NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Climate Resilient Design for Culverts and Pavements

December 5, 2023

2:00 – 3:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING
RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

AICP Credit Information

1.5 American Institute of Certified Planners Certification Maintenance Credits

You must attend the entire webinar

Log into the American Planning Association website to claim your credits

Contact AICP, not TRB, with questions

Purpose Statement

This webinar will provide proven methods of culvert design to minimize damage from climate-related major storms, including the concept of stream simulation. Presenters will discuss techniques to minimize pavement damage.

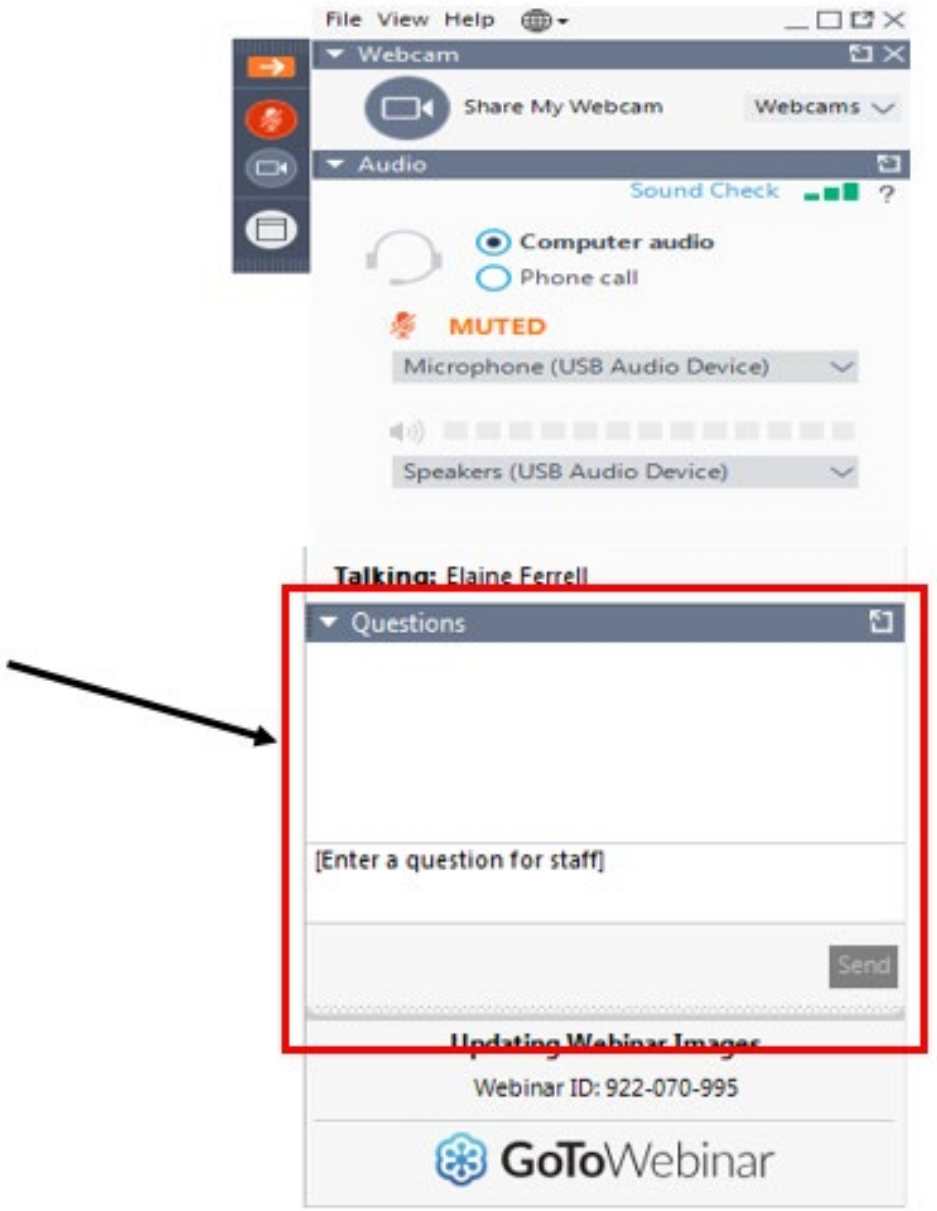
Learning Objectives

At the end of this webinar, you will be able to:

- Design culverts to simulate actual stream dimensions and function to reduce the risk of failure during storms
- Better understand the design of low-volume roads and how their pavements may be adapted to changing climate conditions

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Laura Fay
laura.fay1@montana.edu
Western Transportation Institute, Montana

David Orr
david.orr@cornell.edu
Cornell University

Mark Weinhold
mark.weinhold@usda.gov
U.S. Forest Service

Road-Water Interactions

Toward Climate Resilient Infrastructure

Mark Weinhold, P.E.
Hydraulic Engineering / Hydrology
US Forest Service

National Forest System

380,000 MI LOW VOL ROAD
(65,000 STREAM CROSSINGS)

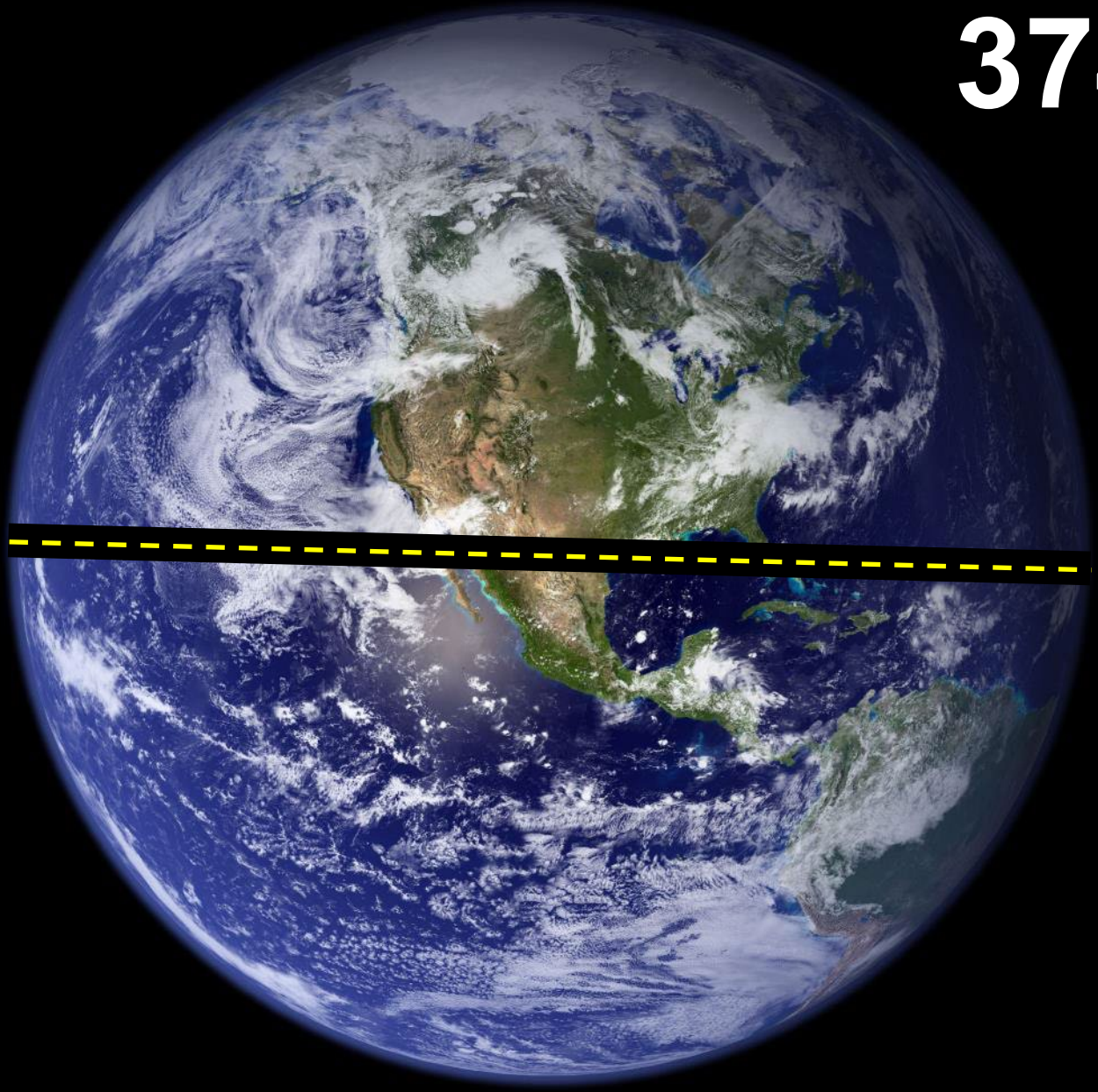
193 MILLION ACRES

Access to Manage Natural Resources

“The road to development begins with the road”


15 million km
18 10 2005
Photo: G. Keller

374 x

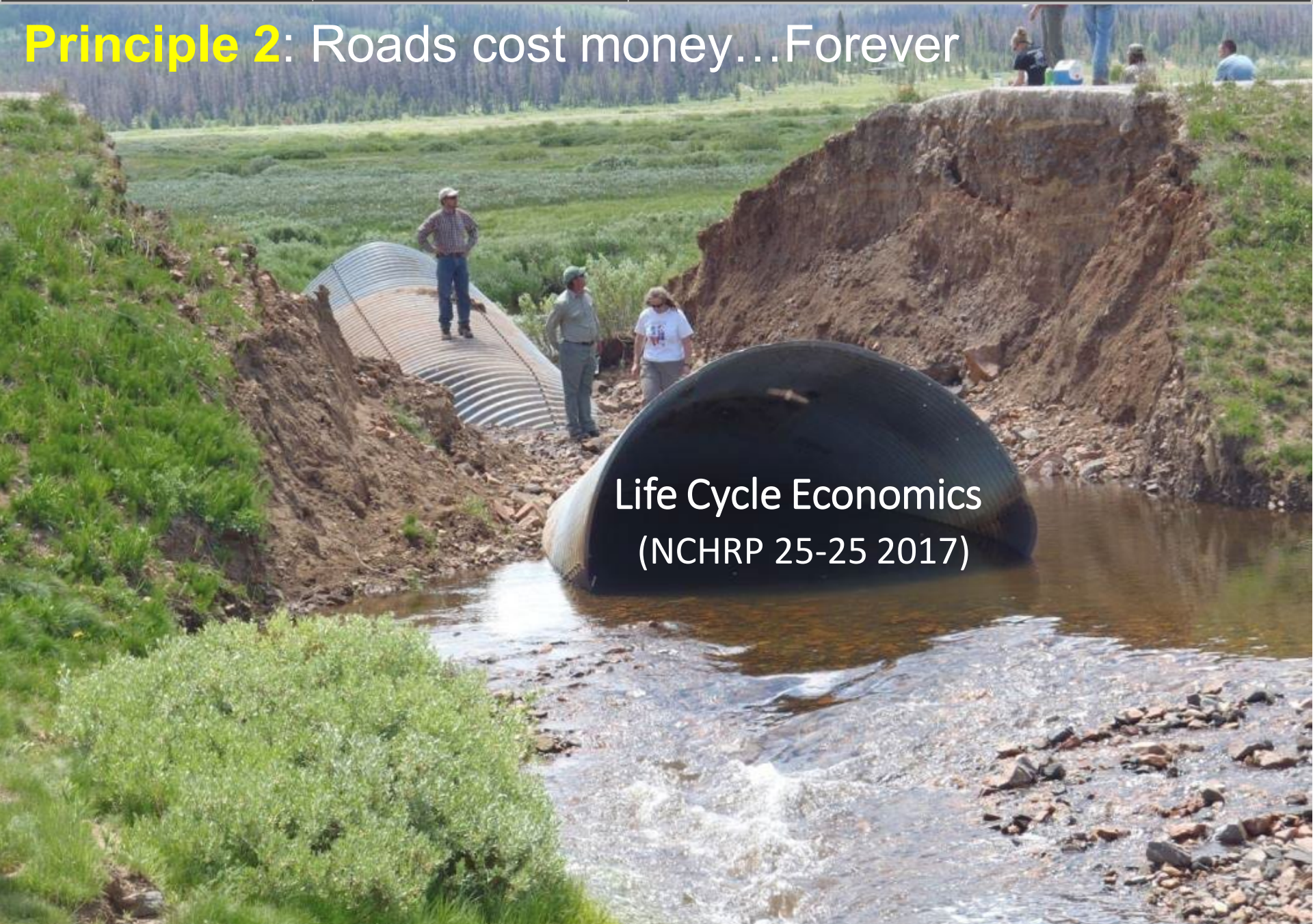


Some guidance might be helpful…

Trishuli River, Nepal

Principle 1: Money builds roads; Geology and Climate decide if they stay

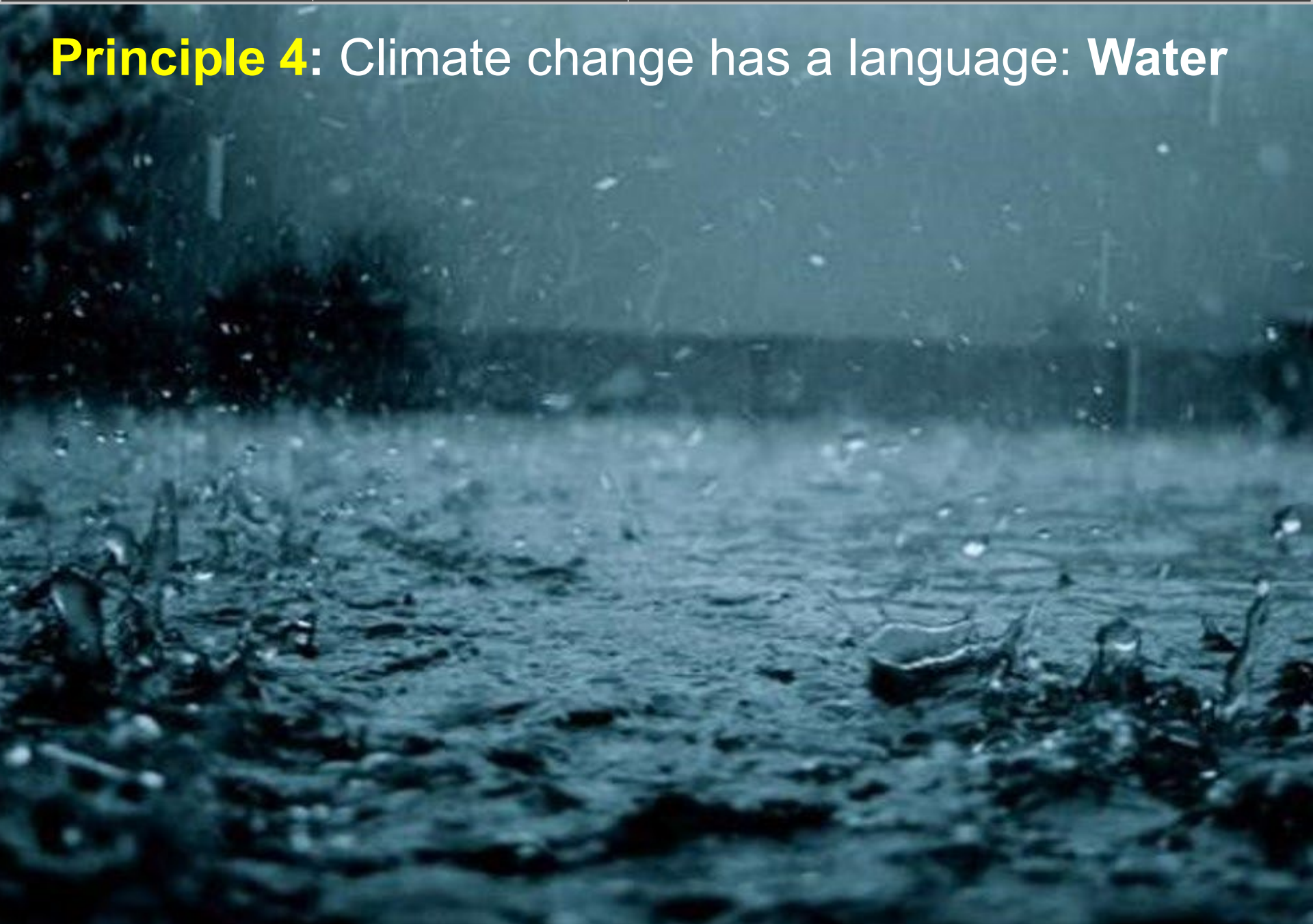
Principle 2: Roads cost money…Forever

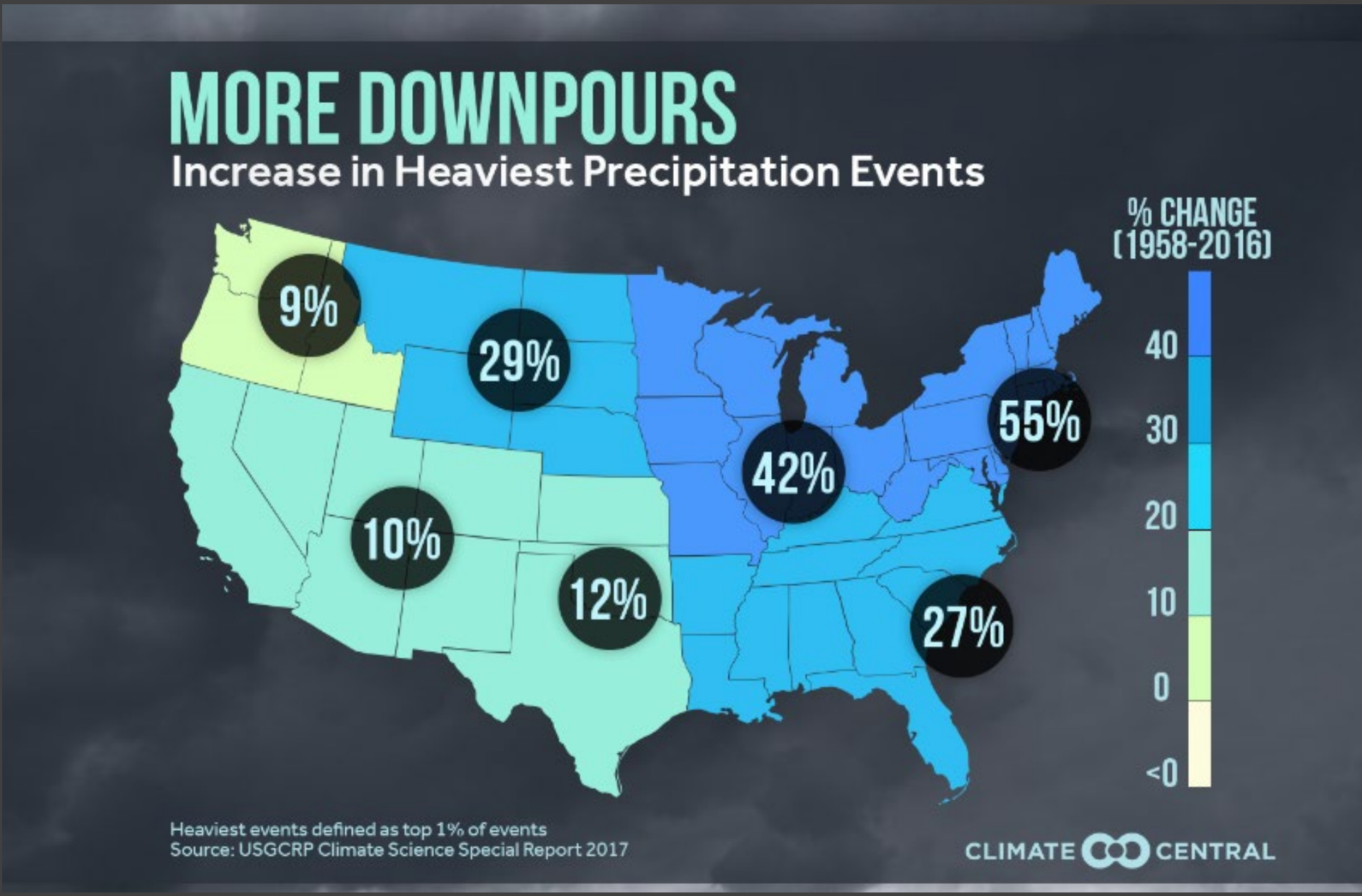


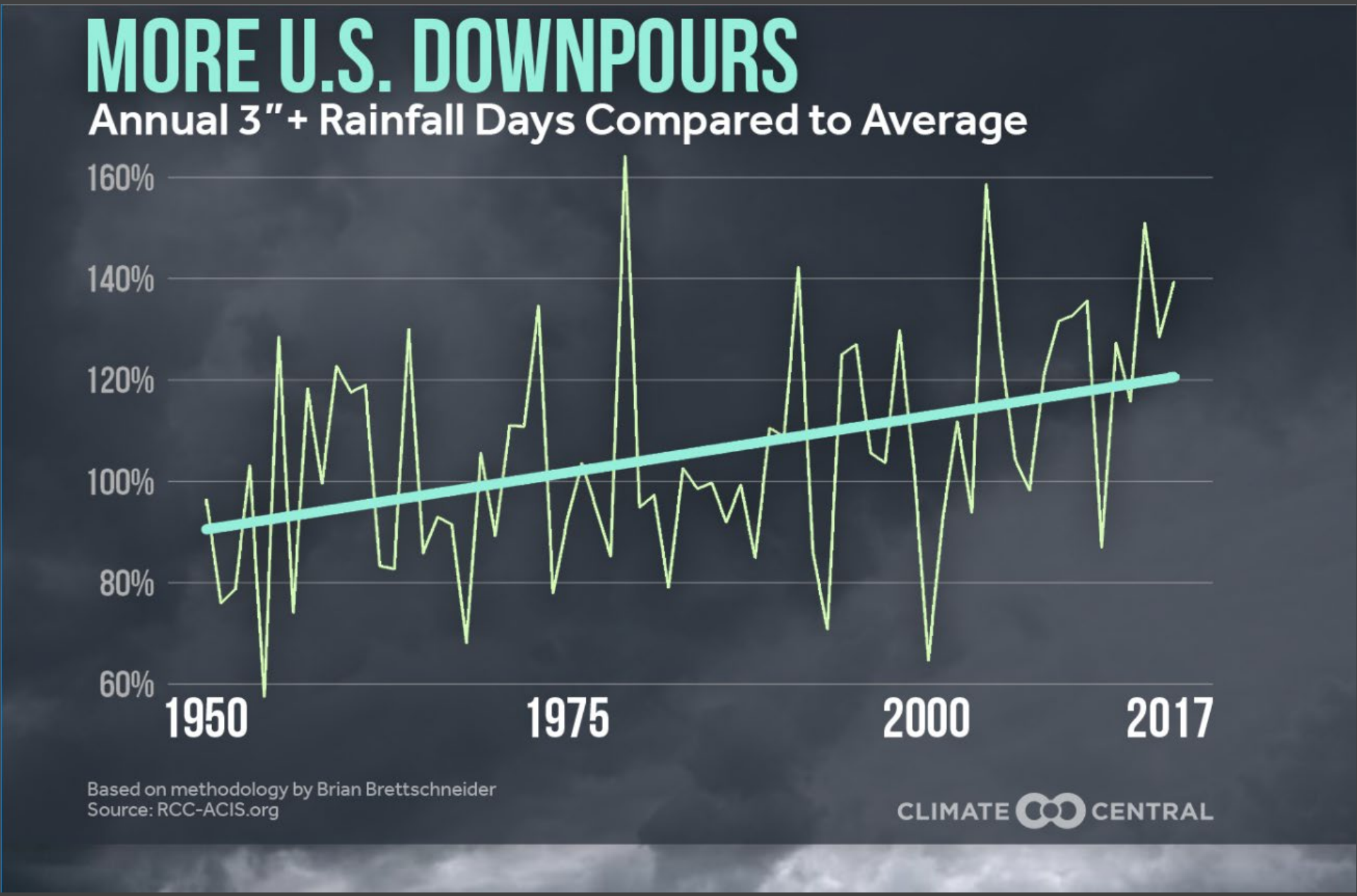

Principle 3: Best predictor of failure is proximity to water

Road-Stream crossings are ground zero

Principle 4: Climate change has a language: **Water**




MORE DOWNPOURS
Increase in Heaviest Precipitation Events
% CHANGE (1958-2016)
40
30
20
10
0
<0
9%
29%
55%
42%
10%
12%
27%
Heaviest events defined as top 1% of events
Source: USGCRP Climate Science Special Report 2017
CLIMATE CENTRAL


MORE U.S. DOWNPOURS
Annual 3"+ Rainfall Days Compared to Average
160%
140%
120%
100%
80%
60%
1950
1975
2000
2017
Based on methodology by Brian Brettschneider
Source: RCC-ACIS.org
CLIMATE CENTRAL

Principle 5: Rivers play the long game

Corollary: Water always wins

Principle 6a: More than water arrives at a pipe inlet

Principle 6b: More than water arrives at a pipe inlet


non-fish fish
WEMAYFLY.ORG
© FRESHWATERS ILLUSTRATED


210 amphibians
WEMAYFLY.ORG
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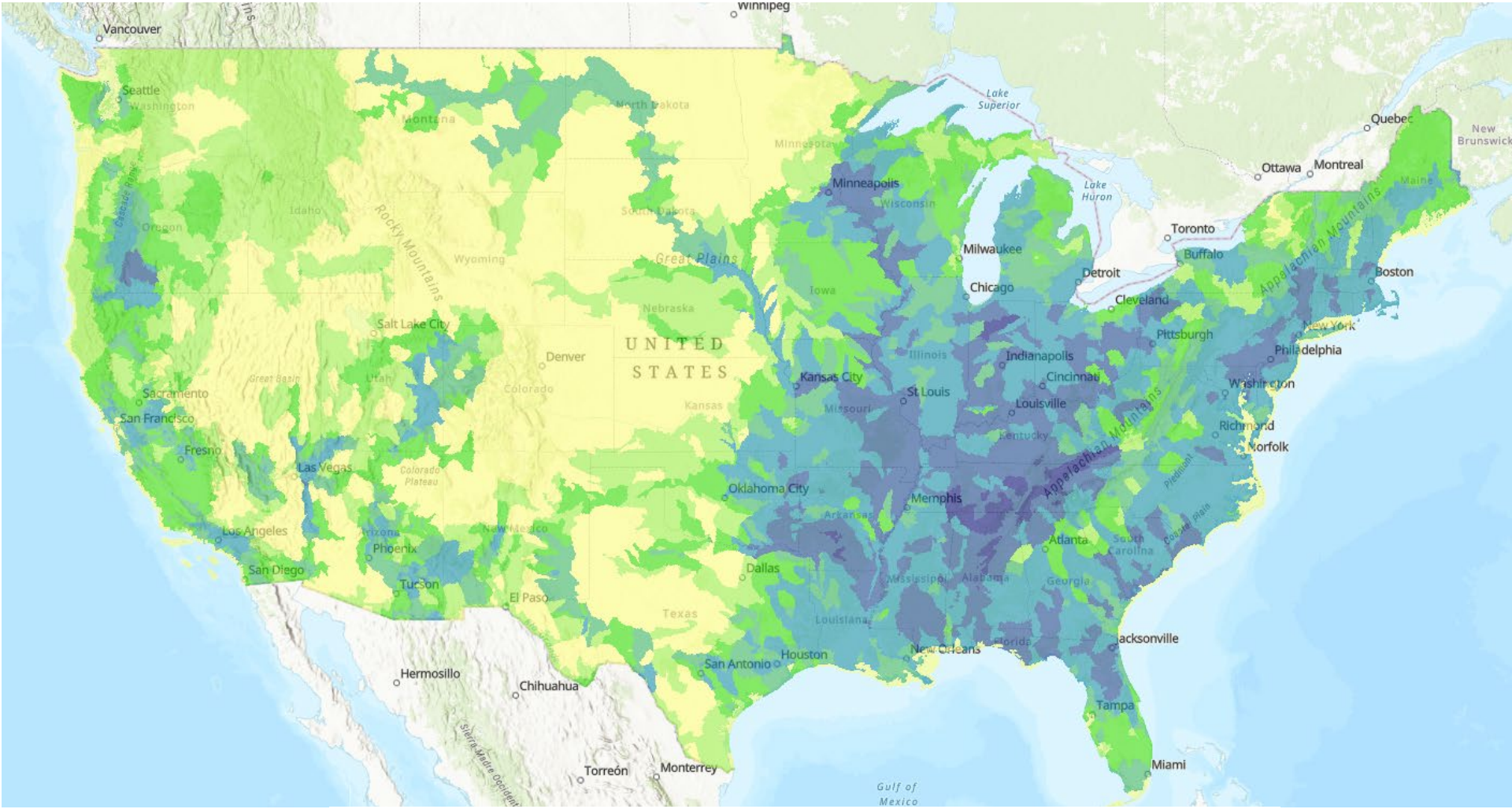
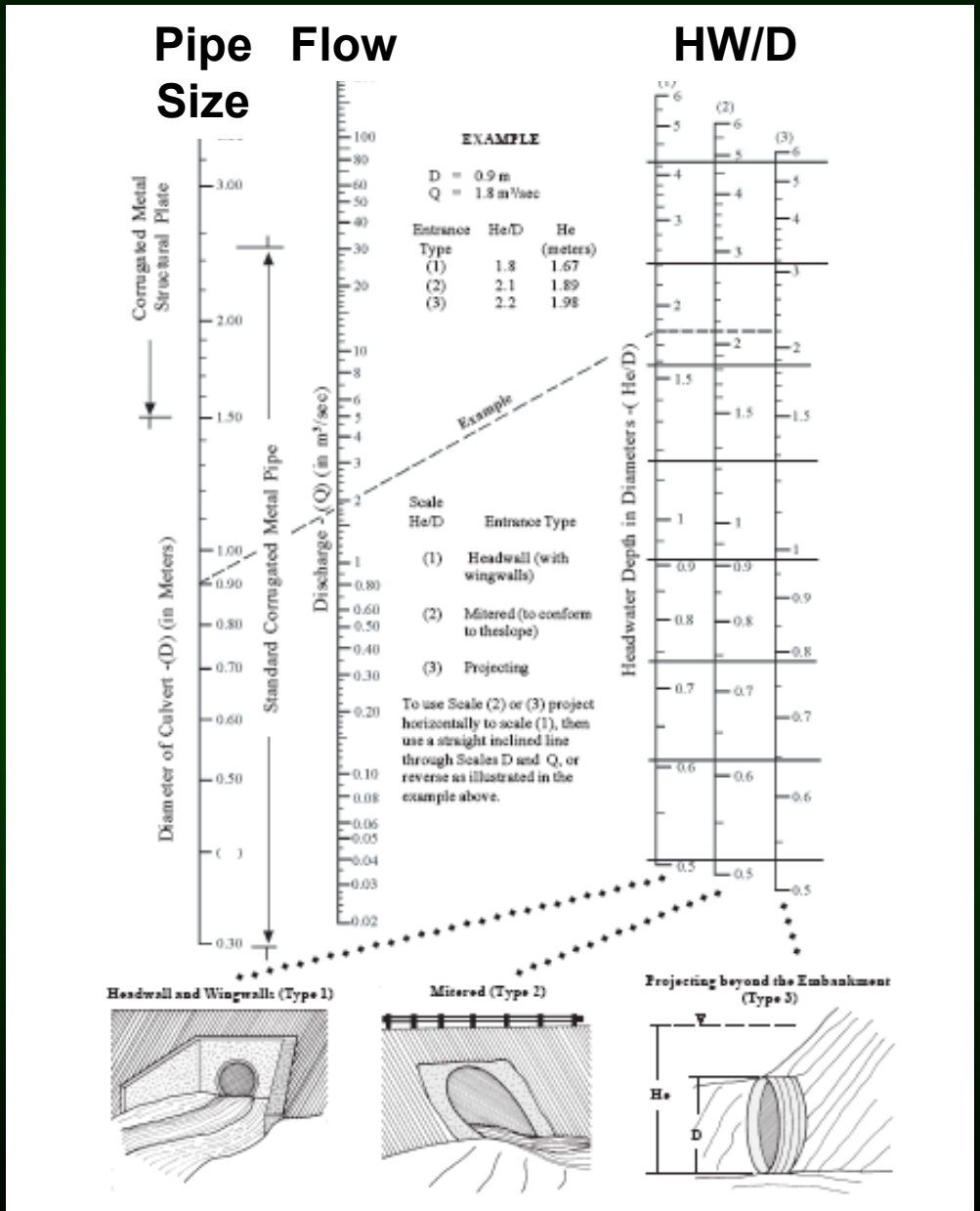
Vulnerable Aquatic Species

187 THREATENED OR ENDANGERED



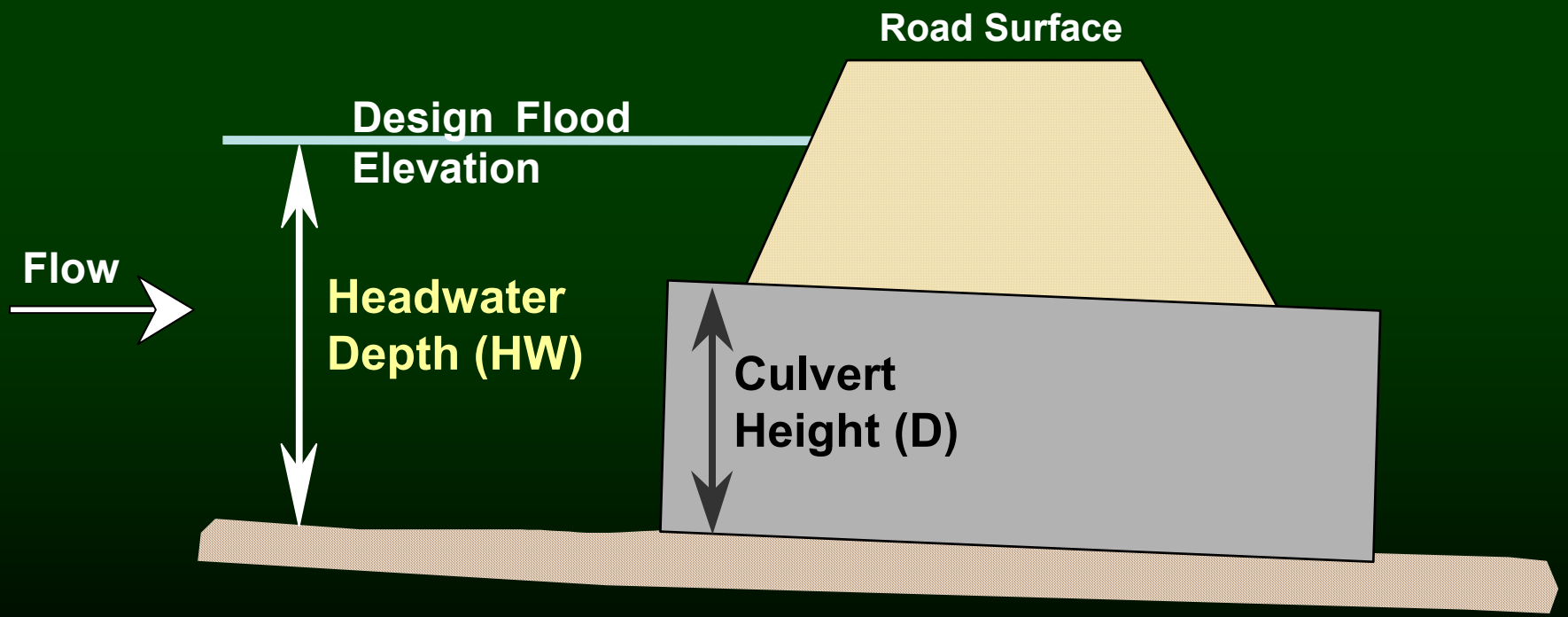
https://enviroatlas.epa.gov/enviroatlas/interactivemap/

Principle 7: Transcend the nomograph

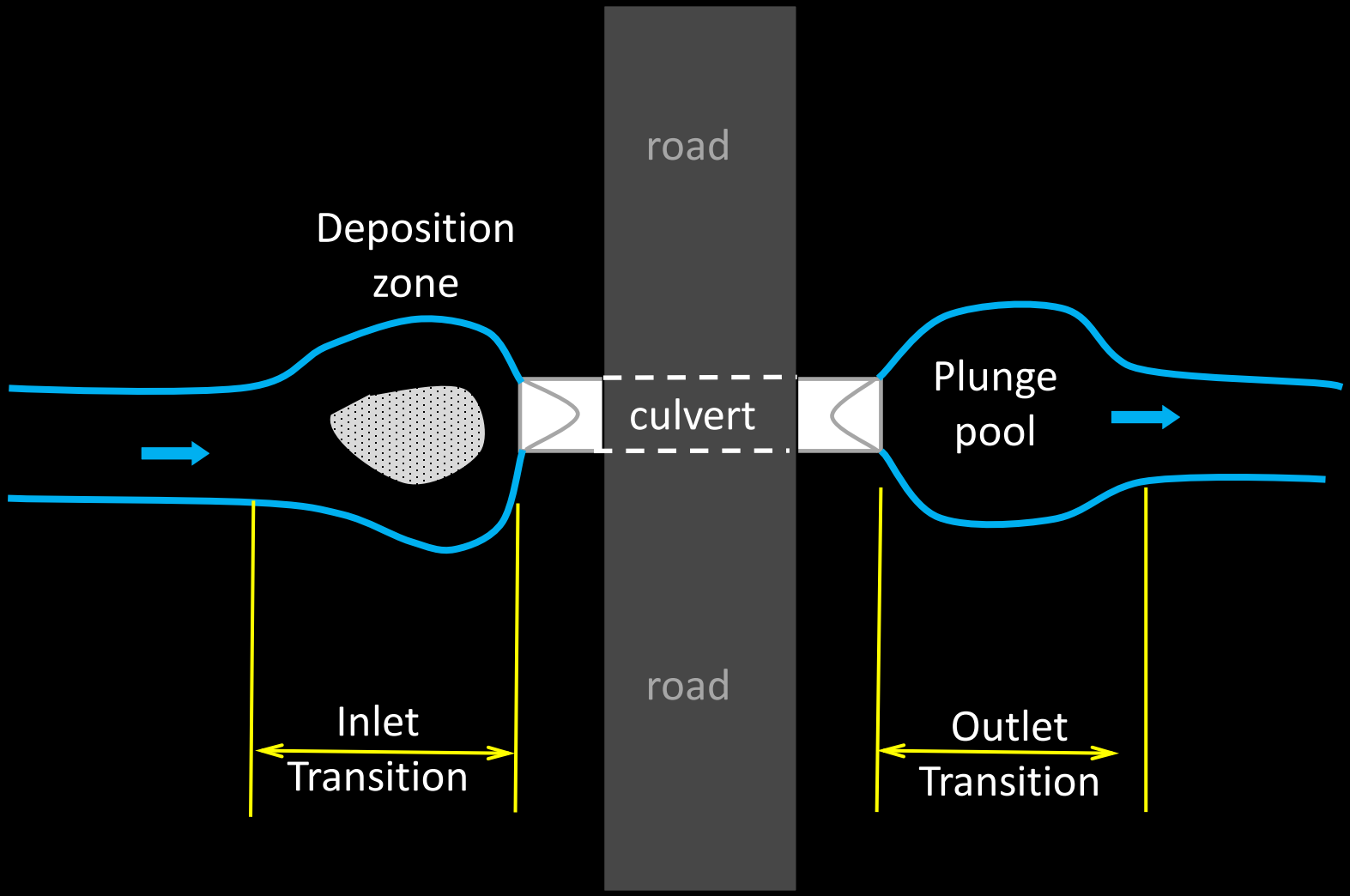


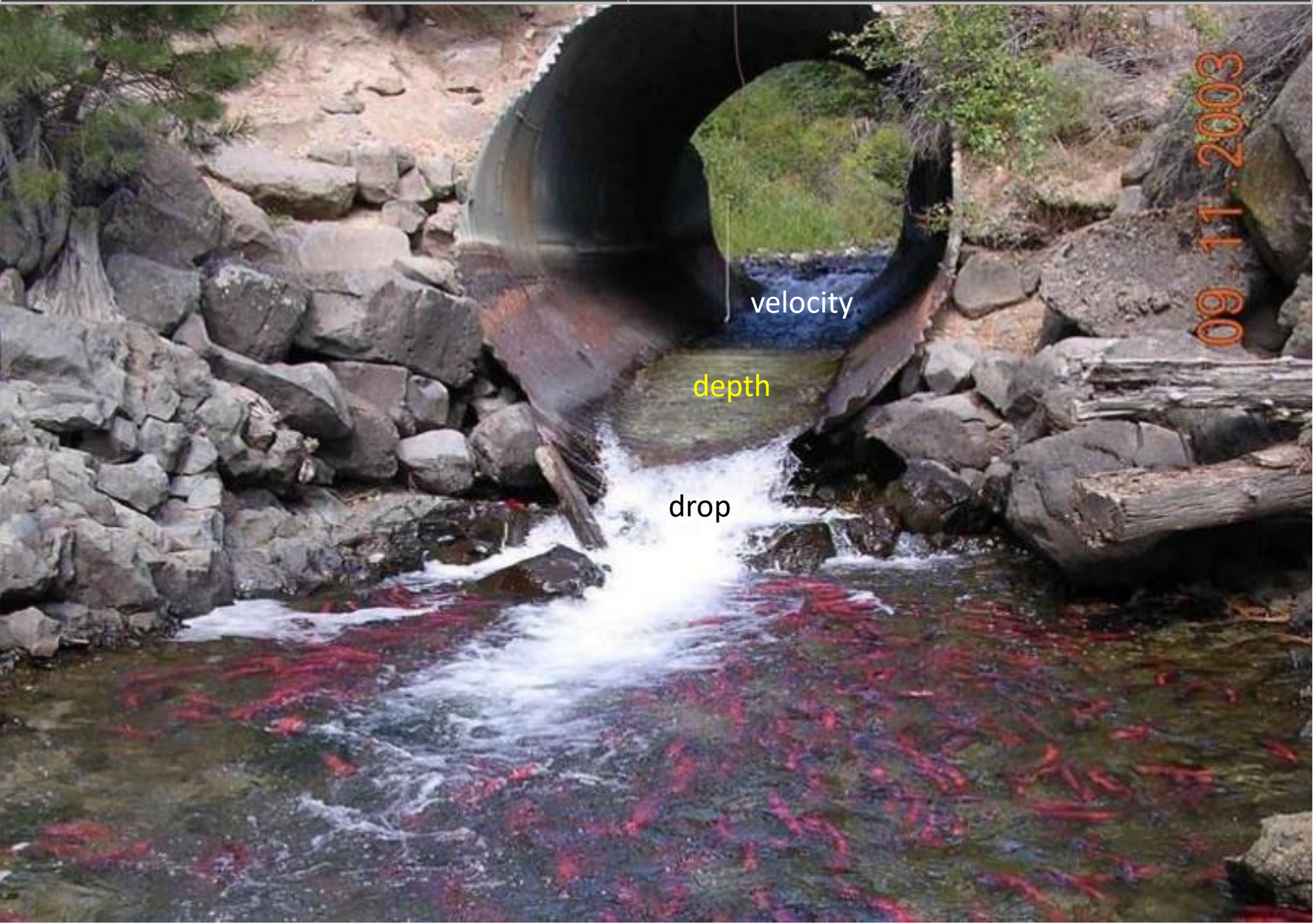
Hydraulic Design:

An old way of thinking



Undersized Culvert Anatomy




09 11 2003
velocity
depth
drop

Failure by abrasion


Streams have something to tell us…
Diameter
Width


(ESA inspired) culture shift

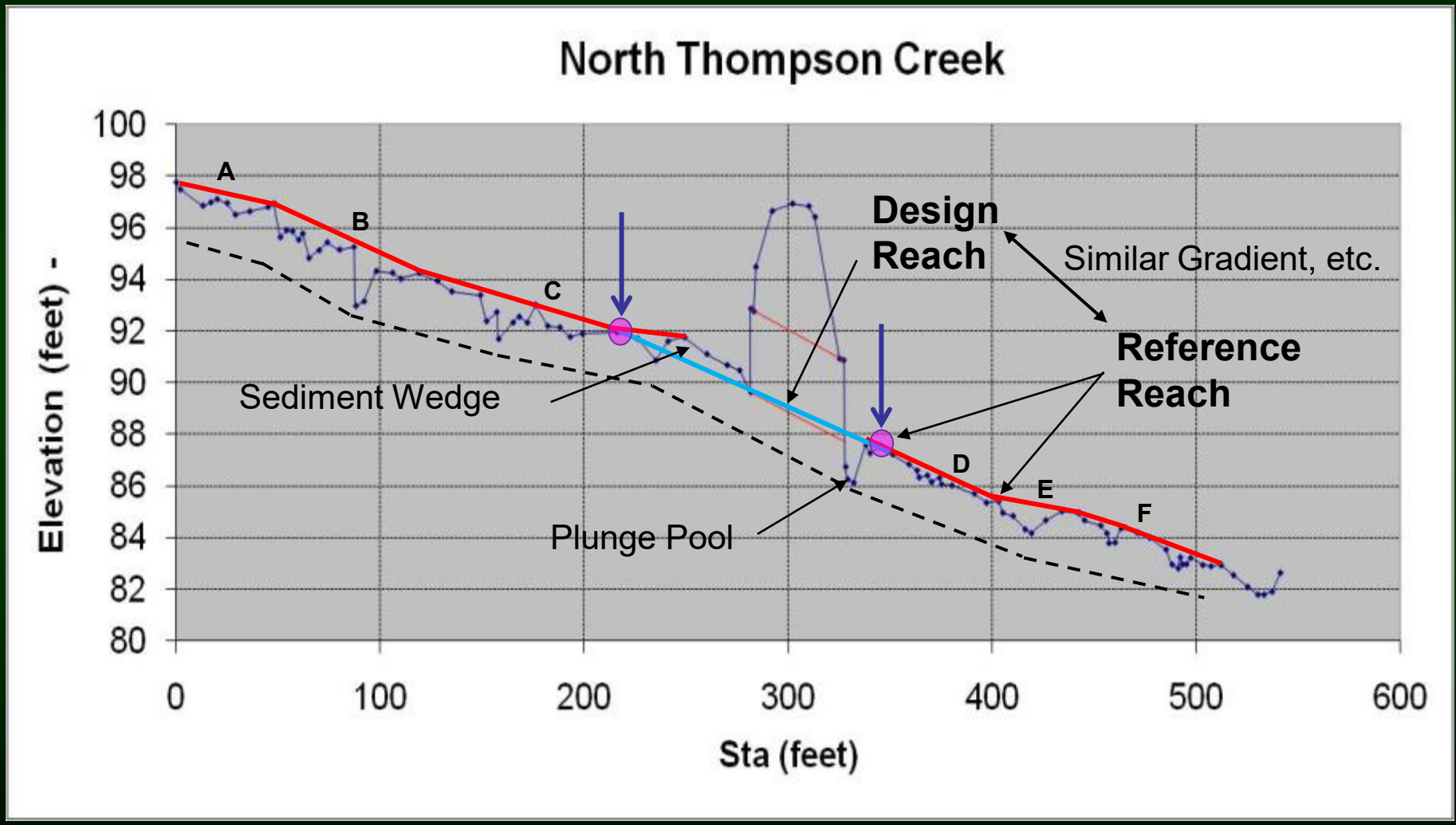
USFS Methodology – Stream Simulation

Build a stream and put a lid over it

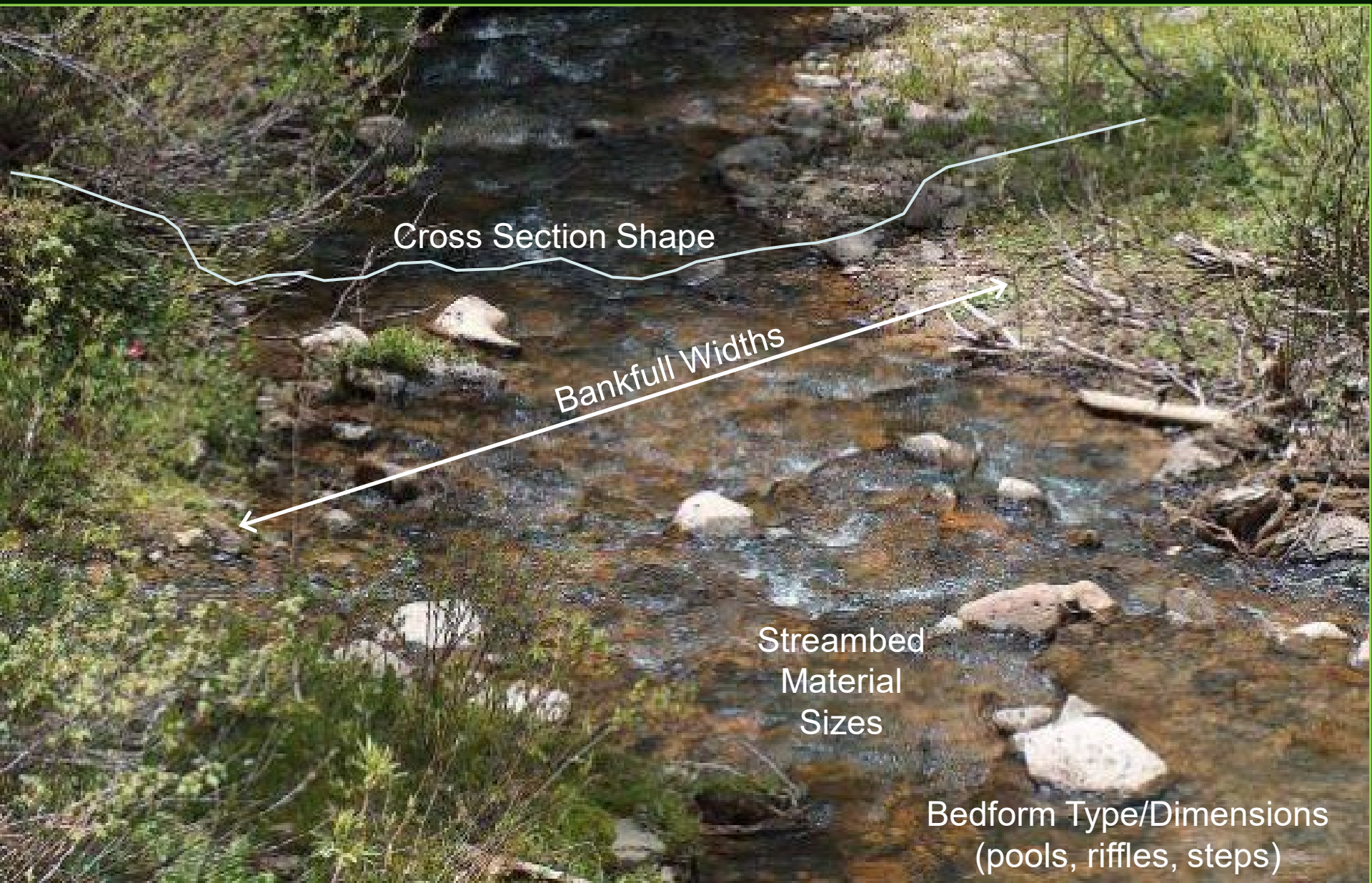
Stream Simulation Fundamentals

- Reference reach
  - Simulate natural channel
  - Bankfull cross section shape and dimensions
  - Channel slope
  - Channel structure
- Geomorphic design
  - Fits with and in equilibrium with adjacent reaches
  - Dynamically sustained over a broad range of flows
  - “Mobile bed in stable channel”

Project Design Profile

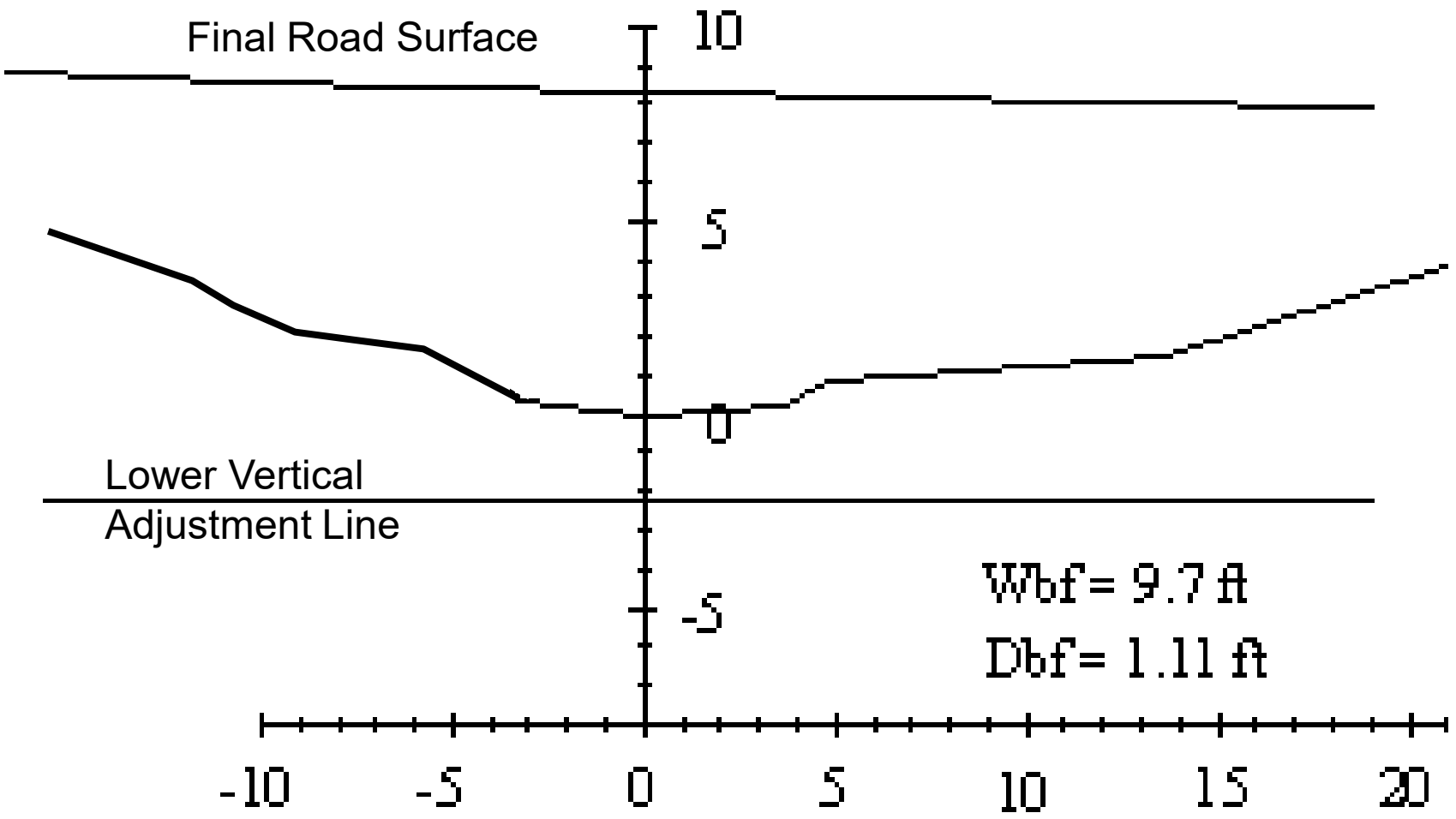


Reference Reach Concept ~ TEMPLATE

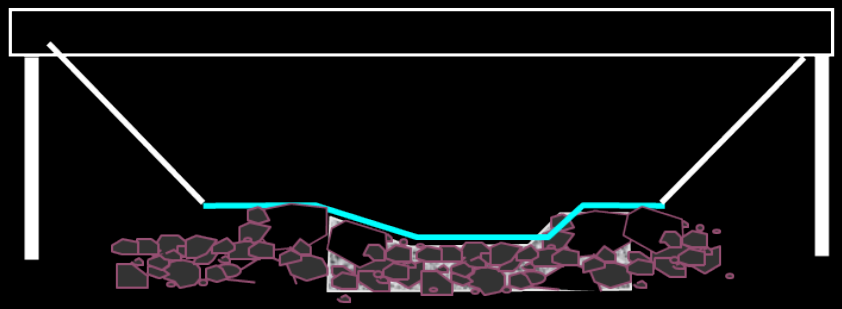


Structure Selection –

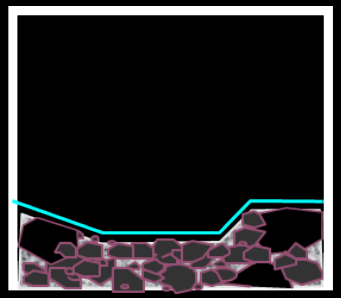
Shape from Reference Reach XSECT



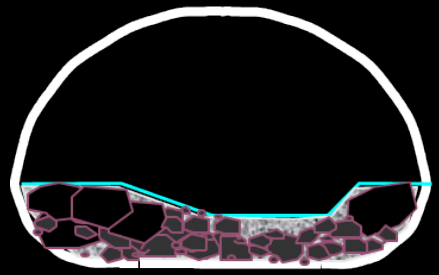
Same stream, different lid



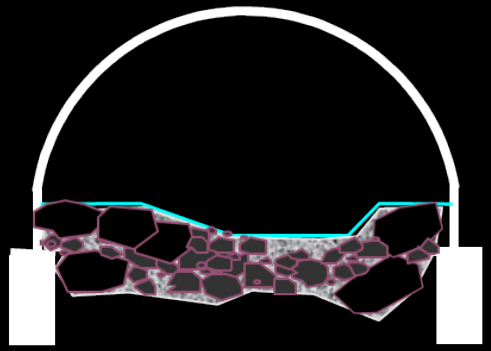
a. Bridge



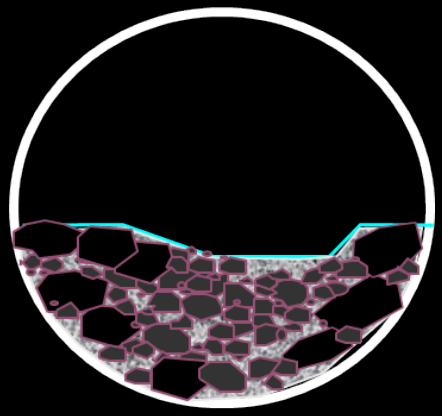
b. Box



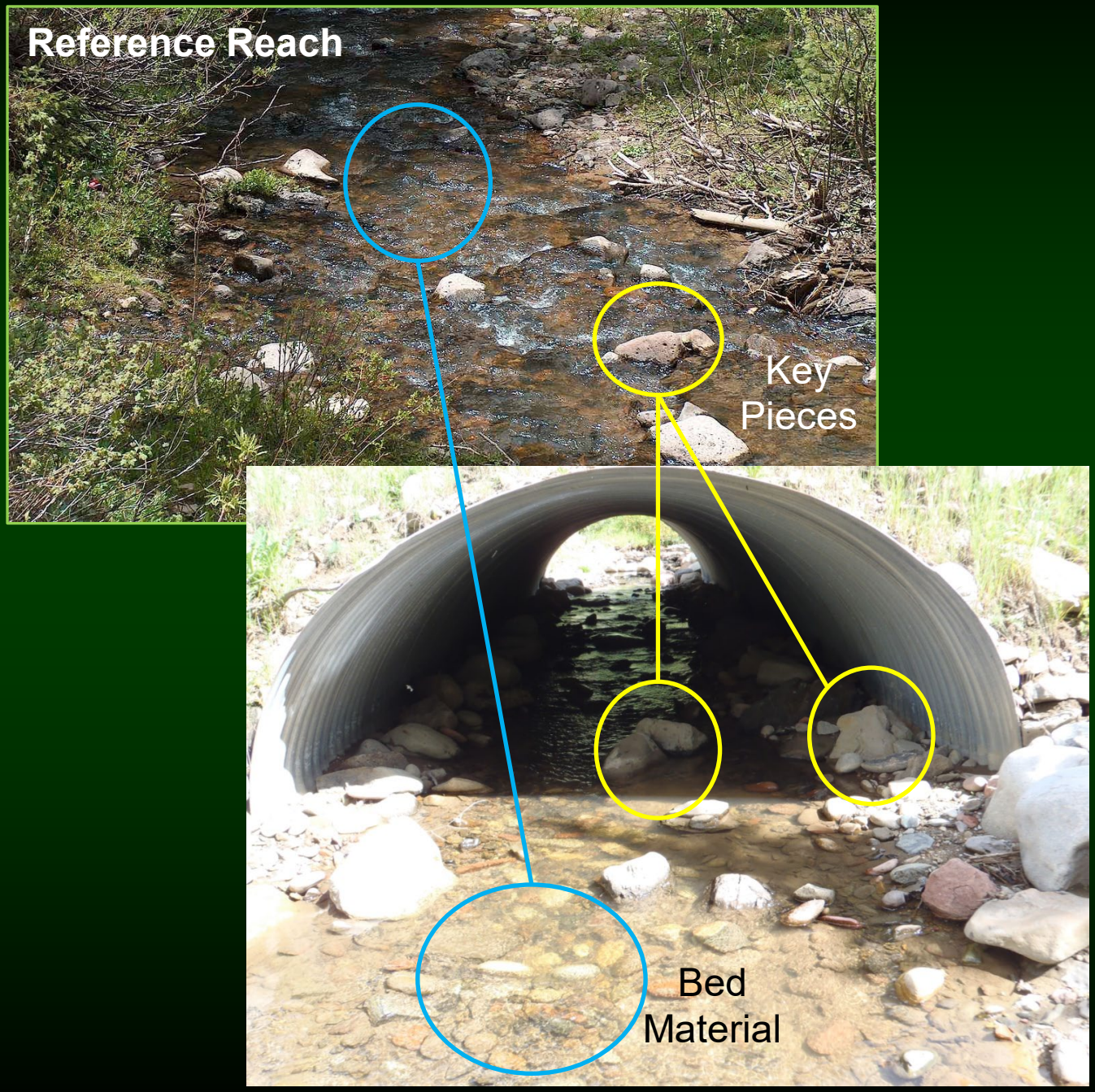
c. Pipe Arch



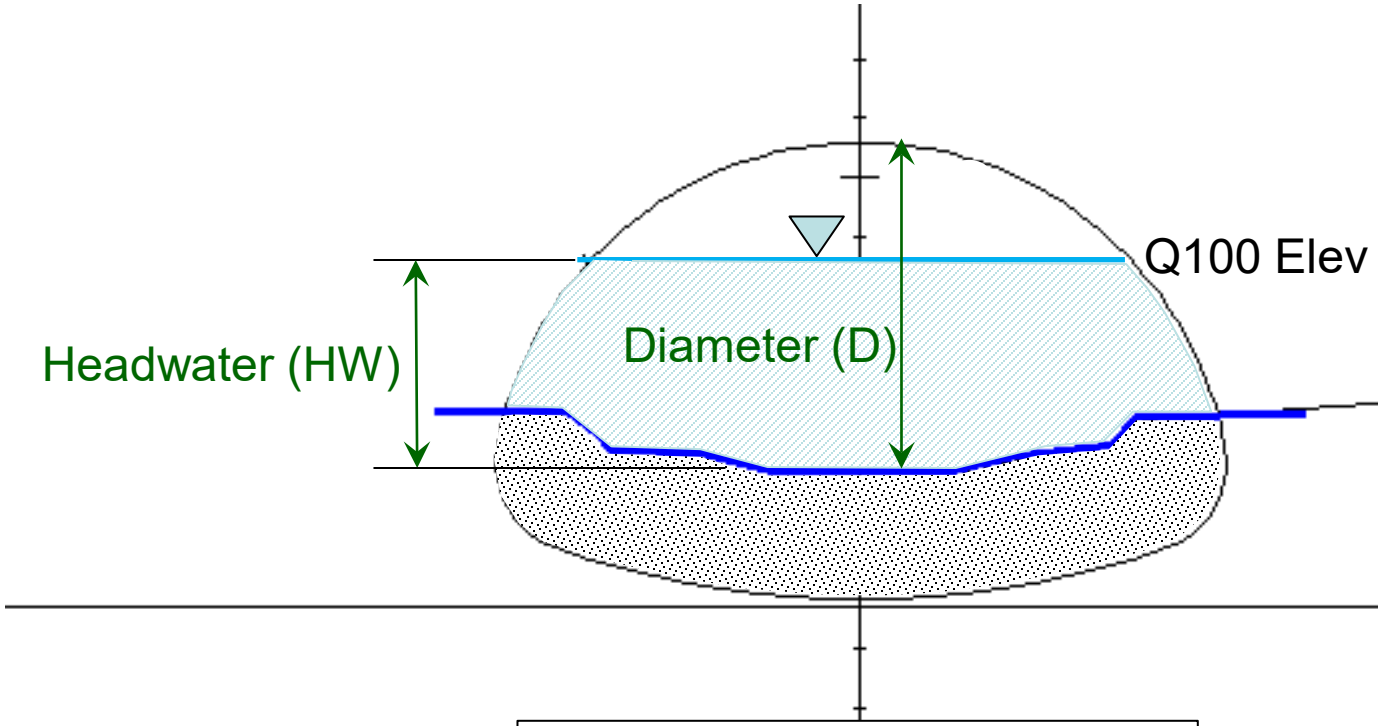
d. Bottomless Arch



e. Round


Reference Reach
Key Pieces
Bed Material

Hydraulic Capacity Check



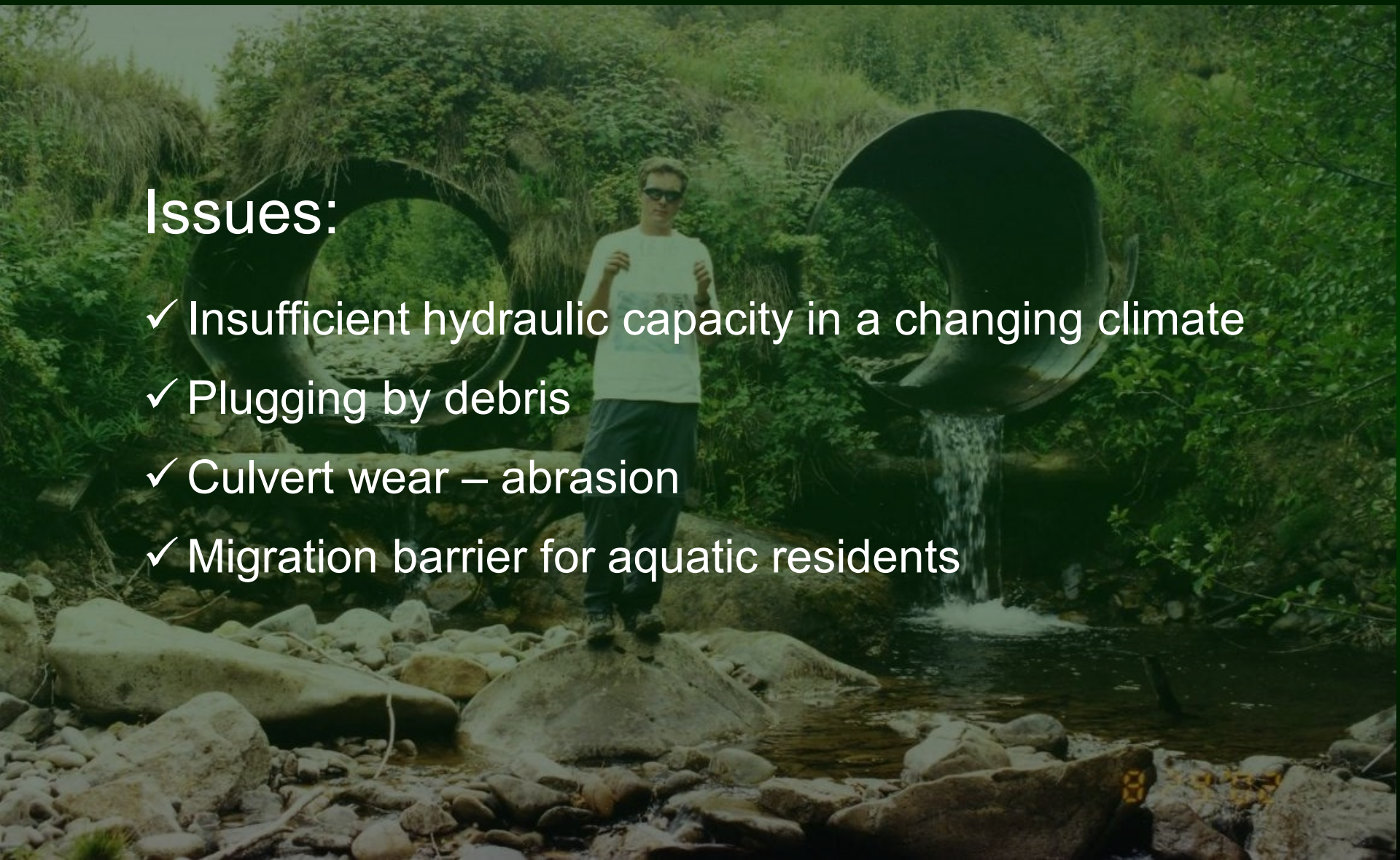
HW/D < 0.8*

(20% Freeboard)

* Always design with failure in mind – minimize consequences

Before

Before



Issues:

- ✓ Insufficient hydraulic capacity in a changing climate
- ✓ Plugging by debris
- ✓ Culvert wear – abrasion
- ✓ Migration barrier for aquatic residents


After
Width Continuity
Profile Continuity

After

Benefits:

- ✓ Ample hydraulic capacity in a changing climate
- ✓ Minimized plugging by debris
- ✓ No abrasion on metal surfaces
- ✓ Unimpeded passage for aquatic residents

Green Mountain NF - Vermont

Tropical Storm Irene ~ 500-year Flood

Before (2010)

After (2011)

Chequamegon-Nicolet N.F – Wisconsin

~ Q500 Flood

Before (2009)

After (2016)

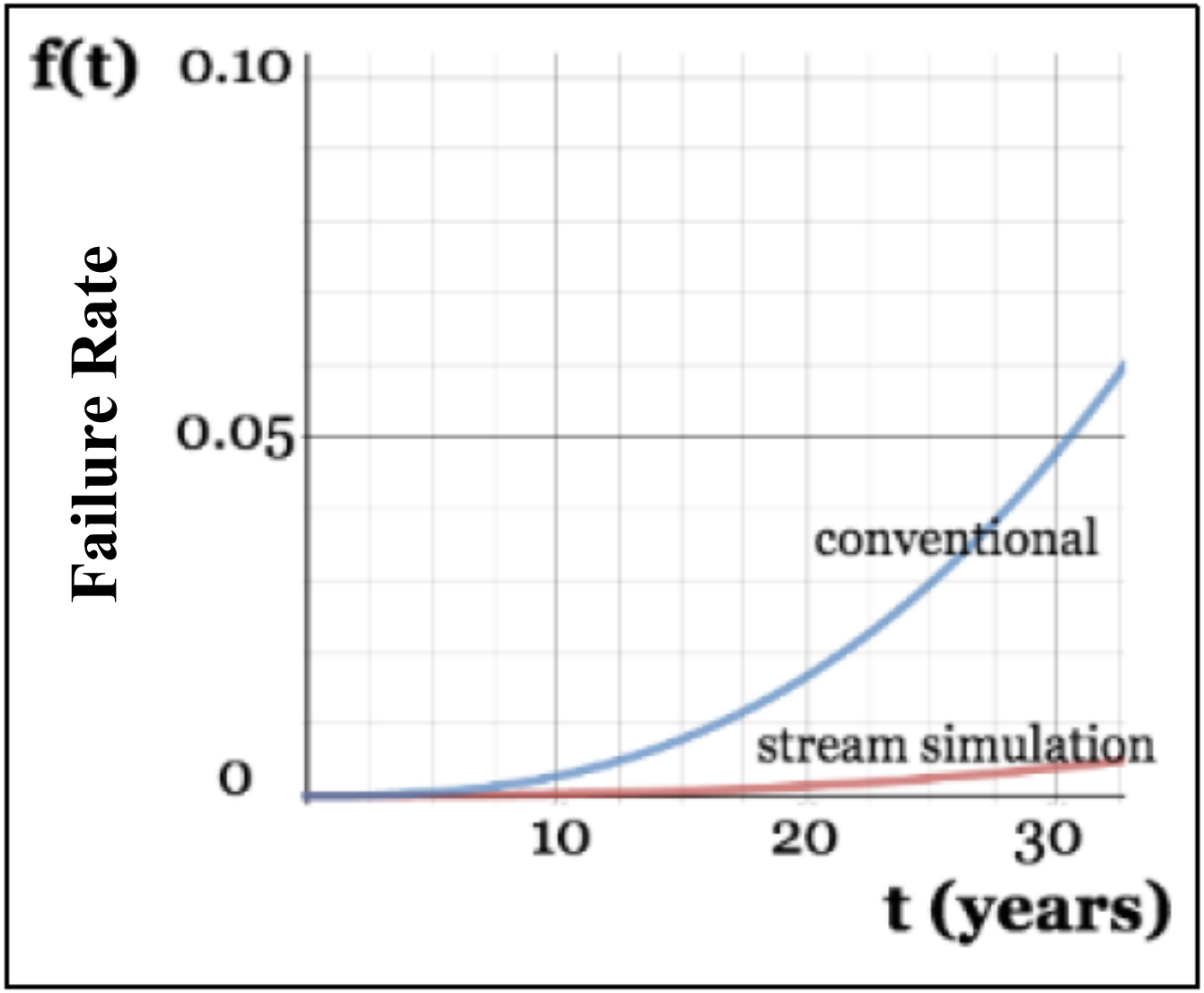
Cost Comparison

- Green Mountain National Forest examples demonstrate real costs for upgrading to Stream Simulation Design Standards ranged from **9-22% above** conventional hydraulic design

- Similar data suggest that a 50% increase in structure width results in **20% to 33% increase** in total project cost (Gubernick 2011) from across U.S. Forest Service Lands

- Most cost comparisons are made a Year 0, not extended out to the 50-75 year time frame.

Cost-Benefit Analysis of Stream Simulation Culverts

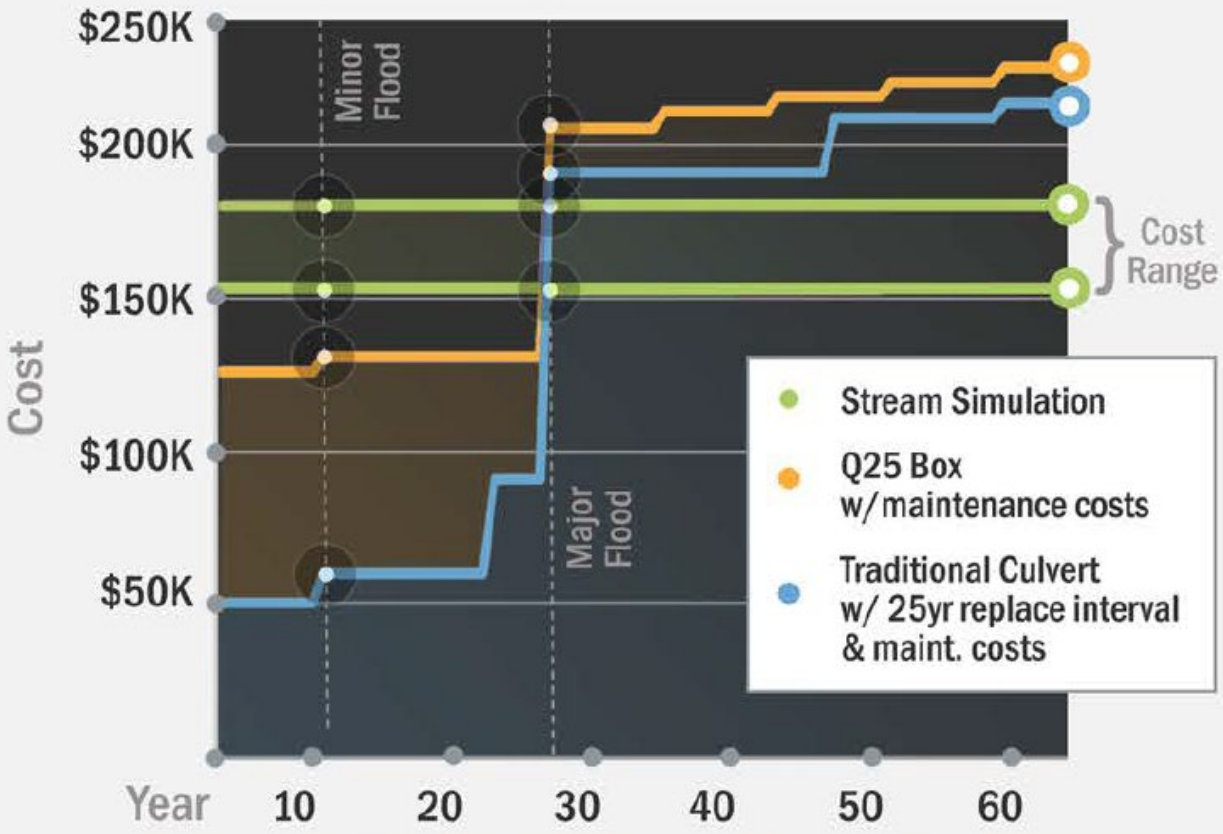


Wisconsin DNR, 2014

Prepared by:

Carl Christiansen
Angela Filer
Matthew Landi
Eric O'Shaughnessy
Mallory Palmer
Travis Schwartz

STREAM CROSSING
COSTS OVER TIME



(theoretical watershed, model of three designs over same period of time assuming catastrophic failure at undersized structures in flood event and annual maintenance of undersized culverts)

U.S. Department of Agriculture

Forest Service

National Technology and Development Program

7700—Transportation Management

0877 1801—SDTDC

May 2008

STREAM SIMULATION: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

Search: USDA Stream Simulation 2008

United States Department of Agriculture

Forest Service

Technology & Development Program

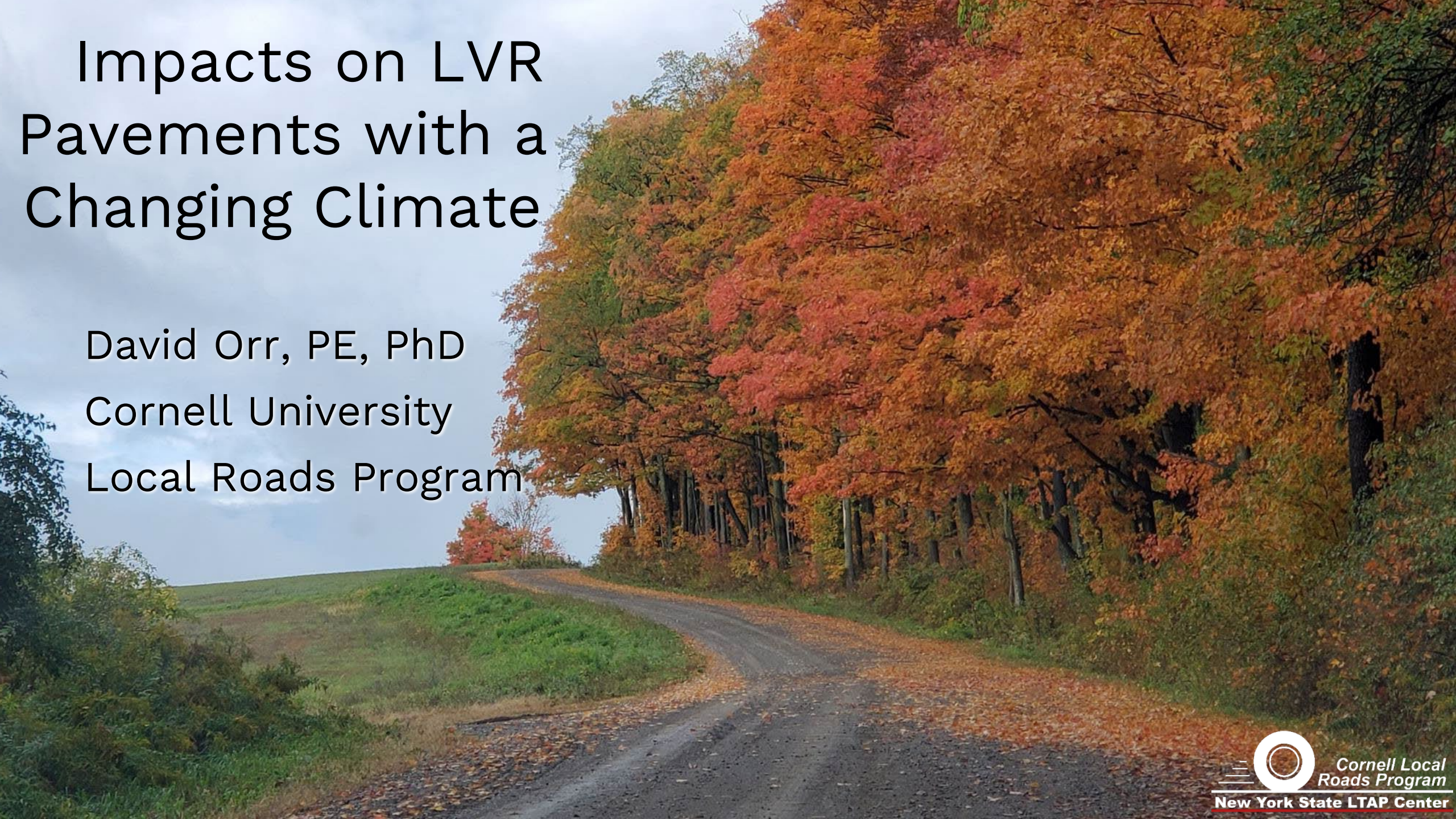
7700—Transportation System
2500—Watershed and Air Management
September 1997
9777 1805—SDTDC

The Water/Road Interaction Technology Series: An Introduction

Search: USDA Water-Road Interactions

Impacts on LVR Pavements with a Changing Climate

David Orr, PE, PhD
Cornell University
Local Roads Program



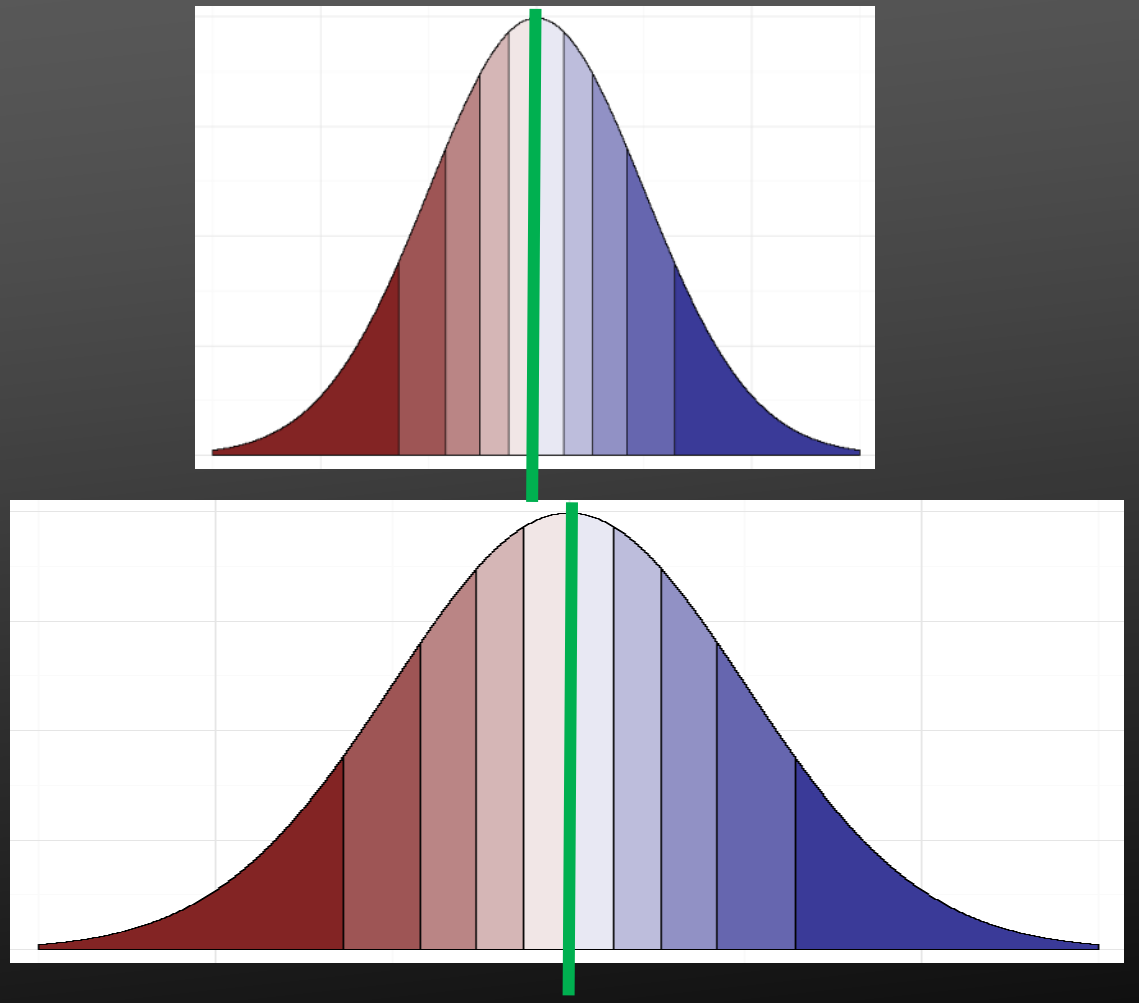
Cornell Local Roads Program
New York State LTAP Center

LVR & Changing Climate

- What is an LVR?
- Weather extremes
- Pavement design issues
- Other issues

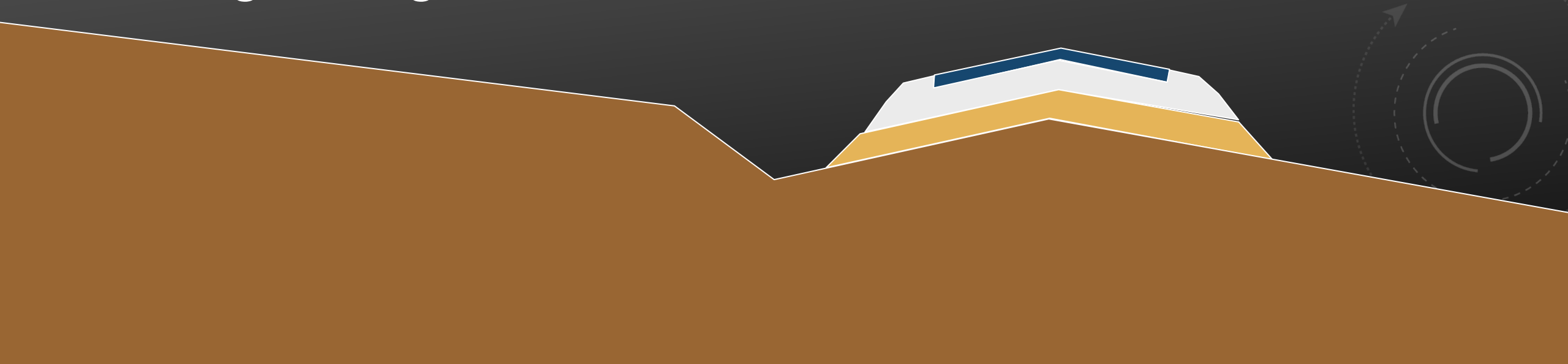
Low Volume Roads & Streets

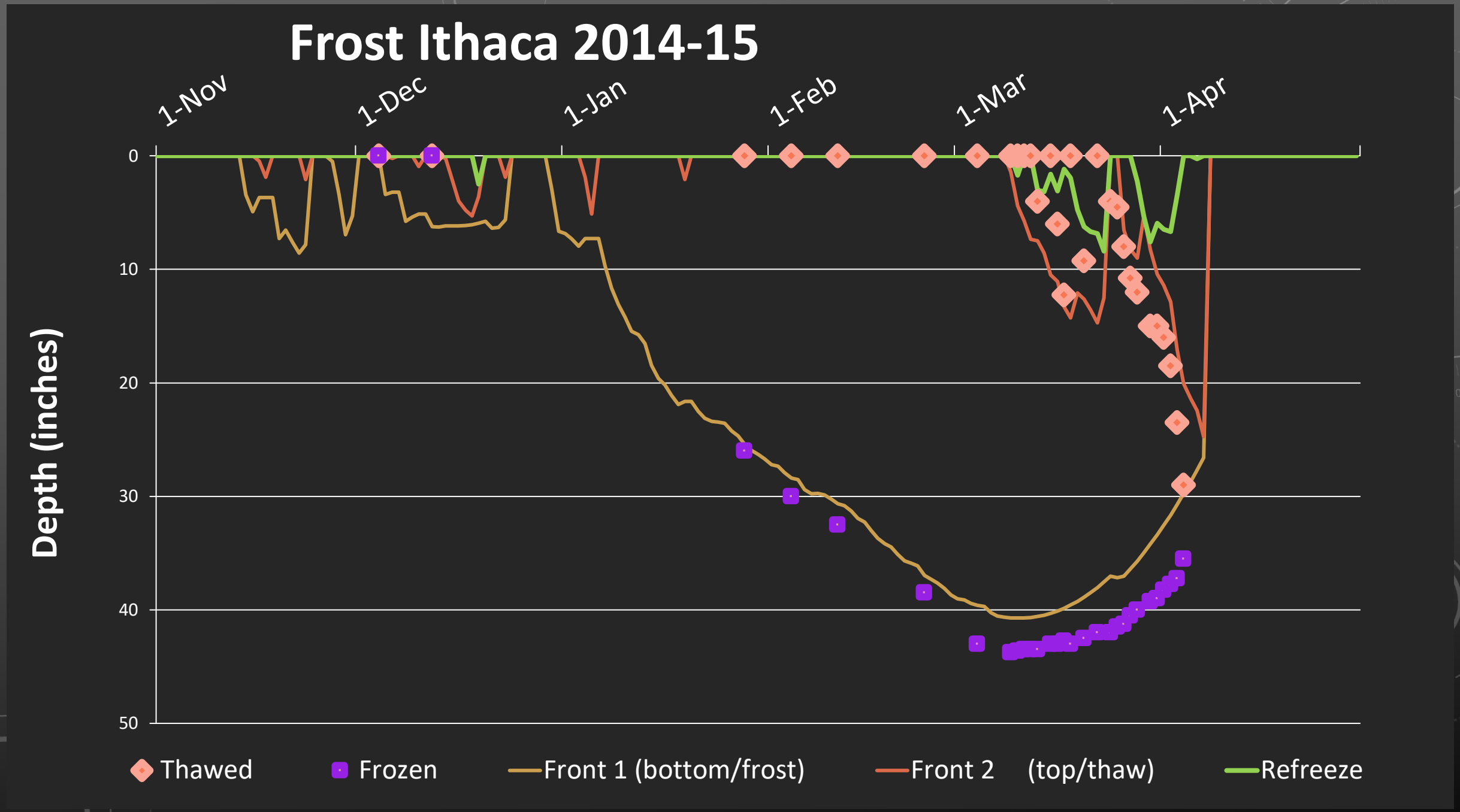
Weather Extremes



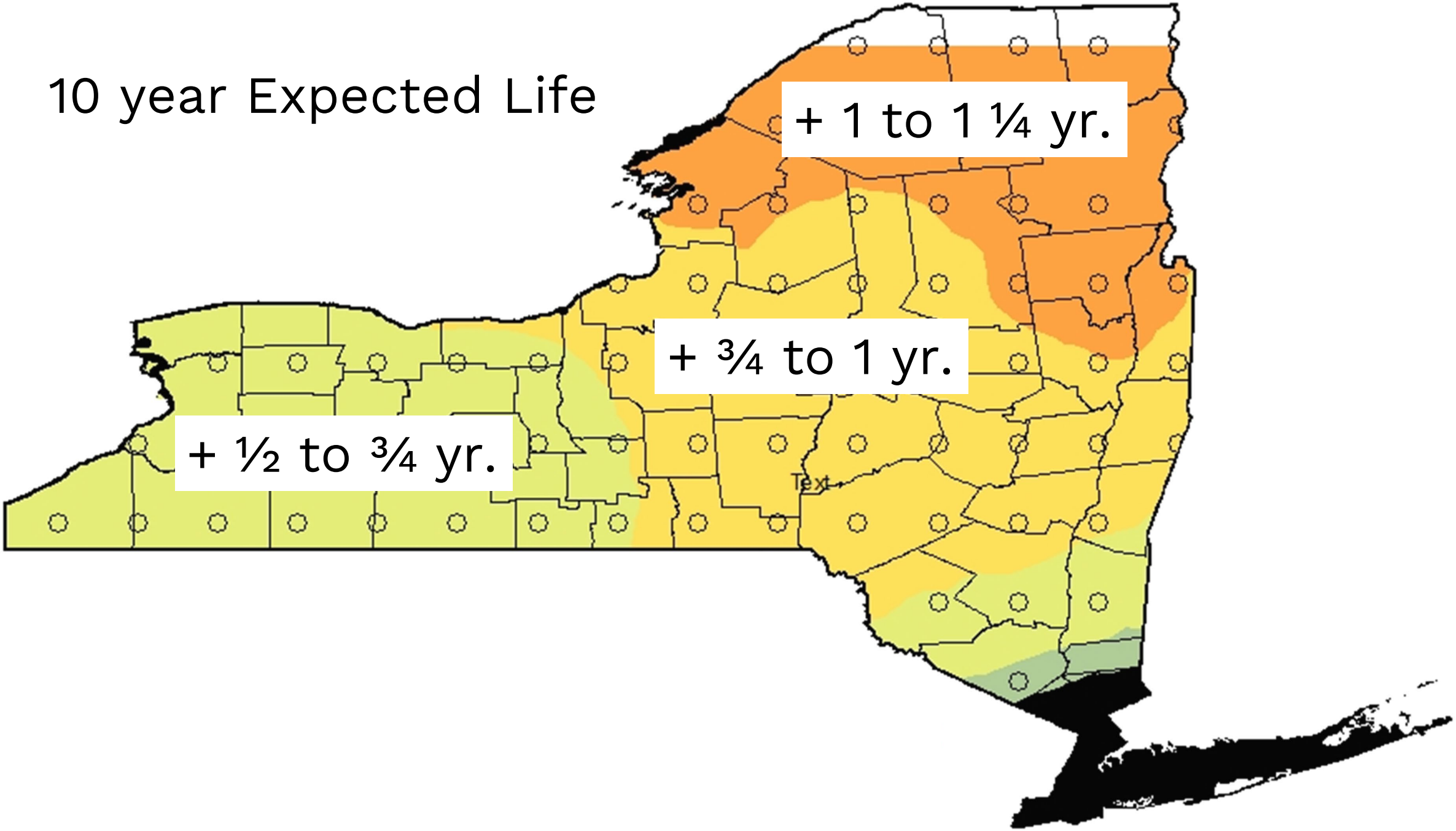
Pavement Design Issues

- Surface
- Base
- Subgrade
- Design changes



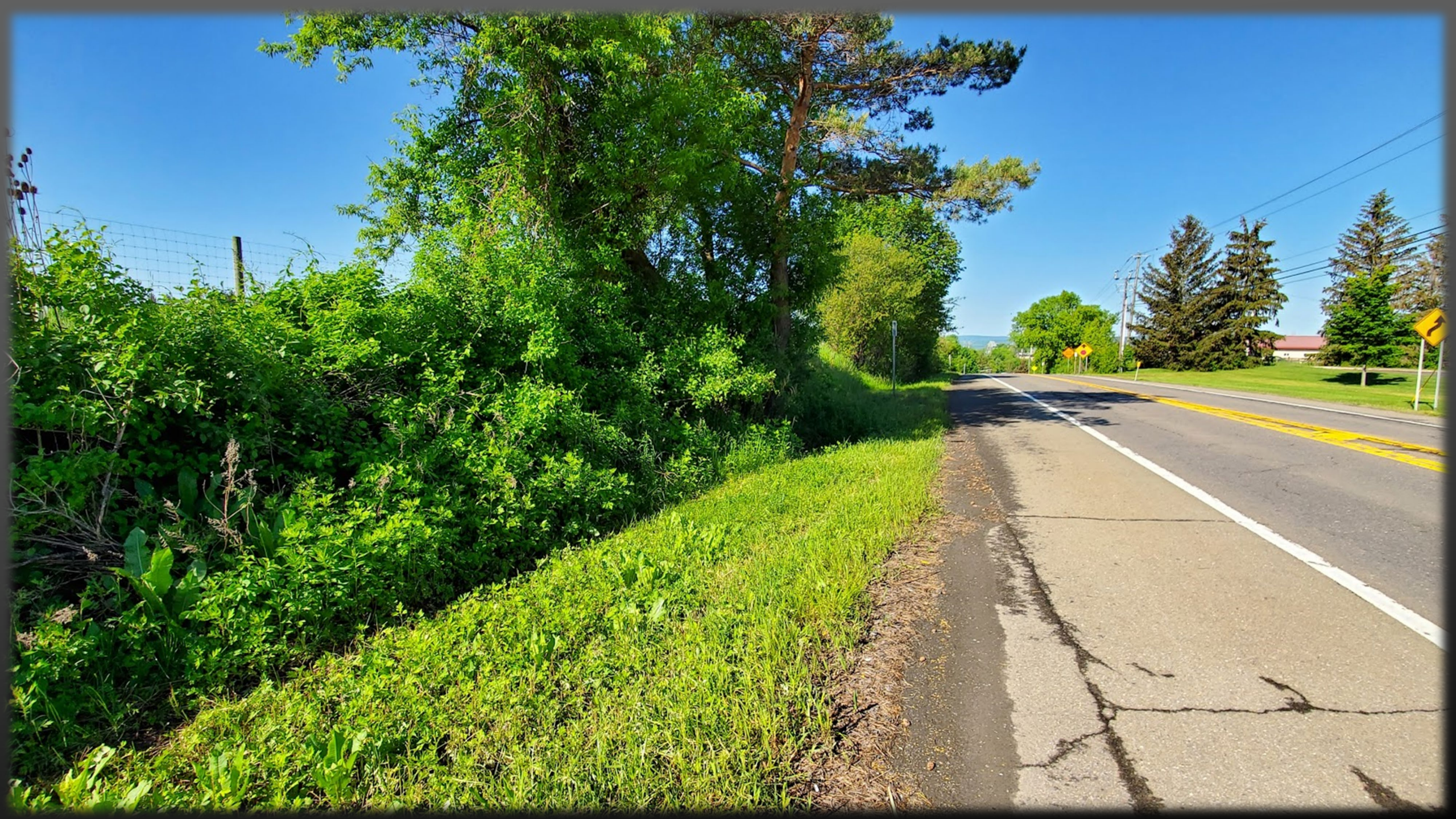

Frost Ithaca 2014-15
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
0
10
20
30
40
50
Depth (inches)
Thawed
Frozen
Front 1 (bottom/frost)
Front 2 (top/thaw)
Refreeze

10 year Expected Life




DYNAPAC
44

Other Issues



With a changing climate we are likely to see less flooding and droughts? True or False

With a changing climate, what do we need to change for LVR pavement design?

The three most important issues for LVR pavement design?


Thank You
david.orr@cornell.edu
Cornell Local Roads Program
New York State LTAP Center

Today's presenters

Laura Fay
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Western Transportation Institute, Montana

David Orr
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Cornell University

Mark Weinhold
mark.weinhold@usda.gov
U.S. Forest Service

Upcoming events for you

December 11, 2023

TRB Webinar: Understanding Evacuation Behavior and Regional Resilience

December 12, 2023

TRB Webinar: Next Stop—Inclusive Virtual Public Involvement

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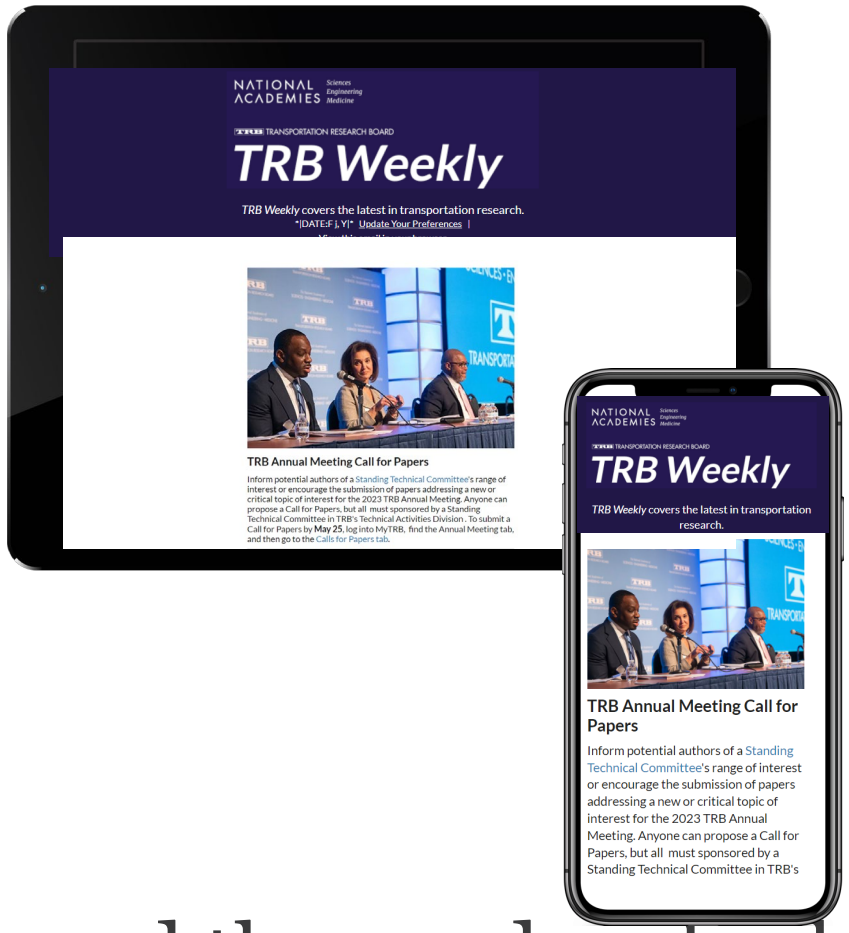

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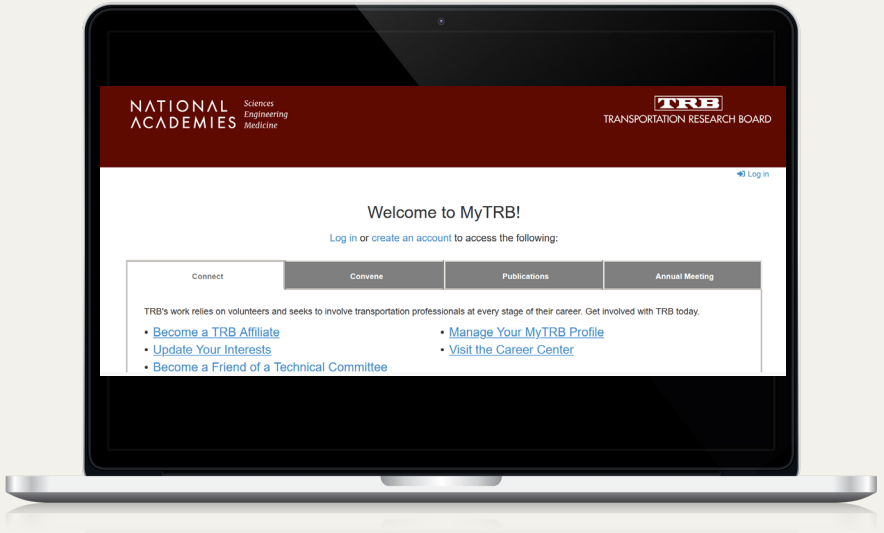

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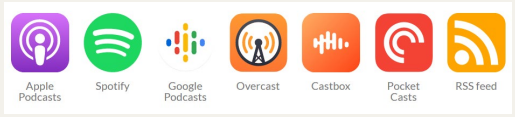

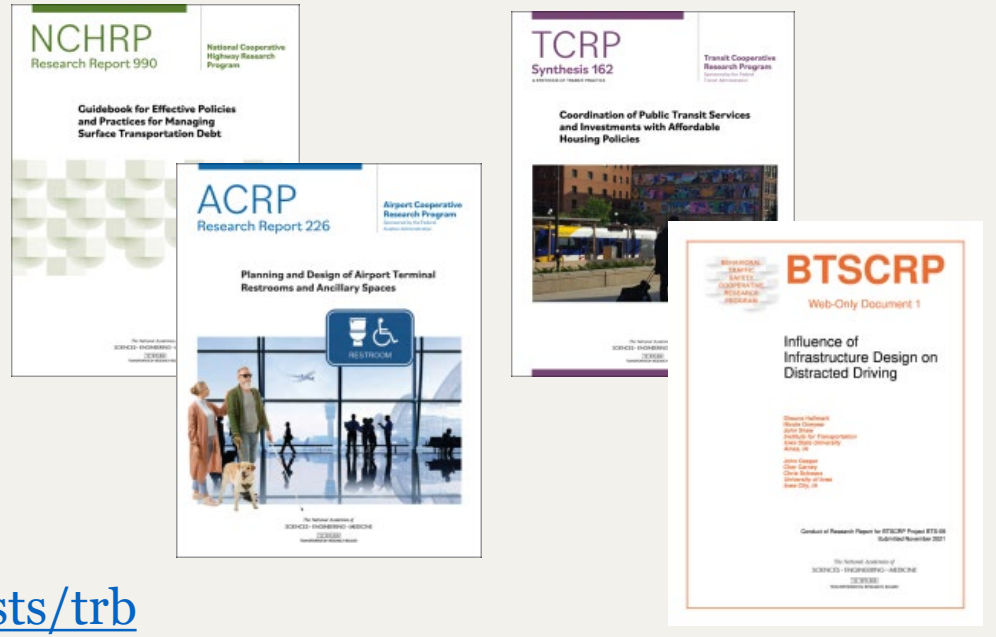

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