Stream Ecosystems and their Restoration

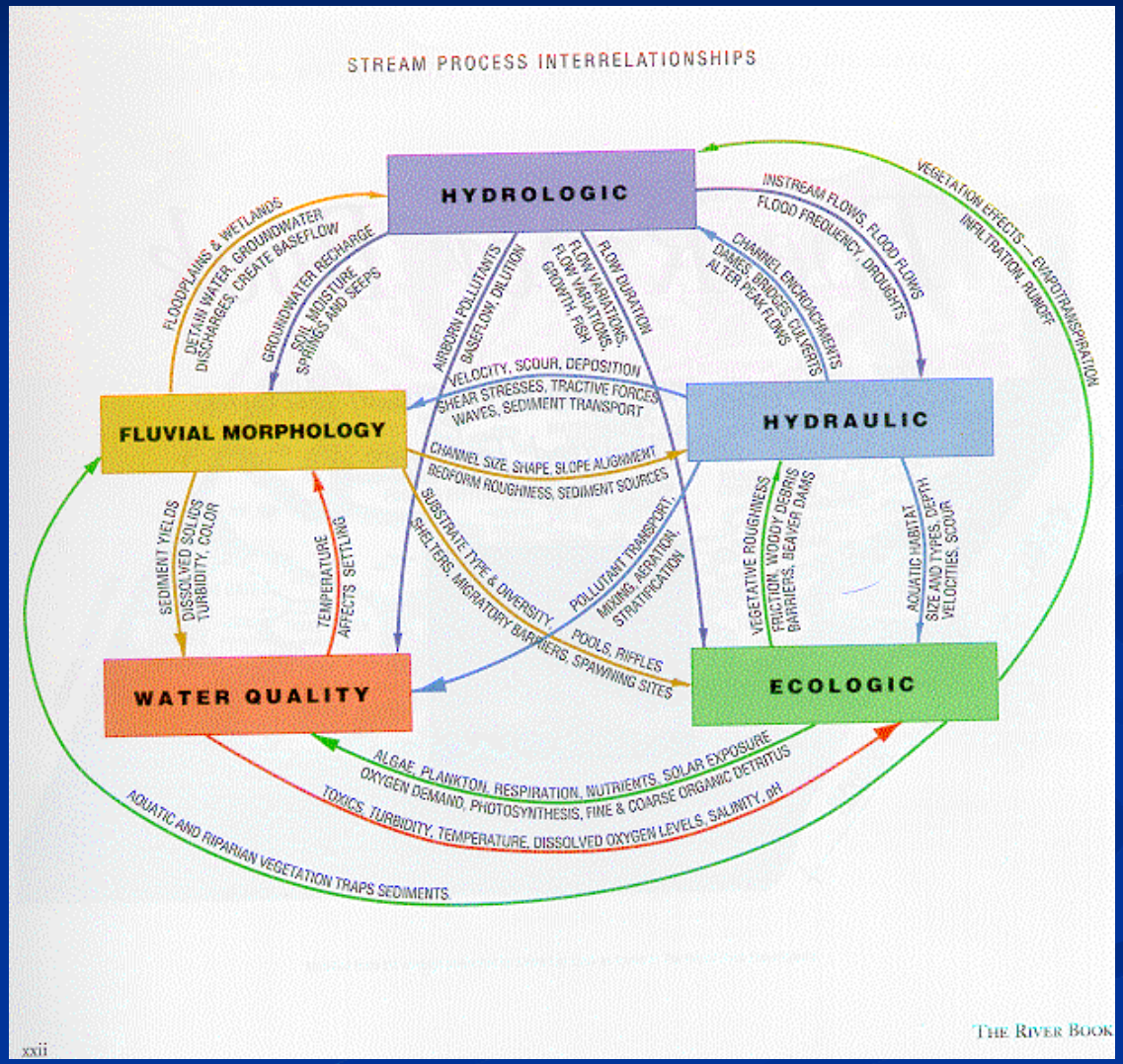
NHDES Watershed Conference – November 21, 2009

Jim MacCartney, TU – John Magee, NHFG

Overview

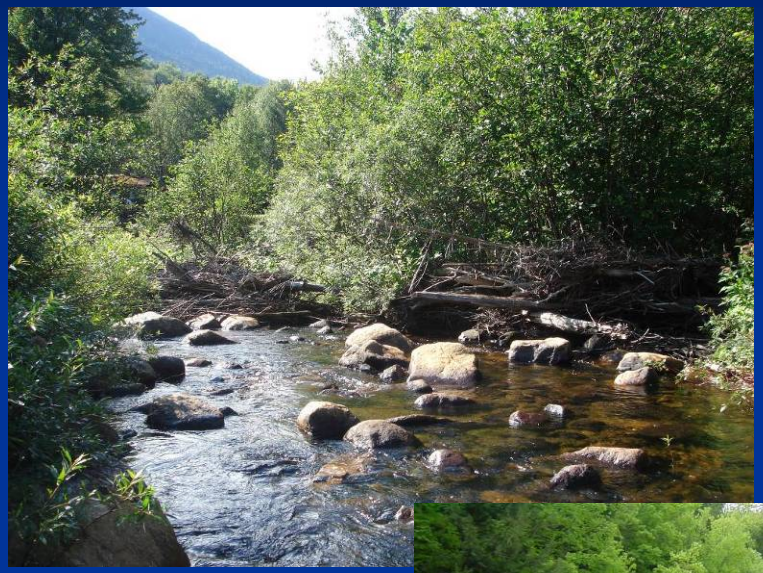
- Fluvial dynamics
  - Fluvial geomorphology
  - Hydrology
  - Hydraulics
- Stream ecology
  - Unique ecosystems
  - Susceptible to dramatic and frequent changes in habitat
  - Activities (active and passive) that can improve the health of streams
  - How human activities impact stream ecosystems
- Fish research at Nash Stream
  - How does habitat influence brook trout populations?
  - Do brook trout travel within the watershed?
  - Do they need to move?
- Nash Stream Restoration Project
  - Significant impacts
  - Selection of treatments from a range of restoration options using geomorphic concepts
  - Examples of restoration activities
  - Plans for the future

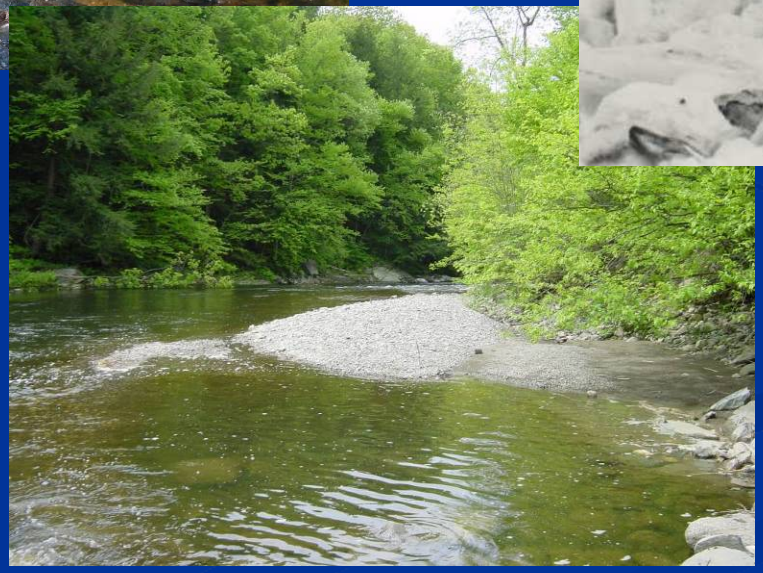
Fluvial dynamics



Courtesy: James MacBroom

Watershed products



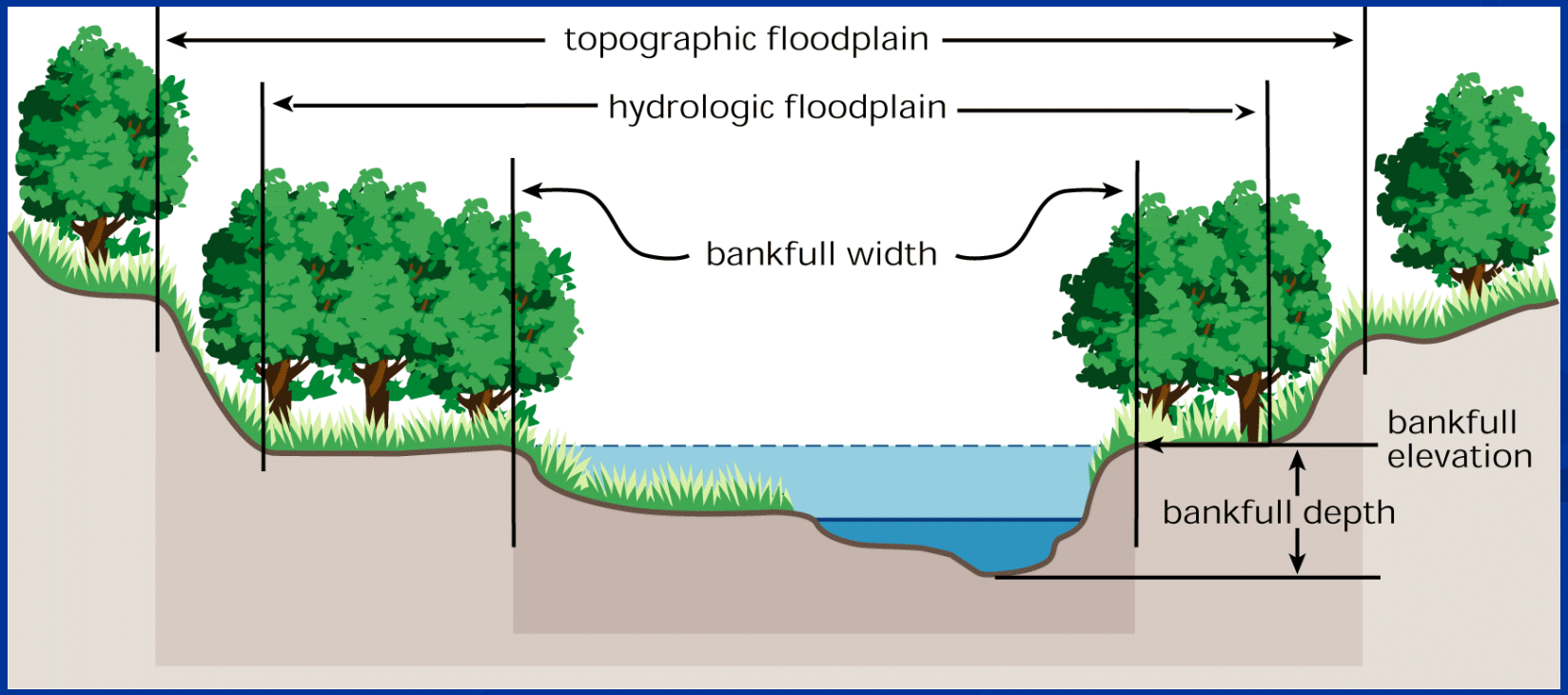


Major sciences of stream dynamics

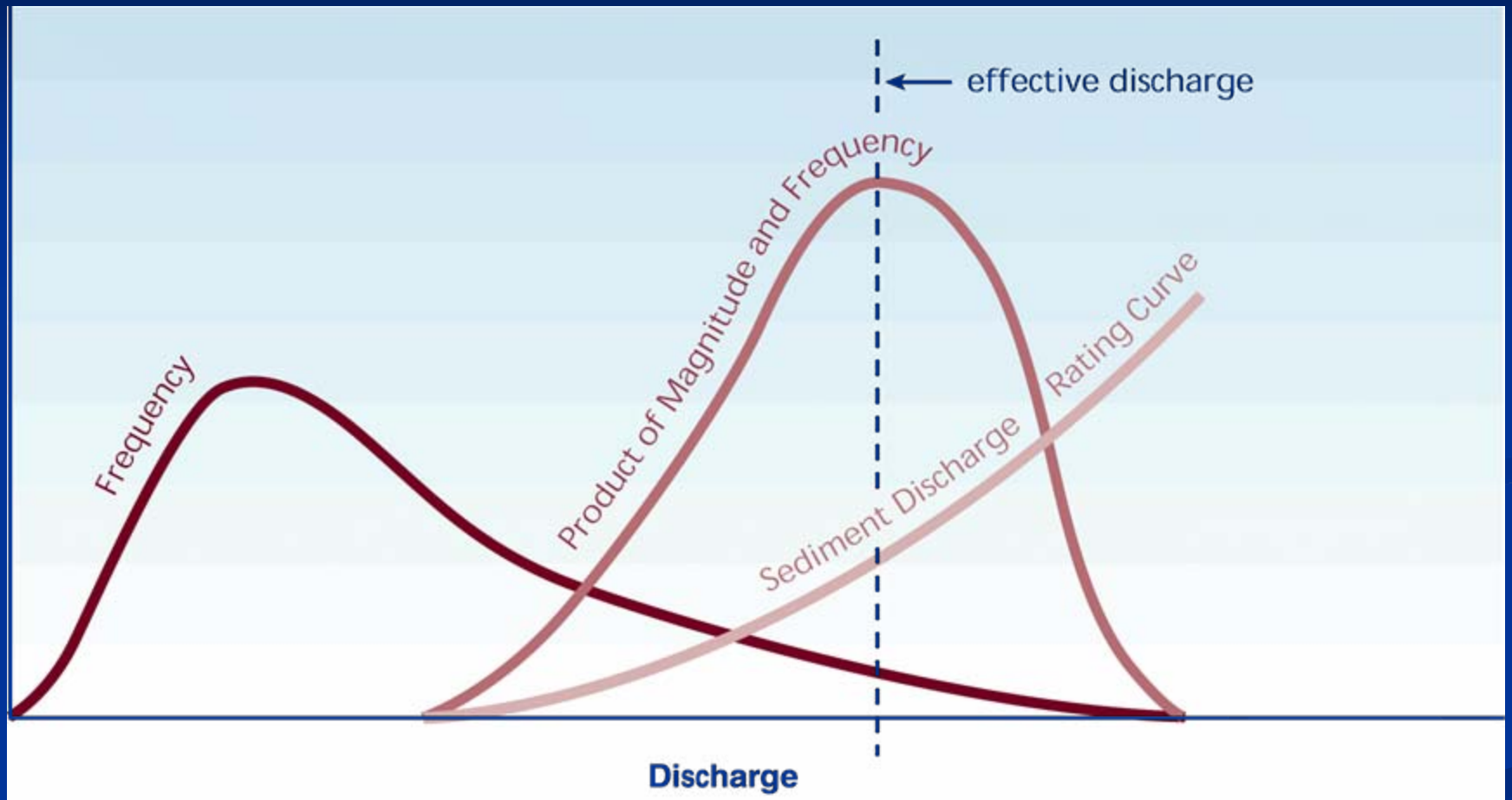
- Fluvial geomorphology – the study of how flowing water shapes the earth and transports watershed products
- Hydrology – the study of the circulation of water above, below and on the earth's surface
- Hydraulics – an applied science dealing with the flow of liquids, such as water

Geomorphic job description

- Streams build the cross section, slope and pattern necessary to transport the products (water, sediment, debris and ice) supplied by their watersheds



Bankfull discharge

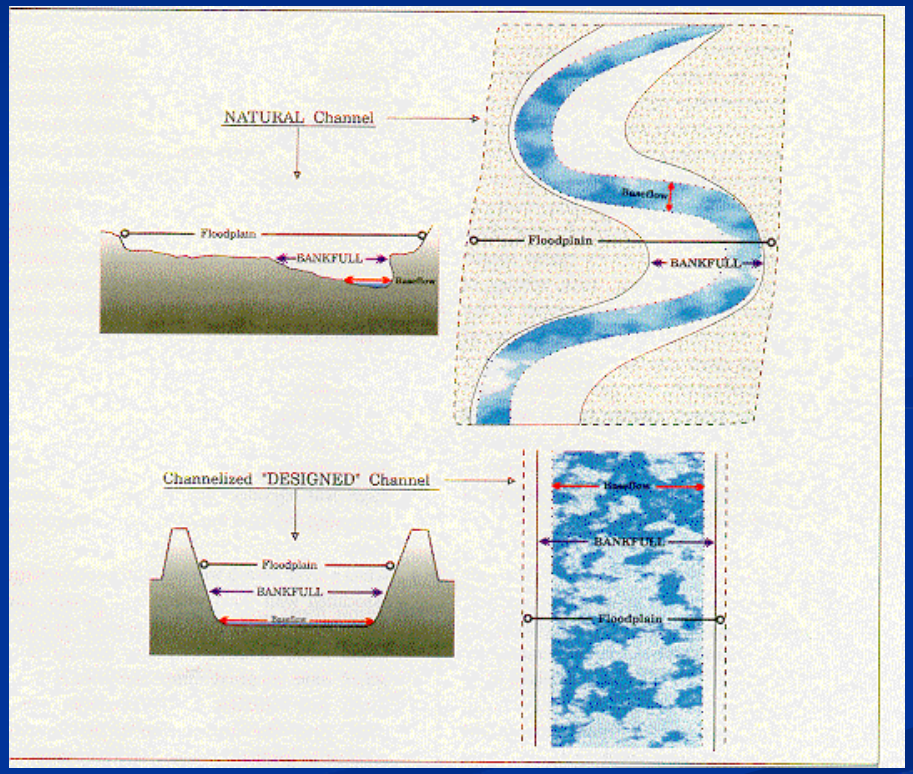


From Wolman and Miller, 1960.

Fig. 7.5 -- Effective discharge determination from sediment rating and flow duration curves.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

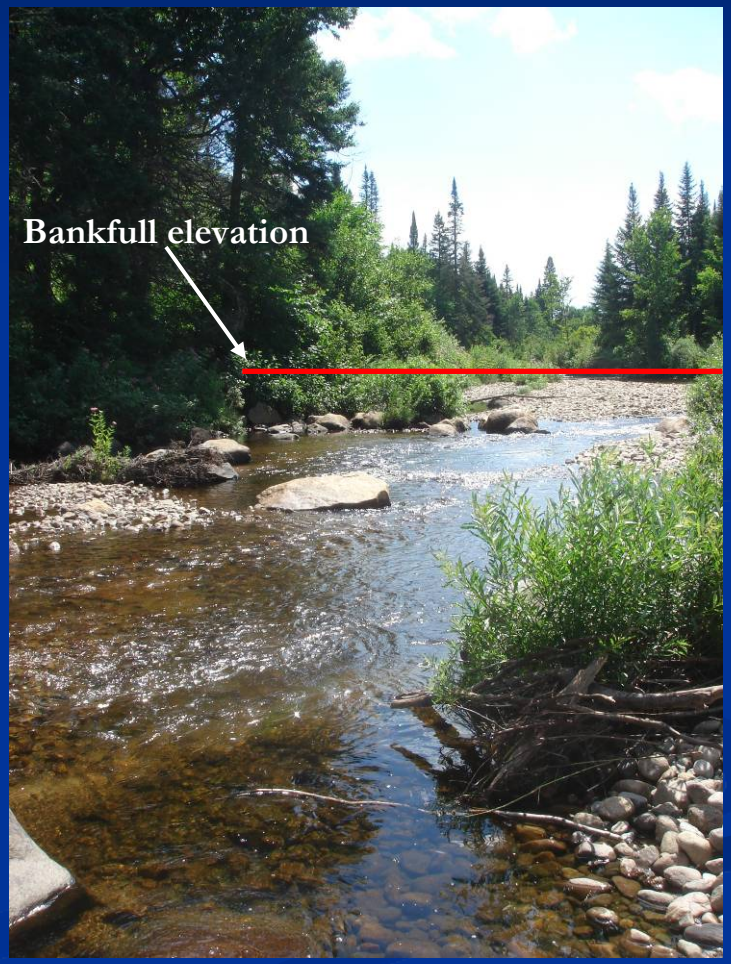
Bankfull channel

- Wider than the area wetted at base flow
- Wider than the active channel scoured during the growing season
- Narrower than the floodplain itself



Bankfull indicators

- Top of point bar
- Deposition
- Break in slope
- Vegetation
- Particle size change
- Stains on rocks



Channel change – watershed position

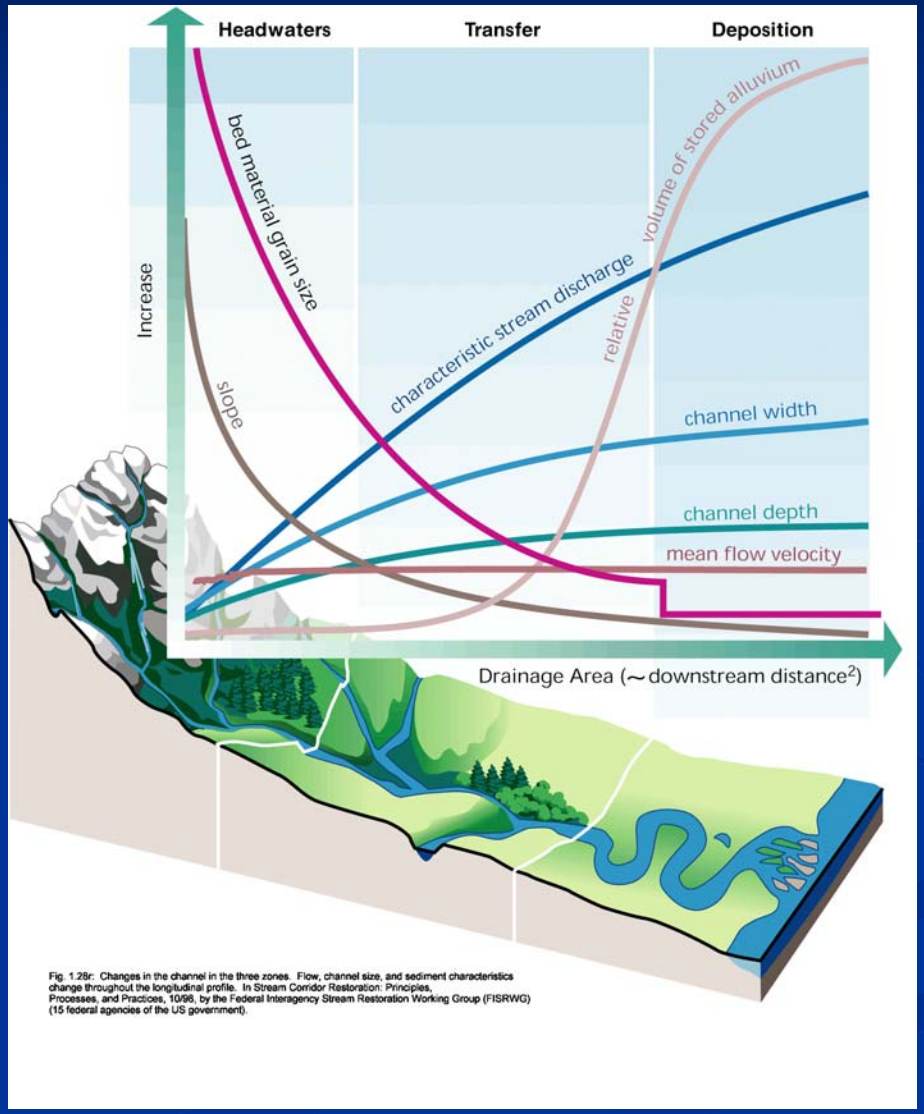


Fig. 1.28r: Changes in the channel in the three zones. Flow, channel size, and sediment characteristics change throughout the longitudinal profile. In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG) (15 federal agencies of the US government).

Geomorphic characteristics

- Channel shape varies by watershed position and local climate and geology

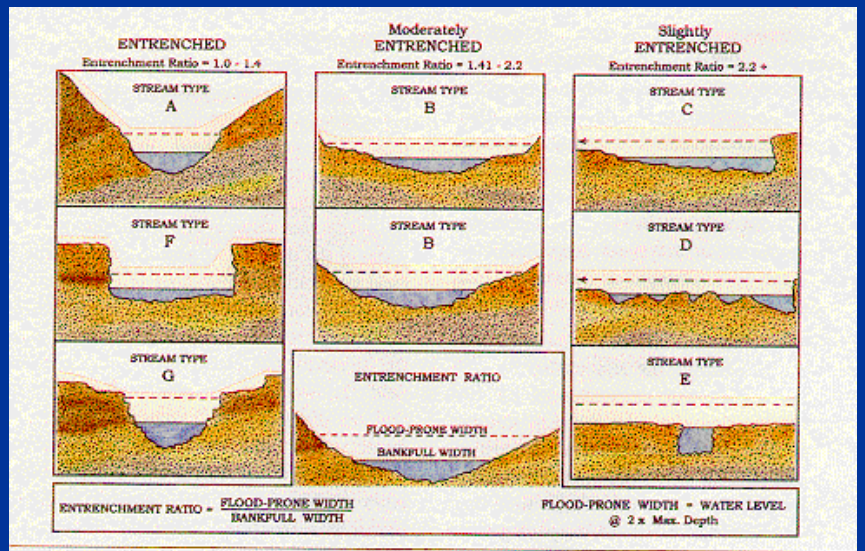


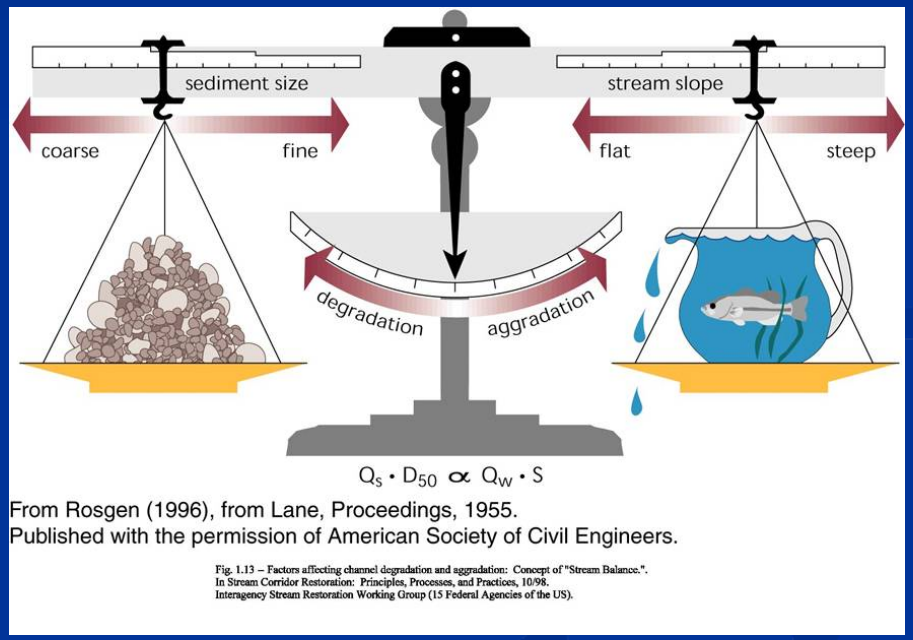
FIGURE 5-10. Representative entrenchment ratios for cross-sections of various stream types.

- Pattern
  - Belt-width
  - Meander length
  - Radius of curvature
- Profile
  - Slope
  - Pool to pool spacing
- Cross-section
  - Access to floodplain
  - Entrenchment ratio

Dynamic equilibrium

Channel stability

- Balance between water and sediment supply
- Balance between particle size and channel slope
- Balance between degradation and aggradation



Lane's Balance

Streams Change!

1979

1998

Stream disturbance

- Natural events
  - Floods
  - Slope failure
  - Debris jams
  - Lateral migration
  - Headcutting

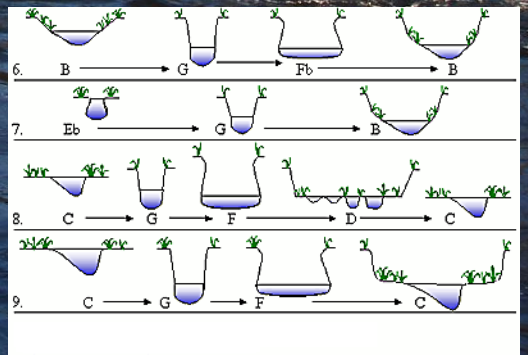
Jian River in Tangjiashan – Sichuan Province, May 2008

- Human activities
  - Land clearing for farming
  - Road / RR encroachment and crossings
  - Straightening & relocation
  - Channel armoring
  - Deforestation
  - Hard rock & gravel mining
  - Floodplain fill
  - Dam construction
  - Flow diversion
  - Discharges

Tendency towards equilibrium

Channel response to disturbance

- Stream channels evolve in predictable ways to regain equilibrium following disturbance
  - Headcut
  - Incision (degradation)/ widening
  - Aggradation / braiding
  - Bank erosion / loss of vegetation
  - Width/depth ratio adjustment
  - Quasi-equilibrium



"Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land"

--- Luna Leopold

"To live on the Land, we must learn from the Sea"

--- John Denver, Calypso (a song in tribute to Jacques Cousteau)

Stream ecology

- Directly and indirectly tied into the watershed
- Ecology is dependent on:
  - Water
  - Sediment
  - Wood
  - Ice
  - Nutrients
  - And the **flow of all of these** – both downstream and between the riparian area and stream

Watersheds

"Water and [wood, leaves, sediment], energy, and organisms meet and interact within the stream corridor over space and time. This movement provides critical functions essential for maintaining life such as cycling nutrients, filtering contaminants from runoff, absorbing and gradually releasing floodwaters, maintaining fish and wildlife habitats, recharging ground water, and maintaining stream flows".

- from: "Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG)."

Take home messages

- Everything in the Watershed is tied together
- Wood is good
- Don’t isolate populations

How watersheds work

Water!

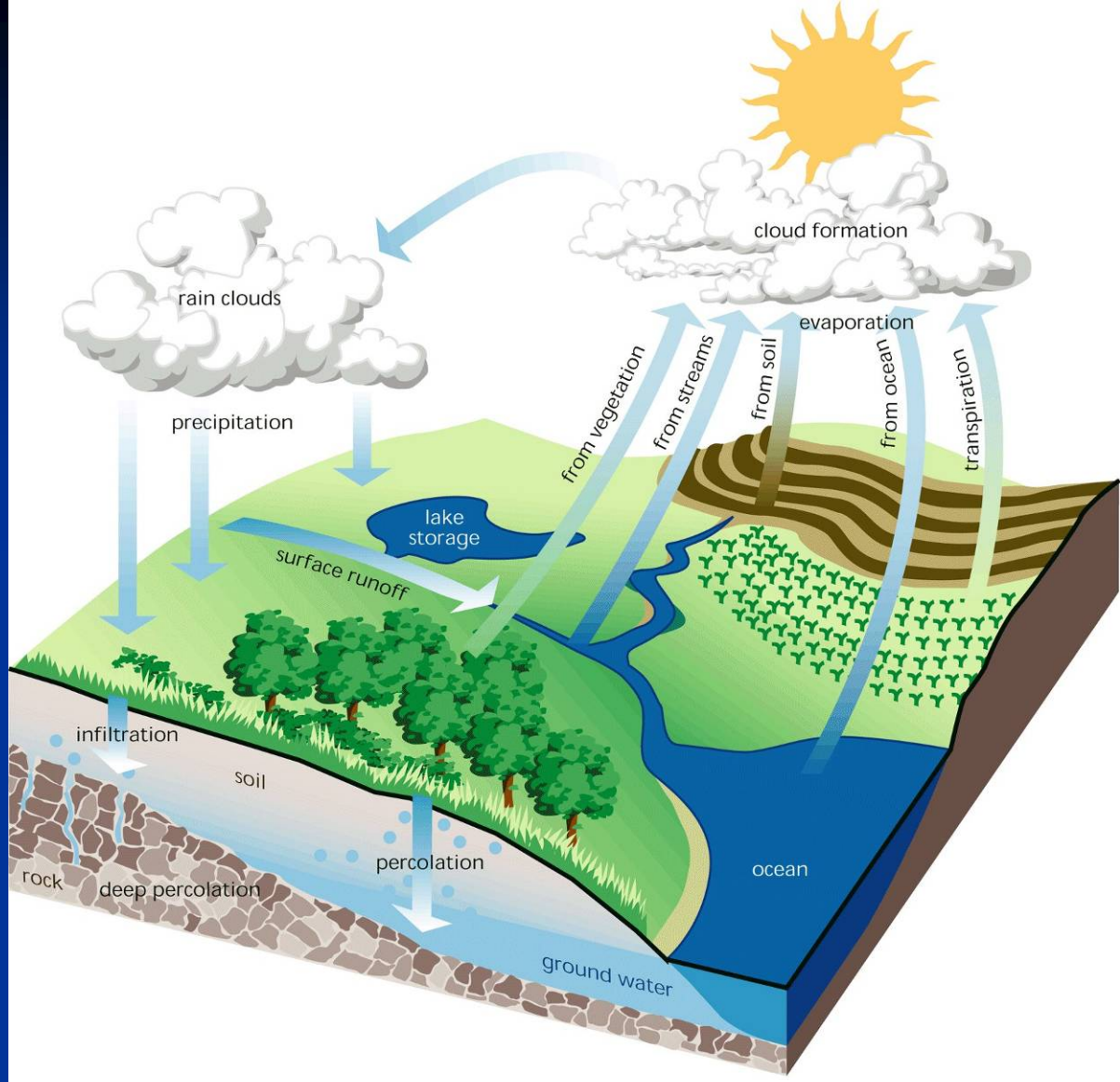


Fig. 2.2 -- The hydrologic cycle. The transfer of water from precipitation to surface water and ground water, to storage and runoff, and eventually back to the atmosphere is an ongoing cycle.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).

Image from: "Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG)."

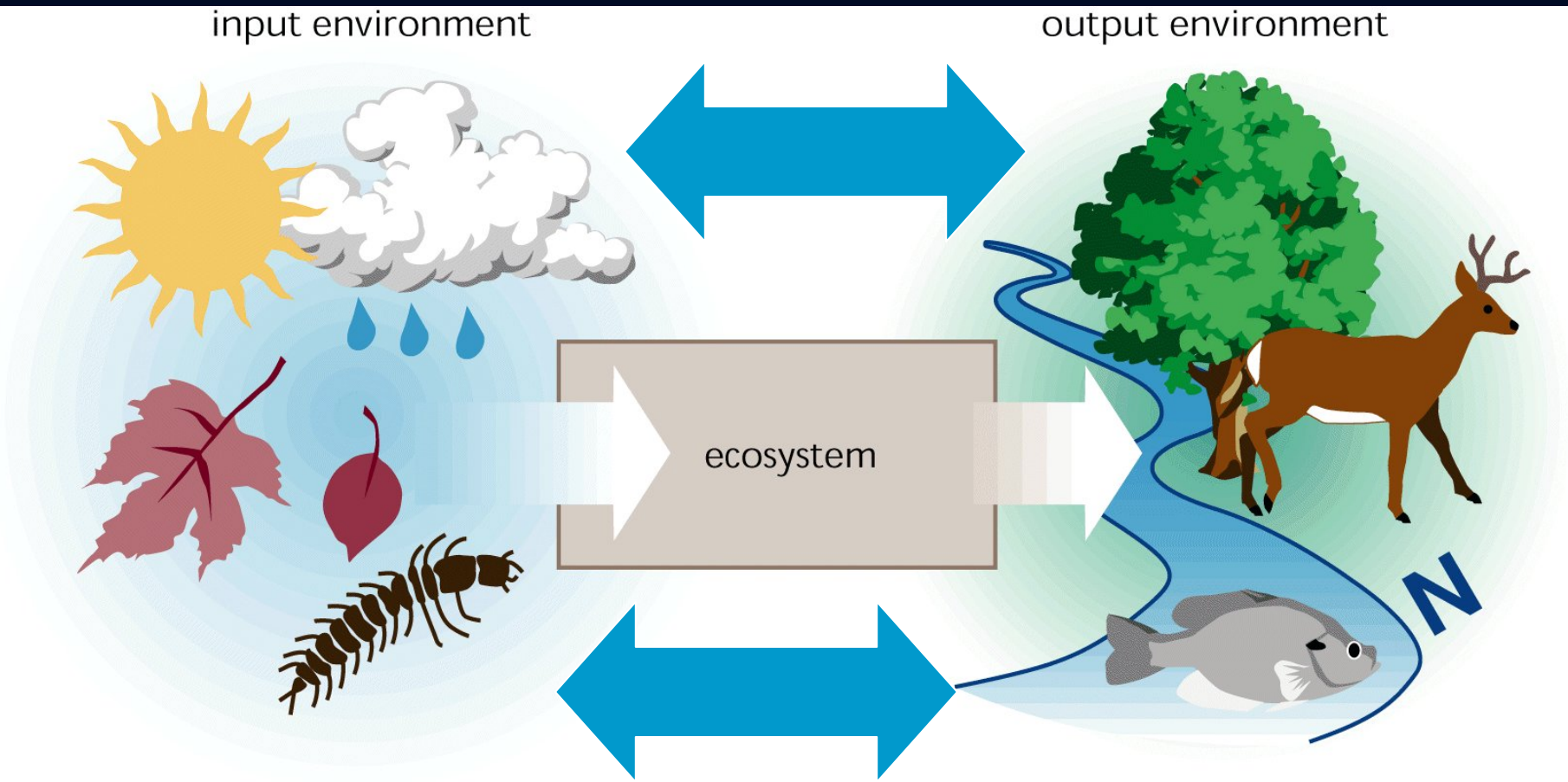


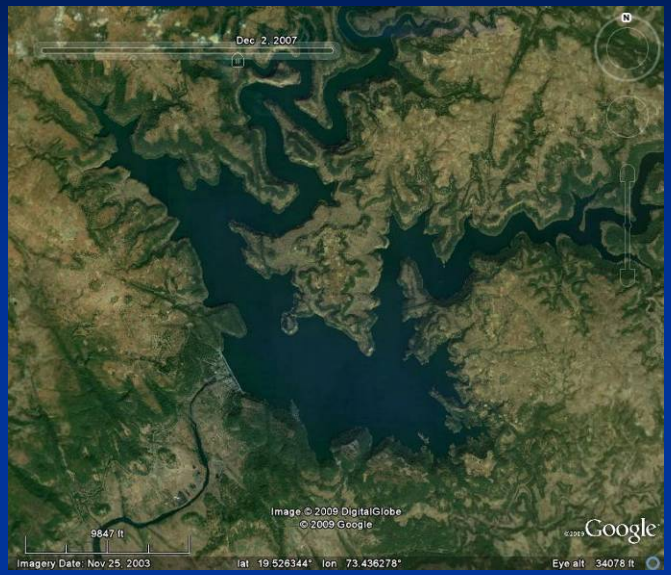
Fig. 1.3 -- A simple ecosystem model. Materials, energy, and organisms move from an external input environment throujgh the ecosystem, and into an external output environment.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

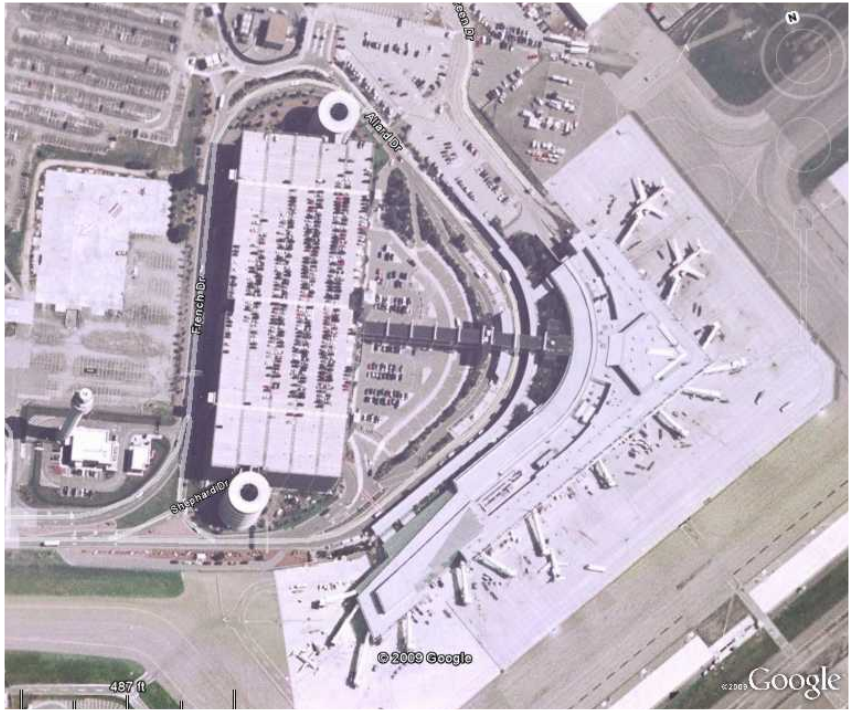
If you alter one, you alter them all…

Image from: "Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG)."

How watersheds work

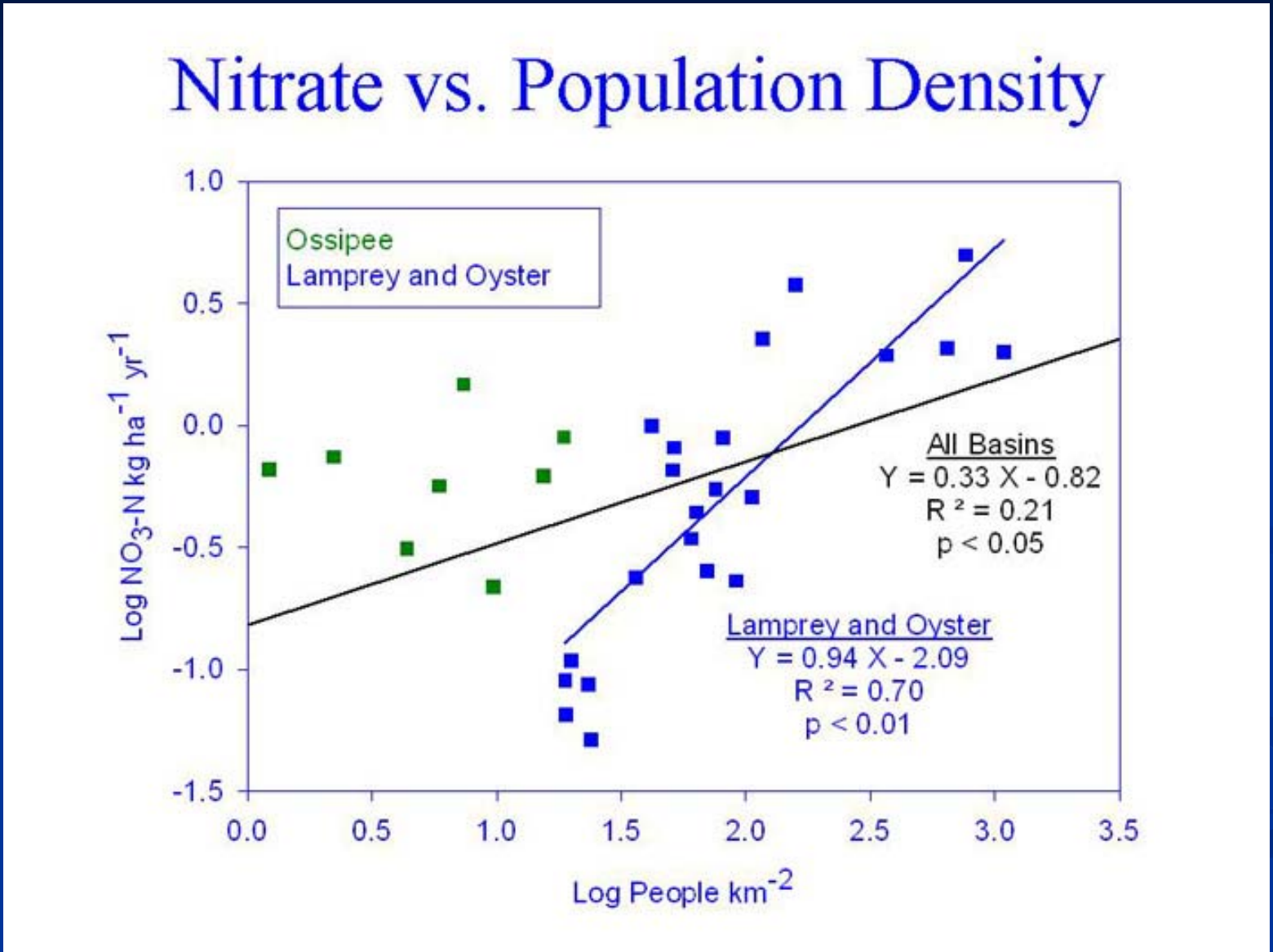
Things that affect water!





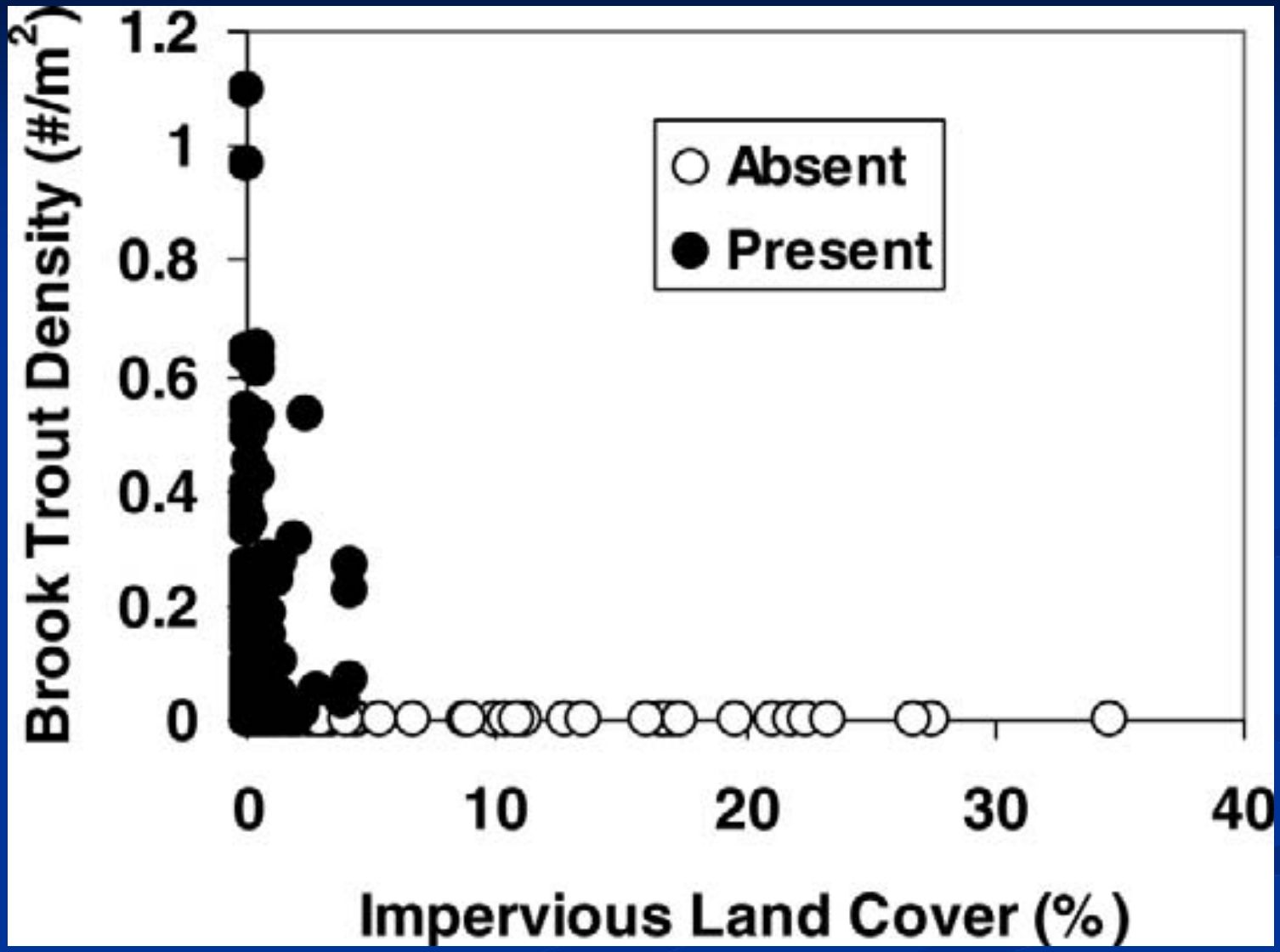
Dams

Impervious surfaces



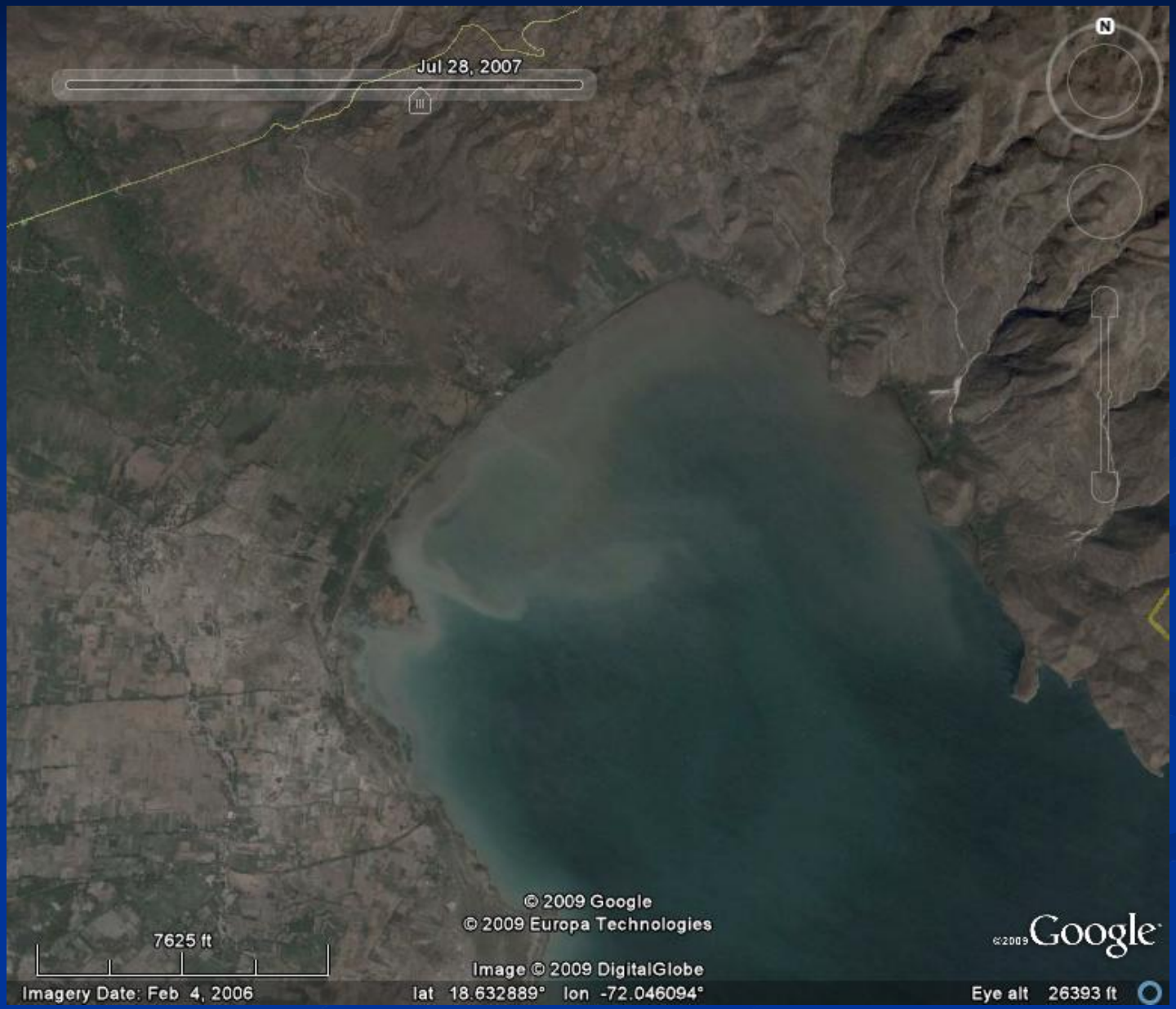
Bill McDowell, UNH. NH Water Resources Research Center

Impervious surfaces



Stranko, et al (2008). Brook Trout Declines with Land Cover and Temperature Changes in Maryland. North American Journal of Fisheries Management 28:1223–1232.

Deforestation



Riparian areas as fish habitat

Research clearly documents that riparian areas are intimately tied to stream habitats, water quality, ecology and the health of aquatic ecosystem. – nutrient exchange

Stream crossings

- Aquatic Organism Passage (AOP)
- Geomorphology (= habitat, erosion/sedimentation, nutrients)

Why fish move

- Fish need to access the habitat that increases their chances of survival
  - Foraging (have to get to the grocery store)
  - Spawning (live in a good neighborhood)
  - Rearing (take the kids to school)
  - Access new or vacant habitat (new subdivision going in)

- Fish avoid certain areas to increase their chances of survival
  - Water quality (thermal or chemical pollution)
  - Lower (or higher) water levels
  - Changing habitat conditions (e.g., due to ice scour/flood)

Fish move for various reasons

- Species specific
  - Some species move:
    - frequently
    - infrequently
    - seasonally
    - very short distances
    - very long distances
    - into intermittent streams

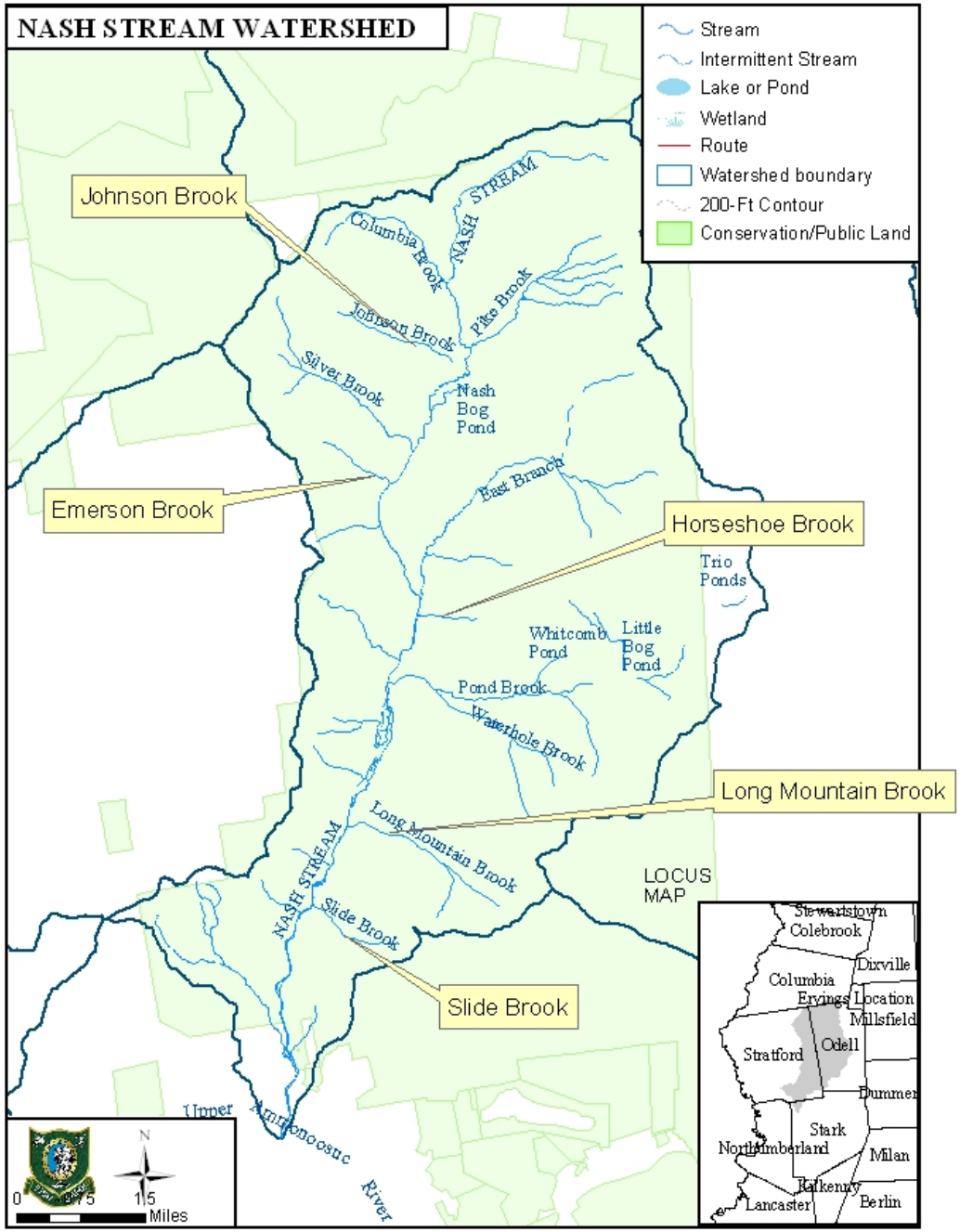
Streams as fish habitat

Habitat

- Water quality
- Water depth
- Velocity
- Substrate
- Wood
- Riparian vegetation
- Instream vegetation

Research at Nash Stream State Forest

- Being done to improve our restoration effectiveness (at Nash and elsewhere)
- Big Questions
  - How does Habitat influence brook trout populations?
  - Do brook trout move around in the streams and watershed?
  - Do they need to move around the Watershed? (genetic data)


NASH STREAM WATERSHED
Stream
Intermittent Stream
Lake or Pond
Wetland
Route
Watershed boundary
200-Ft Contour
Conservation/Public Land
Johnson Brook
Emerson Brook
Horseshoe Brook
Long Mountain Brook
Slide Brook
NASH STREAM
Columbia Brook
Johnson Brook
Pike Brook
Silver Brook
Nash Bog Pond
East Branch
Trio Ponds
Whitcomb Pond
Little Bog Pond
Pond Brook
Waterhole Brook
Long Mountain Brook
Slide Brook
Upper Ammonoosuc River
LOCUS MAP
Stewartstown
Colebrook
Dixville
Columbia
Ervings
Location
Millsfield
Stratford
Odell
Dummer
Stark
Northumberland
Milan
Kilkenny
Lancaster
Berlin
N
0
1.5
Miles

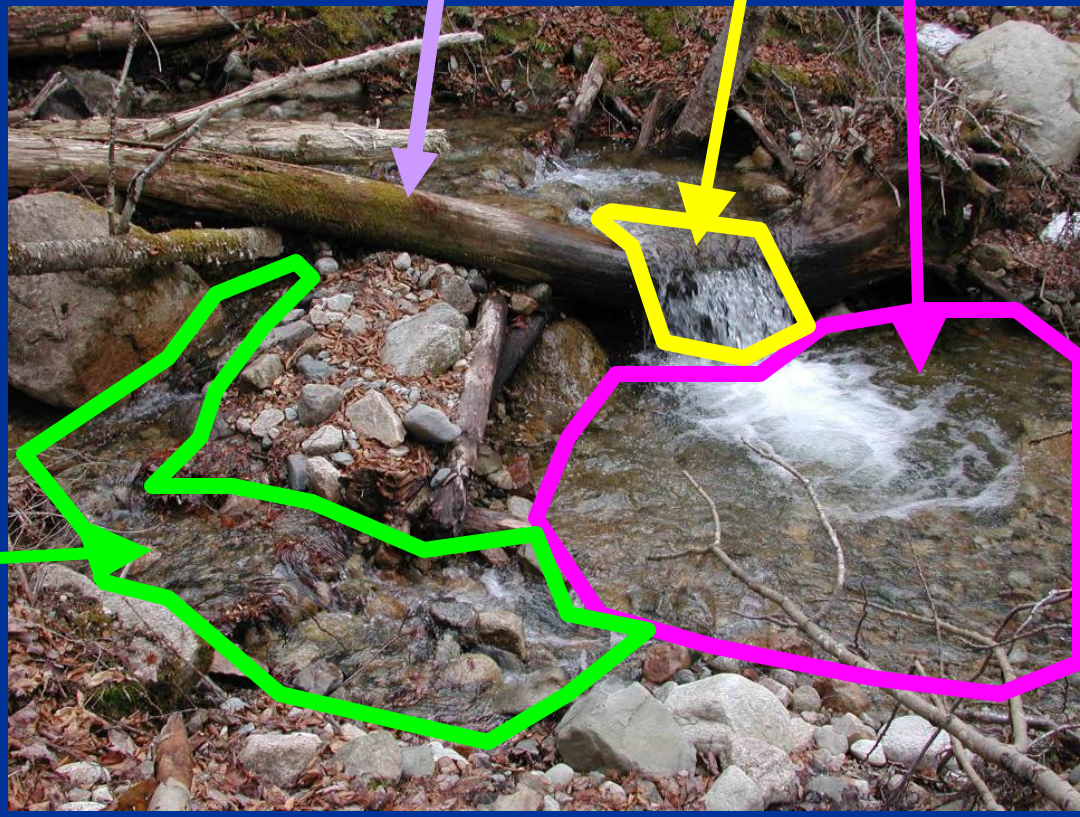
- Big questions
  - How does Habitat influence brook trout populations?

1. Electrofished
2. Habitat survey

Related density and biomass of fish to habitat variables

3. PIT tag
4. Wanding surveys

Used wanding data to determine what habitat trout prefer


Wood
Falls
Pool
Riffle

Wanding survey

- Cover entire wetted width
- Document:
  - PIT tag #
  - Location
  - Alive, Dead or Unknown
  - Habitat detected in
    - Type, substrate, wood

How does habitat influence brook trout populations?

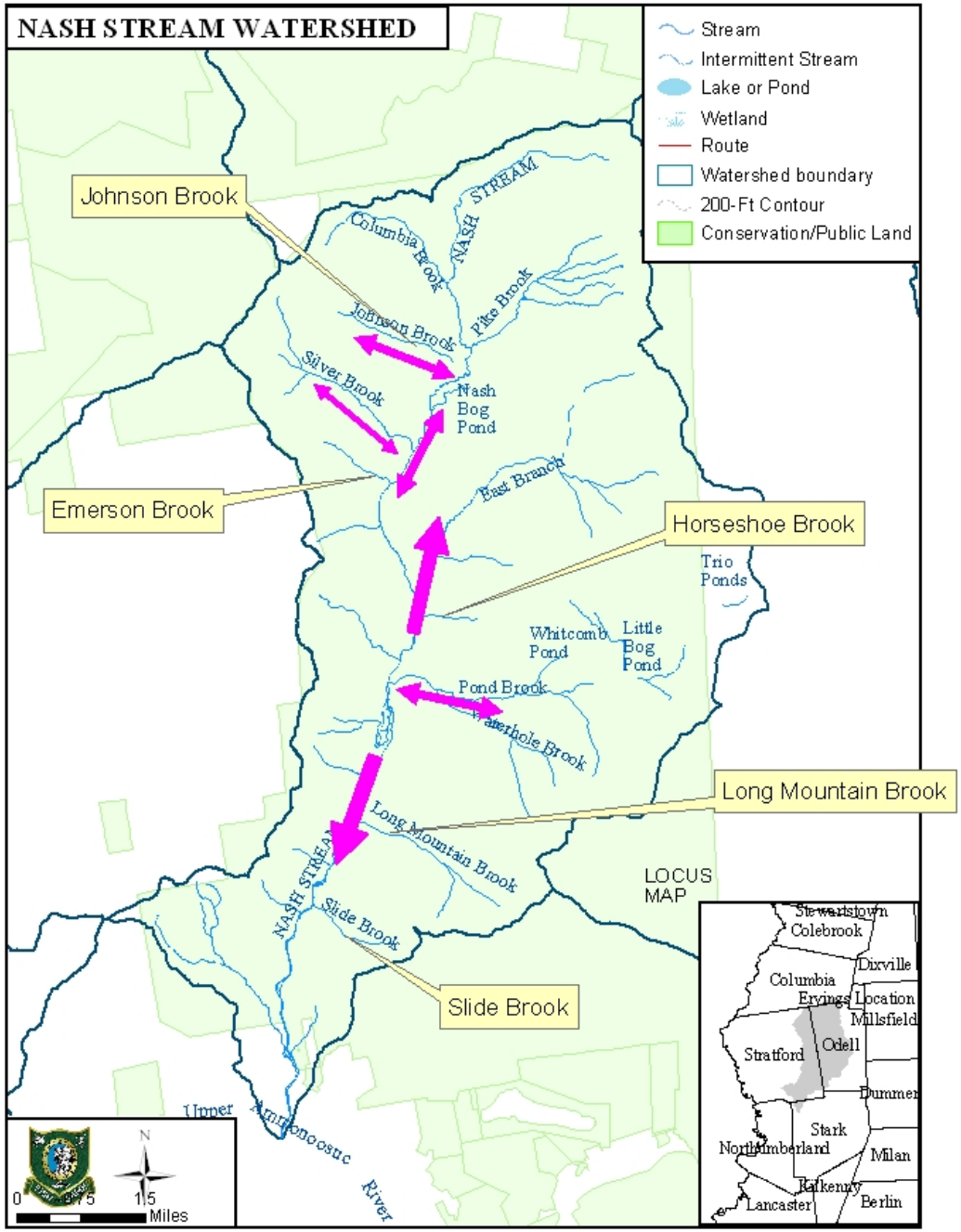
- More pools = more brook trout
- More wood = more brook trout
- Brook trout are clustered around instream wood
- Wood formed many pools, but not all pools

- Big questions
  - Do brook trout move around in the streams and watershed?

1. Electrofished and angled
2. Inserted PIT or radio tags into brook trout
3. Tracked tagged trout

Brook trout moved:

- To avoid warm water
- To get to spawning areas
- To get to overwintering areas



- Big Questions
  - Do they <u>need</u> to move around the Watershed?

•There is a lot of genetic variation in the Nash Watershed

•Isolated populations tend to be very small and are at risk of dying out

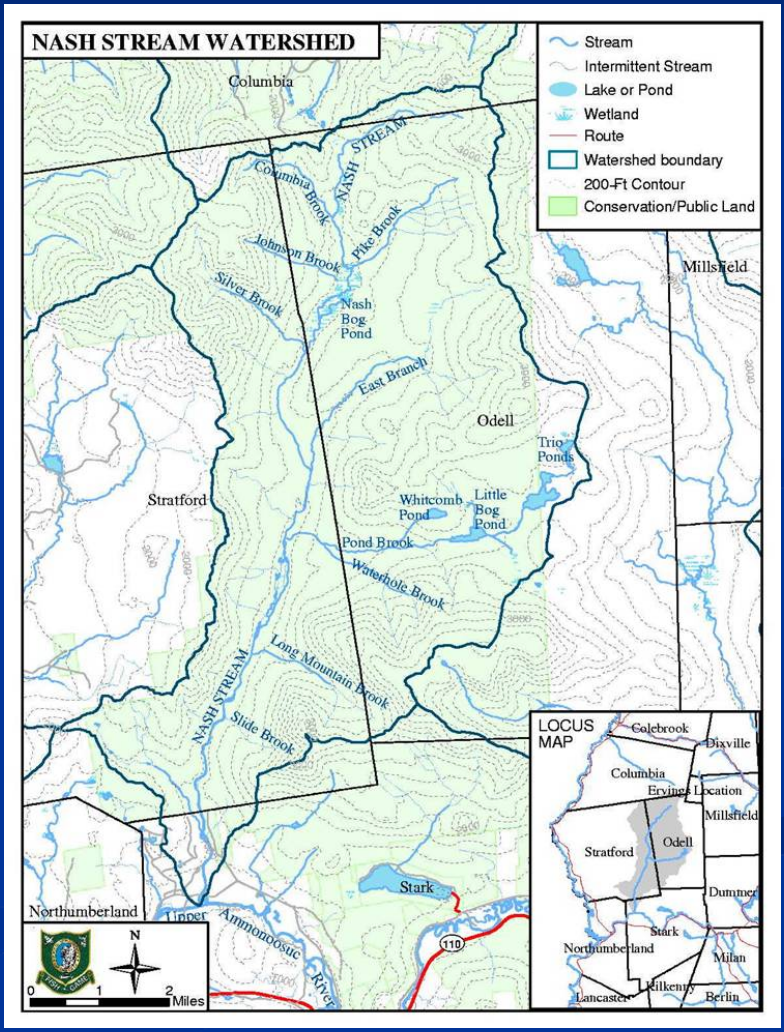
•So, yes, they need to move around to avoid population extirpation (dying out)

Take home messages

- Everything in the Watershed is tied together
- Wood is good
- Don’t isolate populations

Nash Stream Restoration Project

- Forest – 39,601 acres (61.9 square miles)
- Watershed – 28,332 acres (44.3 square miles)
- Located in Stratford, Odell and Stark
- Over 90% of watershed located on public land
- Nash Stream – 13+ miles
- 9 major perennial tribs



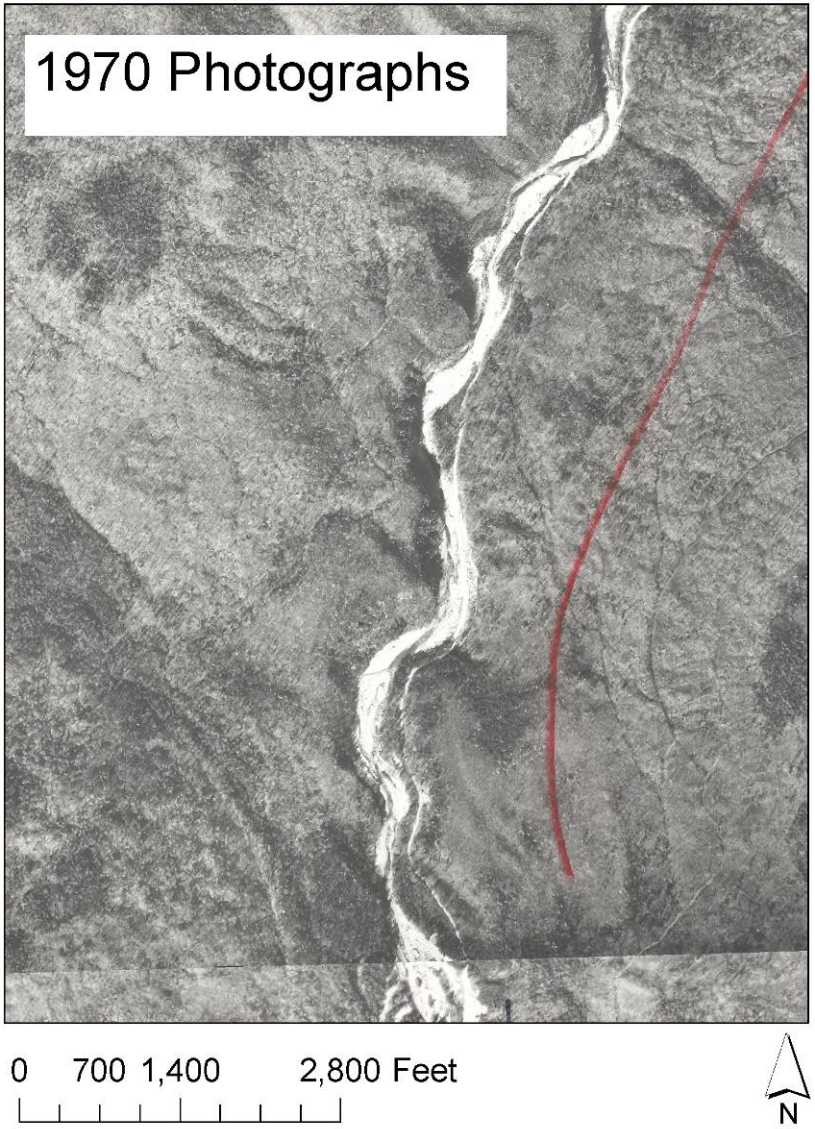
Watershed history

- Working forest
  - Railroad built in 1852 for logging
  - 1870 – Nash Stream Improvement Company incorporated
  - 1900 – Nash Bog Dam completed
  - River drives end in 1930s
  - 1930s – haul roads built
  - 1969 – Nash Bog Dam fails
- Recreational fishery
  - 1896 – first stocking of brook trout
  - 1967 – Nash Bog Pond stocked with rainbows
- State acquires Forest in 1988
  - US Forest Service conservation easement

Dam breach – May 1969

Aftermath of 1969 flood

1969 Flood footprint



Watershed impacts

Mainstem

- Channel straightening
- Disconnected floodplains
- Lack of large woody material
- Lack of pools
- Poor flow regime diversity
- Depleted riparian forest
- Elevated water temps

Tributaries

- Habitat fragmentation - impassable culverts

Project sponsors

- NH Fish & Game Department
- NH Council Trout Unlimited

Partners

- NH Forest & Lands
- US Forest Service
- SPNHF
- US Fish and Wildlife
- NH Dept. Env. Svcs.

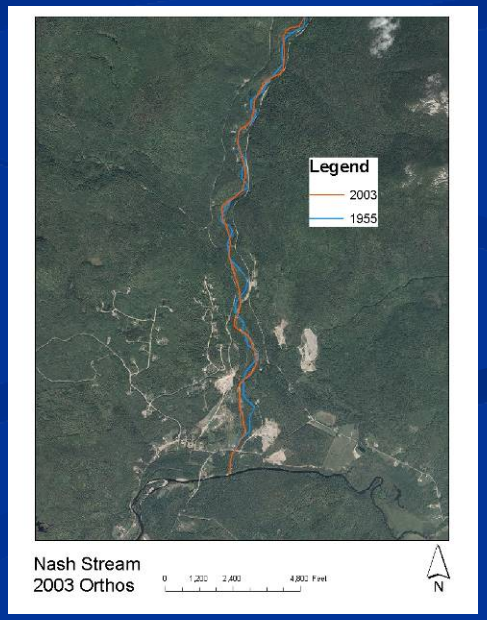
Contributors - $700K

- NH Charitable Foundation
- Trout/Salmon Foundation
- Ammonoosuc & Basil Woods TU
- Upper CT River MEF
- TU Embrace-A-Stream
- Fish America Foundation
- Natural Resource Cons. Service

Project goals

- Restore natural stream function and values
- Diversify and enhance fish habitat
- Re-establish self-sustaining wild, indigenous fish
- Utilize natural channel process concepts

Baseline assessment



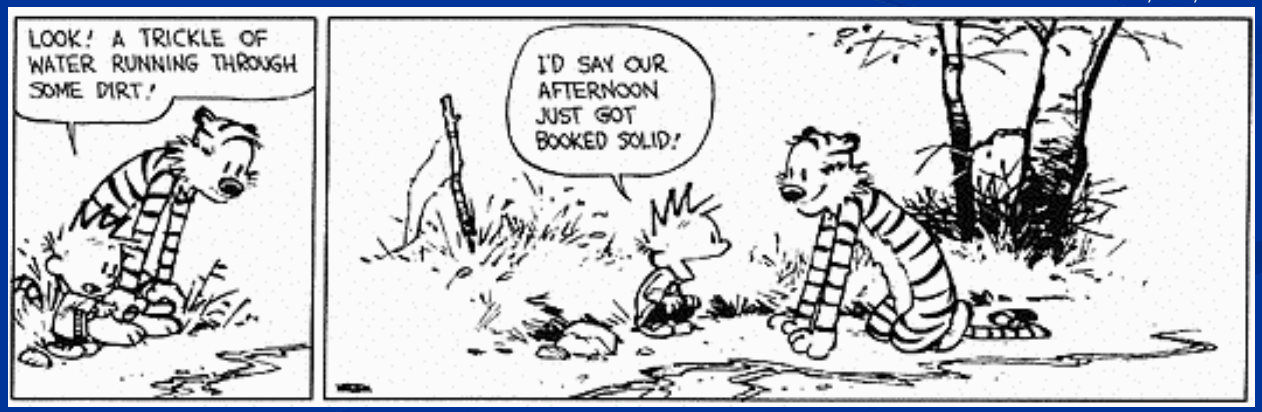
Restoration principles

- Keep all the pieces.
  - "The first rule of an intelligent tinkerer is to keep all of the pieces."

    – Aldo Leopold ~ *A Sand County Almanac*

- Do no harm.

Bill Watterson – 4/29/95



Project design – stream simulation

Mimic nature – match existing width, depth, slope and substrate

If done right, most projects can be self-maintaining

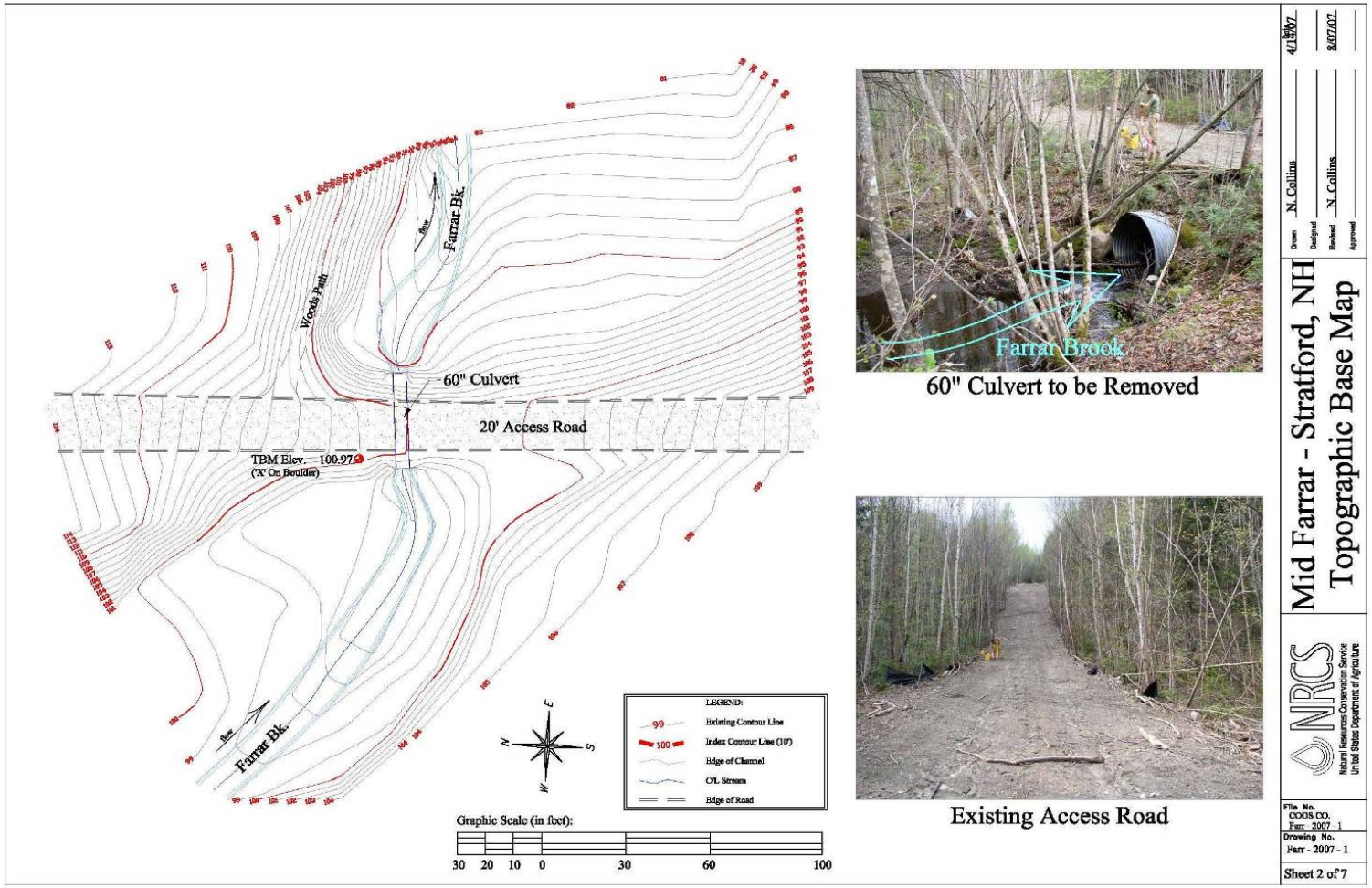
Major accomplishments – to date

- ✓ Riparian restoration – added organics
- ✓ Removed middle Farrer Brook culvert
- ✓ Replaced Long Mt. Brook culvert
- ✓ Removed Lower Pike Brook culvert
- ✓ Removed berm beside mainstem (upstream of Nash Stream Road Bridge)
- ✓ Replaced Johnson Brook culvert with 30' bridge
- ✓ Completed ½-mile of mainstem instream habitat restoration (upstream of bridge)
  - ✓ Installed 10—15 boulder clusters
  - ✓ Constructed three porous rock weirs
  - ✓ Completed two placements of wood on bars
  - ✓ Deployed three mobile wood placements

Restoration: work-to-date

Adding organics to riparian area – November 2006

Culvert remediation design:
middle Farrer Brook



Middle Farrer Brook Culvert Removal

November 6—7, 2007

Pre-removal – looking upstream

Post-removal – looking upstream

Pre-removal – looking downstream

Post-removal – looking downstream

Middle Farrer Brook

1½ weeks post culvert removal

Post-removal – looking upstream

November 19, 2007

Post-removal – looking downstream

November 19, 2007

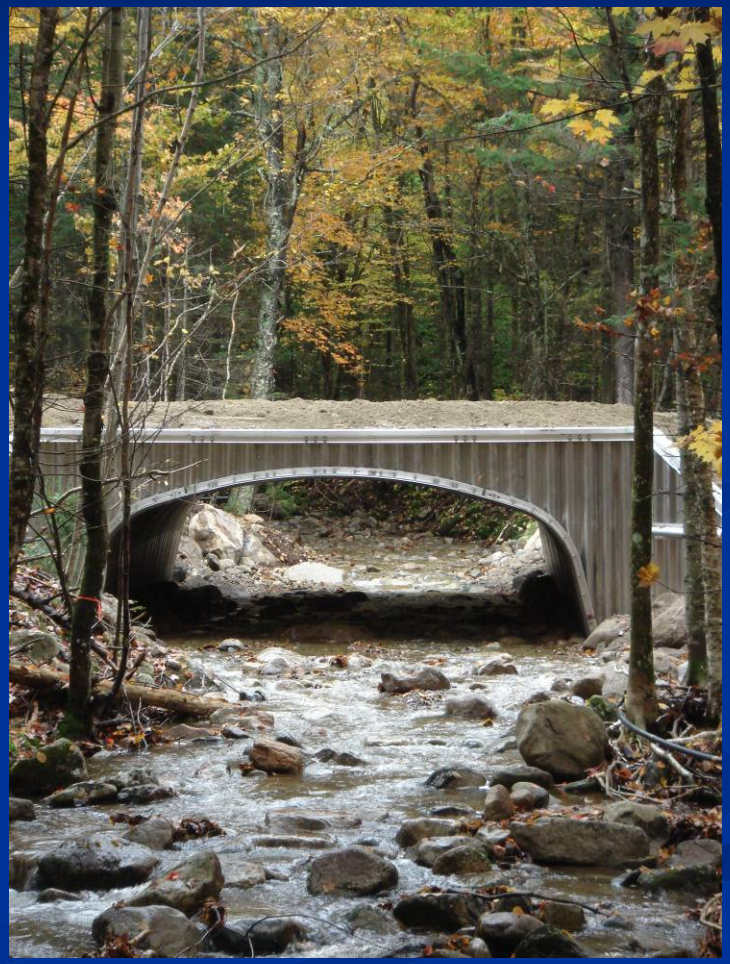
Long Mountain Brook culvert replacement

September 22—29, 2008

Long Mountain Brook
culvert replacement

Pre-replacement – looking upstream

September 22, 2008



Post-replacement – looking upstream

September 29, 2008

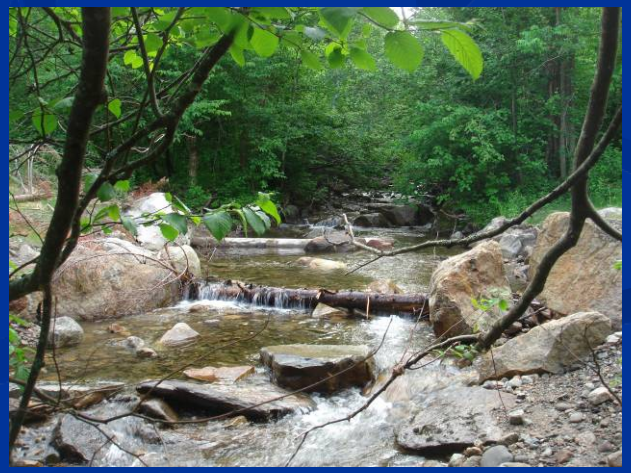
Lower Pike Brook culvert removal

November 5, 2008

Pre-removal – looking downstream

Post-removal – looking downstream

Pre-removal – looking upstream



Post removal – looking upstream

Nash Stream berm removal

November 6—7, 2008

Transplanting tree during berm removal

Transplants: during berm removal

Mainstem berm removal

November 6—7, 2008 and July 7—8, 2008

Pre-removal – from opposite bank

Post-removal – from opposite bank

Loam addition

Conservation mix and mulch

Johnson Brook Culvert Remediation

June 22—24, 2009

Johnson Brook Culvert Remediation

June 22—24, 2009

Pre-removal – looking downstream

Post-removal – looking downstream

Pre-removal – looking upstream

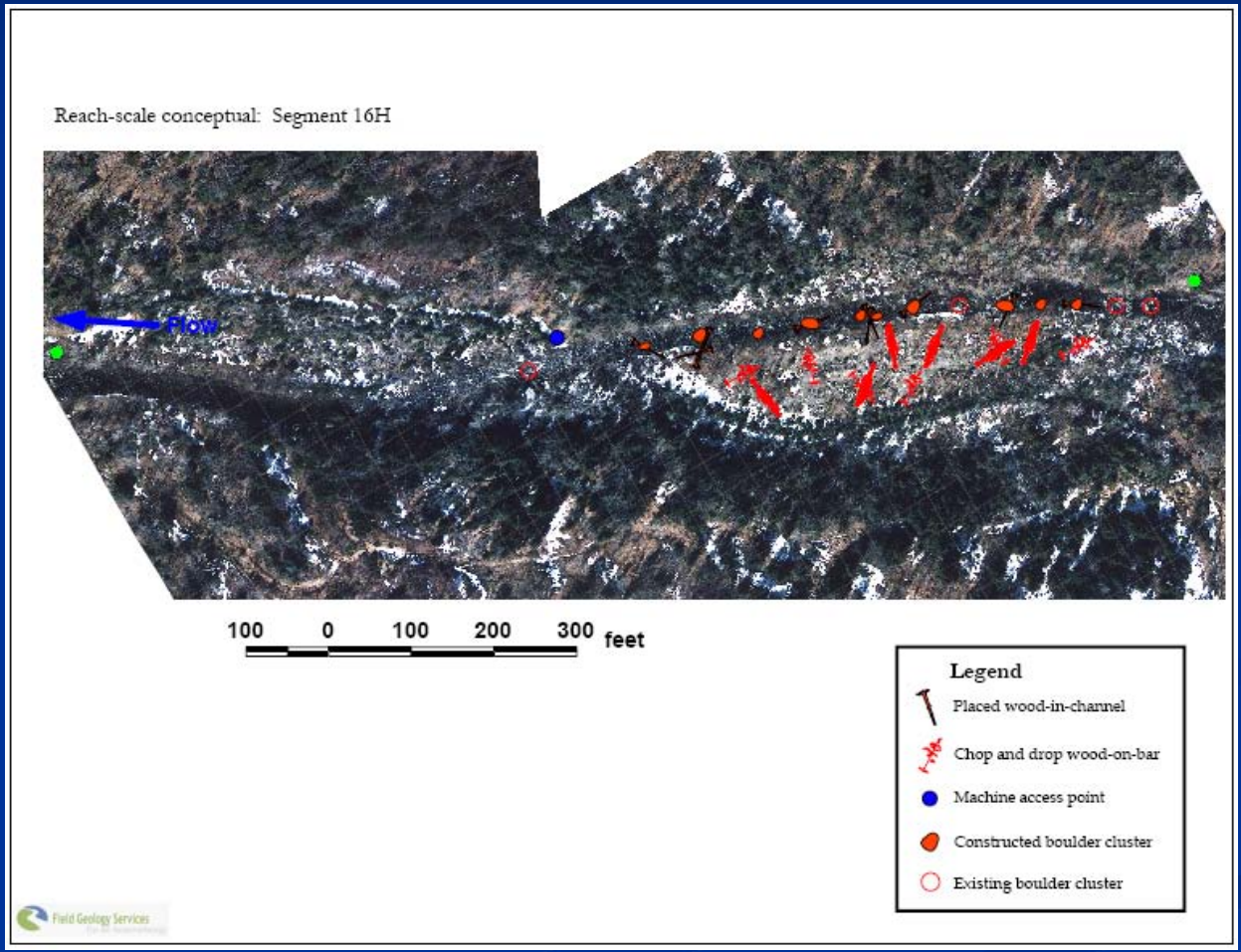
During removal – looking upstream

Mainstem instream restoration

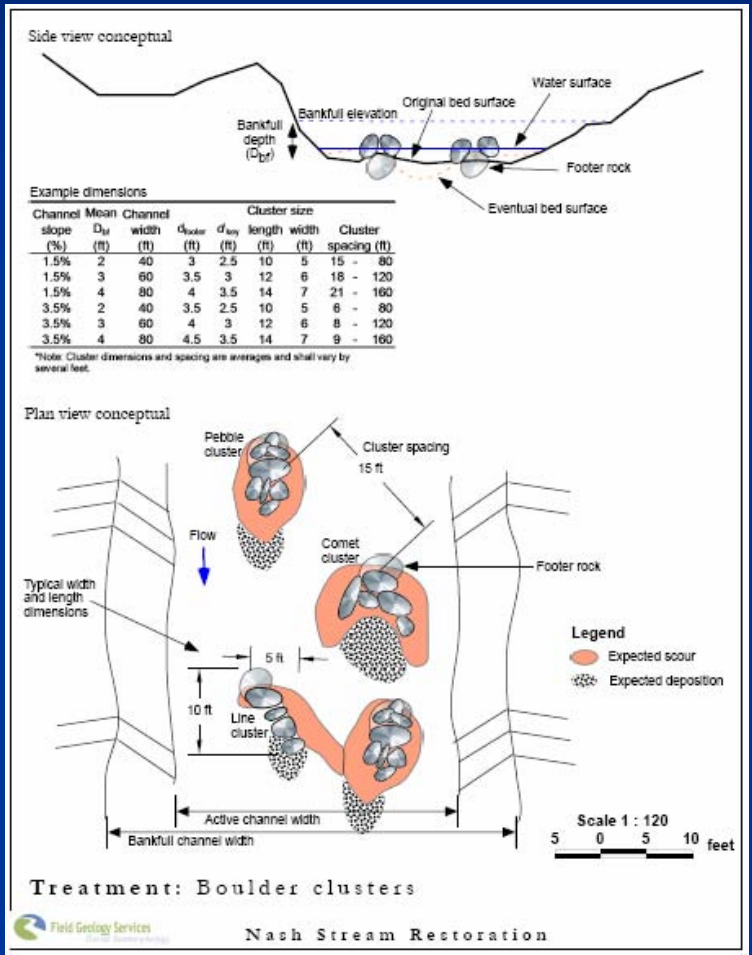
Ranking of treatment options

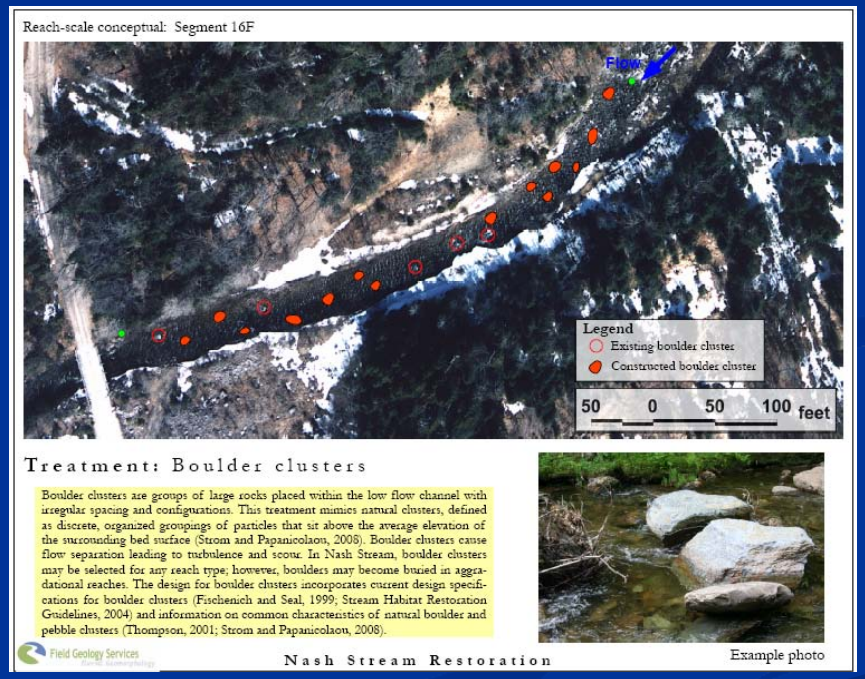
Segment	Needs (threshold)	Appropriate treatments	Scores	Chop and drop	Boulder clusters	Placed wood on-bar	Rock weirs	Placed wood in-channel	Mid-channel log jams	Mobile wood additions	Access	Treatment of choice (suggested by model)	Needs total
17	Wood	Chop and drop, Placed wood on-bar, Placed wood in-channel, Mobile wood additions	All Needs	52.6		40.2		54.6			5	Pick from list	17
			Recommended	4.6		3.0		4.8		4.6			
			Bang-for-buck	11.6		4.1		3.9		6.2			
16I	Pools, Wood, Meanders	Chop and drop, Boulder clusters, Rock weirs, Placed wood in-channel, Bank cutting/Flow diversion, Mobile wood additions	All Needs	79.2	55.4		72.0	81.9		72.0	3	Pick from list	28
			Recommended	9.8	5.8		6.8	10.0		8.8			
			Bang-for-buck	11.6	5.9		4.0	3.9		6.2			
16H	Pools, Wood, Meanders	Boulder clusters, Rock weirs, Placed wood in-channel, Bank cutting/Flow diversion, Mobile wood additions	All Needs		64.2		85.2	95.2		84.0	5	Pick from list	35
			Recommended		5.8		6.8	10.0		8.8			
			Bang-for-buck		5.9		4.0	3.9		6.2			
16G	Pools, Wood, Meanders, Adjustment	Boulder clusters, Placed wood on-bar, Bar apex boulders, Bar apex log jams, Placed wood in-channel, Mid-channel log jams, Trim boulder bar/bkf bench, Bank cutting/Flow diversion, Floodplain lowering, Mobile wood additions	All Needs		63.2	76.8		93.8	122.8	82.8	5	Pick from list	34
			Recommended		7.2	9.6		11.8	16.0	10.4			
			Bang-for-buck		5.9	4.1		3.9	3.5	6.2			
16F	Flows, Pools, Wood, Adjustment, Canopy	Riparian plantings, Breach or remove berm, Boulder clusters, Rock weirs, Placed wood in-channel, Bank bioengineering, Trim boulder bar/bkf bench, Bank cutting/Flow diversion, Floodplain lowering, Mobile wood additions	All Needs		67.4		90.6	99.9		88.4	5	Pick from list	37
			Recommended		9.0		12.2	14.7		13.2			
			Bang-for-buck		5.9		4.0	3.9		6.2			

Restoration design for segment 16H

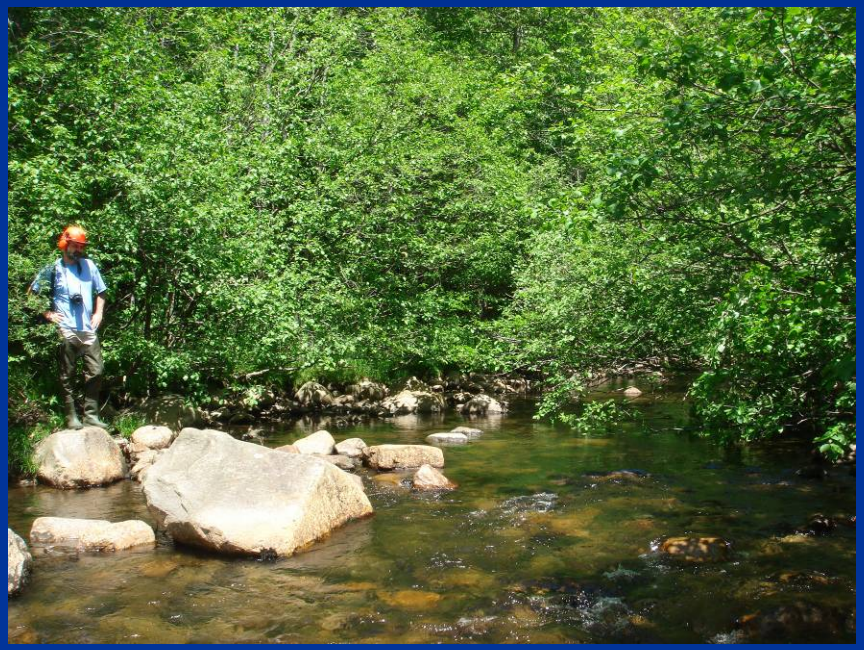


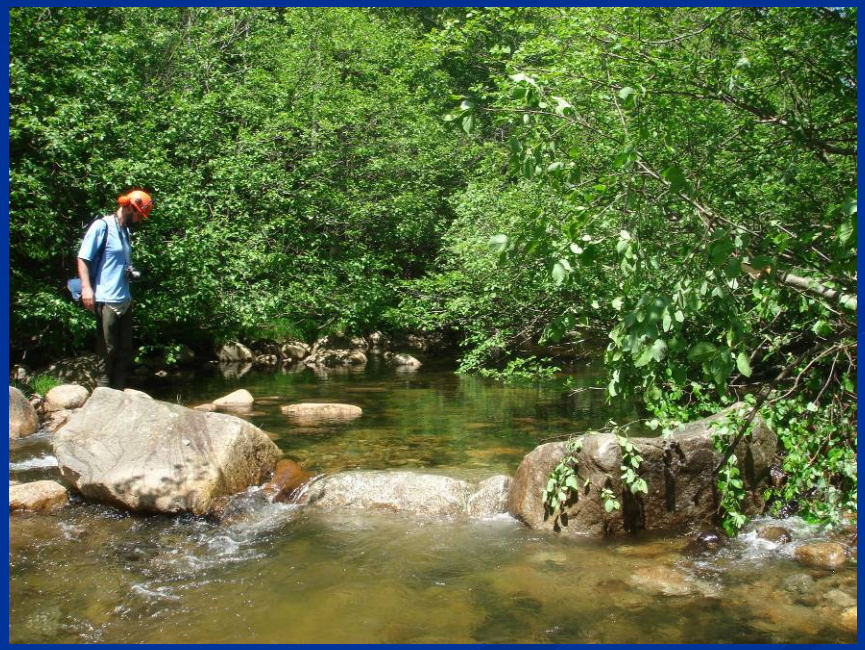
Boulder clusters



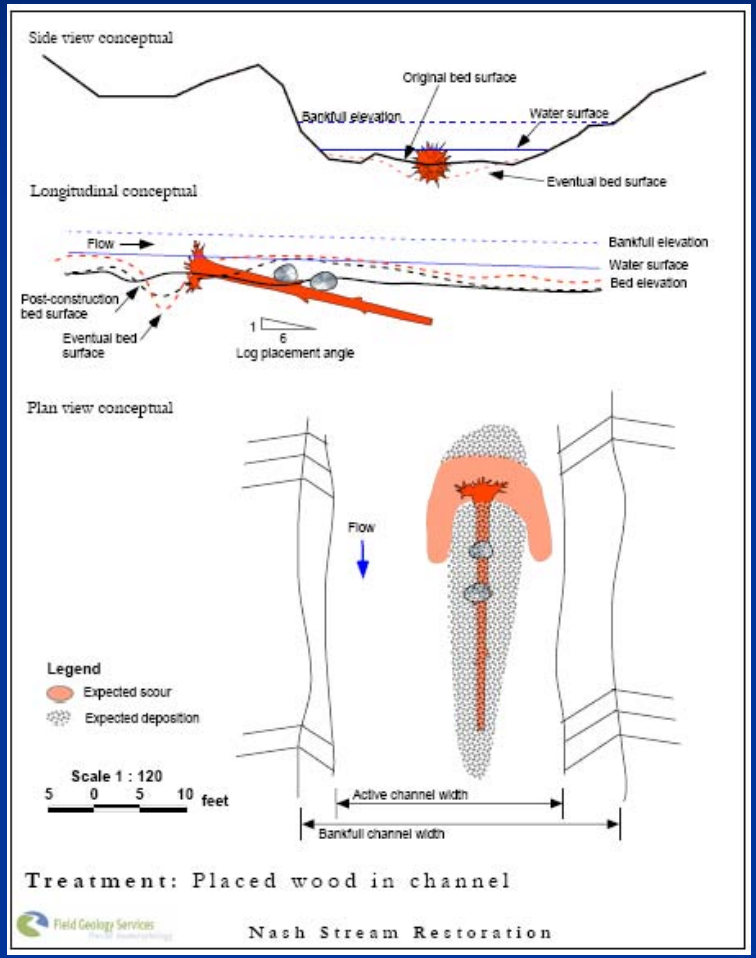


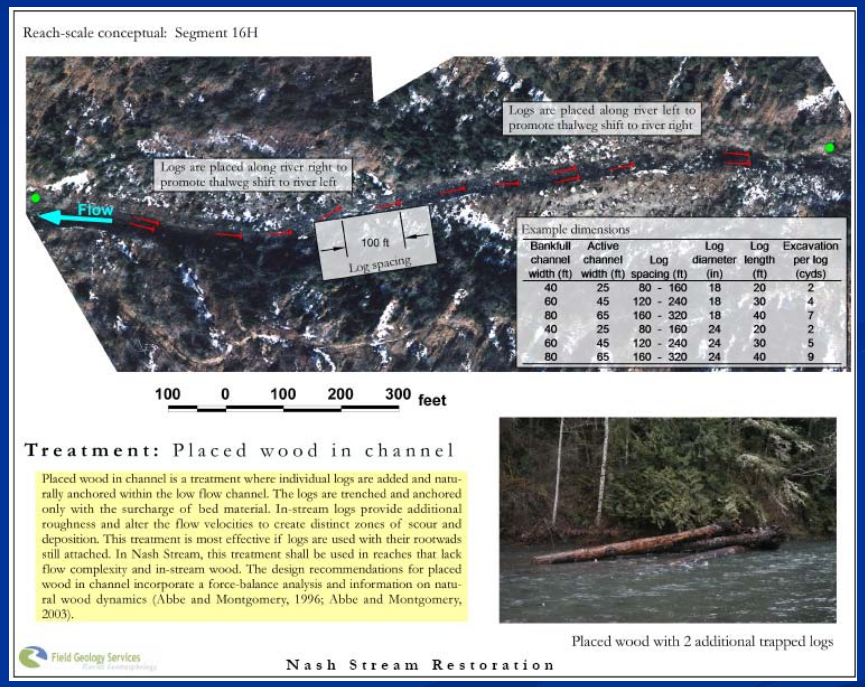
Boulder cluster #1





Placed wood in channel

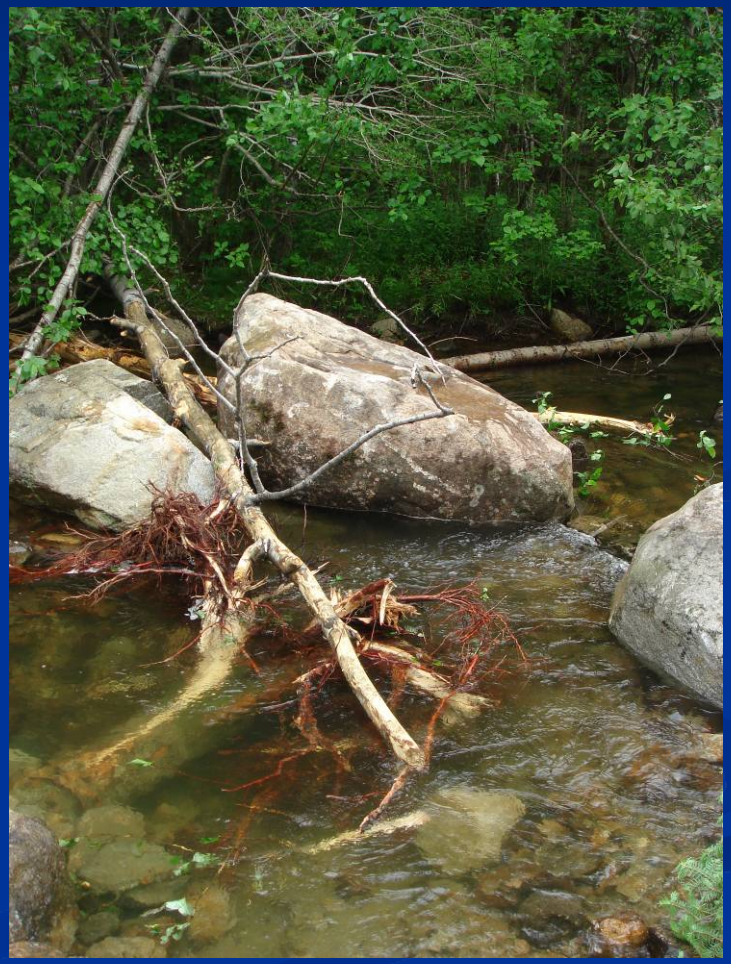




Example dimensions

Bankfull channel width (ft)	Active channel width (ft)	Log spacing (ft)	Log diameter (in)	Log length (ft)	Excavation per log (cyds)
40	25	80 - 160	18	20	2
60	45	120 - 240	18	30	4
80	65	160 - 320	18	40	7
40	25	80 - 160	24	20	2
60	45	120 - 240	24	30	5
80	65	160 - 320	24	40	9

Wood and boulder cluster #2



Boulder cluster #3 at different flows

Boulder cluster #4: sediment sorting

Before

After

Boulder cluster #5

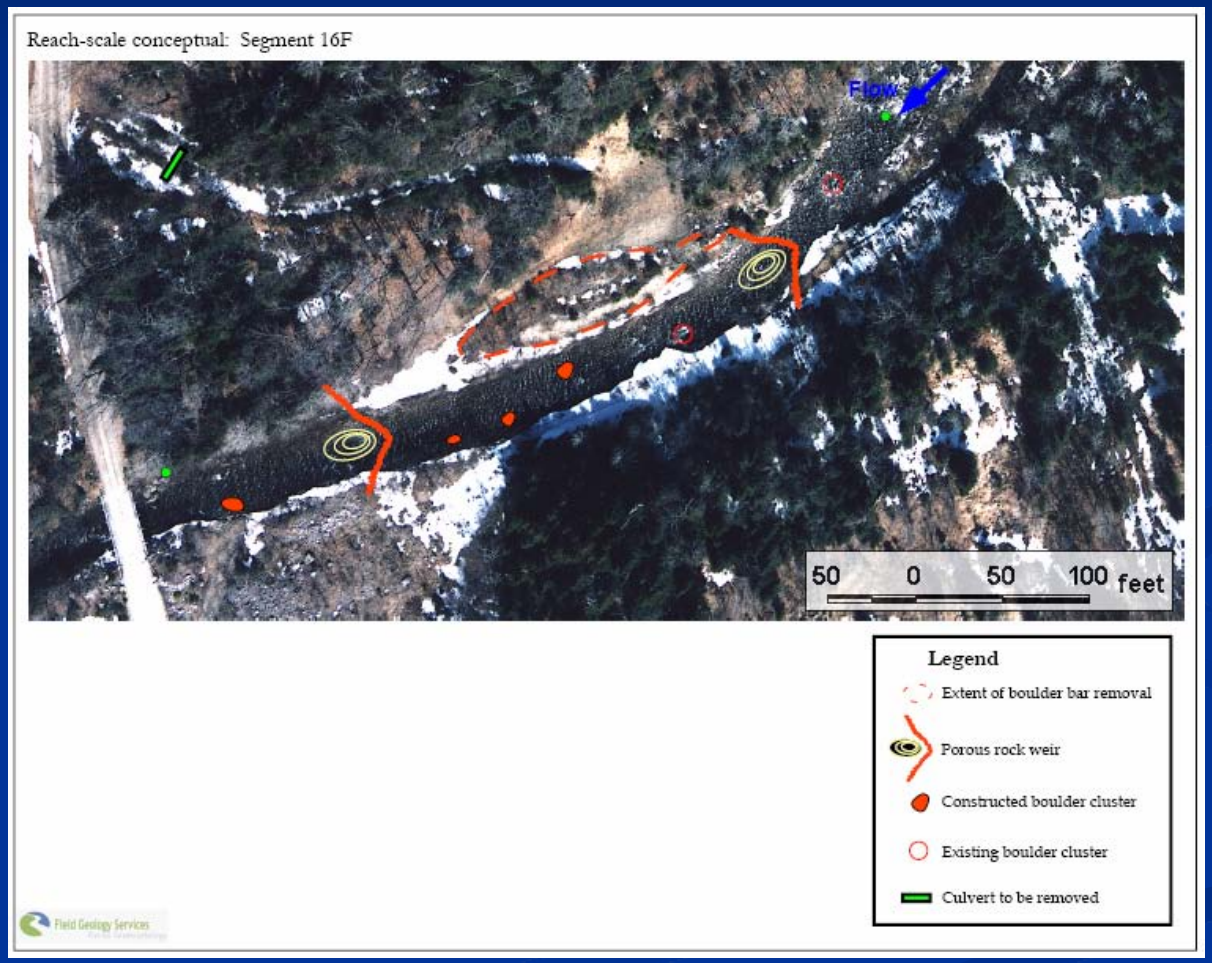
Boulder cluster #5: base and seasonally high flow

Mobile wood additions

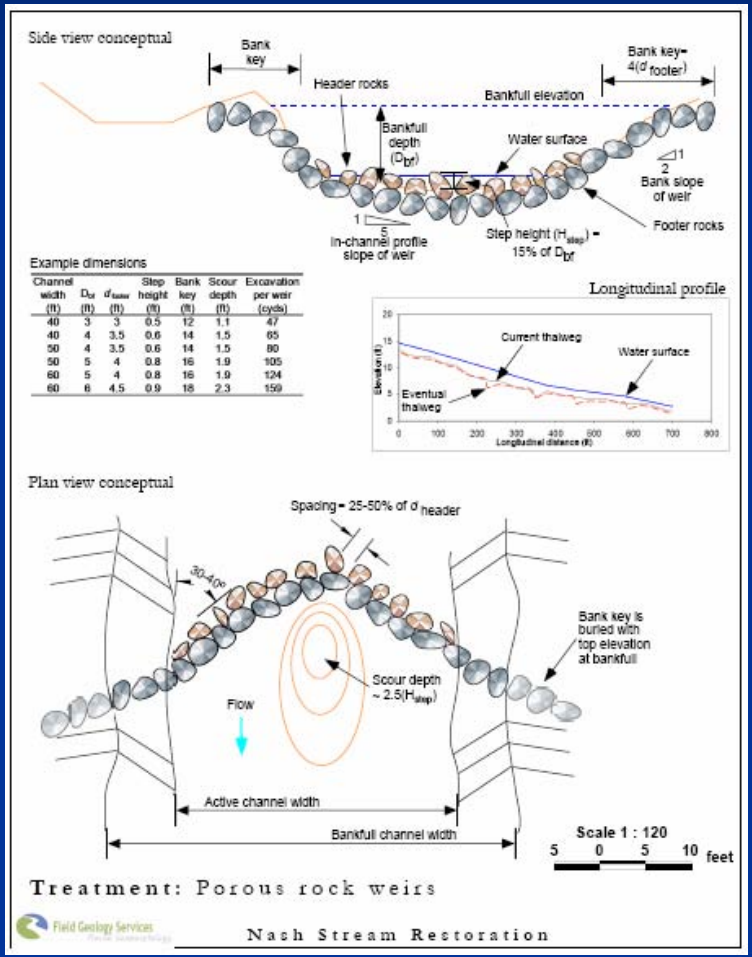
Placed wood on bar

Large wood added to mid-channel bar

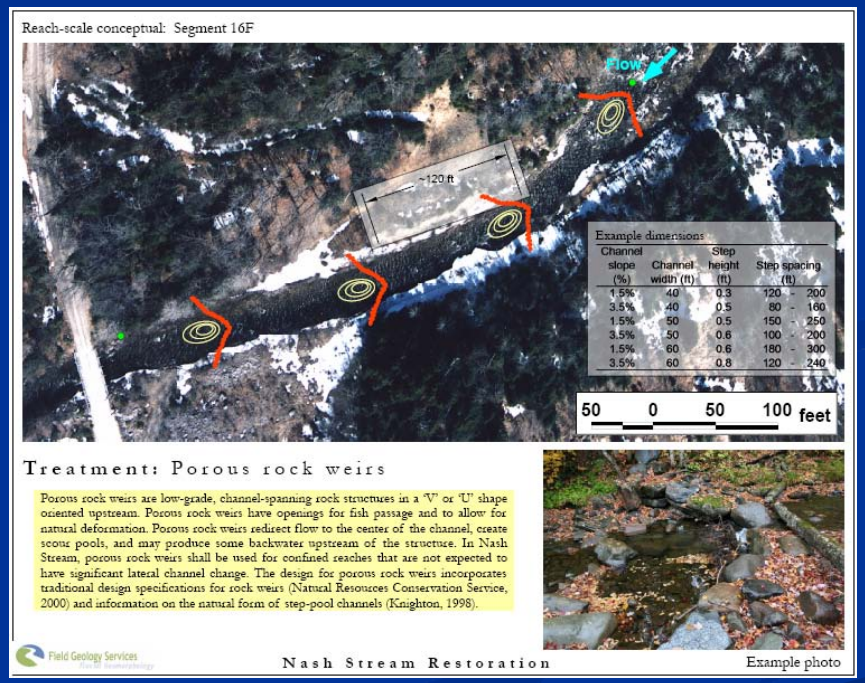
Restoration design for segment 16F



Rock weirs



Channel width (ft)	D_{bf} (ft)	d_{footer} (ft)	Step height (ft)	Bank key (ft)	Scour depth (ft)	Excavation per weir (cyds)
40	3	3	0.5	12	1.1	47
40	4	3.5	0.6	14	1.5	65
50	4	3.5	0.6	14	1.5	80
50	5	4	0.8	16	1.9	105
60	5	4	0.8	16	1.9	124
60	6	4.5	0.9	18	2.3	159



Channel slope (%)	Channel width (ft)	Step height (ft)	Step spacing (ft)
1.5%	40	0.3	120 - 200
3.5%	40	0.5	80 - 160
1.5%	50	0.5	150 - 250
3.5%	50	0.6	100 - 200
1.5%	60	0.6	180 - 300
3.5%	60	0.8	120 - 240

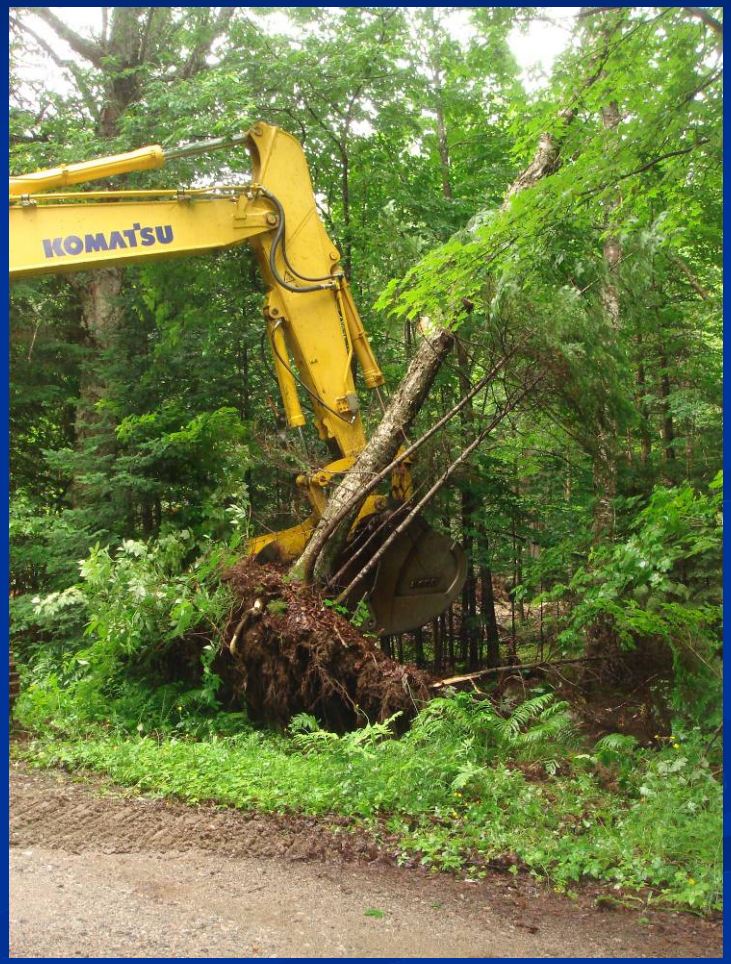
Construction of Weir #1

Weir #1 – continued

Weir #1 at high flow

Weir #2

Construction of Weir #3



Reach 16F: pre and post-construction

The future…

- Complete 8 more miles of mainstem habitat restoration
- Remediate 13 additional perched/failing culverts
- Monitor results of previous work
  - Biota
  - Morphology
  - Habitat
- Catching fish