Maryland
Department of
the Environment

Sediment, Stormwater, and Dam Safety Program

Policy Memorandum #2 - Roadway/Railroad Embankments with Culvert Crossings

(not “MDE Dam Embankment Guidance - Tech Memo # 2”)

February 18, 2020

Presentation Outline

I. MDE

II. The ubiquitous CULVERT

III. The PROBLEM that lead to Policy Memo #2

IV. The SOLUTION

V. The PROCESS for evaluating a culvert crossing

VI. Our OBJECTIVE and what YOU as a designer or reviewer can do to help

Changing of the Guard

Boomers retire and millennials move in.
Gen-xers bridge the transition.

Water and Science Administration
Sediment, Stormwater, and Dam Safety Program

Program Manager
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Deputy Program Manager
Ray Bahr

Administrative Specialist
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Dam Safety Permits Division
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- Vimal Amin
- RCE Senior - Vacant
- RCE Senior - Vacant

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- Kelly Flint
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- Dan Laird
- Collin Hiltner
- Chimere Eaton
- Leah Wenck
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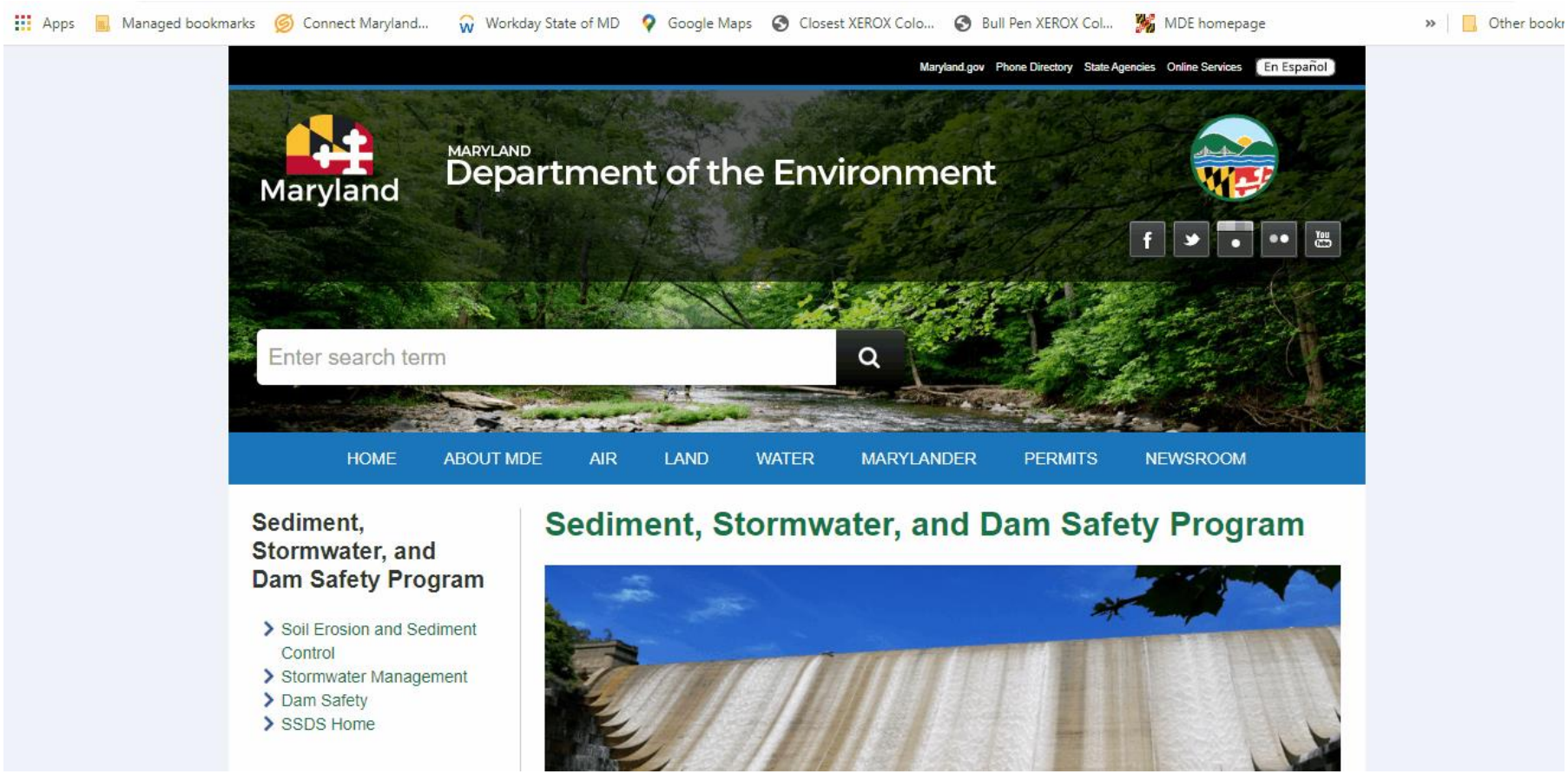
- Deborah Cappuccitti
- Dela Dewa
- Andrew Tagoe
- Brian Cooper
- Christina Lyerly
- Michelle Crawford
- Pat Depkin
- Nora Howard

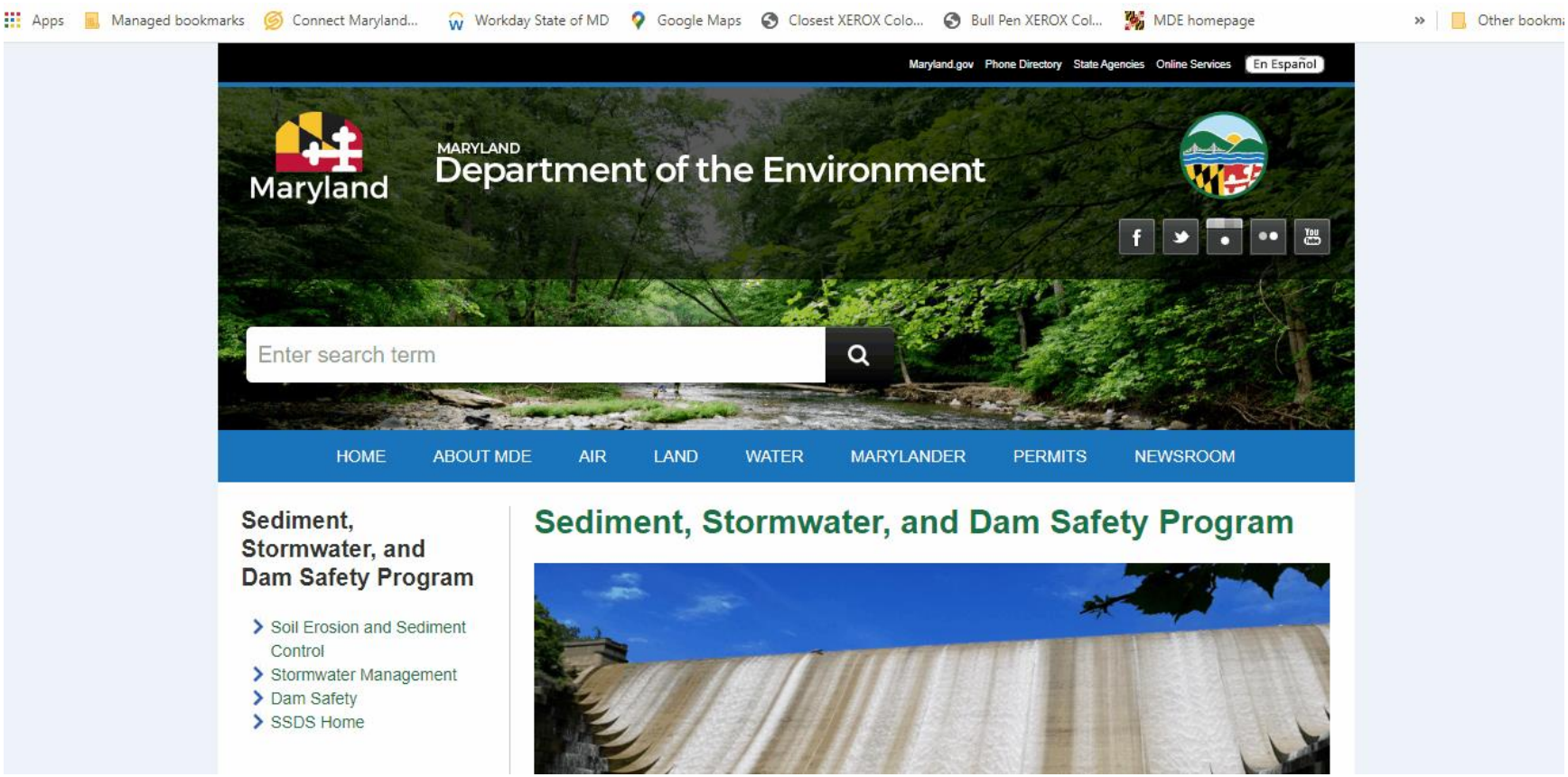
Collaborative Efforts between Dam Safety Permits and Plan Review Division

- Guidance on dam breach analysis (draft posted)
- Policy/technical memos (some posted; more coming)
- Small pond guidance (in progress)
- SHA small pond delegation (in progress)
- CMAC guidance (general guidance forthcoming)
- Electronic approvals (in progress)

Technical Memoranda from the Plan Review Division



Policy Memoranda from MDE Dam Safety



Twin Box Culverts

Little Culvert

Historic Stone Culverts under Railroads

Video of Culvert Failure

“In Climate Change Preparation, the Humble Culvert is Key” Susan Sharon, Maine Public Radio

Culverts must be adequately sized!

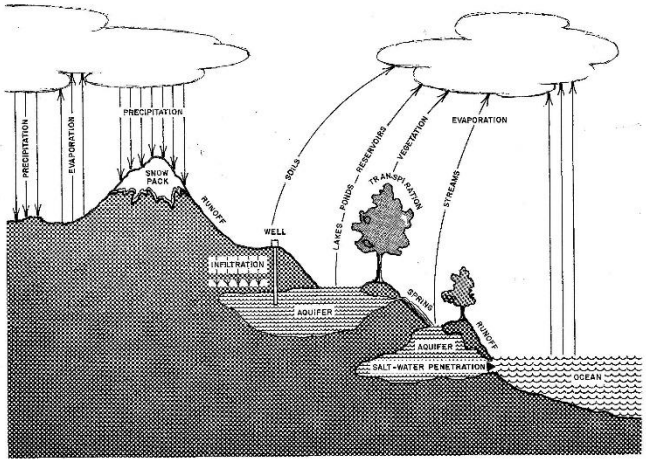
The PROBLEM

Roadway/railroad embankments sometimes function as dams, intentionally or unintentionally, and they are not constructed to impound water.

Culverts fail and dams fail, but the more water impounded behind the roadway/railroad embankment, the greater the hazard and the greater the likelihood of failure.

History – 1981 Drainage Manual

HIGHWAY
DRAINAGE
MANUAL



Maryland Department of Transportation
State Highway Administration

HIGHWAY
DRAINAGE
MANUAL

DECEMBER-1981

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

History

E. Detention Facility Types

1. Highway Projects

Detention areas adjacent to State Highway Administration culverts or grassed areas in medians or interchanges will probably prove to be the most practical and economical means of meeting storage requirements, although in some cases, underground storage may be necessary.

Detention may be accomplished upstream or downstream from the highway. Practical considerations, such as the amount of storage required, cost or availability of the right of way or easement, cost of the facility and the amount of maintenance needed to assure reliable operation will all influence the location. When a sizeable amount of storage capacity is required, storage upstream from the highway will usually prove more practical since the highway embankment will serve to confine the water.

The storage capacity required to manage a 100 year frequency storm must be provided within the State Highway Administration right-of-way or easement and the maximum storage elevation must not exceed the lowest pavement edge elevation.

The State Highway Administration must acquire any area on which it is responsible for raising the 100 year flood plane elevation.

The Chief, Bureau of Highway Design should be consulted to determine which facilities should be fenced to protect the public.

History

G. Control Structures

In general, control structures can be any arrangement of simple culverts or "orifice and weir" structures which will provide the multiple stage release required for the 2 year, 10 year and the 100 year storms.

When simple pipes are used, size, roughness and slope should be selected so that culvert operation (either entrance or outlet control) will not discharge more than the allowable release rate when operating under the head resulting from maximum storage.

A transverse highway culvert may not be used as a control structure if it does not provide the proper release rates for all storms. In these cases, the proper release rates will be achieved by a suitable orifice and/or weir type control structure. Orifice and weir structures should be designed using the following formulas:

Federal Guidance – Highways as Dams

https://www.fhwa.dot.gov/engineering/hydraulics/policymemo/20080910.cfm

Highway Embankments versus Levees and other Flood Control Structures – September 10, 2008

Embankments and Permanent Dams

The FHWA floodplain regulations do recognize that there are times when embankments may interact with or function as permanent dams. In these cases, the FHWA has no design standards. Instead the FHWA regulations require the design have the approval of the State or Federal Agency responsible for the safety of dams or like structures within the State. Even in this case, the FHWA floodplain regulations distinguish between permanent structures and those affected during floods.

Design of Highway Embankments

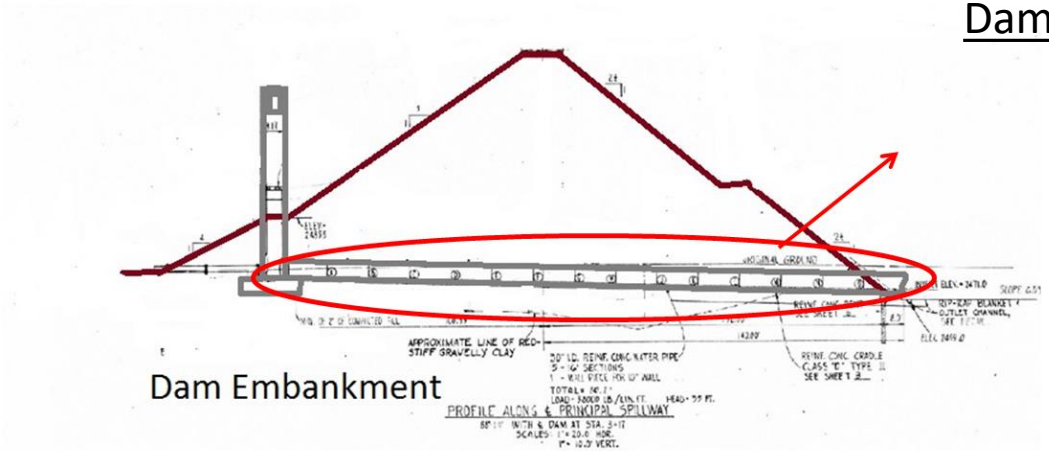
Both new and existing highway embankments reflect the following typical design philosophy and approach:

- Highway embankments do not include design features, such as an internal impervious core and freeboard, required for a levee or other flood control structures;
- The fill material used in the construction of a typical highway embankment is not a sufficient barrier against water; therefore, a highway embankment is subject to piping, seepage, and infiltration; and
- Typical highway embankment construction does not require the same level of geotechnical engineering analysis as required for flood control structures.

The Problems with Culvert Crossings Functioning as Dams

- Pipe
- Embankment
- Hydraulic Capacity

The Conduit - Dam Spillway Pipe vs. Road Culvert

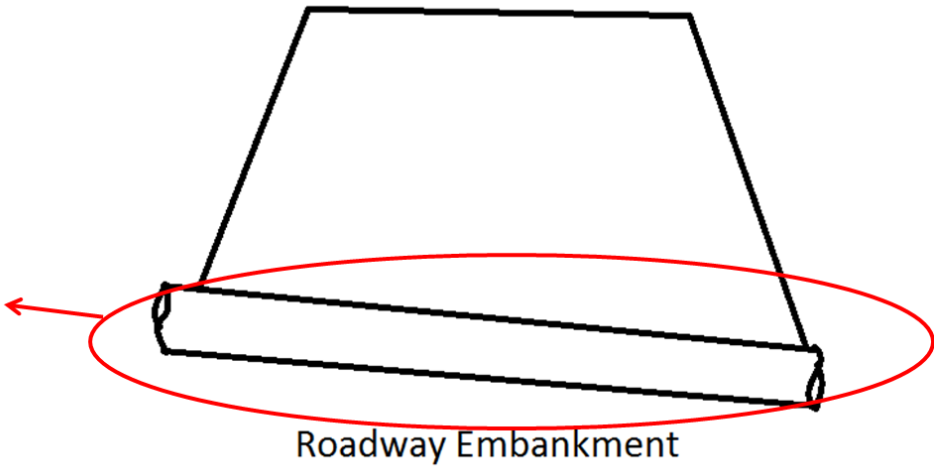


Dam Spillway Pipe

- Concrete cradle
- ASTM C-361 concrete pipe
- Watertight joints
- Construction methods
  - Pipe laid prior/during embankment construction

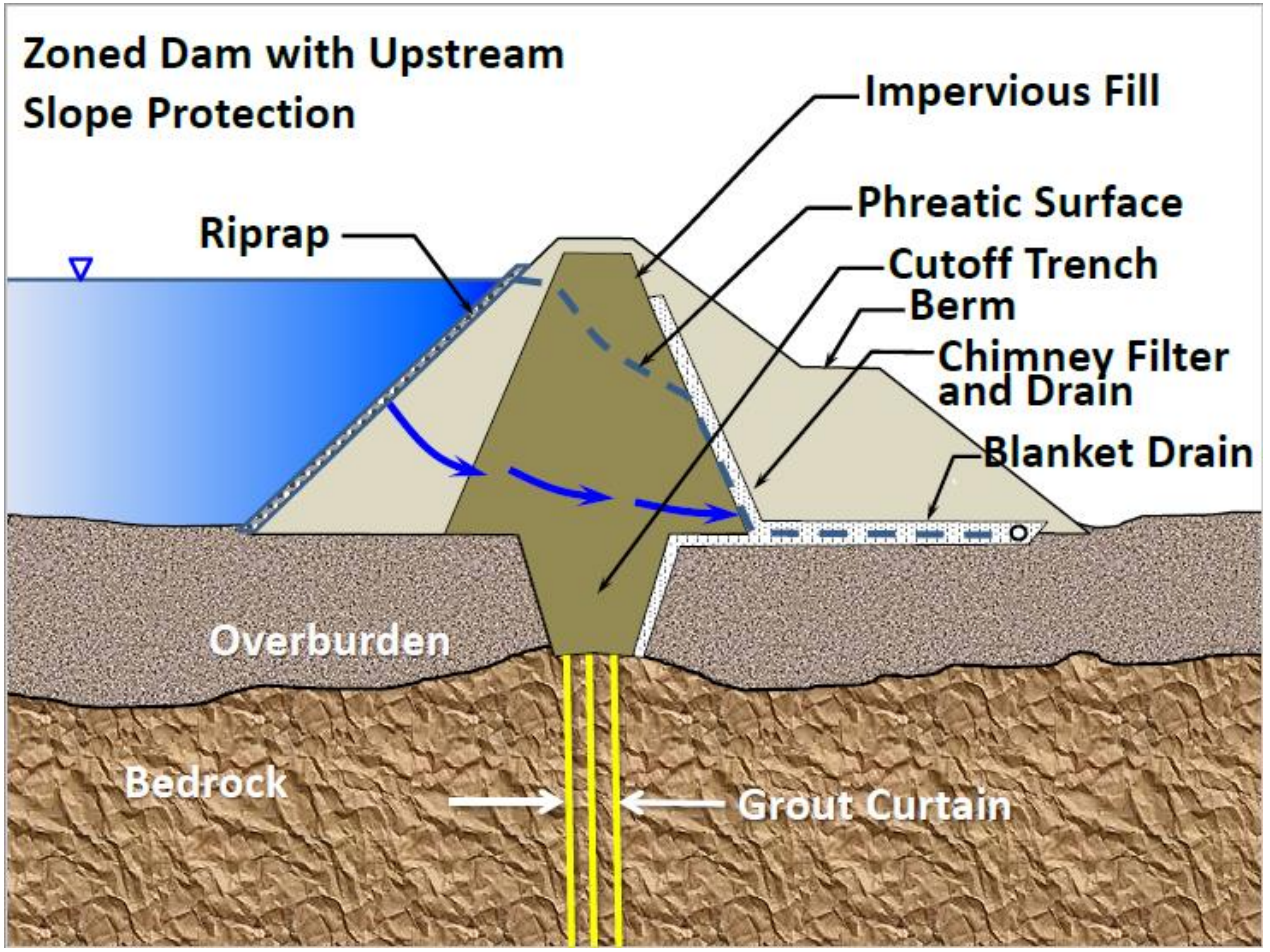
Roadway Culvert

- No concrete cradle
- Gravel bedding
- Pipe material
- Joints probably not watertight
- Construction methods
  - Trench
  - Jack and bore



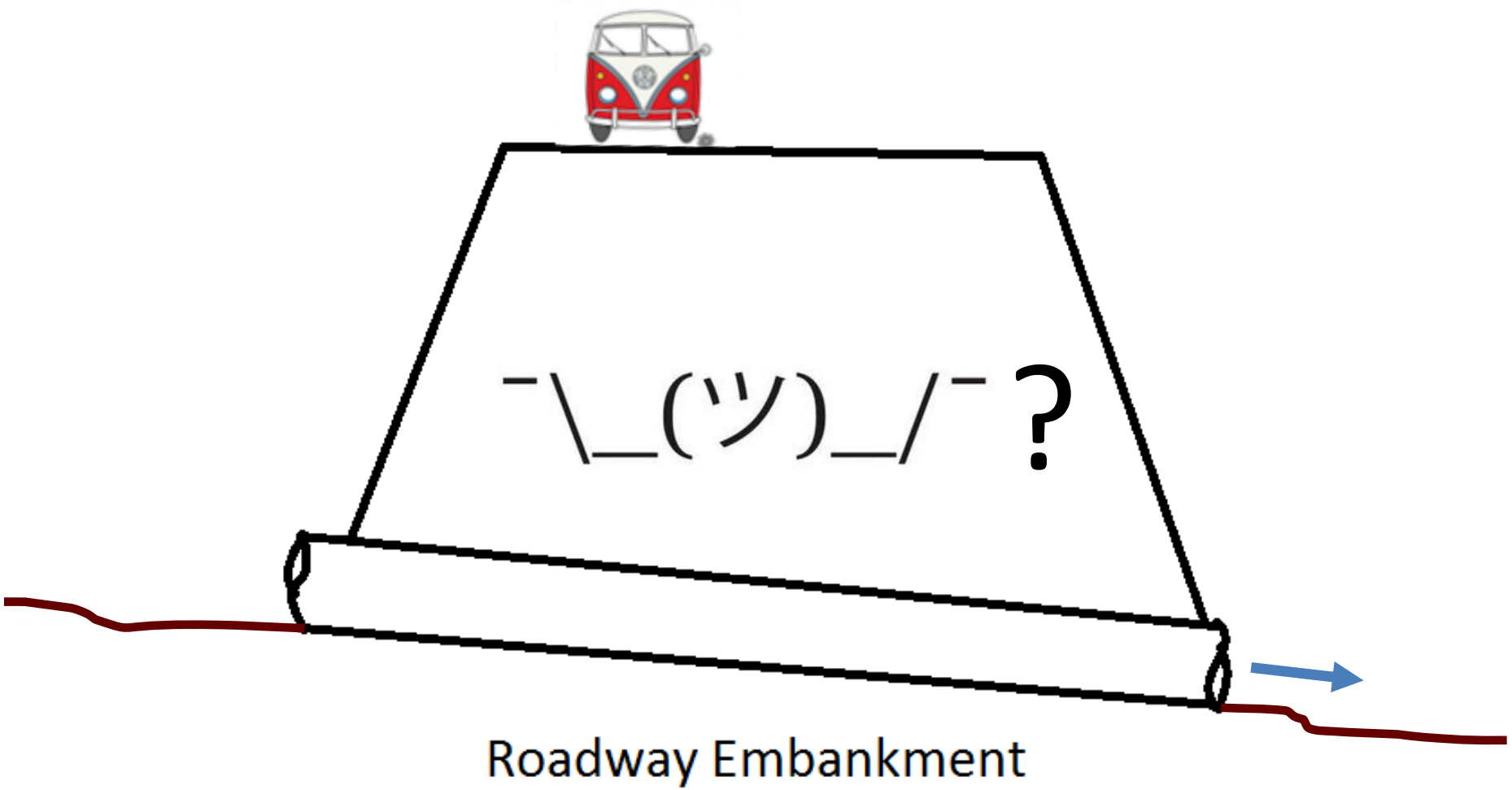
Dam Embankment

- Materials
- Construction
- Foundation
- Cutoff trench
- Impervious core
- Seepage Control
- Freeboard



Source: Paul Schweiger, Gannett Fleming, ASDSO, “Dam Failures and Lessons Learned”

Roadway Embankment



The Drivers

- Poor submittals.
- Debates over what Code 378 says.
- MS4 restoration projects.
- P3 push. The Purple Line. Desire to designate SHA as small pond approval authority. The need for clear and improved guidance.
- Climate change, micro-bursts, more frequent and more severe flooding (like Ellicott City and SC).

Flood Damage from Crazy Weather

The SOLUTION

Policy Memorandum #2!

Basis of policy memo comes from COMAR, State law, Maryland Pond Code 378, Federal Highway Administration, ASDSO survey, Bureau of Reclamation, and policies in other states.

Culvert vs. Spillway?
Roadway Embankment vs. Dam?

April 2012
Publication No. FHWA-HIF-12-026

Hydraulic Design Series Number 5

2.2.5 Allowable Headwater

a. Economic Considerations. Although the use of ponding can reduce the barrel size required, detrimental economic consequences can occur from increased headwater elevations. For example, high headwater can lead to embankment piping around the culvert exterior causing damage and possible failure. Increased headwater can also cause higher outlet velocities and severe outlet scour that might require an energy dissipater. Areas with significant debris loading potential that might clog a culvert may use a lower allowable headwater to minimize potential damage from overtopping. Site specific constraints often

d. Agency Constraints. Some state or local highway agencies place limits on the headwater produced by a culvert. For example, the headwater depth may not be allowed to exceed the barrel height or some multiple of the barrel height, expressed as HW/D. The allowable HW/D ratio varies throughout the country, but commonly ranges from 1.0 to 1.5. Although very low HW/D constraints will severely limit the flexibility inherent in culvert design, they must be followed unless a design exemption is granted.

HYDRAULIC DESIGN OF HIGHWAY CULVERTS
Third Edition

Illinois: Intent, 1 foot of headwater

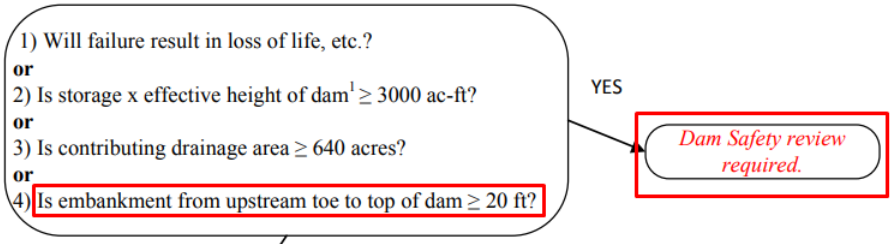
Minnesota: Intent

New Jersey: Hw – Tw < 5 feet

Maryland: Intent, Hw-Tw < 10 ft, Hw/D < 2

ASDSO Survey – Modifying a Dam to a Roadway Culvert
January 2016

Figure 1. Determine Design Category of Pond Embankment



APPENDIX B

ROADWAY EMBANKMENT
DESIGN CRITERIA

HW - TW > 10'* AND HW/D > 2, OR PERMANENT POOL > 3' OR PROPOSED RISER

No → **NO SPECIAL DESIGN**

Yes ↓

MEETS SMALL POND CRITERIA, AND CLASS "A"

No → **MDE DAM SAFETY REVIEW**

Yes ↓

8:1 PROJECTION LINE INTERSECTS DOWNSTREAM SLOPE OF THE EMBANKMENT

No → **SPECIAL EMBANKMENT DESIGN**

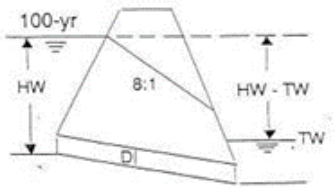
Yes ↓

MD 378 Design

Use any nonorganic soils for the embankment, elimination of the cut-off trench and core based on approval of geotechnical engineer and acceptable to local jurisdictions.

Filter diaphragm is required.

All other MD 378 criteria apply.



* Use HW when TW is below the inlet invert elevation.

Maryland Dam Safety Regulations

Title 26 DEPARTMENT OF THE ENVIRONMENT
Subtitle 17 WATER MANAGEMENT ADMINISTRATION
Chapter 04 Construction on Nontidal Waters and Floodplains
.02 Definitions.

(4) "Dam" means any obstruction, wall, or embankment, together with its abutments and appurtenant works, if any, in, along, or across any stream, heretofore or hereafter constructed for the purpose of storing or diverting water or for creating a pool upstream of the dam, as determined by the Administration.

Policy Memo #2 - Roadway/Railroad Embankments with Culvert Crossings

Maryland Department of the Environment

Larry Hogan, Governor
Boyd K. Rutherford, Lt. Governor
Ben Grumbles, Secretary
Horacio Tablada, Deputy Secretary

DAM SAFETY
POLICY MEMORANDUM #2

TO: Dam Owners, Operators, and Engineers

FROM: Sediment, Stormwater, and Dam Safety Program
Water and Science Administration

DATE: June 11, 2019 (Updated October 9, 2019)

SUBJECT: Roadway/Railroad Embankment with Culvert Crossing

Policy Statement

It is the policy of the Maryland Department of the Environment (the Department) that linear embankments constructed as transportation ways should be designed to avoid impounding water excessively, for any purpose, through the use of adequately sized culverts, bridges or similar elements. Where linear embankments impound excessive depths of water, they will be classified as dams and must be designed, constructed, and operated as such.

Conditions Where this Policy Applies

The criteria below are used to determine whether a roadway or railroad embankment is functioning as a dam. These criteria apply irrespective of embankment width and may be applied to hiker/biker paths, golf cart paths, and narrow access roads. The criteria provide a measure for adequately sizing the culvert crossing to limit the impounded water and eliminate the embankment from being considered a dam. Application for a dam safety permit is required for embankments higher than 35 feet. For roadways, the embankment height is measured from the lowest point of excavation or fill on the upstream slope of the embankment to the incipient point of overtopping. For railroads, the embankment height is measured from the lowest point of excavation or fill on the upstream slope of the embankment to the subballast at the incipient point of overtopping.

1. Headwater and tailwater conditions are based on the 100-year, 24 hour storm event. Headwater depth (HW_{depth}) is measured from the upstream toe of fill to the upstream hydraulic grade line (HGL) or 100-year water surface elevation (HW_{elev}) assuming there is no velocity head. Tailwater depth (TW_{depth}) is measured from the downstream toe of fill to the downstream HGL (TW_{elev}). In the equations below, "HW-TW" refers to the differential between headwater and tailwater elevations. When the 100-year TW_{elev} is lower than the

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www.mde.maryland.gov

elevation of the pipe invert at the upstream end, the HW_{depth} shall be substituted for "HW-TW". D is the diameter of the culvert. For box culverts, twin culverts, and elliptical pipes, consider D to be the height of the opening. Refer to Figures 1 and 2 for illustration of the definitions provided above.

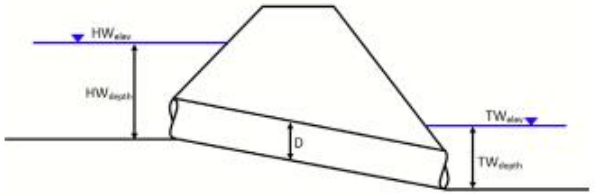


Figure 1: Illustration of condition where TW_{elev} is higher than upstream invert elevation; use HW-TW = HW_{elev} - TW_{elev}

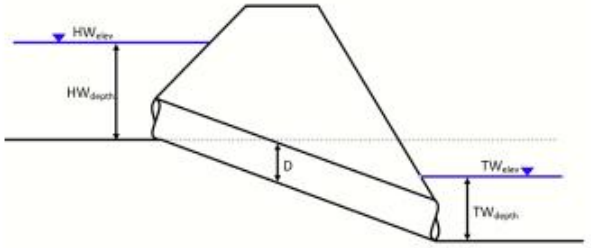


Figure 2: Illustration of condition where TW_{elev} is lower than upstream invert elevation; use HW-TW = HW_{depth}

Policy Memo #2 - Roadway/Railroad Embankments with Culvert Crossings

2. A conduit penetrating a roadway or railroad embankment is considered a dam when any one of these three conditions exists:
    a. HW-TW >10 feet and $HW_{depth}/D > 2$; or
    b. Permanent pool > 3 feet; or
    c. The culvert includes a structure to control water surface elevations (e.g., riser, weir).

   The Rational Method or other suitable method, determined by best professional judgment, may be used to calculate the HW and TW. Land use shall be based on ultimate development.
3. Conversely, a conduit penetrating a roadway or railroad embankment is considered a culvert when all four of these conditions are met:
    a. HW-TW < 10 feet or $HW_{depth}/D \leq 2$;
    b. Permanent pool ≤ 3 feet;
    c. There is no structure to control water surface elevations; and
    d. The embankment height is ≤ 35 feet
4. Crossings consisting of multiple pipes at significantly different invert elevations (more than one (1) foot difference in inverts or as stipulated for animal passage) or box culverts that are taller than they are wide are disqualified from using the criteria above when the capacity of the pipe(s) has been reduced such that it manages stormwater discharges. In these situations, the crossing will be considered to act as a dam. A dam breach analysis will be required, and the embankment will have to be designed in accordance with Dam Safety regulations and policies. The Department encourages the designer to re-configure the crossing and size the culvert(s) to not store water and to address stormwater management requirements in a separate BMP.
5. The above criteria for evaluating whether the roadway/railroad embankment is acting as a dam shall be applied to crossings that are interrupted by a structure (manhole or inlet) or consist of more than one section of pipe. If the downstream pipe section is smaller than the upstream pipe, D shall correspond to diameter of the smaller pipe.
6. Note that based on the roadway/railroad geometry alone, it may be possible to eliminate smaller embankments from consideration without calculating the headwater and tailwater. If the crest of roadway/railroad embankment is less than or equal to ten (10) feet above the downstream toe, then the crossing will be considered a culvert, assuming there is no riser (or similar water control structure) or no permanent pool deeper than three (3) feet.

7. Embankments taller than 35 feet shall be submitted to the Dam Safety Division for review through the Joint Permit Applicant process. The hydrologic & hydraulic analysis shall be based on NRCS methodology and ultimate development land use. A dam breach analysis shall be provided unless the embankment meets the all following criteria:
    a. HW-TW ≤ 10 feet or $HW_{depth}/D \leq 1.5$;
    b. Permanent pool ≤ 3 feet;
    c. There is no structure to control water surface elevations; and
    d. Smaller of brim-full storage volume or probable maximum flood (PMF) storage, is less than indicated in the following table.

Embankment Width*(ft.)	Max. Storage Volume (acre-ft.)
8 to 25 feet	5
25.01 to 50	20
50.01 to 75	60
75.01 to 100	100
100.01 and greater	Less than 150

*When brim-full storage volume controls, embankment width shall be measured at one (1) foot below the crest of the dam. When the PMF water surface elevation is less than the brim-full elevation, embankment width shall be measured at the PMF water surface elevation.

Embankments that meet criteria (a), (b), (c), and (d) will be considered low hazard and may, at the Department's discretion, be considered a culvert and will not require a Dam Safety Permit.

Additional Information

Questions about this policy or other items relating to ponds and dams can be directed to the Chief of the Dam Safety Division at 410-537-3538.

Dam Safety Permit

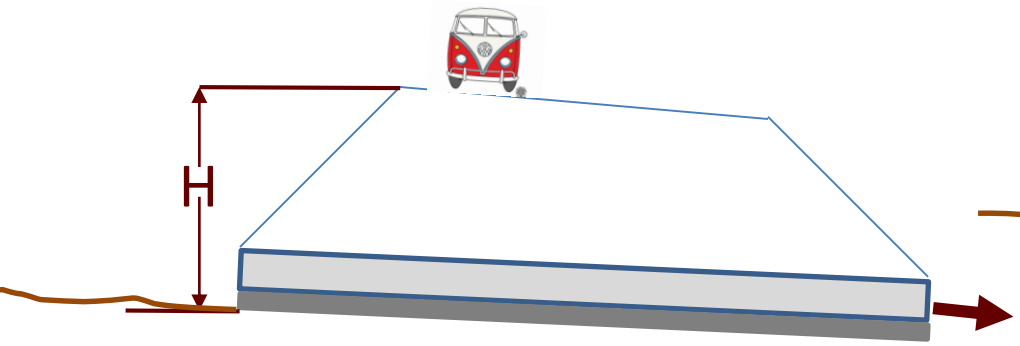
A Dam Safety Permit is required for a dam higher than 20 feet.

An application for a Dam Safety Permit is required for a conduit penetrating a roadway or railroad embankment higher than 35 feet.

20’x32' arch pipe with > 5000 ac-feet of storage at brim full embankment height = approximately 90 feet

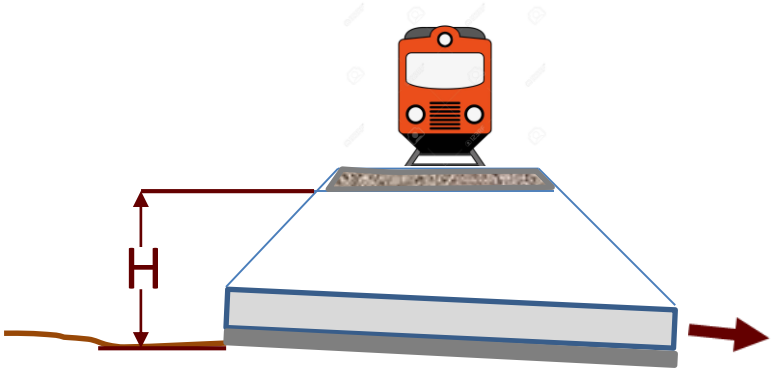
Embankment Height = #$%^?

For roadways:



The embankment height is measured from the lowest point of excavation or fill on the upstream slope of the embankment to the incipient point of overtopping.

For railroads:

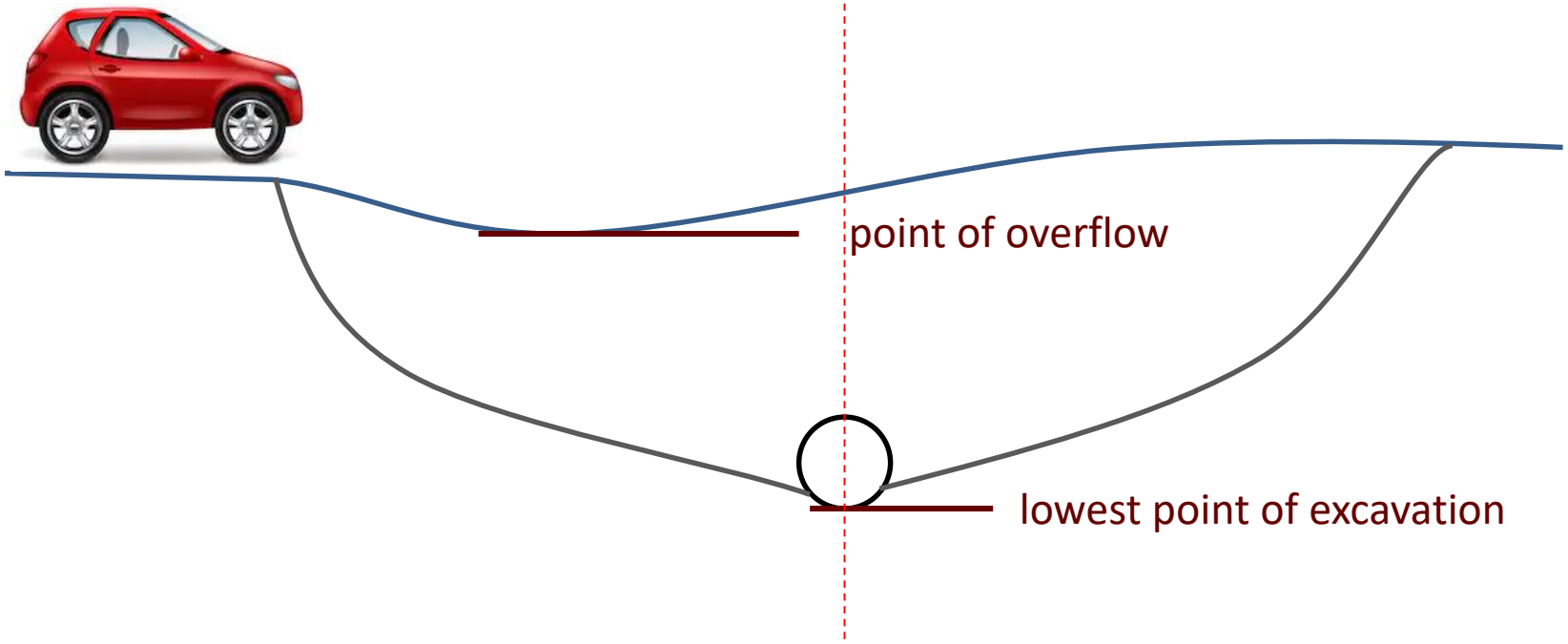


The embankment height is measured from the lowest point of excavation or fill on the upstream slope of the embankment to the subballast at the incipient point of overtopping.

Referred to as the “REGULATORY HEIGHT”

Upper Limit

The incipient point of overtopping may not occur on the same section as the culvert. Consider the profile of the roadway, not just the profile of the pipe.



The engineer's wife

A wife asks her husband, an engineer, "Darling, can you please go to the shop, buy one pint of milk, and if they have eggs, get a dozen!"

Off he goes. Half an hour later the husband returns with 12 pints of milk.

His wife stares at him and asks, "Why on earth did you get 12 pints of milk?"

"Well… they had eggs" he replied.

https://newengineer.com/insight/10-jokes-only-engineers-will-find-funny-1111728

Meaning of “or” and/or “and”????

A conduit penetrating a roadway or railroad embankment is considered a dam when any one of these three conditions exists:

a. HW-TW >10 feet and $HW_{depth}/D > 2$; or

b. Permanent pool > 3 feet; or

c. The culvert includes a structure to control water surface elevations.

Conversely, a conduit penetrating a roadway or railroad embankment is considered a culvert when all four of these conditions are met:

a. HW-TW ≤ 10 feet or $HW_{depth}/D \leq 2$;

b. Permanent pool ≤ 3 feet;

c. There is no structure to control water surface elevations; and

d. The embankment height is ≤ 35 feet

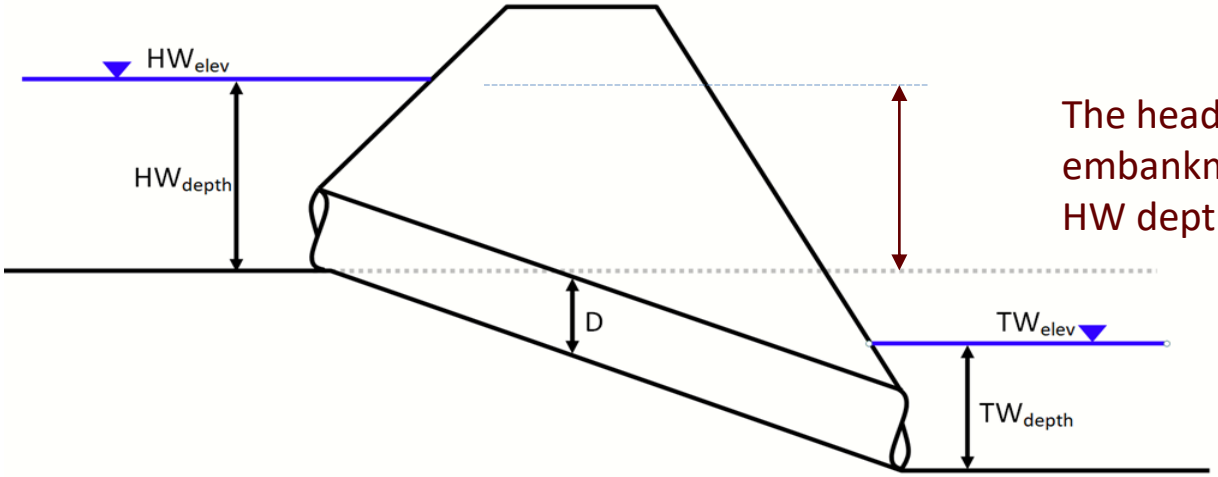
Culvert Criteria

A conduit penetrating a roadway or railroad embankment is considered a culvert when all four of these conditions are met:

a. HW-TW ≤ 10 feet or $HW_{depth}/D \leq 2$;
b. Permanent pool ≤ 3 feet;
c. There is no structure to control water surface elevations; and
d. The embankment height is ≤ 35 feet

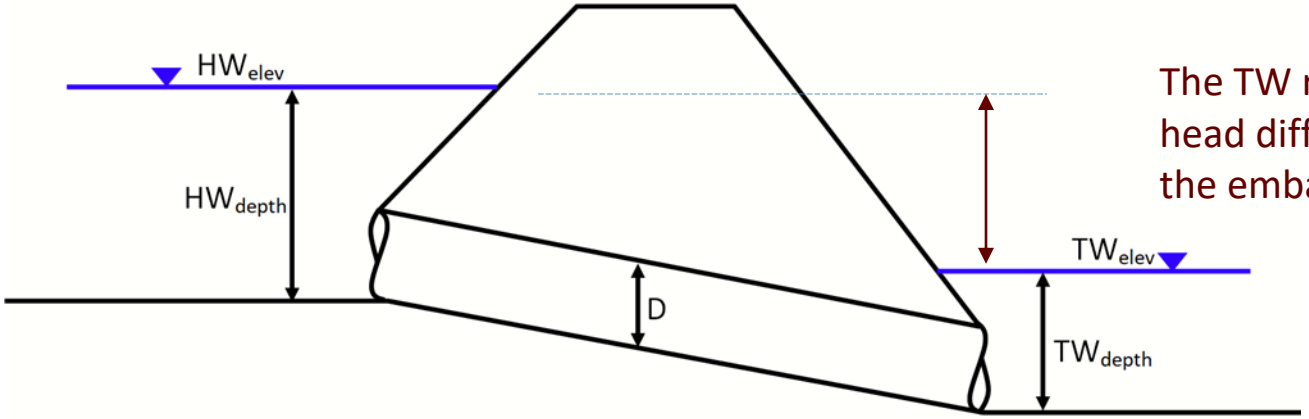
Headwater (HW) and Tailwater (TW)

TW elevation is lower than upstream invert elevation.
HW-TW = HW_{depth}



The head on the embankment is HW depth.

TW elevation is higher than upstream invert elevation.
HW-TW = $HW_{elev} - TW_{elev}$



The TW reduces the head differential on the embankment.

Design Capacity vs. Criteria for Evaluation

MDE is not saying that culverts must be designed to convey 100-year storm.

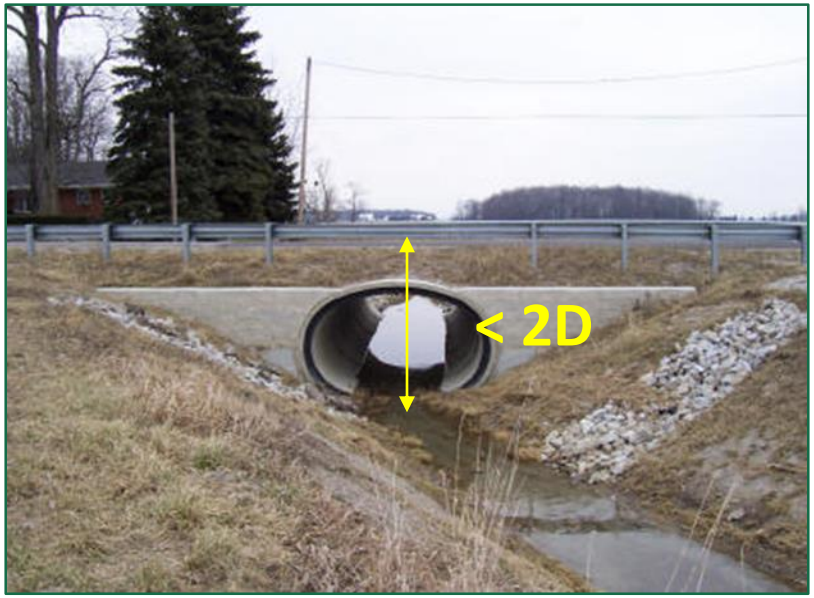
Design capacity is dependent on criteria for the class of road.

From a dam safety perspective, the concern is not whether a road overtops for 100-year storm or even the 10-year storm. The concern is how much water is impounded behind the roadway or railroad.

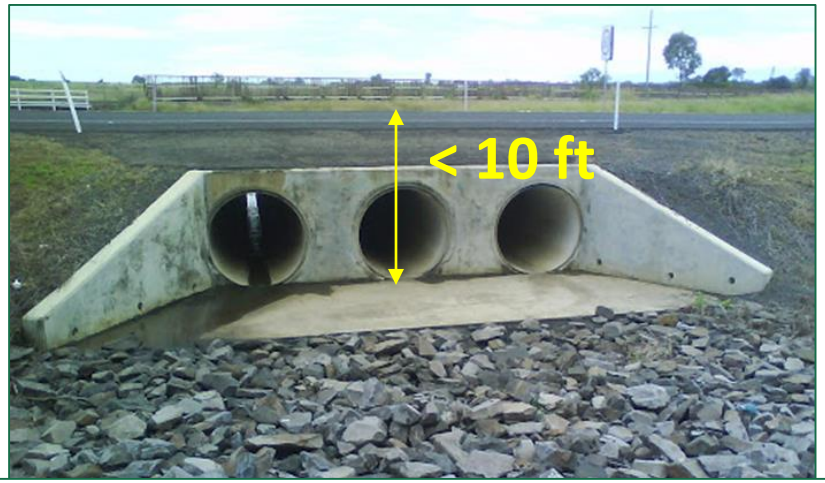
Culvert locations that can be eliminated as dams based on geometry

Assuming there is no control structure or no permanent pool deeper than 3 feet, then a crossing will not be considered a dam:

if the distance from the upstream toe to the crest of the roadway/railroad is less than twice the diameter of the pipe



if the crest of roadway/railroad embankment is ≤ 10 feet above the downstream toe



Note that D = diameter of single pipe, not the effective diameter of three pipes.


WAKE
UP!

A TRAIN IS COMING!!

Acceptable Hydrologic Modeling

NRCS methodology (TR-55 and TR-20) - yes ✓

Routing that includes storage behind culvert - yes ✓

Rational Method - no ✗

PM #2 currently states that the Rational Method is acceptable for embankments under 35 feet, but that is going to be revised.

“structure to control WSEL”

A conduit penetrating a roadway or railroad embankment is considered a dam when any one of these three conditions exists:

a. HW-TW >10 feet and $HW_{depth}/D > 2$; or

b. Permanent pool > 3 feet; or

c. The culvert includes a structure to control water surface elevations.

Conversely, a conduit penetrating a roadway or railroad embankment is considered a culvert when all four of these conditions are met:

a. HW-TW ≤ 10 feet or $HW_{depth}/D \leq 2$;

b. Permanent pool ≤ 3 feet;

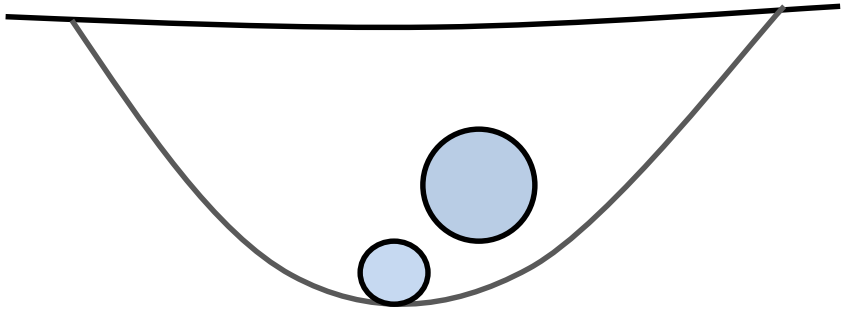
c. There is no structure to control water surface elevations; and

d. The embankment height is ≤ 35 feet

What Constitutes a Control Structure?

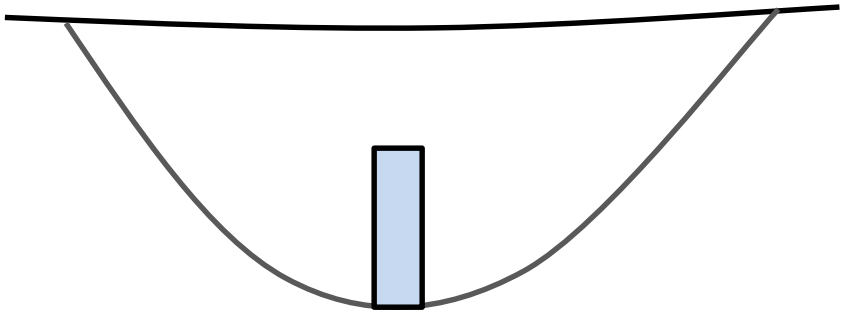
- Riser
- Weir or orifice plate
- Valve
- Multiple culverts set at different elevations
- Weir wall upgrade of culvert
- Gabion baskets configured in a horseshoe around culvert entrance
- Upstream “dam” that really isn’t a dam
- In short, any structure that controls the flow into the culvert!

“No Go’s”



Two culverts under the roadway

- Lower culvert to convey the 10-year storm
- Higher culvert to convey the 100-year storm.

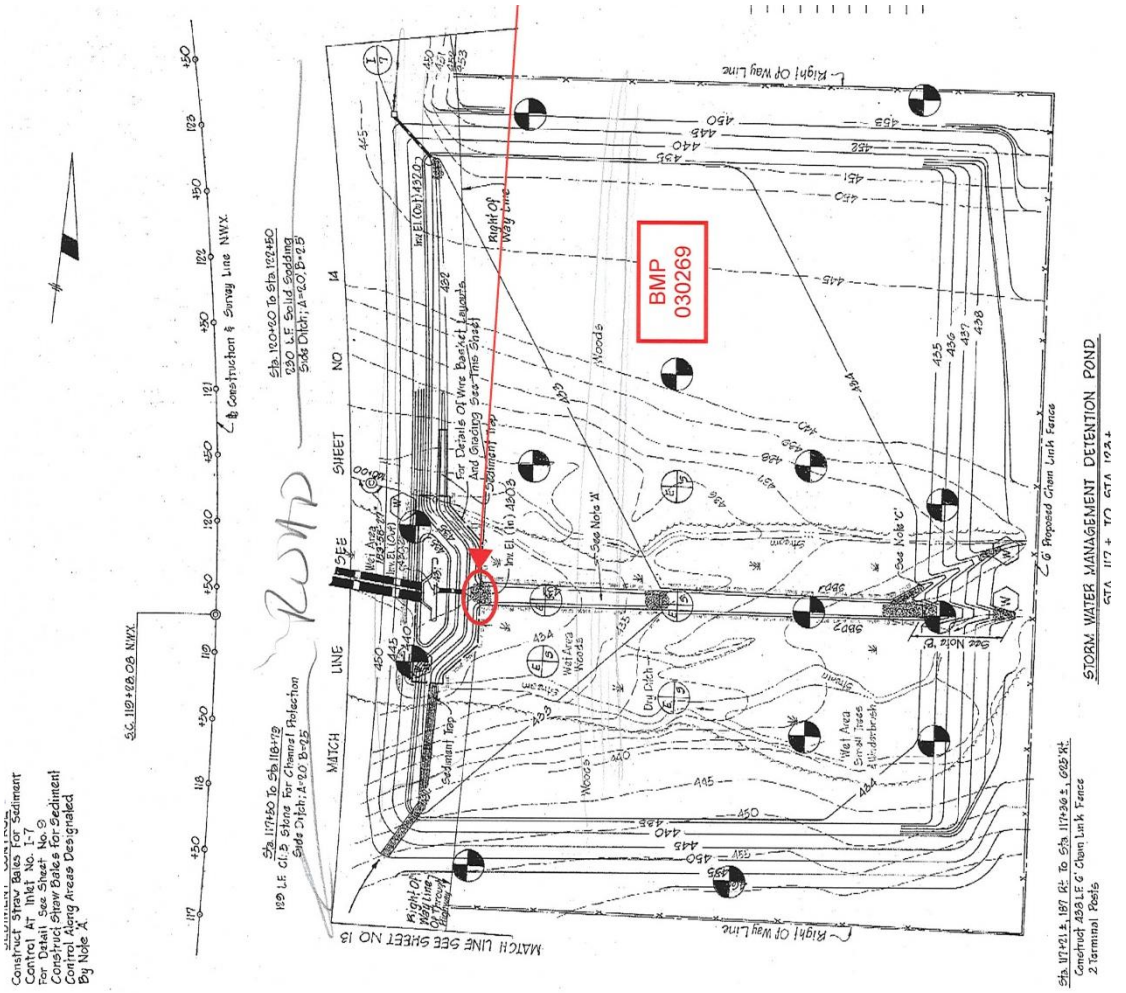


Tall, narrow box culvert

The only reason for doing this is to intentionally attenuate 10-year flow attenuation.

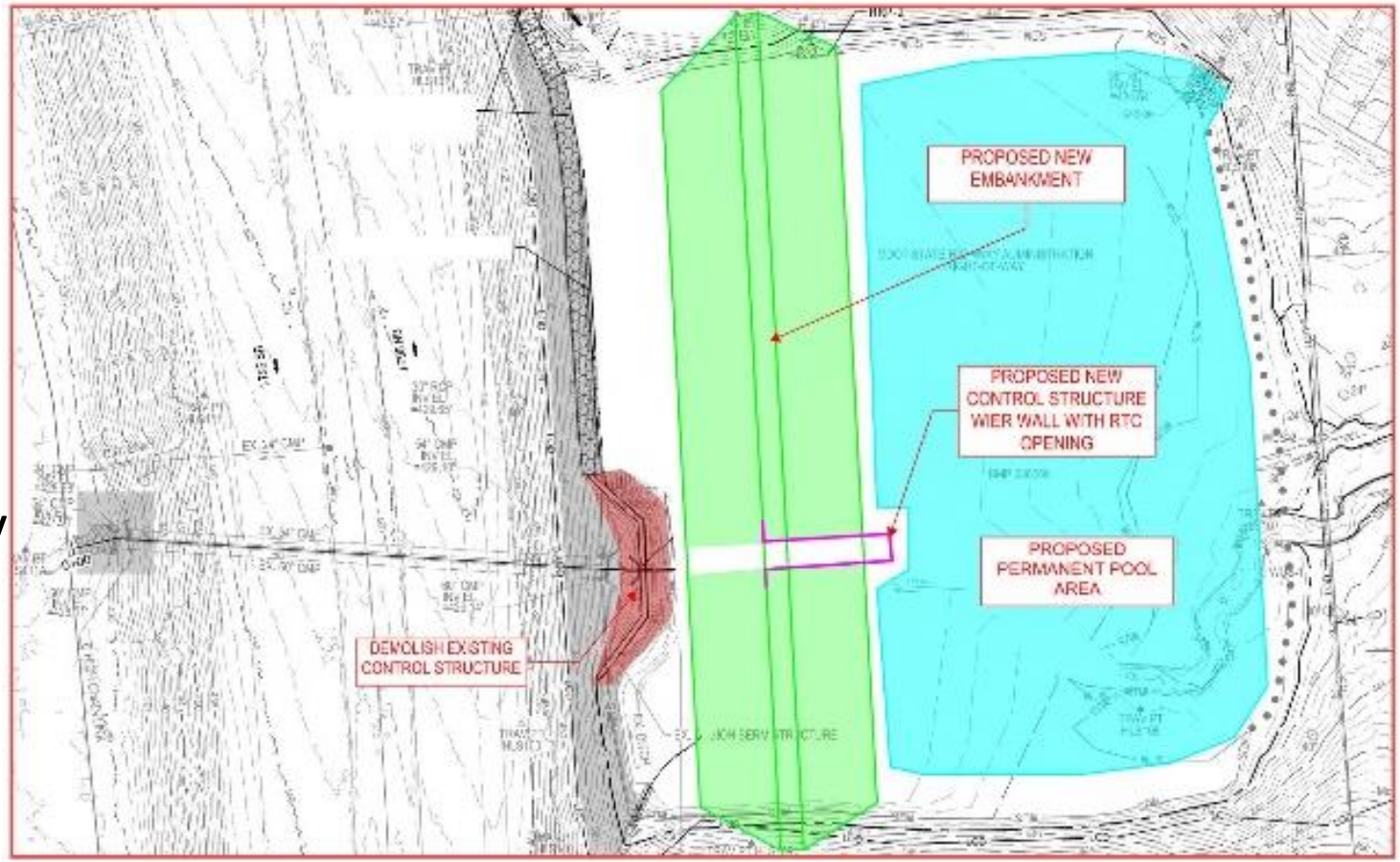
Control Structure vs. Interior Dam

The berm constructed with a low flow pipe upstream of the roadway culverts is a <u>control structure</u> because the 100-year water surface is impounding against the roadway embankment.



Control Structure vs. Interior Dam

The proposed embankment upstream of the roadway acts as dam independent of the roadway embankment.



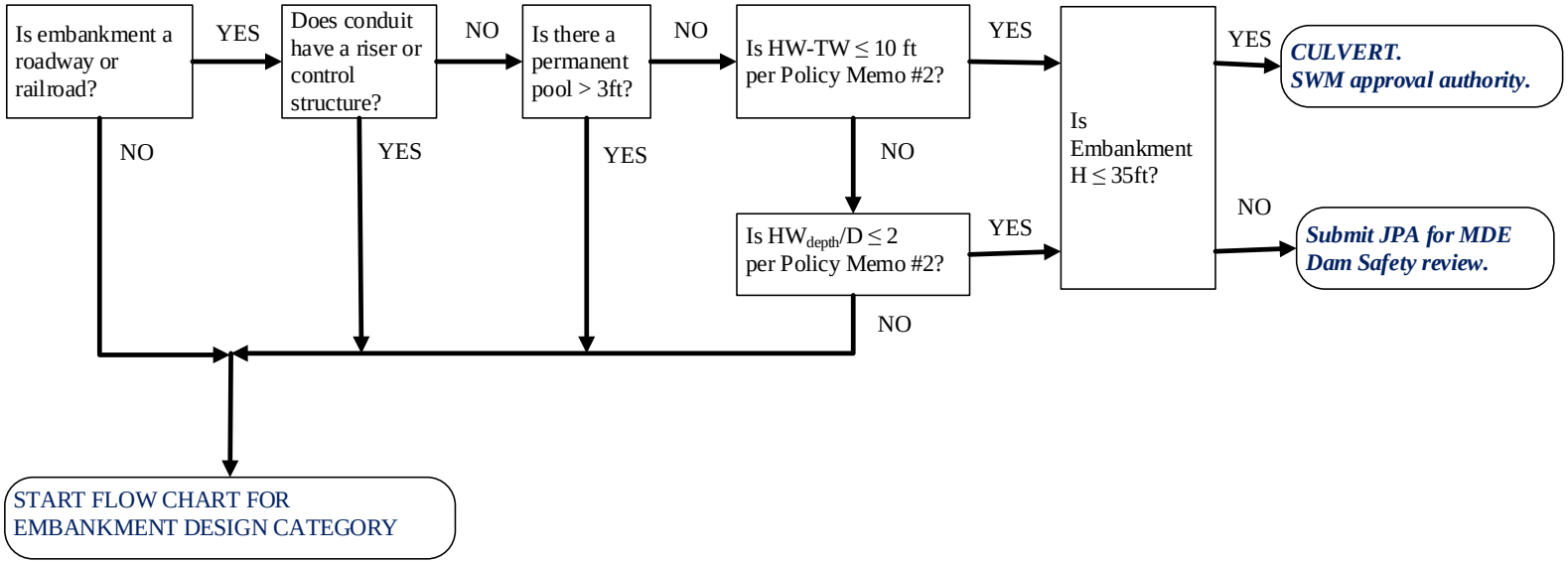
Culvert? Small pond? Dam?

A roadway/railroad embankment with a culvert crossing will fall into one of three categories:

- If H ≤ 35 feet and culvert criteria is met, the embankment is a culvert crossing.
- If H ≤ 20 feet and the culvert criteria is not met, then a DBA is needed to determine the hazard class of the dam. Low hazard structures are Code 378 small ponds (reviewed by small pond approval authority), and higher hazard structures require a Dam Safety Permit.
- If 20 feet ≤ H ≤ 35 feet and the culvert criteria is not met, then the embankment is a dam and requires a DBA and Dam Safety Permit.
- If H > 35 feet, an application for a Dam Safety Permit and DBA are required, and MDE Dam Safety will decide the category.

Confused? Here's a flow chart.

MDE Sediment, Stormwater, and Dam Safety Program
Flow Chart for Determining Embankment Design Category and Approval Authority



The Objective

1. Size new culverts to avoid damming behind railway/roadway embankment.

2. Identify existing problem spots through screening,
   – when culvert repairs or extensions are being proposed
   – when existing culverts are present on a project

3. Consider competing interests:
   - Controlling peak discharge rates
   - Avoiding hydraulic trespassing upstream and downstream

4. Work together to determine corrective measures.

What can you do?

- Evaluate culverts within the footprint of your project.

  (Hopefully, it will only take a quick screening.)

- Include your evaluation in the SWM report and submit to the approval authority.

- Be up front. It's in everyone's best interest to flag problem locations.

The Million Dollar Question

What happens when an existing culvert crossing does not meet the culvert criteria?

Provide as much information as possible: dam breach analysis, full inspection, compaction tests, as-built plans.

Case-by-case evaluation, taking into consideration:

- Proposed work, if any;
- Integrity of embankment and pipe;
- Girth of embankment;
- Results of dam breach analysis and hazard classification;
- Purpose of transportation way (type of road, freight rail, or passenger rail);
- Potential upstream and downstream impacts from changing design;
- Effectiveness and feasibility of no action vs. remedial action vs. corrective action;
- Everything else that's important.

Culvert under Railroad

Culvert Slip Lining

Trenchless Railroad Culvert Replacement

Hurry back John!

The newest addition to the Dam Safety team.