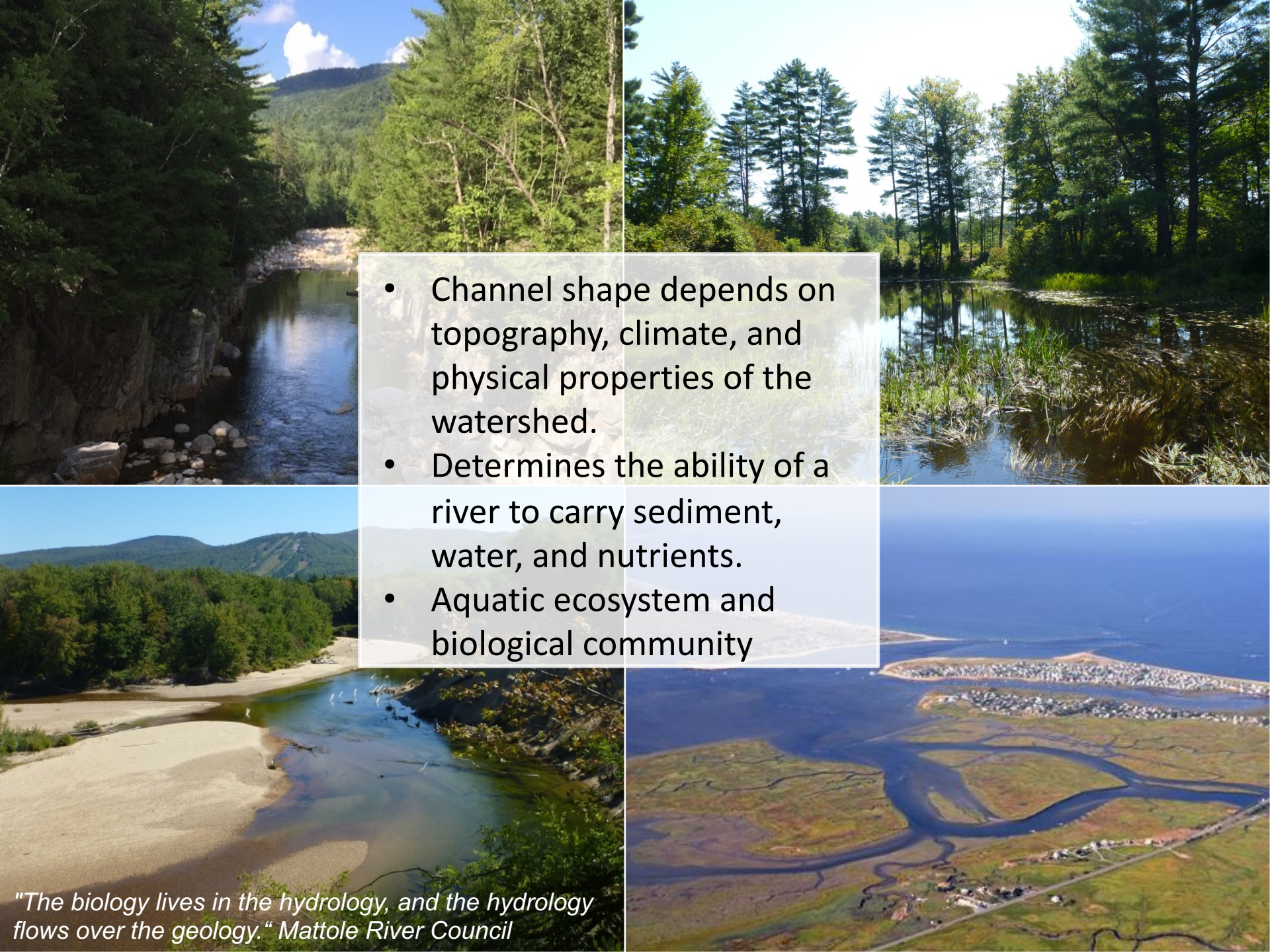
REPLACING CULVERTS FOR FLOOD RESILIENCY AND AQUATIC CONNECTIVITY

Cheryl Bondi and Lori Sommer
NHDES Aquatic Resource Mitigation Program

- How do stream crossings impact aquatic ecosystems and public safety?
- What work is being done to address the problem of deficient crossings in NH?
- How do you prioritize culvert replacements for wildlife passage and flood resiliency in a changing climate?



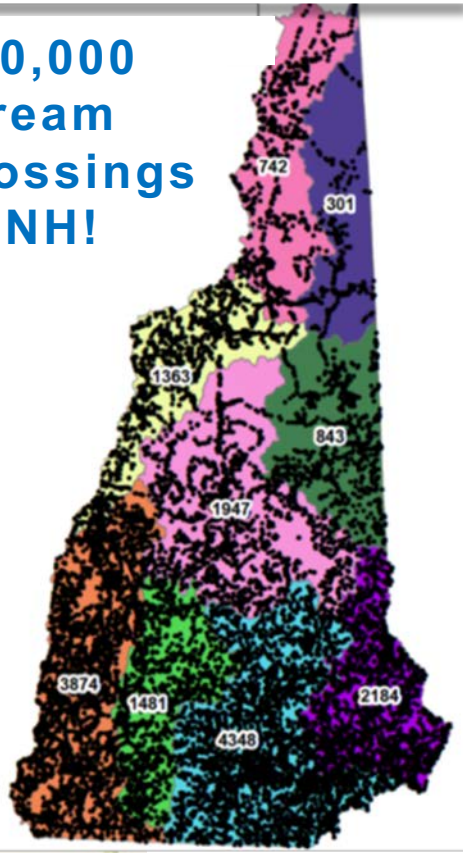
- Channel shape depends on topography, climate, and physical properties of the watershed.
- Determines the ability of a river to carry sediment, water, and nutrients.
- Aquatic ecosystem and biological community

"The biology lives in the hydrology, and the hydrology flows over the geology." Mattole River Council

"The biology lives in the hydrology, and the hydrology flows over the geology." Mattole River Council

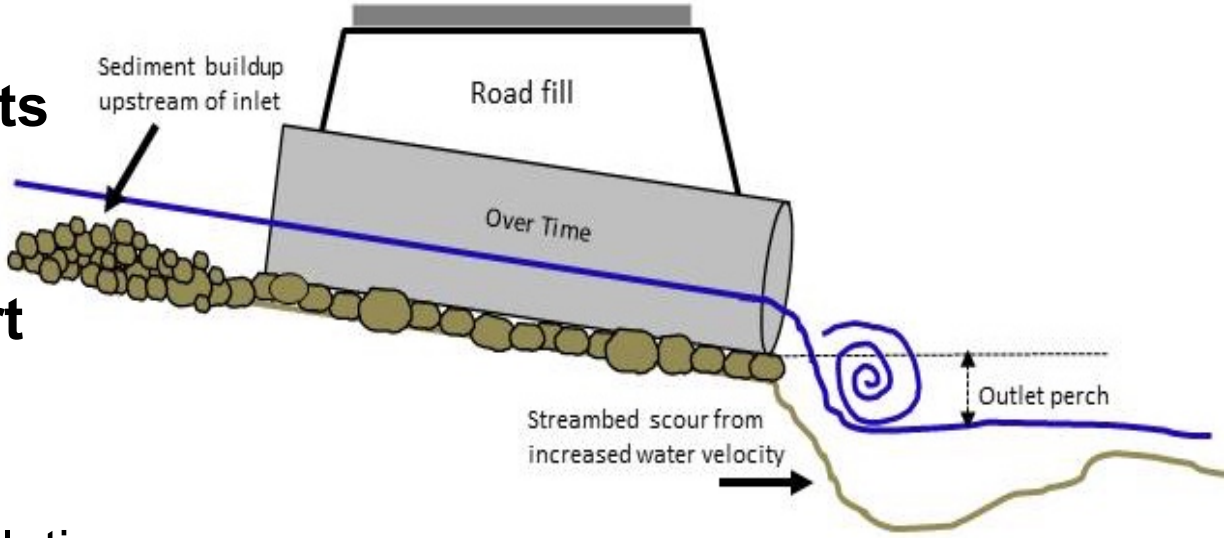
STREAM CROSSINGS: WHERE RIVERS AND ROADS MEET

~20,000 stream crossings in NH!



DEFICIENT CROSSINGS IMPACT HOW WATER AND SEDIMENT MOVE DOWNSTREAM

- **Undersized culverts increase water velocity and alter sediment transport**



- **Impacts over time**
  - Sediment accumulation
  - Clogged inlet
  - Channel widens upstream
  - Bank erosion
  - Bed scour
  - Perched

DEFICIENT CROSSINGS IMPACT HOW WATER AND SEDIMENT MOVE DOWNSTREAM

- Create a “pinch point” in the stream
- Upstream ponding and aggradation and downstream scour

Left: Upgraded fish-friendly culvert in Alaska. Right: Same road-stream intersection prior to being fitted with a culvert designed to better accommodate fish and water. Photos: Ken Ayers, Lounsbury & Associates, Inc.

DEFICIENT CROSSINGS IMPACT HOW WATER AND SEDIMENT MOVE DOWNSTREAM

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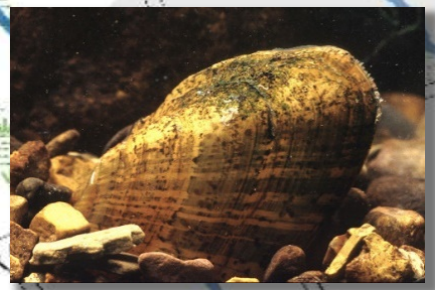
Left: Upgraded fish-friendly culvert in Alaska. Right: Same road-stream intersection prior to being fitted with a culvert designed to better accommodate fish and water. Photos: Ken Ayers, Lounsbury & Associates, Inc.

DEFICIENT CROSSINGS ARE BARRIERS TO AQUATIC ANIMALS

DEFICIENT CROSSINGS DISRUPT AQUATIC CONNECTIVITY



Many turtles require connected wetlands

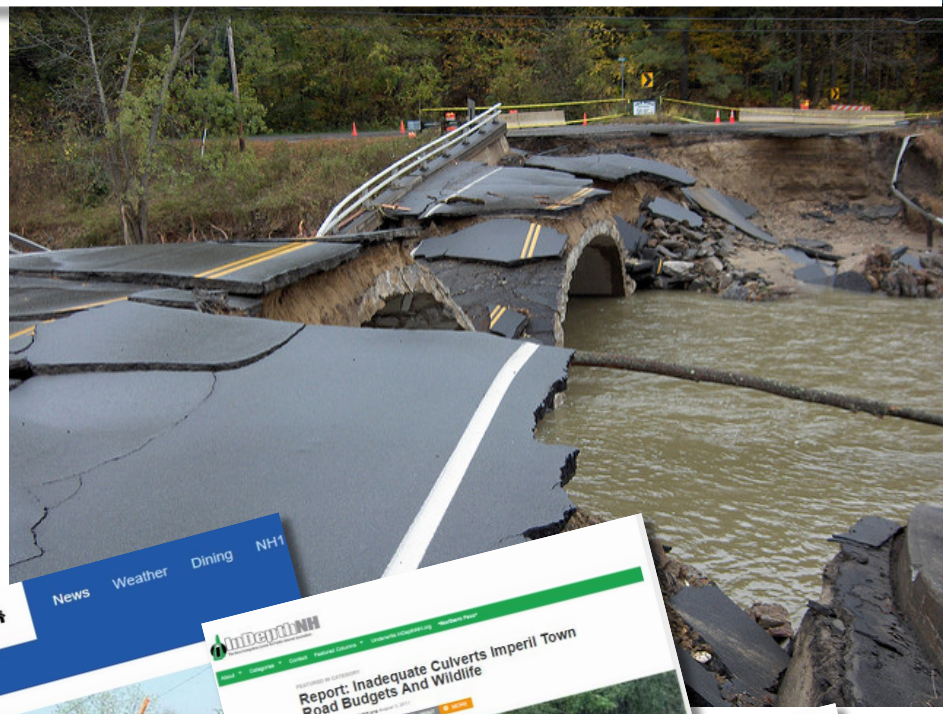
Brook Trout need access to cold water streams

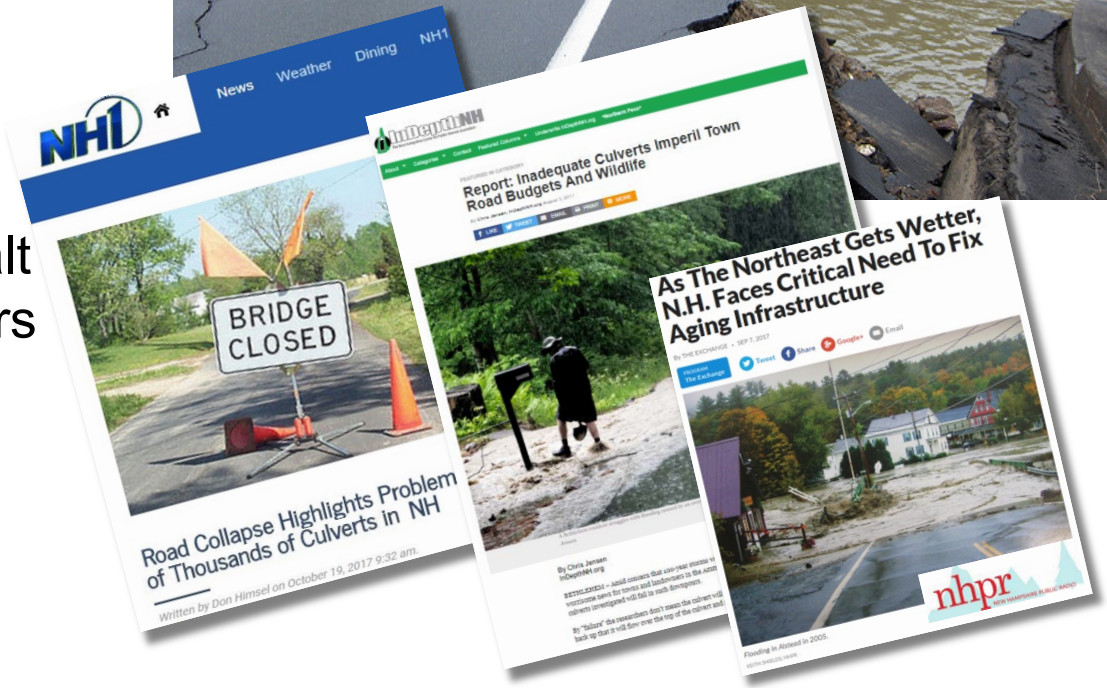
CULVERT WASHOUTS: A FLOOD HAZARD AND AQUATIC HABITAT ISSUE

- **Public safety hazard**
  - Harm to people and property
- **Damage to roads**
  - Prohibit travel/ detours
  - Expensive to repair
- **Instream and riparian habitat degradation**
  - Bank and streambed erosion
  - Washed out sediment and road material ends up in rivers
- **Increased risk of failure:**
  - Watershed development
  - Aging infrastructure
  - **More frequent, large rain events with climate change**

DEFICIENT STREAM CROSSINGS ARE VULNERABLE TO FAILURE

- NH experienced several storms that qualify as 100-year flood in past decade
- Inadequate crossings fail
- Millions of dollars in infrastructure damage
  - Blown out culverts
  - Flooded roads
  - Severe stream erosion
- Sediment, debris, and asphalt washed into stream and rivers





DEFICIENT STREAM CROSSINGS ARE VULNERABLE TO FAILURE

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  - Blown out culverts
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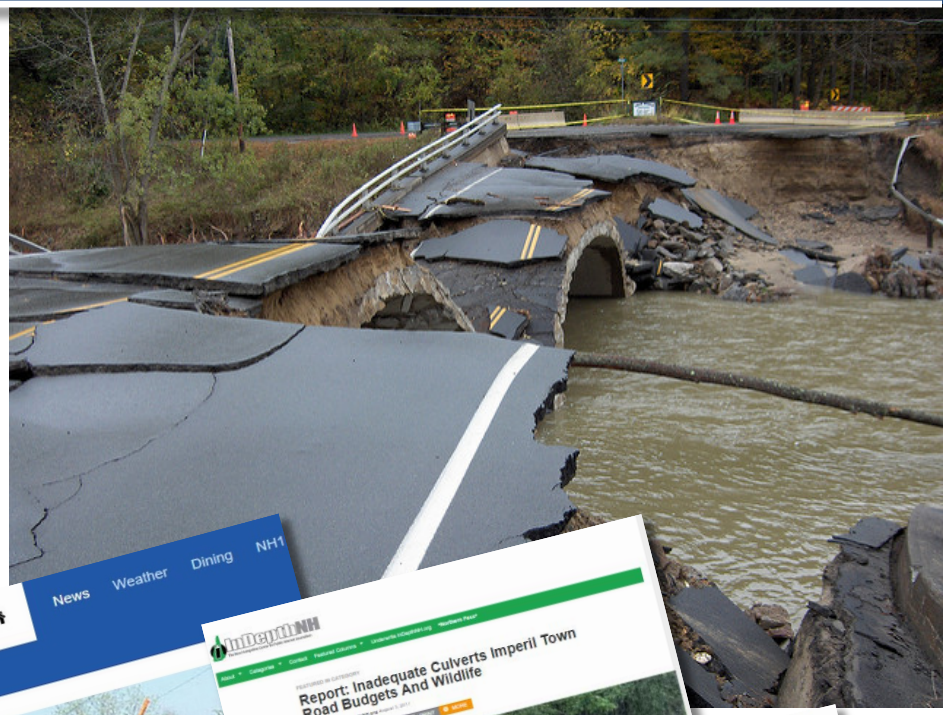
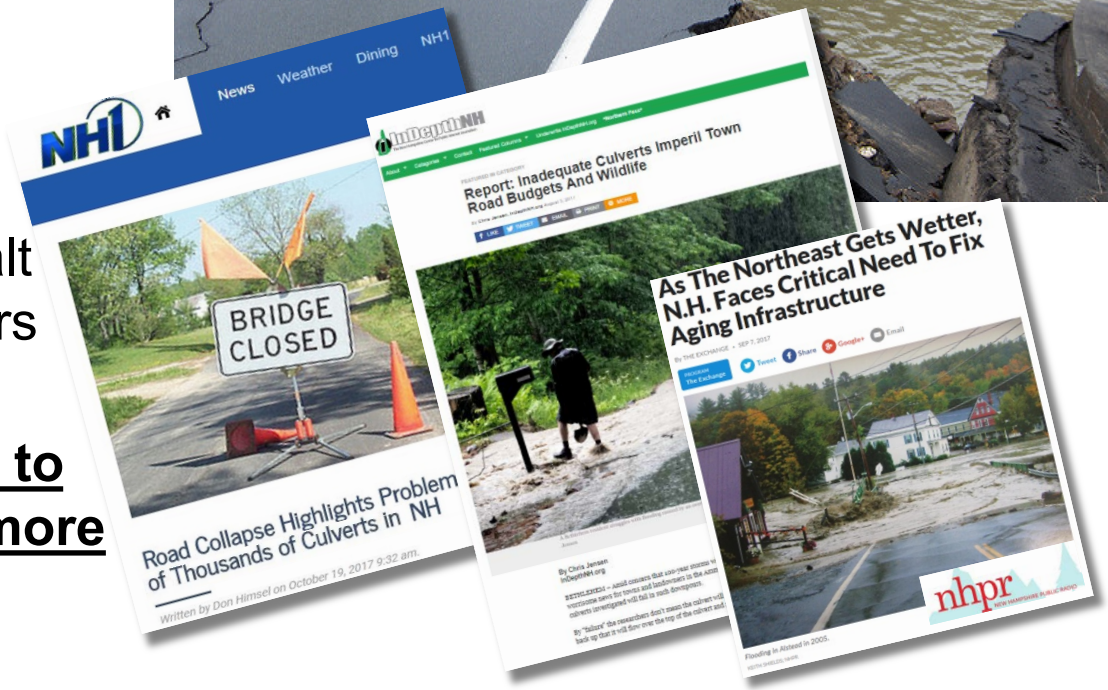
  - Severe stream erosion
- Sediment, debris, and asphalt washed into stream and rivers
- **<u>Replace old, undersized crossings that are barriers to aquatic connectivity with more resilient structures</u>**





UPGRADING CULVERTS
What benefits fish, benefits people

Stream Simulation Design

- Combines geomorphic and ecological principles to mimic the natural channel

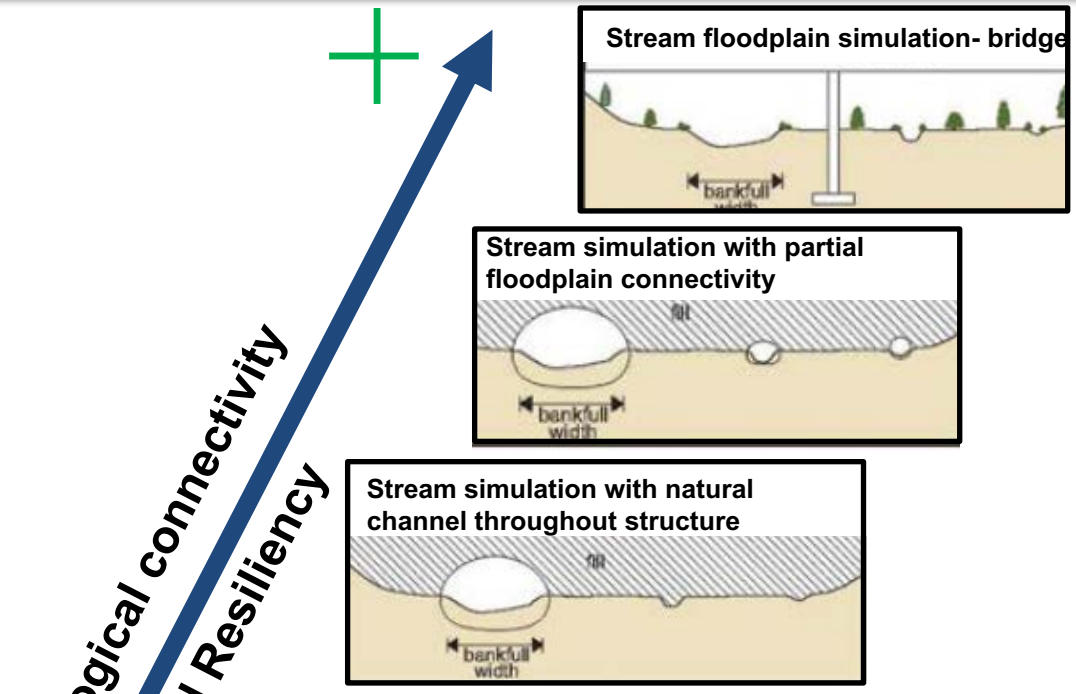
UPGRADING CULVERTS
What benefits fish, benefits people

Stream Simulation Design

- The size and placement of the structure is based on the physical dimensions of the natural channel ***first***

Versus Hydraulic Design

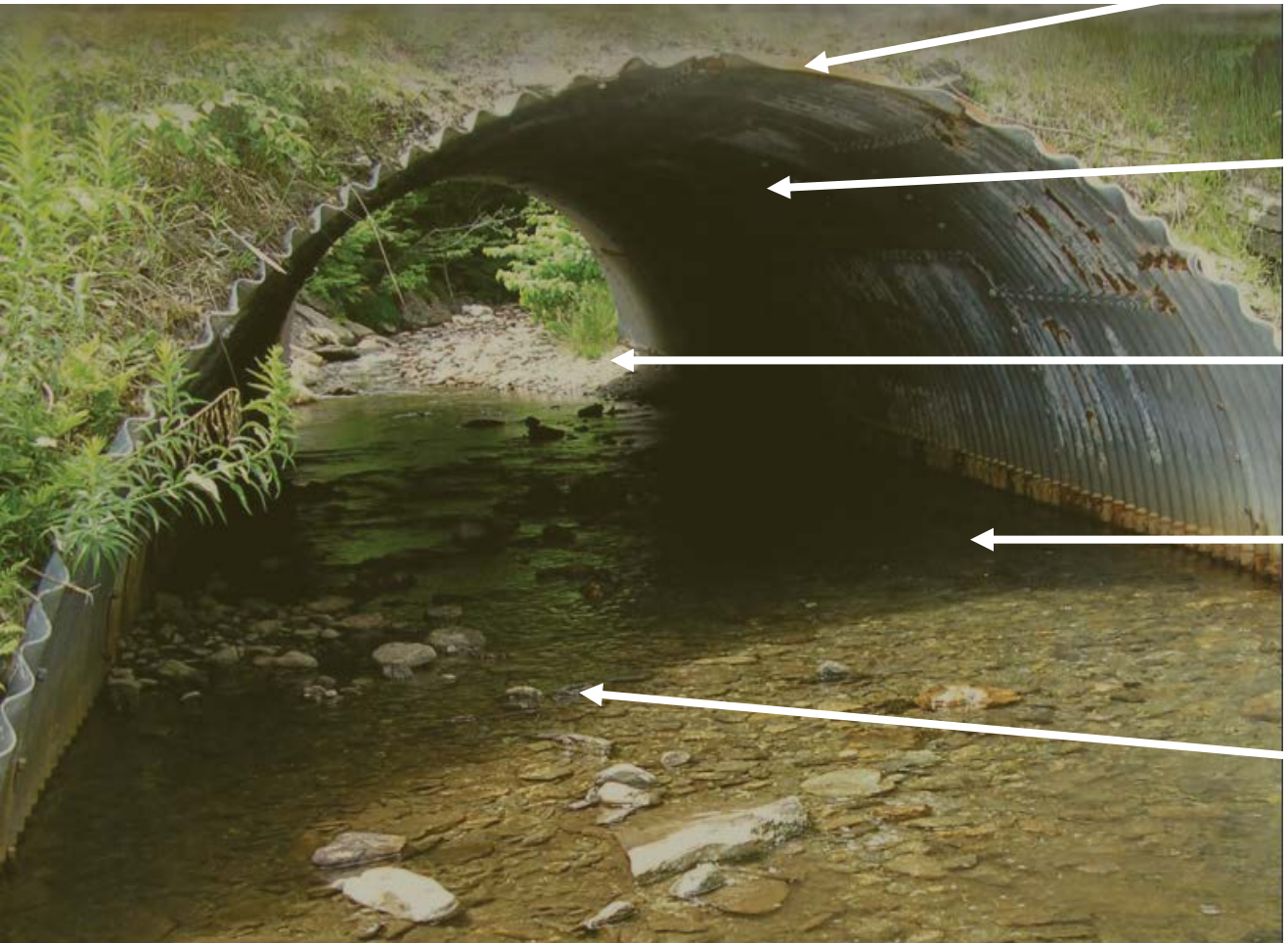
- Structures are sized to pass a design flood using regional flood-discharge equations



Conceptual ecological connectivity and flood resilience continuum for different design approaches at road-stream crossings (adapted from SSWG,2008).

UPGRADING CULVERTS
What benefits fish, benefits people

A Well Designed Crossing with *Stream Simulation*



Open-arch design preserves natural stream channel

Large size to pass 100+ recurrence flood with freeboard for debris

Spans channel width

Water velocity and depth match reference stream conditions

Natural streambed with substrate continuity provides good conditions for aquatic organisms

Incorporated in NH Stream Crossing Guidelines

UPGRADING CULVERTS
What benefits fish, benefits people

- **Lessons learned from Tropical Storm Irene in VT & NY**
  - 7” rain in 48 hours
  - **963 culverts and 277 bridges** were damaged or destroyed
  - Forest Service had recently upgraded several culverts using stream simulation
  - **ALL** of those crossings persisted without damage
  - Upfront cost 9-22% above conventional hydraulic design
  - Overall economic benefit after damage assessment


International Conference on Engineering and Ecohydrology for Fish Passage

Jun 22nd, 11:40 AM - 11:55 AM

Session B1: Lessons Learned from Tropical Storm Irene 2.0: How Flood Resiliency Benefits of Stream Simulation Designs Are Changing Policy within the U.S.

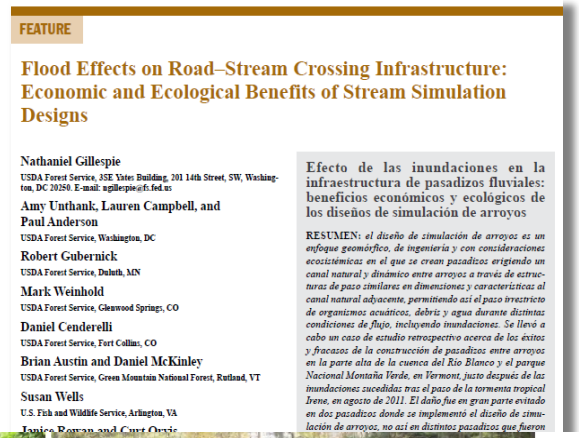
Nathaniel Gillespie
United State Department of Agriculture, Forest Service

Robert Gubernick
USDA Forest Service

Dan Cenderelli
USDA Forest Service

Mark Weinhold
USDA Forest Service

Brian C. Austin
USDA Forest Service


FEATURE

Flood Effects on Road–Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs

Nathaniel Gillespie
USDA Forest Service, 3SE Yates Building, 201 14th Street, SW, Washington, DC 20250. E-mail: ngillespie@fs.fed.us

Amy Unthank, Lauren Campbell, and Paul Anderson
USDA Forest Service, Washington, DC

Robert Gubernick
USDA Forest Service, Duluth, MN

Mark Weinhold
USDA Forest Service, Gleanwood Springs, CO

Daniel Cenderelli
USDA Forest Service, Fort Collins, CO

Brian Austin and Daniel McKinley
USDA Forest Service, Green Mountain National Forest, Rutland, VT

Susan Wells
U.S. Fish and Wildlife Service, Arlington, VA

Efecto de las inundaciones en la infraestructura de pasadizos fluviales: beneficios económicos y ecológicos de los diseños de simulación de arroyos

RESUMEN: *el diseño de simulación de arroyos es un enfoque geomórfico, de ingeniería y con consideraciones ecosistémicas en el que se crean pasadizos erigiendo un canal natural y dinámico entre arroyos a través de estructuras de paso similares en dimensiones y características al canal natural adyacente, permitiendo así el paso irrestricto de organismos acuáticos, debris y agua durante distintas condiciones de flujo, incluyendo inundaciones. Se llevó a cabo un caso de estudio retrospectivo acerca de los éxitos y fracasos de la construcción de pasadizos entre arroyos en la parte alta de la cuenca del Río Blanco y el parque Nacional Montaña Verde, en Vermont, justo después de las inundaciones sucedidas tras el paso de la tormenta tropical Irene, en agosto de 2011. El daño fue en gran parte evitado en dos pasadizos donde se implementó el diseño de simulación de arroyos, no así en distintos pasadizos que fueron*

Before

Credit: USFS

Open Arch Replacement 2010

100 Year Flood Level Design

Green Mountain National Forest
FR17A/Jenny Coolidge Brook
Bottomless Arch Inlet

Post-Irene Survivor 2011

NEW HAMPSHIRE STREAM CROSSING INITIATIVE

- **How can New Hampshire prepare for increased flood frequency and intensity with climate change?**

- Multi-agency team
- Partnerships with NGOs & RPCs
- Address complex problem of undersized and deficient crossings

MISSION

Inventory stream crossings throughout the state to inform decisions on culvert replacement and stream restoration

Catastrophic culvert failure
Warren Brook, Alstead 2005

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

New Hampshire DOT Department of Transportation

HSEM NEW HAMPSHIRE DEPARTMENT OF SAFETY

New Hampshire Technology Transfer Center

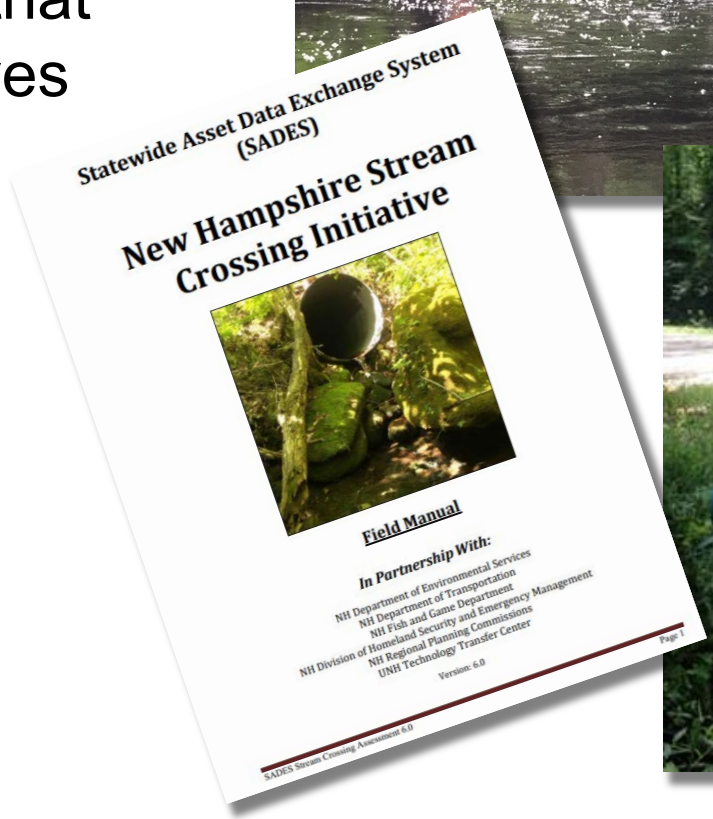
STATE OF NEW HAMPSHIRE LIVE FREE OR DIE FISH AND GAME

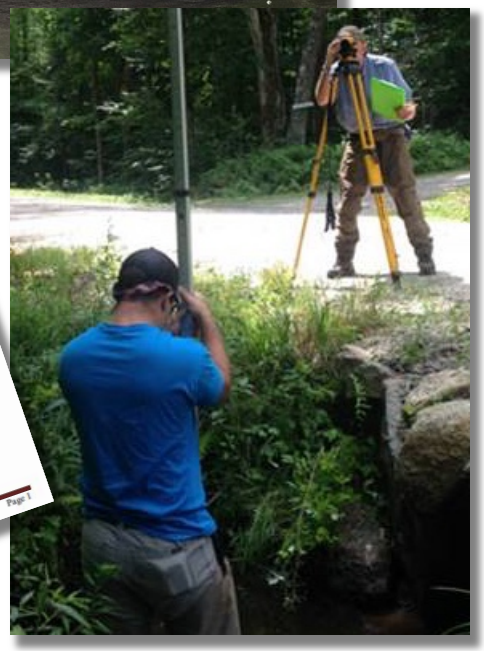
NEW HAMPSHIRE STREAM CROSSING INITIATIVE

- Stream crossing surveys
- Multiple partners collecting data
- Consistent protocol that meets many objectives
- Training and QAQC

Score culverts

- ✓ Geomorphic compatibility
- ✓ Aquatic organism passage
- ✓ Asset condition
- ✓ Flood vulnerability



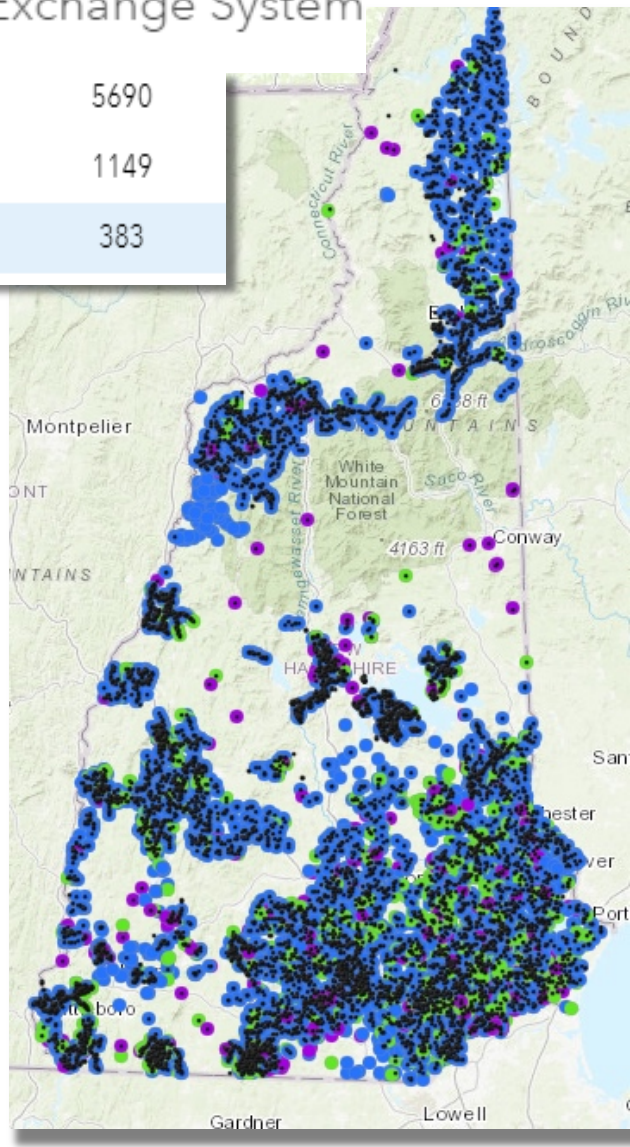


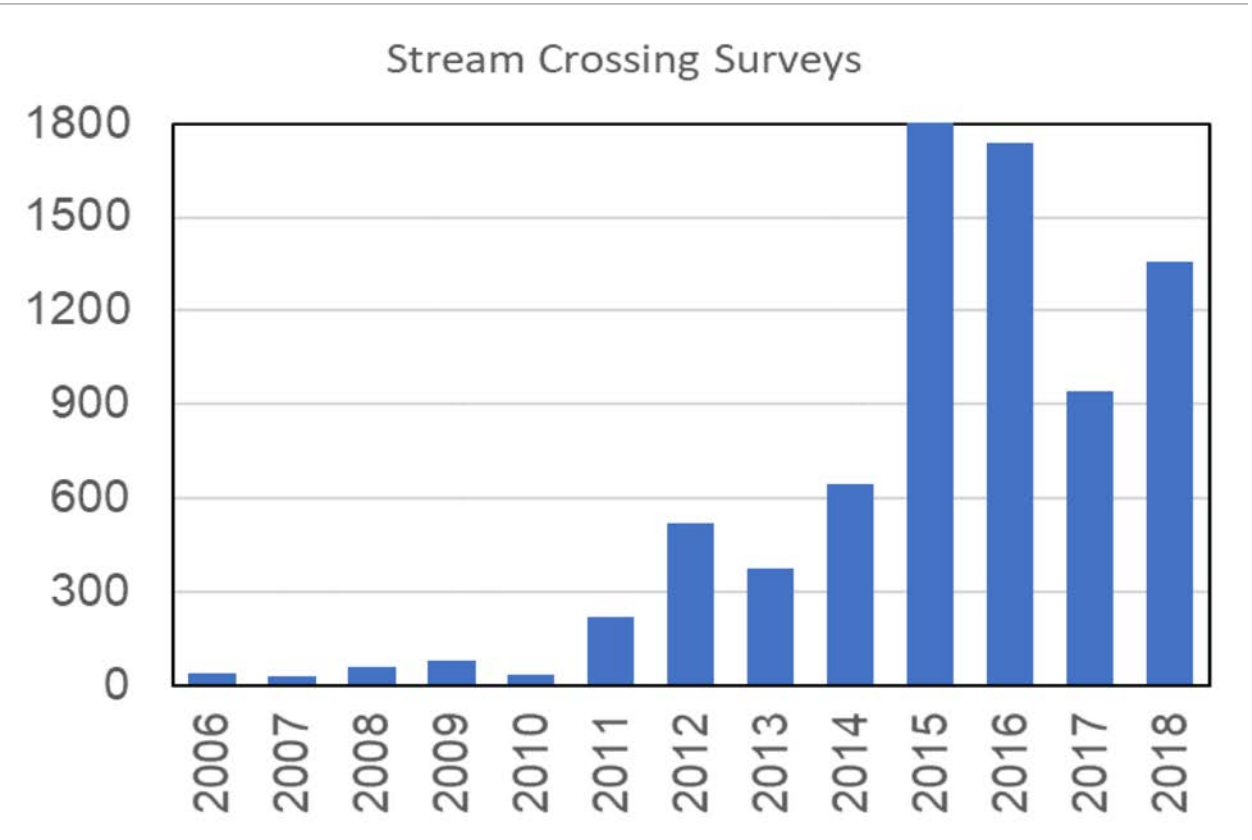
NEW HAMPSHIRE STREAM CROSSING INITIATIVE

NH Statewide Asset Data Exchange System

- Cloud-based data storage and management
  - "SADES"

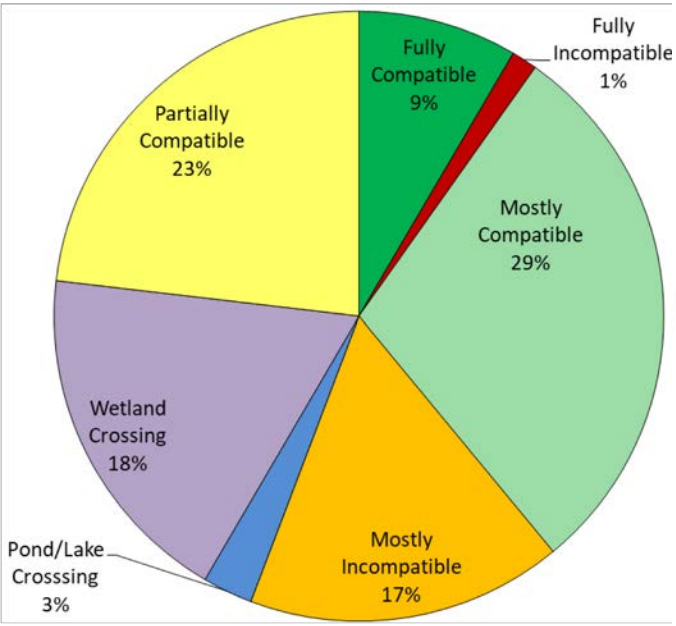
Stream	5690
Wetland	1149
Surface	383

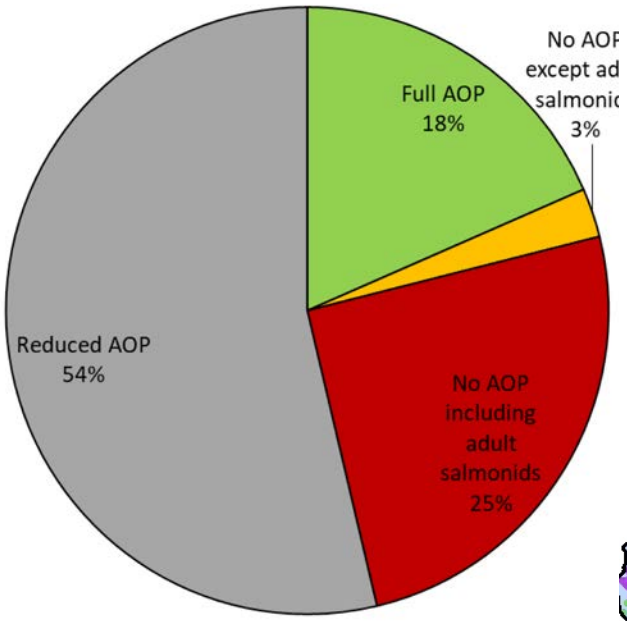


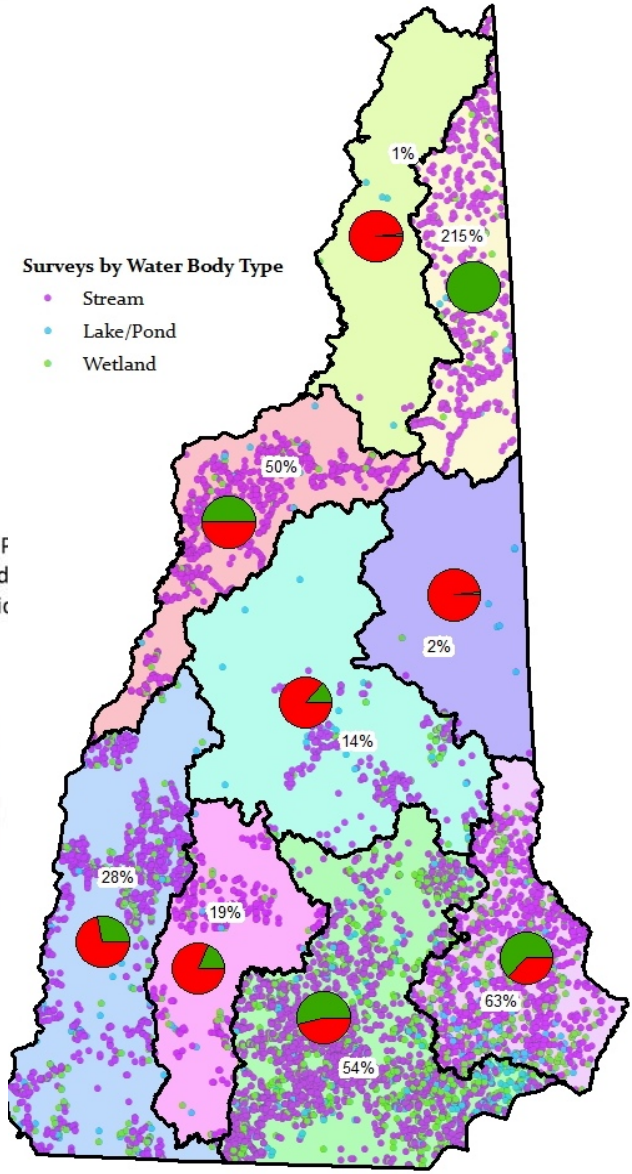


PRIORITIZING CULVERT REPLACEMENTS FOR FISH AND FLOODS

- 7,500 surveys statewide
- Replacements are costly so need to focus efforts where it matters most



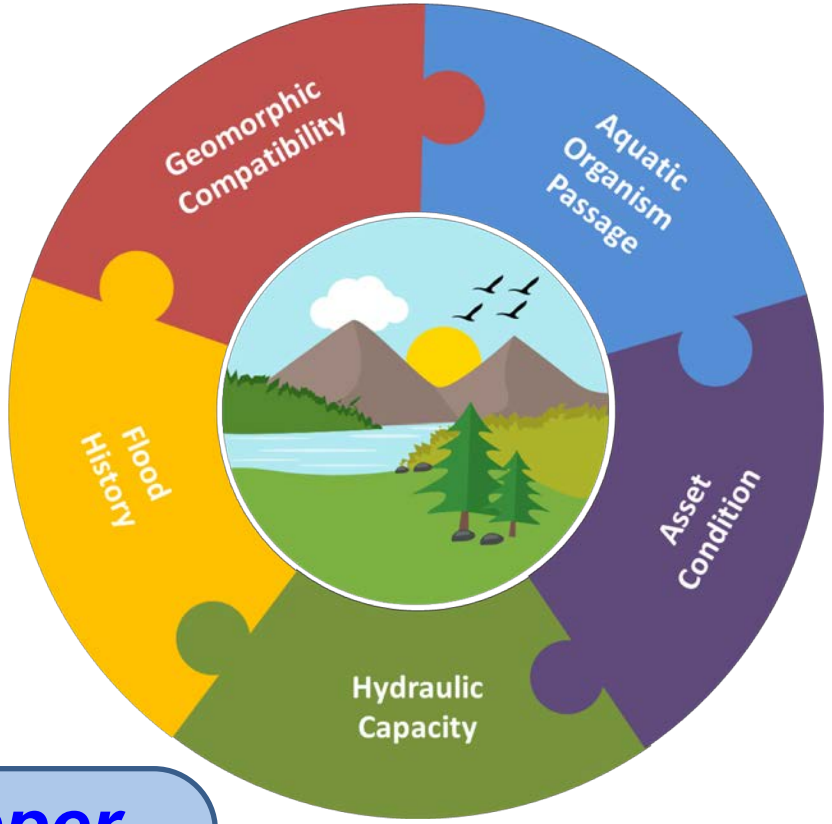




PRIORITIZING CULVERT REPLACEMENTS FOR FISH AND FLOODS

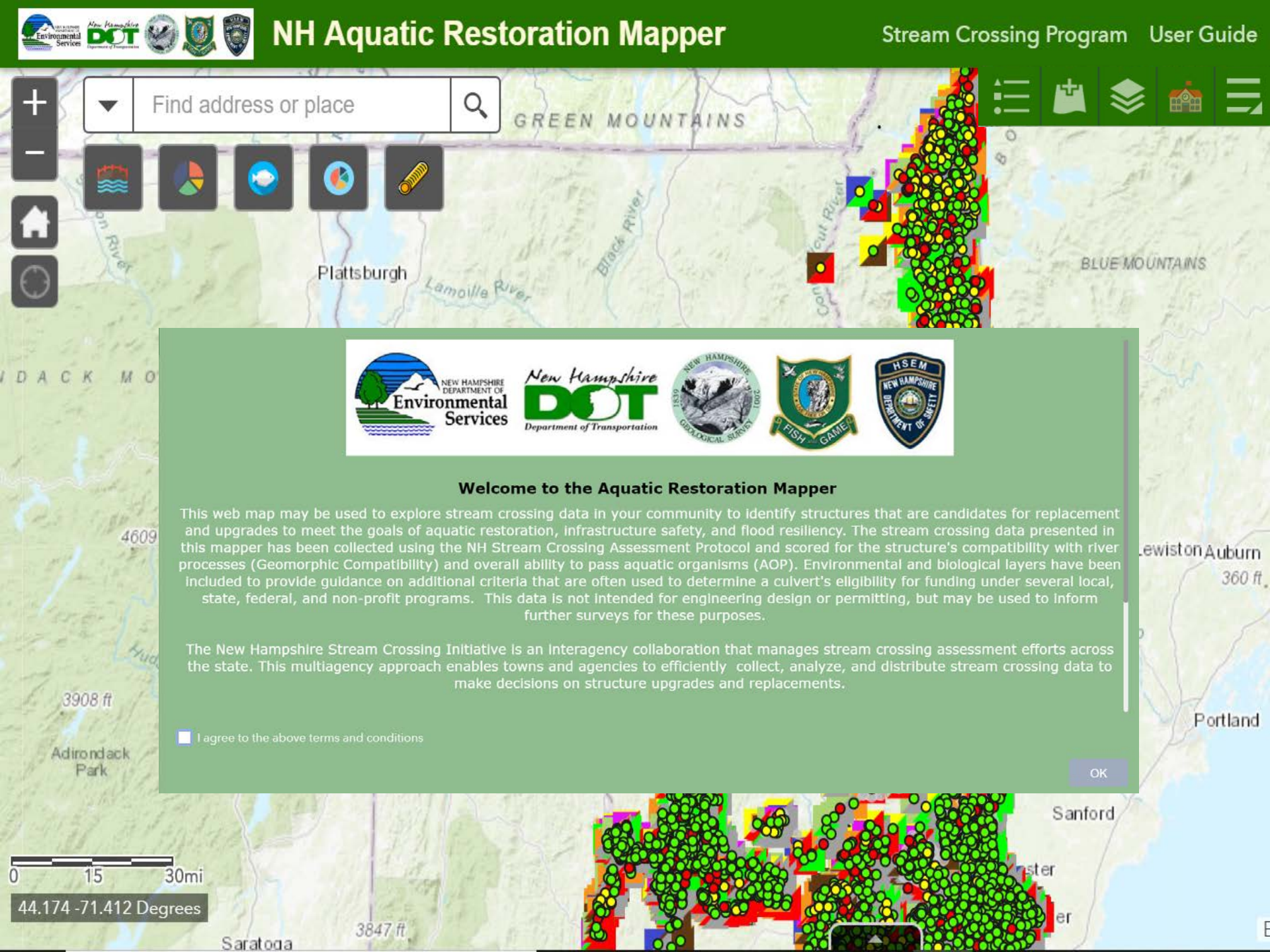
Target Crossings with greatest environmental impact

- ✓ Identify crossings with repeated flood issues and damage
- ✓ Causing bank erosion and scour
- ✓ Barrier to aquatic organism passage
- ✓ Preventing diadromous fish migrations or access to critical spawning habitat
- ✓ Disconnecting T&E species habitat

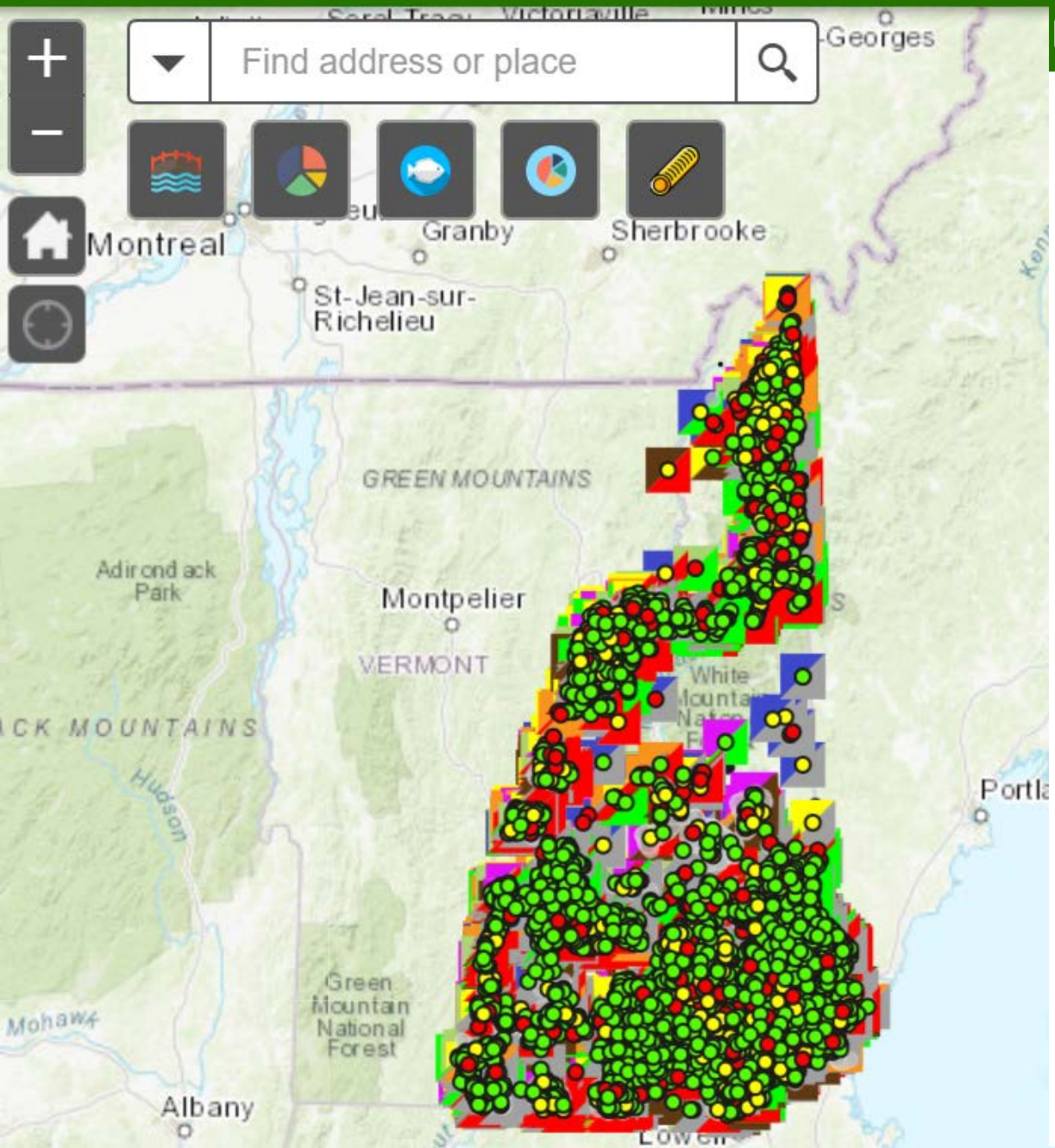


The Aquatic Restoration Mapper

- Interactive mapping tool for prioritizing stream crossing replacements for aquatic connectivity and flood resiliency
- Survey data is now available to the public


NH Aquatic Restoration Mapper
Stream Crossing Program
User Guide
Find address or place
GREEN MOUNTAINS
Plattsburgh
Lamoille River
Black River
BLUE MOUNTAINS
Welcome to the Aquatic Restoration Mapper
This web map may be used to explore stream crossing data in your community to identify structures that are candidates for replacement and upgrades to meet the goals of aquatic restoration, infrastructure safety, and flood resiliency. The stream crossing data presented in this mapper has been collected using the NH Stream Crossing Assessment Protocol and scored for the structure's compatibility with river processes (Geomorphic Compatibility) and overall ability to pass aquatic organisms (AOP). Environmental and biological layers have been included to provide guidance on additional criteria that are often used to determine a culvert's eligibility for funding under several local, state, federal, and non-profit programs. This data is not intended for engineering design or permitting, but may be used to inform further surveys for these purposes.
The New Hampshire Stream Crossing Initiative is an interagency collaboration that manages stream crossing assessment efforts across the state. This multiagency approach enables towns and agencies to efficiently collect, analyze, and distribute stream crossing data to make decisions on structure upgrades and replacements.
I agree to the above terms and conditions
OK
4609
3908 ft
Adirondack Park
Lewiston
Auburn
360 ft
Portland
Sanford
3847 ft
Saratoga
0
15
30mi
44.174 -71.412 Degrees

NH Aquatic Restoration Mapper



Information and Fact Sheets

The New Hampshire Aquatic Restoration Mapper is designed to help you explore stream crossing data in your community to identify structures that are candidates for replacement to meet the goals of aquatic restoration, infrastructure upgrades, and flood resiliency. The stream crossing data has been collected using the New Hampshire Stream Crossing Assessment Protocol and scored for geomorphic compatibility, aquatic organism passage (AOP), and hydraulic vulnerability. Data on stream habitat quality, landscape connectivity, and flood hazards have been included to provide information on additional criteria that are often used to determine a culvert's eligibility for funding under several local, state, federal, and non-profit programs.

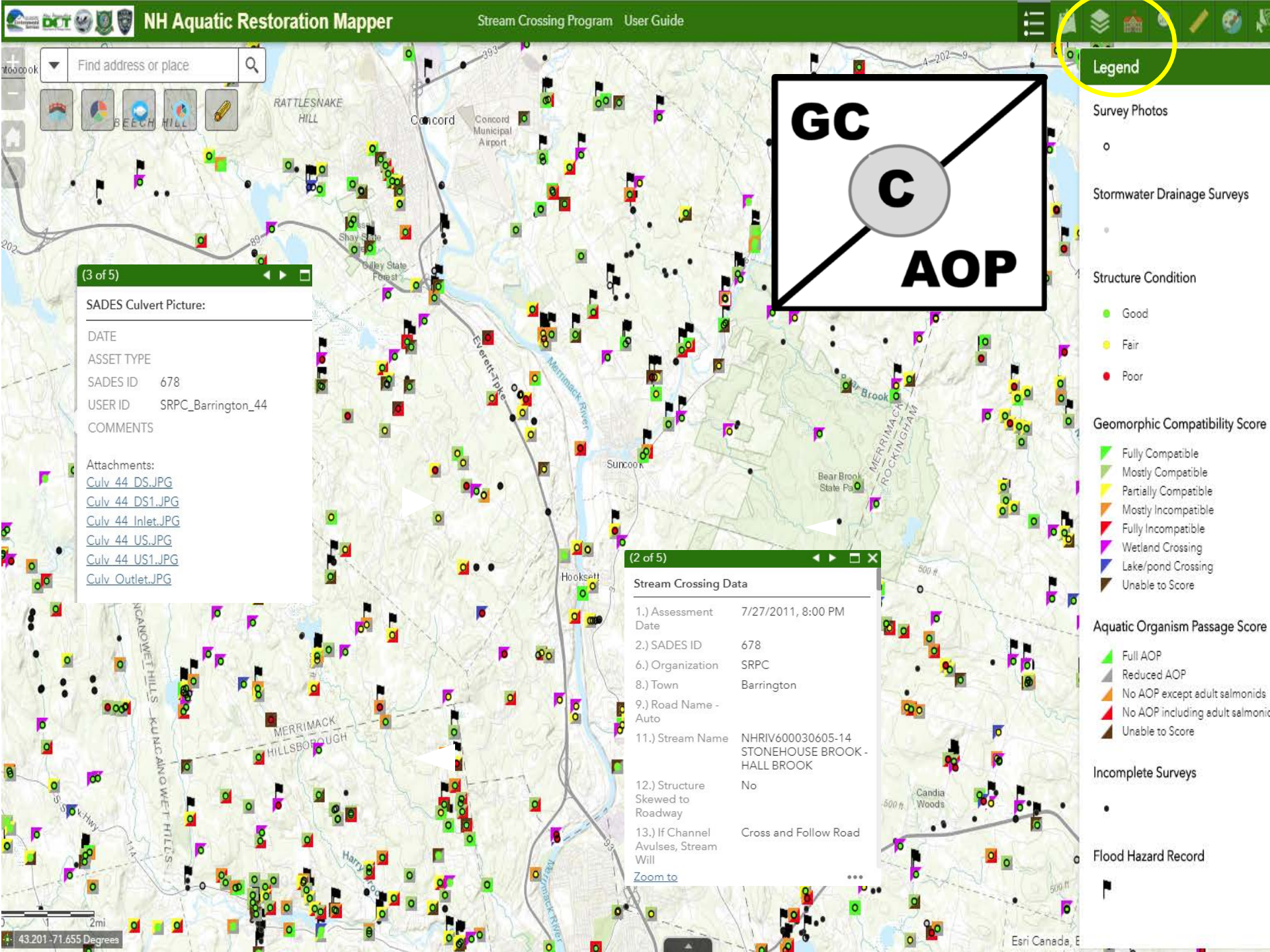
How to use the Mapper- Step by step instructions on how to explore, filter, and export data in the mapper, and information on the data layers and symbology.

- User Guide

How to interpret stream crossing scores-

Refer to the listed handouts for guidance on how to interpret stream crossing scores and the other environmental data provided in this mapper to evaluate stream restoration potential for crossing replacements.

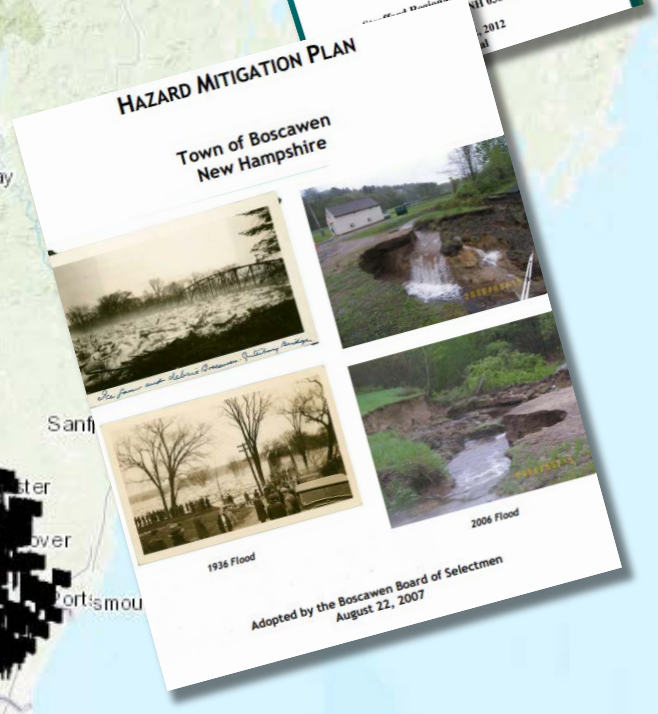
- Geomorphic Compatibility
- Aquatic Organism Passage
- Hydraulic Vulnerability

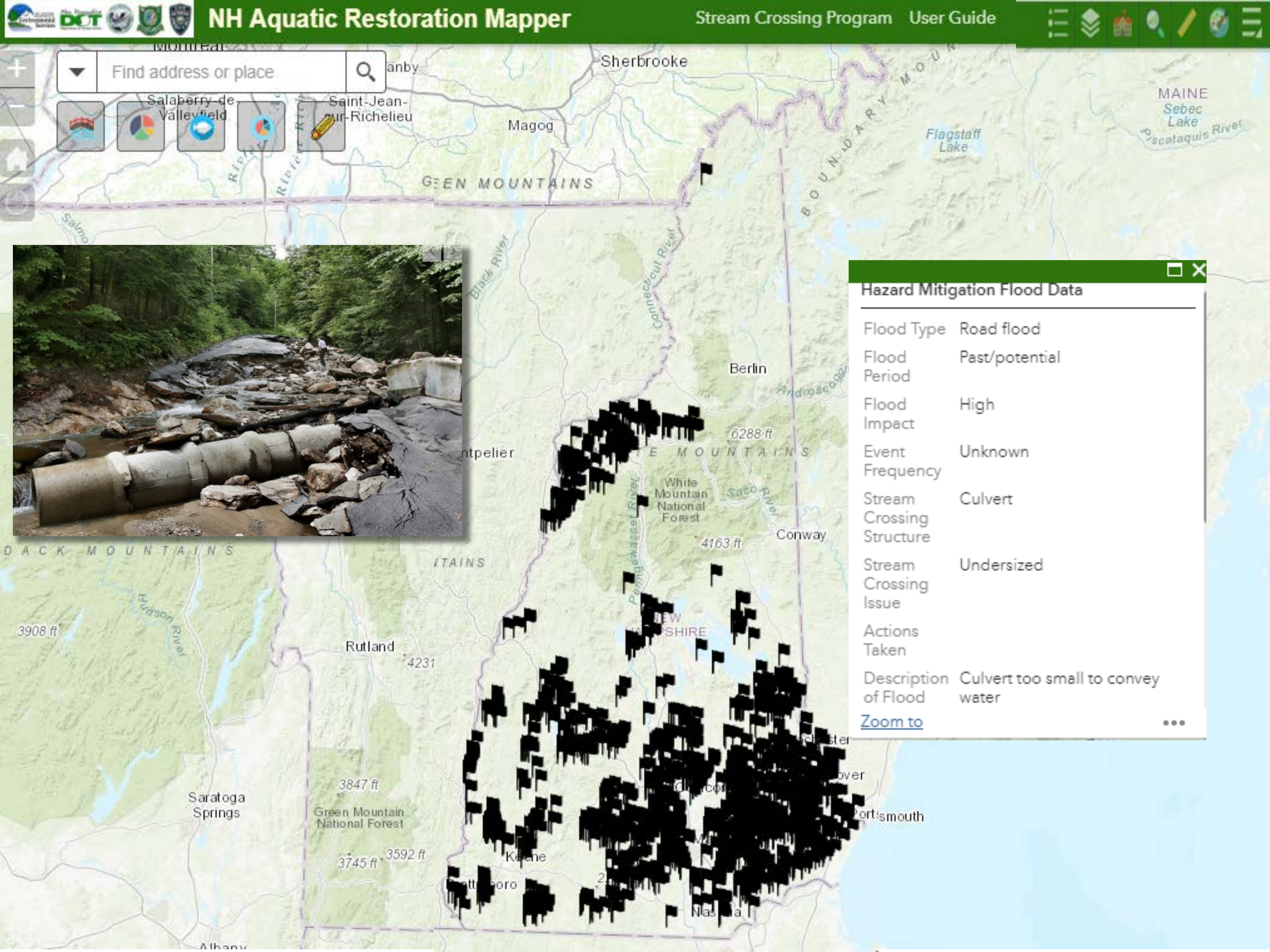

NH Aquatic Restoration Mapper
Stream Crossing Program
User Guide
Find address or place
Legend
Survey Photos
Stormwater Drainage Surveys
Structure Condition
Good
Fair
Poor
Geomorphic Compatibility Score
Fully Compatible
Mostly Compatible
Partially Compatible
Mostly Incompatible
Fully Incompatible
Wetland Crossing
Lake/pond Crossing
Unable to Score
Aquatic Organism Passage Score
Full AOP
Reduced AOP
No AOP except adult salmonids
No AOP including adult salmonid
Unable to Score
Incomplete Surveys
Flood Hazard Record
GC
C
AOP
(3 of 5)
SADES Culvert Picture:
DATE
ASSET TYPE
SADES ID 678
USER ID SRPC_Barrington_44
COMMENTS
Attachments:
Culv_44_DS.JPG
Culv_44_DS1.JPG
Culv_44_Inlet.JPG
Culv_44_US.JPG
Culv_44_US1.JPG
Culv_Outlet.JPG
(2 of 5)
Stream Crossing Data
1.) Assessment Date 7/27/2011, 8:00 PM
2.) SADES ID 678
6.) Organization SRPC
8.) Town Barrington
9.) Road Name - Auto
11.) Stream Name NHRIV600030605-14 STONEHOUSE BROOK - HALL BROOK
12.) Structure Skewed to Roadway No
13.) If Channel Avulses, Stream Will Cross and Follow Road
Zoom to
Concord
Suncook
Hooksett
Bear Brook State Park
Esri Canada

NH Aquatic Restoration Mapper

Stream Crossing Program User Guide

Find address or place

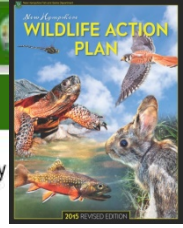



NH Aquatic Restoration Mapper
Stream Crossing Program
User Guide
Find address or place
Hazard Mitigation Flood Data
Flood Type Road flood
Flood Period Past/potential
Flood Impact High
Event Frequency Unknown
Stream Crossing Structure Culvert
Stream Crossing Issue Undersized
Actions Taken
Description of Flood Culvert too small to convey water
Zoom to
Sherbrooke
Magog
Saint-Jean-sur-Richelieu
Salaberry-de-Valleyfield
MAINE
Sebec Lake
Piscataquis River
Flagstaff Lake
BOUNDARY MOUNTAINS
GREEN MOUNTAINS
Connecticut River
Black River
Berlin
Androscoggin
6288 ft
White Mountain National Forest
Saco River
Conway
4163 ft
Pemigewasset River
Hudson River
3908 ft
Rutland
4231
Saratoga Springs
3847 ft
Green Mountain National Forest
3745 ft
3592 ft
Keene
Portsmouth
Albany

NH Aquatic Restoration Mapper

Stream Crossing Program User Guide

Find address or place



Legend

American Brook Lamprey

Bridle Shiner Habitat

Springfed Wild Brook Trout
- Y

Wild Eastern Brook Trout
- P

Species of Concern
- P

NH Fish and Game Fishery Restoration Interest

Predicted Coldwater Fishery
- Coldwater

Herring Stock Location or Migratory Path
- M
- Y

Seacoast Anadromous Fish Habitat

American Shad Spawning Habitat
- Y

(1 of 2)

Wild Eastern Brook Trout

Wild Brook Trout Present	P
Stream Name	Frazier Brook
Stream Description	Stream/River: Hydrographic Category = Perennial

Wild Eastern Brook Trout (Salvelinus fontinalis)

Zoom to

Franklin
Andover
Belmont
Gilmanton
Gilmanton Ironworks
Alton
Salisbury
Loudon
Pittsfield
Chichester
Epsom
Northwood
Concord
Contoocook
Warner
Hirst Wma
Strafford
West Nottingham
Bear Brook State Park
Pawtuckaway State Park
Suncook
Hooksett
North Rd
Merrimack Valley Hwy
Blue Hills Range
Strafford Belknap
Esri Canada, E

NH Aquatic Restoration Mapper

Stream Crossing Program User Guide

Find address or place

Legend

DesignatedRivers

Designated Rivers

Dams

Dam Inventory

Wetlands Inventory

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

Conservation Land Parcels

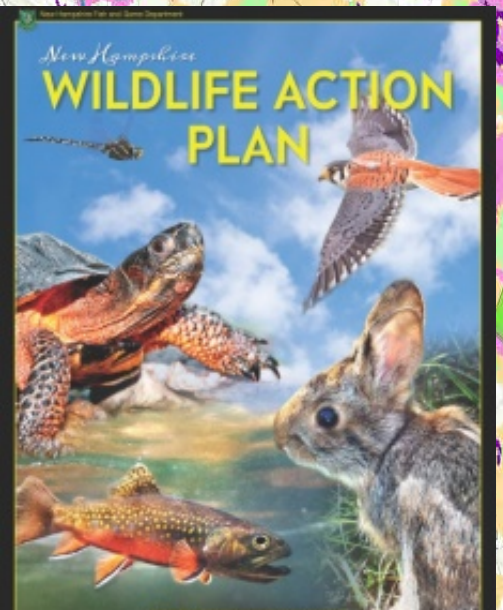
Conservation and Public Lands

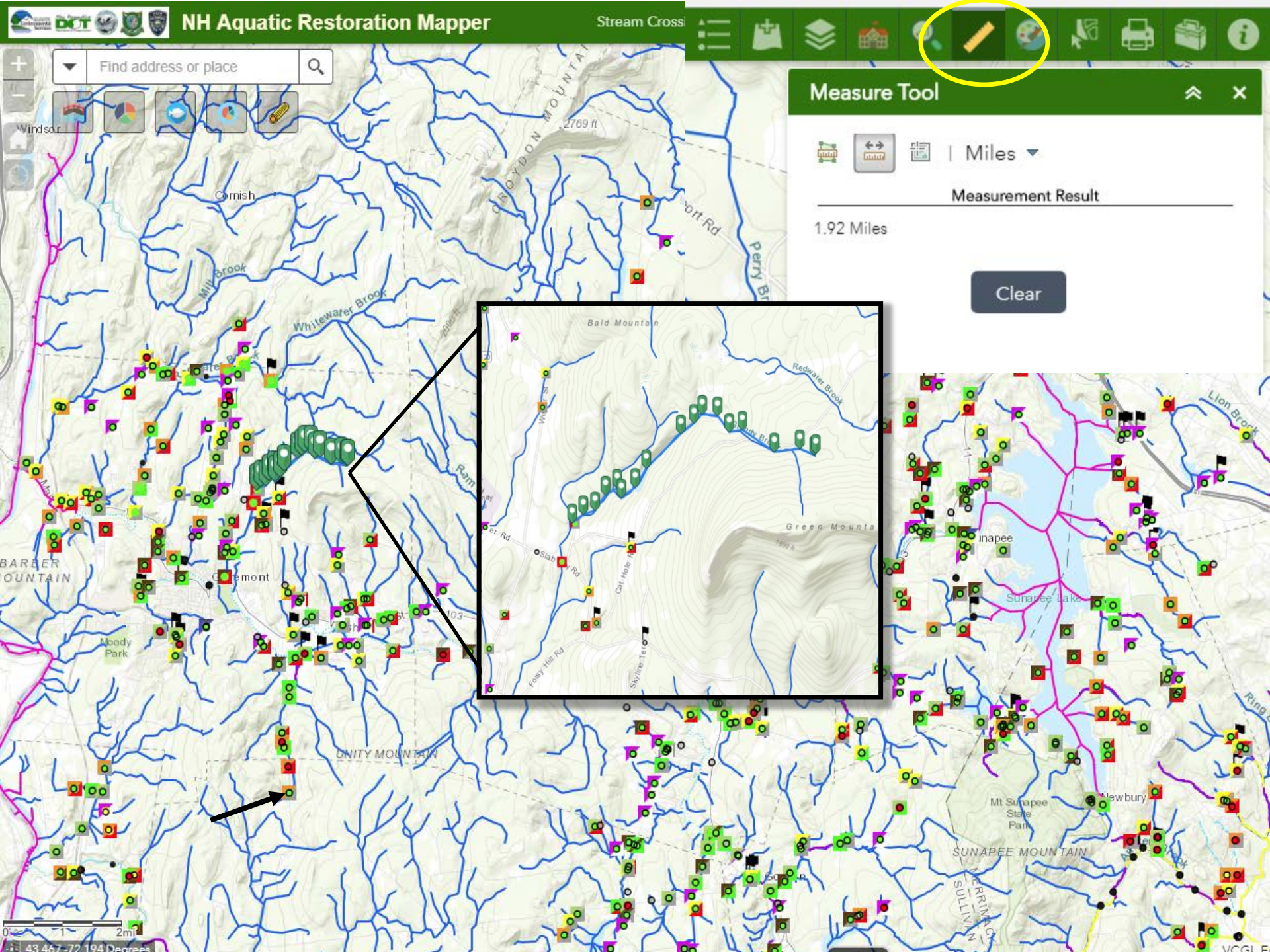
- Permanent conservation land
- Unofficial conservation land
- Unprotected water supply land
- Developed public land
- Unknown

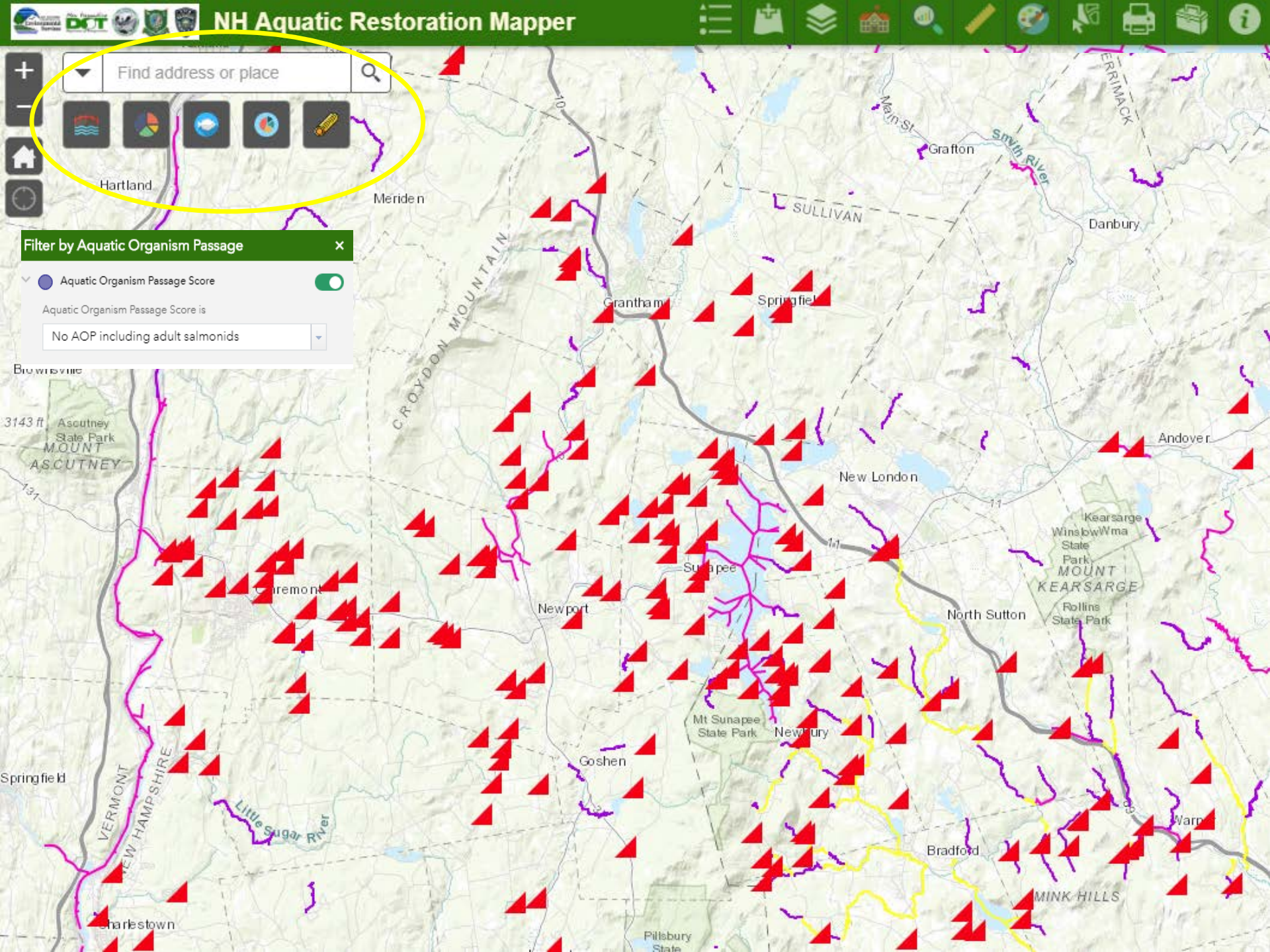
Wildlife Action Plan Habitat Teirs

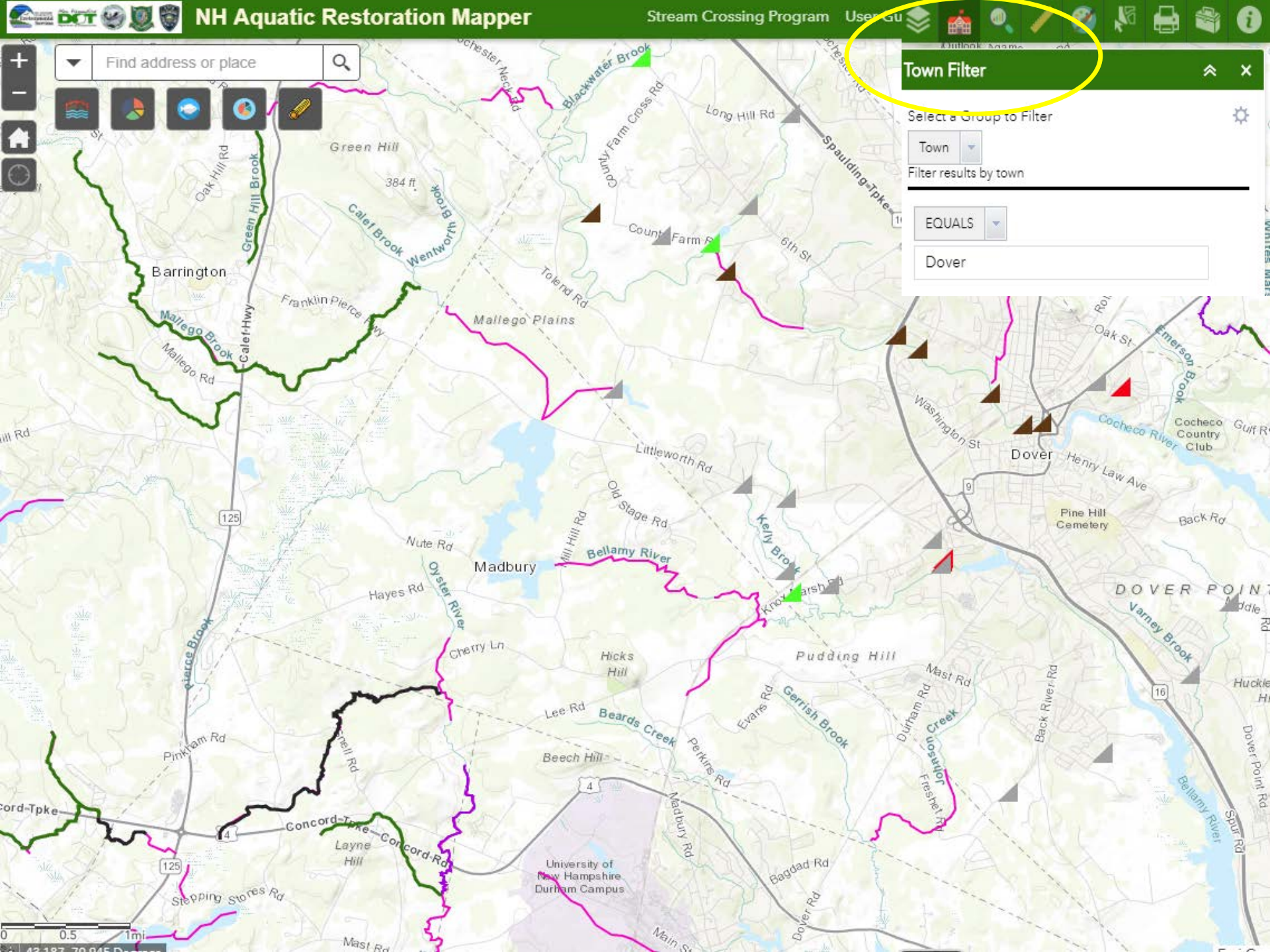
WAP 2015: Highest Ranked Wildlife Habitat

- Not Top Ranked
- Highest Ranked Habitat in NH
- Highest Ranked Habitat in Region
- Supporting Landscape




NH Aquatic Restoration Mapper
Stream Crossi
Find address or place
Measure Tool
Miles
Measurement Result
1.92 Miles
Clear
Windsor
Cornish
Croydon Mountain
2769 ft
Mill Brook
Whitewater Brook
Perry Br
Bald Mountain
Redwater Brook
Green Mountain
Slab City Rd
Foley Hill Rd
Skyline Ter
Claremont
Moody Park
BARBER
OUNTAIN
UNITY MOUNTAIN
Sunapee Lake
Lion Brook
Mt Sunapee State Park
Newbury
SUNAPEE MOUNTAIN
MERRIMACK
SULLIVAN
43.467 -72.194 Degrees


NH Aquatic Restoration Mapper
Find address or place
Filter by Aquatic Organism Passage
Aquatic Organism Passage Score
Aquatic Organism Passage Score is
No AOP including adult salmonids
Hartland
Meriden
Grafton
Danbury
Grantham
Springfield
New London
Andover
Newport
North Sutton
Goshen
Springfield
Bradford
Charlestown
Pillsbury State
Ascutney State Park
MOUNT ASCUTNEY
MOUNT KEARSARGE
Rollins State Park
Mt Sunapee State Park
CROYDON MOUNTAIN
SULLIVAN
MINK HILLS
VERMONT
NEW HAMPSHIRE
Little Sugar River
Smyth River
Main St


NH Aquatic Restoration Mapper
Stream Crossing Program
Find address or place
Town Filter
Select a Group to Filter
Town
Filter results by town
EQUALS
Dover
Barrington
Madbury
Dover
Green Hill
Oak Hill Rd
Green Hill Brook
Calef Brook
Wentworth Brook
Blackwater Brook
County Farm Cross Rd
Long Hill Rd
Spaulding Tpke
Tolend Rd
Mallego Plains
Mallego Brook
Mallego Rd
Calef Hwy
Franklin Pierce Hwy
Littleworth Rd
Old Stage Rd
Mill Hill Rd
Bellamy River
Kelly Brook
Nute Rd
Oyster River
Hayes Rd
Cherry Ln
Hicks Hill
Pudding Hill
Mast Rd
Durham Rd
Gerrish Brook
Evans Rd
Lee Rd
Beards Creek
Perkins Rd
Beech Hill
Pinkham Rd
Concord-Tpke
Layne Hill
Stepping Stones Rd
University of New Hampshire Durham Campus
Madbury Rd
Bagdad Rd
Dover Rd
Oak St
Washington St
Emerson Brook
Cocheco River
Cocheco Country Club
Henry Law Ave
Pine Hill Cemetery
Back Rd
Varney Brook
Back River Rd
Johnson Creek
Bellamy River
Spur Rd
Dover Point Rd
DOVER POINT
6th St
Fresnel Rd
Huckle
125
4
9
16
0
0.5
1mi

NH Aquatic Restoration Mapper

Stream Crossing Program User Guide

Find address or place

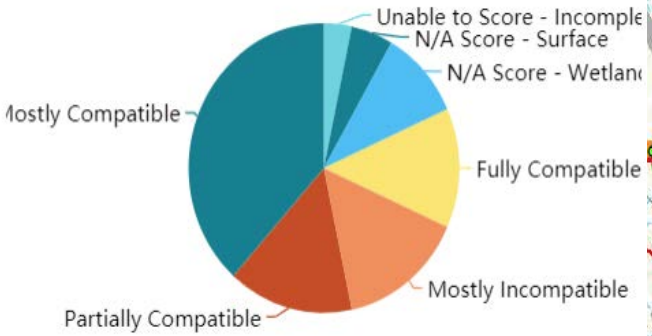
Data Summary

Stream Crossing Summary

Flood Reports Available	33
Flood	12
Road flood	16
Washout	5
Geomorphic Compatibility Summary	63
Fully Compatible	7
Mostly Compatible	25
Mostly Incompatible	10
N/A Score - Wetland	6
undefined	1
N/A Score - Surface	3
Partially Compatible	9
Unable to Score - Incomplete	2
Aquatic Organism Passage Summary	63
Full AOP	9
No AOP except adult salmonids	1
No AOP including adult salmonids	16

Geomorphic Compatibility Stats

Summary of Scores



This pie chart displays the percentage of stream crossings within each Geomorphic Compatibility score for the filtered map extent.

UPGRADING CULVERTS

What benefits fish, benefits people

- Undersized, 50-foot long metal pipe causing bank and bed erosion
- A barrier to local eastern brook trout
- Flood hazard

FALL BROOK CULVERT SWANZEY, NH

- Restore instream aquatic habitat
- Reconnect coldwater stream for brook trout
- Support high ranked wildlife habitat
- Increase resiliency

Project Partners:

Trout Unlimited, Cheshire County Conservation District, Town of Swanzey, NRCS, Fish &Game, Harris Center, NHDES Arm Fund

UPGRADING CULVERTS

What benefits fish, benefits people

- Installed span open-bottom arch
- Open 10 miles upstream access to coldwater spawning habitat on headwater tributaries
- Stream simulation and increased hydraulic capacity to pass 100-year storm event

FALL BROOK CULVERT SWANZEY, NH

- Restore instream aquatic habitat
- Reconnect coldwater stream for brook trout
- Support high ranked wildlife habitat
- Increase resiliency

Project Partners:

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FUNDING FOR STREAM CROSSING UPGRADES

Funding Source	Eligibility Criteria						
	Aquatic barrier	Restores connectivity for T&E/diadromous Spp of concern	Inadequate hydraulic capacity/ overtops	History of costly repairs from flood	Public safety hazard	Builds climate change resiliency	Commercial/ Recreational importance
NHDES Aquatic Resource Mitigation Fund							
NHFG Fisheries Habitat Account							
FEMA-HSEM Hazard Mitigation Assistance Grant Programs[1]							
USFWS National Fish Passage Program							
National Fish Habitat Action Plan- Eastern Brook Trout Joint Venture							
NFWF New England Forests and Rivers Fund							
NHDES Coastal Resilience Grants							
NOAA Coastal and Marine Fisheries Habitat Restoration Grants							

[1]Hazard Mitigation Assistance Grant Programs include: The Hazard Mitigation Grant Program (HMGP), Pre-Disaster Mitigation (PDM) Grant Program, and Flood Mitigation Assistance (FMA) Program.

THANK YOU!

New Hampshire Department of Environmental Services

New Hampshire DOT Department of Transportation

HSEM New Hampshire Department of Safety

New Hampshire Technology Transfer Center

State of New Hampshire Live Free or Die Fish and Game

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The Nature Conservancy
Regional Planning Commissions
University of NH