



Modern Advances in Hydrologic and Hydraulic Studies

ASHE Meeting - February 2011

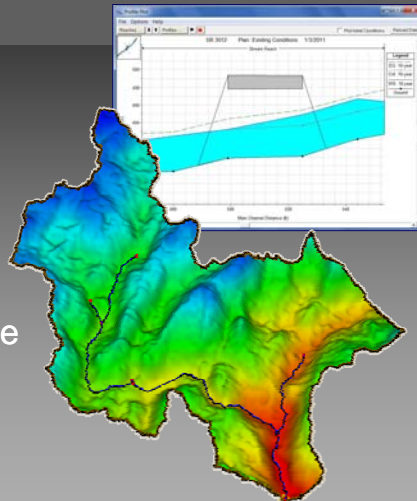
Rachel L. Tereska, PE
NTM Engineering, Inc.

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Agenda

- Hydrologic modeling
- Hydraulic modeling
- 2D project applications
 - CSVT
 - Little Juniata River Bridge

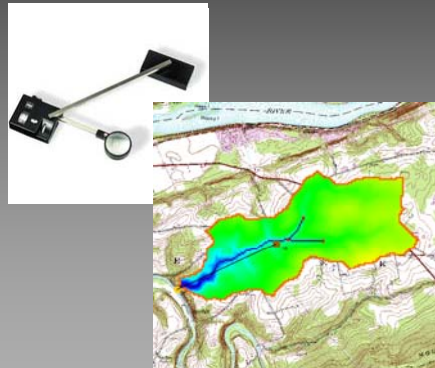


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Hydrologic Modeling

- USGS Regression methods
 - WRIR 00-4189
 - SIR 08-5102 - **update**
- Latest technology
 - NSS & StreamStats
 - WMS
 - HEC-HMS

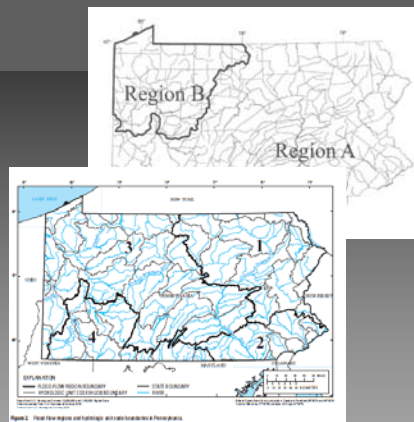


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USGS Regression

- WRIR 00-4189
 - Gage data through 1997
 - Two regions
- SIR 08-5102
 - Gage data through 2006
 - Four regions
- PennDOT evaluated both methods
 - Guidance will be issued in PDM and SOL for DM-2 Chapter 10

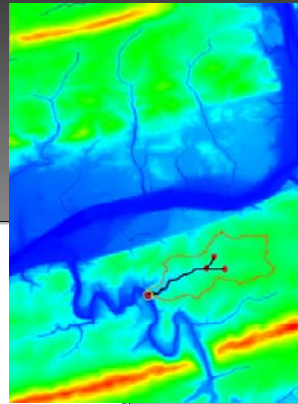
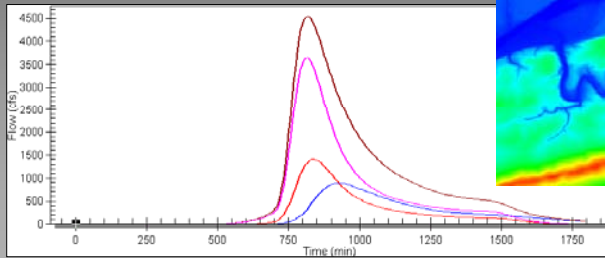


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Hydrologic Modeling

- Latest technology
 - NSS & StreamStats
 - WMS
 - HEC-HMS

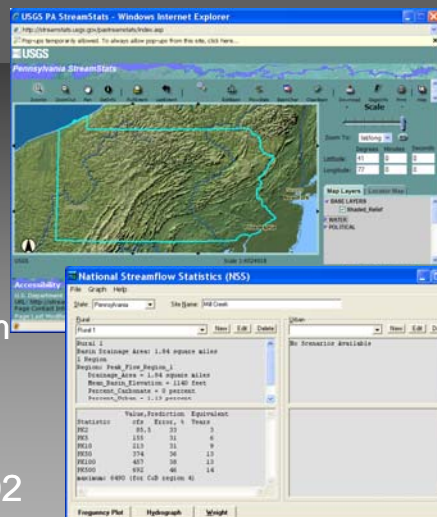


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NSS & StreamStats


- NSS – National Streamflow Statistics Program
- StreamStats
 - Web-based GIS system
 - Watershed delineation
 - Flow estimates
- Uses USGS SIR 08-5102 equations




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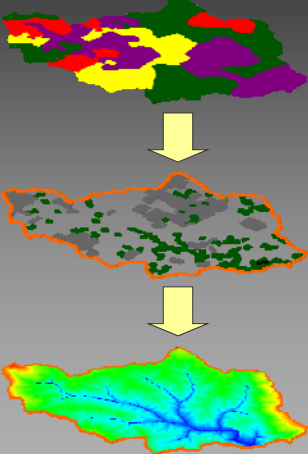


WMS







- Hydrologic model
 - Automated watershed delineation
 - Compute geometric parameters
 - Compute hydrologic variables
 - Run hydrologic model
- GIS data processor




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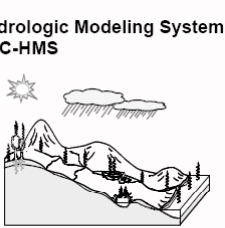


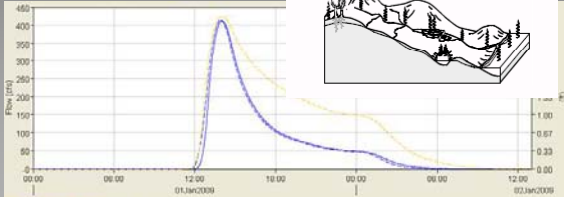
HEC-HMS






- Windows-based hydrologic simulation model
- Incorporates advances in precipitation input and soil moisture methods
- Applicable to wide range of watersheds
 - Size/complexity
 - Land use
- GeoHMS → GIS





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Hydrologic Software Information

- NSS – USGS
 - water.usgs.gov/osw/programs/nss/summary
- StreamStats – USGS
 - water.usgs.gov/osw/streamstats/pennsylvania
- WMS 
 - www.aquaveo.com/wms
- HEC-HMS – US Army Corps of Engineers 
 - www.hec.usace.army.mil/software/hec-hms

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Hydraulic Modeling


- HEC-2 – no longer supported
- HEC-RAS
 - Continually updated
 - New features
- SMS
 - State-of-the-art software
 - Interfaces with many programs



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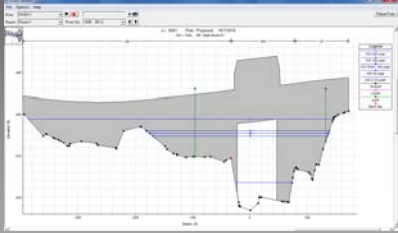


HEC-RAS




**US Army Corps
of Engineers**


- One-dimensional step-backwater program
- Steady and unsteady flow
- Bridges, culverts, dams, weirs
- National standard for hydraulic modeling
- Used to model almost ALL of PennDOT's bridge replacement projects



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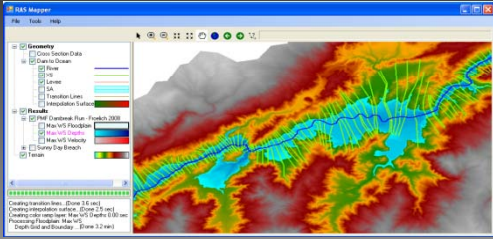


HEC-RAS v4.1 New Features




**US Army Corps
of Engineers**

1. New RAS Mapper Floodplain Delineation
2. Additional Unsteady Flow options
3. Groundwater Leakage for Storage Area
4. Water Quality Modeling Enhancements
5. Sediment Transport Modeling Enhancements

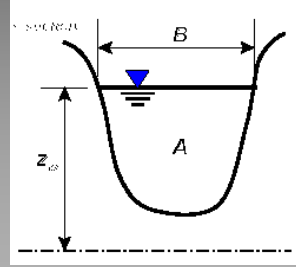
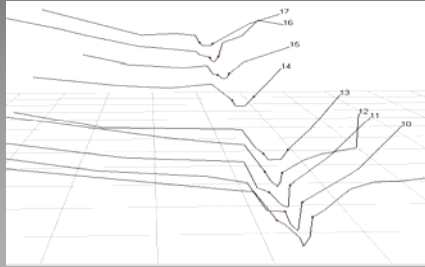


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1D HEC-RAS Assumptions

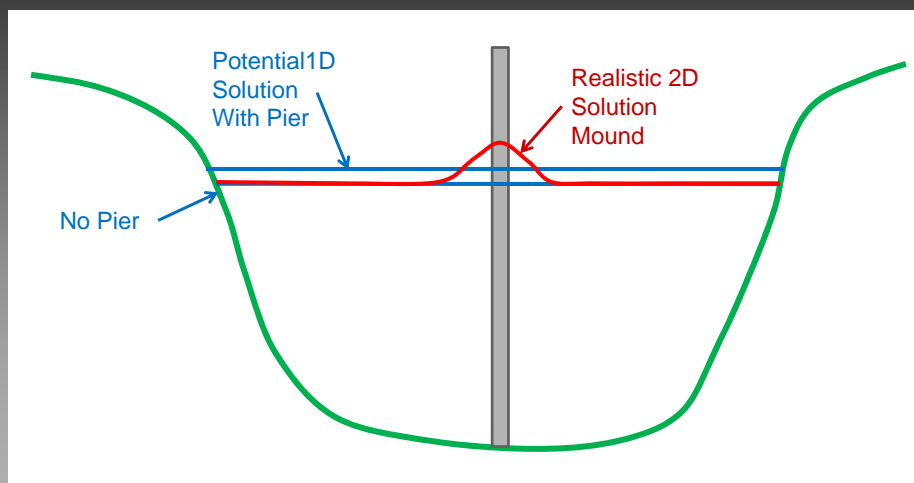
- Cross sections perpendicular to flow direction
- Single water surface elevation at each section
- Flow (velocities) in one direction



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1D HEC-RAS Limitations

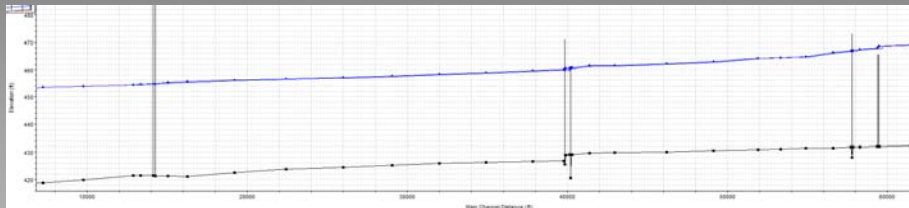


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1D HEC-RAS Limitations

- Increases are averaged across the section
 - Does not reflect localized impacts
 - Applies the increase over a much larger area
- Increases propagate farther upstream



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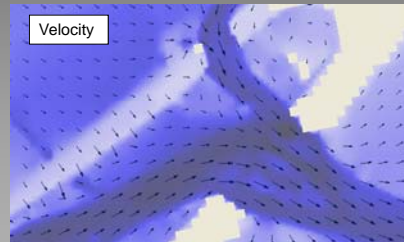


SMS (Surface-water Modeling System)

AQUAVEO™



- One-, two-, and three-dimensional hydrodynamic modeling
- Primary application to compute water surface elevations and flow velocities



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TUFLOW

- 2D and 1D solutions of the free-surface flow equations
- Finite difference model
- Models all flow regimes and is very stable
- Approved for use by PennDOT in Sept 2010
 - SOL 432-10-03
- Submitted for FEMA Certification

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2D Modeling Applications

- Beneficial where complex 2D flow patterns would be difficult to represent using traditional 1D network models
- Consider 2D model when:
 - Structure on channel bend
 - Structure near confluence
 - Multiple structures on wide floodplains
 - Flooding impacts need to be more accurately defined

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Central Susquehanna Valley Transportation (CSVT) Project

- New bridge crossing over WB Susquehanna River (WBSR)
 - Alternatives Analysis
 - Piers as only impact to 100-year floodplain
- FEMA floodway and potential map revision

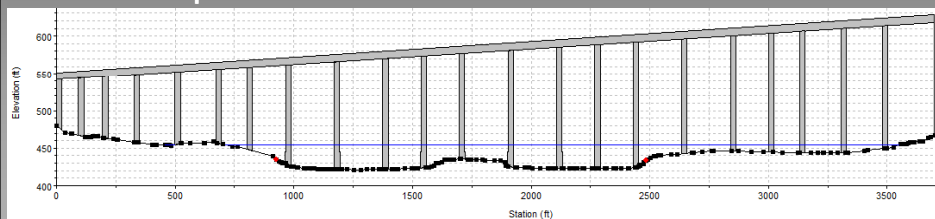


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CSVT - 1D HEC-RAS Model

- Increases applied to entire floodplain width
 - 100-year floodplain - 2,800 feet wide
 - Any increase in 100-year WSE → CLOMR
- Minor increases traveling far upstream due to flat slope of the river



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Pier Impacts to WSE

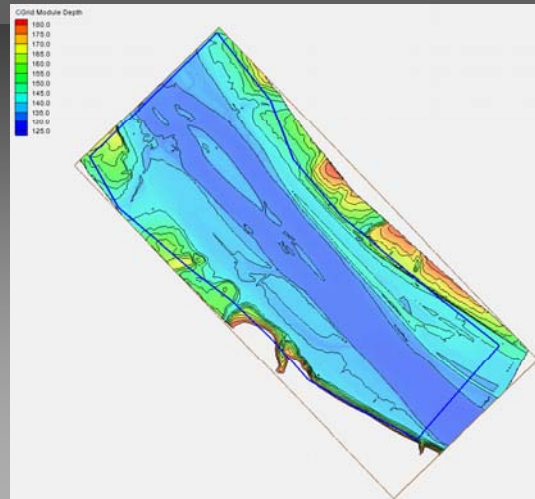
- Recent lab experiments performed by Center for Transportation Research
- *Backwater Effects of Piers in Subcritical Flow* (R. Charbeneau and E. Holley, 2001)
 - 2D mound forms upstream of piers
 - 2D effects are local and are dissipated within an upstream distance equal to channel width
 - WSEL changes are less than those calculated using Yarnell's equation

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CSVT - 2D TUFLOW Model

- WBSR
- 5-meter grid
- Study reach - 1 mile wide & 3.5 miles long
- Proposed bridge alternatives

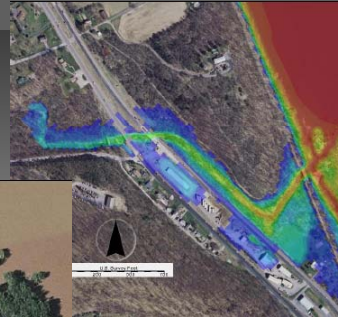


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CSVT - TUFLOW Calibration

- 2004 Ivan Flood
- Gage record
- Aerial photos
- 2D results



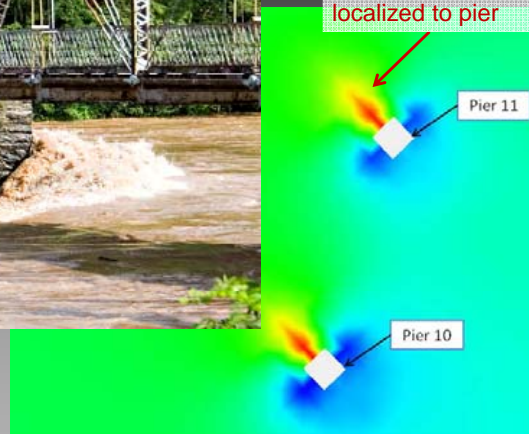
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CSVT - Pier Impacts



Higher WSEL
increase ~0.6 feet
localized to pier

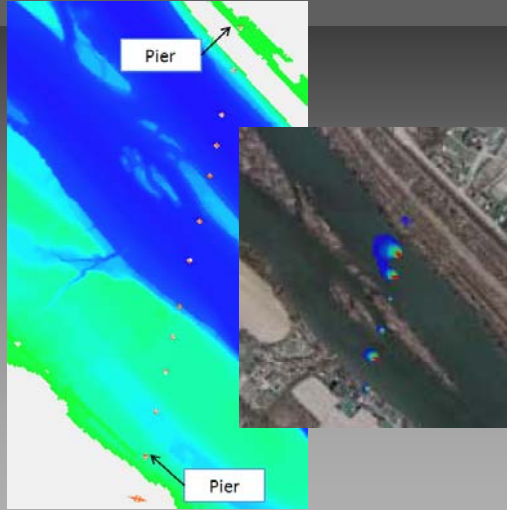


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CSV T - Pier Impacts

- Alternatives analysis to minimize impact
 - Number of piers
 - Width of pier
 - Spacing between piers
 - Pier locations in channel



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CSV T - 2D Model Benefits

- Key consideration in the alternatives analysis
- Indicated more realistic impacts versus the 1D HEC-RAS solution, which showed the increase across the entire channel
- More accurately evaluate pier configurations to determine the design that minimized impacts to the floodplain and adjacent properties
- Allow more accurate assessment of impacted areas for ROW purchase

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SR 1001 Over Little Juniata River

- 3-span bridge replacement over Little Juniata River
 - 100-year event passes under bridge
 - No overtopping
- Tipton Run tributary
- FEMA floodway



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Little Juniata River - 1D Limitations

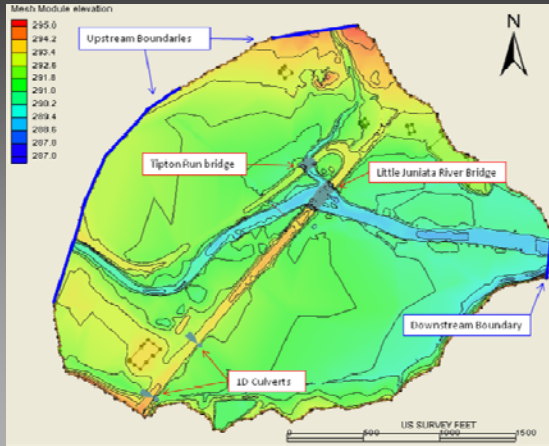
- Complex 2D flow characteristics at structure
 - Severe skew angle of the Little Juniata River to the bridge
 - Tributary confluence at the upstream bridge face
 - Multiple roadways in the floodplain



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Little Juniata River - 2D TUFLOW Model

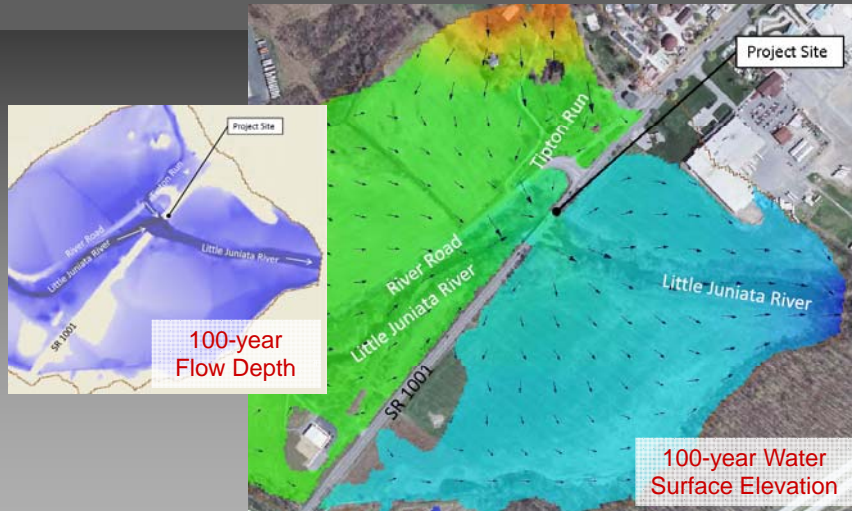


- LJ River
- Tipton Run
- 2000' wide floodplain
- SR 1001 and Tipton Run bridges
- Relief culverts

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Little Juniata River - Confluence



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Little Juniata River - Pier Impacts

- Proposed decreases in water surface elevation
 - Narrower piers
 - Larger hydraulic opening



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Little Juniata River - 2D Model Benefits

- Reflects the confluence location for different flood events
- Accounts for the 2D flow direction and velocities under the bridge
- Defines localized decreases due to larger hydraulic opening
- Did not require a FEMA map revision

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Hydraulic Software Information

- HEC-RAS – Army Corps of Engineers 
 - www.hec.usace.army.mil/software/hec-ras

- SMS 
 - www.aquaveo.com/sms

- TUFLOW
 - www.tuflow.com

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Continuing Education

- NTM Training
 - Introduction to HEC-RAS
 - www.ntmtraining.com

- PennDOT H&H Professional Development Series
 - WMS
 - HEC-RAS



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Thank you!

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