Roberto G. Ruiz and Mark Gosselin

Sea Level Rise (SLR) poses significant challenges to transportation infrastructure worldwide. As water elevations in coastal communities continue to rise, roads, bridges and causeways become increasingly vulnerable to inundation, erosion, and storm surge events, leading to disruptions in mobility, economic activities, and societal well-being. Many governmental agencies have offered a range of SLR scenarios that represent projections of SLR through the year 2100. In an effort to incorporate those scenarios and create an effective policy required to build resilient infrastructure, the South Carolina Department of Transportation and INTERA, Inc. are utilizing innovative engineering solutions, creating tools designed to build resilient structures capable of withstanding the challenges posed by SLR while utilizing fiscally responsible principles. This presentation summarizes the SLR hazards that South Carolina faces along with the methodology and approaches proposed to mitigate risk to state highways and bridges.

Using Cumulative Celerity to Predict Damage and Mitigate Risks for Coastal
Presenter: Garland Pennison

A model that predicts the likelihood of system failure during extreme events provides the opportunity to reduce risk and improve coastal highway resilience. A resilient transportation system is a priority for Federal Highway Administration (FHWA) and U.S. Department of Transportation (DOT) climate change adaptation policies. Coastal highway adaptation involves optimizing ability of engineered systems to protect against impacts caused by changes in climate and extreme weather events (Douglass, Webb et al. 2014). Coast highways that parallel coastlines are at greater risk due to increased exposure to extreme storms, climate change, and relative sea level rise.
Cumulative celerity dispersion (CCD) functions were found to predict the likelihood of damage to coastal highways when triggered by extreme tropical storm forces. Research is ongoing to better understand the underlying damage mechanics. CCD functions were found to predict when limit states for damage are likely to be exceeded and the probable processes that cause significant roadway damage and catastrophic failures.

Climate

Programmatic Discussion of FHWA's Floodplain Program
Presenter: Susan Jones

In an era where we need sustainable solutions for a dynamic future, flooding and floodplains continues to be an ongoing transportation issue. How did we get where we are and what are those future solutions? This presentation seeks to provide context and pose challenges. Any actions in base floodplains must comply not with Floodplain Management EO 11988, but with FHWA's 23 CFR 650 Subpart A. EO 11988 directs the federal agencies to develop management policies to: reduce flooding; minimize impact of flooding; and restore or preserve floodplain values. The USDOT complied with EO 11988 by issuing DOT Order 5650.2 which set policy for all DOT modes, after which, FHWA then updated its floodplain regulation in 1979. Although FHWA's floodplain regulation has not been updated since then, its applicability still holds true for Federal-aid highway actions. This regulation is applicable to all actions which affect base floodplains and all encroachments. The presentation will discuss briefly how some terminology used in EO is not cited in 23 CFR 650 Subpart A as well as the use of significant encroachment versus critical action. This presentation will then go through the requirements for 23 CFR 650.111 Location Hydraulic Studies. EO 14030 reinstated EO 13690, reestablishing Federal Flood Risk Management Standard (FFRMS). FFRMS takes into account changing flood hazards due to climate change, redefining the base floodplain using one of three approaches to determine the vertical flood elevation and the corresponding horizontal extent of the floodplain. We will discuss what USDOT has done to implement EO 11988 as amended by EO 13690.

Climate change altering geomorphic processes in New England
Presenter: Nicole Buck

Climate change is driving the need for application of geomorphic principles to evaluate and mitigate impacts on transportation infrastructure. As an example, extreme precipitation events in the Northeast have caused increased sediment loads in some rivers and streams, decreasing the hydraulic capacity of channels and increasing flooding extent during high flow events. In such locations, assessing sediment flux is becoming nearly as important as determining the impact of flood flows on infrastructure. Increased sediment yield is now occurring on historically stable alluvial fan systems. Throughout the humid Northeast, these alluvial fans are hidden by vegetation and have appeared stable for centuries, so the apparently sudden change is surprising and alarming. In this presentation, impacts to transportation and other infrastructure are discussed for several alluvial fans. Mitigation strategies, such as sediment traps were proposed for two systems to shift impacts to locations that are easier to access for material management. These proposed sediment traps are designed to create miniature alluvial fans, able to store material from several storms, thus reducing the need to respond after every storm event. For each system, sediment transport and deposition characteristics were modeled in SMS SRH2D. For one system, SMS SRH2D sediment transport simulations helped determine that creating a space for sediment storage would likely decrease deposition in developed areas, maintaining hydraulic capacity near transportation infrastructure. Other mountainous portions of the U.S. are facing similar challenges. This presentation illustrates the value of considering infrastructure as part of a larger system, particularly as climate change alters geomorphic processes.

NCDOT Interstate 95 Flood Resiliency
Presenters: Tyler Longberry and David Markwood

Interstate 95 in North Carolina is a critical transportation corridor that has experienced major flood events, such as Hurricane Matthew (October 2016) and Hurricane Florence (September 2018), that inundated portions of I-95 for extended durations. NCDOT is continuing to upgrade the transportation assets with consideration of future flood resiliency. Advancements to the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) and River Analysis System (HEC-RAS) software provide capabilities for utilizing spatially varied rainfall over a 2-dimensional (2D) mesh for evaluating flood impacts and flood resiliency of transportation infrastructure.

HEC-RAS 2D models of the Lumber River and Big Swamp watersheds were developed to analyze the flood resiliency of improvements to I-95 from mile marker 13 in Lumberton north to mile marker 40 in Cumberland County. MRMS QPE gridded products for Hurricanes Matthew and Florence were used for calibration and validation of the watershed models. Simulated future hurricanes and future Atlas 14 gridded rainfall were applied to the watershed models to "stress test" the flood resiliency of the system in the future, incorporating the effects of climate change.

Climate and weather modeling experts at North Carolina State University (NCSU - Katy Hollinger, Dr. Gary Lackmann, Dr. Jared Bowden) simulated versions of observed Matthew and Florence events, using Weather Research and Forecasting (WRF) modeling. The NCSU team developed simulated future hurricane rainfall products for Matthew and Florence using 2050 and end of century time horizons, assuming a Representative Concentration Pathway (RCP) of 8.5 watts per square meter due to increased carbon concentrations—a "high-emissions" scenario. Simulated observed hurricane events were compared with NOAA's Multi-Radar/Multi-Sensor Quantitative Precipitation Estimate (MRMS QPE) gridded products for Hurricanes Matthew and Florence. Ratios of recurrence interval rainfall to future rainfall were also developed, regionally and on a countywide basis. These ratios were applied to Atlas 14 GIS products to produce recurrence interval rainfall that incorporates the effects of climate change.

The modeling results identify the potential impacts of current and future flooding events. The stress test of proposed roadway profiles and hydraulic structures allows for resilient planning to improve any flooding hotspots or deficient areas in proposed design. The stress test provides a better understanding of vulnerability that enhances operational forecasting, resource allocation, and event response.

New Inland Flooding Design Standards and Procedures for Resilience and Sustainability in the Face of Climate Change
Presenter: Roger Kilgore

Existing design standards and procedures may fall short in our goal of creating transportation infrastructure that is resilient and sustainable with changing climate. Assumptions based on the past can be misleading when applied to the future. This presentation describes the proposed new design standards and procedures for designing roads and bridges to withstand inland flooding that enhance resilience to changes in climate. This research and development effort is part of the National Cooperative Highway Research Program (NCHRP) dedicated to applied research (Project NCHRP 15-80).

Historically, inland flooding has been a significant consideration in the design of roadways and potential changes in climate may increase these stresses. Stressor characteristics include the nature and degree of the stressor, e.g., a flood with a peak flow of a certain amount. A stressor can be described using a target stressor, e.g., the 0.01 annual exceedance probability (AEP) flood, or a small number of target stressors. Alternatively, a stressor can be described using a range of characteristics for more detailed analyses. Specific assets of interest for this design flow process are bridges, culvert stream crossings, stormwater collection, and stormwater detention and retention.

The presentation describes a new risk screening methodology that leads to recommendations for the level of analysis appropriate for specific road and bridge projects including when and to what degree future climate should be considered. The risk screening considers criticality, exposure, equity, and other factors that can be customized by transportation agencies. Not all projects are exposed in the same way and, therefore, many more routine types of projects will not demand intensive analysis. Conversely, some projects will benefit significantly from comprehensive analysis of risks and how a changing climate might affect those risks.

The presentation will also describe proposed new standards for design that depend on the type of project and degree of climate risk. These new standards are based on taking the current AEP flood standards and providing multiple options for appropriate standards that consider the uncertainty related to climate change and the risk of flooding over the project lifetime. The proposed standards are simplified so that they can be easily integrated into the design process.