
Overview of
Drainage Design
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GOALS

- Basic drainage design
- Where to find MDOT drainage policy
- Look at more than the road surface
- Know what you don't know

Hydraulics Unit

- Erik Carlson– Supervisor
- Liz McCann – Assistant - QA/QC
- Justin Logsdon – Scour/Hydraulics
- Kim Moody-Holmes – Permits/Hydraulics
- Jacob Moyer- Hydraulics
- Jack Krueger - Hydraulics
- Jim Davis – County Drain Coordination
- Ron McKee – County Drains/Apportionments
- Milad Alesmail – Student Assistant

Hydraulics Unit Lead Items

- Hydraulic Analyses
  - Task 3520
- County Drains
- Bridge Scour Analyses & Countermeasures
- EGLE Permit (NREPA Part 31 - Floodplain)
- Hydraulic Connection Permits

Hydraulics Unit Assistance Items

- General scoping
- Hydrology
- Bridge Deck Drainage
- Drainage Agreements - Cost Participation
- Drainage Studies – task 3522
- Storm Sewer Design
- Stormwater Quantity/Quality
  - Detention basins and BMP's

Drainage Manual

- MDOT Policy and Procedure for design of Drainage Facilities
- Stormwater Program, NPDES Phase 2
  - Best Management Practices - BMPs
  - Public Education – Internal & External
  - Being partially replaced with Post-Construction BMP Manual
- Design Contract Document
- https://www.michigan.gov/mdot/business/design/drainage-manual

Drainage Manual continued

- FHWA Program Review – March 2021
  - 15 Observations and Recommendations
    - Hydrology - outdated rainfall
      - Atlas 14
      - Research with EGLE/MTU
      - Pooled fund research with USGS
    - Design Standards
      - Risk based to include Federally funded LAP projects
      - Temporary structures
    - Updated culvert and bridge summary tables
    - Updated bridge scour coding and procedures
    - Working with Design Support with rollout of ORD's Drainage and Utilities software

Chapter Two – Legal

- Covers Federal, State, and local laws affecting drainage
- Perpetuate natural drainage – look outside of ROW
- State is held to a higher standard than a private citizen
- Stream vs. Drainage course (Part 301)
- Order of law supremacy
- Participation agreements

Chapter Two – Legal continued

- 23 CFR 650.115
  - Establishes design standards for encroachments on the Interstate System (50-yr, 2% chance)
  - Remaining design standards left up to the States
    - AASHTO Drainage Manual
    - State drainage manual/standards
- Flood Disaster Protection Act 1973
  - Established the Flood Insurance Program
- Federal EO 11988 (1977)
  - Floodplain Management
  - Applicable to participating communities

Chapter Two – Legal continued

- Federal EO 11988 (cont)
  - EGLE serves as liaison with FEMA
- Federal EO 13690 – Not currently in DM
  - Flood Risk Reduction Standard
  - Signed by Pres. Obama and rescinded by Pres. Trump
  - Reinstated May 20, 2021
    - No clear direction yet
- FHWA Task Order 5520 (2014) – Not currently in DM
  - Policy on preparedness and resilience to climate change and extreme weather events
  - No changes defined (yet) for MDOT Drainage Manual, but Climate Resiliency Chapter to be added to AASHTO DM.

Chapter Two – Legal continued

- FHWA considers HEC-18 required guidance for bridge scour
  - Design and check events left up to the States
- State EO 1977-4 & EO 2001-5
  - State flood hazard mitigation
  - 2001-5 updated 1977-4
    - Requires mitigation strategy
    - EGLE lead agency with input from MDOT & other agencies
    - Requires hazard mitigation planning including bridges
      - Current plan from 2019 - 2024

Chapter Two – Legal continued

- P.A. 451 of 1994 (Michigan)
  - EGLE Regulatory Authority
  - Part 301 – Inland Lakes and Streams (Task 3522)
    - Permit required for work below the OHWM for any stream consisting of a defined bed and bank.
  - Part 31 – Floodplains (Task 3520)
    - Permit/hydraulic analysis required for work below the 100-yr (1% chance) floodplain with crossings having drainage areas > 2 sq. miles
    - Road grade raise > 4 inches
    - No differentiation between permanent or temporary conditions, unless temporary structure(s) is in place less than 14 days
    - Contact the Hydraulic Unit supervisor

Not a stream

No bed, banks, or evidence of flow

Stream

Bed, banks, or evidence of flow

Chapter Two – Legal continued

- Common law drainage requirements
  - "The owner of the dominant estate has no right to divert, concentrate, or increase the velocity of the natural surface water."
  - "The owner of a lower or servient estate is obligated to receive surface water from the upper or dominant estate in its natural flow."

Chapter Three – Hydrology

- Drainage basin required information
  - Stream characteristics
  - Floodplain characteristics
  - Precipitation amounts, type, and rates
- A science and an art
  - Incorrect assumptions can lead to discharge errors of +/- 30%
- FHWA requirements for highway encroachments (23 CFR 650.115)
  - Plans must show magnitude, frequency, and water surface elevations for 50 (2%) and 100 (1%) year floods
  - 50 year shall not overtop the road (Interstate)

Chapter Three – Hydrology continued

- Hydrologic Method Selection
  - Use the rational formula for drainage area of 20 acres or less. (Q=CIA)
  - Over 20 acres, use EGLE's "Computing Discharges for Small Ungaged Watersheds"
  - Over 2 square miles, determined by EGLE

- Design examples and rainfall intensity charts
  - Will be updating for rational method with Atlas 14 with designs starting in FY2024.

Chapter Three – Hydrology continued

- EGLE Requirements
  - No harmful interference over a range of flows – regardless of drainage area
- MDOT Requirements
  - Culverts – 50 year design event, 100 year check for NHI
  - Bridges – 100 year design event, 500 year scour check
  - Storm sewers – 10 year design
  - Depressed roadway – 50 year design
  - Ditches – 50 year design, 100 year check for NHI
  - Ditch enclosures???

Chapter Four – Natural Channels and Roadside Ditches

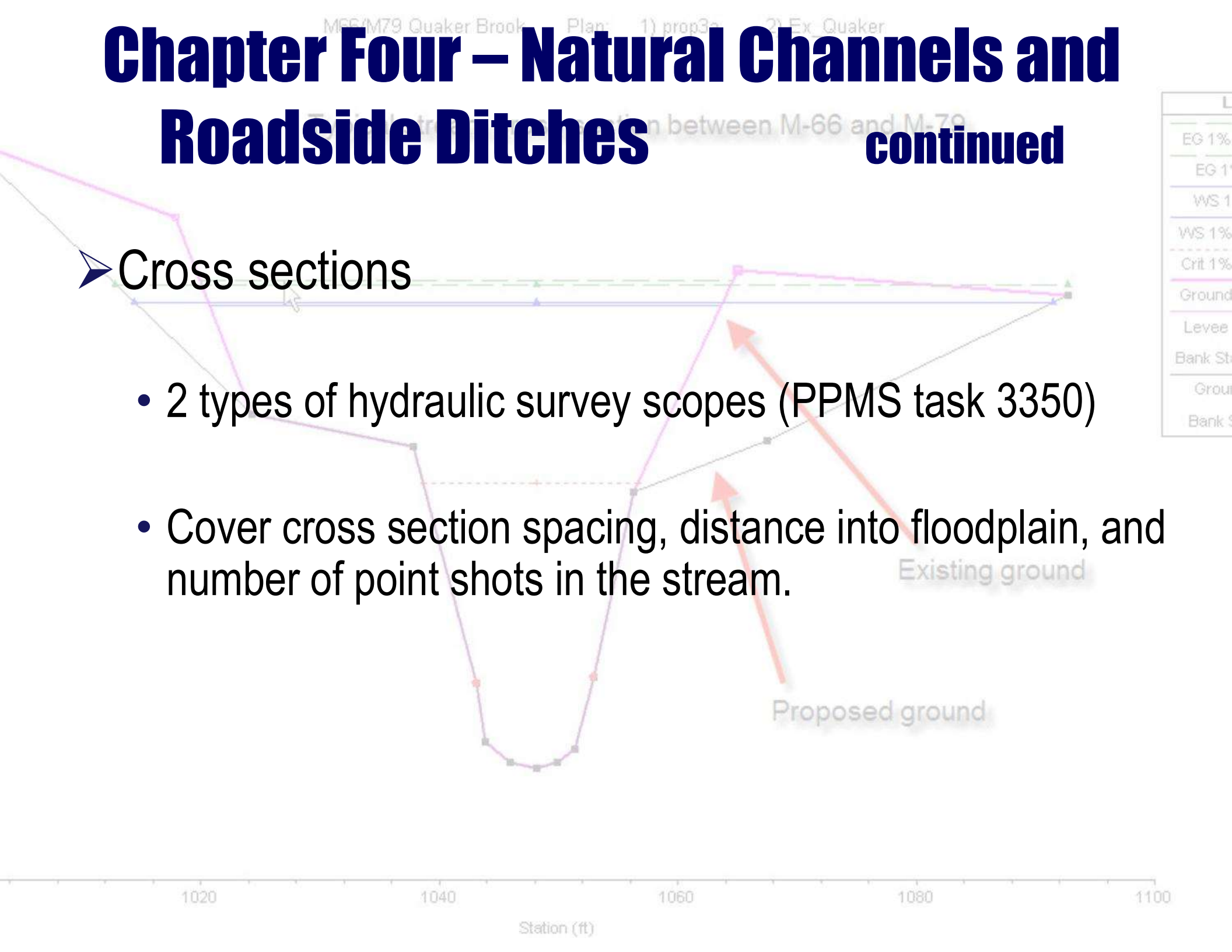
- Natural Channels
  - Evaluate hydraulic conditions over a range of flows 10 year to 100 year
  - Avoid relocation whenever possible
    - Relocated channels should mimic cross section and slope of existing
  - Stabilize stream banks with high velocity or poor angle of attack
  - Can be analyzed using HY-8, HEC-RAS, or SRH2D (SMS)

Chapter Four – Natural Channels and Roadside Ditches continued

- Ditches
  - 50 year storm event, check harmful interference for 100 year storm event.
  - Grades from 0.1% to 0.3% (desirable) minimum
  - The water in the ditch needs a minimum of 18 inch freeboard below the road's shoulder
  - If in clear zone, 2' depth at design event without guardrail can be analyzed using HY-8, HEC-RAS, or SRH2D

Chapter Four – Natural Channels and Roadside Ditches continued

- Cross sections
  - 2 types of hydraulic survey scopes (PPMS task 3350)
  - Cover cross section spacing, distance into floodplain, and number of point shots in the stream.



Chapter Five – Culverts

- Culvert Selection
  - Satisfy topography and budget, including maintenance
- Culvert Analysis
  - Environmental impacts
  - Harmful interference
  - Risk and costs
  - Practical site access for maintenance

Chapter Five – Culverts continued

- Culvert Design Criteria
  - All culverts require a hydraulic analysis
    - Compare existing vs proposed conditions for a range of flows up to the 100-yr (1% chance) event
  - Design life = design storm = 50 years
  - Culvert material can be site specific
    - If not specifying, assume worst case for hydraulic analysis
  - Multiple culverts should be avoided
  - Regularly inspected and maintained (2 yr. cycle)
  - Shortest length possible and aligned with channel
  - May need to be recessed into channel bottom
  - Avoid steep slopes

Chapter Five – Culverts continued

- Culvert Design Criteria
  - Maximum headwater 1.5’ below shoulder at design event
  - No harmful interference compared to existing
  - Outlet velocity < 6 fps or natural velocity
  - DA>2 sq. miles done by Hydraulics Unit
  - Culvert recess??
    - Grade control with perched existing culverts
    - Beware of long-term degradation in steep streams and future cleanout/legal drain elevations with County Drains

Chapter Five – Culverts continued

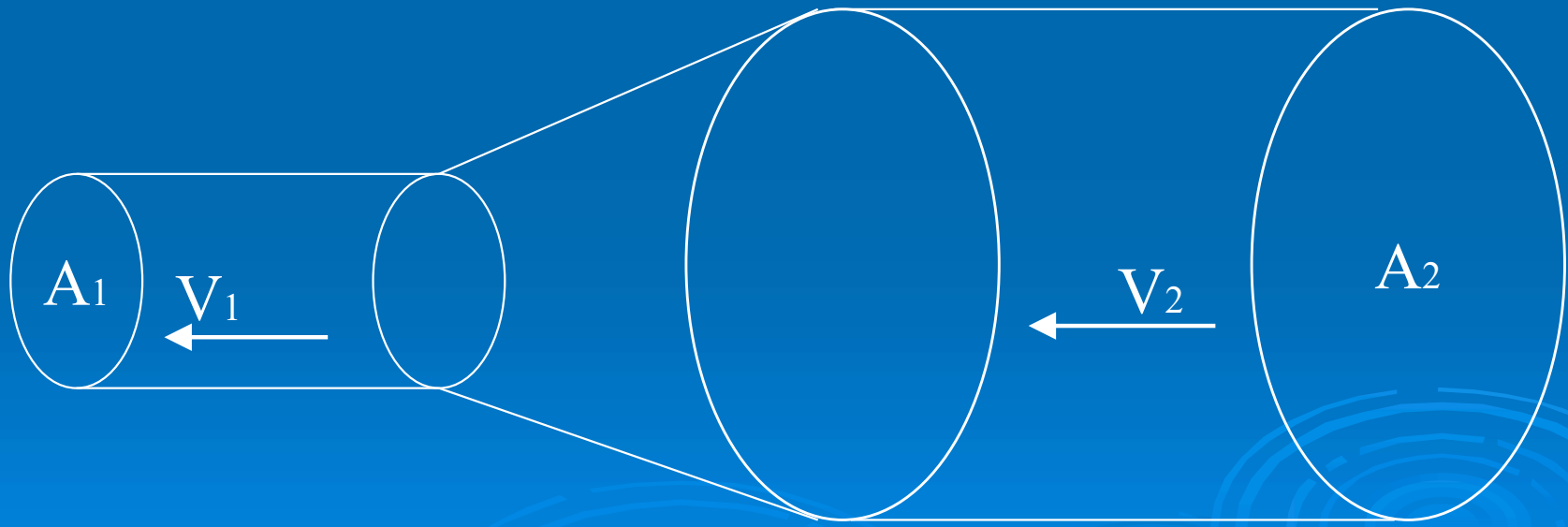
- Culvert Extensions
  - Can be done with dissimilar materials and shapes but best if consistent throughout
  - Extending slab culverts is not recommended
  - Perched culverts should not be extended
  - < 24 ft. extensions exempt from Part 31 review
    - Still have liability for harmful interference

Chapter Five – Culverts continued

- Culvert linings are only allowed for
  - Drive culverts carrying ditch flow
  - Cross culverts
  - CMP's that don't experience inlet control
- Can create other problems
  - Reduce area, increase velocity

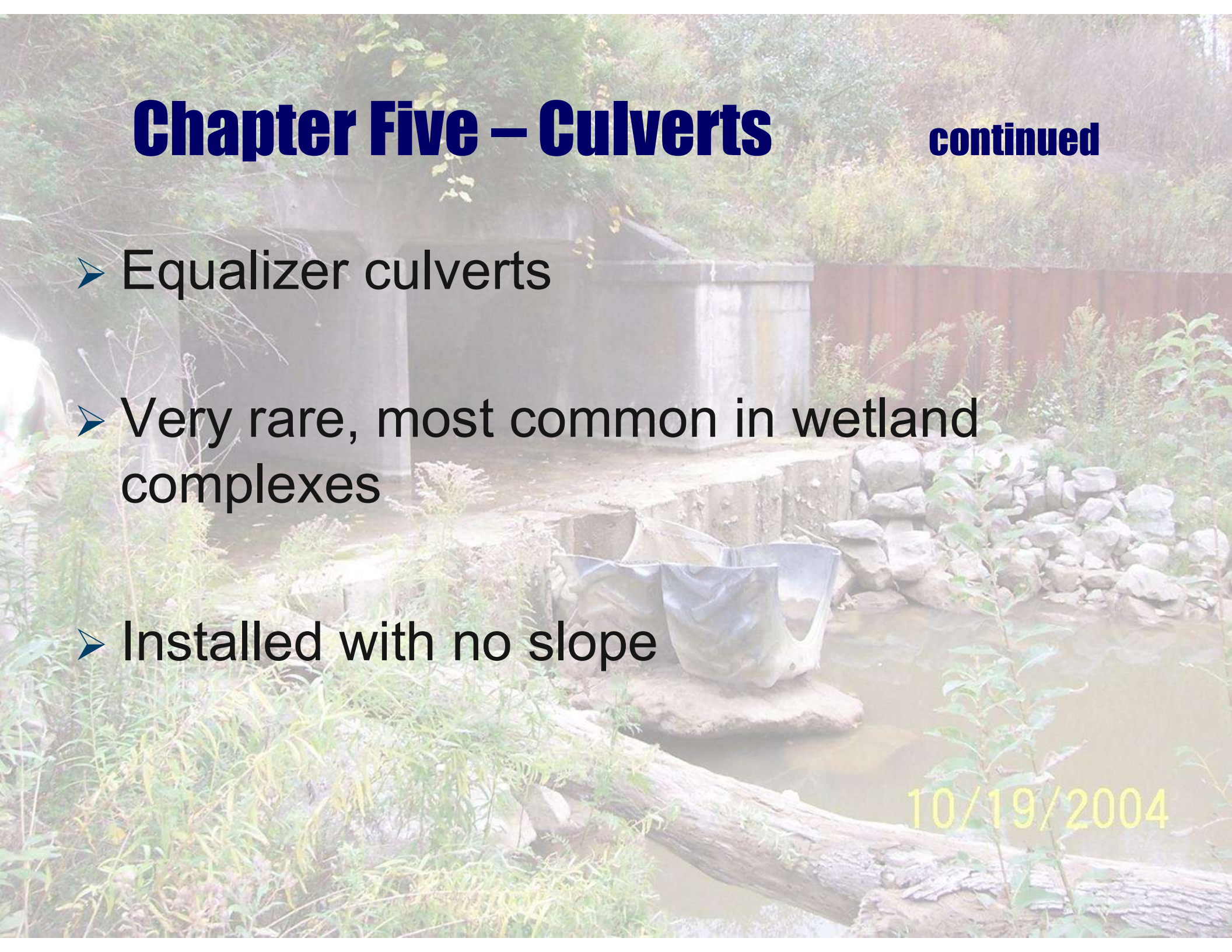
Chapter Five – Culverts continued

- $Q = V_1 A_1 = V_2 A_2$
- Discharge constant from one cross section to the next.

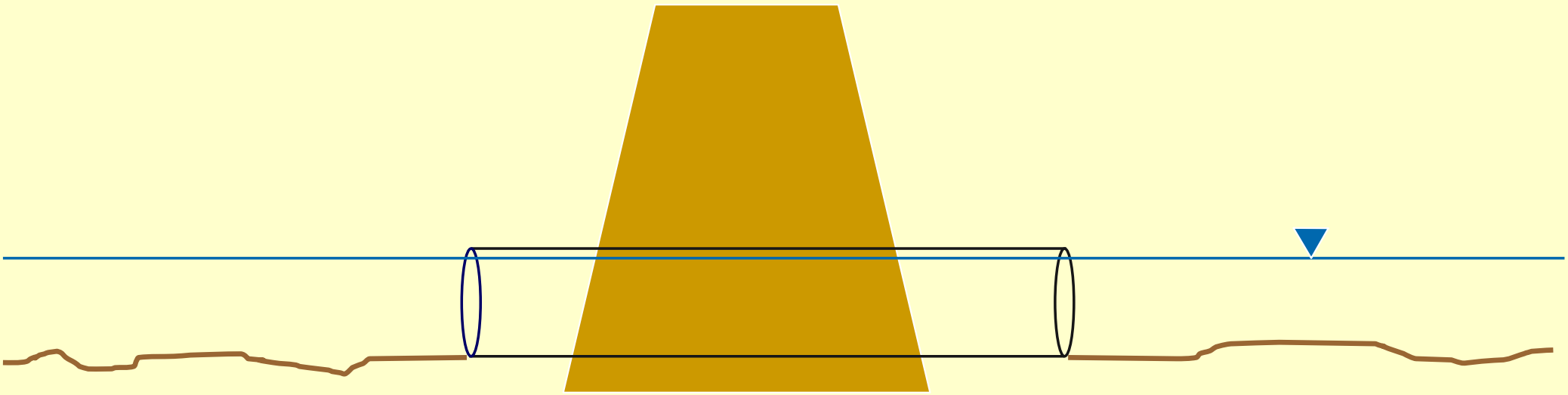


Chapter Five – Culverts continued

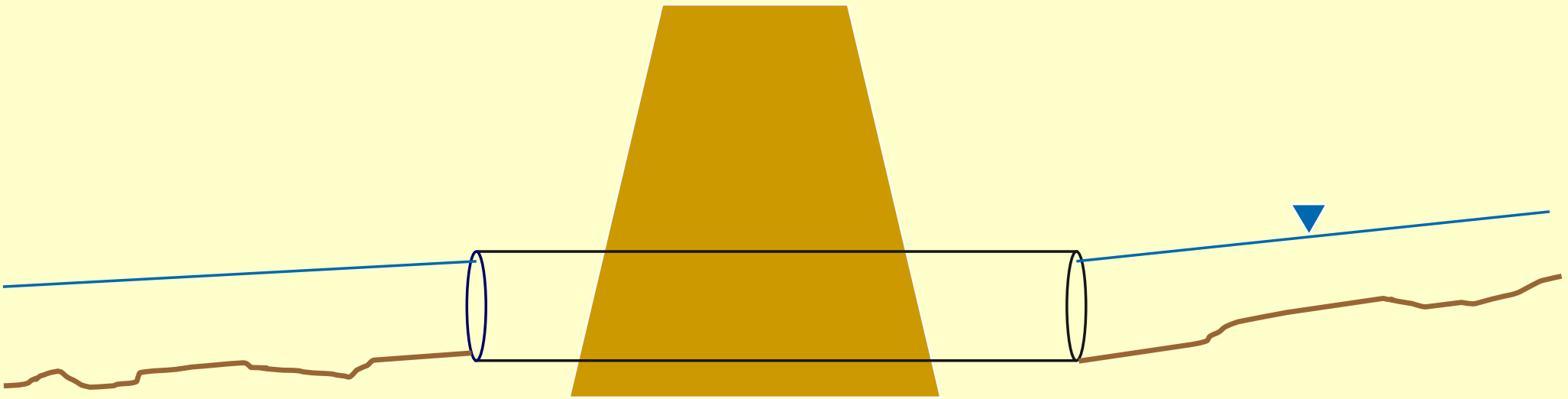
- Equalizer culverts
- Very rare, most common in wetland complexes
- Installed with no slope



This is an equalizer culvert



This isn’t



Culverts and the Scoping Process

- Important to look at all existing culverts
  - Condition
  - Drainage area and discharge values
  - Watershed changes
- Including them later impacts schedule and budget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Chapter Six – Bridges

- Bridge Design Criteria
  - Design storm = 100 years
    - May be updating freeboard return with DM updates.
  - No harmful interference compared to existing
  - 2 ft. freeboard where practical but avoid pressure flow
  - Require scour calculations
  - Foundations must be stable for a 500 yr. scour event
  - Blend with environment
  - Analyzed with HEC-RAS or SRH2D (SMS)
    - Recommend 2D modeling for designing scour countermeasures and computing scour for multi-span structures.

Chapter six – Bridges continued

- Chapter also covers
  - Hydraulic analysis using HEC-RAS
  - Scour analysis using SRH2D (SMS) and FHWA HEC-18
  - Bridge Deck Drainage / Maintenance
    - HEC-21 methodologies
      - We don't assume 15 min. time of concentration for bridge deck drainage
  - Hydraulic Report format
  - Bridge Hydraulic summary tables
  - MDOT Scour evaluation process

Chapter Seven – Storm Drainage Systems

- Design for 10 year storm, use 50 year for depressed roadways
  - Design life is 70 years
  - Rational method Q=CiA for most drainage to catch basins
  - 15 minute Tc, 10 minute Tc for depressed roadways
  - Use all contributing drainage area, not just ROW
  - Pipes most efficient at 90% full
  - Velocities < 12 fps in pipe, 6 fps at outlet
  - Pipe slope minimums given in chapter
  - Inlets not further than 300’ – meet design spread
  - Avoid placement of trunks in traffic lanes

Chapter Seven – Storm Drainage Systems
continued

- Spiral ribbed cmp or concrete – same Manning's "n" value
- 20 years future development
- Surcharge only allowed when caused by high tailwater
  - Keep HGL 1' below gutter grade
- Can be analyzed by hand or computer program (GEOPAK Drainage; future ORD Drainage & Utilities)

Chapter Seven – Storm Drainage Systems

continued

- Water does not acknowledge jurisdictional, property, ROW lines
- Laws/Permits/Agreements/Litigation – Chapter 2
- Receiving Waters
  - Drainage Course
  - County Drain
  - Intermittent Stream
  - Inland Lake, Stream

Chapter Eight – Storage Facilities

- Used for flood control requirements
  - Overhaul with new MS4 permit and Post Construction BMP Manual
  - Reduce direct discharges
  - Reduce runoff velocity
  - Design by hand or computer model (Hydraulic Toolbox)
- Routing requires stage/storage, stage/discharge curves, and inflow hydrograph
- Need borings for groundwater elevations in ponds. No storage to be included below groundwater table.
- Detention vs. Retention (infiltration)

Chapter Eight – Storage Facilities
continued

- Design Criteria
  - Criteria to be updated with DM updates
  - Pre-project discharge >= post-project dischargeSpillway design: 1% post development, 1.5’ freeboard
  - 2’ maximum depth if located in clear zone
  - Spillway preference of sheet pile orifice/weir over perforated riser
    - Email Hydraulic Unit Supervisor for details
  - Requirements for side slopes, fencing, and embankment

Chapter Nine – Stormwater BMP's

- Stormwater Quality
  - SESC (Soil Erosion and Sedimentation Control)
    - Water quality during construction
  - May be eliminated with Drainage Manual updates
    - MDOT Soil Erosion and Sedimentation Control Manual
    - MDOT Post Construction BMP Manual coming soon

Chapter Ten – Pump Stations

- Prefer gravity drainage
  - Long term maintenance costs

- Design Criteria
  - 50 year design event
  - Storage in station 2’ below gutter line low point
  - When upgrading, can’t increase capacity of pump(s)
  - Need to evaluate storage upstream of the pumpstation if inflow greater than outflow.


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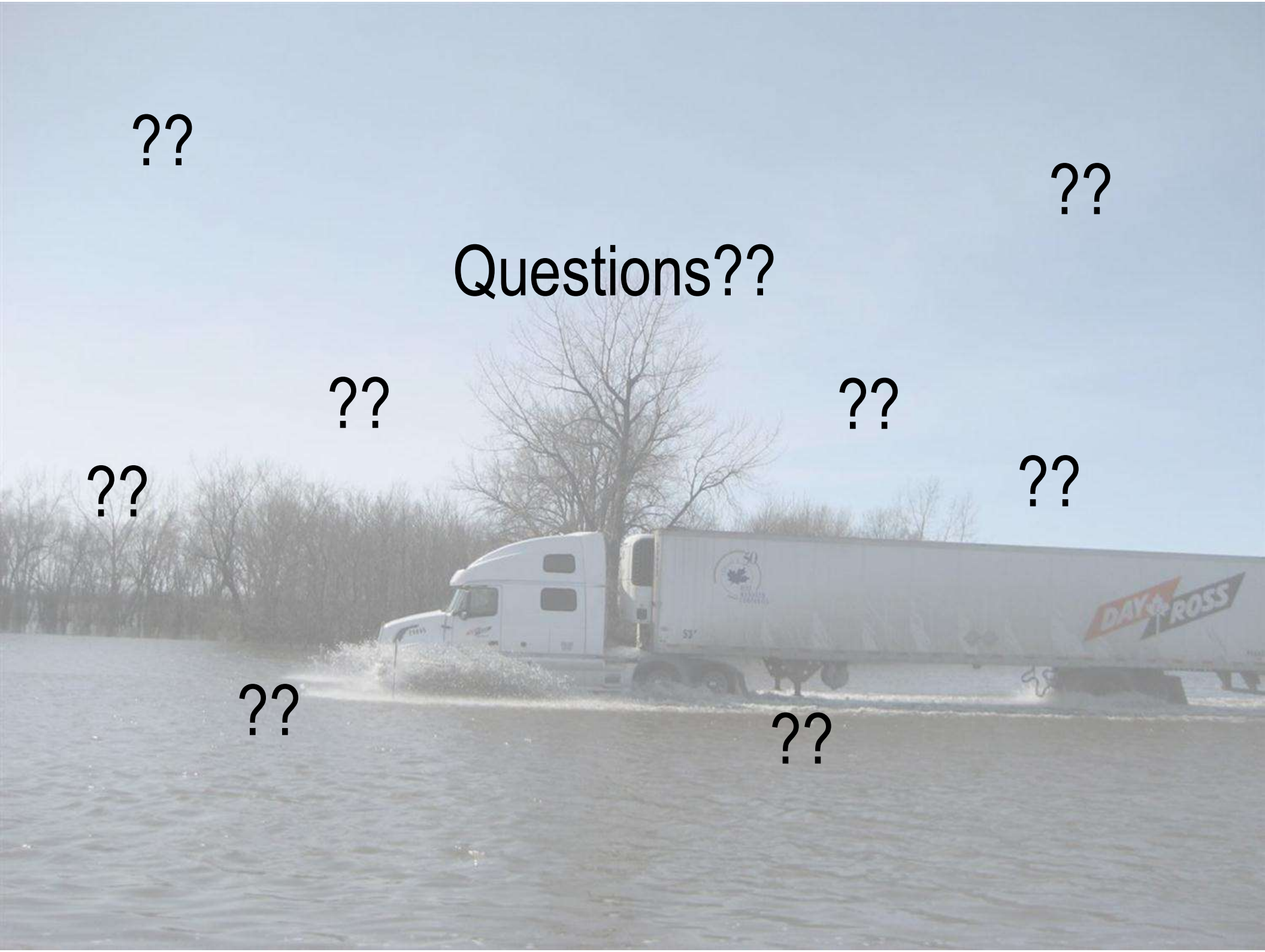
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