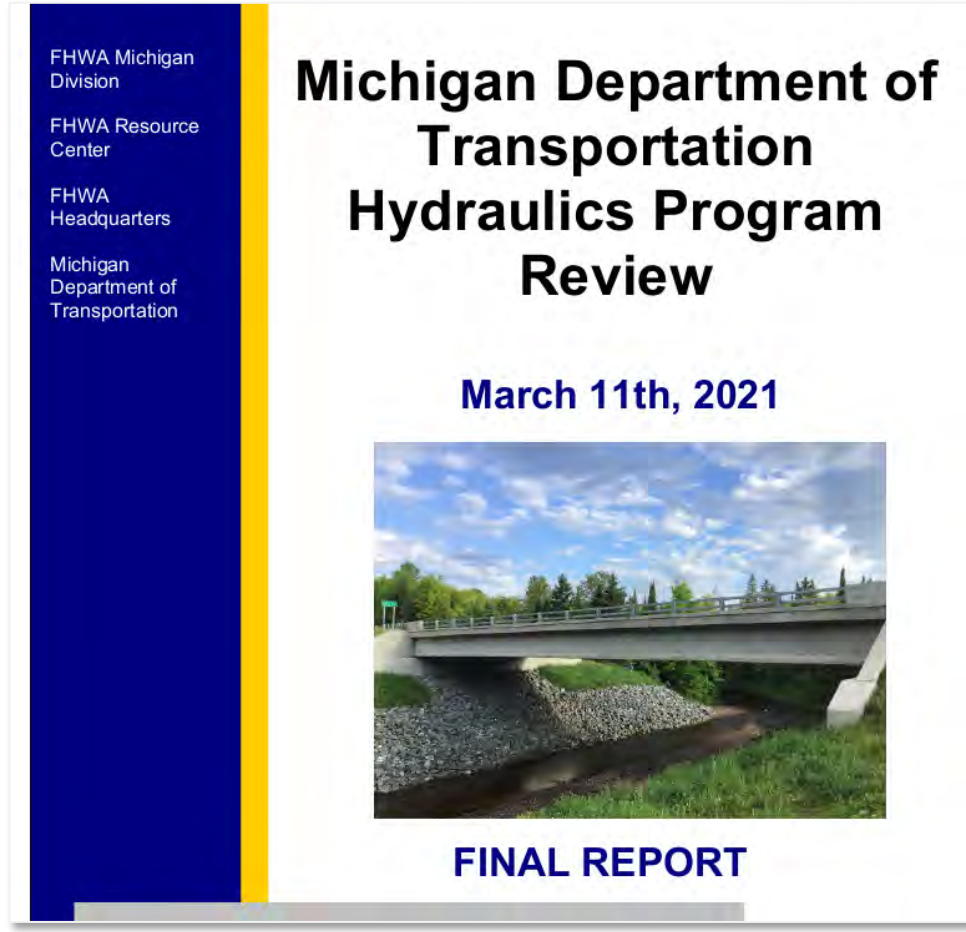
FHWA Hydraulic Program Review

ACEC Conference

February 2, 2023



FHWA Hydraulic Program Review
Key Staff

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FHWA Hydraulic Program Review

Review from FHWA Resource center staff and Michigan Division office

Sample plans and calculations provided in December 2020

Interviews complete in January 2021

- Various MDOT and EGLE staff

Final report March 2021

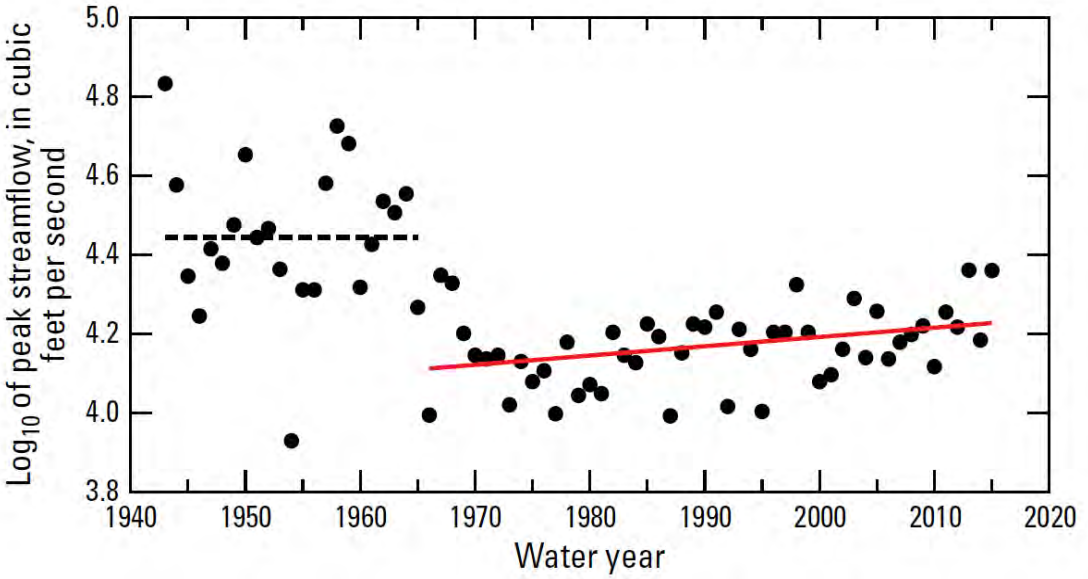
15 observations and recommendations

FHWA Hydraulic Program Review

Program Manager Consultant (PMC) added in Fall 2022 to help address findings and with Drainage Manual Updates

On-going Research Projects

- MTU – Update of Michigan Hydrologic Procedures
- Pooled Fund
  - Non-stationarity with USGS gages
  - CFD modeling for efficiency of storm sewer grates



FHWA Hydraulic Program Review

Observation 1 – Design standards in MDOT Drainage Manual

- No design standards or definition for “temporary” drainage assets
- Standards for Federally funded LAP projects?
- Look at risk-based design standards – HEC-17

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AASHTO Drainage Manual (2014):

Table 9-1. Design Storm Selection Guidelines

Roadway Classification	Exceedence Probability (%)	Return Period (Year)
Interstate, Freeways (Urban/Rural)[a]	2%	50
Principal Arterial	2%	50
Minor Arterial System with ADT >3,000 VPD	2%	50
Minor Arterial System with ADT = <3,000 VPD	4%	25
Collector System with ADT >3,000 VPD	4%	25
Collector System with ADT = <3,000 VPD	10%	10
Local Road System[b]	20%–10%	5–10

[a] Federal regulation requires Interstate highways to be provided with protection from the two percent flood event. Underpasses and depressed roadways should also be designed to accommodate the two percent flood. Where no embankment overflow relief is available, drainage structures should be designed for at least the one percent or 100-yr event.

[b] At the discretion of the designer, based on Risk Analysis and Design Hourly Volume (DHV).

FHWA's HEC-17 (2016):

Table 6.1. Design event selection guidelines.

Roadway Classification*	Exceedance Probability (percent)	Return Period (years)
Interstate, Freeways (Urban/Rural)	2%	50
Principal Arterial	2%	50
Minor Arterial System, ADT>3000 VPD	2%	50
Minor Arterial System, ADT=<3000 VPD	4%	25
Collector System with ADT>3000 VPD	4%	25
Collector System with ADT=<3000 VPD	10%	10
Local Road System	20%-10%	5-10

*Average Daily Traffic (ADT): Vehicles per Day (VPD)

FHWA's HEC-18 (2011):

Table 2.1. Hydraulic Design, Scour Design, and Scour Design Check Flood Frequencies.

Hydraulic Design Flood Frequency, Q_D	Scour Design Flood Frequency, Q_S	Scour Design Check Flood Frequency, Q_C
Q_{10}	Q_{25}	Q_{50}
Q_{25}	Q_{50}	Q_{100}
Q_{50}	Q_{100}	Q_{200}
Q_{100}	Q_{200}	Q_{500}

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	Bridges						Culverts[g]		
	Overtopping	Freeboard (where practical)[f]	Backwater[c]	Scour Design	Scour Check	Countermeasure	Design	Harmful Interference	Backwater[c]
Interstate, Freeways (Urban/Rural)	50[a]	50[a]	100	100[d]	500	100	50	100	100
Principal Arterial	50	50	100	100	500	100	50	100	100
Minor Arterial System with ADT>3000 VPD	50	50	100	100	500	100	50	100	100
Minor Arterial System with ADT<3000 VPD	50	50	100	100	500	100	50	100	100
Minor Arterial System with ADT<3000 VPD, non-MDOT	25	25	100	100	500[e]	100	25	100	100
Collector System with ADT>3000 VPD	25	25	100	100	500[e]	100	25	100	100
Collector System with ADT<3000 VPD	10	10	100	100	500[e]	100	10	100	100
Local Road System[b]	10	10	100	100	500[e]	100	10	100	100
Pedestrian crossings[b]	10	10	100	100	500[e]	100	10	100	100

	Pipe Sizing		Spread, On Grade		Spread, Sag	
	Return Period	Min. tc (min)	Design Return	Max	Design Return	Max
Interstate, Freeways (Urban/Rural)	10	15	10	Shoulder	50	Shoulder[g]
Depressed Interstate, Freeway	50	10	50	Shoulder	50	Shoulder[g]
MDOT owned with pump station at outlet	50	10	50	Shoulder[g]	50	Shoulder[g]
Principal Arterial	10	15	10	Shoulder[g]	50	Shoulder[g]
Minor Arterial System with ADT>3000 VPD	10	15	10	Shoulder[g]	50	Shoulder[g]
Minor Arterial System with ADT<3000 VPD	10	15	10	Shoulder[g]	50	Shoulder[g]
Minor Arterial System with ADT<3000 VPD, non-MDOT	10	15	10	Shoulder[gh]	50	Shoulder[gh]
Collector System with ADT>3000 VPD	10	15	10	Shoulder[gh]	10	1/2 driving lane
Collector System with ADT<3000 VPD	10	15	10	Shoulder[gh]	10	1/2 driving lane
Local Road System[f]	5 - 10	15	5 - 10	1/2 driving lane	5 - 10	1/2 driving lane

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Observation 2 – Outdated Rainfall Data Use

- "Computing Flood Discharges for Small Ungaged Watersheds" (Sorrell) utilizes outdates rainfall (Bulletin 71 vs. Atlas 14)
- Joint research project between MDOT & EGLE to update.
  - MTU kickoff in November 2021

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Observation 2 – Outdated Rainfall Data Use

- MDOT to adopt Atlas 14 for rainfall tables
  - Will go live in October 2023
  - No longer will have 10 climate zones
  - Point precipitation downloaded in CSV format from NOAA website
  - May break this data down to County or Town/Range (1,240 townships)
  - Should be able to plug data into ORD Drainage & Utilities

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Observation 3 – MDOT staff unaware of Hydrologic Policies

- 23 CFR 650.115
  - 50 year (2%) min. for Interstates
- P.A. 451 of 1994
  - Part 31
- Executive Orders
  - State EO 1977-4, updated with EO 2001-5
    - State Flood Hazard Mitigation Plan
      - Establishes 100 year (1%) as baseline for hazard protections
      - 5-year plan (current 2019-2024)

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Observation 3 – MDOT staff unaware of Hydrologic Policies

- Executive Orders
  - Federal EO 11988
    - Established the National Flood Insurance Program
  - Federal EO 13690
    - Federal Flood Risk Management Standard
  - FHWA Task Order 5520
    - Preparedness/Resilience to Extreme Weather

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Observation 4 – Timeframes when Hydraulic Unit is brought into Design Process

- Seeking input in scoping process/call for projects
  - Early input for culvert call

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Observation 5 – Hydraulic and Scour Reports

- Recommendations to combine
  - Still need to be separate for Part 31 review
- Review of LAP hydraulic reports missing critical information:
  - Location, topography, road classification, modeling assumptions
- LAP scour
  - Missing references to scour equations and pertinent information from calculations

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Observation 6 – Information on Bridge sheets

- Proposed updates to the Hydraulic and Scour summary tables in 5D and 6B in the Drainage Manual.

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LOCATION	
STRUCTURE NUMBER	
CONTROL SECTION	
JOB NUMBER	
LOCATION	
WATERCOURSE	
TOWNSHIP	
COUNTY	
DISCHARGE	
10-YEAR	
50–YEAR	
100-YEAR	
ADDITIONAL INFORMATION	
DRAINAGE AREA	
METHOD OF ANALYSIS	

Stream: **County:**	**EXISTING (ft)**	**PROPOSED (ft)**	**CHANGE**
CULVERT TYPE			
SPAN			
RISE			
LENGTH			
ENTRANCE TYPE			
U/S INVERT ELEV			
D/S INVERT ELEV			
U/S FLOWLINE			
D/S FLOWLINE			
K_e:	0.5	0.5	
50-YEAR			
VELOCITY AT OUTLET			
HEADWATER			
100-YEAR			
VELOCITY AT OUTLET			
HEADWATER			
50-YR AND 100-YEAR FLOOD ELEVATIONS ARE FOR COMPARISON ONLY			
Note:			

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SUMMARY OF HYDRAULIC ANALYSIS							
EXISTING				PROPOSED			
FLOOD DATA	DISCHARGE (CFS)	WATER SURFACE ELEV. AT U/S FACE OF STRUCTURE (FT)	VELOCITY AT D/S FACE (FT/S)	WATER SURFACE ELEV. AT U/S FACE OF STRUCTURE (FT)	VELOCITY AT D/S FACE (FT/S)	WATERWAY AREA AT D/S FACE (SQ.FT)	CHANGE IN WSEL FROM U/S FACE OF PROPOSED STRUCTURE (FT)
10-YEAR							
50-YEAR							
100-YEAR							
500-YEAR							
PROPOSED BRIDGE AREA BELOW LOW CHORD IS **xxx** SQUARE FEET							

SUMMARY OF SCOUR ANALYSIS						
FLOOD DATA		ABUT. A ELEVATION (FT.)	ABUT. B ELEVATION (FT.)	PIER 1 ELEVATION (FT.)	PIER 2 ELEVATION (FT.)	PIER 3 ELEVATION (FT.)
100-YEAR	DESIGN					
500-YEAR	CHECK					
	OVERTOP					
ITEM 113 RATING -						

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Observation 7 – Bridge Foundation Design Process

- Drainage Manual 6D updated with comments from BOBS
- Will have Drainage PMC review before publishing

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Observation 8 – Scour Calculations Quality Assurance

- Concerns on who is performing QAQC on Federally funded LAP projects.
  - LAP QA contract
  - Hydraulic PMC contract as backup

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Observation 9 – 2D Hydraulic Models

- Recommend more use of 2D hydraulic models
  - Drainage Manual to include more language of 2D modeling
    - Becoming standard for scour modeling for multispan structures
    - Links to HDS-7 and “Two-Dimensional Hydraulic Modeling for Highways in the River Environment” in the Drainage Manual

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Observation 10 – Scour Plan of Action (POA) Reports

- Risk based approach for prioritizing POA's
  - POA breakout group
  - MDOT's Vulnerability & Criticality spreadsheet

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Observation 11 – Not clear on who is responsible for ownership of POA's

- Drainage Manual 6D updates
- SI&A updates

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Observation 12 – Recoding of NBIS Item 113 after mitigation

Observation 13 – Installation of countermeasures that do not meet HEC-23 guidance

- Survey of Midwestern States
- Softened language on requirements for Item 113 = 7
- POA's required for LAP owned bridges for Item 113 = 7
- Updates included in SI&A manual

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- Observation 14 & 15 – Training
  - Recommend additional training in hydraulics/hydrology in MDOT and LAP staff
  - Training of Road Design Staff
    - Unclear if road design engineers understand the concepts of roadway hydraulic calculation. Road designers see value in more frequent training.
      - Design Basic Training – MDOT wiki
      - NHI Training
  - Software
    - Staff not utilizing free FHWA software. Staff utilizing spreadsheets for storm sewer design.
      - ORD updates
      - Hydraulic toolbox
      - HY-8

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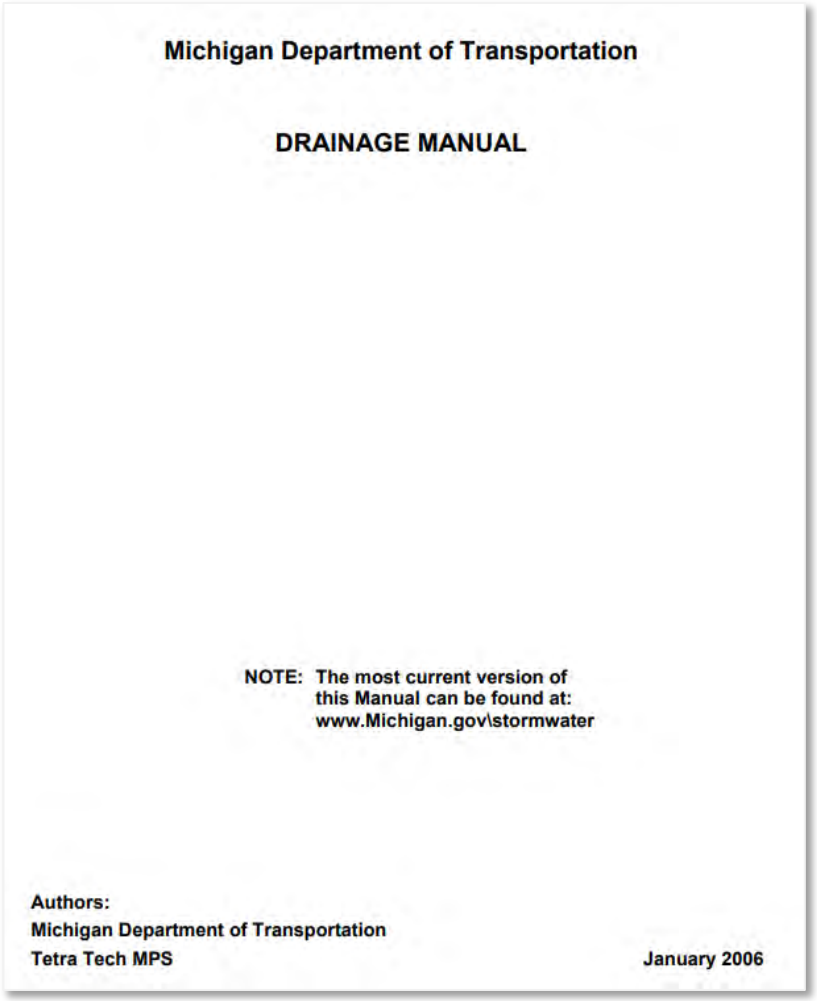
Drainage Manual Update

Drainage Manual Contributors / Partners

1. MDOT (Including LAP)
2. FHWA
3. EGLE
4. Research
   - Michigan Tech
   - USGS
5. PMC Team
   - Wade Trim
   - Spicer Group
   - Great Lakes Engineering Group
   - GeoTran Consultants

Drainage Manual Update


Michigan Department of Transportation

DRAINAGE MANUAL

NOTE: The most current version of this Manual can be found at: www.Michigan.gov\stormwater

Authors:
Michigan Department of Transportation
Tetra Tech MPS

January 2006

Current Drainage Manual published in 2006

- Focused on MDOT trunkline

Entire manual is being reviewed and updated

- FHWA, MDOT comments, hydraulic circulars, other DOT manuals, research

Stakeholder input

- Local Agency Program Unit, Office of Rail

New topics / chapters

- Drainage report outlines
- Master glossary
- Advanced hydraulics
- Coastal chapter

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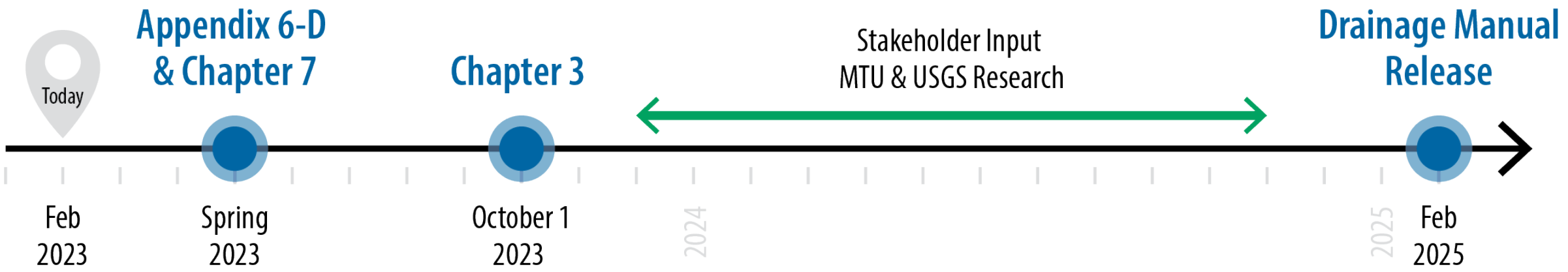
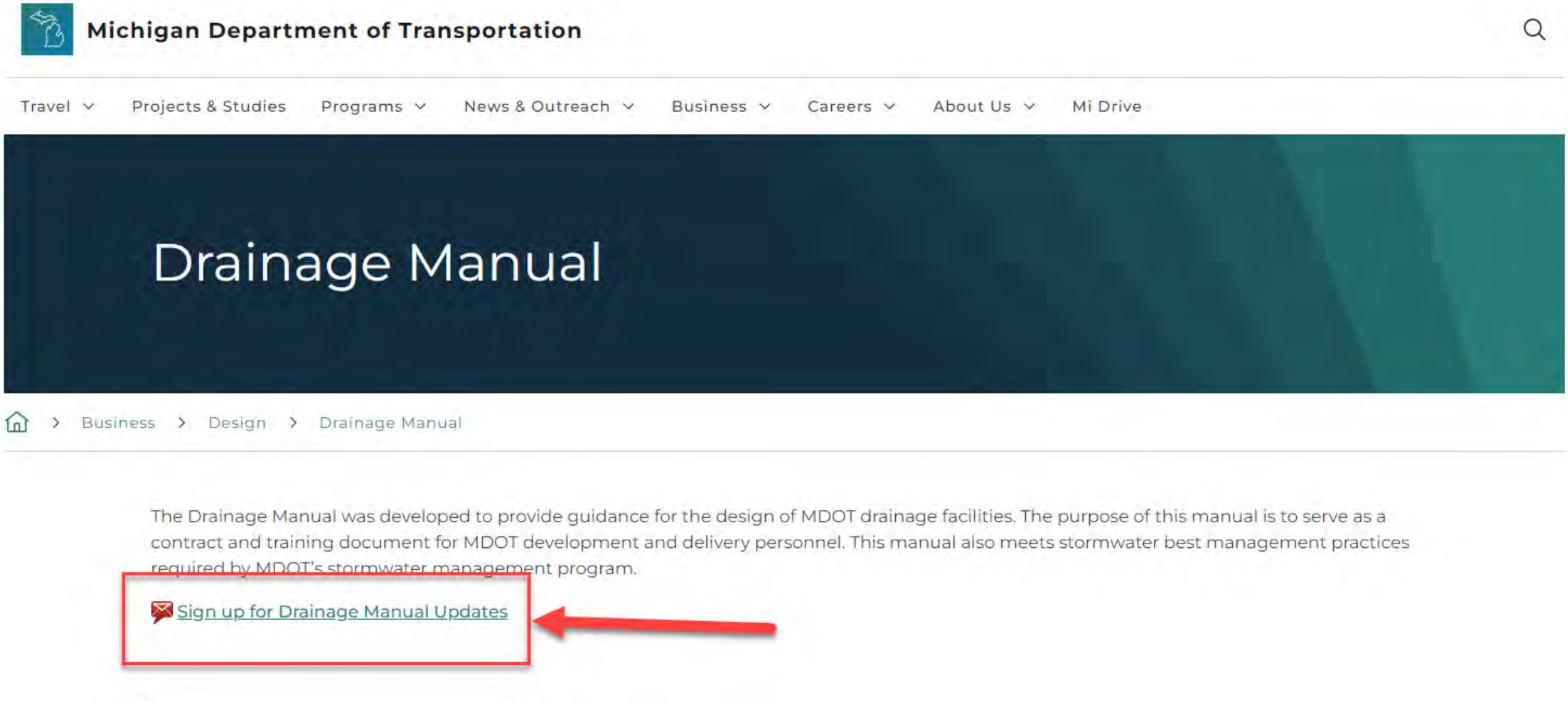
Drainage Manual Update



Drainage Manual Update



Advanced Hydraulics Updates and Additions

1. Hydrology
2. Tunnel Hydraulics
3. Computational Fluid Dynamic Modeling (CFD)
4. 2-Dimensional Modeling
5. Coastal Engineering

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Advanced Hydraulics - Hydrology

1. Adoption of Atlas 14 rainfall totals and distribution
2. EGLE - Computing Flood Discharges for Small Ungaged Watersheds spreadsheet
   - Should be used with Bulletin 71 rainfall data for now
   - Using current spreadsheet with Atlas 14 rainfall data estimates unrealistically high peak discharges
   - MTU updating EGLE spreadsheet
     - (will be updated at a later time to incorporate Atlas 14)

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.286 (0.228-0.369)	0.336 (0.268-0.435)	0.424 (0.337-0.550)	0.502 (0.396-0.655)	0.618 (0.472-0.841)	0.713 (0.529-0.983)	0.813 (0.581-1.15)	0.920 (0.628-1.34)	1.07 (0.699-1.60)	1.19 (0.753-1.80)
10-min	0.418 (0.334-0.541)	0.492 (0.392-0.637)	0.621 (0.493-0.806)	0.735 (0.580-0.958)	0.904 (0.691-1.23)	1.04 (0.775-1.44)	1.19 (0.851-1.68)	1.35 (0.919-1.96)	1.57 (1.02-2.34)	1.74 (1.10-2.63)
15-min	0.510 (0.407-0.659)	0.600 (0.478-0.776)	0.757 (0.601-0.982)	0.897 (0.707-1.17)	1.10 (0.843-1.50)	1.27 (0.945-1.76)	1.45 (1.04-2.05)	1.64 (1.12-2.39)	1.91 (1.25-2.86)	2.12 (1.34-3.21)
30-min	0.743 (0.593-0.961)	0.871 (0.694-1.13)	1.10 (0.870-1.42)	1.30 (1.02-1.69)	1.60 (1.22-2.18)	1.85 (1.37-2.55)	2.11 (1.51-2.99)	2.39 (1.63-3.48)	2.79 (1.82-4.17)	3.11 (1.97-4.70)
60-min	0.965 (0.770-1.25)	1.14 (0.904-1.47)	1.43 (1.14-1.86)	1.70 (1.34-2.21)	2.09 (1.60-2.85)	2.42 (1.80-3.34)	2.76 (1.98-3.91)	3.13 (2.14-4.55)	3.65 (2.38-5.46)	4.06 (2.57-6.14)
2-hr	1.19 (0.959-1.51)	1.40 (1.13-1.78)	1.77 (1.42-2.26)	2.10 (1.68-2.70)	2.59 (2.00-3.48)	2.99 (2.25-4.07)	3.41 (2.47-4.77)	3.87 (2.67-5.56)	4.51 (2.98-6.66)	5.01 (3.21-7.50)
3-hr	1.31 (1.07-1.66)	1.55 (1.26-1.96)	1.96 (1.59-2.49)	2.33 (1.88-2.97)	2.88 (2.24-3.84)	3.33 (2.52-4.50)	3.81 (2.77-5.28)	4.32 (3.00-6.16)	5.03 (3.35-7.40)	5.61 (3.61-8.33)
6-hr	1.54 (1.27-1.92)	1.81 (1.49-2.25)	2.29 (1.88-2.85)	2.72 (2.22-3.41)	3.38 (2.67-4.46)	3.93 (3.02-5.25)	4.52 (3.34-6.20)	5.16 (3.63-7.29)	6.07 (4.08-8.83)	6.80 (4.42-9.99)
12-hr	1.80 (1.51-2.20)	2.08 (1.74-2.55)	2.61 (2.17-3.21)	3.11 (2.57-3.84)	3.89 (3.13-5.09)	4.57 (3.56-6.04)	5.30 (3.97-7.21)	6.12 (4.36-8.57)	7.29 (4.96-10.5)	8.25 (5.42-12.0)
24-hr	2.08 (1.76-2.51)	2.38 (2.01-2.86)	2.95 (2.49-3.57)	3.51 (2.94-4.27)	4.41 (3.61-5.71)	5.20 (4.11-6.81)	6.08 (4.61-8.18)	7.06 (5.10-9.79)	8.49 (5.85-12.1)	9.67 (6.42-13.9)
2-day	2.39 (2.05-2.84)	2.71 (2.32-3.21)	3.33 (2.84-3.96)	3.94 (3.34-4.71)	4.92 (4.08-6.28)	5.78 (4.63-7.47)	6.75 (5.19-8.97)	7.83 (5.72-10.7)	9.42 (6.57-13.3)	10.7 (7.20-15.2)
3-day	2.63 (2.28-3.09)	2.95 (2.55-3.46)	3.58 (3.08-4.21)	4.20 (3.59-4.97)	5.20 (4.34-6.57)	6.08 (4.91-7.78)	7.07 (5.47-9.31)	8.18 (6.02-11.1)	9.80 (6.88-13.7)	11.1 (7.53-15.7)
4-day	2.83 (2.47-3.30)	3.16 (2.74-3.68)	3.79 (3.28-4.43)	4.41 (3.79-5.19)	5.42 (4.55-6.80)	6.31 (5.12-8.01)	7.30 (5.67-9.55)	8.41 (6.21-11.4)	10.0 (7.07-14.0)	11.4 (7.72-16.0)
7-day	3.34 (2.94-3.84)	3.69 (3.24-4.25)	4.36 (3.82-5.04)	5.01 (4.35-5.81)	6.03 (5.10-7.44)	6.93 (5.67-8.66)	7.92 (6.21-10.2)	9.02 (6.72-12.0)	10.6 (7.54-14.6)	11.9 (8.17-16.6)
10-day	3.78 (3.35-4.31)	4.18 (3.70-4.77)	4.92 (4.33-5.63)	5.62 (4.91-6.46)	6.69 (5.69-8.15)	7.62 (6.27-9.42)	8.64 (6.81-11.0)	9.75 (7.30-12.9)	11.4 (8.11-15.5)	12.7 (8.72-17.5)
20-day	5.08 (4.56-5.68)	5.65 (5.06-6.33)	6.64 (5.93-7.47)	7.53 (6.68-8.53)	8.85 (7.58-10.5)	9.95 (8.26-12.0)	11.1 (8.84-13.9)	12.3 (9.33-16.0)	14.1 (10.1-18.9)	15.5 (10.8-21.1)
30-day	6.20 (5.61-6.87)	6.91 (6.25-7.66)	8.11 (7.31-9.03)	9.15 (8.18-10.2)	10.6 (9.16-12.5)	11.8 (9.90-14.1)	13.1 (10.5-16.2)	14.4 (10.9-18.4)	16.2 (11.7-21.5)	17.6 (12.3-23.8)
45-day	7.67 (7.01-8.41)	8.54 (7.79-9.38)	9.96 (9.05-11.0)	11.1 (10.1-12.4)	12.8 (11.1-14.8)	14.1 (11.8-16.6)	15.3 (12.3-18.7)	16.6 (12.7-21.1)	18.4 (13.4-24.1)	19.7 (13.9-26.5)
60-day	8.97 (8.24-9.77)	9.95 (9.13-10.9)	11.5 (10.5-12.6)	12.8 (11.6-14.1)	14.5 (12.6-16.6)	15.8 (13.3-18.4)	17.0 (13.8-20.6)	18.3 (14.0-22.9)	19.9 (14.5-25.9)	21.0 (14.9-28.1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

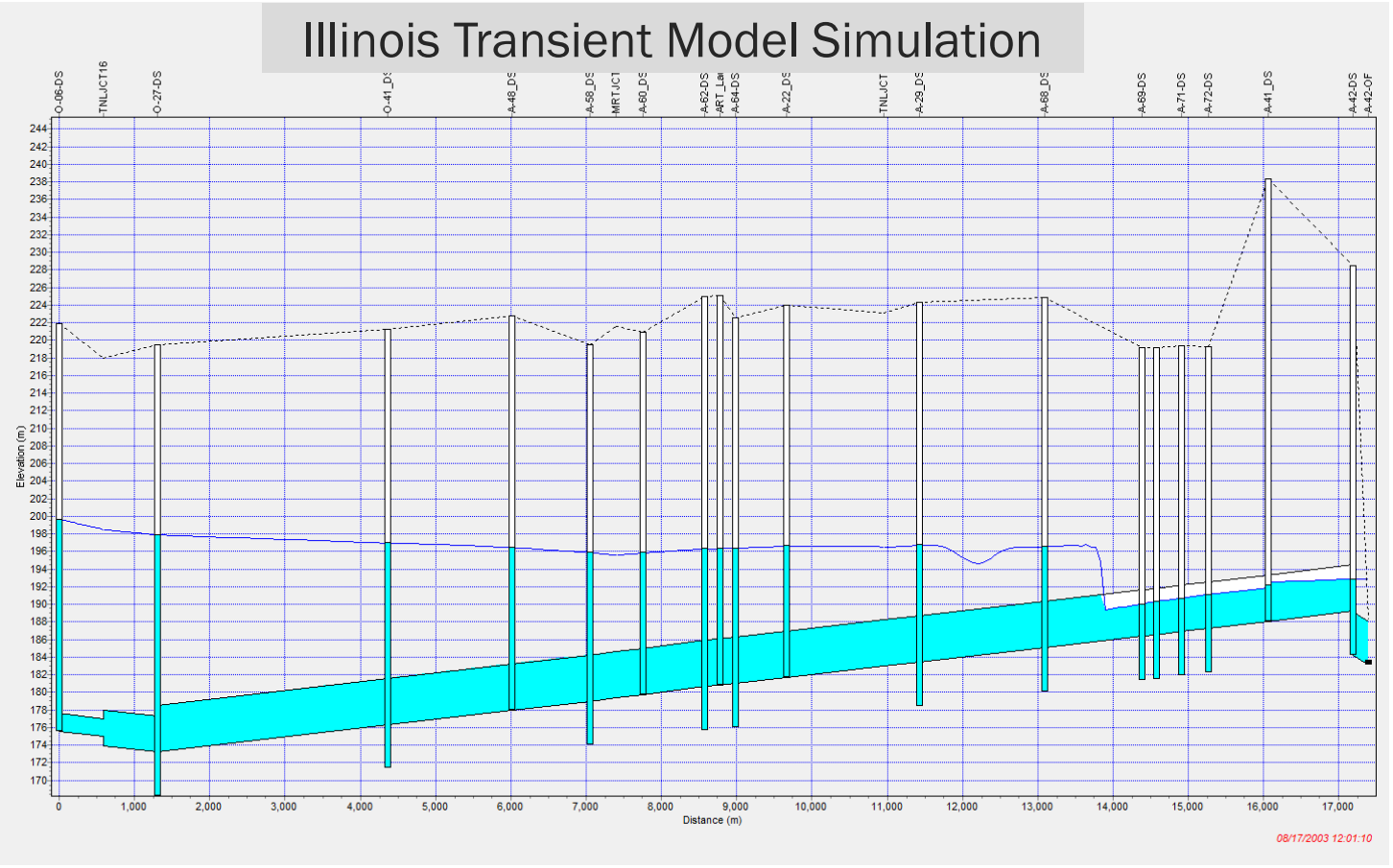
Please refer to NOAA Atlas 14 document for more information.

Advanced Hydraulics – Tunnel Hydraulics

1. Recent MDOT projects have included large storage and conveyance tunnels
2. Tunnel design should include the following
   - Tunnel surge analysis with appropriate software
   - Drop shaft design to manage hydraulic energy and entrained air
   - Venting analysis
     a) Volumetric displacement
     b) Surge wave

Modernize I-75

Advanced Hydraulics – Tunnel Hydraulic Analysis



Tunnel Surge Analysis

Evaluate potential formation of surge waves

Test alternatives to mitigate surge

Verify tunnel storage requirements

Calculate venting requirements

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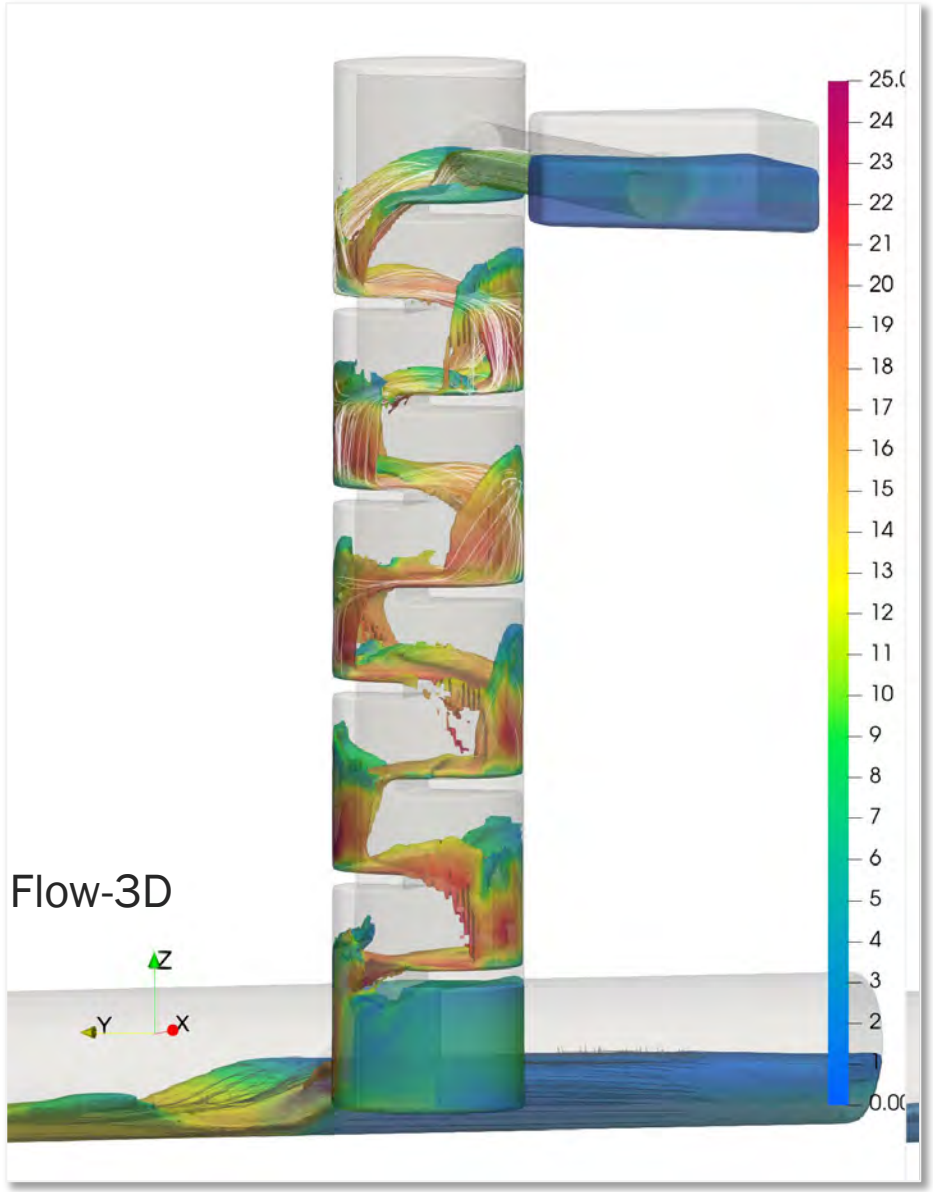
Advanced Hydraulics – Tunnel Drop Shaft Design



1. Identify drop shaft type
   - Direct vs. offline
   - Vortex
   - Plunge
   - Helicoidal
   - Baffle
2. Drop shaft design should be based on
   - Standard design
   - CFD modeling
   - Physical modeling
3. Drop shaft must
   - Manage hydraulic energy
   - Manage air entrainment

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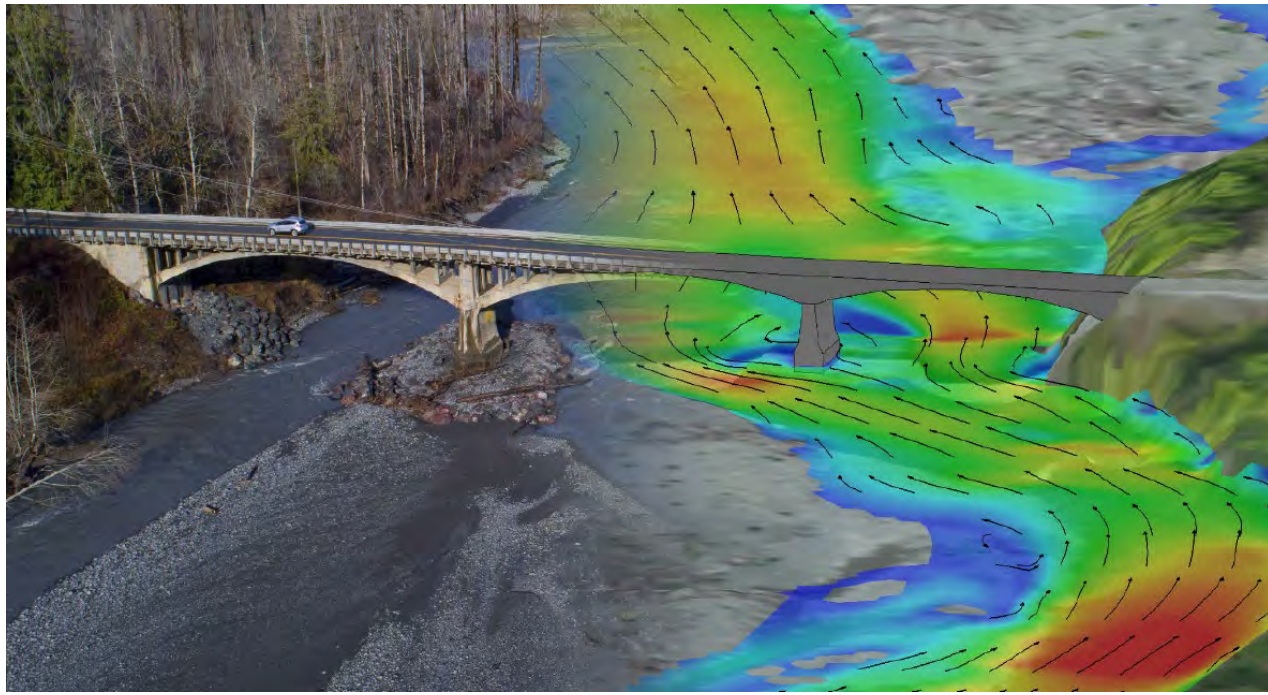
Advanced Hydraulics – 2-Dimensional Modeling

1. Applied for bridge scour design
   - Complex bridges
   - Extreme skew
   - Multi span
   - Split flow
2. FHWA does not recommend HEC-RAS 2D
3. Sedimentation and River Hydraulics (SRH-2D)
   - Available from Aquaveo - Surface-Water Modeling System (SMS)



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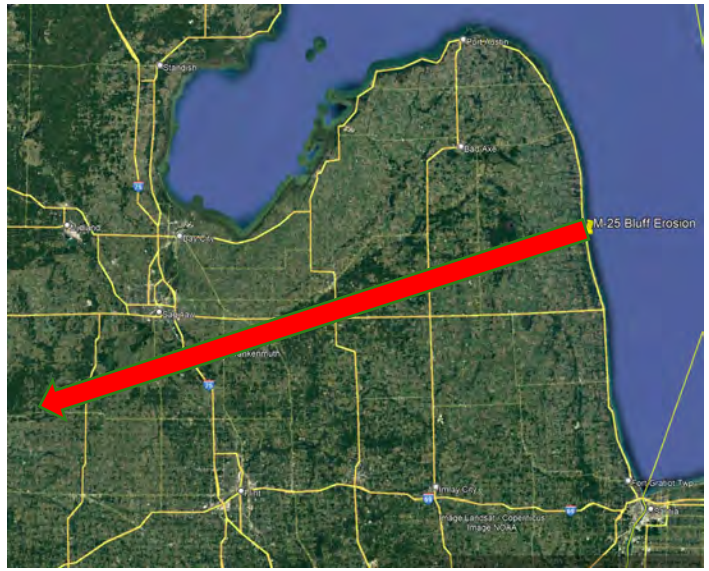
Advanced Hydraulics – Coastal Engineering

Recent high great lakes levels have drawn attention to Michigan's coasts.



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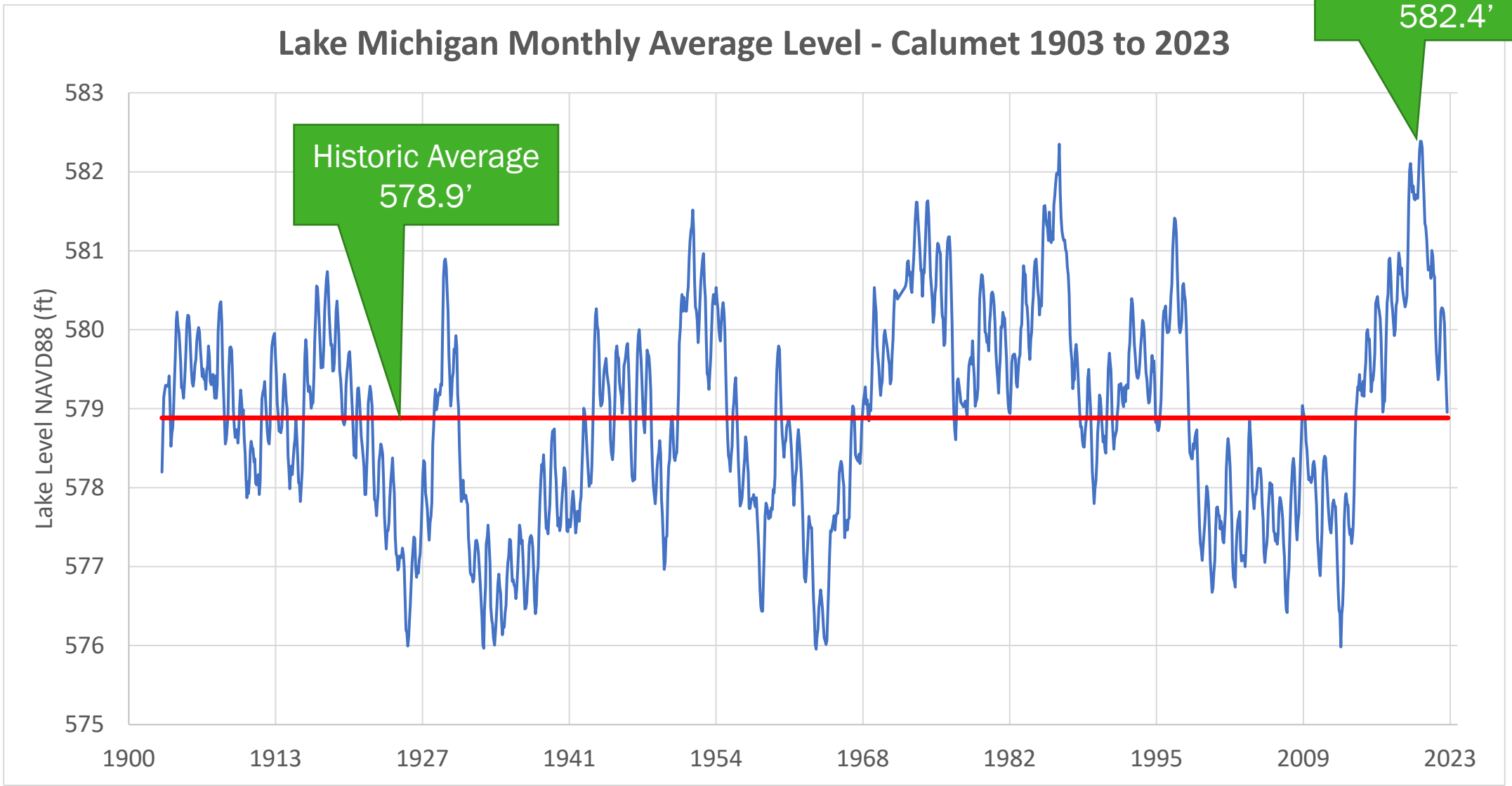

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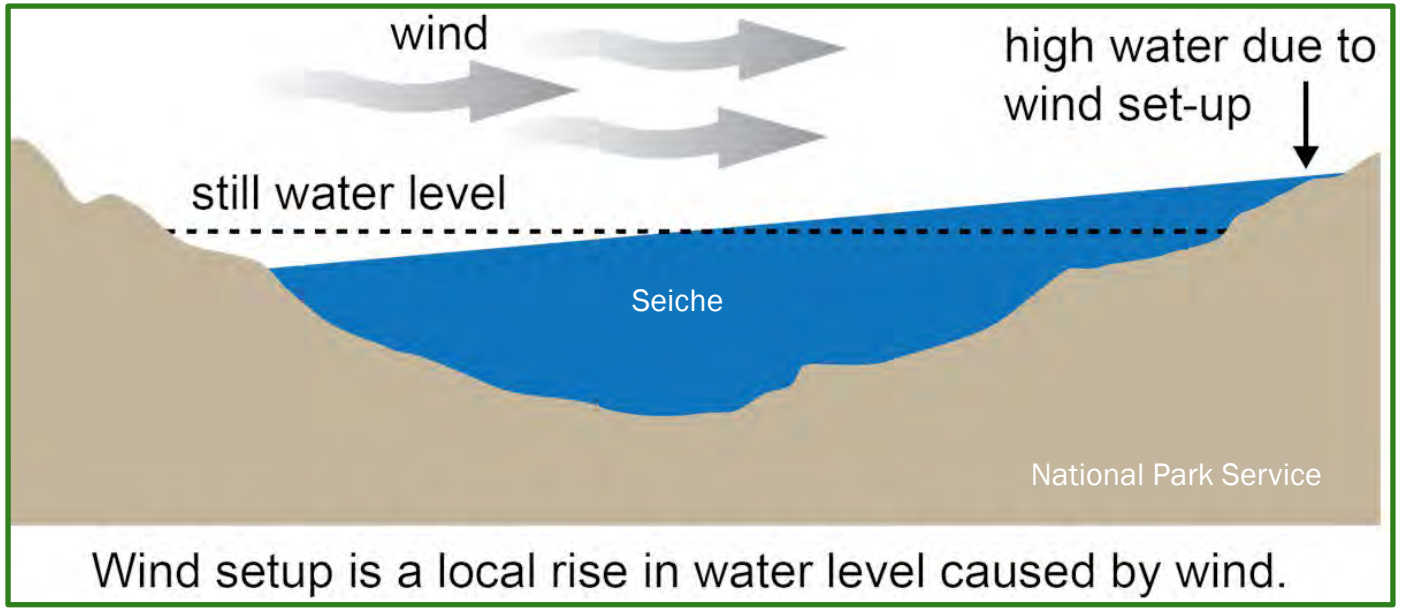
1. Manual update may include a coastal engineering chapter
2. Additional chapter may include:
   - Required freeboard for extreme great lake levels
   - Revetment design
   - Wave height estimates
   - Seiche
   - Ice dams



Questions?