FirstLight Power Resources

Turners Falls Hydroelectric Project (FERC No. 1889)

Northfield Mountain Pumped Storage Project (FERC No. 2485)

Oct/Nov 2016 Study Report Meeting

October 31-November 1, 2016

Report Filings

- 10 reports filed on 10/14/2016.
- 3 addendums filed on 10/14/2016.

Relicensing Process - Next Steps

Study Report Meeting (Stakeholders and FirstLight)

- October 31-November 1, 2016

Study Report Meeting Summary Filed (FirstLight)

- November 15, 2016

Disagreements/Modifications to Study/Propose New Study (Stakeholders)

- December 15, 2016

File Responses to Disagreements (Stakeholders and FirstLight)

- January 14, 2017 (Saturday, thus defaults to January 16, 2017)

FERC Issues Determination

- February 13, 2017

Study Recap

FERC Filing Date	No. of Studies	Study Name Abbreviations
09/15/2014	2	Full River Reconnaissance, Rec Inventory
12/31/2014	2	Archaeological- Phase 1A only, Historic Structures
09/14/2015	9	Hydraulic Model Study, Aquatic Habitat Mapping, Tributary Access, Canal Drawdown, NFM Land Management, Whitewater, Day/Overnight Rec Facilities, Rec Study of NFM, Traditional Cultural Properties.
03/01/2016	13	Water Quality, US Passage Eel, Shad Spawning, CFD Modeling, River2D model of NFM tailrace, Odonates, Fish Assemblage, Cabot Emergency Gates, Ichthyoplankton, Terrestrial Wildlife & Botanical, RTE, Rec Use/User Survey, Land Use Inventory
10/14/2016	10	Erosion Causation, Sediment Monitoring, IFIM Study, US & DS Adult Shad, DS Juvenile Shad (Interim), Entrainment, Littoral Zone, Sea Lamprey Spawning, Mussels, Project Ops impact on Rec
12/31/2016		Supplemental Ichthyoplankton (Year 2), Supplemental Odonate Work (Year 2)
03/01/2017	3	DS Eel (2-year study), Ultrasound Array, Operations Model
Total	39	

Agenda

October 31, 2016

Times	Study
9:00-9:30 am	Introductions, Review of Meeting Purpose, Meeting Objectives, Schedule
	Fish and Aquatic
9:30 am-Noon (15 min break built into schedule)	3.3.1- Instream Flow Study in Bypass Reach and below Cabot (45 minutes)
	3.3.16- Habitat Assessment, Surveys and Modeling of Suitable Habitat for State-Listed Mussel Species in the Connecticut River below Cabot Station (45 minutes)
	3.3.2- Evaluate Upstream and Downstream Passage of Adult American Shad (45 minutes)
Noon-1:00 pm	**Lunch on your own**
1:00-4:00 pm (15 min break built into schedule)	3.3.3- Evaluate Downstream Passage of Juvenile American Shad (40 minutes)
	3.3.7- Fish Entrainment and Mortality (40 minutes)
	3.3.13- Impacts of the Turners Falls Project and Northfield Mountain Project on Littoral Zone Fish Habitat and Spawning Habitat (40 minutes)
	3.3.15- Assessment of Adult Sea Lamprey Spawning within the Turners Falls Project and Northfield Mountain Project Area (40 minutes)

November 1, 2016

Times	Study
	Geology and Soils
8:30-11:20 am (15 min break built into schedule)	3.1.3- Northfield Mountain Project Sediment Management Plan (30 minutes)
	3.1.2- Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability (120 minutes)
	Recreation
11:20-Noon	3.6.6- Assessment of Effects of Project Operation on Recreation and Land Use (40 minutes)
Noon	Adjourn

Fish and Aquatic Resources

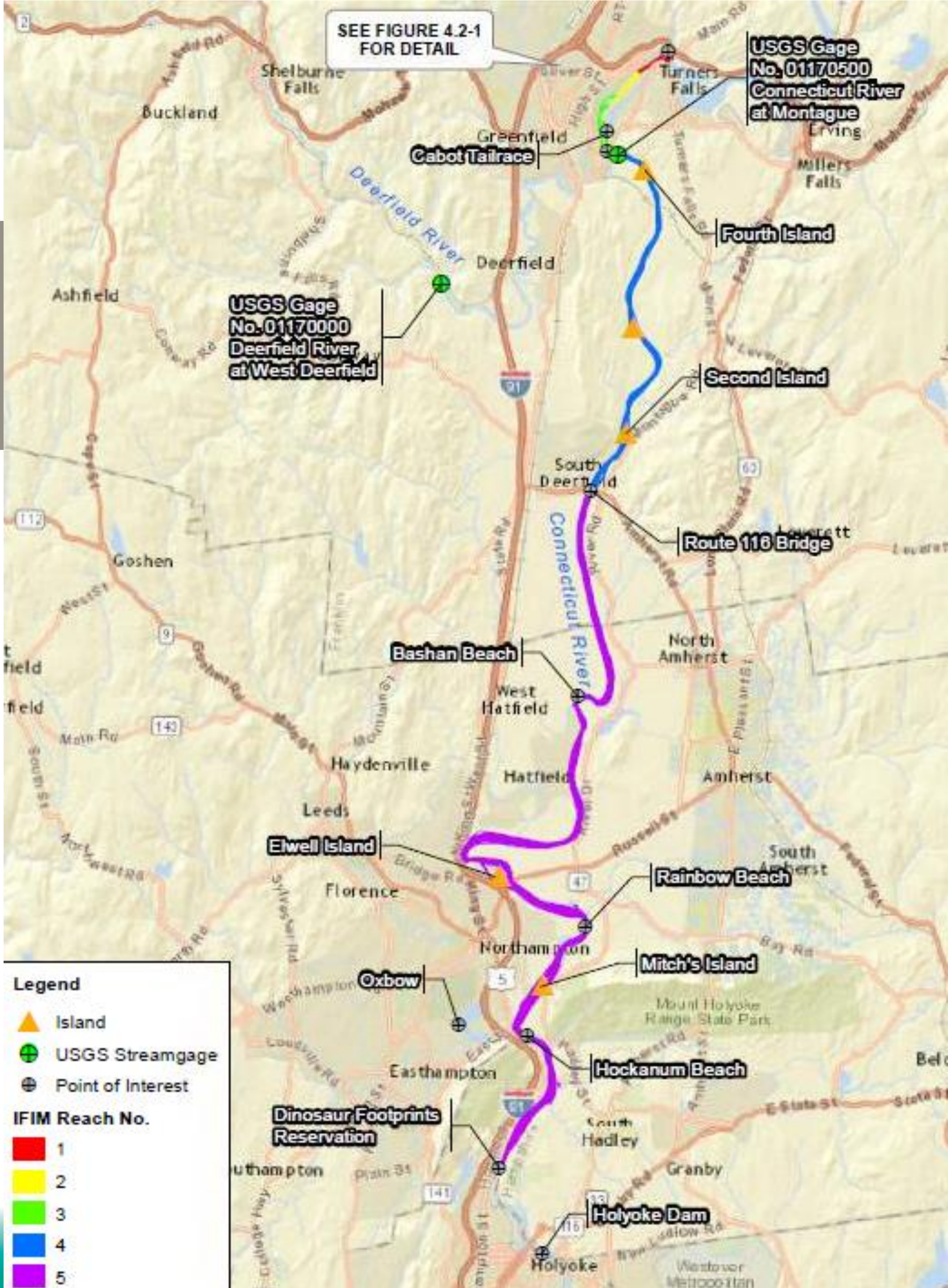
3.3.1-Instream Flow Study

Study Objectives

Assess the potential effects of discharges from Turners Falls Dam, Station No. 1, and Cabot Station on wetted area and aquatic habitat suitability in the Connecticut River:

- between Turners Falls Dam and Cabot Station (i.e., the bypass reach),
- below Cabot Station downstream to the Route 116 Bridge in Sunderland, MA, and
- between the Route 116 Bridge and Dinosaur Footprints Reservation

3.3.1-Instream Flow Study



FirstLight Power Resources

3.3.1-Instream Flow Study

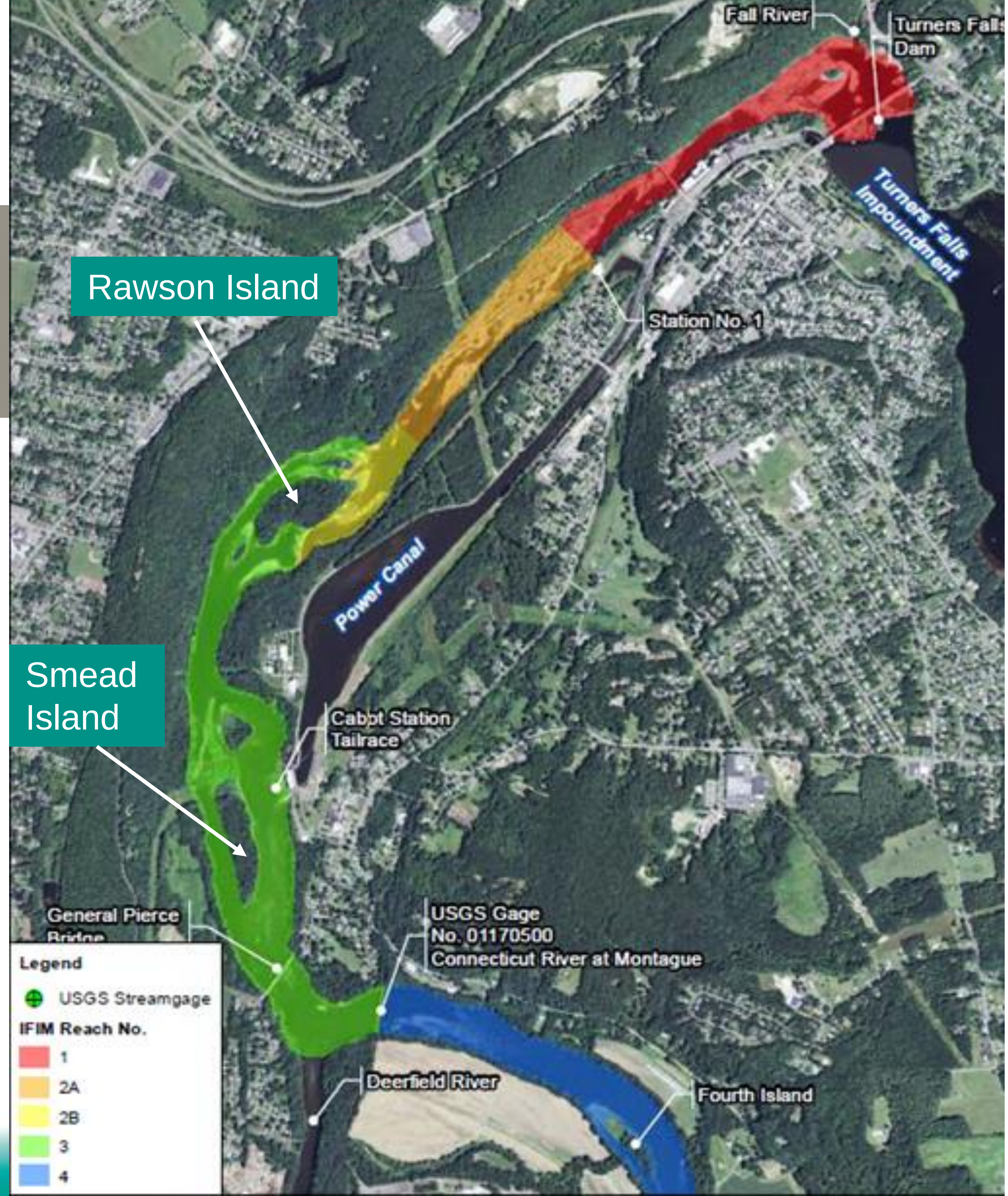
Reach 1 Study Area

- Plunge Pool- objective to develop stage vs discharge & wetted area relationship
- Left Channel- objective to determine ZOP of most limiting barrier at various discharges
- Center Channel- objective to describe channel hydraulic at various discharges
- Right Channel- objective to determine habitat in channel at various discharges.
- Lower Reach 1- includes Transects T-10 and T-11 (above Station No. 1 and part of steady state habitat assessment)

FirstLight Power Resources

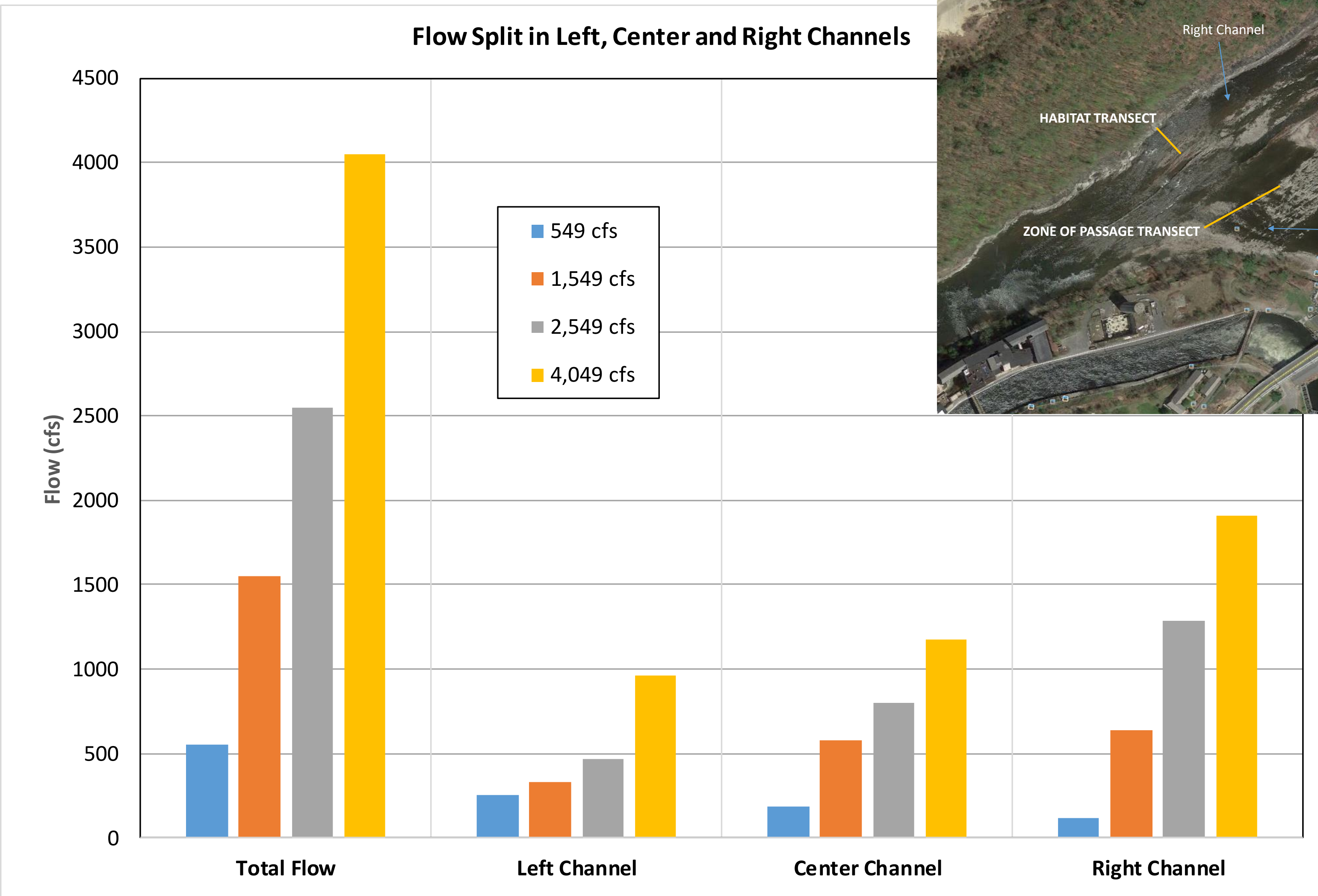
Study Reaches 1, 2A, 2B, 3, 4

- Reach 1- TF Dam to Station No. 1 tailrace--includes plunge pool, left channel, center channel, right channel. Habitat assessment of Lower Reach 1 Transects T-10 and T-11 using 1D Modeling.
- Reach 2A- Station No. 1 tailrace to ~1,000 ft upstream of Rawson Island. Habitat assessment of Transects T-1 to T-9 (1D Modeling).
- Reach 2B- ~ 1,000 ft upstream of Rawson Island to Rock Dam. Habitat assessment using 2D Modeling.
- Reach 3- Rock Dam to Montague USGS Gage. Habitat assessment using 2D Modeling.
- Reach 4- Montague USGS Gage to Route 116 Bridge. Habitat assessment using 1D Modeling.



3.3.1-Instream Flow Study

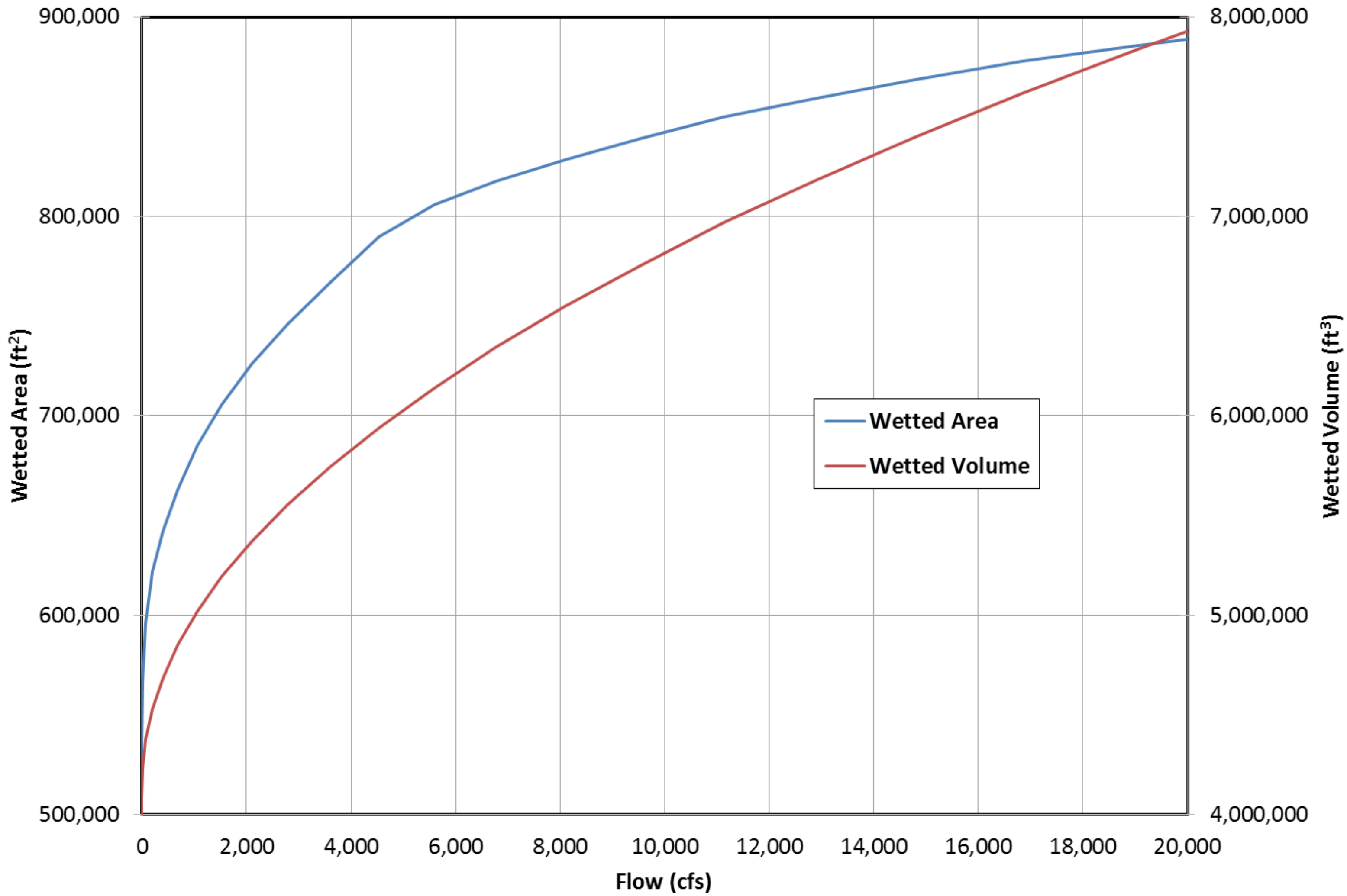
Reach 1- Flow Distribution in Left, Right and Center Channels



3.3.1-Instream Flow Study

Reach 1- Plunge Pool

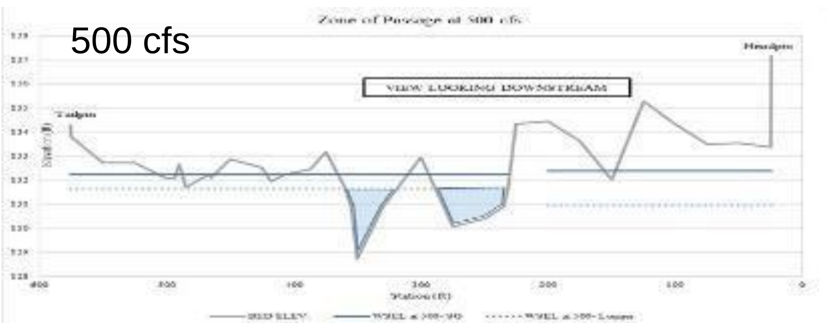
- Wetted Area and Volume vs Discharge

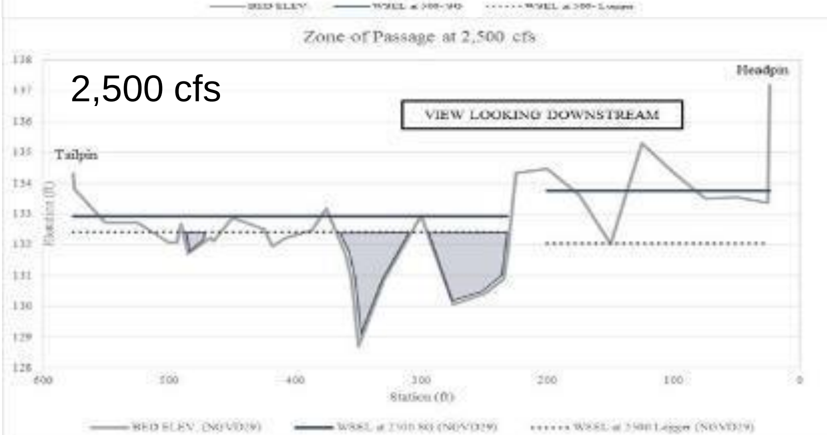


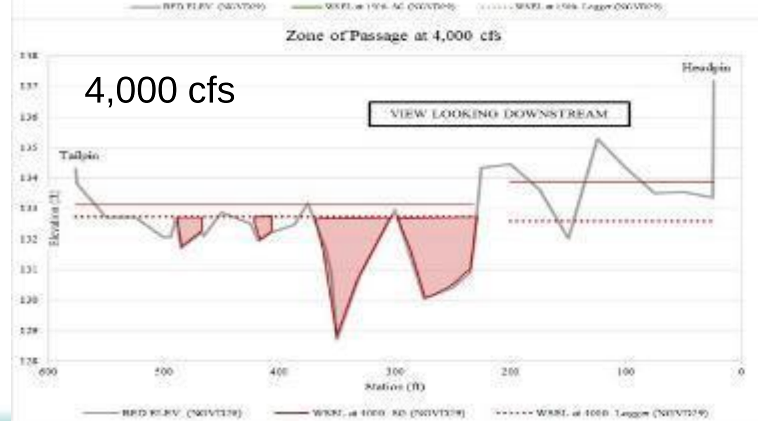
3.3.1-Instream Flow Study

<u>Reach 1-Left Channel (ZOP)</u>

- The channel passage barrier transect is 576 feet long;
- Deepest portion 3.5 feet deep at a total bypass flow of 125 cfs
- Bypass flow releases less than 1,500 cfs wet only the right-most 300-ft portion of the channel (looking downstream),
- higher flow wets the left-most 150 feet of the transect.

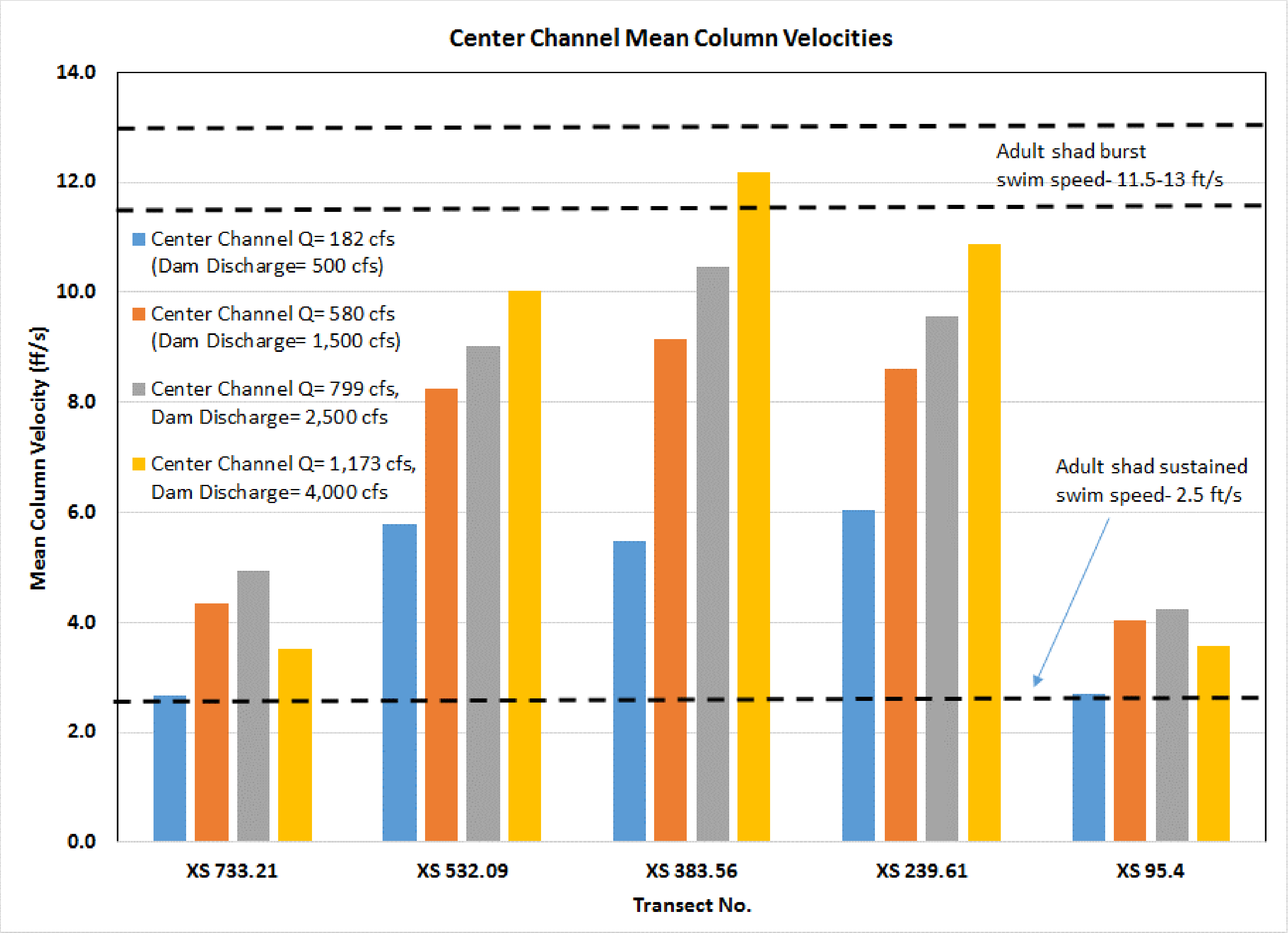






3.3.1-Instream Flow Study

<u>Reach 1 Center Channel</u>- Mean Channel Velocities



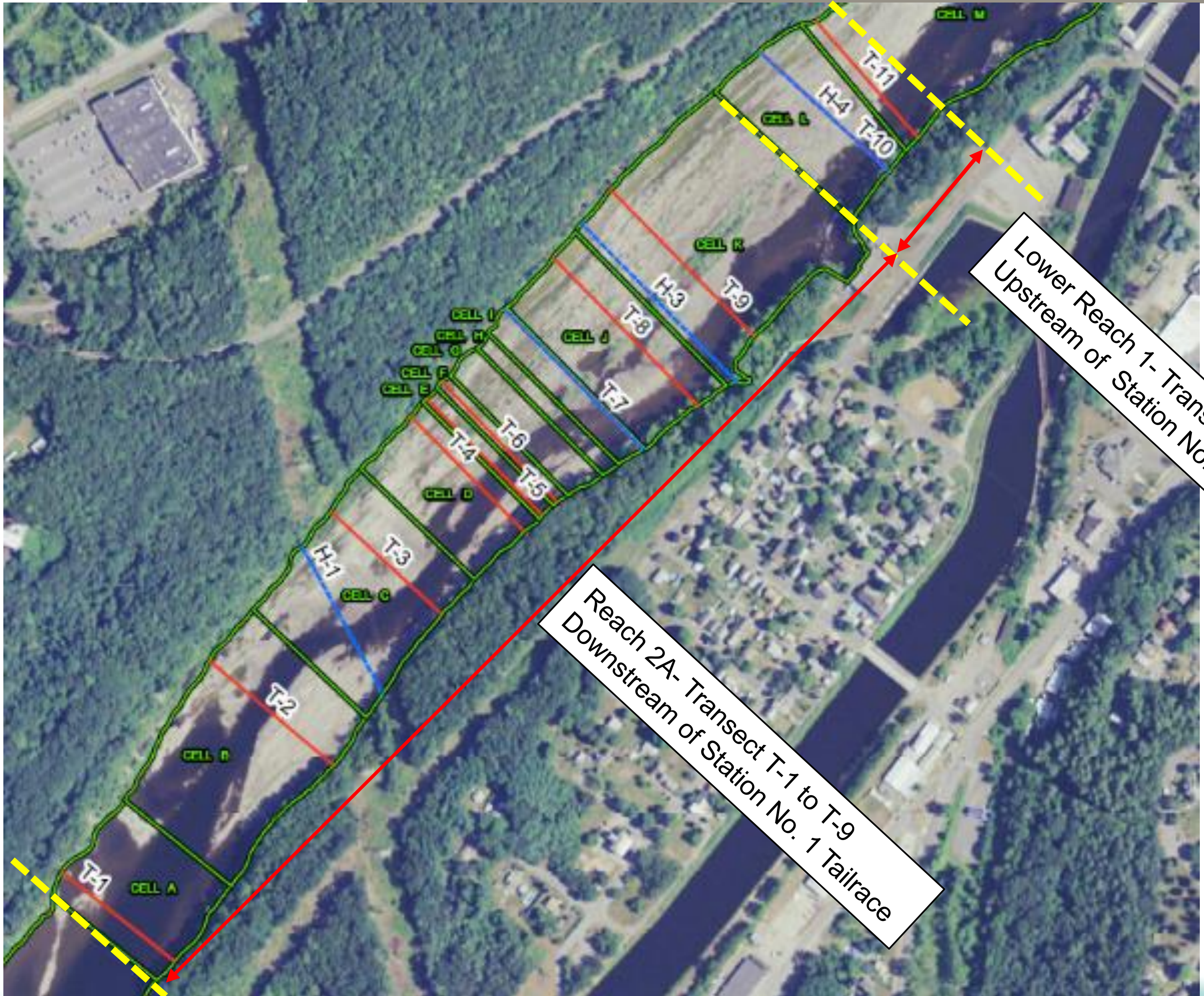
Reach 1-Right Channel- Habitat analysis

- Flow shown represents full bypass flow

Table 7.1.1.1-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 1 (Right Channel-Flow shown is full bypass flow)

Species	Life stage	Months Present	Maximum WUA Total Flow (cfs)	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	562 (cfs) 0.08 (cfsm)	591 (cfs) 0.08 (cfsm)	802 (cfs) 0.11 (cfsm)	1,281 (cfs) 0.18 (cfsm)	1,583 (cfs) 0.22 (cfsm)	1,719 (cfs) 0.24 (cfsm)	2,106 (cfs) 0.3 (cfsm)	2,551 (cfs) 0.38 (cfsm)	3,062 (cfs) 0.43 (cfsm)	4,105 (cfs) 0.53 (cfsm)
Fallfish	Spawning/Incu	May-June	802	250	86,628	90%	95%	100%	88%	68%	56%	34%	26%	20%	13%
Fallfish	Fry	May-June	591	140	66,936	99%	100%	79%	65%	43%	39%	32%	17%	12%	8%
Fallfish	Juvenile	Year Round	802	250	83,561	83%	89%	100%	83%	77%	68%	46%	35%	32%	24%
Fallfish	Adult	Year Round	1583	662	33,506	49%	52%	72%	96%	100%	98%	88%	76%	66%	39%
Longnose Dace	Juvenile	Year Round	802	250	83,561	83%	89%	100%	83%	77%	68%	46%	35%	32%	24%
Longnose Dace	Adult	Year Round	591	140	74,344	98%	100%	97%	63%	43%	37%	29%	23%	21%	13%
White Sucker	Spawning/Incu	May-June	591	140	41,330	98%	100%	87%	70%	48%	37%	26%	28%	21%	8%
White Sucker	Fry	Apr-May	591	140	66,936	99%	100%	79%	65%	43%	39%	32%	17%	12%	8%
White Sucker	Adult/Juvenile	Year Round	562	0	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Walleye	Spawning/Incu	April-May	3062	1,500	86,372	8%	10%	21%	45%	60%	72%	92%	98%	100%	99%
Walleye	Fry	April-May	562	125	13,105	100%	92%	42%	16%	5%	9%	16%	1%	3%	2%
Walleye	Juvenile	Year Round	591	140	58,234	98%	100%	75%	47%	30%	25%	18%	24%	13%	5%
Walleye	Adult	Year Round	562	0	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tessellated Darter	Adult/Juvenile	Year Round	562	125	38,259	100%	98%	54%	28%	16%	12%	17%	17%	5%	5%
Sea Lamprey	Spawning/Incu	May-June	1583	662	18,221	60%	65%	77%	83%	100%	87%	58%	32%	33%	16%
Macroinvertebrates	Larva	Year Round	1719	750	74,190	41%	45%	68%	95%	99%	100%	96%	93%	87%	79%
Shallow Slow	Shallow Slow	Year Round	562	125	45,830	100%	91%	44%	23%	3%	7%	23%	1%	2%	4%
Shallow Fast	Shallow Fast	Year Round	562	125	56,586	100%	97%	69%	32%	23%	20%	22%	16%	8%	5%
Deep Slow	Deep Slow	Year Round	1281	500	14,944	7%	17%	66%	100%	36%	16%	0%	0%	0%	0%
Deep Fast	Deep Fast	Year Round	1719	1,000	98,741	0%	3%	24%	70%	89%	96%	100%	89%	80%	63%

3.3.1-Instream Flow Study



3.3.1-Instream Flow Study

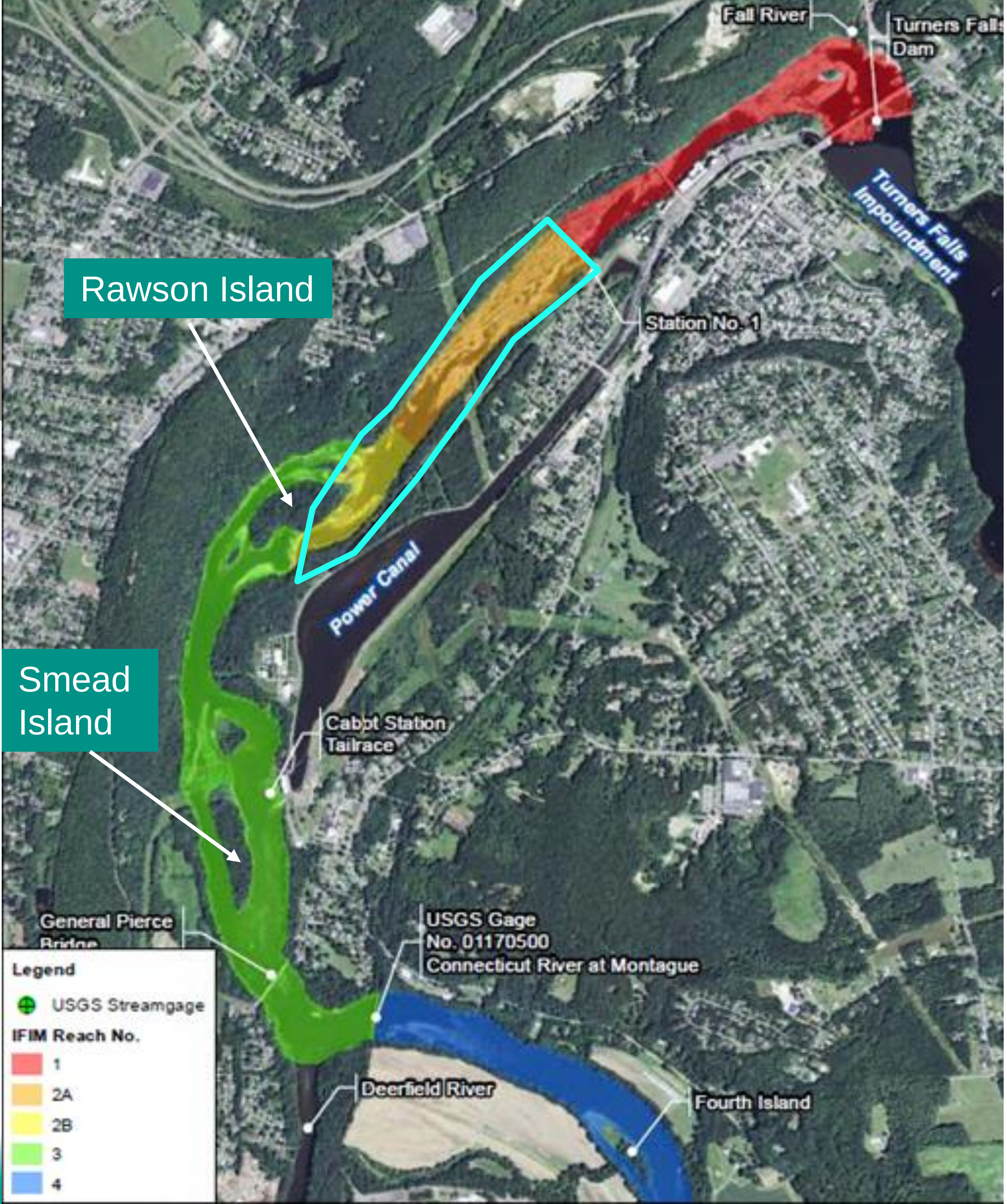
Reach 1-Transects T-10 & T-11, Low Backwater (also one for high backwater)- Steady State Habitat Results

Table 7.1.1.2-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 1 (Transects 10 & 11) for Low Backwater Condition

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	120 (cfs)	150 (cfs)	200 (cfs)	250 (cfs)	400 (cfs)	500 (cfs)	600 (cfs)	700 (cfs)	800 (cfs)	1000 (cfs)	1200 (cfs)	1400 (cfs)	1600 (cfs)	1800 (cfs)	2000 (cfs)	3000 (cfs)	4000 (cfs)	5000 (cfs)
					0.02 (cfsm)	0.02 (cfsm)	0.03 (cfsm)	0.03 (cfsm)	0.06 (cfsm)	0.07 (cfsm)	0.08 (cfsm)	0.1 (cfsm)	0.11 (cfsm)	0.14 (cfsm)	017 (cfsm)	0.2 (cfsm)	0.22 (cfsm)	0.25 (cfsm)	0.28 (cfsm)	0.42 (cfsm)	0.56 (cfsm)	0.70 (cfsm)
American Shad	Spawning/Incu	May-June	7,500	870,142	9.5%	11.0%	13.3%	15.4%	18.9%	21.6%	24.1%	26.5%	28.8%	32.8%	37.9%	43.1%	47.5%	52.9%	58.2%	71.7%	81.6%	88.8%
American Shad	Juvenile	June-Oct	2,000	619,823	27.3%	29.7%	33.6%	36.9%	42.1%	43.8%	45.0%	46.1%	47.6%	52.8%	66.3%	78.8%	86.1%	93.8%	100.0%	96.9%	89.1%	80.4%
American Shad	Adult	May-June	7,500	626,206	10.8%	12.5%	14.8%	17.0%	18.8%	21.1%	23.5%	25.5%	27.5%	31.4%	35.7%	39.7%	42.2%	46.0%	49.7%	65.8%	80.6%	89.3%
Shortnose Sturgeon	Spawning	April-May	6,000	874,855	7.2%	10.1%	13.7%	16.3%	21.4%	23.8%	26.4%	28.6%	30.5%	33.0%	37.2%	43.0%	49.0%	56.7%	65.5%	84.2%	94.4%	98.8%
Shortnose Sturgeon	Egg-Larvae	May	3,000	1,360,780	20.3%	22.2%	25.1%	27.9%	32.4%	33.7%	35.1%	37.4%	41.4%	51.0%	67.4%	80.2%	87.5%	94.3%	99.4%	100.0%	99.9%	99.2%
Shortnose Sturgeon	Fry	May	700	59,453	57.3%	63.0%	71.0%	79.1%	89.9%	94.9%	98.2%	100.0%	100.0%	97.5%	95.4%	94.5%	91.5%	91.3%	91.8%	70.6%	52.7%	38.0%
Fallfish	Spawning/Incu	May-June	120	6,038	100.0%	91.1%	78.0%	66.5%	58.5%	44.5%	31.8%	20.3%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fallfish	Fry	May-June	200	28,739	85.9%	96.3%	100.0%	97.6%	86.8%	82.2%	68.5%	53.3%	46.0%	33.6%	28.2%	25.4%	21.9%	18.5%	15.5%	4.8%	1.5%	0.7%
Fallfish	Juvenile	Year Round	2,000	233,847	49.6%	48.0%	50.7%	58.0%	67.2%	72.5%	73.0%	72.8%	75.5%	77.0%	80.6%	89.6%	95.2%	99.3%	100.0%	89.7%	67.8%	47.7%
Fallfish	Adult	Year Round	2,000	437,958	41.4%	44.3%	49.3%	52.4%	49.9%	48.0%	45.9%	44.6%	45.2%	49.3%	63.5%	78.3%	85.2%	94.3%	100.0%	93.2%	77.5%	64.7%
Longnose Dace	Juvenile	Year Round	2,000	196,805	13.0%	14.5%	17.5%	22.5%	44.0%	43.4%	35.0%	31.2%	29.0%	31.0%	49.1%	68.0%	83.9%	95.4%	100.0%	46.2%	17.1%	5.4%
Longnose Dace	Adult	Year Round	2,000	462,096	9.5%	10.1%	12.5%	14.4%	28.5%	29.8%	27.3%	26.7%	25.6%	23.3%	41.7%	62.0%	79.8%	93.0%	100.0%	68.6%	29.4%	8.8%
White Sucker	Spawning/Incu	Apr-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
White Sucker	Fry	May-June	1,200	639,270	38.2%	38.7%	42.1%	49.0%	39.4%	47.3%	58.4%	70.1%	79.3%	96.8%	100.0%	91.8%	73.5%	52.8%	28.4%	6.5%	1.4%	1.1%
White Sucker	Adult/Juvenile	Year Round	1,600	202,982	87.2%	82.8%	77.1%	73.5%	58.0%	47.4%	40.0%	35.2%	32.9%	43.5%	70.4%	95.9%	100.0%	97.6%	79.0%	38.5%	10.9%	3.4%
Walleye	Spawning/Incu	April-May	3,000	151,950	8.8%	9.9%	11.3%	12.5%	18.9%	23.4%	28.2%	34.5%	40.9%	50.0%	55.8%	57.6%	68.0%	69.1%	69.2%	100.0%	95.4%	86.4%
Walleye	Fry	April-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Walleye	Juvenile	Year Round	150	179	71.4%	100.0%	100.0%	100.0%	71.4%	57.1%	57.1%	42.9%	28.6%	14.3%	5.7%	11.4%	8.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Walleye	Adult	Year Round	3,000	6,289	38.2%	47.6%	53.3%	54.1%	47.6%	53.3%	58.2%	62.6%	65.9%	70.0%	74.7%	76.9%	77.7%	78.9%	83.4%	100.0%	39.0%	1.4%
Tessellated Darter	Adult/Juvenile	Year Round	2,000	169,159	8.6%	8.6%	11.5%	14.1%	32.9%	32.5%	21.5%	18.7%	19.4%	26.1%	47.4%	68.0%	85.3%	97.3%	100.0%	39.3%	5.5%	0.0%
Sea Lamprey	Spawning/Incu	May-June	800	8,809	15.0%	17.2%	23.3%	25.9%	68.7%	89.8%	92.6%	95.2%	100.0%	93.4%	59.5%	58.9%	57.5%	64.0%	68.0%	26.2%	12.4%	3.6%
Macroinvertebrates	Larva	Year Round	4,000	961,042	1.9%	3.0%	4.9%	6.6%	13.8%	18.0%	21.7%	24.7%	26.7%	28.7%	31.5%	37.0%	45.1%	55.4%	68.0%	91.8%	100.0%	98.0%
Shallow Slow	Shallow Slow	Year Round	1,200	789,695	22.3%	25.5%	31.7%	46.9%	58.3%	62.2%	68.3%	70.7%	78.5%	92.4%	100.0%	88.6%	78.8%	75.9%	71.6%	20.7%	0.0%	0.0%
Shallow Fast	Shallow Fast	Year Round	1,800	556,171	15.8%	18.5%	21.5%	23.5%	30.8%	30.3%	26.6%	21.7%	22.2%	33.4%	64.6%	85.2%	96.0%	100.0%	96.1%	43.8%	12.0%	3.0%
Deep Slow	Deep Slow	Year Round	1,400	385,669	49.4%	54.3%	60.7%	68.0%	37.5%	31.6%	25.5%	25.1%	37.3%	61.4%	83.7%	100.0%	84.7%	65.2%	54.3%	18.2%	3.5%	1.3%
Deep Fast	Deep Fast	Year Round	3,000	126,639	25.0%	33.7%	47.3%	57.5%	71.1%	63.4%	61.0%	56.0%	49.3%	53.7%	74.7%	87.8%	89.4%	91.4%	93.9%	100.0%	86.0%	69.2%

3.3.1-Instream Flow Study

Reach 2A (1-D) and Reach 2B (2-D): Station No.1 tailrace and Rock Dam



3.3.1-Instream Flow Study

Reach 2- Reach 2A and 2B Steady State Habitat Results

Table 7.1.2-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 2

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	120 (cfs) 0.02 (cfsm)	150 (cfs) 0.02 (cfsm)	200 (cfs) 0.03 (cfsm)	250 (cfs) 0.03 (cfsm)	400 (cfs) 0.06 (cfsm)	500 (cfs) 0.07 (cfsm)	600 (cfs) 0.08 (cfsm)	700 (cfs) 0.1 (cfsm)	800 (cfs) 0.11 (cfsm)	1000 (cfs) 0.14 (cfsm)	1200 (cfs) 017 (cfsm)	1400 (cfs) 0.2 (cfsm)	1600 (cfs) 0.22 (cfsm)	1800 (cfs) 0.25 (cfsm)	2000 (cfs) 0.28 (cfsm)	3000 (cfs) .42 (cfsm)	4000 (cfs) 0.56 (cfsm)	5000 (cfs) 0.7 (cfsm)
American Shad	Spawning/Incu	May-June	10,000	1,487,041	13.0%	14.1%	15.8%	17.4%	21.8%	24.1%	26.3%	28.4%	30.3%	34.0%	38.0%	41.9%	45.3%	48.6%	52.1%	62.8%	70.6%	78.0%
American Shad	Juvenile	June-Oct	3,000	1,094,797	26.0%	29.1%	33.9%	38.6%	49.3%	52.4%	55.3%	57.5%	59.5%	64.9%	73.5%	81.0%	86.4%	91.3%	95.7%	100.0%	97.6%	94.3%
American Shad	Adult	May-June	10,000	1,200,278	19.6%	20.7%	22.4%	24.0%	28.8%	31.3%	33.8%	35.9%	37.8%	41.4%	44.3%	47.0%	49.1%	51.2%	53.7%	60.4%	66.2%	74.6%
Shortnose Sturgeon	Spawning/Incu	April-May	10,000	950,854	2.7%	3.8%	5.4%	6.8%	10.6%	13.0%	15.0%	17.5%	19.9%	24.2%	29.2%	34.5%	39.3%	44.0%	48.9%	62.6%	74.2%	85.1%
Shortnose Sturgeon	Egg-Larvae	May	7,000	2,020,957	22.9%	25.2%	28.8%	32.2%	39.1%	41.6%	43.9%	45.9%	47.8%	54.9%	64.5%	71.7%	77.6%	83.2%	88.6%	95.5%	97.7%	99.2%
Shortnose Sturgeon	Fry	May	6,000	437,325	17.6%	21.5%	27.7%	33.8%	48.7%	52.8%	56.7%	59.2%	61.6%	65.7%	71.0%	76.7%	81.0%	85.0%	88.7%	94.9%	97.8%	99.6%
Fallfish	Spawning/Incu	May-June	3,000	44,809	28.8%	29.7%	31.3%	32.6%	33.8%	34.7%	36.2%	38.7%	41.3%	44.9%	53.7%	63.4%	73.1%	76.9%	81.3%	100.0%	94.4%	80.2%
Fallfish	Fry	May-June	1,600	107,763	61.8%	62.9%	64.7%	68.5%	73.8%	75.3%	76.2%	77.5%	80.3%	89.4%	95.3%	98.7%	92.1%	99.5%	98.0%	80.7%	59.9%	49.0%
Fallfish	Juvenile	Year Round	3,000	566,109	34.8%	38.4%	44.1%	49.4%	59.7%	61.4%	62.9%	64.5%	66.5%	69.3%	76.2%	85.3%	90.6%	95.4%	99.1%	100.0%	88.3%	74.2%
Fallfish	Adult	Year Round	1,800	822,519	45.4%	50.5%	57.4%	63.3%	71.6%	75.0%	77.8%	80.0%	81.8%	84.9%	90.7%	96.7%	92.1%	100.0%	99.0%	91.8%	82.5%	75.6%
Longnose Dace	Juvenile	Year Round	3,000	311,117	32.3%	33.0%	34.0%	35.6%	37.1%	37.5%	37.4%	36.7%	35.8%	38.3%	51.7%	66.0%	77.6%	88.8%	99.7%	100.0%	66.6%	40.6%
Longnose Dace	Adult	Year Round	3,000	615,175	22.3%	23.0%	24.1%	25.6%	29.0%	29.9%	30.3%	30.4%	30.6%	33.2%	46.3%	60.4%	71.9%	82.3%	92.2%	100.0%	89.3%	60.1%
White Sucker	Spawning/Incu	April-May	10,000	13,636	10.1%	8.0%	8.8%	10.1%	11.3%	12.1%	13.1%	15.3%	19.3%	27.4%	35.3%	41.9%	49.8%	56.6%	65.2%	86.4%	51.8%	43.5%
White Sucker	Fry	May-June	1,000	1,036,376	74.6%	75.4%	77.0%	79.5%	84.8%	87.4%	89.7%	91.9%	94.7%	100.0%	97.4%	89.7%	78.2%	65.6%	52.3%	34.9%	24.3%	19.1%
White Sucker	Adult/Juvenile	Year Round	1,400	436,799	42.9%	46.9%	52.4%	57.9%	71.2%	75.4%	80.2%	83.6%	85.8%	89.5%	95.6%	100.0%	98.2%	92.8%	85.0%	67.2%	49.7%	39.2%
Walleye	Spawning/Incu	April-May	8,000	482,932	6.4%	7.3%	9.0%	10.8%	16.8%	20.3%	24.4%	28.4%	31.6%	36.8%	39.0%	41.6%	45.3%	49.0%	52.4%	67.9%	80.5%	88.0%
Walleye	Fry	April-May	1,000	19,515	74.0%	77.0%	80.4%	82.8%	88.6%	91.1%	93.2%	95.5%	97.8%	100.0%	96.7%	92.5%	86.7%	79.6%	72.9%	61.8%	63.5%	61.4%
Walleye	Juvenile	Year Round	1,600	11,769	91.5%	91.4%	91.2%	91.1%	92.6%	93.8%	94.5%	94.0%	93.4%	94.2%	95.9%	98.2%	100.0%	99.5%	95.9%	79.1%	79.6%	77.7%
Walleye	Adult	Year Round	400	108,908	90.1%	91.4%	93.7%	96.0%	100.0%	95.4%	90.8%	83.5%	76.1%	62.8%	55.5%	51.5%	48.5%	46.1%	43.9%	37.5%	35.3%	35.2%
Tessellated Darter	Adult/Juvenile	Year Round	2,000	221,890	23.6%	23.2%	23.2%	23.9%	24.1%	24.3%	24.2%	24.0%	23.5%	26.5%	46.2%	66.6%	79.8%	90.9%	100.0%	93.7%	51.5%	25.5%
Sea Lamprey	Spawning/Incu	May-June	3,000	40,615	30.6%	36.5%	44.3%	49.8%	60.3%	61.9%	63.1%	62.4%	63.0%	63.3%	66.9%	71.4%	77.0%	81.3%	86.5%	100.0%	94.1%	72.0%
Macroinvertebrates	Larva	Year Round	6,000	1,343,516	5.9%	7.1%	9.0%	10.7%	15.1%	16.9%	18.5%	19.6%	20.7%	22.6%	25.9%	30.9%	37.6%	45.7%	55.5%	80.0%	93.5%	98.8%
Habitat Guild	Shallow Slow	Year Round	1,200	750,888	59.6%	59.0%	59.1%	63.4%	66.4%	66.7%	70.8%	75.8%	82.9%	95.8%	100.0%	99.0%	95.8%	90.0%	82.7%	50.4%	24.6%	15.6%
Habitat Guild	Shallow Fast	Year Round	2,000	618,960	28.2%	28.4%	29.4%	30.5%	32.4%	32.1%	32.2%	32.8%	33.4%	42.5%	64.5%	80.2%	89.7%	96.5%	100.0%	78.3%	49.5%	29.6%
Habitat Guild	Deep Slow	Year Round	1,400	822,968	72.4%	73.7%	75.7%	78.1%	83.6%	84.6%	86.8%	89.0%	90.6%	96.7%	98.9%	100.0%	95.2%	88.1%	78.6%	51.5%	40.2%	35.9%
Habitat Guild	Deep Fast	Year Round	7,000	456,895	2.8%	4.7%	8.8%	11.8%	17.2%	20.6%	24.7%	28.9%	32.1%	36.7%	40.6%	43.4%	46.8%	51.6%	57.4%	67.9%	75.8%	82.8%

FirstLight Power Resources

3.3.1-Instream Flow Study

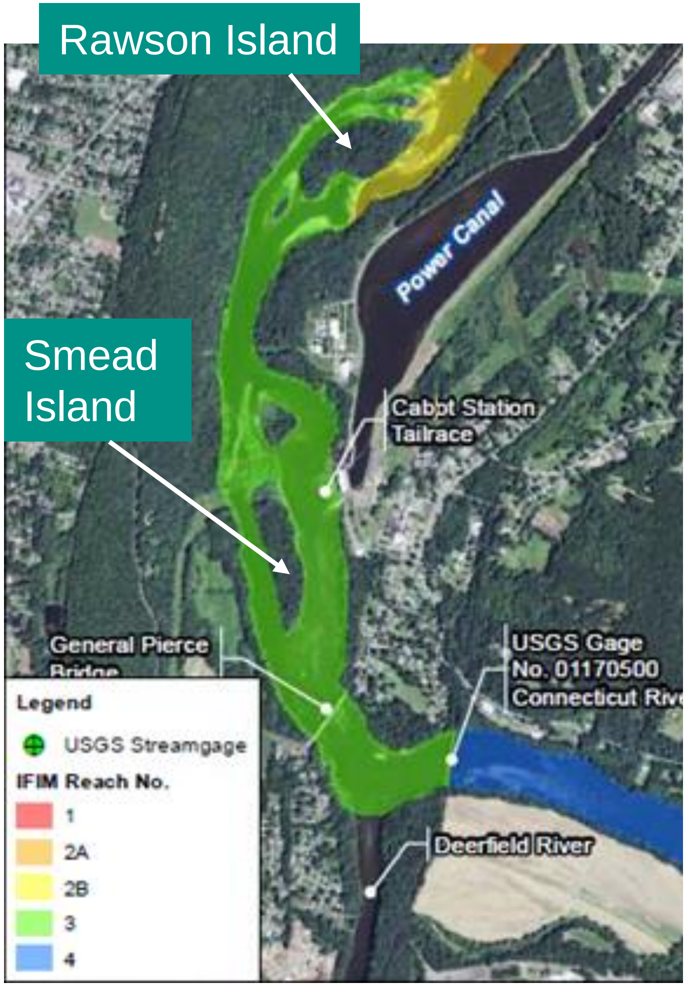
Reach 3

Hydraulics in Reach 3 impacted by:
- Bypass Flow
- Cabot Operations
- Deerfield River Flow

Scenarios Evaluated for Steady State Habitat Assessment:

Scenario	Bypass Q	Cabot Q	Deerfield Q
1	120, 200, 300, 500, 700, 1,000, 2,000, 3,000, 5,000 cfs	2,500 cfs	200 cfs
2	Same as Scenario 1	7,000 cfs	200 cfs
3	Same as Scenario 1	14,000 cfs	200 cfs

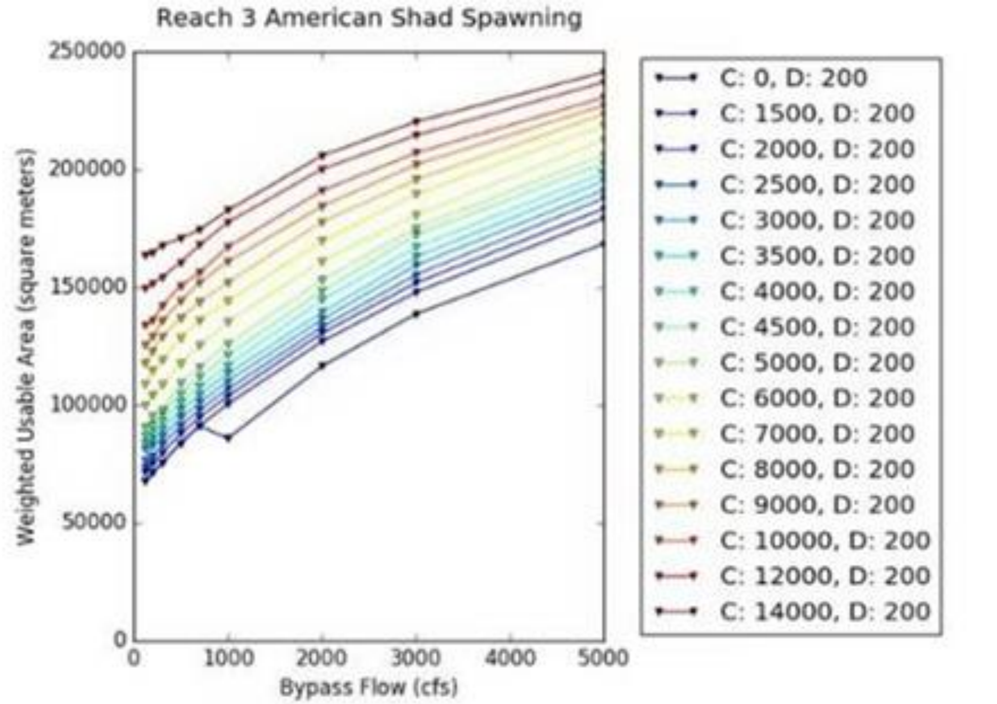
Analyses
- Steady State Habitat Assessment
- Persistent Habitat Mapping
- Habitat Time Series (still needs to be completed)

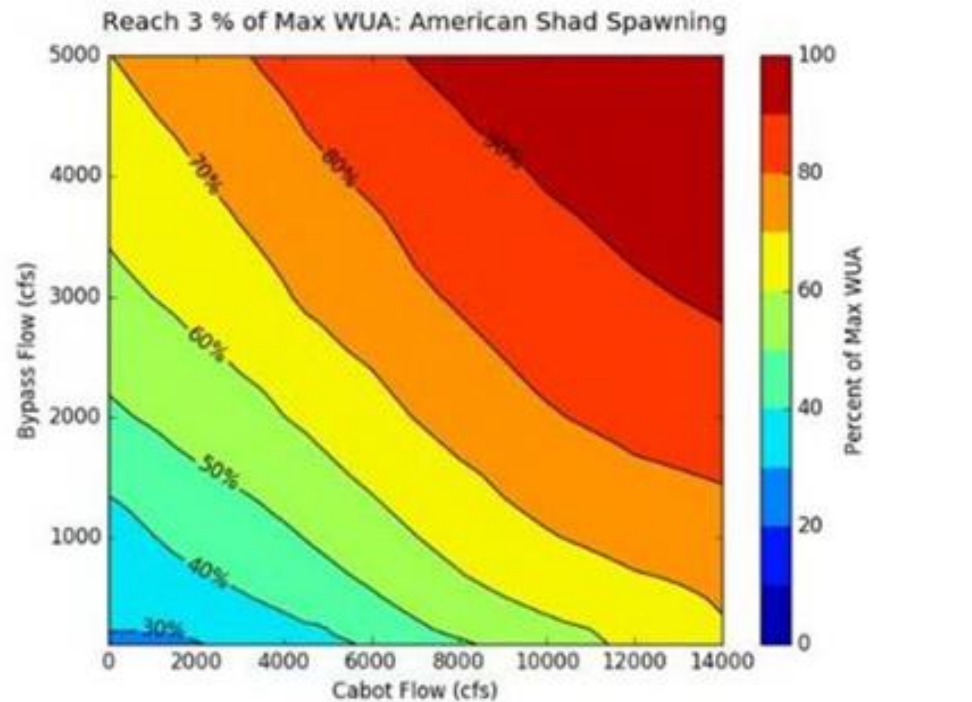


3.3.1-Instream Flow Study

<u>Reach 3</u>

Example Output for Steady State Habitat Results for American Shad spawning and incubation under different bypass flows, and Cabot discharges, and Deerfield = 200 cfs

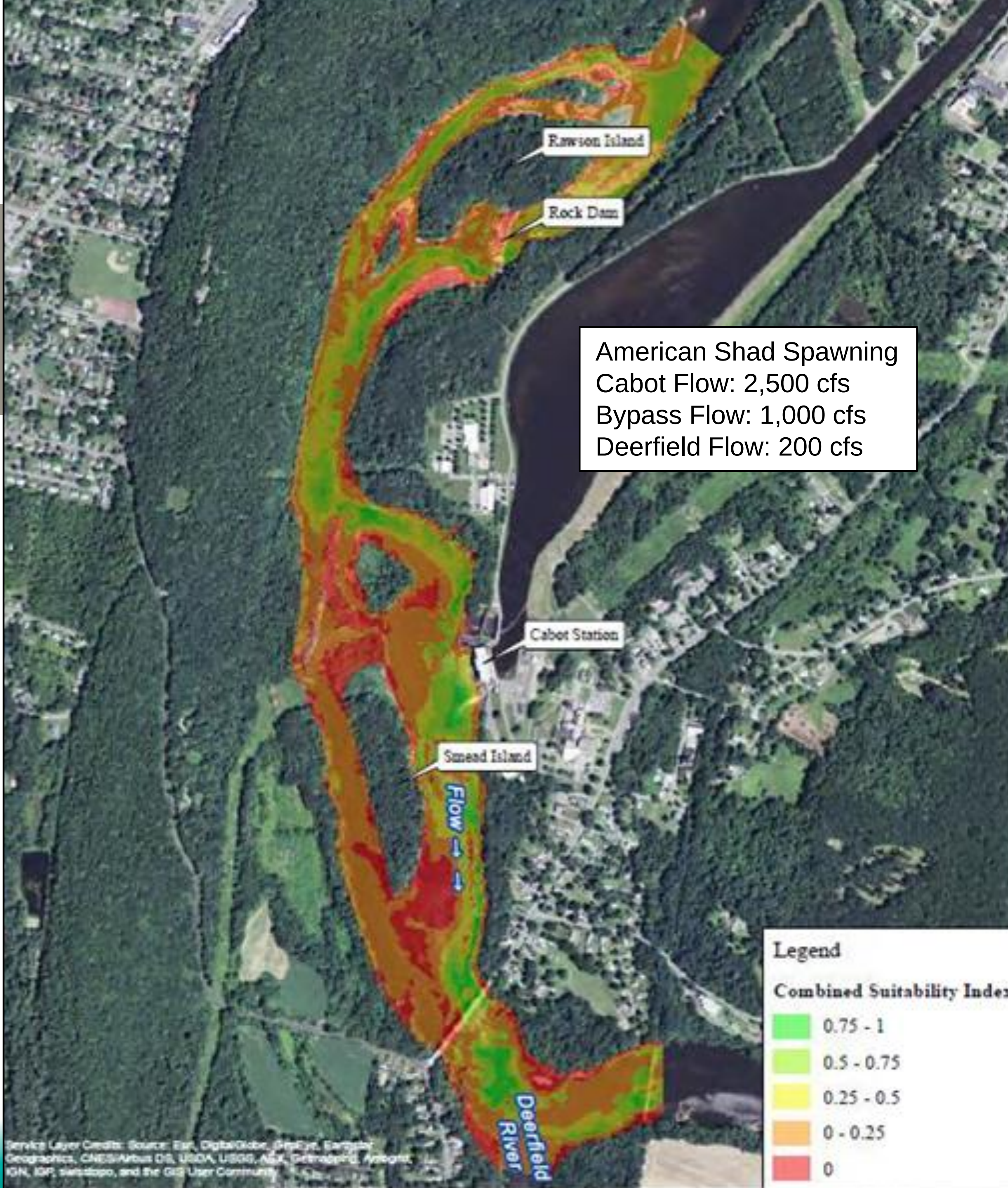




3.3.1-Instream Flow Study

<u>Reach 3</u>

Example Output for Combined Suitability Index Results for American Shad spawning and incubation under Cabot discharge of 2,500 cfs, bypass flow of 1,000 cfs, and Deerfield flow of 200 cfs (steady state analysis)

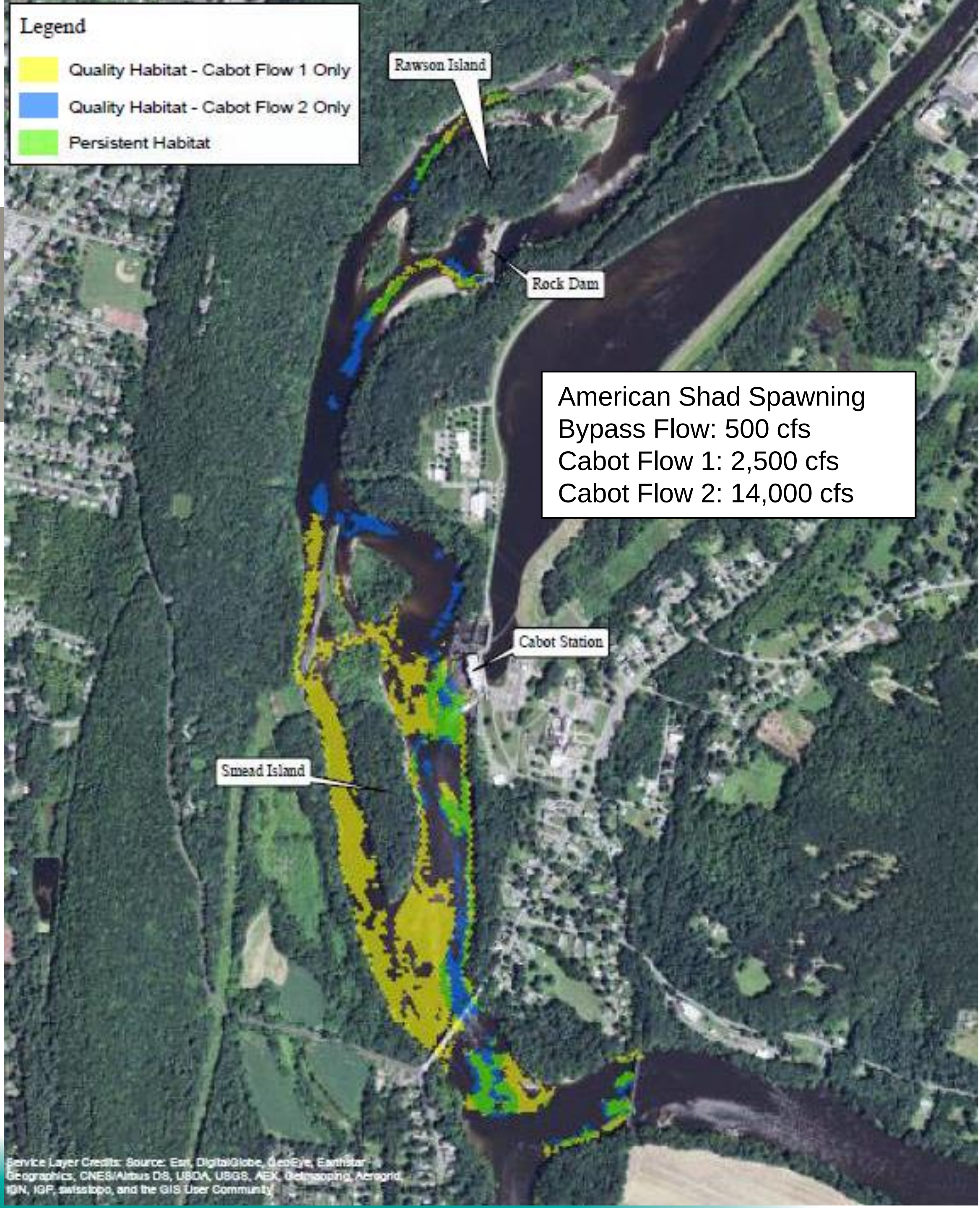


FirstLight Power Resources

3.3.1-Instream Flow Study

Reach 3

Example Output of Persistent Habitat Mapping for American Shad spawning and incubation under bypass flow of 500 cfs and Cabot discharges of 2,500 and 14,000 cfs

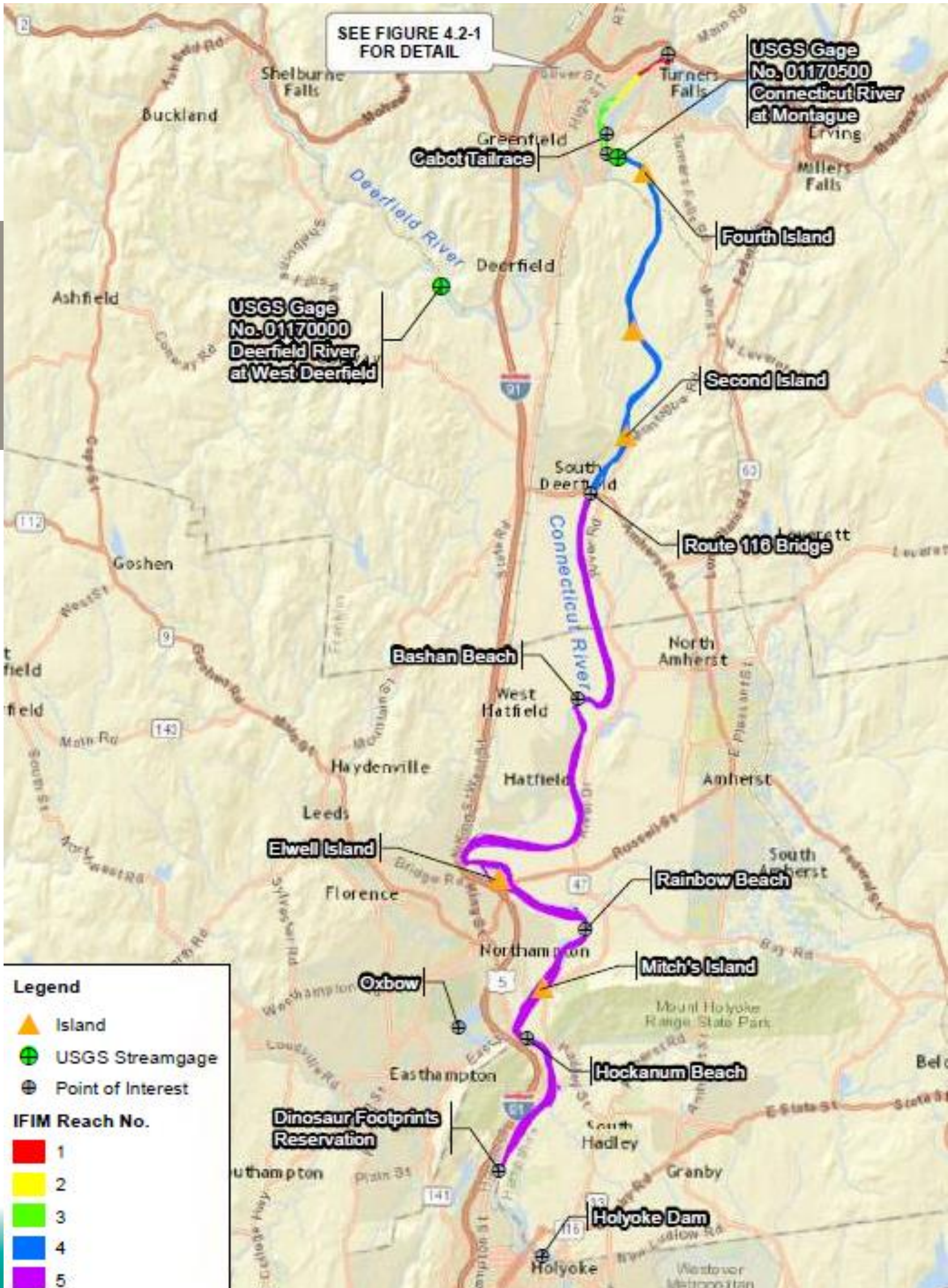


FirstLight
Power Resources

3.3.1-Instream Flow Study

Reach 4

- Steady State Habitat Analysis
- Dual Flow Analysis
- Habitat Time Series Analysis



FirstLight Power Resources

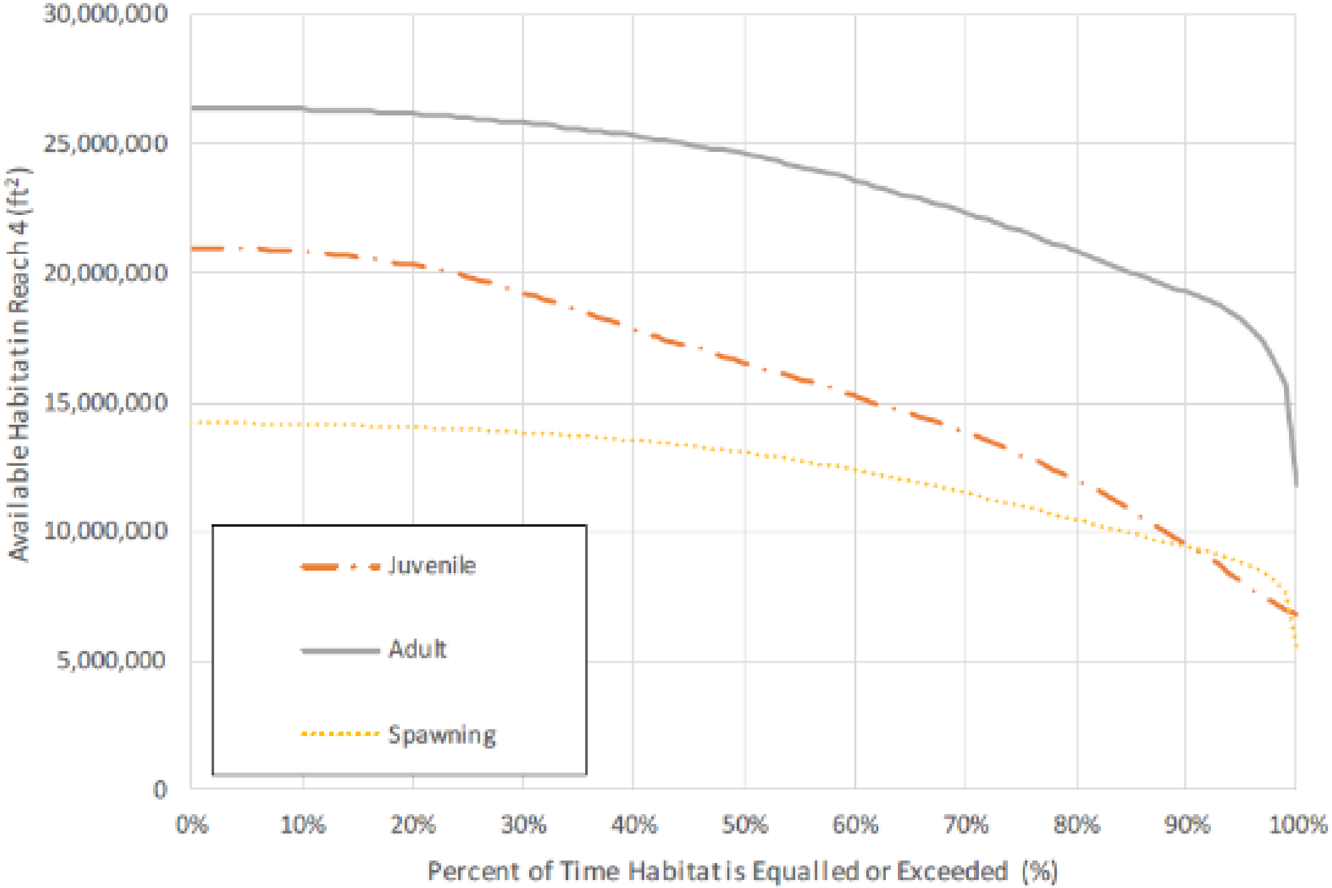
3.3.1-Instream Flow Study

Reach 4- Steady State Habitat Results

Table 7.1.4-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 4

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	1200 (cfs) 0.15 (cfsm)	1600 (cfs) 0.2 (cfsm)	2000 (cfs) 0.25 (cfsm)	2800 (cfs) 0.36 (cfsm)	4000 (cfs) 0.51 (cfsm)	5000 (cfs) 0.64 (cfsm)	6000 (cfs) 0.76 (cfsm)	8000 (cfs) 1.02 (cfsm)	10000 (cfs) 1.27 (cfsm)	12000 (cfs) 1.53 (cfsm)	14000 (cfs) 1.78 (cfsm)	15000 (cfs) 1.91 (cfsm)	17500 (cfs) 2.23 (cfsm)	20000 (cfs) 2.54 (cfsm)	25000 (cfs) 2.86 (cfsm)	30000 (cfs) 3.82 (cfsm)	37500 (cfs) 4.77 (cfsm)
American Shad	Spawning/Incu	May-June	12,000	14,182,397	46.8%	53.6%	59.3%	68.0%	77.4%	83.4%	88.2%	94.8%	98.5%	100.0%	99.6%	98.9%	96.0%	92.0%	82.3%	72.5%	59.4%
American Shad	Juvenile	June-Oct	4,000	20,970,703	87.3%	92.5%	95.8%	99.3%	100.0%	98.4%	95.7%	89.4%	83.2%	77.9%	72.1%	69.3%	62.9%	57.2%	47.4%	39.5%	32.2%
American Shad	Adult	May-June	12,000	26,411,552	52.7%	59.2%	64.9%	72.8%	80.6%	85.6%	89.7%	95.9%	99.1%	100.0%	99.3%	98.6%	96.0%	93.0%	86.6%	79.9%	70.8%
Shortnose Sturgeon	Fry	May	5,000	16,338,131	69.9%	79.8%	86.6%	95.3%	99.7%	100.0%	98.8%	95.1%	90.0%	84.7%	79.3%	76.7%	70.4%	64.7%	55.1%	47.8%	39.8%
Shortnose Sturgeon	Juveniles	June	5,000	20,325,318	78.8%	84.3%	88.9%	94.8%	98.8%	100.0%	99.8%	97.0%	92.2%	86.9%	81.8%	79.5%	73.8%	68.7%	59.8%	52.9%	45.3%
Shortnose Sturgeon	Adults	Year Round	5,000	20,657,503	79.8%	85.6%	90.1%	95.6%	99.3%	100.0%	99.3%	95.9%	90.9%	85.8%	80.8%	78.5%	72.8%	67.6%	58.9%	52.1%	44.6%
Fallfish	Spawning/Incu	May-June	800	5,014,615	88.5%	78.9%	73.1%	66.1%	55.6%	44.6%	34.3%	17.7%	10.8%	7.9%	6.6%	6.1%	4.4%	2.4%	0.2%	0.0%	2.2%
Fallfish	Fry	May-June	800	7,657,464	91.2%	82.0%	73.7%	61.9%	44.9%	35.4%	27.7%	18.3%	13.5%	11.7%	9.4%	8.0%	4.7%	2.9%	2.3%	2.6%	5.9%
Fallfish	Juvenile	Year Round	800	8,226,027	98.3%	95.0%	91.5%	88.5%	82.0%	73.0%	62.6%	43.3%	32.2%	27.2%	23.0%	21.4%	16.9%	13.1%	8.7%	7.1%	7.3%
Fallfish	Adult	Year Round	2,000	18,844,747	96.9%	99.3%	100.0%	98.2%	93.1%	87.7%	82.1%	71.3%	62.7%	57.4%	53.2%	51.5%	47.3%	43.3%	37.4%	33.5%	30.5%
Longnose Dace	Juvenile	Year Round	2,400	1,226,425	89.2%	98.7%	99.7%	96.4%	65.1%	38.4%	21.9%	9.4%	10.9%	11.8%	7.0%	4.7%	2.2%	1.2%	0.7%	1.3%	8.9%
Longnose Dace	Adult	Year Round	2,400	2,146,515	86.0%	92.9%	98.8%	96.0%	73.2%	49.3%	27.5%	9.2%	8.4%	10.3%	10.3%	8.3%	2.2%	1.3%	1.8%	2.2%	5.9%
White Sucker	Spawning/Incu	Apr-May	1,600	654,203	96.6%	100.0%	92.5%	91.4%	52.4%	23.9%	11.3%	8.9%	12.7%	12.1%	9.2%	6.7%	4.1%	3.3%	4.0%	5.8%	24.1%
White Sucker	Fry	May-June	800	17,311,497	93.3%	84.4%	76.9%	63.6%	49.6%	42.5%	38.2%	33.4%	31.1%	28.7%	26.4%	25.1%	22.7%	21.1%	19.0%	17.8%	17.8%
White Sucker	Adult/Juvenile	Year Round	1,000	11,466,039	98.6%	91.5%	83.1%	68.4%	52.9%	44.6%	38.2%	29.1%	24.3%	23.5%	22.2%	21.0%	17.6%	14.7%	10.8%	8.4%	7.0%
Walleye	Spawning	April-May	5,000	2,557,617	58.7%	68.1%	76.9%	89.4%	99.2%	100.0%	95.3%	84.4%	68.9%	49.4%	30.9%	24.1%	11.3%	7.1%	4.7%	2.4%	0.9%
Walleye	Fry	April-May	8,000	955,697	77.2%	85.4%	94.0%	93.6%	84.9%	77.5%	83.1%	100.0%	90.9%	67.5%	45.8%	39.9%	25.6%	11.6%	0.0%	0.0%	0.0%
Walleye	Juvenile	Year Round	800	1,789,966	88.8%	80.1%	74.1%	68.9%	64.7%	61.2%	58.0%	55.9%	59.0%	58.4%	55.2%	53.5%	47.4%	41.5%	30.8%	25.0%	21.4%
Walleye	Adult	Year Round	800	7,030,738	89.7%	80.0%	72.8%	61.3%	54.9%	53.9%	53.6%	52.8%	51.9%	53.3%	55.3%	54.7%	52.5%	50.0%	44.8%	41.0%	37.3%
Tessellated Darter	Adult/Juvenile	Year Round	1,600	1,097,027	92.5%	100.0%	86.3%	82.9%	51.8%	27.3%	15.2%	8.5%	13.8%	15.2%	8.8%	5.4%	4.3%	3.7%	3.7%	6.1%	25.8%
Sea Lamprey	Spawning/Incu	May-June	2,800	209,778	67.1%	83.7%	94.3%	100.0%	78.8%	44.0%	20.1%	3.4%	6.0%	8.3%	7.0%	6.9%	1.2%	0.5%	0.2%	0.3%	6.7%
Macroinvertebrates	Larva	Year Round	5,000	3,812,597	41.0%	54.5%	67.8%	87.3%	98.4%	100.0%	97.2%	87.2%	76.9%	67.9%	61.4%	59.1%	54.7%	51.7%	46.4%	42.6%	40.2%
Shallow Slow	Shallow Slow	Year Round	800	2,811,288	88.2%	89.5%	92.9%	84.6%	64.2%	60.6%	51.6%	34.2%	15.8%	12.3%	9.4%	7.8%	1.7%	1.3%	1.6%	0.2%	4.7%
Shallow Fast	Shallow Fast	Year Round	800	2,627,730	93.4%	94.6%	97.1%	89.2%	60.5%	41.8%	29.0%	16.3%	14.0%	12.7%	10.7%	6.8%	3.7%	2.4%	0.7%	0.5%	5.0%
Deep Slow	Deep Slow	Year Round	1,000	19,235,977	99.1%	96.4%	93.6%	87.4%	76.7%	66.8%	55.9%	43.6%	38.0%	36.0%	34.1%	33.1%	30.0%	27.4%	23.9%	21.7%	20.6%
Deep Fast	Deep Fast	Year Round	1,600	4,451,275	86.0%	100.0%	98.4%	90.7%	79.1%	72.0%	68.1%	62.3%	38.5%	19.4%	8.7%	6.2%	9.4%	8.4%	1.7%	0.5%	0.3%

Reach 4 – Example Habitat Time Series results for American Shad
Based on hourly flow for period Jan 1, 2000 to Sep 30, 2015



Reach 4 – Results – Habitat Duration Exceedance Curves for various lifestages of American Shad

3.3.1-Instream Flow Study

Summary

- Work Completed
  - Reach 1- ZOP, steady state
  - Reach 2- steady state
  - Reach 3- steady state, persistent habitat mapping (for select flow combinations)
  - Reach 4- steady state, dual flow analysis, habitat time series analysis
  - Reach 5- steady state for mussels only

- Outstanding Work
  - Reach 3- persistent habitat mapping- need further input from stakeholders on flow combinations
  - Reach 3- habitat time series analysis

Variances

- None

3.3.16 State-Listed Mussels

Study Objectives

- **Conduct Field Surveys to delineate populations of state-listed mussels and suitable habitat downstream from Cabot Station and characterize the distribution, abundance, demographics, and habitat use of these populations. Identify and map potential habitat for state-listed mussel species based on habitat preferences.**

- **Develop a Binary Habitat Suitability Index for all state-listed mussel species found to occur in the 35-mile reach downstream from Cabot Station.**

3.3.16 State-Listed Mussels

Objective 1: Mussel Survey and Habitat Assessment (Completed in 2014)

- In June 2014, a habitat assessment and survey was completed throughout the 13-mile reach of the Connecticut River between Cabot Station and the Sunderland Bridge. A summary report of these findings was posted to the relicensing website in January 2015.

- The mussel community in the reach from Cabot Station to the Route 116 Bridge is dominated by a single species, Eastern Elliptio.

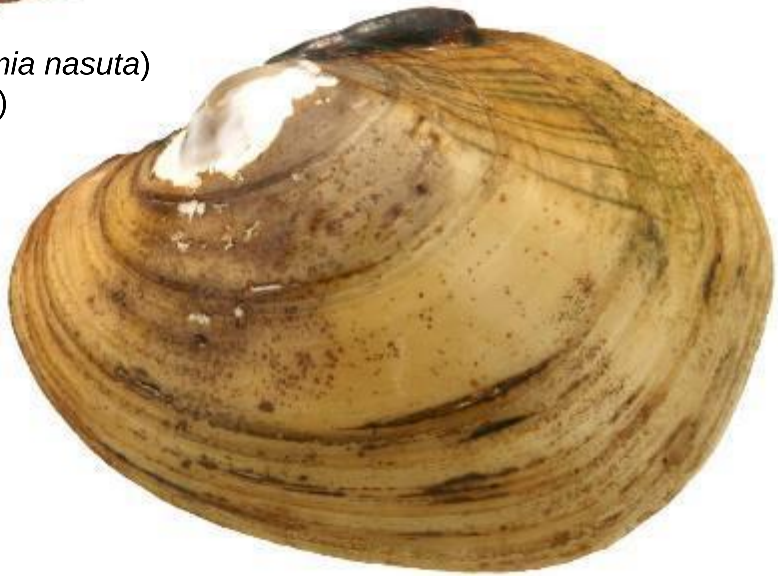
- No live state-listed mussels were found in the survey areas. One relic *Lampsilis cariosa* shell was found.

- As part of FERC-required studies for Holyoke Gas & Electric, three state-listed mussel species were documented in the lower end of Holyoke Dam impoundment (Reach 5 of FirstLight's study area).

3.3.16 State-Listed Mussels

Eastern Pondmussel (*Ligumia nasuta*)
(Special Concern)

Tidewater Mucket (*Leptodea ochracea*)
(Special Concern)



Yellow Lampmussel (*Lampsilis cariosa*)
(Endangered)

3.3.16 State-Listed Mussels

Objective 2: HSI Curve Development

- Delphi Panel
  - Developed from initial list of experts in conjunction with NHESP
- Panelists
- Instructions
- Process
  - Three Rounds
- Parameters
- HSI Results
- Application

3.3.16 State-Listed Mussels

Delphi Panel

- Five Invitees, Four Participants
- Moderator

- Dr. David Strayer (Cary Institute of Ecosystem Studies)
- Dr. Barry Wicklow (St. Anselm's College)
- Dr. Cynthia Loftin (US Geological Survey/ME Cooperative Fish and Wildlife Research Unit)
- Ethan Nedeau (Biodrawversity)

3.3.16 State-Listed Mussels

Habitat Parameters

- **Depth** of water where individual mussels or mussel beds occur.
- **Flow velocity** refers to benthic (or "nose') velocity that mussels are subjected to.
- **Substrate** is specifically what mussels burrow in and generally where they spend their lives (recognizing limited mobility), and refers to dominant particle sizes in the top ~10cm of the river/lake bottom.
- **Cover** is any feature that can provide reduced lighting, reduced flow velocity, increased isolation; something that mussels can get under or behind. It may be important to host fish, which would in turn influence habitat suitability for mussels.
- **Shear stress** is the force exerted on the streambed by water per unit area of streambed, and is reflective of the stream's flow intensity and its ability to entrain and transport sediment particles.
- **Relative shear stress** is the ratio of observed to critical shear stress; critical shear stress is the shear stress that is required to initiate movement for a given particle size.
- **Additional** as dictated by panelists

3.3.16 State-Listed Mussels

Round 1

- Panelists ranked suitability of parameters from 0.0, 0.1… to 1.0.
- Panelists provided a confidence in their scores based on personal level of certainty.
- References and data sources provided.

- Scores composited into a binary score as unsuitable “0” or suitable “1”
- Juvenile and adult life stages considered separately
- Anonymous scores, notes and references compiled for Round 2

3.3.16 State-Listed Mussels

Round 2

- Round 1 results summarized
    - Depth
    - Benthic Velocity
    - Substrate
    - Cover Type and %

- Shear Stress and Relative Shear Stress
    - Tentative scores compiled
    - Memo explaining SS/RSS considerations
    - RSS in Connecticut River under flood flows

3.3.16 State-Listed Mussels

Round 3

- Round 2 results provided
    - Depth
    - Benthic Velocity
    - Substrate
    - Cover – low importance

- Shear Stress and Relative Shear Stress
    - Memo updated
    - No HSI agreed upon for shear

Benthic Velocity

Parameter		Yellow Lampmussel		Eastern Pondmussel		Tidewater Mucket	
		Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Class	Benthic Velocity Range (ft/s)						
1	<0.16	1	1	1	1	1	1
2	0.16-0.34	1	1	1	1	1	1
3	0.35-0.67	1	1	1	1	1	1
4	0.68-0.99	1	1	1	1	1	1
5	1.00-1.32	1	1	1	1	1	1
6	1.33-1.65	1	1	1	1	1	1
7	1.66-2.47	0	1	0	0	0	1
8	2.48-3.29	0	0	0	0	0	0
9	3.30-4.93	0	0	0	0	0	0
10	4.94-6.56	0	0	0	0	0	0
11	>6.56	0	0	0	0	0	0

3.3.16 State-Listed Mussels

Water Depth

Parameter		Yellow Lampmussel		Eastern Pondmussel		Tidewater Mucket	
		Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Class	**Water Depth Range (feet)**						
1	0	0	0	0	0	0	0
2	0.03-0.34	0	0	0	0	0	0
3	0.35-0.83	1	1	1	1	1	1
4	0.84-1.65	1	1	1	1	1	1
5	1.66-2.47	1	1	1	1	1	1
6	2.48-3.29	1	1	1	1	1	1
7	3.30-4.93	1	1	1	1	1	1
8	4.94-6.56	1	1	1	1	1	1
9	6.57-9.85	1	1	1	1	1	1
10	9.86-13.12	1	1	1	1	1	1
11	>13.12	1	1	1	1	1	1

3.3.16 State-Listed Mussels

Substrate

Parameter		Yellow Lampmussel		Eastern Pondmussel		Tidewater Mucket	
		Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Class	**Particle Size**						
1	Organic Material	0	0	0	0	0	0
2	Clay	0	0	0	0	0	0
3	<0.002 in [mud/silt]	1	1	1	1	1	1
4	0.002 – 0.08 in. [sand]	1	1	1	1	1	1
5	0.08- 1.26 in. [fine gravel]	1	1	1	1	1	1
6	1.26 – 2.52 in. [coarse gravel]	1	1	0	1	1	1
7	2.52 – 5.90 in. [small cobble]	1	1	0	0	0	0
8	5.90 – 9.84 in. [large cobble]	0	0	0	0	0	0
9	9.84 – 157.5 in. [boulder]	0	0	0	0	0	0
10	Bedrock	0	0	0	0	0	0

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Application of 3.3.16 Mussel Criteria to Reach 5 IFIM

- HEC-RAS transects selected based on NHESP recommendations
    - Based on abundance of target species

- Benthic Velocity
    - HEC-RAS model calculated average water column velocity
    - Converted to benthic velocity using model/formula from literature

- Applied Velocity and Depth Criteria to Determine Suitability
    - Criteria 1: Yellow Lampmussel Juvenile; Eastern Pondmussel Juvenile and Adult; Tidewater Mucket Juvenile
    - Criteria 2: Yellow Lampmussel Adult; Tidewater Mucket Adult

- Limitations
    - Assumed sand substrate for modeling of velocity – No detailed substrate survey
        - Suitability of substrate was not a limiting factor for the modeling results

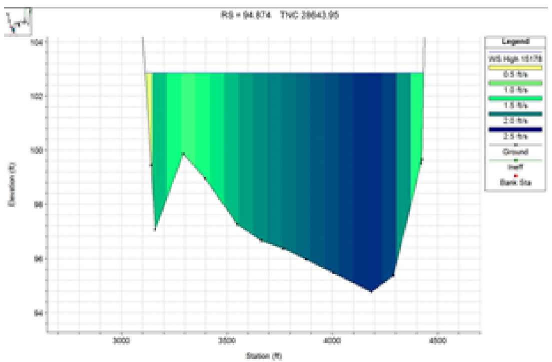
3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Scenario No.	Holyoke Dam Impoundment Elevation	Deerfield River Flow	Turners Falls Hydroelectric Project Flow	Total Flow
1	Min- 99.47 ft NGVD	Deerfield Hydroelectric Project Station No. 2 Min Flow 200 cfs	Turners Falls Project Min Flow 1,433 cfs	1,633 cfs
2	Max- 100.67 ft, NGVD	Deerfield Hydroelectric Project Station No. 2 Min Flow 200 cfs	Turners Falls Project Min Flow 1,433 cfs	1,633 cfs
3	Min- 99.47 ft NGVD	Deerfield Hydroelectric Project Station No. 2 Max Hydraulic Capacity 1,450 cfs	Cabot Station Hydraulic Capacity 13,728 cfs	15,178 cfs
4	Max- 100.67 ft, NGVD	Deerfield Hydroelectric Project Station No. 2 Max Hydraulic Capacity 1,450 cfs	Cabot Station Hydraulic Capacity 13,728 cfs	15,178 cfs
5	Min- 99.47 ft NGVD	Mean April Flow at the Montague USGS Gage		38,600 cfs

- **Scenarios 1-4 were used to examine "operational effects" that are within Project Capacity – Plus effects of Holyoke**
- **Scenario 5 was used to evaluate suitability during typical higher river flow conditions**

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

HEC-RAS Model Output (Provides Depths and Mean Water Column Velocities for 20 Equally-Spaced Intervals)



Converted Mean Water Column Velocities to Benthic Velocities (Logarithmic Functions)

Matrix of Parameters by Cross-Section Interval

Interval	Depth(ft)	Benthic Velocity (ft/s)
1	2.09	0.57
2	5.17	1.41
3	3.92	1.20
4	3.23	1.08
5	3.81	1.19
6	4.54	1.31
7	5.29	1.43
8	5.81	1.51
9	6.16	1.56
10	6.38	1.59
11	6.6	1.62
12	6.85	1.65
13	7.11	1.70
14	7.37	1.73
15	7.64	1.76
16	7.9	1.80
17	7.98	1.81
18	7.57	1.76
19	5.94	1.52
20	3.72	1.16

Evaluated Binary Suitability using Depth and Benthic Velocity (Substrate was Assumed Medium Sand)

Matrix of Suitability by Cross-Section Interval

Species/Life Stage Criteria 1				
Interval	Depth	Benthic Velocity	Substrate	Suitable
1	1	1	1	YES
2	1	1	1	YES
3	1	1	1	YES
4	1	1	1	YES
5	1	1	1	YES
6	1	1	1	YES
7	1	1	1	YES
8	1	1	1	YES
9	1	1	1	YES
10	1	1	1	YES
11	1	1	1	YES
12	1	0	1	NO
13	1	0	1	NO
14	1	0	1	NO
15	1	0	1	NO
16	1	0	1	NO
17	1	0	1	NO
18	1	0	1	NO
19	1	1	1	YES
20	1	1	1	YES

Calculated Cross-Section Suitability

13/20 Intervals Suitable = 65% of Cross-Section for <u>this</u> Species/Life Stage

Calculated Suitability for All Species/Life Stages

Transect	94.874	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	65.00%	100.00%

Calculated Suitability for All Modeling Scenarios

Transect	94.874	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	65.00%	100.00%
15,178	Low	45.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		13.64%	100.00%

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Qualitative Categorization

- None (No effect) – 0%
- Minimal – up to 10%
- Low – 10-20%
- Moderate – 20-40%
- Moderate-High – 40-60%
- High – 60-80%
- Severe – 80-100%

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

100 – 81.25 = 18.75% Lower Habitat Due to Increased Flow from 1,633 to 15,178:
"Low" Operational Effect on Criteria 1

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

93.75 – 81.25 = 12.5% Lower Habitat Due to Decreased Backwater during 15,178 cfs
"Low" Backwater Effect on Criteria 1

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

100 – 18.75 = 81.25% Lower Habitat Due to Mean April River Flow:
"Severe" High River Flow Effect on Criteria 1

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

No Operational or Backwater Effects on Criteria 2

Moderate High River Flow Effect on Criteria 2

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Modeling Results

- High suitability for most model runs
- Criteria 1 more sensitive to increases in flow
- Limited effects of backwatering
- Mean April Flows (High River Flow) most limiting
- No longitudinal pattern

Transect	88.5988	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	90.91%	100.00%
1,633	High	90.91%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.18%	100.00%

Transect	89.5413	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	95.45%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		31.82%	100.00%

Transect	90.653	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	90.48%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		4.76%	52.38%

Transect	91.8435	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	95.00%	100.00%
38,600		85.71%	100.00%

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

Transect	92.69	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		19.05%	100.00%

Transect	92.9704	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	95.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	89.47%	100.00%
38,600		31.82%	100.00%

Transect	94.298	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	93.75%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		39.13%	73.91%

Transect	94.874	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	65.00%	100.00%
15,178	Low	45.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		13.64%	100.00%

Transect	96.347	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	52.94%	100.00%
15,178	Low	52.94%	100.00%
1,633	High	84.62%	100.00%
1,633	Low	90.91%	100.00%
38,600		35.00%	60.00%

Transect	96.461	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	36.36%	63.64%
15,178	Low	40.00%	60.00%
1,633	High	100.00%	100.00%
1,633	Low	71.43%	100.00%
38,600		40.91%	72.73%

Transect	96.837	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		52.17%	86.96%

Transect	100.169	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	95.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		27.27%	81.82%

Transect	100.917	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	95.00%	100.00%
38,600		18.18%	100.00%

Transect	106.344	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	9.09%	100.00%
15,178	Low	9.09%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	73.68%	100.00%
38,600		9.09%	9.09%

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Yellow Lampmussel Abundance	Number of Transects	Criteria 1 (Includes Yellow Lampmussel Juveniles)		Criteria 2 (Includes Yellow Lampmussel Adults)	
		Operational Effect Range	High River Flow Effect Range	Operational Effect Range	High River Flow Effect Range
Absent (n = 0)	4	Minimal - Severe[1]	High - Severe	None	None - Severe[2]
Low (n = 1-4)	1	Minimal	High	None	Moderate
Medium (n = 5-50)	4	None - Moderate/High	Moderate/High - Severe	None - Moderate/High	None - Moderate/High
Medium-High*	3	Minimal - Low	Low - Severe	None	None - Moderate
High (n > 50)	3	None - Minimal	High - Severe	None	None - Moderate/High

*Medium-High was included for transects where values from 2009/2013 varied between medium and high

[1]Only one Severe value, the remaining three were Minimal

[2]Only one Severe value, the remaining three were None/Low

Abundance and presence/absence of Yellow Lampmussel was not correlated to the effects on suitability from the models

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Conclusions

- Flow conditions within operational parameters at Turners Falls Dam do not appear to be correlated with State-Listed mussel presence/absence or abundance
  - Mussels absent from seemingly suitable areas under a variety of flows
  - Mussels present in areas where typical spring (April) river flows can result in low suitability
- Other factors independent of operations at Turners Falls Dam are likely the primary driver of State-Listed mussel distribution in Reach 5. Potential other factors include:
  - Dispersal and successful colonization
  - Shear Stress during high flow events (scouring of habitat and displacement of mussels)
  - Distribution of suitable substrate

3.3.2- Upstream/Downstream Passage of Adult American Shad

Study Objectives

Our analysis methods were designed to assess each objective using appropriate statistical methods that return an estimate of the parameter of interest (e.g. proportion of successful passage) while also providing an estimate of precision with 95% confidence intervals.

- Describe the effectiveness of the **Cabot fish ladder**;
- Evaluate attraction, entrance efficiency and internal efficiency of the **Gatehouse ladder**;
- Identify **migration delays** resulting from operation of the Turners Falls Project;
- Determine **route selection** and behavior of upstream migrating shad at the Turners Falls Project under **various spill** flow levels;
- Evaluate attraction, entrance efficiency and internal efficiency of the **Spillway ladder** for shad reaching the dam spillway, under a range of spill conditions;
- Evaluate **migration** through the Turners Falls Impoundment (**TFI**);
- Identify **impacts of** Northfield Mountain, Cabot Station and Station No. 1 **operations** on upstream and downstream adult shad migration, including delays, entrainment, behavioral changes and migration direction shifts.
- Estimate **downstream passage route selection**, timing/delay, and survival at Turners Falls Dam; and
- Estimate passage rates and routes taken by shad **migrating downstream through the canal**, and evaluate Cabot Station fish bypass effectiveness.

3.3.2- Upstream/Downstream Passage of Adult American Shad

Work Completed

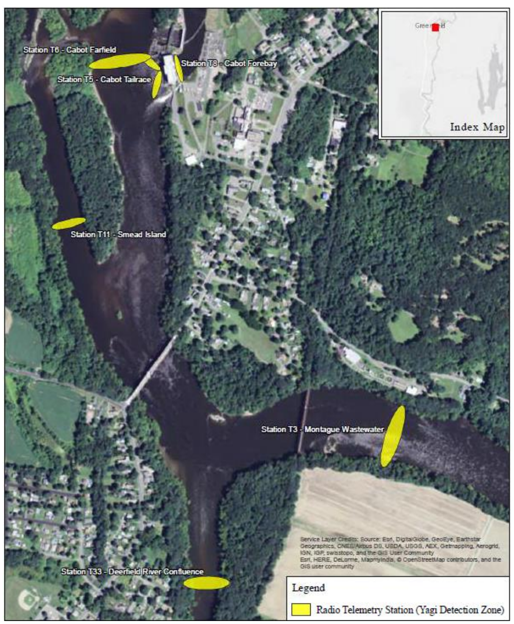
- Beginning in March 2015, FirstLight designed, installed and tested a fixed telemetry network (29 radio telemetry and 14 PIT) consisting of both passive and active radio telemetry monitoring equipment within the study area to answer specific questions related to the study objectives.
- Additional monitoring was conducted during mobile surveys throughout the entire study area, with the exception of the Power Canal and bypass reach to inform on migration and mortality events between fixed stations.
- A total of 33 mobile tracking surveys were conducted over 9 weeks between May 15, and July 7, 2015.

3.3.2- Upstream/Downstream Passage of Adult American Shad

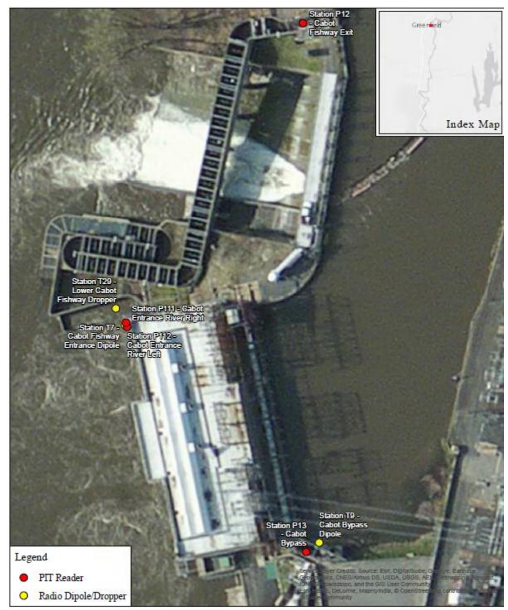
FirstLight
Power Resources

Red Cliff Canoe Club

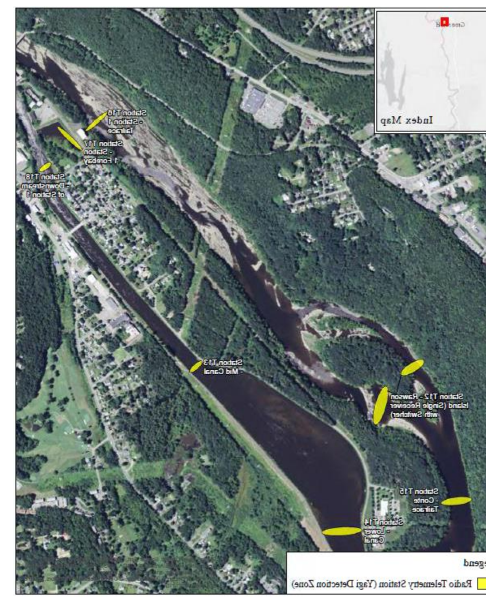
Sunderland Bridge



Montague Spoke

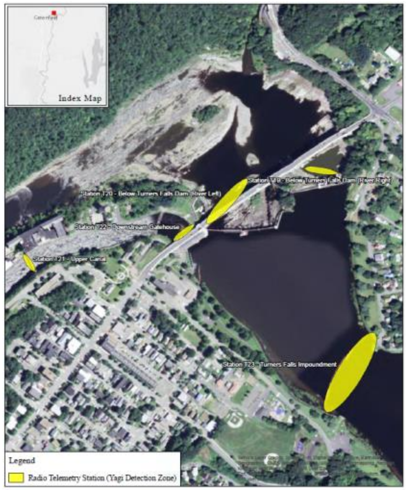


Cabot Ladder

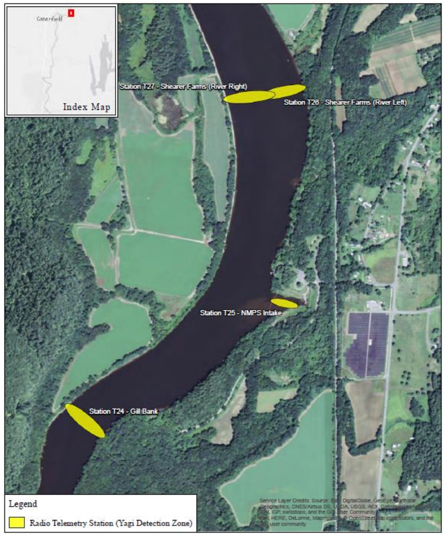


Bypass Reach

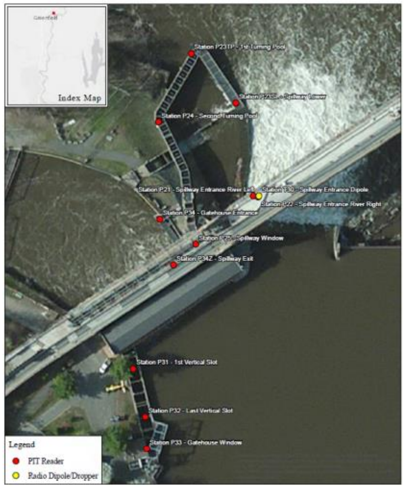
3.3.2- Upstream/Downstream Passage of Adult American Shad



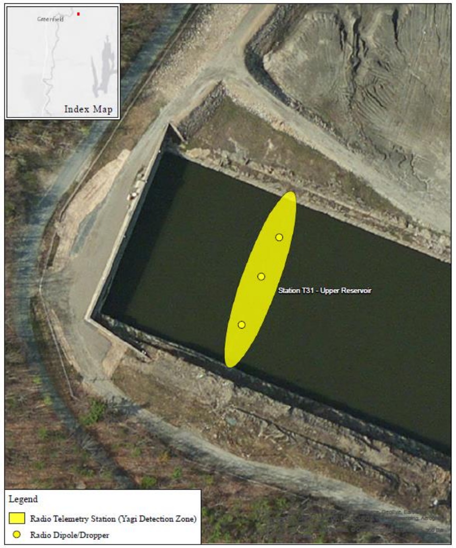
TFI



Northfield Area



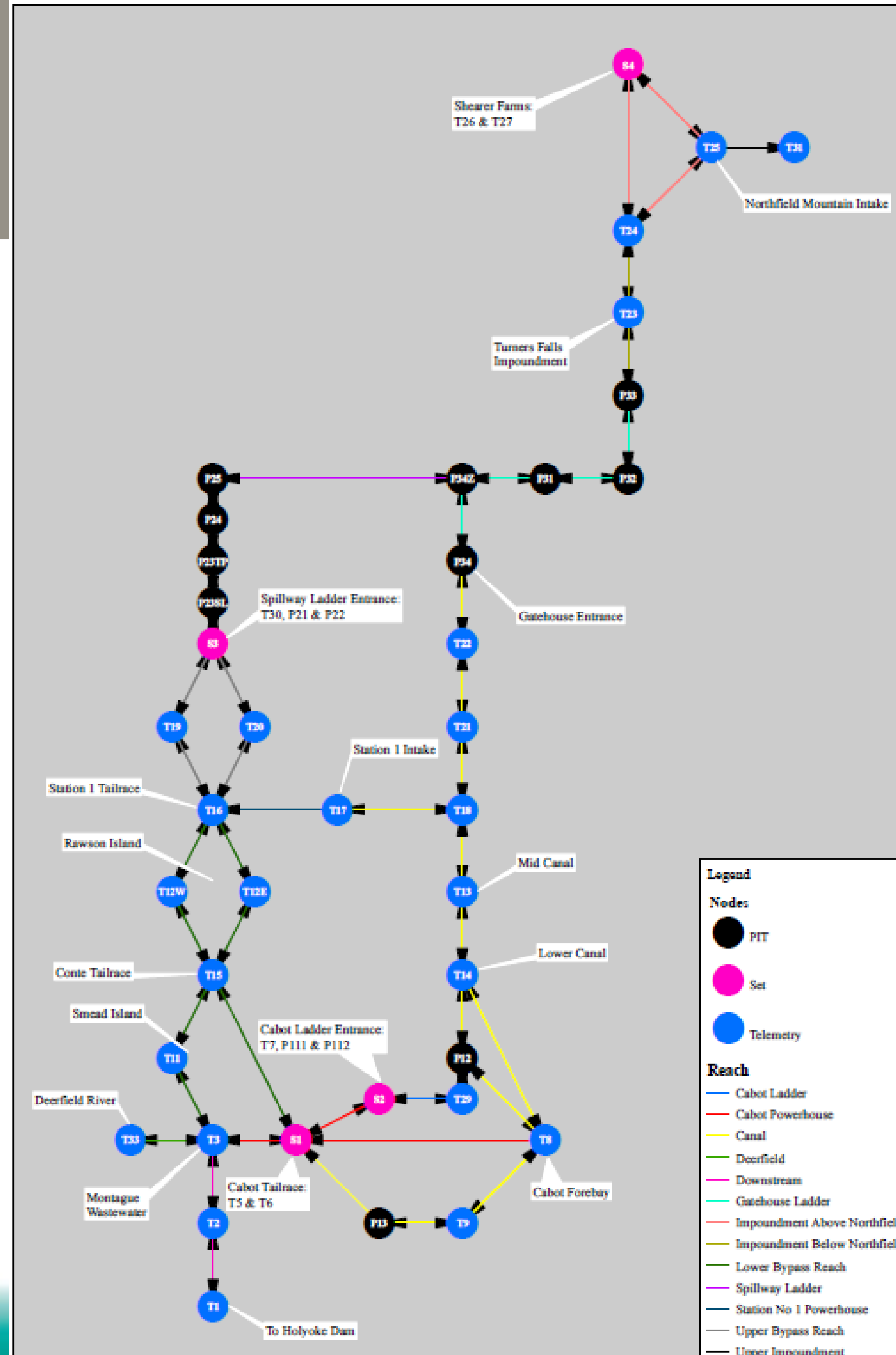
Spillway Ladder



Upper Reservoir

FirstLight™ Power Resources

Telemetry Network Model



3.3.2- Upstream/Downstream Passage of Adult American Shad

Tagging occurred over 12 days from the period beginning on May 6, and ending on June 8, 2015. Approximately half of the shad were tagged with radio and PIT tags (double tagged) (n=397) and half tagged with PIT only (n=396).

Fishway Passage Peak

- Cabot – 5,066 on 5/12/15
- Spillway – 4,414 on 5/13/15
- Gatehouse – 6,395 on 5/13/15
- Holyoke - ~42,000 on 5/10/15
- Vernon - ~4,013 on 5/18/2015.

Table 4.2-1. FirstLight shad collection, tagging and release summary.

Date of Collection/Release	Collection Location	Release Location	Number of Double Tagged Shad	Number of PIT only Shad	Total Tagged and Released
5/6/15	Holyoke	Holyoke	72	1	73
5/7/15	Holyoke	Holyoke	0	72	72
5/12/15	Holyoke	Holyoke	48	1	49
5/13/15	Holyoke	Holyoke	0	47	47
	Cabot	Canal	25	25	50
5/15/15	Holyoke	TFI	33	29	62
5/16/15	Cabot	TFI	33	33	66
5/18/15	Cabot	Canal	0	25	25
5/19/15	Holyoke	Holyoke	48	48	96
	Cabot	Canal	25	0	25
5/22/15	Holyoke	TFI	33	33	66
5/23/15	Cabot	TFI	33	33	66
5/26/15	Holyoke	Holyoke	24	24	48
6/8/15	Holyoke	Holyoke	23	25	48
Totals			**397**	**396**	**793**

3.3.2- Upstream/Downstream Passage of Adult American Shad

TransCanada collected, tagged and released 154 Shad over six days in May, 2015 beginning on the 10th and ending on the 30th.

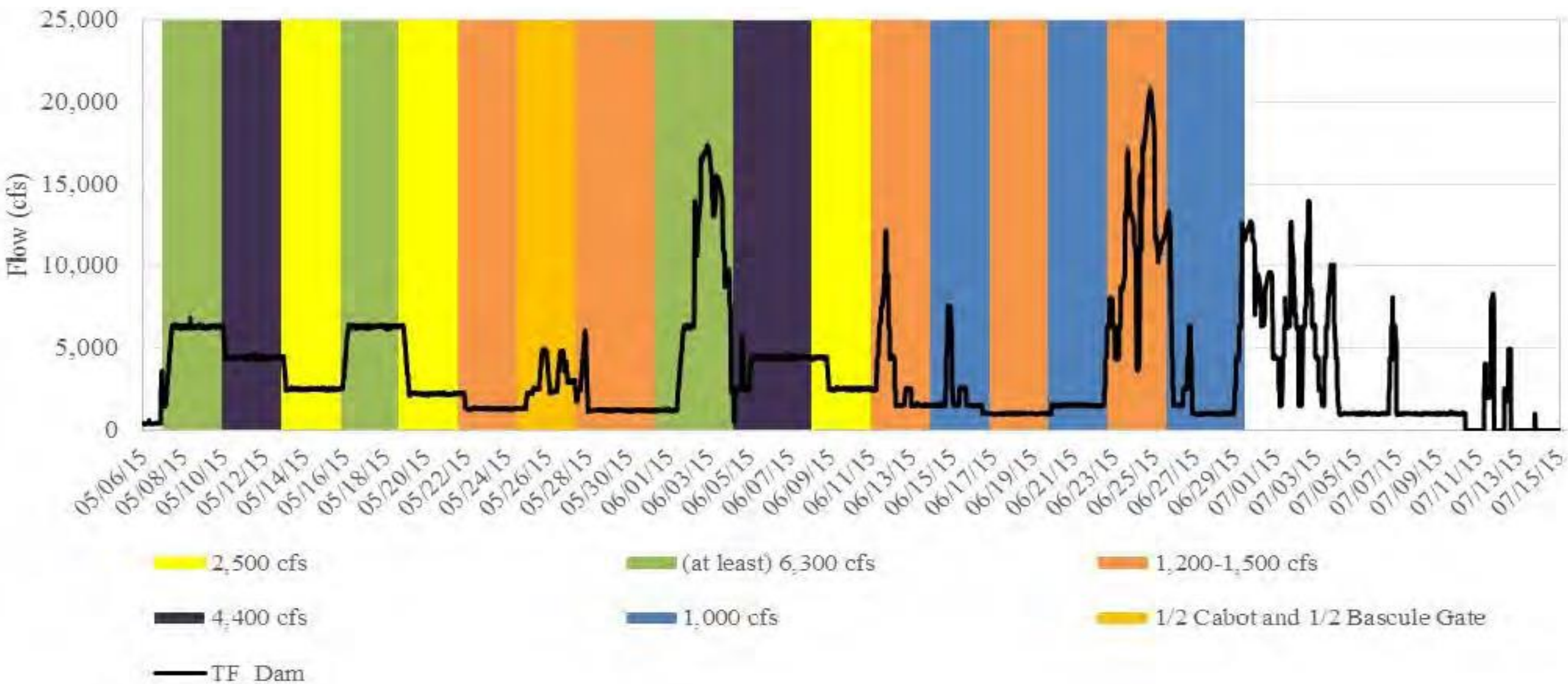
Table 4.2-2. Shad collection, tagging and release by TransCanada.

Date of Collection/ Release	Collection Location	Release Location	Number of Double Tagged Shad	Number of Radio Only Tagged Shad	Number of PIT only Shad	Total Tagged and Released
5/10/15	Holyoke	Pauchaug Brook Boat Launch	20	0	20	40
5/14/15	Holyoke	Pauchaug Brook Boat Launch	20	0	20	40
5/17/15	Vernon	Old Ferry Boat Ramp Brattleboro, VT	0	20	0	20
5/24/15	Vernon	Old Ferry Boat Ramp Brattleboro, VT	0	23	0	23
5/28/15	Holyoke	Pauchaug Brook Boat Launch	12	0	8	20
5/30/15	Vernon	Old Ferry Boat Ramp Brattleboro, VT	0	11	0	11
Totals			**52**	**54**	**48**	**154**

3.3.2- Upstream/Downstream Passage of Adult American Shad

- Relevant operations and environmental data were collected including river flow, generation (MW), water temperature and dissolved oxygen. These parameters were monitored continuously at fifteen-minute intervals throughout the study period.

- A series of test flows were released in the Turners Falls bypass reach during this study to investigate how bypass flows may affect shad migration into and through the bypass reach.
    - Flows ranged between 1,000 and 6,300 cfs



3.3.2- Upstream/Downstream Passage of Adult American Shad

Methods

- 5 main statistical procedures on top of basic ratios were used to understand adult American Shad migration.

- Hot spot analyses identified spatial clusters in mobile tracking data
  - Where did most of the fish turn around and where did they die?

- Multi-state Markov models (MSM) identified routes of passage, attraction towards receivers, and enumerated the expected number of visits (forays) to receivers of interest
  - Our understanding of movement is limited to the joint probability of an animal surviving, transitioning from and being detected at the next receiver
  - Further, it is the probability of movement between locations for each foray, not the overall probability of movement between two locations. If the number of forays are small than this probability is very close to the overall probability of movement.
  - MSM is descriptive of the study results, but it provides us with confidence intervals

- Cox proportional hazards (CoxPH) assessed the delay incurred by changing operations
  - Do fish take longer to migrate through a stretch of the project if flows increase?

- Cormack-Jolly-Seber (CJS) open population mark recapture model assessed the internal and overall efficiencies of the Project’s ladders and provided <u>unbiased</u> efficiencies with respect to receiver detection.

- Catch curve analysis developed rates of mortality by day and by river mile.

3.3.2- Upstream/Downstream Passage of Adult American Shad

Analysis Matrix

Our analysis took a geographic approach and followed shad as they passed Holyoke, migrated up to the Deerfield confluence, navigated through the maze of choices at the Project, arrived in the TF impoundment, and how they reacted to NMPS and turned back downstream after spawning. On their return approach, we follow fish as they make an emigration route choice at TF, navigate their way through the canal and to their eventual downstream passage at Cabot Station.

(Table 3.2.1-2)

Subnetwork Model	Analysis Objective	Analytical Method
Holyoke to Project	To understand bi-directional movement and residence time within the downstream portion of the project from the Holyoke Dam upstream to Montague Wastewater.	• MSM • CoxPH
Montague Spoke	To understand route selection as shad migrate upstream from the Montague area to the Cabot tailwater area and how discharge effects route selection and time-to-event.	• MSM

3.3.2- Upstream/Downstream Passage of Adult American Shad

Analysis Matrix cont'd

Subnetwork Model	Analysis Objective	Analytical Method
Cabot Ladder Attraction	To understand attraction and delay to the Cabot Ladder under varying bypass flows with competing routes to the lower bypass reach and downstream locations.	• MSM • CoxPH
Cabot Ladder Internal Efficiency and Delay	To understand the internal efficiency of the ladder and ladder entrance.	• CJS • CoxPH
Rawson Island	To understand passage around and delay at Rawson Island and Station No. 1 under varying bypass flows.	• MSM
Spillway Ladder Attraction	To understand attraction to the spillway ladder and delay under varying bypass flows.	• MSM • CoxPH
Spillway Ladder Internal Efficiency	To understand the internal efficiency of the ladder.	• CJS
Spillway Ladder Passage and Delay	To understand overall ladder passage efficiency and delay.	• MSM • CoxPH

3.3.2- Upstream/Downstream Passage of Adult American Shad

Analysis Matrix cont'd

Subnetwork Model	Analysis Objective	Analytical Method
Cabot Forebay and Downstream bypass	To understand migration delay in the Cabot forebay area and the risk of entrainment.	• MSM • CoxPH
Power Canal	To understand migration routes and delay within the canal and the risk of entrainment at Station No. 1. Separate models created for migration and emigration	• MSM • CoxPH
Gatehouse Internal Efficiency	To understand the internal efficiency of the ladder.	• CJS
Gatehouse Ladder Passage and Delay	To understand overall ladder passage efficiency and delay.	• MSM • CoxPH
TF Impoundment	To understand migration and delay in the TFI and investigate the risk of entrainment at the NMPS intake.	• MSM • CoxPH
TF Dam Spoke	To understand route selection during emigration.	• MSM

3.3.2- Upstream/Downstream Passage of Adult American Shad

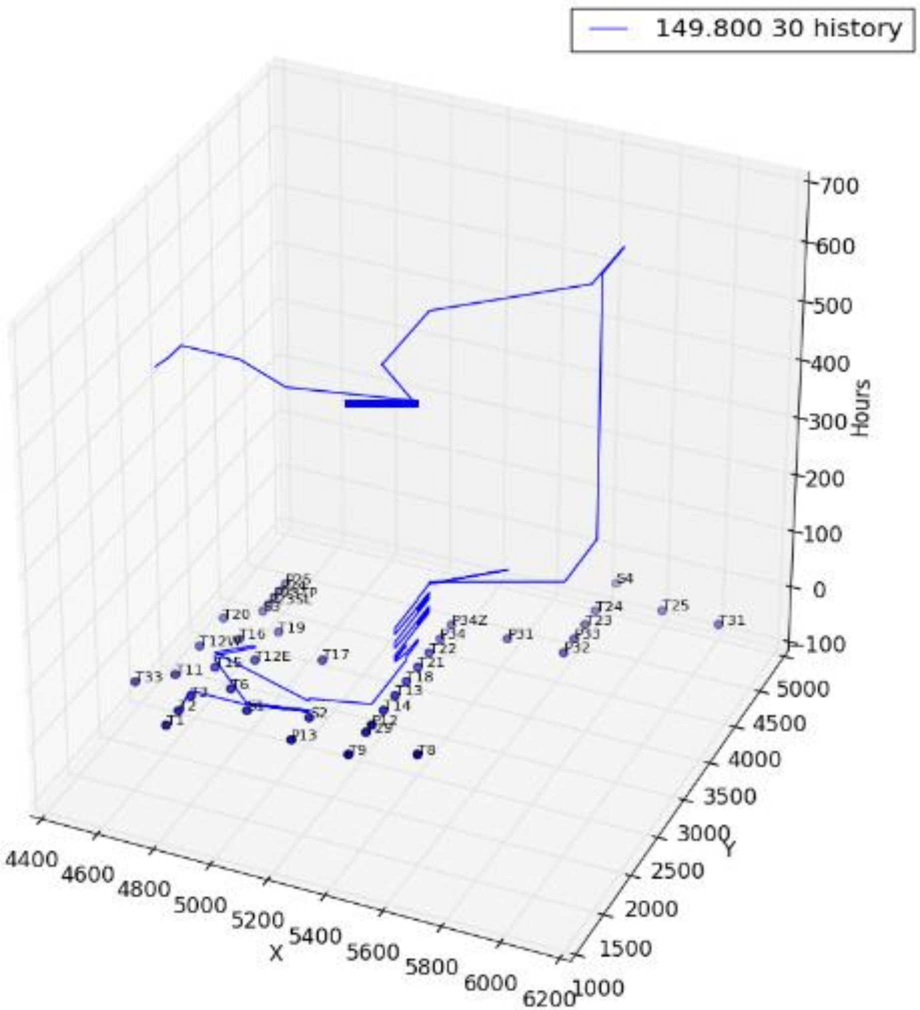
Work Completed

- Study work conducted in spring/summer 2015

- 3 Step data reduction & false positive removal – fall 2015 through spring 2016
  1. Naïve Bayes classifier algorithm
  2. SQL data reduction (MS Access)
  3. Visual Inspection

- Data dissemination meeting held in July 2016 for interested parties

- Record Stats:
  - 1034 tagged fish in river during spring 2015
  - Initial record length: 19,177,280
  - Reduced record length : 16,784,468



3.3.2- Upstream/Downstream Passage of Adult American Shad

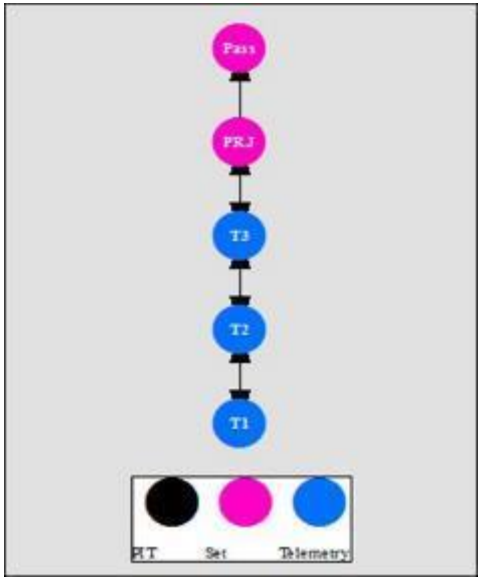
<u>Conclusions</u>
Holyoke to Montague

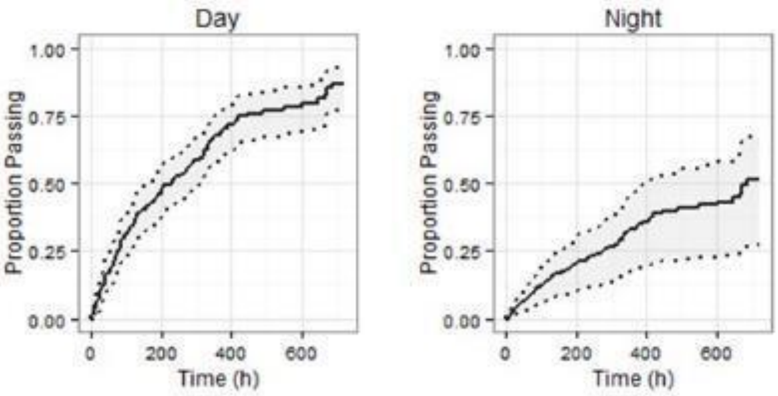
- Released 215 dual tagged shad at Holyoke

- Detection histories from 164 adult shad used in MSM analysis, 162 in CoxPH

- Once a fish reached Montague, the probability of a fish surviving, transitioning and being detected next at the "Project" site was 72% at 7,070 cfs. At 17,100 cfs this probability was 65%. Fish naturally move upstream through this reach seeking passage and or spawning (see Study No. 3.3.6), but seem to be affected by increasing flow.

- CoxPH found that animals marked experienced the event 2.8 times faster during the day than at night, we achieved 50% arrival at the project within 232 hours



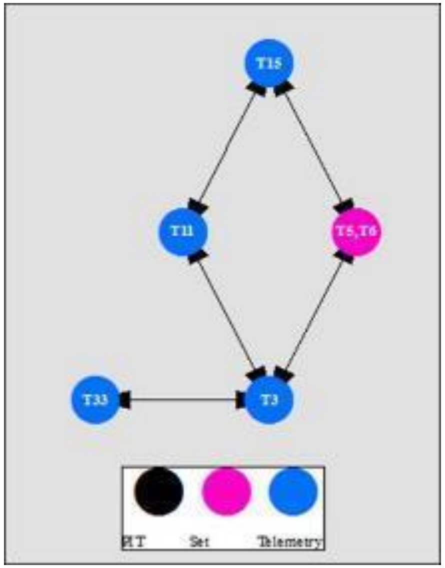


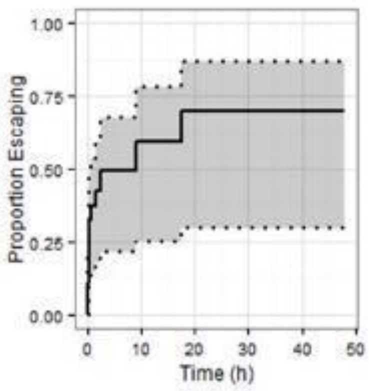
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Montague Spoke

- Released 215 dual tagged shad at Holyoke
- Detection histories from 105 adult shad used in MSM analysis
- Probability that a fish will survive, transition from Montague and be detected next within Cabot Tailrace decreased from 74% to 44% as flow increases from 2,327 cfs at Cabot and 2,500 cfs Bypass to 11,375 cfs Cabot and 5,275 cfs Bypass
- Probability that a fish survives, transitions from Montague and is detected next at the West Channel of Smead Isl. Increases from 7% at low flow to 26% at high flow.



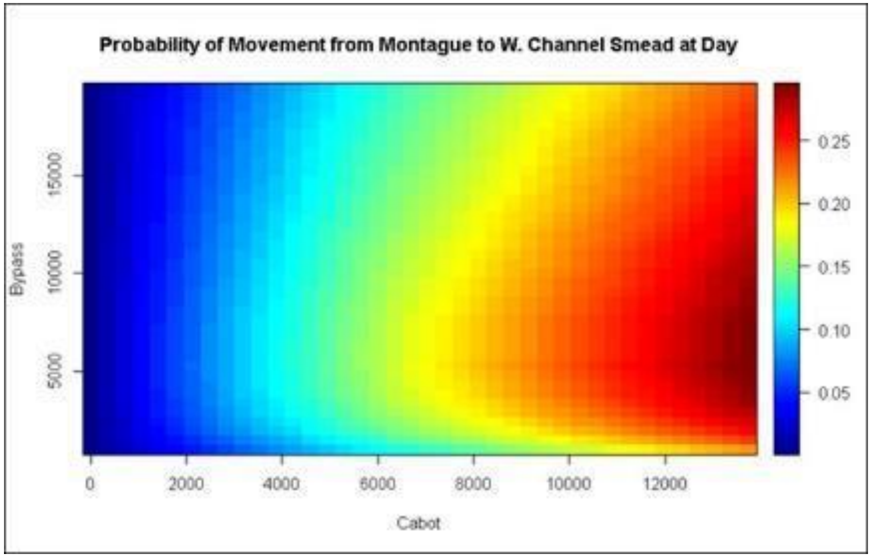


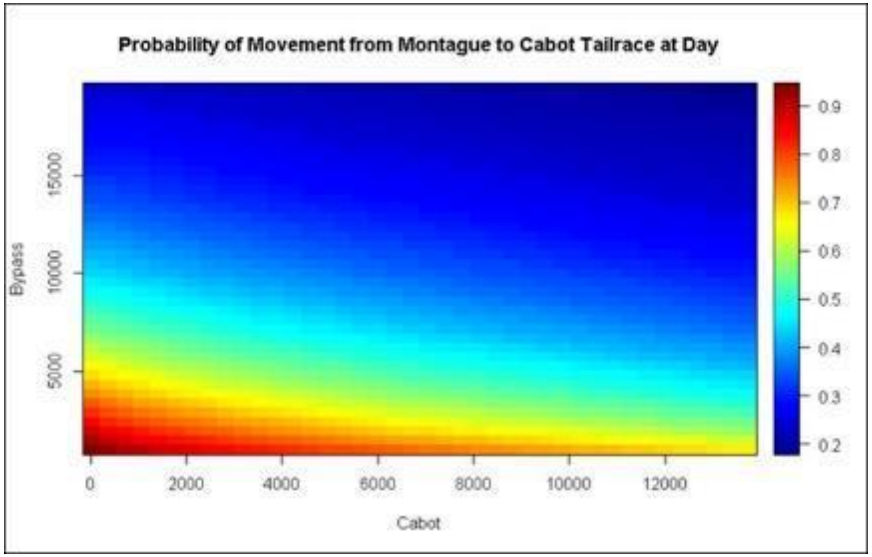
Kaplan Meier curve of time to escape the Deerfield River

3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Montague Spoke cont'd



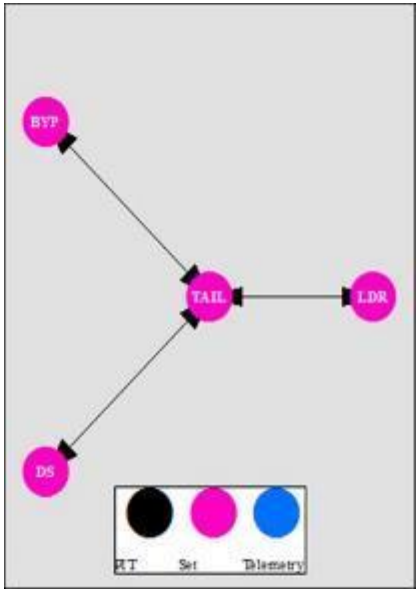


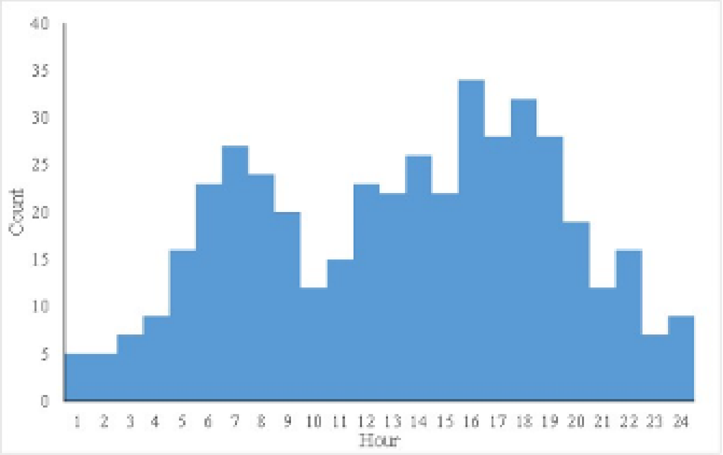
3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>

Cabot Ladder Attraction

- Released 215 dual tagged shad at Holyoke
- Detection histories from 107 adult shad used in MSM analysis
- State table counts 137 forays into Cabot Ladder with 120 of those coming from the tailrace
- Highest probability (60%) of a fish surviving, transitioning from the tailrace and being detected next at the ladder was when Cabot discharge high and bypass flow low (11,380 and 2,500 respectively)
- Best CoxPH model incorporated bypass flow and diurnal cues
  - Fish are 10.9 x more likely to experience event during the day, however as bypass flow increases by 1000 cfs, 0.7 times less likely to experience the event



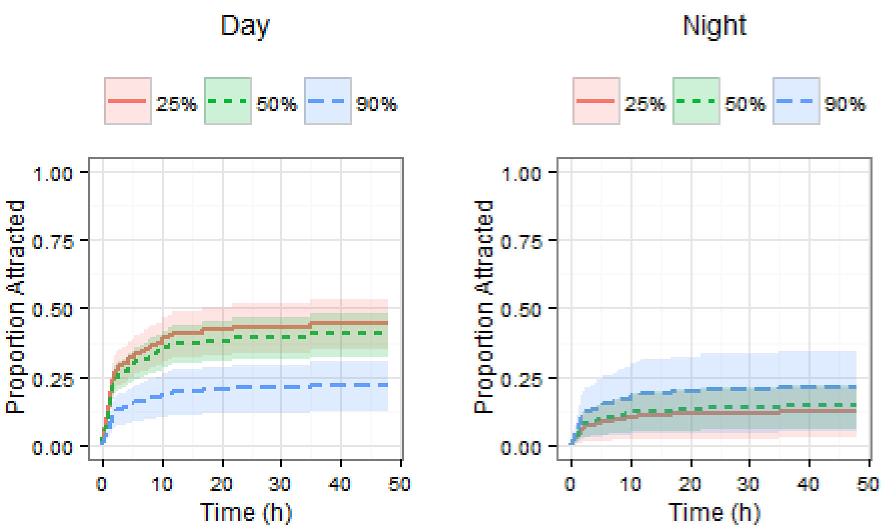


3.3.2- Upstream/Downstream Passage of Adult American Shad

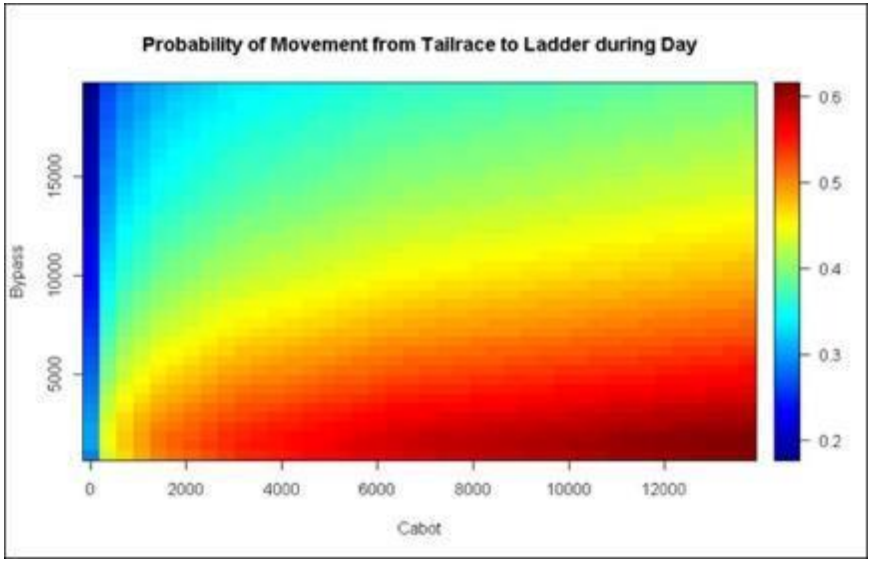
Conclusions

Cabot Ladder Attraction cont'd

- Time-to-first foray found that 50% completed their first foray in only 7.55 hours from Montague



Time-to-Cabot Ladder Attraction from tailrace. Note, fish incur delay as flow is increased



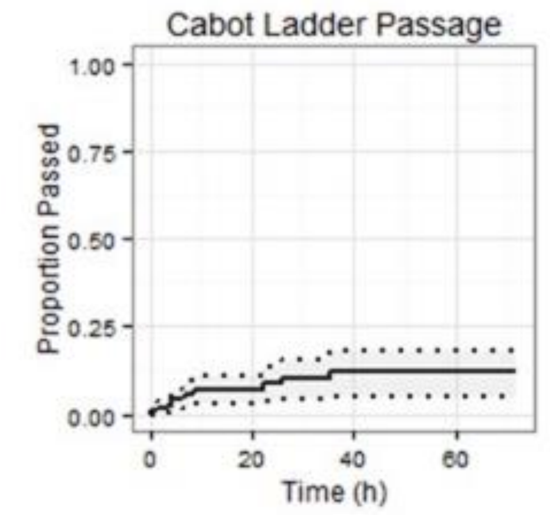
Probability of movement from tailrace to ladder during day and under various bypass flow and Cabot discharge. Note that the probability of movement is greater the higher the flow, however we see with time-to-event that as flows increase so does time to Cabot Ladder entrance.

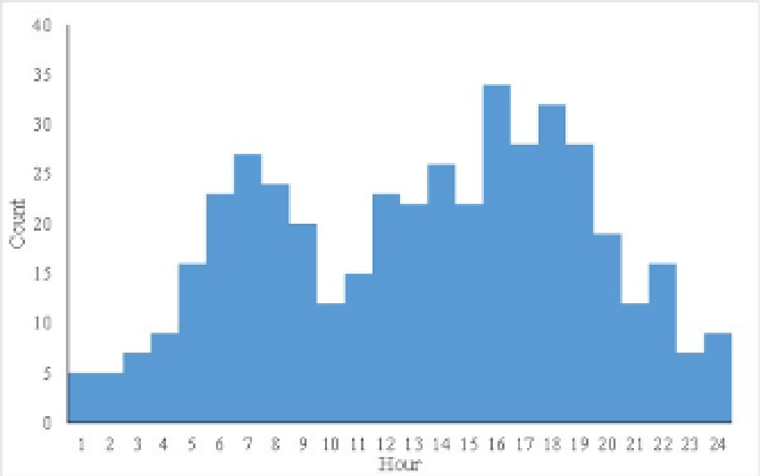
3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>

Cabot Ladder Efficiency

- Of the 103 dual and PIT tagged fish known to use the ladder, 16 made successful events
- Best CJS model fully time dependent
- Entrance efficiency: 68%
- Internal efficiency: 15.3%
- Overall: 10.2%
- Time-to-event analysis showed that all fish to pass did so within 40 hours



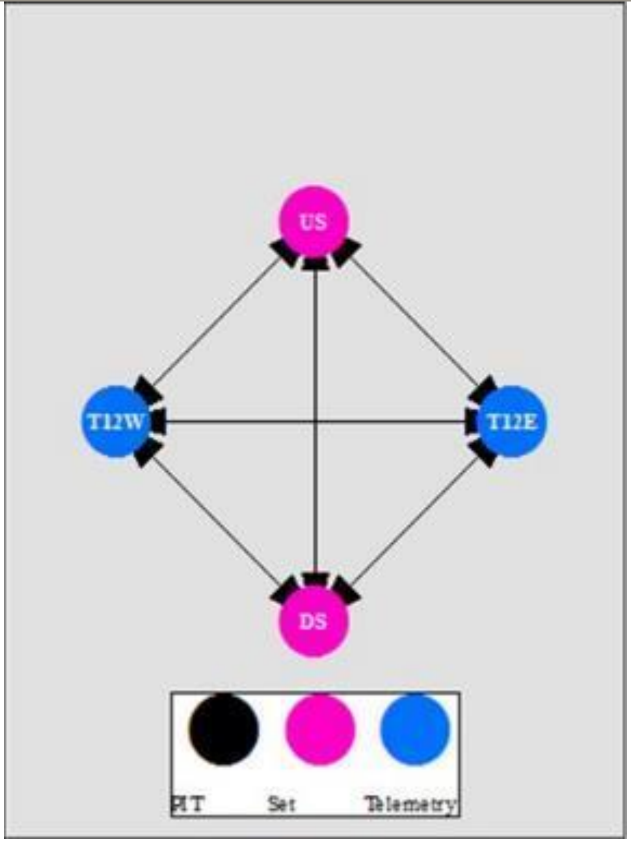


3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions
Bypass Reach

- Rawson Island MSM model incorporated recaptures from 95 dual tagged fish released at Holyoke
- The eastern channel (rock dam) appears to be a natural migratory barrier with little upstream passage success (i.e. probability that a fish will survive, transition from rock dam and be detected next within the spillway) is only 2%
  - State table only shows 1 successful transition

	To			
From	Downstream	T12W	T12E	Upstream
Downstream	2,160	21	22	17
T12W	16	57	23	9
T12E	19	24	240	1
Upstream	19	3	0	767



3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Spillway Ladder Attraction

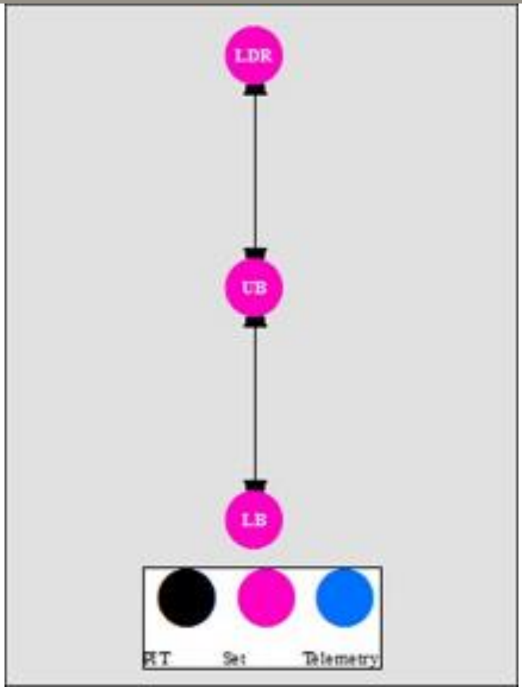
- MSM model incorporated 57 dual tagged fish released at Holyoke known to be within the upper bypass reach

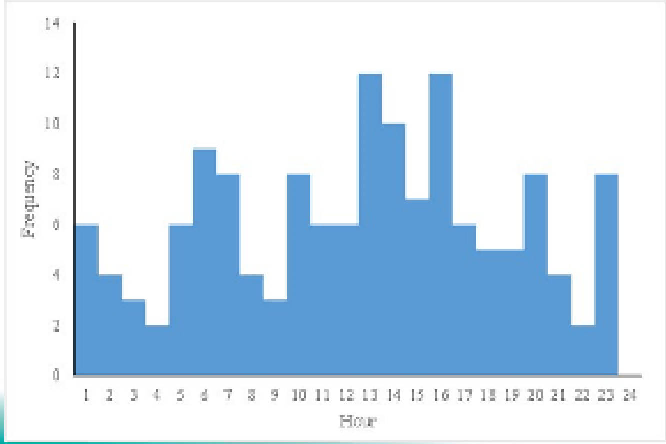
- Probability that a fish survives, transitions from the spillway and is detected next within the spillway ladder is 65% at low flow (2,569 cfs) and drops to 41% at high flow (6,226 cfs)

- Forays (msm: envisits) decrease from 3.47 at low flow to 2.47 at high flow

- Time to first foray – 50% experienced event after migrating from Montague within 94.4 hours.

- Time to attraction from spillway:
  - 7.3 x more likely to enter spillway ladder during day than at night

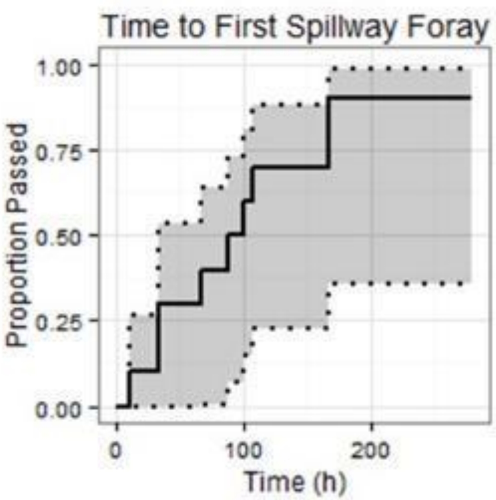




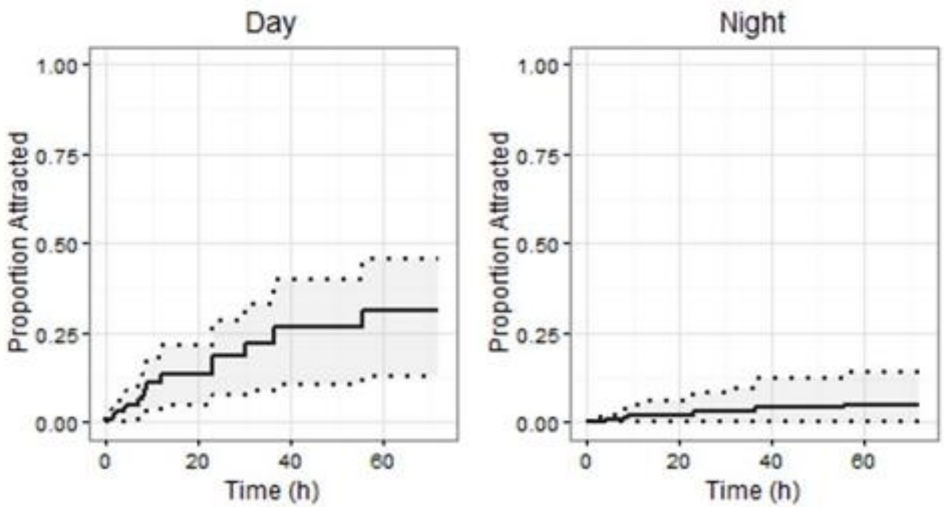
3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>

Spillway Ladder Attraction cont'd



Time-to-first foray
Montague -> Spillway

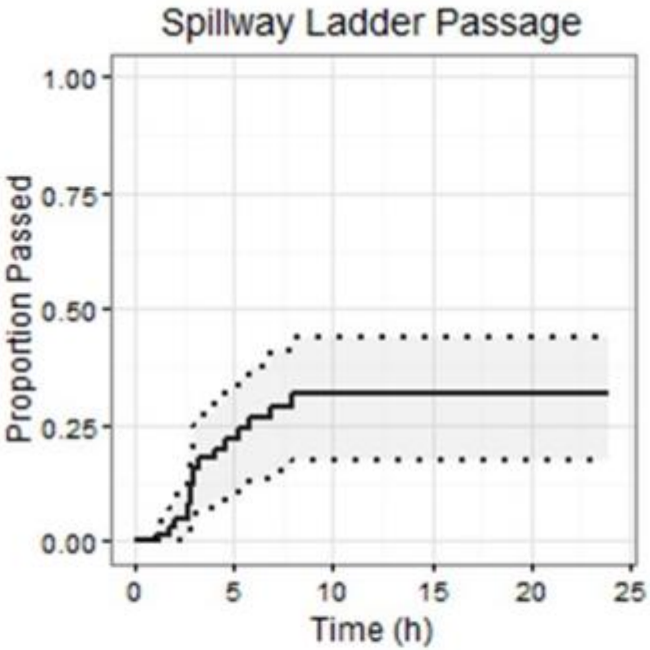


Time to spillway ladder attraction – spillway - > ladder

3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>
Spillway Ladder Efficiency

- Best CJS model was fully time dependent
- Spillway entrance efficiency was 91.5%
- Overall ladder efficiency was 32.7%
- Time-to-event:
  - Of the 35 dual and PIT tagged only fish released at Holyoke that attempted Spillway Ladder, 16 successful attempts out of 87 tries
  - Fish take between 1.1 and 7.9 hours to pass spillway ladder .



3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Overall

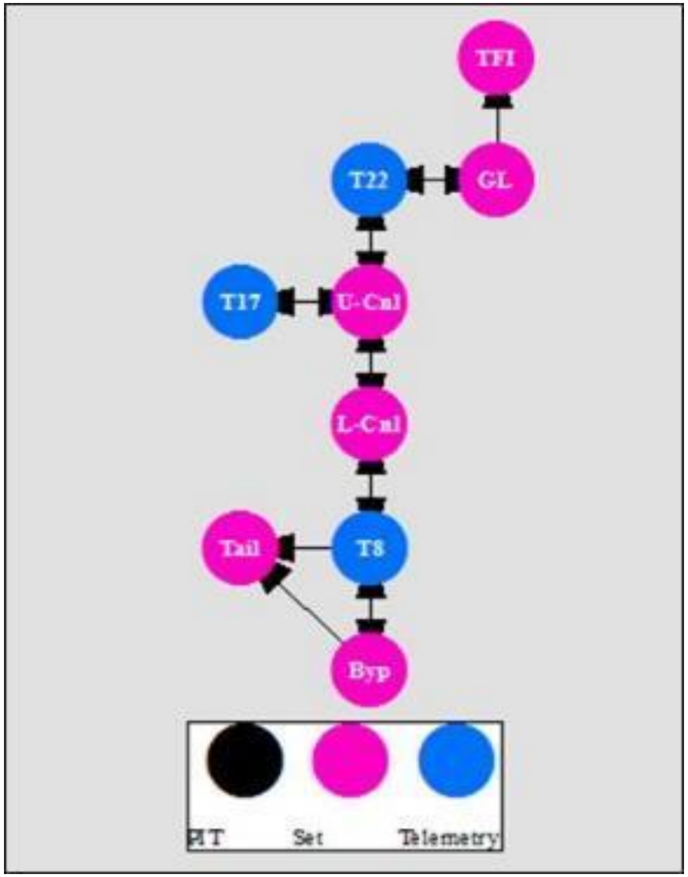
- Of 50 canal released fish, all were recaptured in Forebay, 9 within the Gatehouse Ladder and 7 within TFI Impoundment

Upstream Migration Through Canal (MSM)

- MSM and CoxPH incorporated recaptures from the 60 dual tagged fish released into the canal or at Holyoke that passed Cabot Ladder

- State table indicates considerable milling forebay (T8) and downstream bypass (T9, P13)
  - 866 transitions from forebay to bypass
  - 813 transitions from bypass back to forebay

- Probability that a fish survives, transitions from the Gatehouse Yagi (T22) and into Gatehouse Ladder increases with increasing canal flow from 11% (25th: 3,340 cfs) to 15% (75th:12,016 cfs)



3.3.2- Upstream/Downstream Passage of Adult American Shad

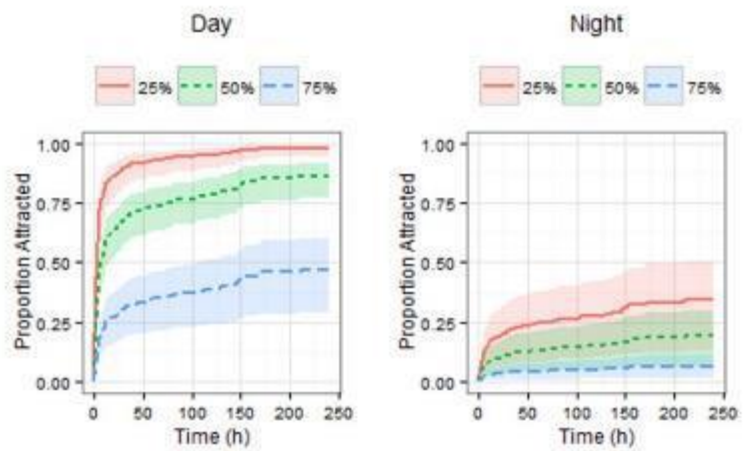
Conclusions

Upstream Migration Through Canal (CoxPH)

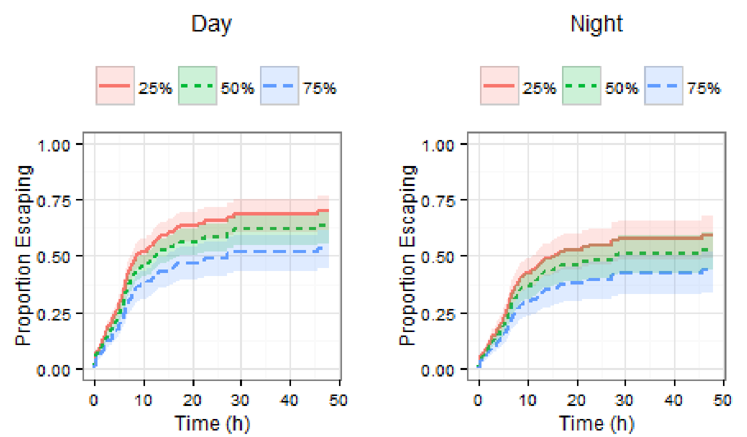
- Time-to-upper canal (first recapture to Gatehouse Yagi (T22)
  - 60 fish, 122 successful forays
  - As flows increase the rate at which fish experience the event decreases

- Time-to-escape Station No. 1 Forebay
  - 6 fish made 7 successful attempts
  - Fish attracted to forebay leave within 15 hours

- Time-to-escape Cabot Forebay
  - As flows increase, the rate at which fish experience the event decreases
    - 50% escape within 8.84 hours at 25th
    - 50% escape within 27.2 hours at 75th



Time to overall upstream canal passage under different flow regimes.



Time to escape Cabot Forebay under different flow regimes.

3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Gatehouse Ladder Efficiency

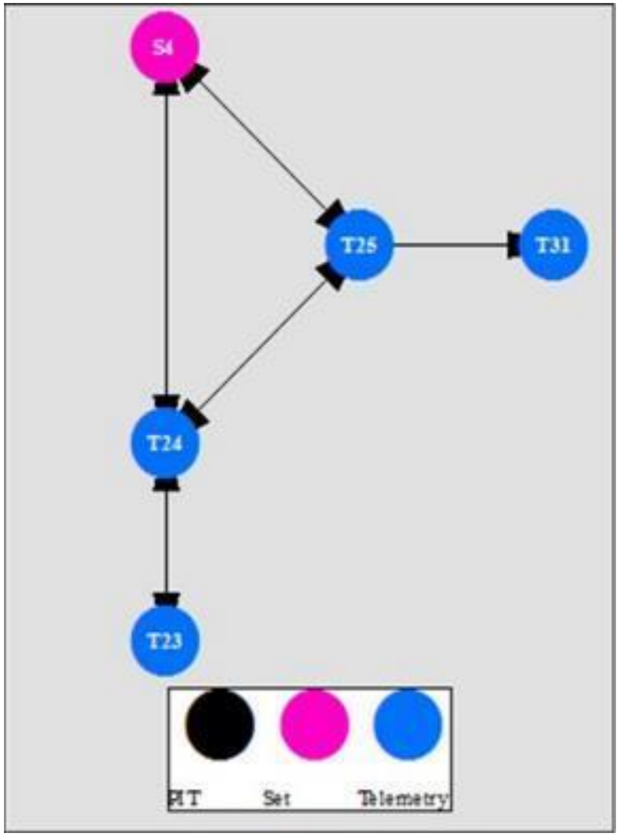
- Overall the entrance efficiency was high passing 84.8% of the fish that attempt the ladder, however there was evidence of milling between the gatehouse yagi (T22) and the ladder because only 11 – 15% of the individual forays from T22 are successful– meaning that a fish must make more than 1 transition from T22
- Internal efficiency was very high 91%
- Overall efficiency: 76.9%
- Time-to-Gatehouse Ladder passage not computed considering issues at P34Z – we never have a start time

3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Upstream directed impoundment migration

- We only received a list of fish making it to Vernon and not time of arrival or exit, therefore we could not include time-to-Vernon in our assessments
- No fish detected in upper reservoir
- MSM model incorporated 204 dual tagged fish from the Impoundment release, Cabot release, Holyoke release and those fish released at TC
- Pumping:
  - Fish downstream of intake have 60% chance of transitioning to Shearer Farms next at - 3,346 cfs to 53% at (- 9,887 cfs) –
  - Probability of fish transitioning into the intake as pumping rates increase: -3,346 cfs = 9%, -9,887 cfs = 33%
- Idle:
  - fish downstream of the intake (T24) had a 68% chance of transitioning to Shearer Farm and a 24% chance of transitioning into the intake next
- Generation:
  - Fish downstream of intake had a 72% chance of transitioning to Shearer Farms and only 19% chance of transitioning towards the intake (25th discharge, 2,360 cfs) with little change through 75th discharge (5,301 cfs)



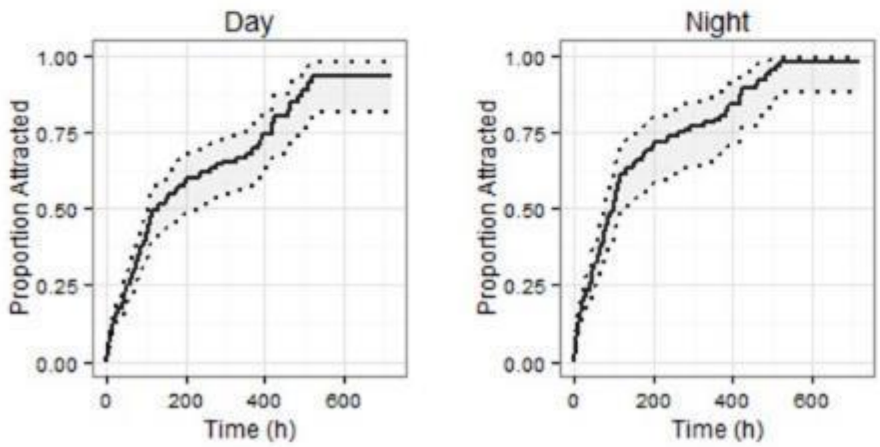
3.3.2- Upstream/Downstream Passage of Adult American Shad

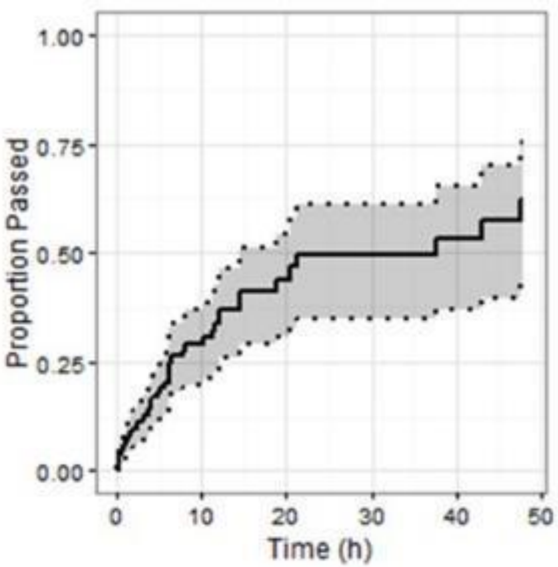
Conclusions

Upstream directed impoundment migration

- Time-to-escape NFM Intake
  - 32 fish made 52 successful escape attempts

- Time-to-Shearer Farms from d/s Intake
  - 142 fish made 228 attempts at Shearer Farms
  - Fish were 1.2 times more likely to experience event during day than at night



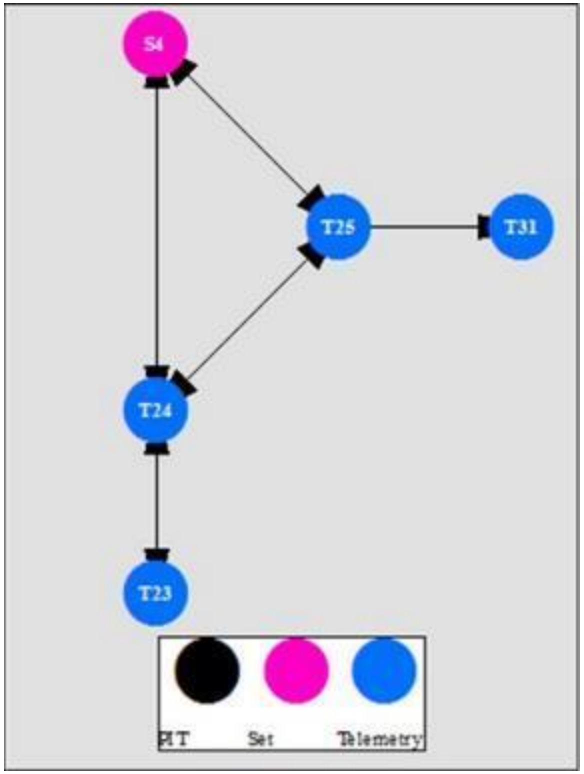


Time to escape NMPS intake

Conclusions

Downstream directed impoundment migration

- MSM model incorporated 204 dual tagged fish from the Impoundment release, Cabot release, Holyoke release and those fish released at TC
- Pumping:
  - Probability that fish transition from Shearer Farm to downstream of the Intake (T24) was 95% at -3,346 cfs and 69% at -9,887
  - Transition to intake increased from 5% to 30% over this range
- Idle:
  - Probability that fish transition downstream during day 88%
  - Transition to intake during day 12%
- Generation:
  - Probability that fish transition downstream increased from 93% to 97% (25th : 2,360 cfs to 75th: 5,301 cfs)
  - Transition to intake decreased from 7% to 3%



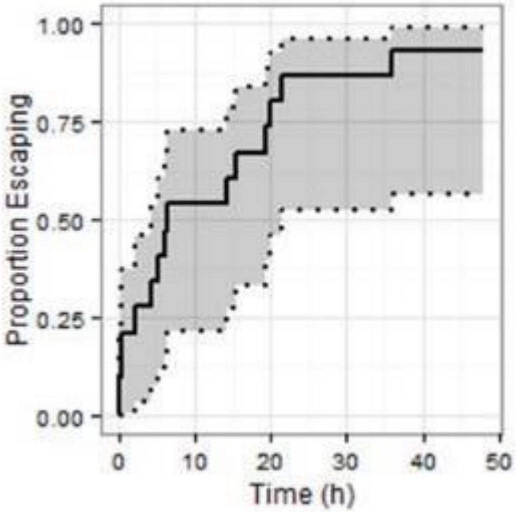
3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>

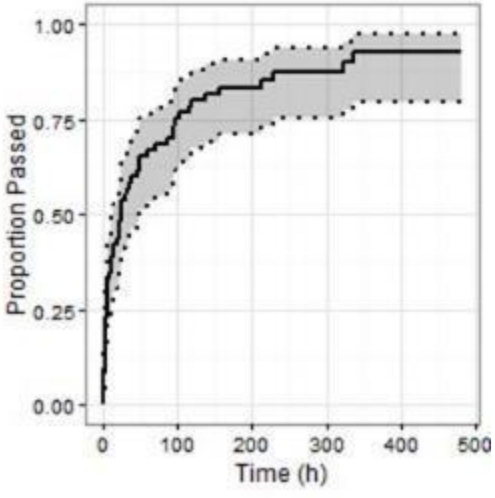
Downstream directed impoundment migration

- Time-to-escape NFM Intake
  - 10 fish made 15 successful events with 50% escaping within 6.42 hours and 75% escaping within 20 hours

- Time-to-downstream of the NFM intake from Shearer Farms
  - Downstream obligated (TC only fish)
  - 50% reach the lower TFI Impoundment (T23/T24) within 25 hours, 75% within 100 hours



Time to escape intake



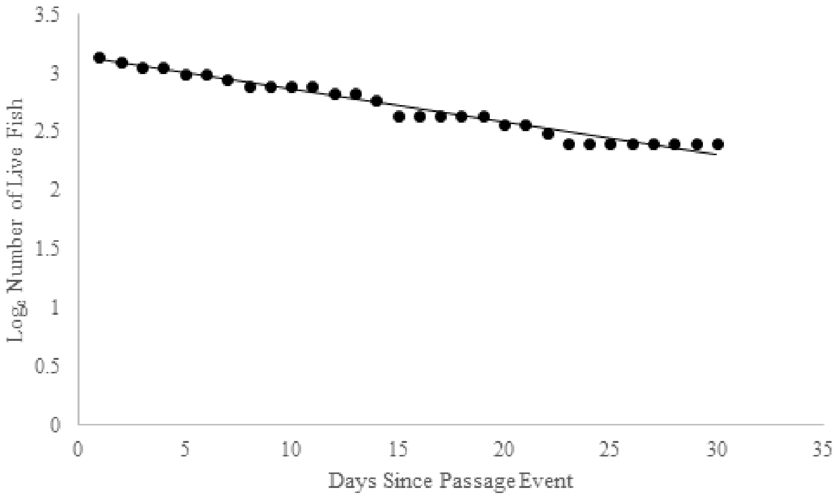
Time to migrate past intake

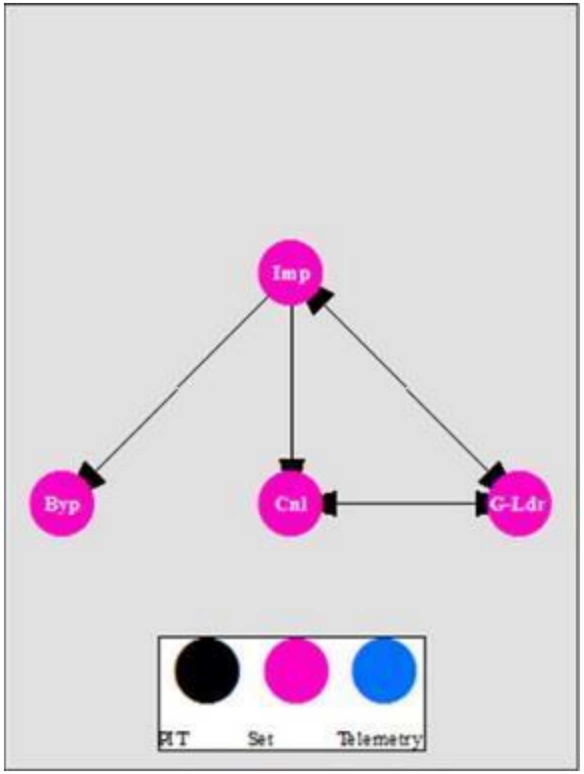
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Turners Falls Route Selection

- MSM incorporated recaptures from 165 fish
  - Probability that a fish will survive, transition from the TFI and be detected next within the bypass reach (aka spill) 26%, while 74% will transition into canal
- Catch curve mortality estimates were 3% per day
  - Fish that died after passing via spill travelled an average of 13 miles over an average of 21 days before mortality signals emitted from the tags were detected.
- Catch curve analysis for ‘natural mortality’ aka those fish that do not pass any structure found a 1% mortality per day



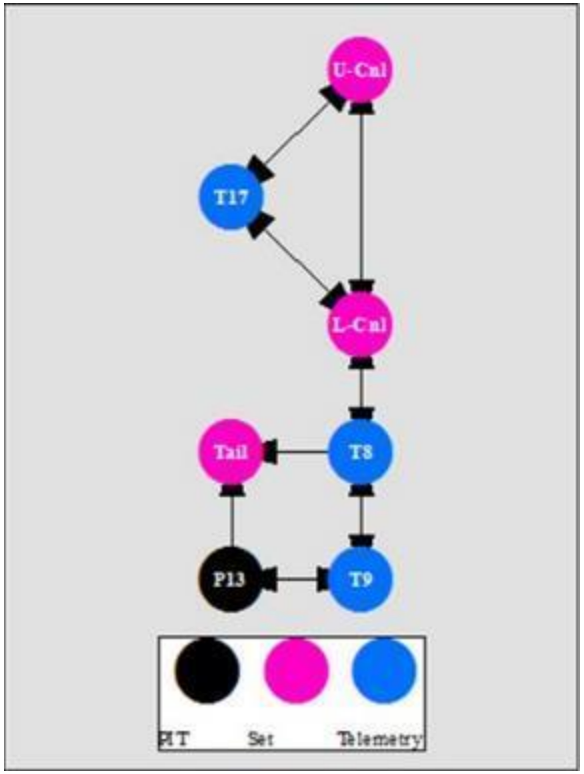


3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Downstream Migration through Canal

- MSM included recaptures from 86 fish
- Overall 71 fish escaped canal (82%) with 39 passing via bypass (45%) and 28 via powerhouse (32%) – remaining fish passed undetected
- Of the 76 fish that attempted the bypass, 39 were successful
- State tables indicate considerable milling within forebay area with 599 forays from the forebay into the bypass and 547 from the bypass into the forebay
- Probability of transitioning from the forebay to the tailrace (entrainment) next increased from 2% at 3,340 cfs to 5% at 12,016 cfs
- Probability of transitioning from the bypass to the tailrace next increased from 4% at low flow to 11% at high flow

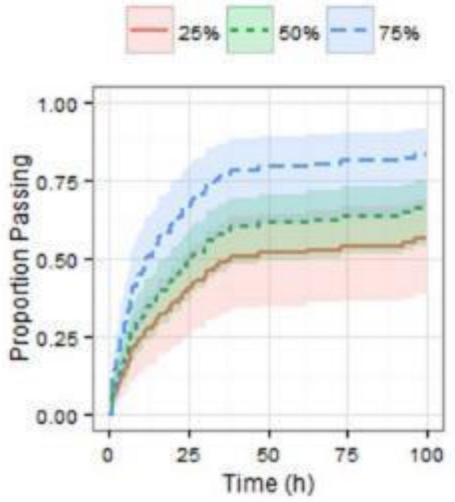


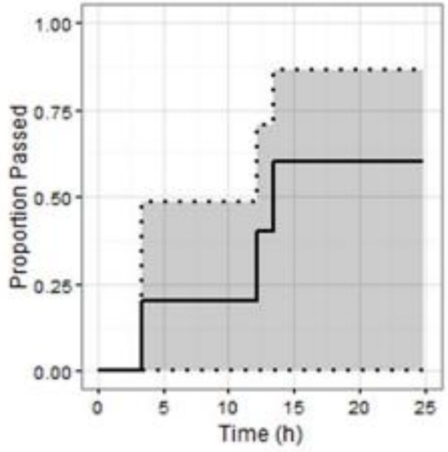
3.3.2- Upstream/Downstream Passage of Adult American Shad

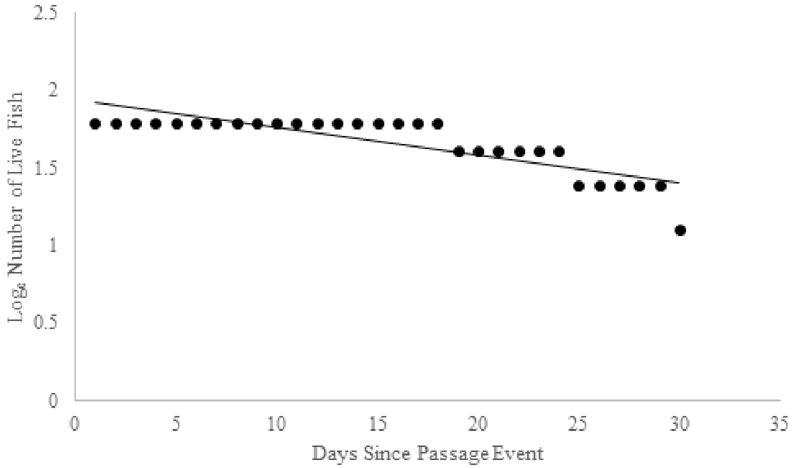
Conclusions

Downstream Migration through Canal

- Overall delay in the canal is reduced with increasing flow
  - 50% pass downstream within 23 hours (75th percentile), however a portion remains in the canal after 10 days
- 50% of the shad attracted to the Station No. 1 Forebay escape within 14 hours
- We were able to track 9 fish known to have passed via the powerhouse, and 5 died.
- Catch-curve estimate of mortality rate = 0.02 per day







3.3.2- Upstream/Downstream Passage of Adult American Shad

Variances

- An additional radio telemetry monitoring station was established within the Cabot fish ladder approximately 40 ft upstream of the entrance at the request of the USGS and U.S. Fish and Wildlife Service (USFWS). The monitoring location employed an Orion receiver and a dropper antenna. The noise floor was set and tested such that only those fish entering the fishway were detected to differentiate from those fish that were attracted to the attraction jet but did not enter the fishway.

- Per the RSP and the SPDL, a total of 100 shad were to be collected at the Cabot fish ladder and released into the TFI. However, due to a miscommunication within the study team a total of 132 shad were collected at the Cabot ladder and released into the TFI. This deviation to the study resulted in a greater number of shad collected at Cabot and released in the TFI and fewer fish collected and released at Holyoke than was planned. However since a large number of fish were tagged and released at Holyoke this reduction represented only 6% of all the fish released at Holyoke.

3.3.3- Downstream Passage of Juvenile American Shad

Study Objectives

The goal of this study is to assess the effects of Project operations on juvenile shad emigration success. The specific objectives are as follows:

- Assess the effects of the Projects on the timing, orientation, routes, migration rates, and survival of juvenile shad;
- Determine the proportion of juvenile shad that pass downstream through the power canal versus over the dam under varied operational conditions, including a range of spill conditions;
- Determine the rate of downstream movement within the impoundment, over the dam and through the bypass reach, or through the power canal;
- Determine survival rates for juveniles spilled over/through dam gates, under varied operation conditions, including up to full spill during the annual fall power canal outage period;
- Determine downstream passage timing, route selection, and rate of movement of juvenile shad through the power canal to Station No. 1, Cabot Station and the Cabot Station bypass;
- Determine the rate of entrainment at the Northfield Mountain Project;
- Determine the survival rate for juvenile shad entrained into Station No.1; and
- Determine the survival rates for juvenile shad entrained at Cabot Station.

3.3.3- Downstream Passage of Juvenile American Shad

Work Completed

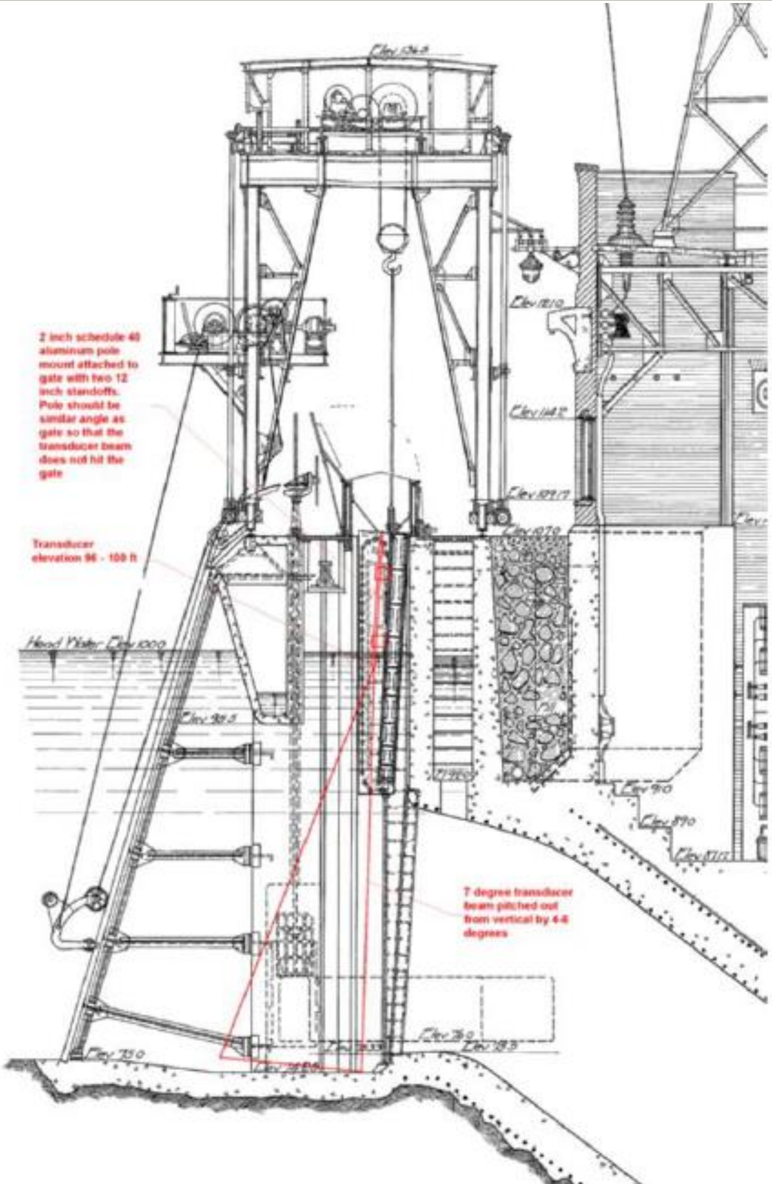
The impact of Projects operations on juvenile shad emigration was assessed using a combination of techniques, including hydroacoustics, radio telemetry, and HI-Z Turb'N tags.

The run timing, duration, magnitude and entrainment of juvenile American Shad were evaluated through the use of hydroacoustics at Cabot Station, the Turners Falls power canal and at NMPS.

- Monitoring was conducted using a Simrad 333-kHz frequency multiplexing sonar, each with four 7° circular split beam transducers.

3.3.3- Downstream Passage of Juvenile American Shad

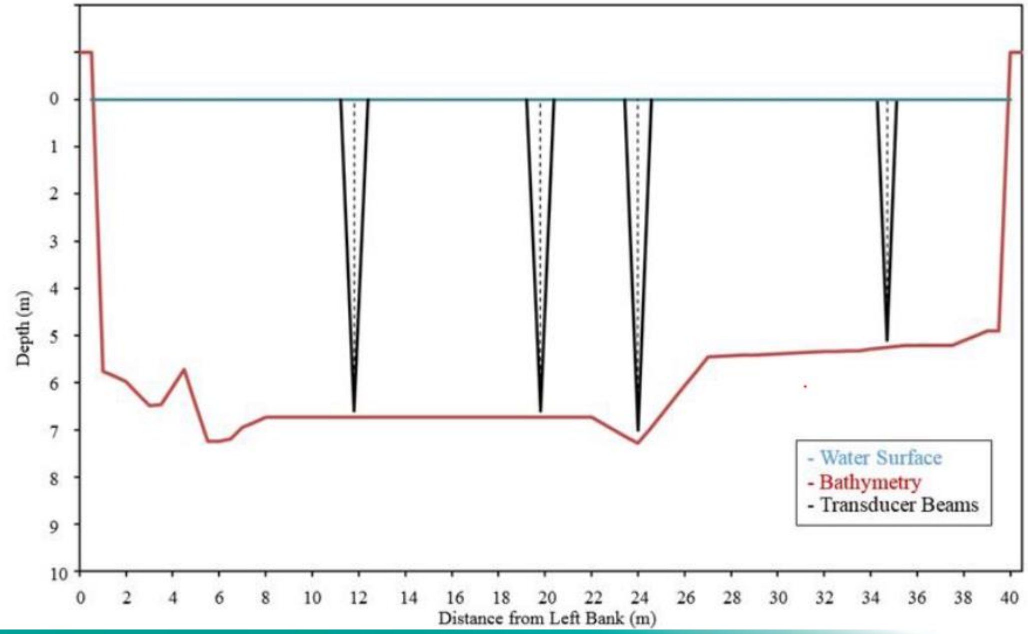
Sampled ~10% of the intake



3.3.3- Downstream Passage of Juvenile American Shad

<u>Turners Falls Canal</u>

Sampled ~9% of the canal



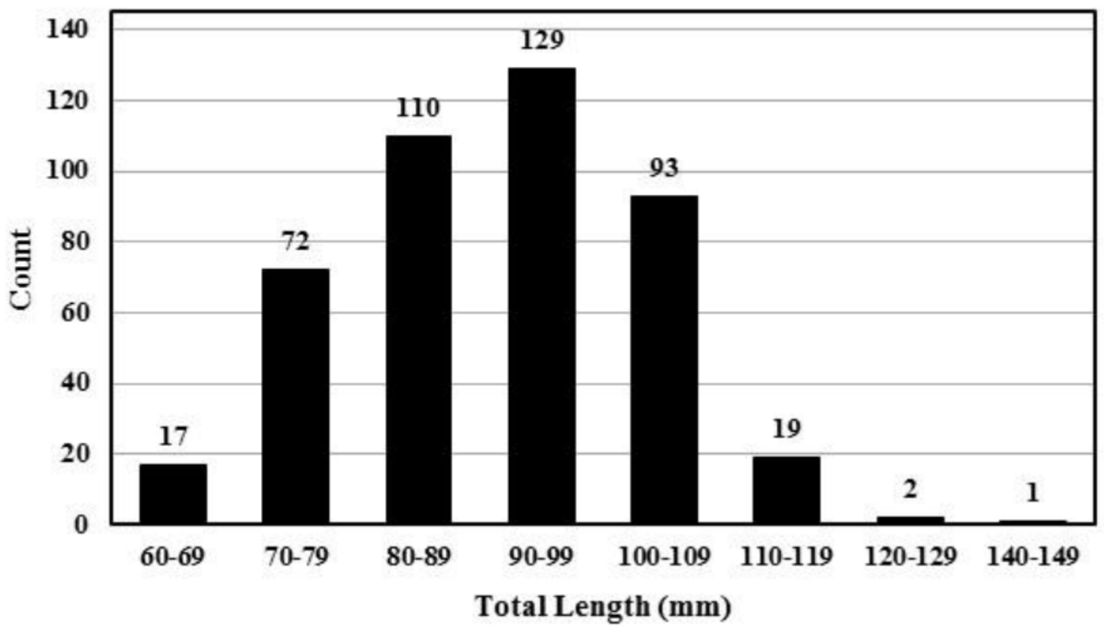
3.3.3- Downstream Passage of Juvenile American Shad

Sampled ~24% of the intake

3.3.3- Downstream Passage of Juvenile American Shad

Verification Sampling

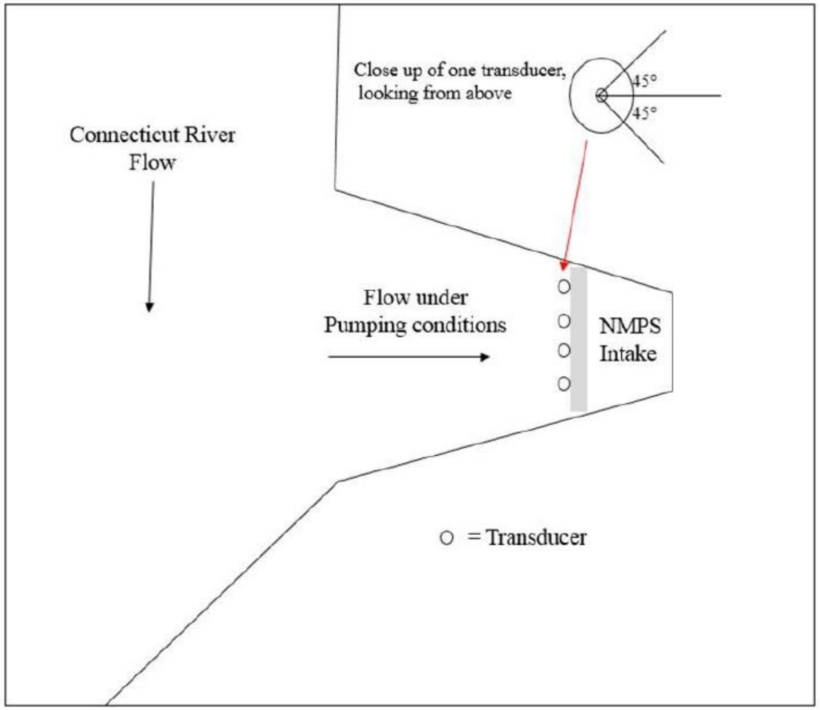
- Concurrent with the hydroacoustic study, sampling was performed at the Cabot Station bypass sampler over several discrete events (15) to determine the species identity of targets observed in the hydroacoustic data and compare the proportion of juvenile shad passing via the downstream bypass (in the Turners Falls Power Canal) and Cabot Station.
- Sampling was conducted during evening hours (generally between 16:00-22:00 hrs) beginning on September 9, 2015 and continuing through October 28, 2015.
- Nearly all fish collected were juvenile American Shad, 50 of which were randomly selected and measured for total length per event. These length data were used to set the ranges for targets detected by hydroacoustic transducers at Cabot Station and Northfield Mountain to be identified as juvenile shad .



3.3.3- Downstream Passage of Juvenile American Shad

Results

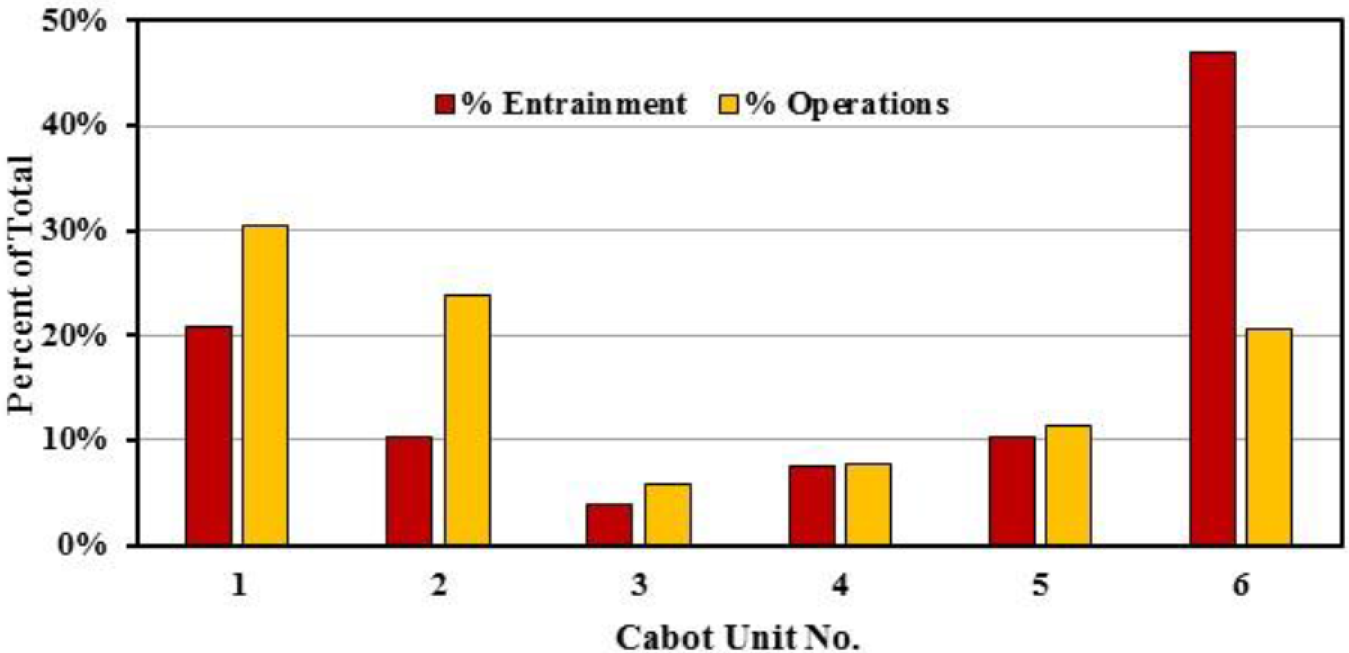
- The locations of the transducers at the Northfield Mountain intake area and in the Turners Falls Power Canal did not allow for data reduction to accurately estimate the run timing, duration, magnitude or entrainment of juvenile shad outmigration, thus rendering some objectives unattainable as scoped in the Revised Study Plan (RSP).
  - Analysis of the data for these two locations revealed a substantial number of targets in these locations engaging in a milling behavior, rather than simply moving in a downstream direction. This behavior reduces the ability of the split beam system to enumerate individual targets and would lead to overestimates, as targets moving in and out of the beam are subject to being counted multiple times.



3.3.3- Downstream Passage of Juvenile American Shad

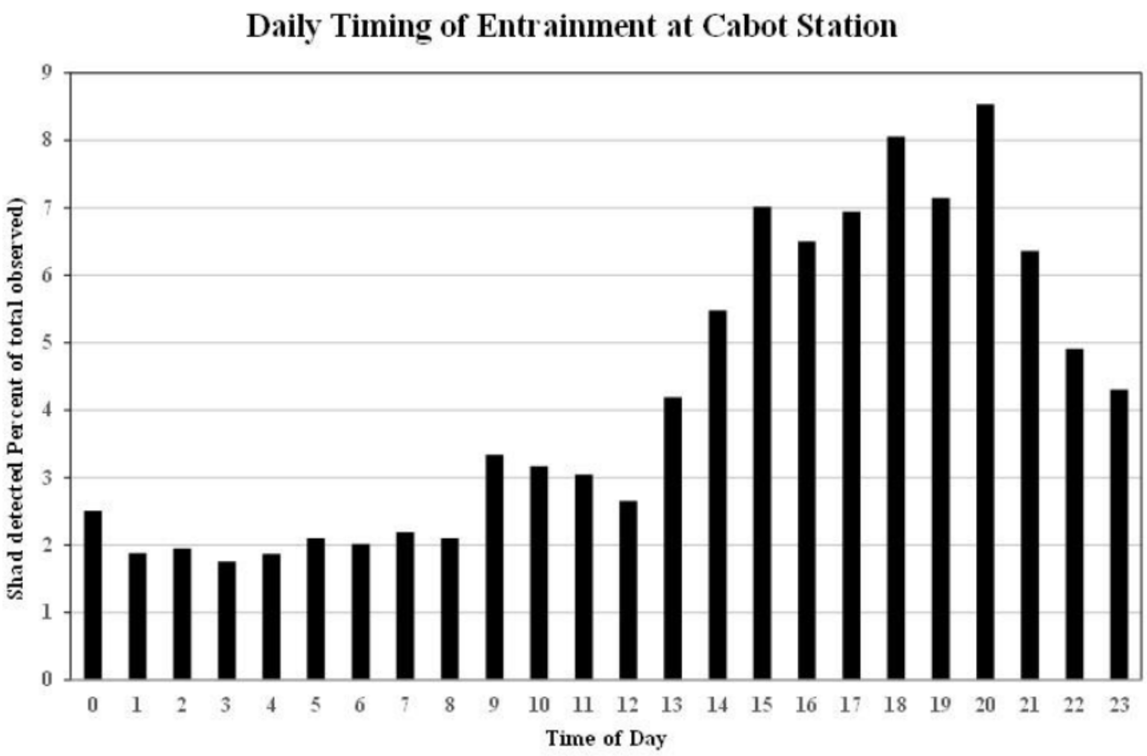
Cabot Station

- Review of the split beam sonar data indicated juvenile shad-sized targets were present in the vicinity of Cabot Station throughout the monitoring period spanning August 1 to November 14, 2015.
- About 1,660,166 shad-sized targets (62-120 mm in length) were estimated to be entrained at Cabot Station between August 1 and November 14, 2015.
- The distribution of entrainment by unit was such that almost half (46%) of the overall entrainment was attributable to Unit 6, despite the more frequent operation of Unit 1.



3.3.3- Downstream Passage of Juvenile American Shad

- Based on concurrent observations at the bypass sampler and Cabot Station intake, it was estimated that an average of approximately 43% of juvenile shad exit the canal via the downstream bypass and 57% are subject to entrainment at Cabot Station.
- Diel movement was investigated at the Cabot Station intake using hydroacoustics methods. Shad size targets were observed to be entrained during each hour of the day at Cabot station but were most prevalent during the afternoon and evening hours, with a peak at 20:00.



3.3.3- Downstream Passage of Juvenile American Shad

Conclusions

- The evaluation of run timing, duration, magnitude and entrainment using split beam hydroacoustics was not possible at NMPS due to high levels of milling.
- Entrainment occurred at Cabot Station and had a significant relationship with daily volume of water that passed through Cabot Station.
- Daily entrainment at Cabot Station was most prevalent during the afternoon and evening hours (75%), with a peak at 20:00.
- Unit 6 exhibits the highest rate of entrainment at Cabot Station.

3.3.3- Downstream Passage of Juvenile American Shad

Evaluation of Passage Routes (Radio Telemetry)

Radio telemetry techniques were used to evaluate route selection and rate of movement of emigrating juvenile shad as they passed through the Northfield Mountain and Turners Falls Projects.

- Tagged juvenile shad were monitored at 13 locations within the study area in accordance with the RSP and FERC's SPDL using a combination of Orion receiver, Lotek SRX 400 receiver or Lotek SRX 800 receiver.

- Both aerial yagi and in-water dropper antennas were used.

- Stations with Lotek SRX 400 or 800 receivers were set up with two receivers to reduce the scan time (2.2 seconds per channel).

- The radio telemetry monitoring system was tested and calibrated in the field prior to tagging and release of test fish

3.3.3- Downstream Passage of Juvenile American Shad

Variances

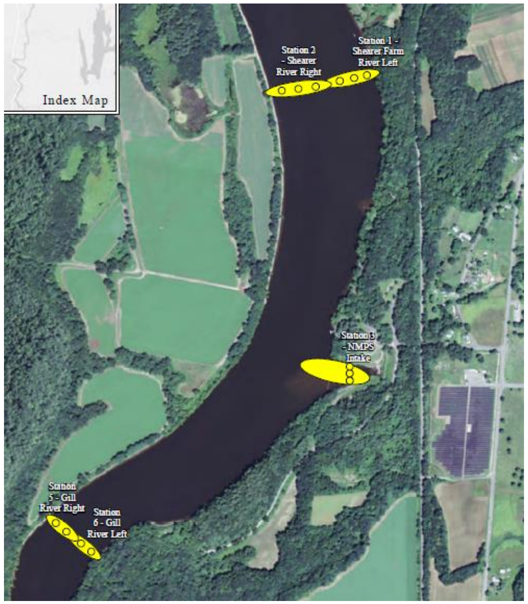
- The RSP envisioned the use of hatchery raised juvenile shad to ensure that they are large enough to tag. This approach will be used for the survival studies but not the route selection studies. Feasibility testing conducted by the TransCanada study team in 2014 showed that the hatchery raised fish did not behave similarly to wild stock. Therefore, while hatchery fish are suitable for survival studies they are not suitable for behavioral studies like route selection.

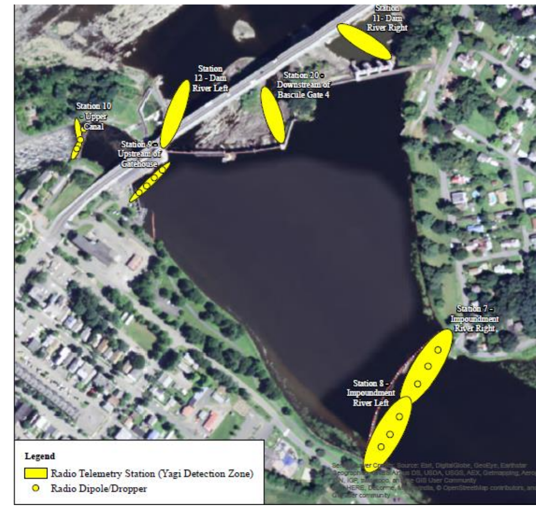
- The specification for the radio tags have been changed as defined herein.

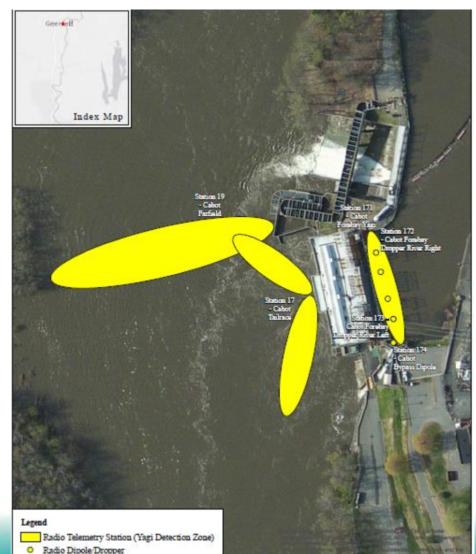
- A Gatehouse monitoring station was added.

- A Cabot Station tailrace monitoring station was added.

3.3.3- Downstream Passage of Juvenile American Shad

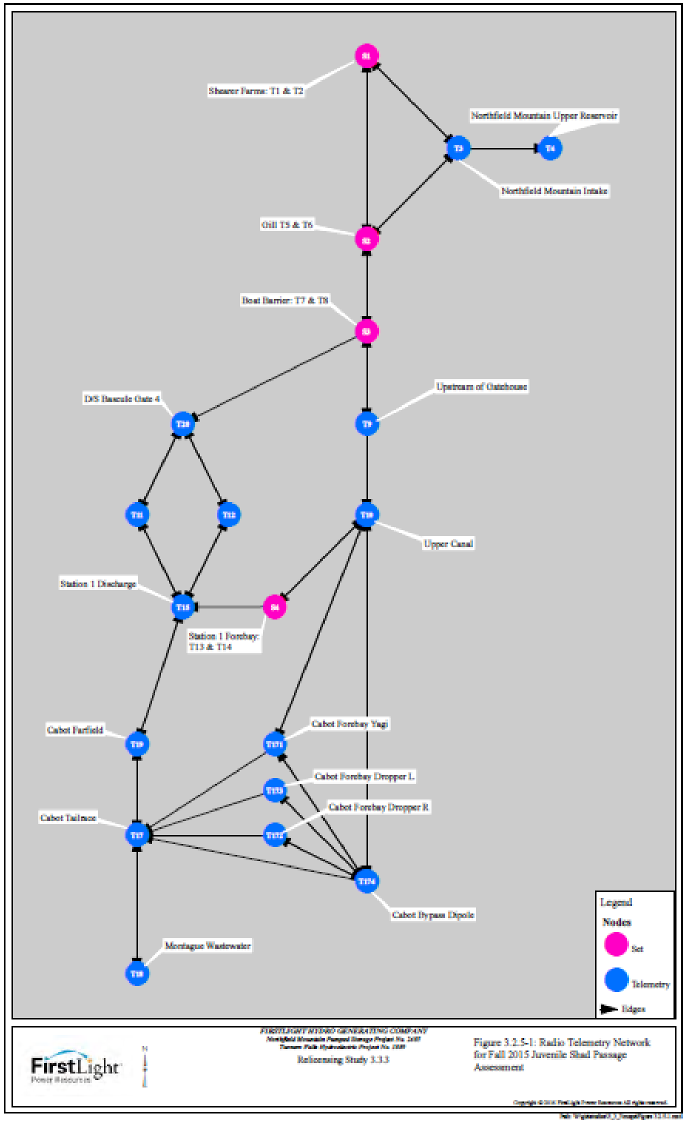






3.3.3- Downstream Passage of Juvenile American Shad

Telemetry Network Model



3.3.3- Downstream Passage of Juvenile American Shad

Tagging and Release

- Juvenile shad were collected in the evenings (generally between 16:00-22:00) and transported in an aerated live well (90 gallons) by truck to the TF Gatehouse where they were divided into three 1,000 gallon circular holding tanks with flow-through ambient river water supplied from the impoundment.
- Juvenile shad from the holding tanks were transported in small groups (~80) to the release location by boat in a live well (90 gallons).
- A Lotek NanoTag Series Model NTQ–1 was externally affixed to 218 juvenile shad.
    - 5 mm wide
    - 3 mm high
    - 10 mm long
    - 0.26 g weight in air
    - A tag life of 10 days at a 2 second burst rate
    - Three frequencies; 150.340, 150.360, and 150.380 MHz.

- Large shad, free from scale loss and observable injuries were selected for tagging. Juvenile shad were transferred from the holding tank by brail and placed in a 5 gallon bath of carbonated water (~1 liter) and ambient river water (~19 liters) for approximately 1 minute, or until anesthetized. Tags were affixed to barbed No. 16 dry fly hooks.
- The fish were kept in the water while the hooks were inserted into the dorsal musculature just below the dorsal fin.
- Once tagged, the fish were held in a small circular recovery tank (~8 gallons) for observation (approximately 15 minutes) to verify initial survival and tag retention.

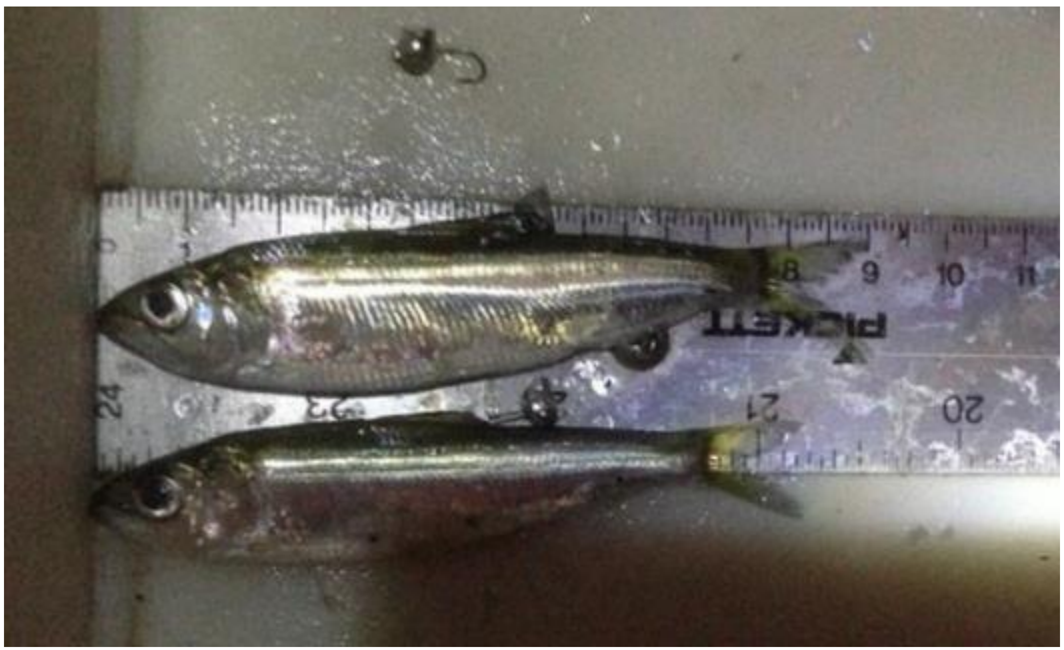
3.3.3- Downstream Passage of Juvenile American Shad

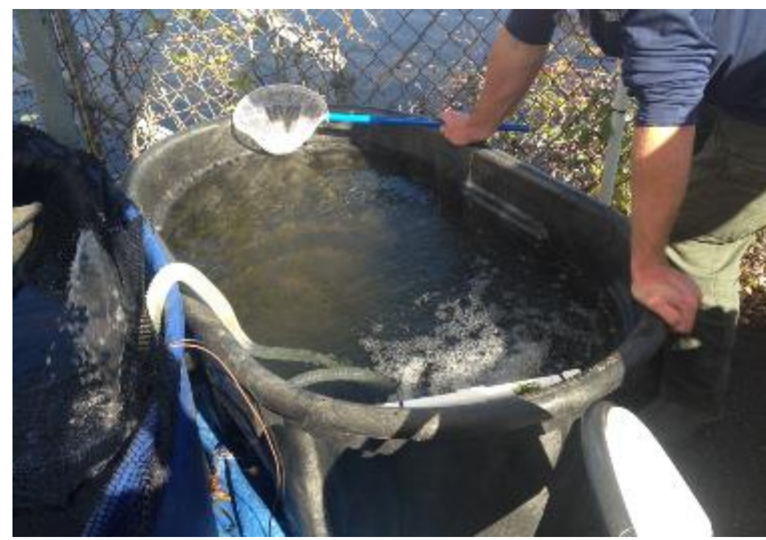
- Tagged shad were released at two sites in the TFI. The first was approximately 1.5 miles upstream of the Northfield Mountain Project intake/tailrace and the other was in the lower impoundment, about 1.25 miles upstream of the TFD.
- The releases upstream of the Northfield Mountain Project occurred on six days between October 12 and 20, 2015 and on three days between October 12 and 15, 2015 at the lower impoundment site upstream of the TFD (Table 3.2.3-1).
- Upstream releases were scheduled such that cohorts of test fish would experience a range of NMPS Project pumping scenarios (i.e. 1, 2 and 3 pumps). Unit 4 was in an outage during the study period and did not operate.

Release Location	Release Date	Release Time	Count	Cumulative Total	No. Units Pumping at NMPS
Upper Canal	October 4, 2015	20:45	8	8	1
Lower Canal	October 4, 2015	22:25	9	17	1
Upstream of TFD	October 12, 2015	19:20	20	37	2
Upstream of NMPS	October 12, 2015	20:45	20	57	2
Upstream of TFD	October 13, 2015	20:45	20	77	3
Upstream of NMPS	October 13, 2015	20:05	24	101	3
Upstream of TFD	October 15, 2015	19:45	23	124	3
Upstream of NMPS	October 15, 2015	20:10	24	148	3
Upstream of NMPS	October 16, 2015	20:55	24	172	2
Upstream of NMPS	October 19, 2015	19:10	24	196	3
Upstream of NMPS	October 20, 2015	20:10	22	218	2

3.3.3- Downstream Passage of Juvenile American Shad

- Fifty (50) juvenile shad were placed in a 90-gallon tank and tagged with mock tags that consisted of tin BB weights attached to dry fly hooks to serve as controls.
- The weight and approximate size of the control tag (~0.3 grams) was similar to the Lotek NanoTag.





FirstLight Power Resources

3.3.3- Downstream Passage of Juvenile American Shad

Rate of Movement

- The amount of time that each fish spent within the impoundment was determined by using the time from release and last known detection at any given fixed telemetry station within the impoundment.

- Distance from the release location to the last known fixed telemetry station detection was determined in RMs. These data were used to calculate migration rate, distance per hour (RM/h).

- If a fish passed through the Turners Falls Project, the time of release to the time of the last detection closest to the dam and/or Gatehouse was used. The same procedure was used for the bypass reach and the power canal.

3.3.3- Downstream Passage of Juvenile American Shad

Canal Escapement during Drawdown

- Prior to the drawdown of the Turners Falls Power Canal juvenile shad were tagged and released into the canal the evening of October 4, 2015.
- 8 tagged juvenile shad were released in the upper portion of the canal just downstream of Gatehouse and 9 were released in the lower portion of the canal where it begins to widen along Migratory Way.
- Subsequent to release, mobile tracking was performed on October 5, 2015 in an attempt to locate the tagged fish and determine escape routes.

An objective of Study 3.3.18 *Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms* was to assess whether juvenile shad and American Eel abundance in the canal increases leading up to the time of its closure, due to delays in downstream passage (e.g., is fish accumulation occurring).

- Shad were monitored at the Cabot intake leading up to the canal drawdown using split beam hydroacoustics.
- These data were used to estimate entrainment at Cabot Station, which has an assumed positive relationship to shad abundance within the power canal such that as the entrainment rate increases so must the abundance in the canal.
- Entrainment rate at Cabot Station was plotted over time and used to investigate the potential for shad accumulation within the power canal leading up to the drawdown.

3.3.3- Downstream Passage of Juvenile American Shad

NMPS Area

- A total of 129 tagged juvenile Shad were released upstream of the NMPS intake/tailrace area. Of those 77 Shad (60% of release) were detected at Shearer Farms fixed telemetry monitoring station (T1 and T2) located approximately 1.2 river miles downstream of the release point and approximately 0.5 miles upstream of the NMPS intake/tailrace. These fish represent the cohort of emigrating fish that entered the NMPS area.
  - Thirty two of these fish emigrated past the NMPS intake/tailrace area and continued downstream approximately 0.66 miles downstream, where they were detected at the Gill Banks monitoring station (T5 and T6) for a passage rate of 41.6% through this reach of the TFI.
  - Of the fish that entered this reach 72.7% were either detected in the NMPS intake/tailrace area, the upper reservoir or downstream of the NMPS intake/tailrace; leaving 27.3% undetected.
  - Three fish were entrained and detected in the Upper Reservoir of Northfield Mountain, suggesting an entrainment rate of 3.9%.
  - Twenty-one (21) additional fish were last detected at the Northfield Mountain intake/tailrace and were never detected again at any of the telemetry receiver stations.
    - Of those 21 fish, 14 were last detected at the Northfield Mountain intake/tailrace during pumping operations.

3.3.3- Downstream Passage of Juvenile American Shad

TFD and Powerhouse

- Only two juvenile shad (1% of releases) passed over the TFD and 16 (9% of releases) passed through the Gate House and into the power canal.

Rate of Movement

- Juvenile shad (n=113, 61.7% of releases) detected at the impoundment receiver stations exhibited a mean rate of downstream movement of 0.31 RM/h.
- Two fish passed over the TFD, one of which continued through the bypass reach to the Station No.1 tailrace at a rate of 1.45 RM/h.
- Three fish were detected in the Cabot Station tailrace. Based on these fish, the mean rate of movement through the canal was 0.03 RM/h.

3.3.3- Downstream Passage of Juvenile American Shad

Canal Release Group

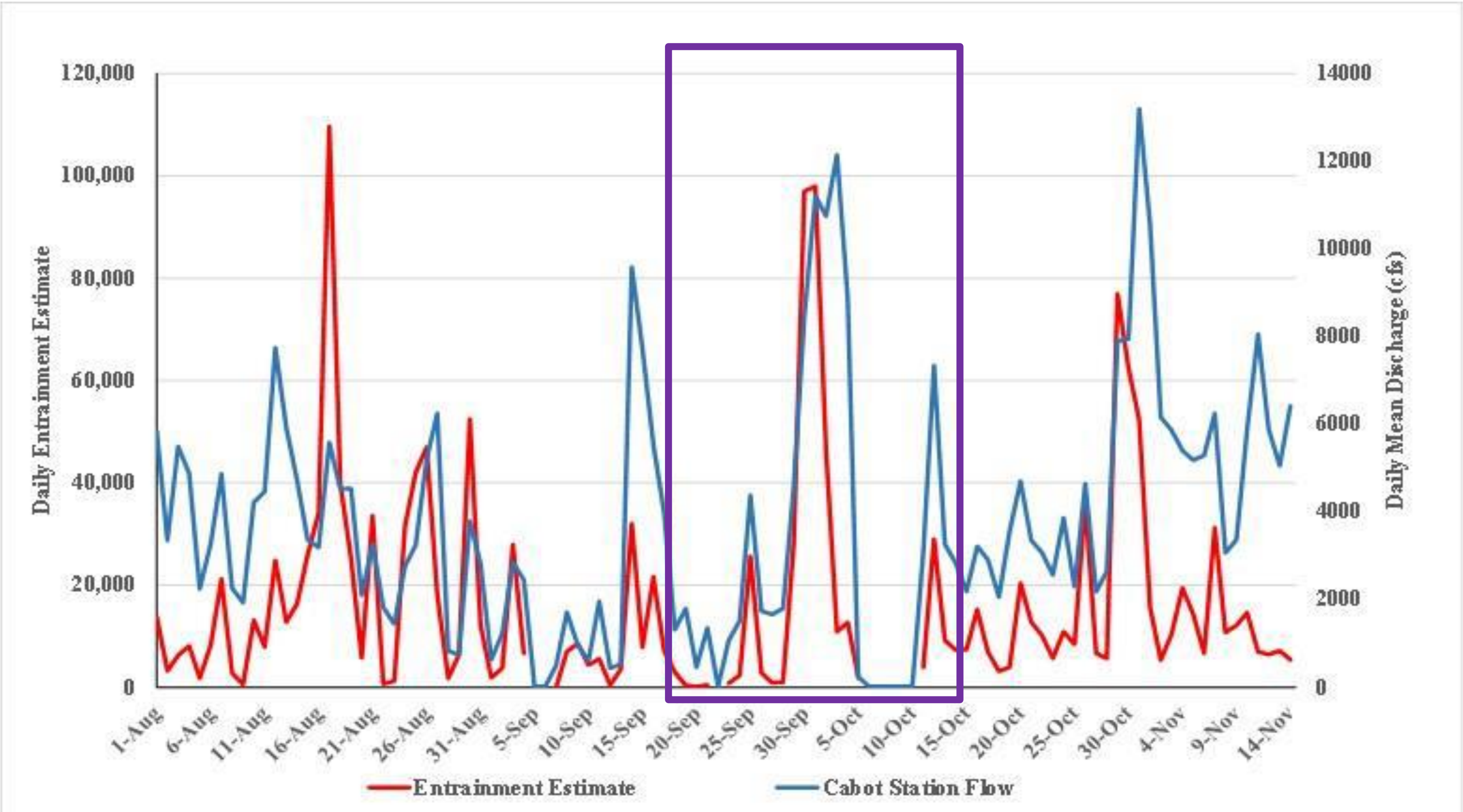
- A separate group of 17 tagged juvenile shad were released into the Turners Falls Power Canal the evening before the annual drawdown on October 5, 2015.
  - Five fish were detected in the area of release; two at the upper canal release site and three at the lower canal release site.
  - One fish released in the upper canal was detected at the Station No. 1 forebay, although passage was not confirmed as Station No. 1 was not operating.
  - Similarly, one fish released in the lower canal was detected in the vicinity of the Cabot Station forebay; however, Cabot Station was not operating at the time of detection and this individual was not detected at any station downstream of Cabot Station.

3.3.3- Downstream Passage of Juvenile American Shad

Fish accumulation - Turners Falls Power Canal

- Split beam hydroacoustics data collected at the Cabot Station intake indicated an increase in entrainment rate during the week leading up to the canal drawdown beginning on September 28, 2015 with a rate of 1,100 shad sized targets per day to a peak of approximately 98,000 entrained per day on October 1.
- This increase in entrainment coincided with an increase in river flow and discharge at Cabot Station, which has a positive relationship with an increase in canal flow and intake velocity.
- The highest river flows experienced during the study (~39,000 cfs) occurred on October 2 and 3, 2015 the days before the start of the drawdown.
- The daily entrainment rate had declined to approximately 13,000 per day on October 4 immediately before the drawdown.
- Entrainment decreased prior to the decrease in discharge at Cabot Station suggesting that an accumulation of shad occurred during the relatively low flow period (9/17/15 – 9/30/15) in the canal leading up to the drawdown but shad were conveyed downstream during the increase in canal flow/discharge at Cabot Station prior to the drawdown.
- Escapement of tagged shad from the canal during the drawdown was poor but tagging and handling mortality may have confounded the results.

3.3.3- Downstream Passage of Juvenile American Shad



3.3.3- Downstream Passage of Juvenile American Shad

Conclusions

- The control experiment revealed significant mortality, tag loss and irregular swimming behavior of tagged shad. These observations leave the reliability of the study results in question.
- The study did not effectively estimate the run timing, duration, or magnitude of juvenile shad entrainment at NMPS rendering these objectives unattainable as scoped in the Revised Study Plan (RSP).
- Of the fish released upstream of NMPS (129) a large proportion (60%) emigrated and were detected at the Shearer farms monitoring Site. Of those 41.6 % emigrated past NMPS and were detected downstream at Gill Banks.
- Three fish were entrained and detected in the Upper Reservoir of Northfield Mountain, suggesting an entrainment rate of 3.9%.
- Passage over the dam and into the Turners Falls power canal was low, 1% and 9% of released, respectively.
- Rate of emigration was highest in the bypass reach (1.45 RM/h) followed by the impoundment (0.31 RM/h) and the slowest rate of emigration was observed in the canal (0.03 RM/h).
- Entrainment rate and thus shad abundance in the canal increased leading up to the canal drawdown and corresponded to increased flows and Cabot Station discharge. However, entrainment rate declined prior to flow and was at a relatively low level at the time of the drawdown.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Background

Study involved qualitative and quantitative approach to characterizing and estimating fish entrainment for the NMPS and TF Projects. Entrainment magnitude and turbine mortality were evaluated. A qualitative desktop entrainment analysis was conducted for resident fish; adult and juvenile American Shad and adult American Eel were quantitatively assessed.

Study Objectives

- Estimate the potential risk of entrainment, impingement, and turbine passage mortality to resident fish species at the Northfield Mountain Project and Turners Falls Project by developing a qualitative scale of risk for resident and migratory fish species.
- Conduct a quantitative assessment of the potential impact of entrainment and turbine passage mortality on American Shad and American Eel.

Work Completed

- Qualitative assessment of entrainment and impingement of resident species.
- Estimation of turbine passage mortality rates for juvenile American Shad and adult American Eel.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Conclusions

- Entrainment of resident species was ranked as low to moderate risk; no population wide impacts are expected.
- Turbine passage survival rates for juvenile shad ranged from 95% at Cabot Station to 68% at Station 1 Units 2/3.
- Survival of shad passing the dam via the Bascule Gates ranged from 48% (1,500 cfs) to 76% (5,000 cfs) at BG1 and from 59% (2,500 cfs) to 74% (5,000 cfs) at BG4. Survival rates were highest under the 5,000 cfs discharge scenario .
- Turbine passage survival rates for adult eels ranged from 96% (48 h) at Cabot Station to 62% (48 h) at Station 1 Units 2/3. Survival at Station 1 Unit 1 was 90% (48 h).
- Bascule Gate survival of adult eels ranged from 85.7% (2,500 cfs) to 88.8% (1,500 cfs) at BG1 and from 82.9% (1,500 cfs) to 93% (5,000 cfs) at BG4 .

Variances

- Due to safety concerns regarding access to the gates, survival testing at the dam occurred at Bascule Gates 1 and 4 only.
- Estimates of 48 hour survival for juvenile shad was deemed unreliable because of high control mortality.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species

- Species assessed based on observations in TFI during 2015 Fish Assemblage Assessment (Study No. 3.3.11)
- Traits Based Assessment used to evaluate risk of entrainment and/or impingement at Northfield, Station No. 1 and Cabot Station
- Susceptibility to entrainment/impingement based on habitat preferences, life history strategies, behavior, and morphology
- Degree of entrainment/impingement depends on swimming capabilities
- For entrainment, if sustained swim speed < mean intake velocity, then entrainment assumed
- For impingement, smaller fish with body widths < trashrack spacing were assumed not to be susceptible to impingement. If body width > trashrack spacing, then potential for impingement based on swimming performance as compared to mean intake velocity
- Turbine passage mortality estimates for resident species were extrapolated from an empirical dataset of more than 30 hydro projects with similar characteristics (head, peripheral runner velocity, and hydraulic capacity) as Cabot Station and Station No. 1

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species - NMPS

Species	Habitat & Biology	Swim Speed	Survival	Likelihood	Population Impact	Risk Score
Banded Killifish	1	2	3	1	0	7
Black Crappie	1	2	3	1	0	7
Bluegill	1	2	3	1	0	7
Brown Bullhead	1	2	3	1	0	7
Chain Pickerel	1	2	3	1	0	7
Channel Catfish	1	2	3	1	0	7
Common Carp	1	2	3	1	0	7
Common Shiner	1	2	3	1	0	7
Fallfish	1	2	3	1	0	7
Golden Shiner	1	2	3	1	0	7
Largemouth Bass	1	2	3	1	0	7
Longnose Dace	1	2	3	1	0	7
Mimic Shiner	1	2	3	1	0	7
Northern Pike	1	2	3	1	0	7
Pumpkinseed	1	2	3	1	0	7
Rock Bass	2	2	3	1	0	8
Rosyface Shiner	1	2	3	1	0	7
Smallmouth Bass	2	2	3	1	0	8
Spottail Shiner	1	2	3	1	0	7
Tessellated Darter	1	2	3	1	0	7
Walleye	1	2	3	1	0	7
White Perch	2	2	3	1	0	8
White Sucker	2	2	3	1	0	8
Yellow Perch	1	2	3	1	0	7

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species - Station No. 1

Species	Habitat & Biology	Swim Speed	Survival	Likelihood	Population Impact	Risk Score
Banded Killifish	1	2	1	1	0	5
Black Crappie	2	2	1	2	0	7
Bluegill	1	0	1	1	0	3
Brown Bullhead	1	0	2	1	0	4
Chain Pickerel	1	2	1	1	0	5
Channel Catfish	1	0	3	1	0	5
Common Carp	2	0	2	1	0	5
Common Shiner	1	0	2	1	0	4
Fallfish	1	0	2	1	0	4
Golden Shiner	1	0	2	1	0	4
Largemouth Bass	1	1	1	1	0	4
Longnose Dace	1	2	2	1	0	6
Mimic Shiner	1	2	2	1	0	6
Northern Pike	1	0	0	1	0	2
Pumpkinseed	1	0	1	1	0	3
Rock Bass	1	2	1	1	0	5
Rosyface Shiner	1	2	2	1	0	6
Smallmouth Bass	1	1	1	1	0	4
Spottail Shiner	1	0	2	1	0	4
Tessellated Darter	1	2	2	1	0	6
Walleye	1	0	2	1	0	4
White Perch	1	0	1	1	0	3
White Sucker	2	0	1	1	0	4
Yellow Perch	1	0	2	1	0	4

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species - Cabot Station

Species	Habitat & Biology	Swim Speed	Survival	Likelihood	Population Impact	Risk Score
Banded Killifish	1	2	2	1	0	6
Black Crappie	1	2	1	2	0	6
Bluegill	1	2	1	1	0	5
Brown Bullhead	1	2	3	2	0	8
Chain Pickerel	1	2	1	2	0	6
Channel Catfish	1	0	3	2	0	6
Common Carp	3	2	2	2	0	9
Common Shiner	1	2	2	2	0	7
Fallfish	1	2	2	1	0	6
Golden Shiner	2	2	2	2	0	8
Largemouth Bass	1	2	1	1	0	5
Longnose Dace	1	2	2	2	0	7
Mimic Shiner	1	2	2	2	0	7
Northern Pike	1	0	0	2	0	3
Pumpkinseed	1	2	1	1	0	5
Rock Bass	1	2	1	2	0	6
Rosyface Shiner	1	2	2	2	0	7
Smallmouth Bass	1	2	1	1	0	5
Spottail Shiner	1	2	2	2	0	7
Tessellated Darter	1	2	2	1	0	6
Walleye	1	2	2	2	0	7
White Perch	2	2	1	2	0	7
White Sucker	2	0	1	2	0	5
Yellow Perch	1	2	2	1	0	6

3.3.7 - Fish Entrainment and Turbine Passage Mortality
Migratory Species

Adult American Shad
- No adults were confirmed to be entrained at NMPS or Station No. 1 (Study No. 3.3.2).
- A total of 86 double tagged shad emigrated through the canal, of those 24 were entrained through Cabot (9 of those detected further downstream) and 39 adult shad exited the area via the sluiceway.

Juvenile American Shad
- Hydroacoustics set-up at NMPS did not allow for reliable entrainment estimate. Based on radio telemetry methods, 3.9% of those that passed the intake were entrained.
- Of the 16 juveniles that migrated through the Power Canal, only one was detected at Station No. 1, but no entrainment confirmed.
- Hydroacoustics data suggested over 1.6M juveniles entrained at Cabot; however, turbine passage survival of 95% suggests the majority survive entrainment at Cabot.

Adult American Eel
- Data analysis remains ongoing and entrainment potential will be discussed in report for Study No. 3.3.5 due to FERC in March 2017.

3.3.7- Fish Entrainment and Turbine Passage Mortality

Migratory Species

- The goal of these studies was to assess turbine survival (1 and 48 h) at Cabot Station Unit 2, Station No. 1 (Units 1 and 2/3) and over the Bascule Gates (1 and 4) of emigrating juvenile American Shad and adult silver-phase American Eels.

- The results were obtained using the HI-Z Tags recapture techniques.

- Juvenile shad collected in the Connecticut River and adult silver-phase eels imported from Newfoundland were released into the intakes of designated Francis units at Cabot Station, Station No. 1, and over Bascule Gates 1 & 4 at three discharge scenarios (1,500, 2,500, and 5,000 cfs).

- After passage, live and dead fish were captured and the condition of each was examined.

- At the end of the 48 h holding period, all live and uninjured shad were released to the river.

- Survival rates were estimated for each passage location and descriptions of the observed injuries were recorded to help assess the probable causal mechanisms for injury/mortality.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Tag-Recapture Data and 1 hour Survival Rates for Juvenile Shad, October 14-24, 2015.

Juvenile Shad	Cabot	Station No. 1		Bascule Gate 1 (cfs)			Bascule Gate 4 (cfs)			Controls	
	Unit 2	Units 2/3	Unit 1	1,500	2,500	5,000	1,500	2,500	5,000	Cabot & Station 1	Bascule Gates
Number released	120	90	90	60	60	62	60	60	60	71	75
Number recaptured Alive	113	59	59	38	27	45	37	34	41	67	72
Number recaptured Dead	2	6	9	4	7	4	4	6	0	0	3
1 hour survival rate	0.95	0.68	0.77	0.69	0.48	0.76	0.64	0.59	0.74		
Number Held	113	59	59	38	27	45	37	34	41	67	72
Number Alive at 48 hours	86	48	31	28	4	9	4	6	7	45	48
Number Dead at 48 hours	27	11	28	10	23	36	33	28	34	22	24
*48 hour survival not reliable because of high control mortality											

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Tag-Recapture Data and 1 and 48 hour Survival Rates for Adult Eels, November 4-9, 2015.

Adult Eels	Cabot	Station No. 1		Bascule Gate 1 (cfs)			Bascule Gate 4 (cfs)			Controls
	Unit 2	Units 2/3	Unit 1	1,500	2,500	5,000	1,500	2,500	5,000	Combined
Number released	50	30	30	35	30	30	35	30	30	25
Number recaptured Alive	49	18	27	30	24	25	31	27	28	25
Number recaptured Dead	0	1	0	0	0	0	0	1	0	0
1 hour survival rate	0.98	0.62	0.90	0.88	0.86	0.86	0.89	0.9	0.93	
Number Held	49	18	27	30	24	25	29	27	28	25
Number Alive at 48 hours	48	18	27	30	24	25	29	27	28	25
Number Dead at 48 hours	1	0	0	0	0	0	2	0	0	0
48 hour survival rate	0.96	0.62	0.90	0.88	0.86	0.87	0.83	0.90	0.93	0

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Juvenile Shad

Survival rate (1 h) was 95.0% for juvenile shad passed through Cabot Station Unit 2.

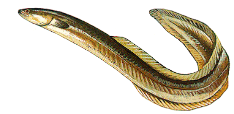
Survival rate (1 h) was about 68% at Unit 1 of Station No. 1 and 77% for fish passed through the common penstock of Units 2 and 3 .

Cabot Station turbines are larger and rotate slower than Station No. 1 turbines.

Juvenile shad are more likely to survive turbine passage than passage via the dam. Combined (for three flows tested) survival at Bascule Gate 1 was about 63% and about 65% at Bascule Gate 4.

The boulder and concrete sill structures directly below the discharge of Bascule Gates 1 and 4 likely impacted survival of juvenile American Shad passed via the dam .

Adult Eels



Adult eels incur minor mortality (≤4%) passing the large Francis units at Cabot Station.

Eels exhibited 90% survival (48 h) and little injury passing the larger of the Francis units (Unit 1) at Station No. 1.

Station 1 Units 2/3 with a common penstock inflict up to about 38% mortality.

Testing at 3 discharges (1,500, 2,500, and 5,000 cfs) through Bascule Gates 1 and 4 indicated survival estimates of 86-88% at Bascule Gate 1 and 83-93% at Bascule Gate 4.

Very few injuries were observed with recaptured fish.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Background

The goal of this study is to collect information to determine if Project operations negatively impact fish species so that appropriate mitigation measures may be developed, if warranted, to protect and conserve the species utilizing project waters.

Study Objectives

- Assess timing and location of fish spawning in the littoral zone.
- Delineate, qualitatively describe (*e.g.* substrate composition, vegetation type and relative abundance),and map shallow water habitat types subject to inundation and exposure due to project operations.
- Evaluate potential impacts of impoundment fluctuation on nest abandonment, spawning fish displacement and egg dewatering.

Work Completed

- Field data collected during 2015 field season
- Draft report prepared June 2016

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Field crew systematically traversed the littoral zone (depth < 6 feet) of the entire TFI to visually identify any fish nests, egg masses/deposits, and/or spawning habitat.

Used an RTK-GPS unit to determine:

- Position and elevation of nests and/or potential habitat surveyed to the NGVD29 datum.
- Prevailing water surface elevation at each site

Early Spring - Broadcasted adhesive eggs. Gravel shoals, point bars etc. At locations where eggs could be embedded in gravel interstices, substrates were inspected using underwater surveillance. Aquatic and riparian vegetation also examined

Late Spring - Nearshore shoal areas where nest construction could occur searched for evidence of either nest construction, redd formation, or spawning aggregations of adult fish.

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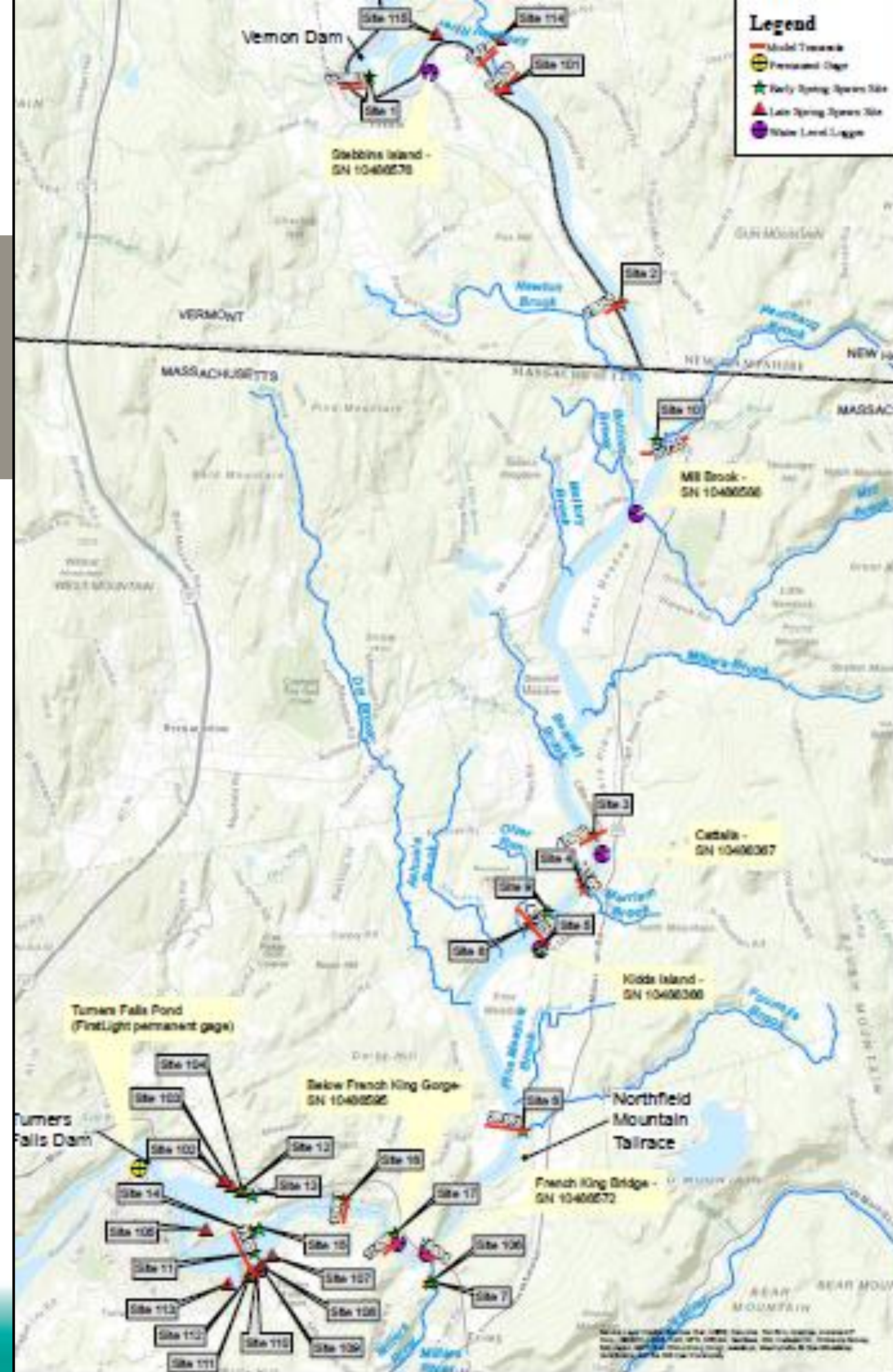
3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

- To supplement the WSEL data collected, used the hydraulic model of the TFI (part of Study No. 3.2.*2 Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot)*.

- Location of each spawning site was mapped and compared against hydraulic model transects. The transect in closest proximity to each spawning location was used to determine whether spawning sites could have been dewatered.

- 32 spawning sites (17 in the early spring and 15 in the late spring) were discovered throughout the survey



3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

TFI WSELs during the course of early spring surveys were relatively close to the long-term median (181.3 ft). Thus fish selected spawning sites under relatively "typical" TFI water levels in 2015.

Early spring spawning:
Early May 2015
Areas where either evidence of spawning was observed, or habitat and substrates suitable to such spawning, were limited to isolated patches.

- Several gravel-rubble beds in the upper TFI appear to provide suitable spawning conditions for walleye; it was assumed that spawning could occur at these sites given the availability of suitable substrates, however direct observation of spawning was not possible due to relatively high flows and turbid water

- SAV or emergent vegetation beds were concentrated in the section below French King Gorge to Barton Cove. A few were scattered throughout the middle and lower reaches of the TFI

- All life stages (including young of year, YOY) of walleye and yellow perch were detected in the fish assemblage study(Study No. 3.3.11), indicating that reproduction using these habitats was successful in 2015 and earlier years.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

TFI WSEL recorded between 180.5 and 181.1(in Barton Cove); an elevation of 184.6 ft was recorded at the upstream extent of the TFI near Stebbins Island instrument during late spring surveys; therefore fish selected spawning sites under relatively "typical" TFI water levels.

Late spring spawning:

Early-late June

- The vicinity of Barton Cove, and the boat club had the greatest concentrations of nests
- Scattered spawning was observed in the upper TFI between Stebbins Island and the vicinity of the Ashuelot River mouth
- Spawning nests were not detected in the middle reaches of the TFI, although YOY centrarchids were collected in all reaches of the TFI during the late summer fish assemblage survey
- Sea lamprey spawning was observed in areas such as riffles in the Millers River (*discussed in detail in the report for Study No. 3.3.15*)
- YOY lifestages of lamprey and centrarchids were detected in the fish assemblage study (Study No. 3.3.11), in reasonably close proximity to where nesting was observed

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Shallow water habitat types subject to inundation and exposure were mapped and profiled in detail in the report for Study No. 3.3.14 (Aquatic Habitat Mapping of Turners Falls Impoundment).

- Littoral areas were characterized by lotic riverine areas in the upstream most two-thirds of the TFI (approximately 13 miles), and a lacustrine embayed section of the TFI downstream from French King Gorge.

- *Upstream reach* is relatively uniform and located within a broad floodplain. There are a few narrow islands comprised of alluvial materials such as gravel, cobble and fines.

- The reach between the Northfield Mountain tailwater downstream through the gorge is comprised of steep, vertical bedrock walls and lacks significant littoral habitat.

- The *downstream reach* extends from the outlet of French King Gorge to the Turners Falls Dam, defined by both bedrock and depositional features, includes a complex of embayment, points, coves, islands and a wide range of substrates, and includes shallow lacustrine littoral habitat.

- Fines and cobble collectively accounted for about 50% of all littoral substrate. Coarser materials are more common in the upper reach, and fines, muck and organic sediments are common in the lower reach.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Potential impacts of impoundment fluctuation on fish spawning

Early Spring Spawning

White sucker and walleye

- Depths greater than 1 ft up to 9.8 ft provide at least a suitability rating of 0.5 or greater for white sucker; and depths from approximately 1.2 ft up to 6 ft also meet or exceed a habitat suitability rating of 0.5.

- TFI WSELs are frequently met at Site 2; however, Site 1, and Site 10 (in Pauchaug Brook) are only submerged about 50% or less of the time during April and May.

  - Site 1 is directly in the Vernon tailwater and at times directly influenced by Vernon discharges;

  - Site 10 is a cattail bank near the edge of the riparian zone and is inherently shallow.

  - Although walleye likely use shoals such as that at Site 2, they also undergo migrations to find suitable riffles for spawning (McMahon, 1984) and it is possible that additional spawning areas exist in tributaries outside of the study area.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Northern Pike

- SAV bed spawning sites for pike were very limited in the upper TFI.
- Site 10 is submerged about 50% of the time in April (the month most likely for pike spawning), therefore not consistently usable.

Yellow Perch

- Spawning suitability conditions in the **upper TFI** would be marginally available under any circumstances. Yellow perch spawning would potentially occur on cattail stubs and other emergent vegetation submerged from approximately 3 to 12 ft in areas of extremely low velocity (less than .075 ft/sec)
- Spawning habitat in the **lower TFI:** Median operating conditions create water levels generally suitable for spawning conditions at most, but not all, SAV beds.
  - (*sites 11&12*) submerged adequately about 75% of the time
  - (*sites 13 - 17*) submerged adequately about 50-70% of the time

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Late spring spawning

- Dominated by nest building species such as centrarchids.
- Confined to the upper (limited) and lower (very abundant) extremities of the TFI.
- Embayment's and coves below French King Gorge and throughout the Barton Cove area.
- Nests built at the shallowest observed elevations generally remain adequately deep 90-95% of the time at most spawning locations and nests built at the deeper elevations remain adequately submerged nearly 100% of the time.
- Under median conditions most nest depths ranged between 2 and 4 ft and would be considered optimal.
- Nests constructed under approximately median conditions at sites 1.8 ft depth or shallower may become abandoned if the TFI WSEL falls below 179.8 ft.
- Should TFI elevation rise following nest construction, the increased depth did not appear to prohibit spawning and nesting success would not be affected.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Summary

Early Spring spawning

Upper impoundment

- spawning sites are scattered
- Some upstream sites affected by inflow from Vernon
- Emergent vegetation bed habitat adequately submerged 50%
- Gravel redds adequately submerged most of the time

Lower impoundment

- Median operating conditions create water levels generally suitable for spawning conditions at most SAV beds

Late Spring spawning

- spawning sites are scattered in upper impoundment, abundant in lower impoundment
- remains above179.8 ft, few nests established under median conditions would be abandoned
- If the TFI water level rises following nest construction, nesting success would not be affected.

3.3.15 Sea Lamprey Spawning

Study Objectives

- Identify areas within the Project area where suitable spawning habitat may exist for adult Sea Lamprey
- Conduct spawning surveys to confirm use of areas identified as containing suitable spawning habitat
- Describe spawning mound characteristics, including location, size, substrate, water depth, and velocity
- Collect the information to assess whether operations of the Turners Falls Project and Northfield Mountain Project are adversely affecting spawning areas (*e.g.,* if flow alterations are causing dewatering and scouring of lamprey area)

3.3.15 Sea Lamprey Spawning

Tagging:

- In total 40 adult Sea Lamprey were tagged for this study
- 20 released in the early portion of the run (5/21/15), and 20 in the later portion of the run (5/28/15) at two locations

Mobile Tracking:

- Seventeen days of mobile tracking occurred between June 3 and July 17, 2015
- During tracking potential spawning habitats and/or redds were inspected along the CT River and its confluences

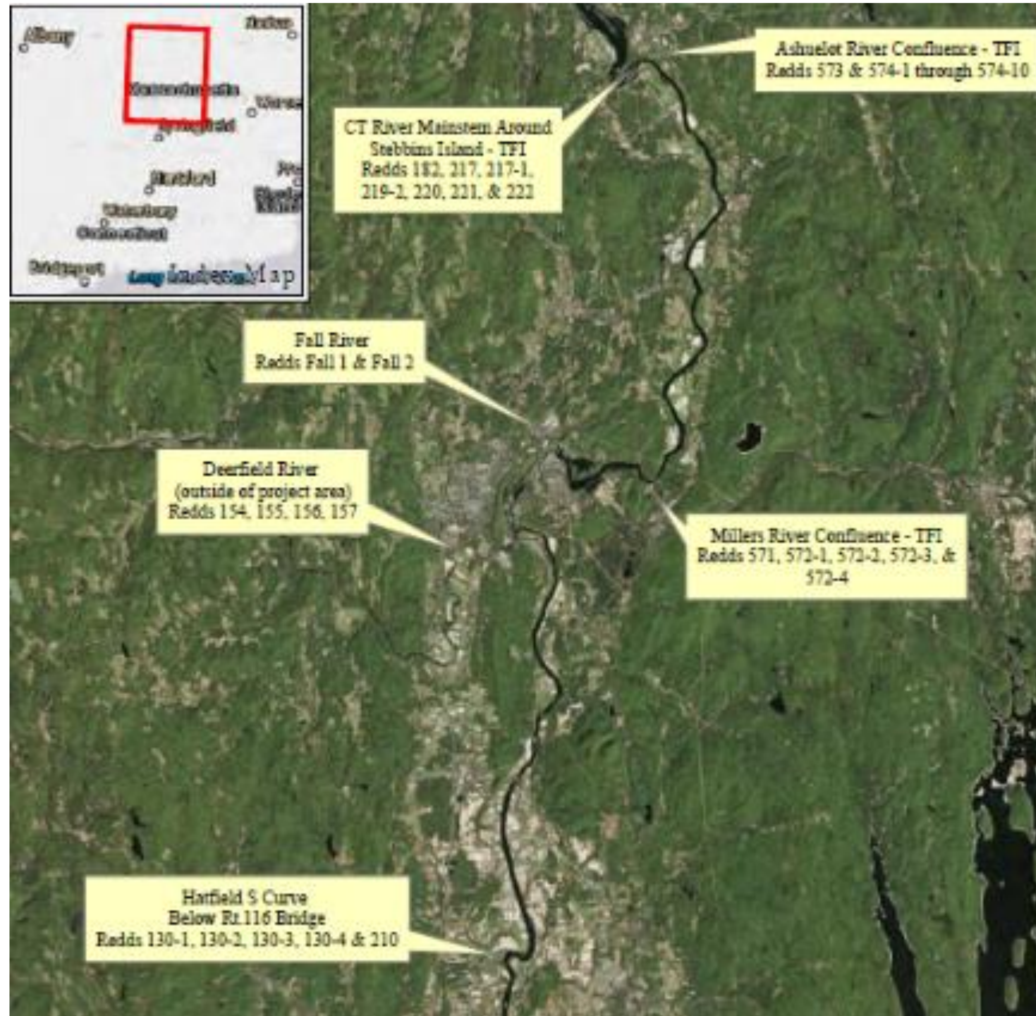
Date of Collection/Release	Collection Location	Number tagged and release location	Number tagged and release location	Total Tagged and Released
5/21/2015 (Early)	Holyoke Dam	10 – Rt. 116 Bridge	10 – Turners Falls Gatehouse	20
5/28/2015 (Late)	Holyoke Dam	10 – Rt. 116 Bridge	10 – Turners Falls Gatehouse	20

FirstLight Power Resources

3.3.15 Sea Lamprey Spawning

Spawning Grounds and Habitat Assessment:

- 29 redds were GPS located in 5 spawning sites
- Marked redds were routinely monitored for:
  - *Depth, velocity, temperature, substrate characteristics, damage and general observations*
- 5 redds were capped using 4x4 ft, weighted PVC framed collection net (1 mm Mesh) to collect any emerging larvae (*Ammocoetes*)

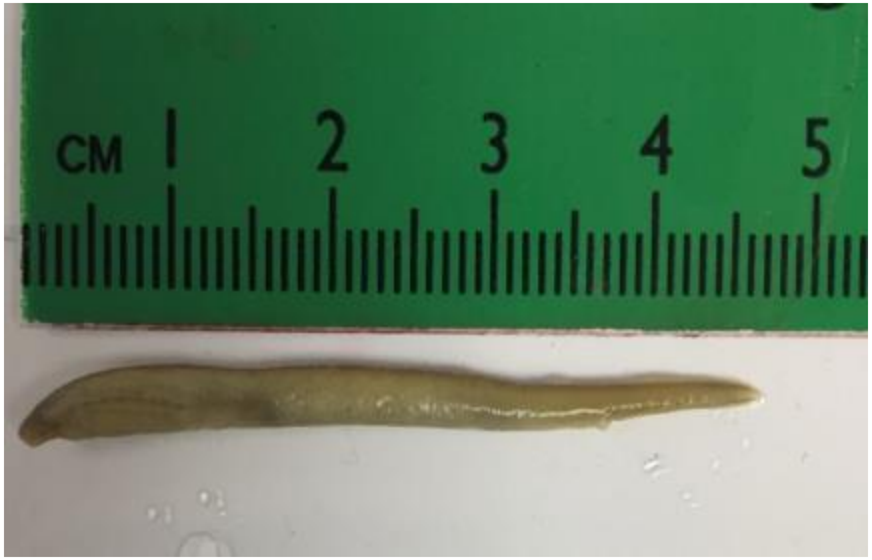


3.3.15 Sea Lamprey Spawning

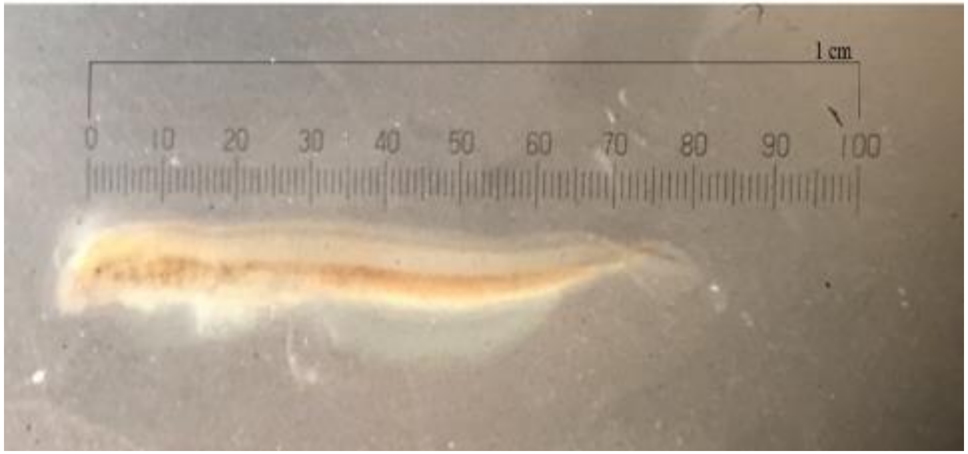
Spawning:

- Caps were left in place for 2 to 3 weeks
- There were 2 caps that successfully captured ammocoetes
- It is difficult to determine the age of these ammocoetes based on length but they are clearly in different stages of development and/or metamorphosis

Hatfield S Curve



Fall River



3.3.15 Sea Lamprey Spawning

Site Specific Habitat Measurements:

Site	Dates Surveyed	Depth (ft)		Velocity (fps)		Dominant Substrate
		Range	Mean	Range	Mean	
Millers River	6/12/15-7/6/15	1.1-2.9	1.91	0.21-4.25	1.98	Cobble
Ashuelot River	6/12/15-7/6/15	0.6-5.8	2.94	0.06-3.02	1.24	Gravel/Cobble
Hatfield S Curve	6/16/15-7/7/15	2.8-7.9	3.96	1.41-2.84	1.77	Cobble
Stebbins Island	6/19/15-7/10/15	1.3-8.8	4.59	0.11-6.08	2.99	Cobble
Fall River	6/17/15-7/31/15	0.6-4.8	1.53	0.02-2.38	0.82	Gravel/Cobble

- The 7 redds around Stebbins Island recorded the highest mean velocity (4.64 fps) and the highest mean depth (7.96 ft) of any spawning sites on June 24, 2015
- The 2 redds in the Fall River recorded the lowest mean velocities (0.44, 0.14 fps) on June 24, 2015 and July 2, 2015, respectively

3.3.15 Sea Lamprey Spawning

Habitat Suitability Mapping:

Turners Falls Impoundment:

- A map of suitable lamprey habitat within the TFI was created based on the HSI criteria developed for FirstLight's IFIM Study No. 3.3.1. Each transect in the TFI hydraulic model was divided into 20 equally sized cells.

- Within in each cell, the hydraulic model produced the mean velocity and depth. These variables, coupled with the substrate data obtained from Study No. 3.3.14 were used to compute the combined suitability index (CSI) value based on the HSI criteria for the sea lamprey spawning life stage

- CSI values range from 0 to 1 with values closest to 1 representing the species' optimal spawning and incubation conditions

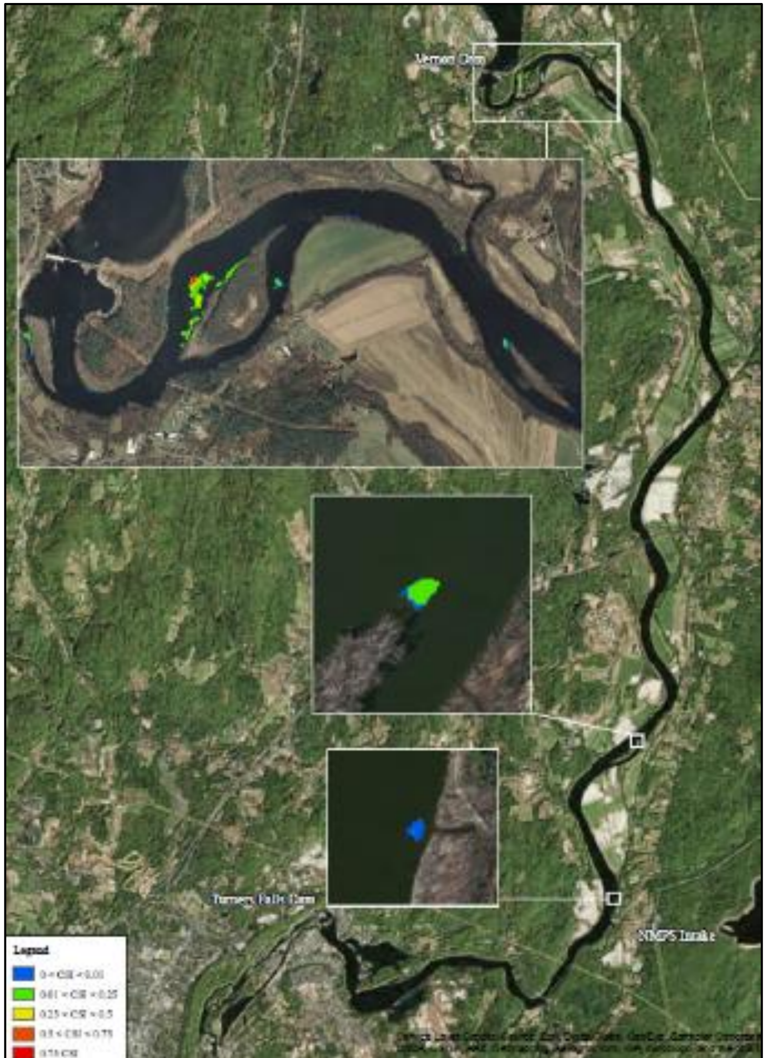
Below Turners Falls Dam:

- FirstLight proposed to evaluate suitable sea lamprey spawning habitat using the IFIM Study No. 3.3.1

Habitat Classification:

- Sea Lamprey spawning habitat within the project area was classified as 1) Non-suitable habitat 2) Suitable habitat no observed spawning 3) Active spawning area 4) Active spawning area with larval sampling

3.3.15 Sea Lamprey Spawning



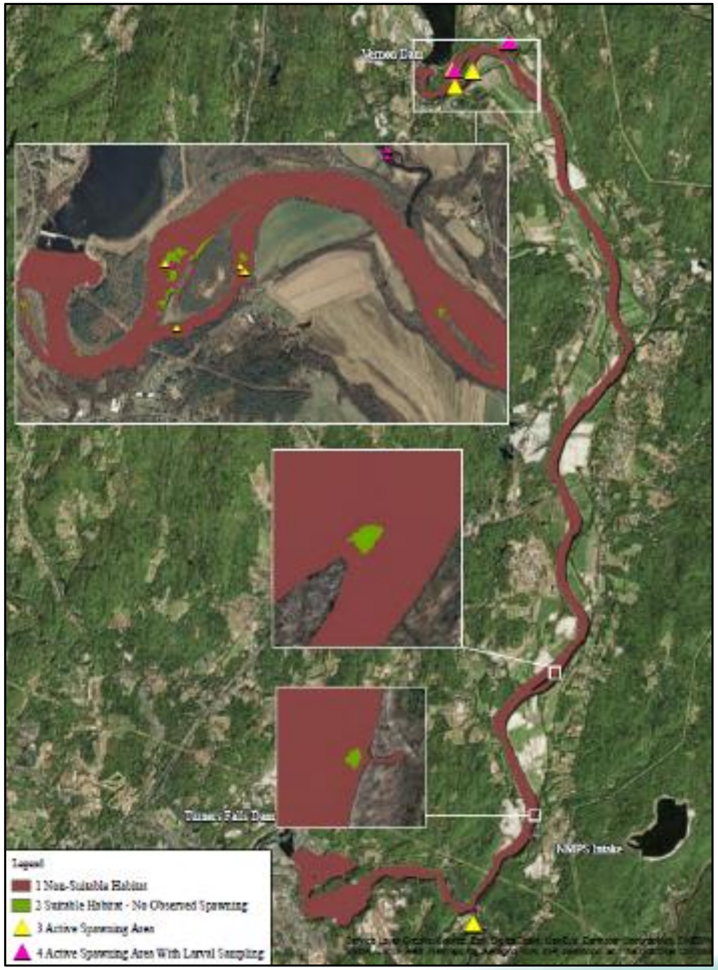
- Suitable Lamprey spawning habitat in TFI with 9,630 cfs at Vernon and NMPS off
- Almost all suitable sea lamprey spawning habitat in the TFI is found near Stebbins Island

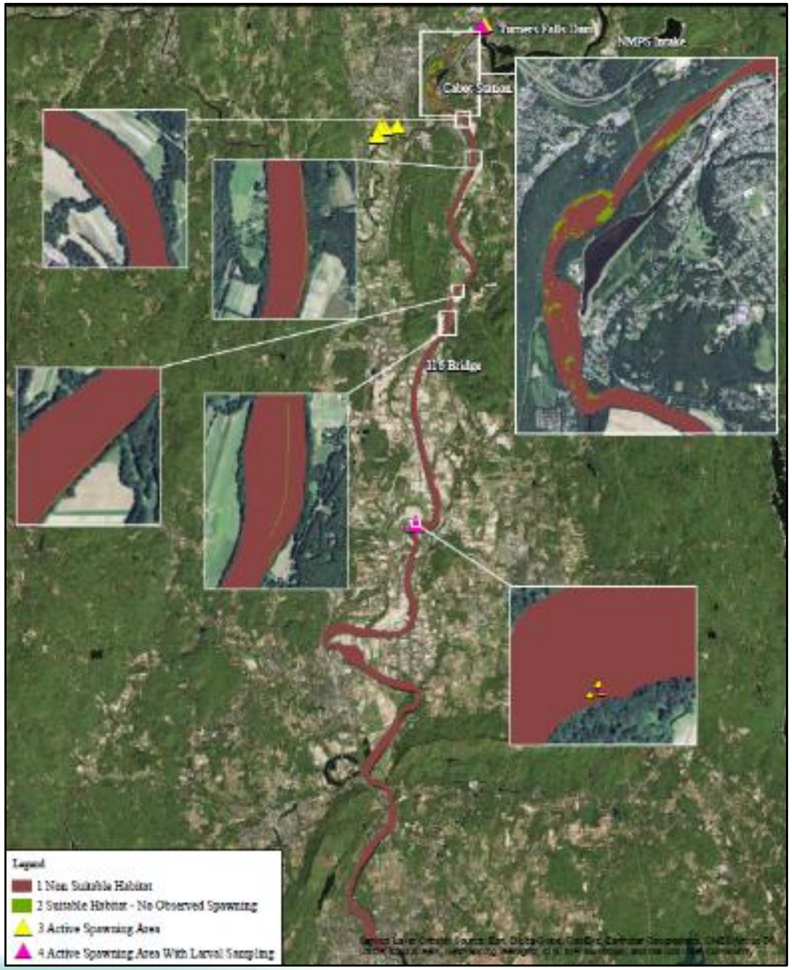
Habitat Suitability Index Values for Velocity, Depth and Substrate

Velocity		Depth		Substrate	
Velocity (fps)	**SI Value**	**Depth (ft)**	**SI Value**	**Substrate Class**	**SI Value**
0.00	0.00	0.00	0.00	Detritus – 1	0.00
0.30	0.00	0.13	0.00	Mud/soft clay – 2	0.00
1.28	0.34	0.46	0.50	Silt – 3	0.00
2.26	1.00	0.79	1.00	Sand – 4	0.04
3.25	0.86	1.12	1.00	Gravel – 5	1.00
4.23	0.30	1.44	0.60	Cobble/Rubble – 6	0.50
5.22	0.12	1.77	0.40	Boulder – 7	0.02
6.20	0.08	2.20	0.20	Bedrock – 8	0.00
6.23	0.00	2.30	0.00		

3.3.15 Sea Lamprey Spawning

Classification of suitable Lamprey spawning habitat above and below Turners Falls Dam





3.3.15 Sea Lamprey Spawning

Effect of Project operations on spawning habitat:

Spawning Site	Classification	Comments
Stebbins Island	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	-Inside Project area - -High velocity and depth under high Vernon discharge conditions
Ashuelot River	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	-Inside Project area --Backwater causing low velocity and increased depth
Millers River	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	N/A
Fall River	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	Backwater causing low velocity and increased depth during high TFD discharge
Hatfield S Curve	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	N/A

3.3.15 Sea Lamprey Spawning

Conclusions:

- Following the criteria for possible Project effects, all five spawning sites monitored in this study were deemed to show no adverse effect due to operations
- Redds in the Fall River are susceptible to backwatering during times of high discharge at the TFD but there were no observation differences to habitat/redd structure or lamprey activity
- Fall River was one of two sites where an ammocoete was successfully captured, along with the Hatfield S curve site
- The Stebbins Island and Ashuelot River redds experienced only minor effects due to discharge at Vernon
- Overall, suitable spawning habitat for sea lamprey is limited in the TFI and the only sizable area is located around Stebbins Island
- The remainder of the TFI lacks appropriate conditions (relatively shallow, fast moving water in cobble or riffle area)

Variances:

- No variances existed in this study

Geology and Soils

3.1.3 Sediment Management Plan

Background

- Majority of the work was completed by the end of 2015
- 2016 activities included:
  - Finishing the physical model
  - Developing the sediment management measures
  - Drafting the final report
- Final Study Report filed October 14, 2016

Study Objectives

- To better understand sediment transport and dynamics between the Connecticut River and Upper Reservoir and to evaluate management measures to minimize the potential entrainment of sediment into the Project works and Connecticut River.

Work Completed

- Suspended sediment monitoring and grab sample collection (2012-2015)
- Annual Upper Reservoir Bathymetric Surveys (2011-2015)
- Computational modeling, including:
  - Upper Reservoir Computational Hydrodynamic Sedimentation Model (2013-2014), and
  - Northfield Mountain Tailrace CFD Model (2014-2015)
- Development of a physical model of the Northfield Mountain tailrace and surrounding area (2015-2016)
- Pilot dredge of the Upper Reservoir (2015)
- Development of proposed sediment management measures (2016)

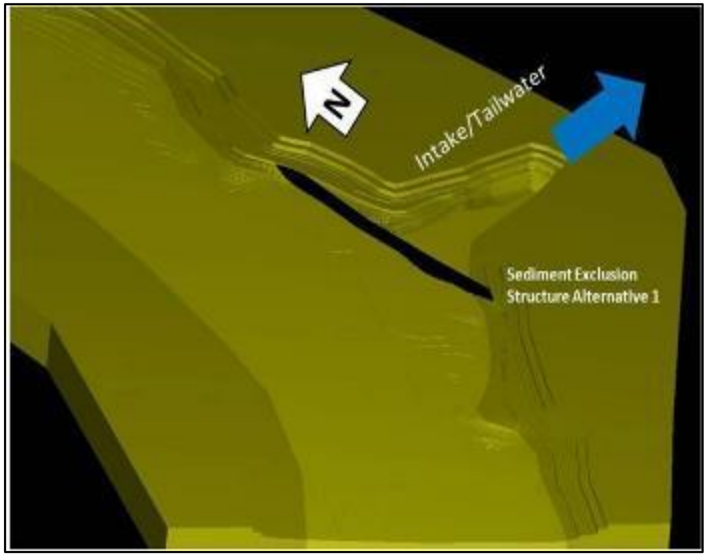
3.1.3 Sediment Management Plan

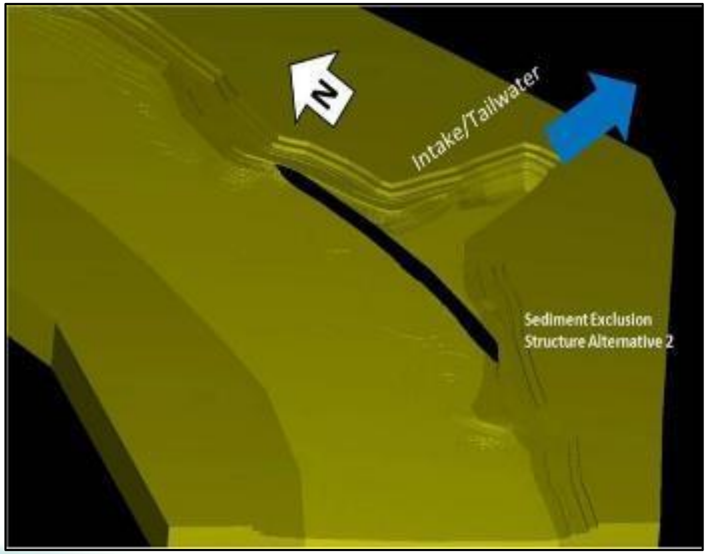
Conclusions

- **Computational hydrodynamic sedimentation model of the Upper Reservoir**:
  - Root cause of sedimentation in the Upper Reservoir likely begins with relatively high concentrations of entrained bed and suspended sediment loads from the Connecticut River transported during pumping phases
  - Once the water and sediment reach the wider and deeper Upper Reservoir intake channel a deceleration of the sediment rich pumped water occurs as well as subsequent deposition of the sediment in the upper reservoir
  - Exit velocities are lower in the intake channel under generation, meaning that much of the deposited sediment is not re-entrained during generation and discharged to the Connecticut River.
  - Findings are consistent with the observations made from the bathymetric and suspended sediment data analyses.
  - Changes in operating procedures and/or physical modifications to the Upper Reservoir intake channel which were analyzed were found to have minimal impact on reducing the amount of sediment entrained.

3.1.3 Sediment Management Plan

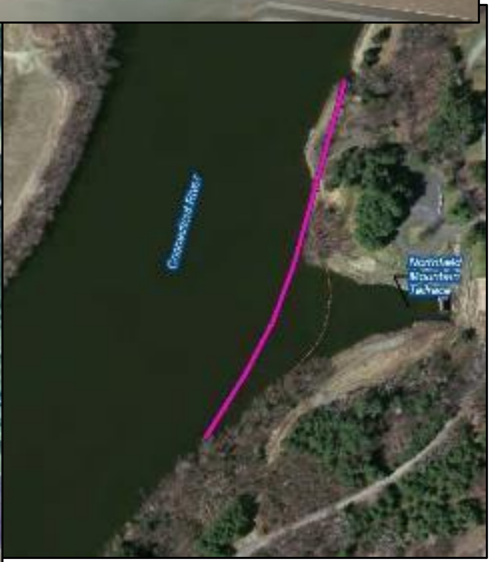
- **CFD modeling of the tailrace area**:
  - Operational conditions with 3 or 4 pumps were found to cause the majority of sediment uptake to the Upper Reservoir
  - Model examined the effectiveness of constructing two different types of sediment exclusion structures including a shorter convex and longer concave sill built above the bed of the intake and spanning the width of the tailrace
  - Modeling results showed that these potential management measures were more effective than the Upper Reservoir alternatives, however, they were still found to have limited effectiveness overall





3.1.3 Sediment Management Plan

- **Physical model of the tailrace area**:
  - Examined the effectiveness of two different 1,000 ft. long sediment exclusion structures, one with a 700 ft. long fixed crest overflow section and the other with a 700 ft. long moveable crest overflow section
  - Potential structures were modeled in the approximate location of the original riverbank prior to construction of NFM
  - The model found that constructing a sediment exclusion structure would have low to moderate effectiveness
    - The fixed crest overflow alternative had a similar, limited effectiveness as observed from the results of the tailrace CFD model.
    - The moveable crest overflow section was found to be slightly more effective than the fixed crest section
- Based on the findings of the various modeling efforts, operational changes or physical modifications were not considered for further evaluation as potential sediment management measures due to their limited effectiveness



3.1.3 Sediment Management Plan

Pilot Dredge:

- Approximately 46,000 cubic yards of sediment were successfully removed from within and immediately upstream of the Upper Reservoir intake by deep water hydraulic dredging
- On average 26 cubic yards of sediment per hour were removed
- The availability of the Project for generation and pumping was not affected by the dredging operations
- The dredging operation successfully removed sediment from within and upstream of the Upper Reservoir intake channel without having any material sediment impacts to the Project works or sediment discharges to the Connecticut River
- Hydraulic dredging was found to be a viable sediment management measure

3.1.3 Sediment Management Plan

Proposed Sediment Management Measures

- Encompass the most effective and successful management measures examined over the course of the study
- Focus on minimizing the entrainment of sediment into the Project works and Connecticut River during dewatering activities
- Proposed measures include:
  1. Employ a monitoring program based on bathymetric surveys of the Upper Reservoir and intake channel (conducted every 1-2 years) to determine the amount of sediment present at a given time
  2. Results of the surveys will be reviewed to determine: the estimated depth, location, and shape of accumulated sediment as well as the estimated incremental amount of sediment which has accumulated between surveys
  3. Based on this review, excavation of the intake channel and/or other target areas will be planned and initiated as needed to minimize the potential for entrainment of sediment into the Project works and Connecticut River during dewatering activities
  4. Excavation would occur via methods including, but not limited to, hydraulic dredging prior to dewatering or mechanical excavation after dewatering. The method will be developed based on the location and amount of sediment, the necessary timeframe for removing the sediment, and then-available technologies and methods
  5. FirstLight will notify MADEP, FERC, and USEPA in advance of any excavation activities

3.1.3 Sediment Management Plan

Proposed Sediment Management Measures (cont.)

6. Following completion of excavation activities, a bathymetry survey of the excavated area will be conducted in order to establish an updated baseline
7. FirstLight will develop protocols to be followed in the event of a dewatering (both emergency and maintenance or other types). Dewatering protocols will be provided to MADEP, FERC, and USEPA. Protocols may be updated periodically as needed
8. In the event of a dewatering, FirstLight will visually monitor turbidity in the tailrace area throughout the dewatering for any noticeable increases
9. FirstLight may explore other sediment management measures as technological advancements occur and the understanding of sediment dynamics at the Project continues to evolve. FirstLight will consult with MADEP, FERC, and USEPA in the event that future modifications are made.

Variances

- None, however, the study scope was expanded as the study progressed (i.e., additional monitoring years, computational modeling, physical model, pilot dredge).

3.1.2 Erosion Causation Report

Background

- Study was initiated in 2013 following issuance of FERC SPDL
- Addendum to the RSP was filed in 2014 to examine the impacts of ice as a result of the closure of Vermont Yankee
- Study examined a 15-year period (2000-2014)
- Data gathering, field data collection/post processing, and data analyses occurred 2013-2016
- BSTEM, HEC-RAS, and River2D Modeling occurred 2015/2016
- Supported by data from other studies, including:
  - 3.1.1 *Full River Reconnaissance;*
  - 3.1.3 *Northfield Mountain Project Sediment Management Plan;* and
  - 3.2.2 *Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot Station*
- Study team included personnel from Simons & Associates; Gomez and Sullivan Engineers; Cardno; The National Center for Computational Hydroscience at the University of Mississippi; and Dr. Kit Choi, PE. Field support also provided by New England Environmental. Study team was approved by MADEP prior to the study commencing

Work Completed

- All tasks identified in the RSP and addendum to the RSP have been completed

Variances

- Supplemental boat wave data collection and analysis (discussed at 2015 USR meeting)

Study Objectives

- Primary goal of the study was to evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations.
- In order to accomplish this goal a number of objectives were identified:
  1. Conduct a thorough data gathering and literature review effort of existing relevant data to identify data gaps
  2. Conduct field investigations and field data collection to fill data gaps. Gather the field data required to conduct detailed analyses of the causes of erosion and forces related to them
  3. Develop an understanding of the historic and modern geomorphology of the Connecticut River to provide context when analyzing the modern geomorphology
  4. Identify the causes of erosion present in the Turners Falls Impoundment, the forces associated with them, and their relative importance at a particular location. Conduct various data analyses to gain a better understanding of these causes and forces
  5. Identify and establish fixed riverbank transects that will be representative of the range of riverbank features, characteristics, and conditions present in the Turners Falls Impoundment
  6. Conduct detailed studies and analyses of erosion processes at the fixed riverbank transects
  7. Evaluate the causes of erosion using the field collected data and the results of the proposed data analyses. This evaluation will include quantifying and ranking all causes present at each fixed riverbank transect as well as in the Turners Falls Impoundment in general
  8. Develop a final report that will summarize the findings of this study and the methods used

3.1.2 Erosion Causation Report

Potential Primary Causes of Erosion Assessed *(per the RSP)*

- Land management practices and anthropogenic influences
- Ice*
- Hydraulic Shear Stress due to flowing water
- Water level fluctuations due to hydropower operations
- Boat waves

** Originally classified as a potential secondary cause of erosion prior to the closure of Vermont Yankee*

Potential Secondary Causes of Erosion Assessed *(per the RSP)*

- Animals
- Wind waves
- Seepage and piping
- Freeze-thaw

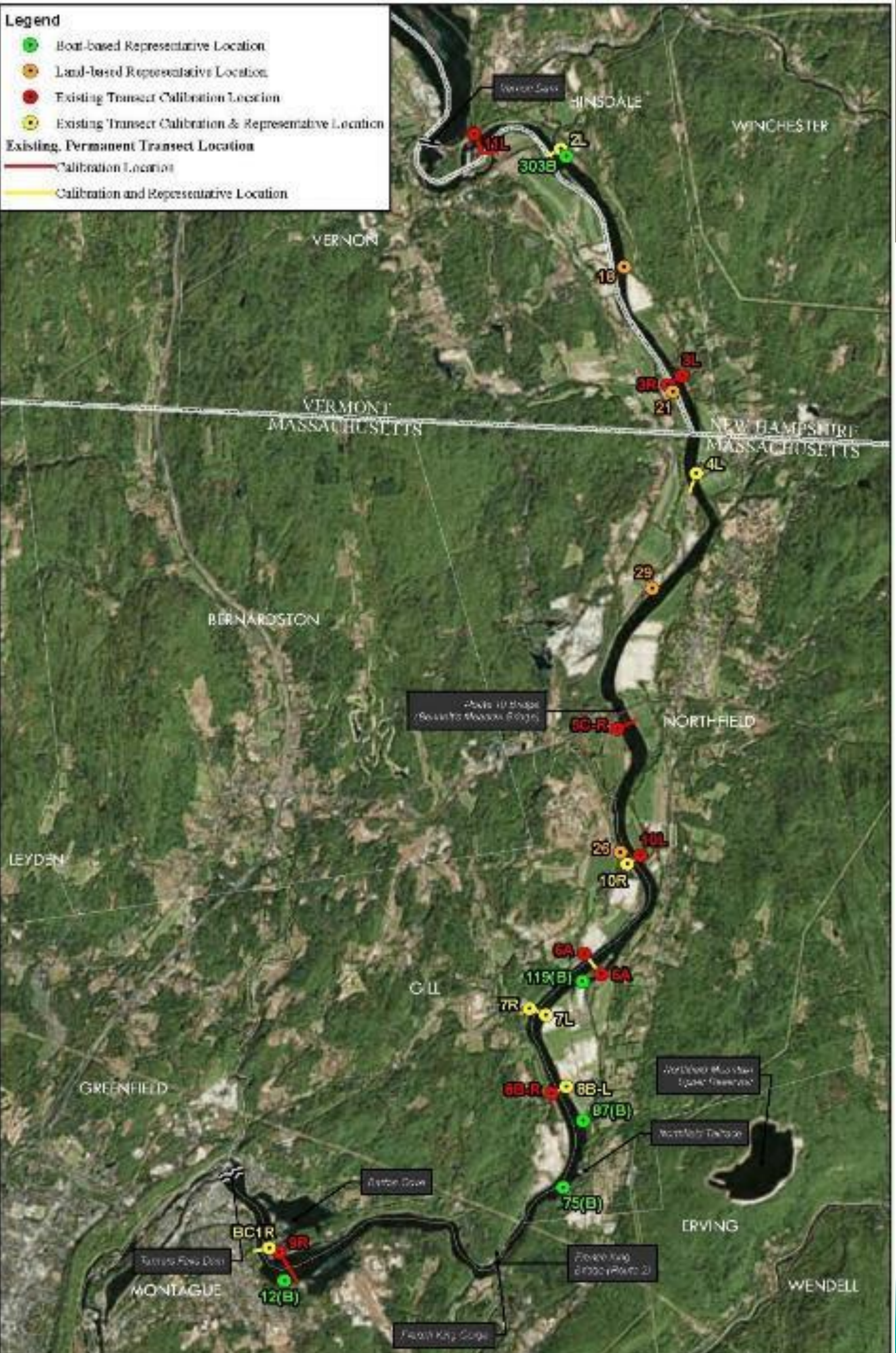
3.1.2 Erosion Causation Report

Data Analyses

- Historic geomorphic assessment and analysis of historic datasets
- Hydrology and hydraulics
  - Hydraulic shear stress, water level fluctuations, energy grade line slope, flow thresholds, etc.
- Near-bank groundwater and pore-water pressure
- Sediment transport
- Geotechnical evaluations
- Hydraulic and geotechnical erosion processes
- Boat waves – physical processes and their impact
- Land management practices
- Ice

Tools Used

- Historic imagery, photos, and documentation
- Various field data collection methods, equipment, and instruments
- Cross-section surveys, Project operations data, hydrologic data – 2000-2014
- HEC-RAS
- River2D
- Bank Stability and Toe Erosion Model (BSTEM)
- GIS – Digital elevation Models, LiDAR, aerial imagery, and other layers



3.1.2 Erosion Causation Report

Detailed Study Sites

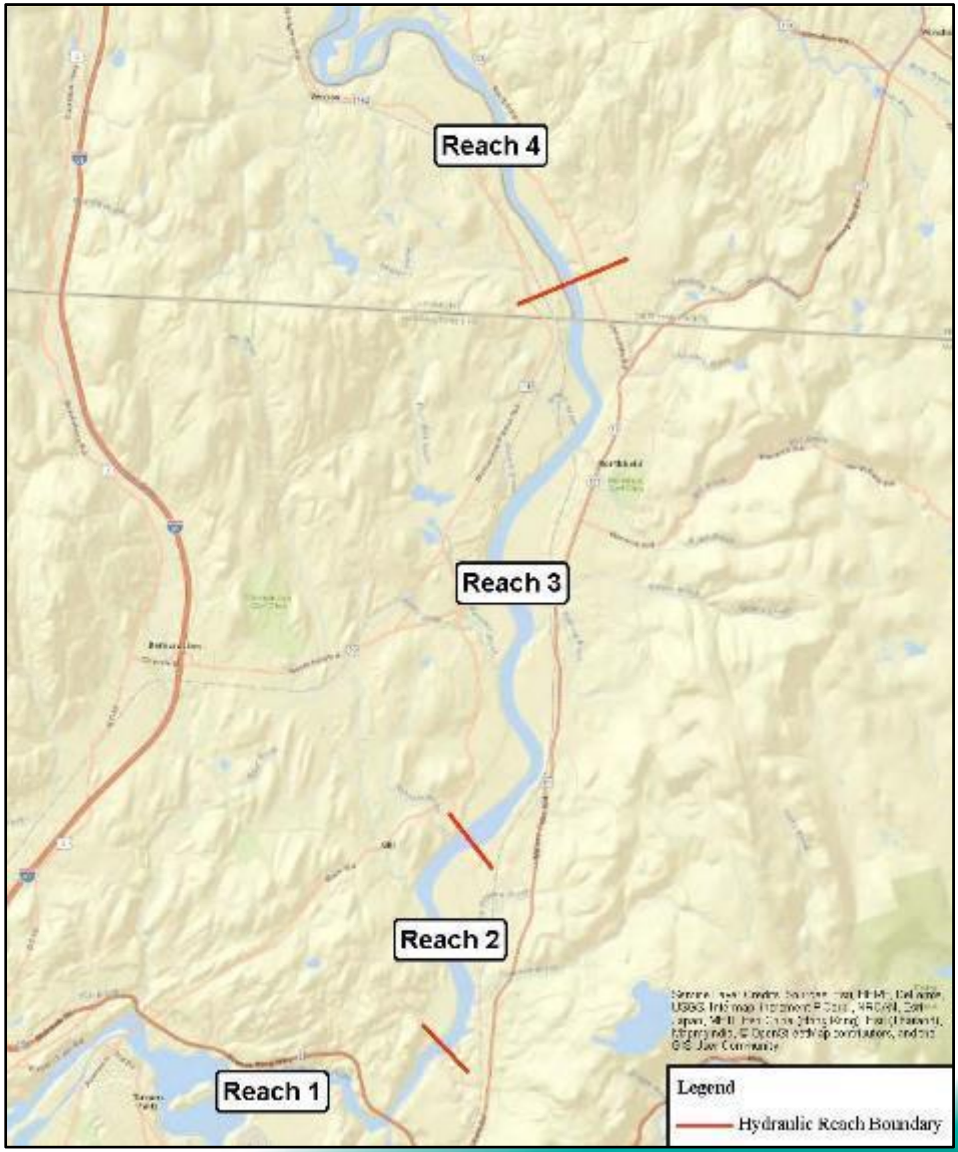
- Selected in collaboration with stakeholders, presented in *Selection of Detailed Study Sites Report* (September 2014)
- 25 sites spanning the geographic extent of the TFI
- Encompassed a representative range of riverbank features, characteristics, erosion conditions, and hydraulic characteristics
- Included both restored and non-restored sites
- Located at sites which have been surveyed annually since the 1990’s (16) and newly identified sites (9)
- Classified as either Calibration or Representative sites
- The potential primary causes of erosion, and the forces associated with them, were analyzed in-depth at each site (i.e., extensive field data collection, hydraulic and BSTEM modeling)
- Results were then extrapolated throughout the TFI

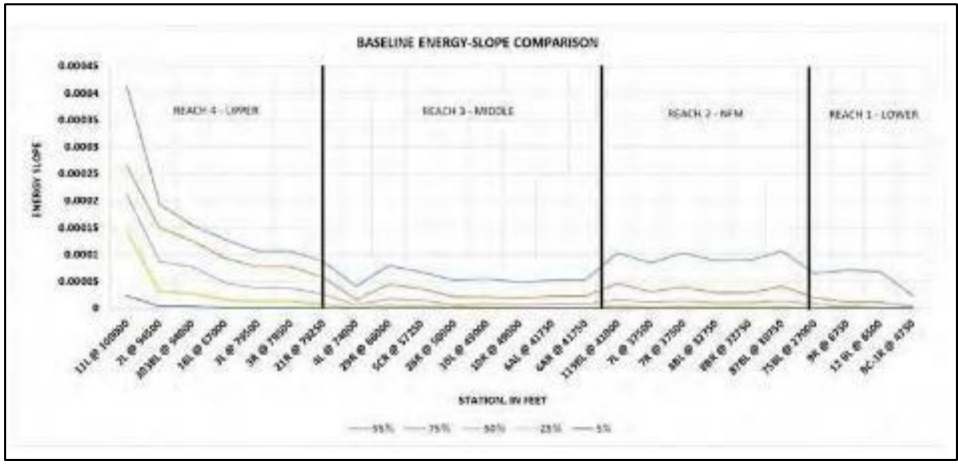
Hydrology & Hydraulics – Key Findings

- The generating capacity of Vernon is 17,130 cfs, NFM is 20,000 cfs (4 units gen) or 15,200 cfs (4 units pump), and Turners Falls is 15,938 cfs
- At flows greater than ~30,000 cfs the French King Gorge becomes the primary hydraulic control for the middle and upper portion of the TFI
- Four hydraulic reaches were identified based on analysis of the Energy Grade Line Slope (HEC-RAS):
  - Lower Reach (Reach 1)
  - Northfield Mountain Reach (Reach 2)
  - Middle Reach (Reach 3)
  - Upper Reach (Reach 4)
- Although hydropower project operations can impact flows and water levels beyond their given hydraulic reach, the impacts at flows which cause erosion (as determined by BSTEM) are minor enough that they do not alter the EGL slope, and therefore the velocity or shear stress, outside of their reach
- The results of the hydraulic and BSTEM modeling indicated that hydropower operations can only potentially impact erosion processes within the hydraulic reach where the project is located due to the varying hydraulic characteristics of the TFI
  - In other words, the models showed that Vernon operations can only potentially impact erosion in Reach 4, NFM operations in Reach 2, and Turners Falls operations in Reach 1

FirstLight Power Resources

3.1.2 Erosion Causation Report





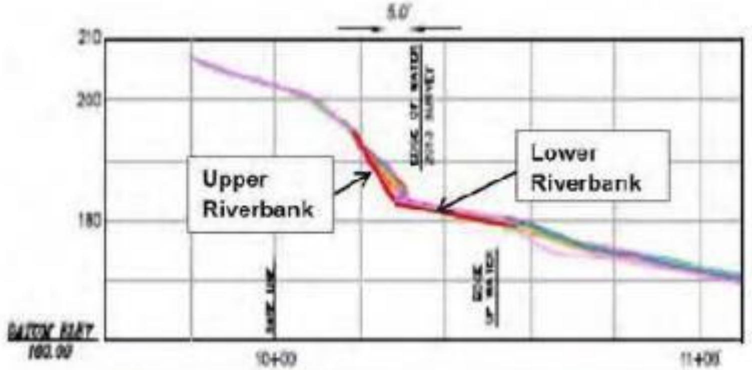
Hydrology & Hydraulics – Key Findings (cont.)

- Three flow ranges present in Reaches 1-3: (1) <17,130 cfs (low flow), (2) 17,130 - 37,000 cfs (moderate flow), and (3) >37,000 cfs (high flow)
  - In Reach 4 (Upper) only two flow ranges were identified: <17,130 cfs (low to moderate) and >17,130 cfs (moderate to high). This was based on the generating capacity of Vernon.
- 37,000 cfs was identified as the high flow threshold for a number of reasons, including:
  - It exceeds the flows at which the French King Gorge becomes the hydraulic control
  - It exceeds the generating capacity of Vernon
  - It exceeds the maximum combined generating capacity for Vernon and NFM at a given location
  - Although NFM can operate at flows >37,000 cfs, historical operating records indicate this only occurred 0.025% (4 units gen) to 2.6% (1 unit gen) of the time during the 15-year modeling period.
- During high flows, the dominant impact on flow and water level is naturally occurring flows, not hydropower operations

3.1.2 Erosion Causation Report

Hydrology & Hydraulics – Key Findings (cont.)

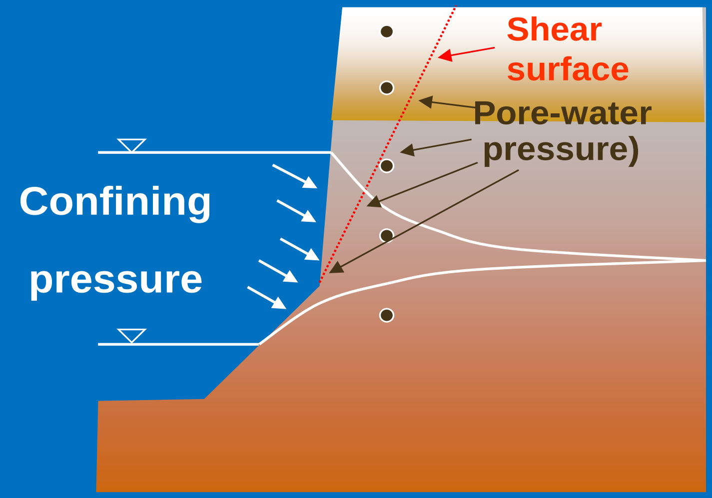
- The results of the study found that the vast majority of erosion only occurs once the water level reaches the upper riverbank
- Water levels rest on the lower bank 78% to 99% of the time depending on the location in the TFI.
- The flows required for the water level to reach the upper bank, and for the majority of erosion to occur, are often greater than the natural high flow threshold (37,000 cfs)
  - Based on the results of the BSTEM flow analysis (50% and 95% erosion flow thresholds), 50% of all erosion occurred at flows much greater than 37,000 cfs for 22 of the 25 simulations which were analyzed. Minimal to no erosion was found to occur at the three other sites.
  - Modeling results also indicated that 95% of all erosion occurred at flows greater than 37,000 cfs for the majority of detailed study sites

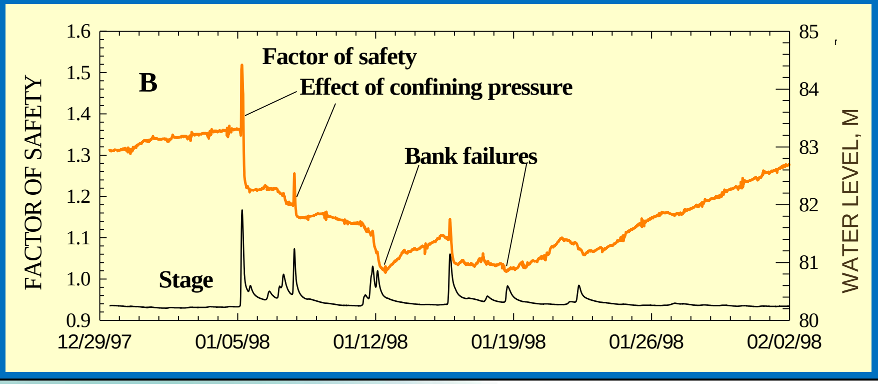


Application of BSTEM-Dynamic Ver. 2.3

- 2-D wedge- and cantilever-failures
- Search routine for failures
- 15-year flow series (1-hour time steps) for stage and water-surface slope
- Hydraulic toe erosion
- Accounts for grain roughness
- Hydraulic roughness by layer
- Complex bank geometries
- Positive and negative pore-water pressures
- Fluctuating groundwater levels
- Confining pressure from flow
- Layers of different strength
- Vegetation effects: RipRoot
- Boat waves
- Inputs from field measurements:

  γ_s, c', ϕ', ϕ^b, h, u_w, k, τ_c





Determination of Primary Causes of Erosion

- **Moderate or High Flows** *(hydraulic shear stress due to flowing water)*: flow analysis which resulted in identification of the erosion flow threshold at which 50% and 95% of all erosion occurs at a given site.

- **Boats** *(boat waves)*: BSTEM was enhanced with a built-in boat wave module for this study. Two BSTEM runs were executed – boat waves “on” and boat waves “off”. The difference in observed erosion between the two model runs determined the sites where boat waves were a cause of erosion

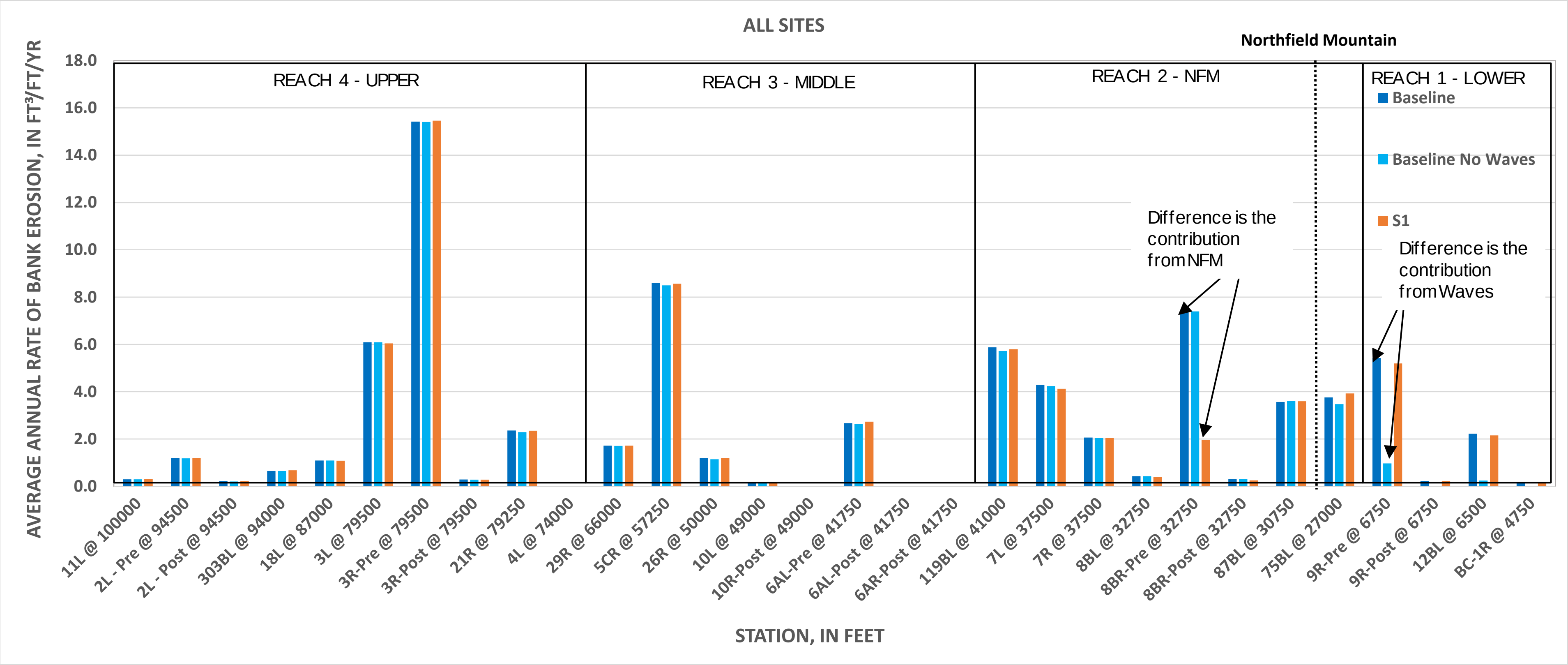
- **Vernon Operations** *(hydraulic shear stress due to flowing water, water level fluctuations due to hydropower operations)*: the results of the flow analysis were used to identify areas within the Upper Reach where erosion was observed at flows below 17,130 cfs

- **Northfield Mountain Operations** *(hydraulic shear stress due to flowing water, water level fluctuations due to hydropower operations)*: two BSTEM runs were executed, one representing the Baseline Condition and one representing NFM as idle. The difference in observed erosion between the two model runs determined the sites where NFM operations were a cause of erosion

- **Turners Falls Operations** *(hydraulic shear stress due to flowing water, water level fluctuations due to hydropower operations)*: modified extrapolation approach which utilized a combination of BSTEM results, geomorphic assessment, and hydraulic model analysis

3.1.2 Erosion Causation Report

BSTEM Results



Study Findings – Dominant Causes

- Dominant Primary Cause of Erosion: the cause of erosion responsible for greater than 50% of erosion at any given site.
- Study results found that naturally occurring high flows were the most prevalent dominant primary cause of erosion, followed by boat waves, and Vernon operations
- Northfield Mountain or Turners Falls Operations were not found to be a dominant primary cause of erosion at any riverbank segment
  - NFM operations contributed to less than 5% of the total erosion at 5 of the 7 sites in the NFM Reach
  - At Site 8BR-Post, NFM operations contributed to ~20% of the total erosion (0.312 ft^3/ft/yr.)
  - At Site 8BL, NFM operations contributed to ~7% of the total erosion (0.427 ft^3/ft/yr.)
- Dominant primary causes of erosion followed a clear spatial pattern
  - Vernon Operations: Vernon Dam to Stebbins Island
  - Natural High Flows: Stebbins Island to upstream of the entrance to Barton Cove
  - Boat Waves: upstream of the entrance to Barton Cove to Turners Falls Dam

Dominant Primary Causes of Erosion	% of Total Riverbank Length	Total length
Natural High Flows	78%	175,900 ft. (33 mi.)
Boat waves	13%	30,800 ft. (6 mi.)
Vernon Operations	9%	20,200 ft. (4 mi)
Northfield Mountain Operations	0%	0 ft.
Turners Falls Operations	0%	0 ft.
Ice	I	I

I = Indeterminate

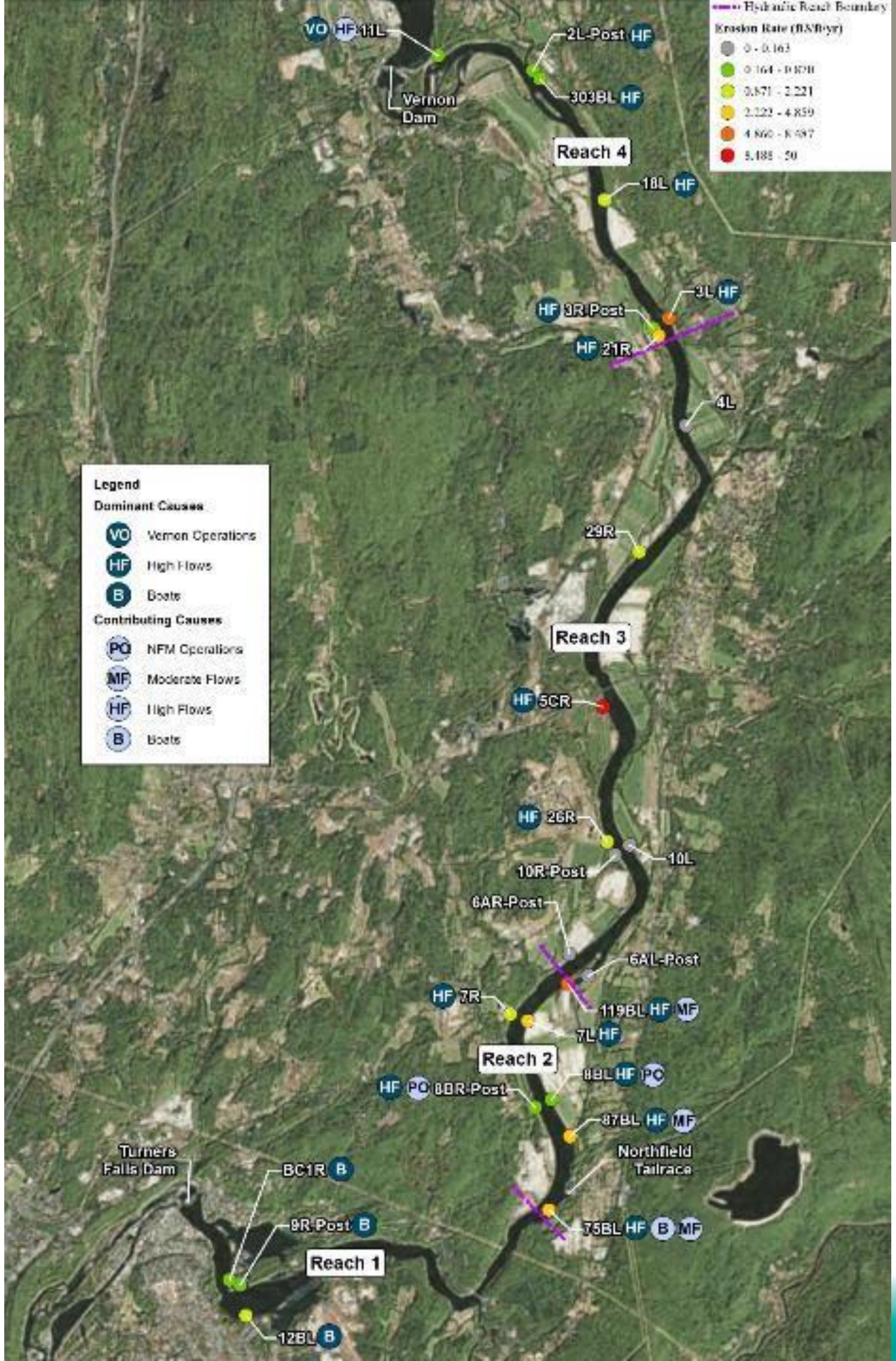
3.1.2 Erosion Causation Report

Study Findings– Contributing Causes

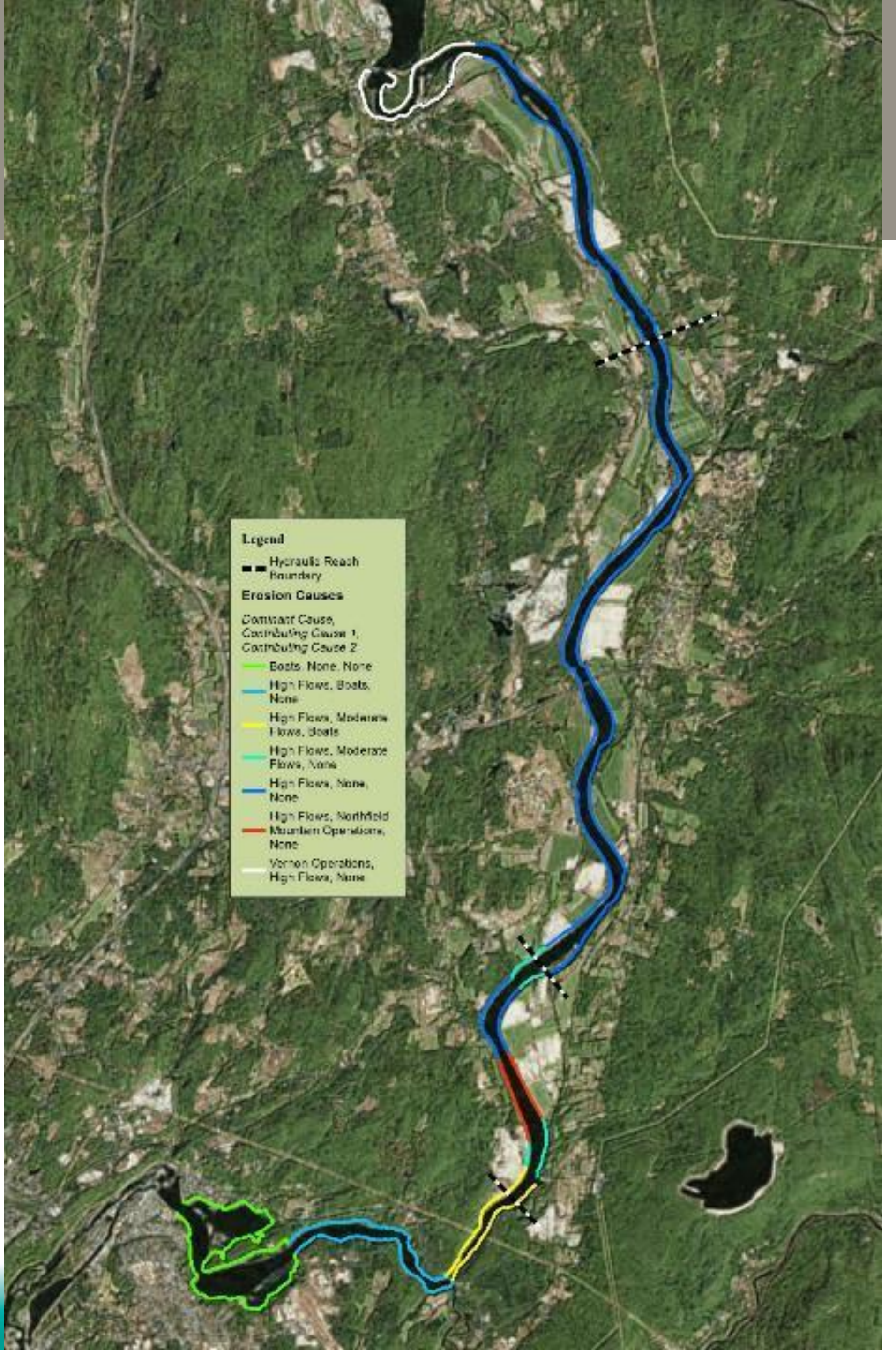
- Contributing Primary Cause of Erosion: the cause(s) of erosion responsible for greater than 5%, but less than 50%, of erosion at any given site.
- Natural high flows were such a dominant factor in erosion processes that no other contributing primary causes of erosion were identified at the majority of riverbank segments
- At riverbank segments that did have contributing primary causes of erosion, boat waves were most prevalent followed by natural moderate flows and Northfield Mountain operations
- Vernon or Turners Falls operations were not found to be contributing causes of erosion at any riverbank segment
- Land-use was found to be a potential contributing cause of erosion at 44% of the riverbank segments
- Secondary causes of erosion (i.e., animals, wind waves, etc.) were not found to be a dominant or contributing cause at any riverbank segment

Contributing Primary Causes of Erosion	% of Total Riverbank Length	Total length
None	68%	153,400 ft. (29 mi.)
Boats	16%	36,000 ft. (7 mi.)
Natural Moderate Flows	10%	23,200 ft. (4 mi.)
Natural High Flows	9%	20,200 ft. (4 mi.)
Northfield Mountain Operations	4%	8,600 ft. (1.5 mi.)
Vernon Operations	0%	0 ft.
Turners Falls Operations	0%	0 ft.
Ice	I	I

I = Indeterminate



Hydraulic Reach Boundary
Erosion Rate (ft3/ft-yr)
0 - 0.163
0.871 - 2.221
2.222 - 4.859
VO HF 11L
2L-Post HF
303BL HF
Vernon Dam
Reach 4
18L HF
3L HF
HF 3R Post
HF 21R
4L
Legend
Dominant Causes
VO Vernon Operations
HF High Flows
B Boats
Contributing Causes
PO NFM Operations
MF Moderate Flows
HF High Flows
B Boats
29R
Reach 3
HF 5CR
HF 26R
10L
10R-Post
6AR-Post
6AL-Post
HF 7R
119BL HF MF
7L HF
Reach 2
8BL HF PO
HF PO 8BR-Post
87BL HF MF
Northfield Tailrace
Turners Falls Dam
BC1R B
9R-Post B
75BL HF B MF
Reach 1
12BL B



Legend
Hydraulic Reach Boundary
Erosion Causes
Boats, None, None
High Flows, Boats, None
High Flows, Moderate Flows, Boats
High Flows, Moderate Flows, None
High Flows, None, None
High Flows, Northfield Mountain Operations, None
Vernon Operations, High Flows, None

3.1.2 Erosion Causation Report

Extrapolation Methodology

- Multi-step process used to extrapolate the results of the detailed study sites to every riverbank segment identified during the 2013 Full River Reconnaissance
- Steps included:

1. **Analyze the variability of hydraulic forces throughout the TFI**
2. **Analyze and review the site specific BSTEM results**
3. **Analyze riverbank features, characteristics, and erosion conditions**
   a) Identify the detailed study sites where hydropower operations were the dominant or contributing cause of erosion
   b) Identify the riverbank features, characteristics, and erosion conditions at those sites based on the 2013 FRR
   c) Identify other segments in the hydraulic reach that have the same features or characteristics
   d) Compare the locations of those segments against (1) the results of the nearest detailed study site, and (2) the hydraulic and geomorphic conditions at each location to determine if the riverbank features and characteristics or the hydraulics/geomorphology are the likely factors influencing erosion
4. **Assign the dominant and contributing causes of erosion to each riverbank segment identified during the 2013 FRR:**
   a) Identify sites where hydropower operations were found to be a dominant or contributing cause of erosion based on Steps 3c and 3d
   b) Extrapolate the results from a given detailed study site, halfway upstream and halfway downstream to the nearest detailed study site
5. **Conduct supplemental hydraulic and geomorphic analyses in Reach 1 to determine the impact, if any, of Turners Falls operations**
6. **Analyze land-use and width of riparian buffers**
7. **Create a map identifying the cause of erosion for each segment and calculate summary statistics**

Ice

- The closure of Vermont Yankee increases the potential for ice formation in the Turners Falls Impoundment
- Included historic analysis of ice formation and break-up in the TFI, upstream impoundments, and other river systems and observations of ice formation and break-up in the TFI during winter 2014/2015
- The impact of ice on erosion processes was not quantified as it was not a cause of erosion examined in BSTEM
- The results of the various analyses and observations found that:
  - Ice typically does not cause erosion if it simply melts in place without significant break-up and if ice floes moving down river causing ice jams and impacting banks do not occur. This is consistent with the findings of the historic analysis conducted and with observations made during the winter 2014/2015 when much of the TFI was frozen over
  - If there is significant break-up and ice floes moving down river occur, then such an event could potentially cause erosion and damage to the riverbanks
  - Analysis of historic data from the TFI and upstream impoundments found that ice has caused severe erosion under the right conditions (i.e., severe break-up, ice floes, and ice jams) and has contributed to bank instability which can eventually lead to erosion
  - These processes can also greatly effect riverbank vegetation thus also impacting the stability of the bank.
  - Available information and observations indicate that Project operations do not cause an ice break-up event to occur, as ice break-up events occur as a result of weather and hydrologic conditions which are independent of Project operations
- Based on the results of the analysis which was conducted, ice has the potential to be a naturally occurring dominant primary cause of erosion in the TFI in the future if the right weather and hydrologic conditions persist.

3.1.2 Erosion Causation Report

<u>Land Management Practices</u>

- Investigation included field observations and geospatial analysis of land management practices and anthropogenic influences to the riparian zone throughout the TFI
- Although a variety of land-uses are found along the banks adjacent to the TFI, the strongest correlations between land-use and erosion have been observed in agricultural or developed areas
- Agricultural land-use practices can lead to erosion or bank instability due to the narrow riparian buffers that often exist at these fields as well as irrigation practices which may be employed
- Erosion has also been observed in areas where houses and other associated development are located in close proximity to the river
- Areas where the riparian buffer was found to be less than 50 ft. and the adjacent land-use was classified as Agriculture or Developed were identified in order to determine the potential impact land management practices may have on erosion processes. Segments that met this criteria were classified as being a potential contributing cause of erosion.
  - The results of this analysis found that 44% of the TFI riverbanks (19 mi.) met this criteria
- In addition, BSTEM's RipRoot sub-model also analyzed the impact of vegetation on bank stability throughout the TFI

3.1.2 Erosion Causation Report

Summary

- The study was conducted in accordance with the RSP and satisfied all study objectives
- The unique and varying hydraulic characteristics of the TFI play an integral role in erosion processes
- NFM or Turners Falls Project operations were not found to be a dominant primary cause of erosion at any riverbank segment in the TFI
- NFM operations were found to be a contributing primary cause of erosion at two detailed study sites in the NFM Reach (4% of total riverbank length). Turners Falls operations were not found to be a contributing primary cause of erosion at any riverbank segment in the TFI
- Naturally occurring high or moderate flows were found to be the dominant primary cause of erosion throughout the vast majority of the TFI
- Boat waves were found to be the dominant primary cause of erosion in the Barton Cove area
- Ice has the potential to be a naturally occurring dominant primary cause of erosion in the TFI in the future if the right weather and hydrologic conditions persist
- Potential secondary causes of erosion (i.e., wind waves, animals, etc.) were found to be insignificant in causing erosion in the TFI beyond the limited, localized areas where they may exist

Recreation

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

<u>Study Objective</u>

Determine if the operation of the Northfield Mountain Project and Turners Falls Project has an effect on recreation facilities or land use within either Project and down to the Sunderland Bridge

Note: While consideration of Project operational effects on land use was included in the objectives statement of this study, this assessment focused on project operational effects, primarily water levels and flows, on recreation sites and facilities. Land use effects were considered in studies 3.1.2 (Erosion Causation Study), 3.1.1 (River Reconnaissance) and 3.6.5 (Land Use Inventory)

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

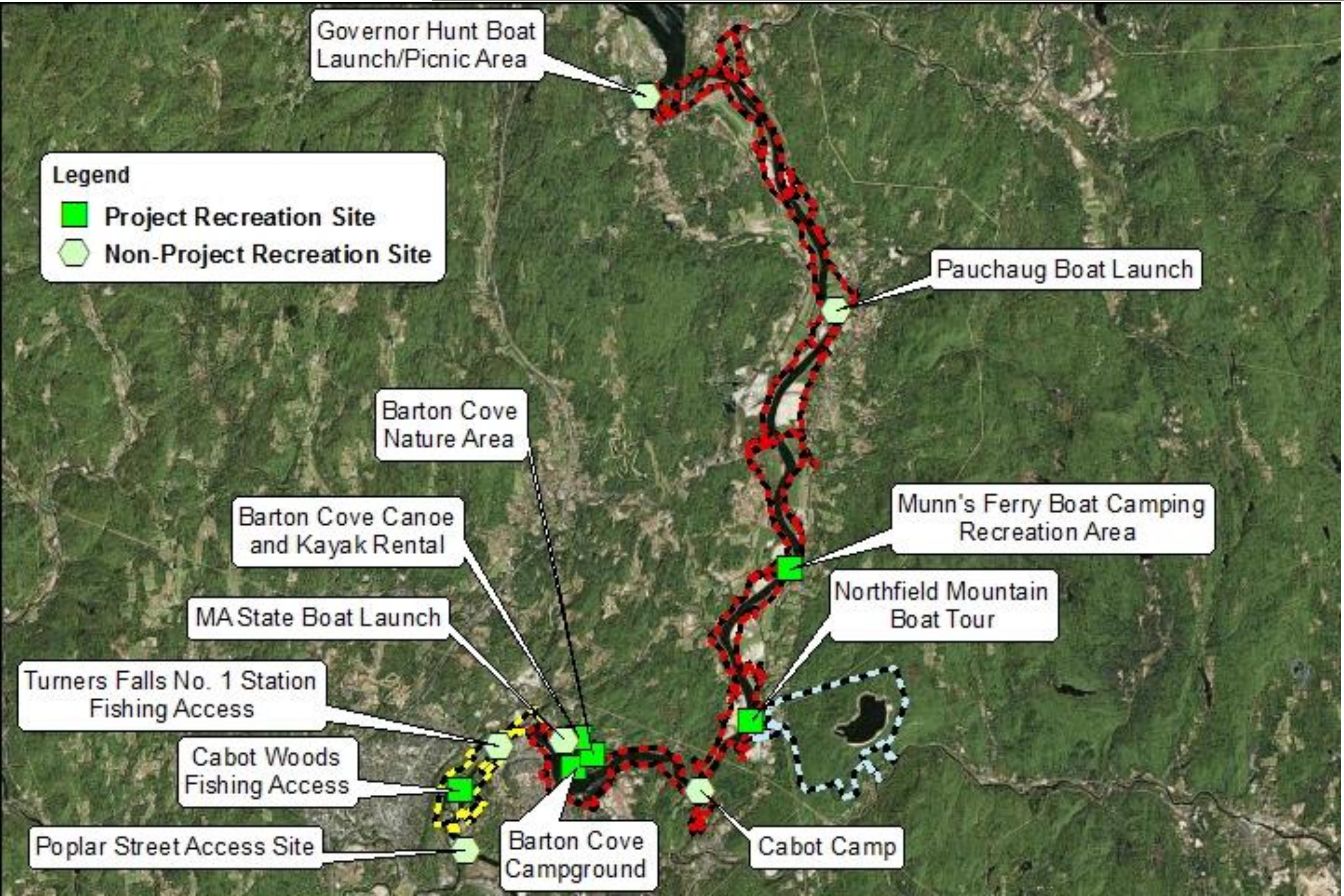
Background

- Study Scope – lands and waters within the Project boundaries, as well as the Connecticut River from the Project downstream to the Sunderland Bridge
- Recreation Sites Assessed – sites providing water access

Table 2-1 Recreation Sites Assessed

Recreation Site	Waters Accessed
Governor Hunt Boat Launch/Picnic Area	Vernon Project Tailwater/ Turners Falls Impoundment
Pauchaug Boat Launch	Turners Falls Impoundment
Munn's Ferry Boat Camping Recreation Area	Turners Falls Impoundment
Boat Tour and Riverview Picnic Area	Turners Falls Impoundment
Cabot Camp Access Area	Turners Falls Impoundment
Barton Cove Nature Area and Campground	Turners Falls Impoundment
Barton Cove Canoe and Kayak Rental Area	Turners Falls Impoundment
State Boat Launch	Turners Falls Impoundment
Turners Falls Station No. 1 Fishing Access	Turners Falls Bypass
Cabot Woods Fishing Access	Turners Falls Bypass
Poplar Street Access Site	Connecticut River
Sunderland Bridge Boat Launch	Connecticut River

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Methods

Reviewed results of other recreation studies:

- Study No. 3.6.1 *Recreation Use/User Contact Survey;*
- Study No. 3.6.2 *Recreation Facilities Inventory and Assessment* ;
- Study No. 3.6.3 *Whitewater Boating Evaluation*;
- Study No. 3.6.4 *Assessment of Day Use and Overnight Facilities Associated with Non-Motorized Boats*; Study No. 3.6.7 *Recreation Study at Northfield Mountain, including Assessment of Sufficiency of Trails for Shared Use*.

Reviewed other studies that contained information relevant to evaluating potential operational effects on recreation sites and facilities that provide water access.

- Study No. 3.2.2 *Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot Station*;
- Study No. 3.3.1 *Instream Flow Studies in Bypass Reach and below Cabot Station;*
- Study No. 3.3.9 *Two-Dimensional Modeling of the Northfield Mountain Pumped Storage Project Intake/Tailrace Channel and Connecticut River Upstream and Downstream of the Intake/Tailrace*;
- Study No. 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability.*

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Methods

Hydraulic models developed as part of the other studies were used to evaluate the range of water levels, flow velocities and flow direction associated with Project operation at/near each recreation site/facility:

- HEC-RAS model developed Turners Falls Impoundment (TFI) from the Turners Falls Dam to the Vernon Dam (“TFI hydraulic model”) (Study No. 3.2.2)
- HEC-RAS model of the Connecticut River from the United States Geological Survey Gage (USGS, Gage No. 01170500) in Montague to the Holyoke Dam (“Montague hydraulic model”) (Study No. 3.2.2)
- Turners Falls bypass reach hydraulic models developed as part of the instream flow study (Study No. 3.3.1).
- River2D 2-dimensional hydraulic model developed for the TFI around the Northfield Mountain Project intake and tailrace channel (Study No. 3.3.9)

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Methods

- Each water access site/facility was evaluated based on hydraulic conditions at the closest modeled transect.

- Assumptions were made regarding the minimum water depth required for the site/facility to remain operational and meet its intended recreation purpose

    - 3 ft water depth for launching trailered watercraft (motor boats) (SOBA, 2006)
    - 2 ft water depth for launching carry-in watercraft (canoes, kayaks, etc.)

- Recreation user survey results (Study No. 3.6.1) were examined individually, to discern what recreation users had to say about the effects of Project operations (primarily water levels), on the usability of a particular recreation site/facility.

- Observations of recreation site/facility conditions under a variety of conditions were gathered from a variety of sources, including observations made by FirstLight during the 3.6.2 Recreation Inventory Study, follow-up reconnaissance of recreation sites/facilities, and personal communication with recreation site managers including FirstLight and MA DFG.

- Emergency response managers were contacted to get more detailed information regarding their use of Project recreation sites/facilities for water rescue efforts.

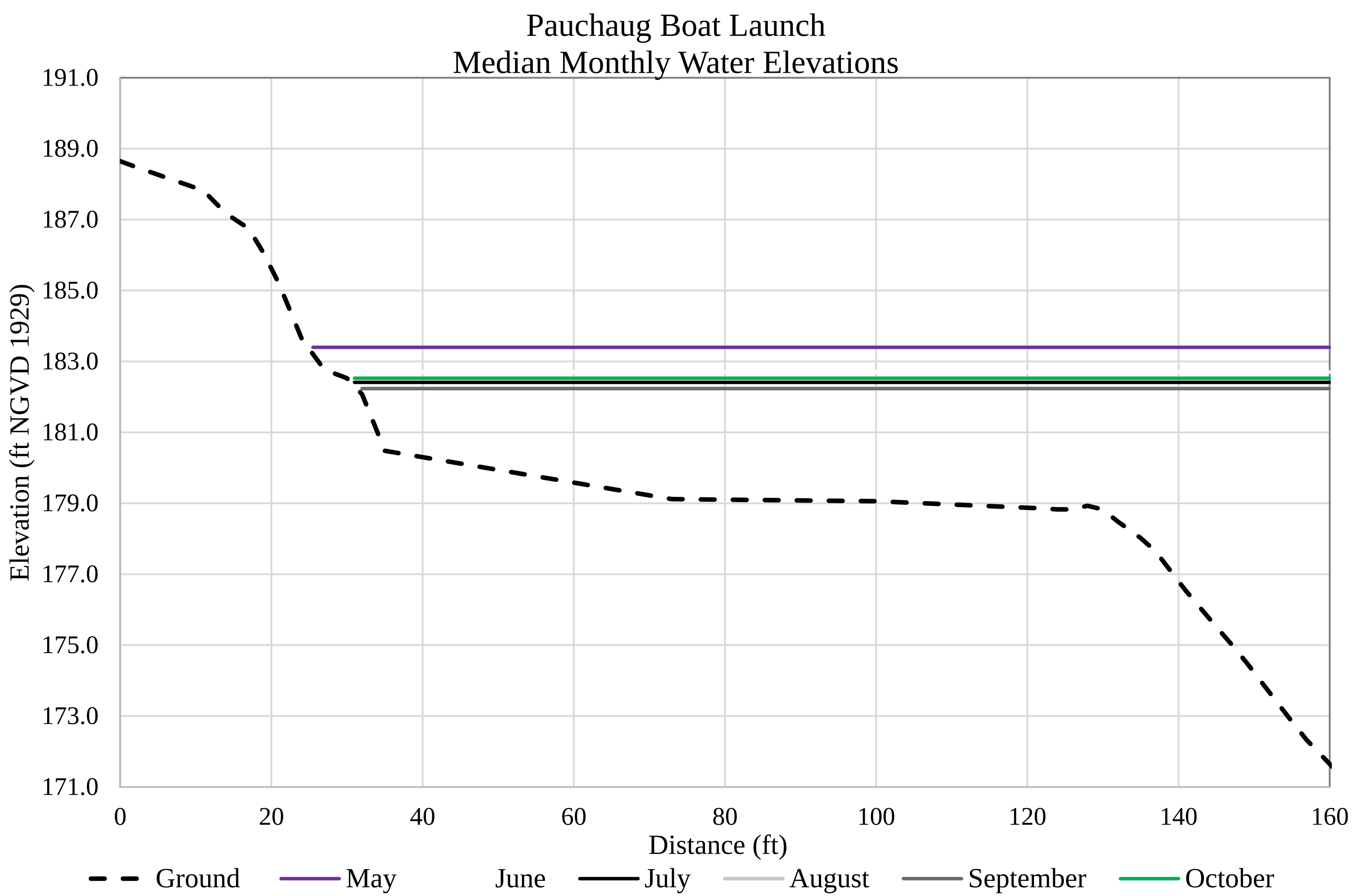
3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Results

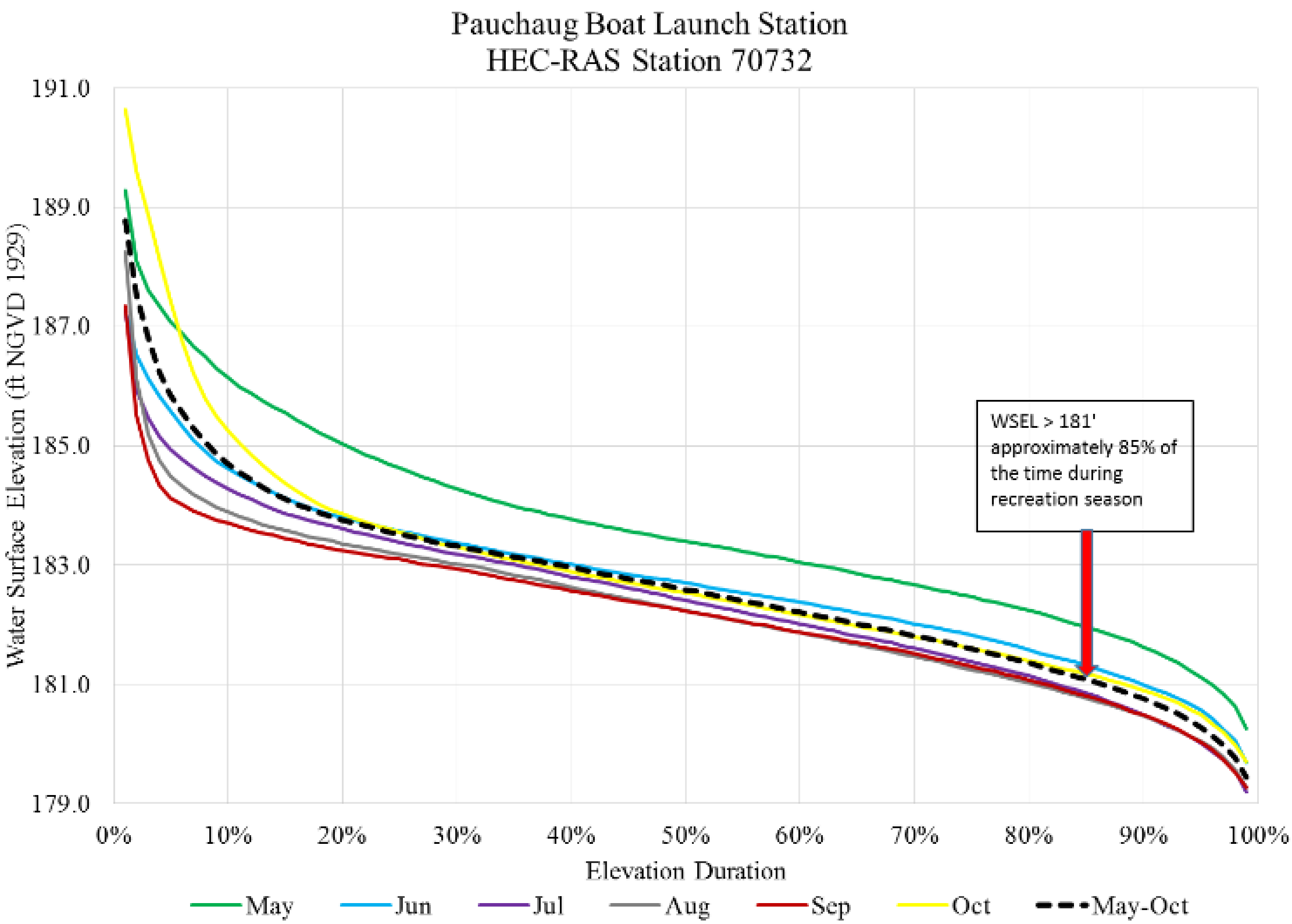
Example - Pauchaug Boat Launch

- Located on south side of Pauchaug Brook– in a narrow cut along a relatively flat, low-lying portion of the river bank
- Owned, operated, and maintained by MA DFG
- Suitable for launching small-moderate power boats, carry-in paddlecraft
- End of boat ramp estimated to be at elevation 178’
- Water surface elevation (WSEL) of 181’ or greater needed for boat ramp to have 3’ water depth for launching

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Results

Example - Pauchaug Boat Launch Results

Water depths at the end of Pauchaug Boat Launch are **3 feet or greater**:

- May 95%
- June 90%
- July 82%
- August 80%
- September 81%
- October 88%.boat

Water depth needed for Northfield Fire Dept rescue boat launching is 2 feet (el 180'). 2 ft water depth available 95-100% of the time throughout the recreation season.

The launch is susceptible to sediment accumulation generally during naturally occurring high spring flows. On an as-needed basis, MADFG clears/plows the launch ramp of sediment that accumulates during seasonal high flows, and excavates accumulated sediment at the end of the ramp to keep the channel open.

Review of 63 recreation user surveys from this site found 11 respondents indicated concerns with “mud”, several indicated the launch ramp was “muddy” due to sedimentation. A few indicated the ramp was slippery and difficult to traverse due to mud. One respondent commented “dredge the boat ramp”.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Conclusions

Example - Pauchaug Boat Launch Results

- Launch has sufficient water depth (WSELs > 181') for small-moderate power boats and hand-carry paddlecraft from 80% (August) of the time to 95% (May) of the time during the recreation season (May-October).

- WSELs of < 181' have the potential to affect use of this site by making it more difficult to launch trailerable boats, although canoes and kayaks can still be launched. WSELs of < 181' occur anywhere from 5% of the time (May) to 20% of the time (August).

- Launch has sufficient water depth for emergency rescue craft use 95-100% of the time (May-October).

- Sedimentation also periodically interferes with the usability of Pauchaug Boat Launch. The ramp is susceptible to sedimentation during seasonal high river flows because of its location within a relatively narrow cut in the river bank, just downstream from the Pauchaug Brook confluence, and its orientation to prevailing river currents.

- MADFG clears/plows accumulated sediment from ramp, on an “as needed” basis, usually following seasonal high flows. MADFG also excavates the end of the launch ramp on an “as-needed basis” to remove accumulated sediment from the end of the ramp, and to maintain the channel cut. FirstLight works cooperatively with MADFG on its excavation efforts by attempting the hold the TFI close to the lowest allowable elevation.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

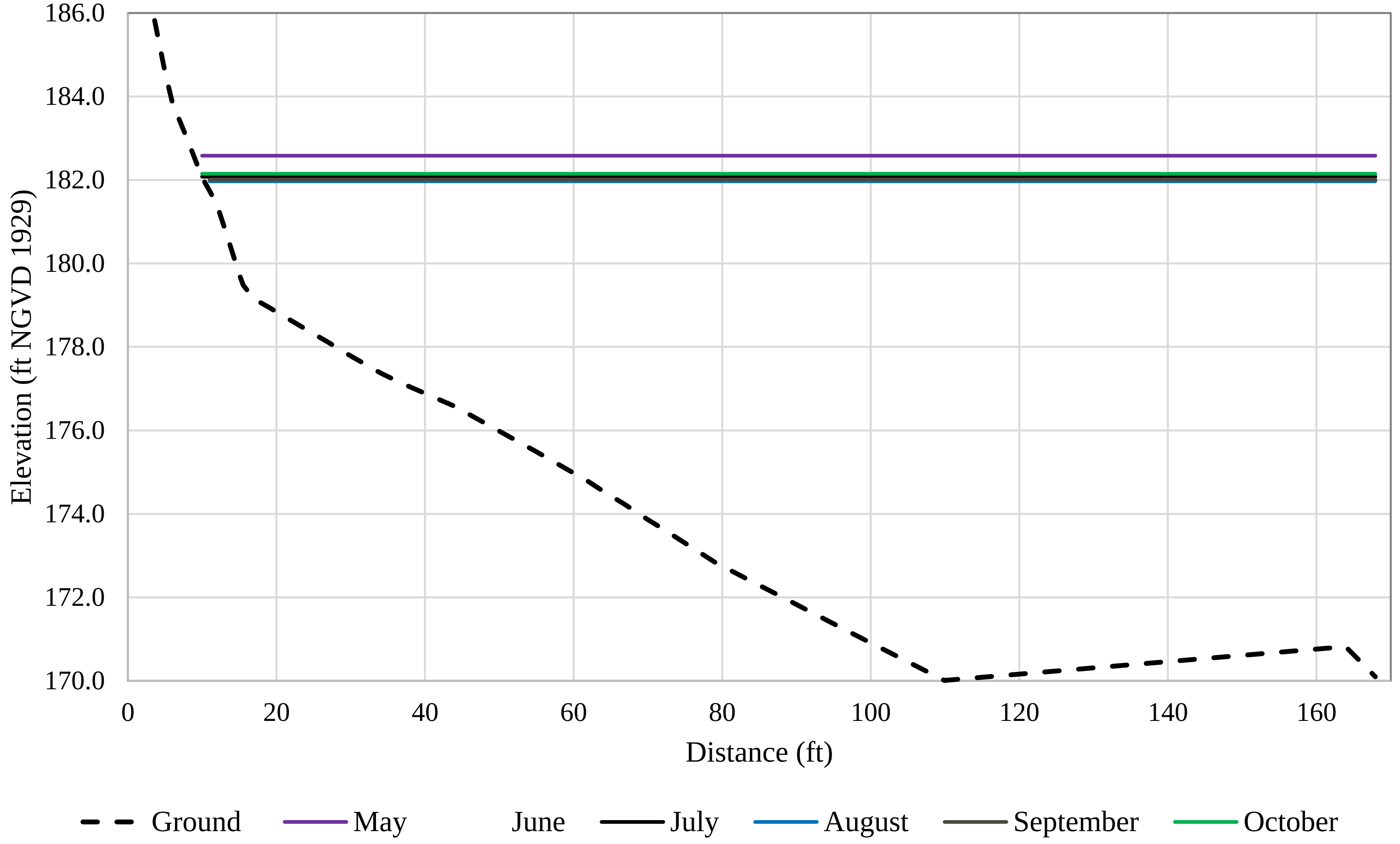
Results

Example – Riverview Boat Dock

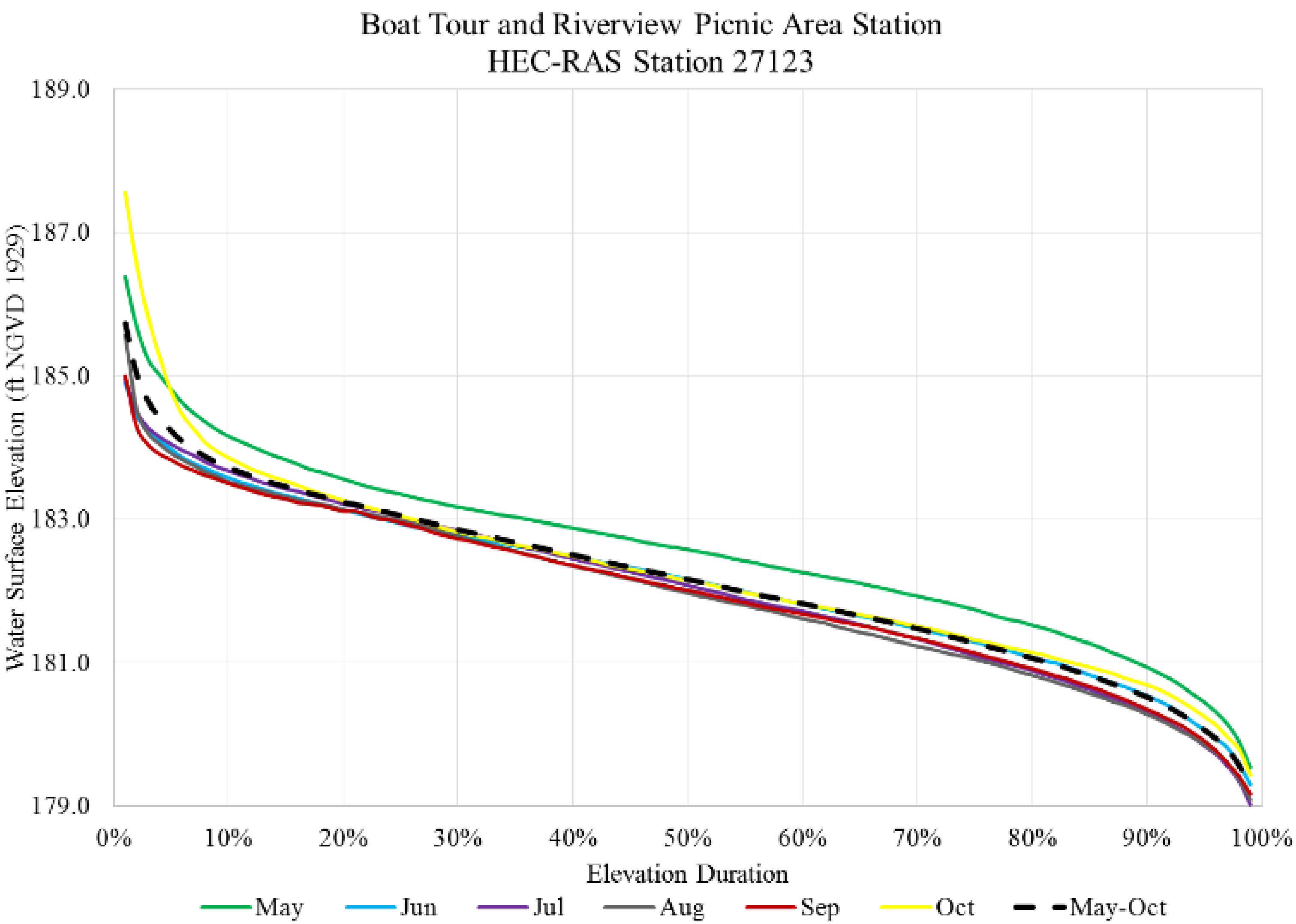
- Located on mid portion of TFI, immediately upstream of NM tailrace
- Owned and operated by FirstLight
- Suitable for docking Quinnetukut II (Q2) and small-moderate power boats
- Bottom elevation at end of boat dock estimated to be at elevation 172’
- Water surface elevation (WSEL) of 175’ or greater needed for boat dock to have 3 ft water depth for Q2 and other power boat use.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Boat Tour and Riverview Picnic Area
Median Monthly Water Elevations



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Results

Example – Riverview Boat Dock

- Water depth needed for Q2 boat docking is 3 feet or more.
- Water depths at the end of Riverview boat dock are greater than 3 feet 100% of the time throughout the recreation season.
- Review of River 2D hydraulic model results show that under the majority of operating conditions (60 combinations were modeled), river flow moves downstream at Riverview with an average channel velocity of 0-2 fps, and median of 0.5 fps; well within the Q2's safe operating range.
- 2D model results also show that when river flow is low, and Northfield Mountain is generating, the Riverview site may experience upstream flows ranging between 0-1 fps, and therefore do not impact the usability of the boat dock by Q2 or other powerboats.
- Review of 53 recreation user surveys from this site found 2 respondents indicated concerns with low water levels at this site. One was boating and indicated "water can be shallow at times". The other commenter was walking and indicated simply "shallow water". Nether commenter specifically indicated a problem with water levels on the use of the Riverview boat dock or other specific recreation activity at this site.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Conclusions

Example – Riverview Boat Dock

- Riverview Boat Dock experiences “None to Minimal” impacts from Project operations.

- At least 3 feet of water depth are maintained at the dock 100% of the time during the recreation season

- When river flow is low and Northfield Mountain is generating, the area experiences flow reversals as water moves upstream. However, upstream velocities are low and do not interfere with useabililty of the boat dock for Q2 or other power boats.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Recreation Site	Water Access Recreation Facilities/ Amenities	Water-based Recreation Uses	Project Operational Impacts
Governor Hunt Boat Launch/Picnic Area	Boat launch	Boating Fishing	**None**; the boat launch is located upstream of a hydraulic control, which limits the water surface elevation from falling below 181-ft
Pauchaug Boat Launch	Boat launch	Boating	**Moderate**; launch ramp use for small-moderate power boats and hand carry paddlecraft is affected at WSELs of < 181 feet. WSELs of < 181' occur from 5 % (May) to 20 % (August) of the time during the recreation season (May-October). Launch also has sufficient water depth for emergency rescue craft 95% to 100% of the time (May-October).
Munn's Ferry Boat Camping Recreation Area	Boat dock (floating)	Boating Fishing	**None**; WSEL of 167 feet is needed for docking power boats. The lowest allowable operating range for the TFI is elevation 176 feet. Thus, the WSEL at the boat dock is above 167 feet 100% of the time.
Boat Tour and Riverview Picnic Area	Boat dock (floating)	Riverboat cruise Boating Fishing	**None to minimal**; WSEL of 175 feet is needed for docking the QII; WSELs >175 feet 100% of the time during the recreation season (May-October); when river flow is low and Northfield Mountain is generating, the Boat Tour and Riverview Picnic Area is subject to flow reversals as water moves upstream. However the upstream velocities are low and do not interfere with the usability of the Riverview boat dock for the QII or other power boats

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Recreation Site	Water Access Recreation Facilities/ Amenities	Water-based Recreation Uses	Project Operational Impacts
Cabot Camp Access Area	None	Fishing	**None**; TFI shoreline remains fully accessible for bank fishing and those launching or retrieving canoes/kayaks under full range of allowable TFI elevations.
Barton Cove Nature Area and Campground	Boat dock (floating)	Fishing	**Minimal** water level impacts; floating boat dock adjusts with WSEL and remains useable at water levels of > 180 feet, which occur 89% to 93% of the time during the months of May through October.
Barton Cove Canoe and Kayak Rental Area	Canoe/Kayak launch	Canoeing/ Kayaking	**None**; the WSELs > 180 feet (2 foot depth) 90 % of the time during the recreation season (May-October); there may be infrequent occasions when a canoeist or kayaker would have to walk a short distance (approximately 15 to 30 feet) further to launch his/her craft at this site.
State Boat Launch	Boat launch	Boating Fishing	**Minimal** water level impacts; boat launch remains useable (3 foot depth at end of launch) at water surface elevations of > 179 feet, which occur 98 % to 99% of the time during the months of May through October. The launch has sufficient depth for emergency water craft 100% of the time between May and October.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Recreation Site	Water Access Recreation Facilities/ Amenities	Water-based Recreation Uses	Project Operational Impacts
Turners Falls Station No. 1 Fishing Access	None	Fishing	**Minimal** flow and water level impacts; Bypass reach shoreline remains accessible for bank fishing under a wide range of bypass flows; amount of available shoreline may diminish when flows exceed hydraulic capacity of the power canal.
Cabot Woods Fishing Access	None	Fishing	**Minimal** flow and water level impacts; Bypass reach shoreline remains accessible for bank fishing under a wide range of bypass flows. But recreation user safety may be impacted at higher bypass flows, particularly in the vicinity of Rock Dam.
Poplar Street Access Area	Canoe portage put-in	Canoeing/ Kayaking Fishing	**None**; River shoreline remains fully accessible for canoe/kayak put-in and take-out under the range of water surface elevations typically produced by normal Project operations.
Sunderland Bridge Boat Launch	Boat launch	Boating Fishing	**None**; Unimproved boat launch remains fully useable for small boat and canoe/kayak launching under the range of water surface elevations typically produced by normal Project operations.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Summary

- Turners Falls and Northfield Mountain Project operations have minimal or no impact on water based recreation facilities at most of the public recreation areas.

- Only one site, Pauchaug Boat Launch was found to be moderately impacted by Project operations due to insufficient water depths, but this site is still useable 86% of the time during the recreation season (May-Oct).

- The site also has sufficient water depths for launching emergency rescue craft nearly 100% of the time during the recreation season.

- The assessment was conducted in accordance with the RSP and satisfied all assessment objectives.