




Merrimack Station NPDES Permit Studies 1967-2008

4 December 2008

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

106

Merrimack 316(a) and 316(b) Studies (1967-2008)

- Completed 316(a) Studies (1967-2005)
- Completed 316(b) Studies (2005-2007)
- Supplemental 316(a) Studies (2008)
- Supplemental 316(b) Studies (2008)

Completed Merrimack 316(a) Studies (1967-2005)

- Support continuation/renewal of existing 316(a) variance
  - Hydrothermal analysis of Hooksett Pool (1984-2004)
  - Migratory fish passage through thermal plume (2003-2005)
  - Retrospective analysis of representative important fish species (1967-2005) and their habitat

Completed Merrimack 316(b) Studies (2005-2007)

- Address finding of no adverse environmental impact (i.e., "AEI") from Station's Unit 1 and Unit 2 CWISs as measured by now suspended Phase II 316(b) Rule's performance standards
  - Entrainment Abundance
    - Entrainment Survival
  - Impingement Abundance
    - Impingement Survival

Supplemental Merrimack Studies (2008)

- Field work completed, reports under preparation for submission to EPA prior to draft permit issuance

- 316(a) Studies
  - Hooksett Dam tailwater temperatures
  - Yellow perch and white sucker age and growth

- 316(b) Studies
  - White sucker entrainment survival
  - White sucker larval transport

- Merrimack River Ambient pH
  - June 2002 – May 2007

Completed Merrimack 316(a) Studies: Overview

- Based on robust data set for Hooksett Pool
  - Fish abundance determined by electrofishing
  - Consistent and documented sampling methodology
  - Sampling performed under technical supervision and direction of federal and state resource agencies, including EPA
  - Used four decades of fisheries data 1972 – 2005
  - Discarded 1967-1971 data due to poor documentation

Completed Merrimack 316(a) Studies: Overview

- Study design appropriate for retrospective analysis
  - Reflects well-accepted principles that ecosystems are not static, and that individual components will change over time (E.P. Odum 1971)
  - Objective of comparing zones within Hooksett Pool
    - Upstream = ambient
    - Downstream = thermally influenced
- Hypothesis:
  - Harm to BIP is revealed by reduced abundance or by declining trends of population in downstream zone compared to upstream zone

Completed Merrimack 316(a) Studies: Overview

- Definition of Ecosystem Change or Succession (E.P. Odum 1971)
  - Is orderly process involving changes in species abundance and composition
  - Results from modification of physical or chemical environment
  - Culminates in maximum biomass per unit of available energy flow

Completed Merrimack 316(a) Studies: Overview

- Hooksett Pool ecosystem changes (1967-2008)
  - Improved water quality (e.g., less algal and macrophyte growth) due to infrastructure improvements in water treatment made at point source discharges upstream from Station (in response to enactment of CWA in 1972)
  - Fish species introductions changed community composition

Completed Merrimack 316(a) Studies: Hooksett Pool Water Quality Improvements (1967-2008)

- Improved water quality (e.g., less algal and macrophyte growth) in system
  - Clean Water Act Implemented in 1970
  - Merrimack River is cleaner now
  - Primary nutrients (nitrite, nitrate, and phosphorus) all decreased by order of magnitude
  - Municipal and industrial discharges were reduced in upper Merrimack River
  - Dissolved oxygen improved due to pollution abatement

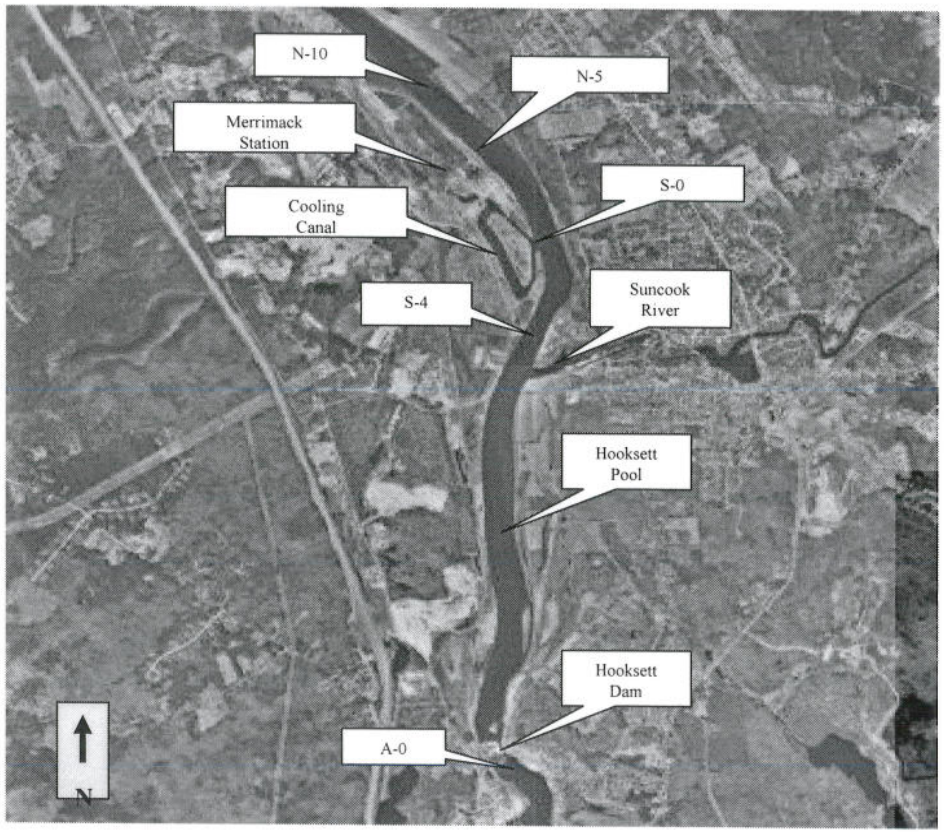
Completed Merrimack 316(a) Studies: Hooksett Pool fish assemblage changes (1967-2008)

- Fish species introductions changed community composition
  - American Shad restoration:
    - 1,861 fish stocked into Hooksett Pool during 2002, and 1,559 fish stocked into upper Merrimack and tributaries during 2003
  - River Herring restoration:
    - 2,750 fish stocked into Merrimack and tributaries in 2002, and 12,500 fish stocked into Merrimack and tributaries in 2003
  - Bluegill first detected during 1995 sampling season (probably introduced during 1970's)
  - Rock bass first detected during 1995 sampling season
  - Black crappie first detected during 2004 sampling season

Completed Merrimack 316(a) Studies: Hydrothermal Analysis

- Objectives of hydrothermal analysis:
  - Describe existing open water period ambient river flows and water temperature
  - Describe thermal plume

Completed Merrimack 316(a) Studies: Hydrothermal Analysis



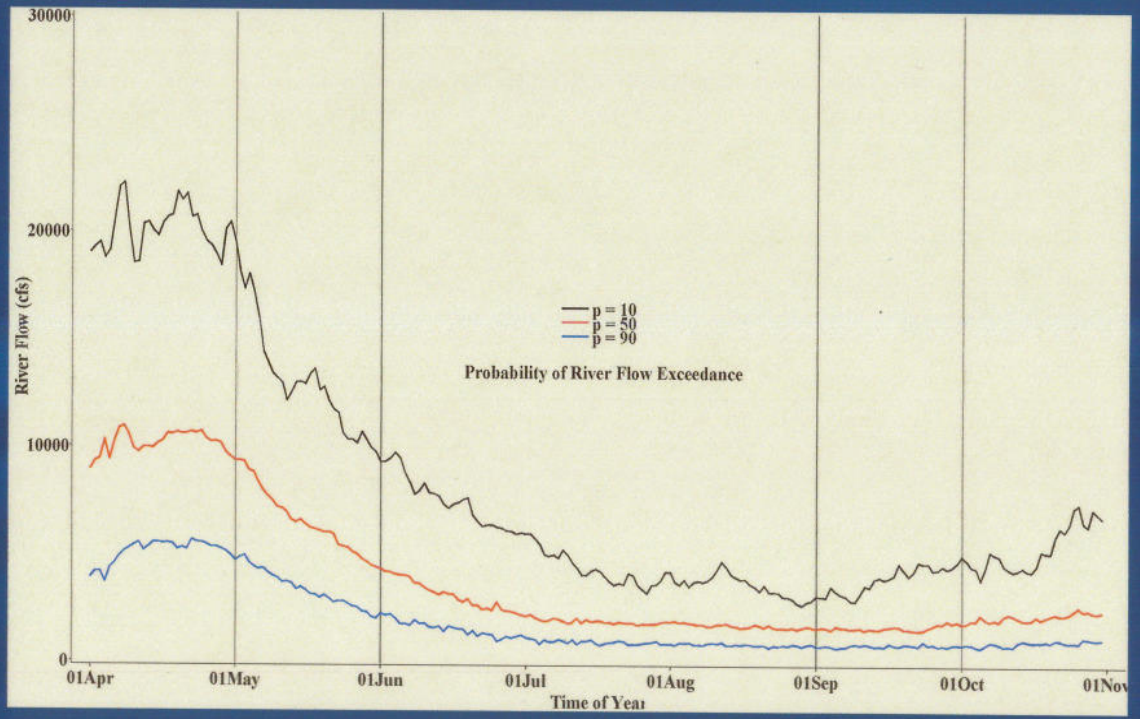
Merrimack River Temperature Monitoring Sites Near Merrimack Station in Bow, New Hampshire

Completed Merrimack 316(a) Studies: Hydrothermal Analysis






Merrimack River Flow (1903-2004)



NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

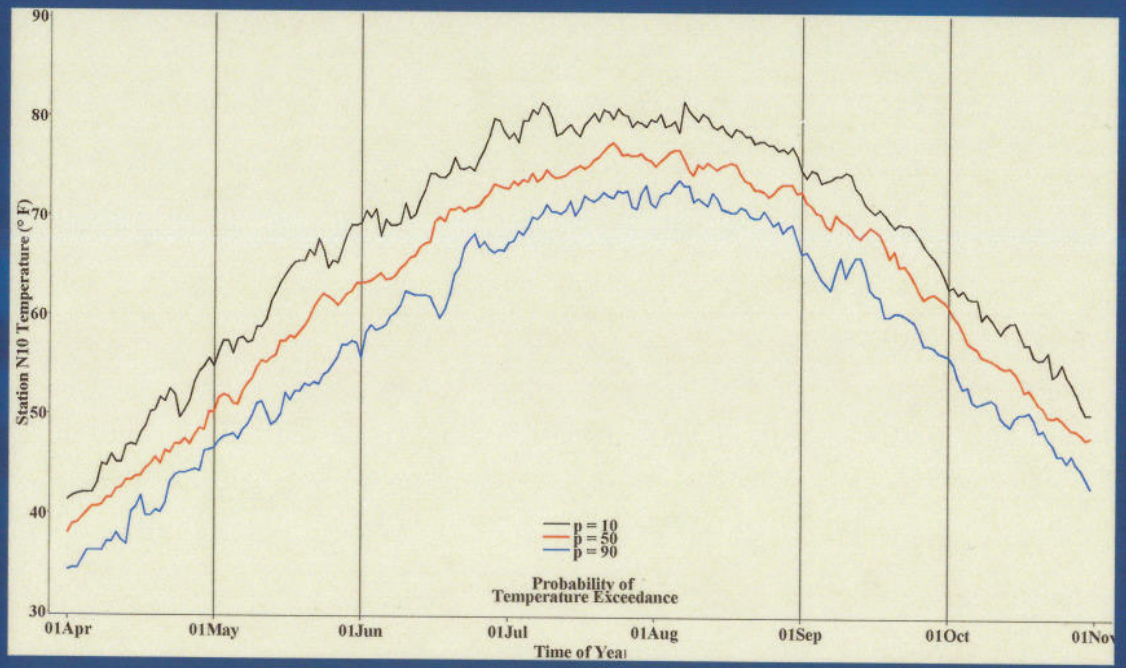
Completed Merrimack 316(a) Studies: Hydrothermal Analysis






Merrimack River Ambient (N-10) Water Temperature

(1984-2004)



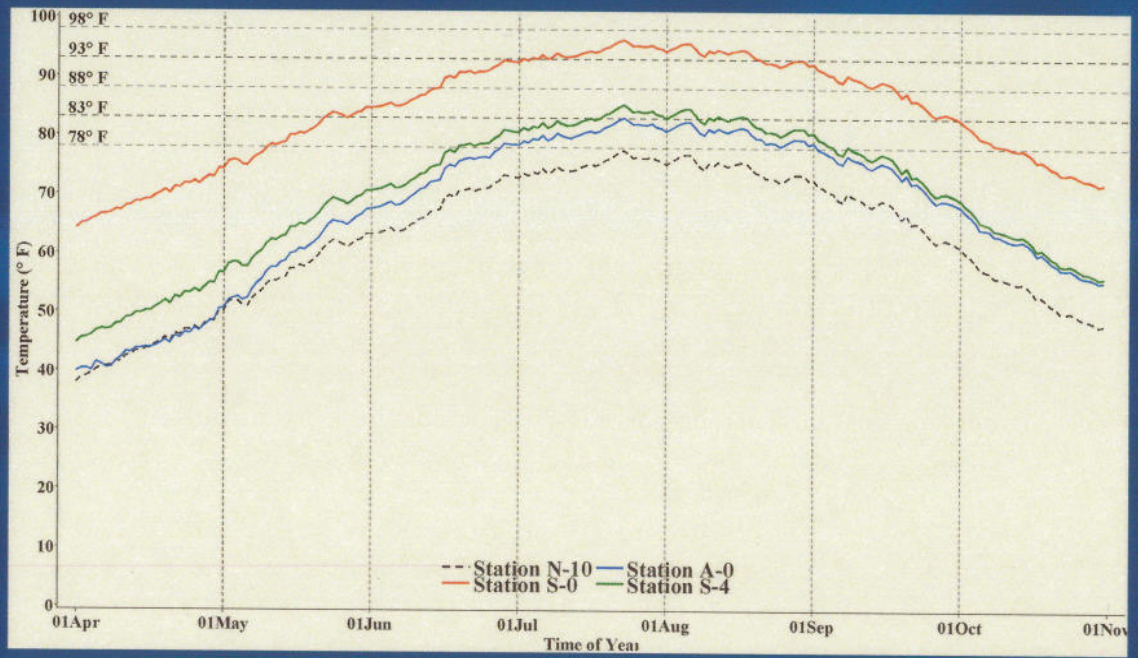
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS






Completed Merrimack 316(a) Studies: Hydrothermal Analysis

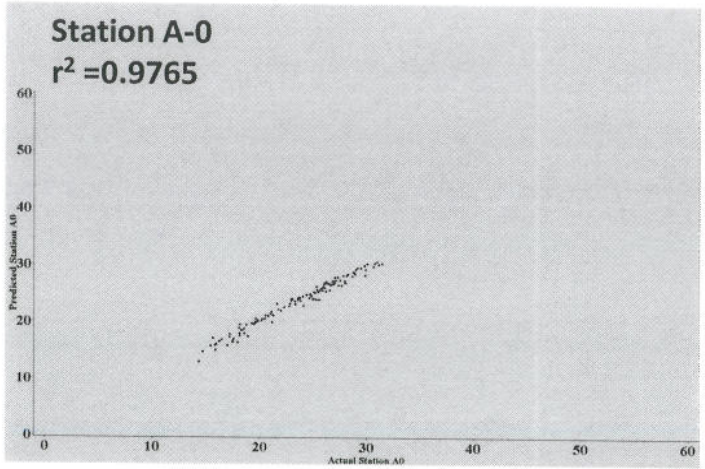
Predicted Merrimack River Temperature at Upstream Ambient Station N-10, and at Downstream Stations S-0 (Discharge), S-4 (Mixing Zone), and A-0 (Fully Mixed at Hooksett Dam) for Median (50%) Flow and Temperature Conditions

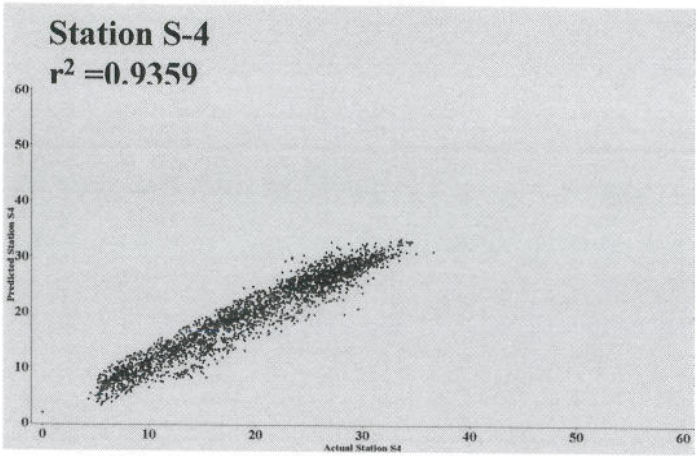


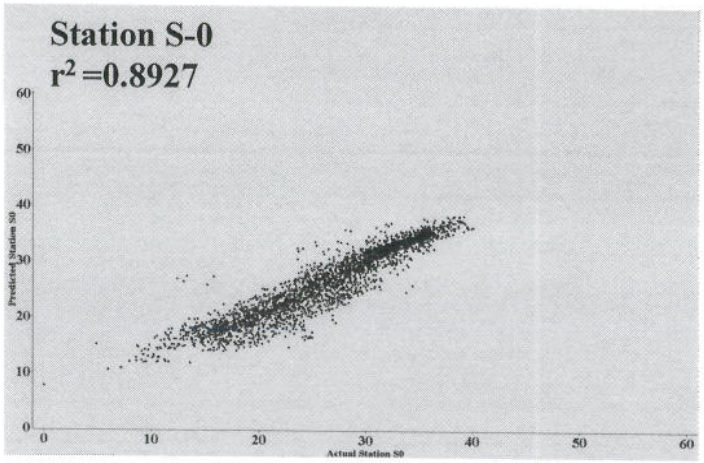
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

Completed Merrimack 316(a) Studies: Hydrothermal Analysis

Comparison of Predictability of Temperature at Downstream Stations S-0, S-4, and A-0 Using Ambient Temperature, River Flow and Merrimack Station Generation







Completed Merrimack 316(a) Studies: Hydrothermal Analysis

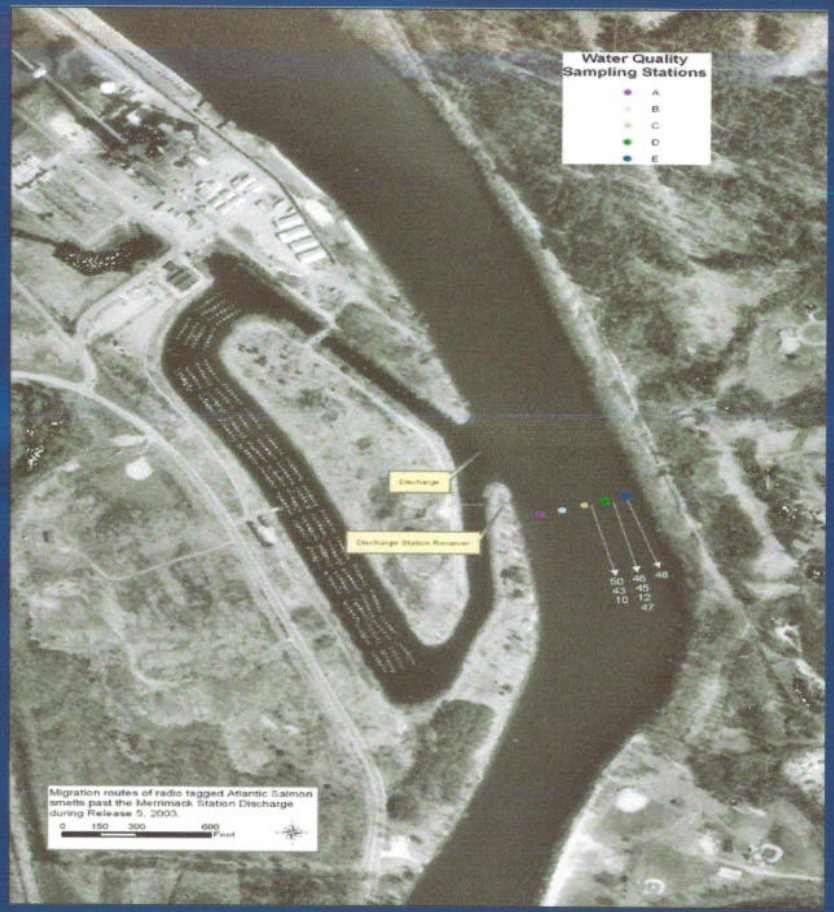
- Merrimack River Thermal Environment
  - Downstream conditions determined largely by upstream conditions
  - Instream river water temperatures are most reliably predicted for Station A-0 located at foot of Hooksett Dam
  - Station A-0 represents completely mixed thermal conditions
  - Water temperatures at Station S-0 located at end of cooling canal water ("end of pipe") are not representative of river thermal conditions and are least reliably predicted

Completed Merrimack 316(a) Studies: Migratory Fish Passage





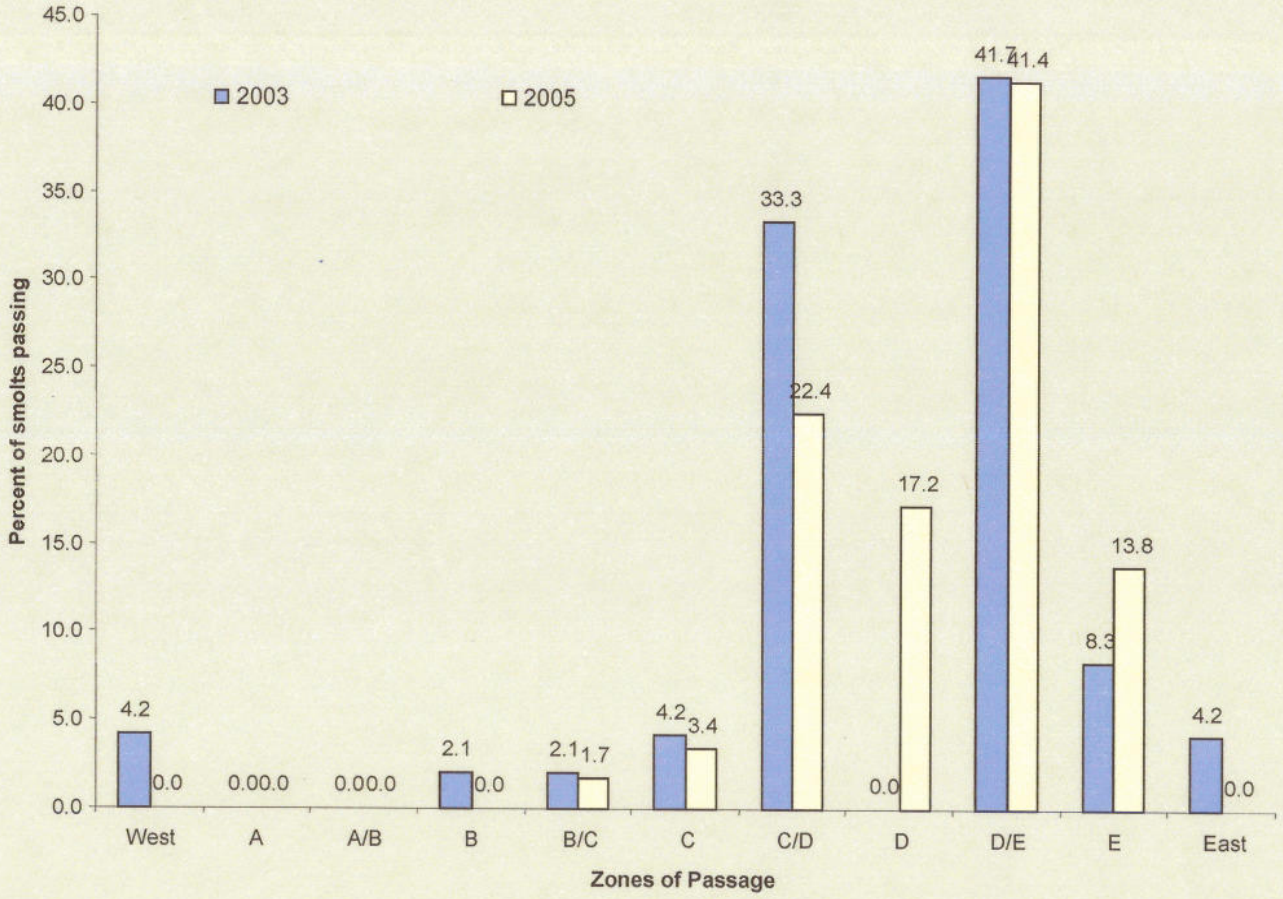

Passage routes for downstream migrating smolts past Merrimack Station thermal plume during 2003 and 2005.



NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

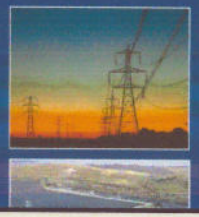
Completed Merrimack 316(a) Studies: Migratory Fish Passage

Smolt Zones of Passage



Completed Merrimack 316(a) Studies: Migratory Fish Passage

- Conclusion: There is effective zone of passage for Atlantic salmon smolts
- No differences in smolt movement rates upstream and downstream of Merrimack Station's thermal plume
- Tagged smolts moved significantly faster between Discharge and S4 during 2005 than 2003
  - Coincided with higher river flows during the 2005 releases



Completed Merrimack 316(a) Studies: RIS Retrospective Analysis

Literature Values for Thermal Tolerances of Hooksett Pool Fish

Fish Species	RIS	Maximum (UILT)	Upper Avoidance
Am. Shad (juveniles)	Yes	90°F	86°F
Alewife (juveniles)	Yes	90°F	84°F
Atlantic salmon (smolts)	Yes	82°F	78°F
Smallmouth Bass	Yes	98°F	95°F
Largemouth Bass	Yes	95°F	90°F
Pumpkinseed	Yes	94°F	88°F
Yellow perch	Yes	90°F	83°F
White sucker	No	88°F	86°F
Fallfish	No	90°F	82°F

NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

Completed Merrimack 316(a) Studies: RIS Retrospective Analysis

RIS or Non-RIS	Maximum Percent Habitat Exclusion in Hooksett Pool Due to Limiting Thermal Effects Parameters (UILT or Avoidance)			
	Spring	Summer	Fall	Winter
Alewife	1.5%	0.0%	0.3%	0.0%
Am. shad	0.1%	0.0%	0.0%	0.0%
Atl. Salmon smolts	0.0%	N/A	N/A	N/A
Pumpkinseed	0.0%	0.0%	0.0%	0.0%
Largemouth Bass	0.0%	0.0%	0.0%	0.0%
Smallmouth Bass	0.0%	0.0%	0.0%	0.0%
Yellow Perch	2.6%	0.0%	1.0%	0.0%
Fallfish	3.9%	0.0%	2.5%	0.0%
White Sucker	0.1%	0.0%	0.0%	0.0%

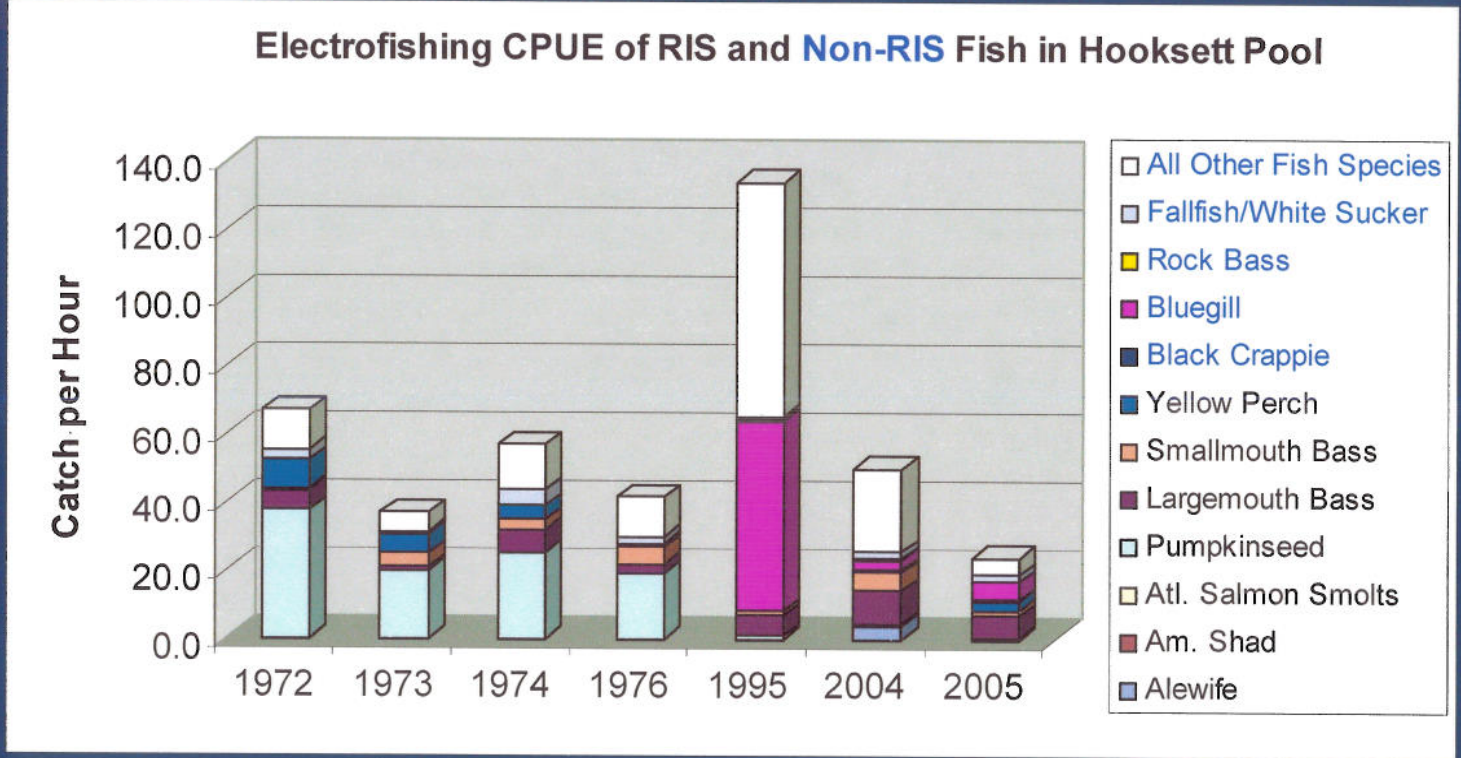
= Non-Zero Cells

Completed Merrimack 316(a) Studies: RIS Retrospective Analysis

RIS or Non-RIS	Maximum Percent Habitat Exclusion in Amoskeag Pool Due to Limiting Thermal Effects Parameters (UILT or Avoidance)			
Common Name	Spring	Summer	Fall	Winter
Alewife	0.0%	0.0%	0.0%	0.0%
Am. shad	0.0%	0.0%	0.0%	0.0%
Atl. Salmon smolts	0.0%	N/A	N/A	N/A
Pumpkinseed	0.0%	0.0%	0.0%	0.0%
Largemouth Bass	0.0%	0.0%	0.0%	0.0%
Smallmouth Bass	0.0%	0.0%	0.0%	0.0%
Yellow Perch	0.0%	0.0%	0.0%	0.0%
Fallfish	0.0%	0.0%	0.0%	0.0%
White Sucker	0.0%	0.0%	0.0%	0.0%

= Non-Zero Cells

Completed Merrimack 316(a) Studies: RIS Retrospective Analysis



Completed Merrimack 316(a) Studies: RIS Retrospective Analysis

Decadal Trends of RIS and Non-RIS Fish in Hooksett Pool Based on Mann-Kendall[1] time Series Analysis.

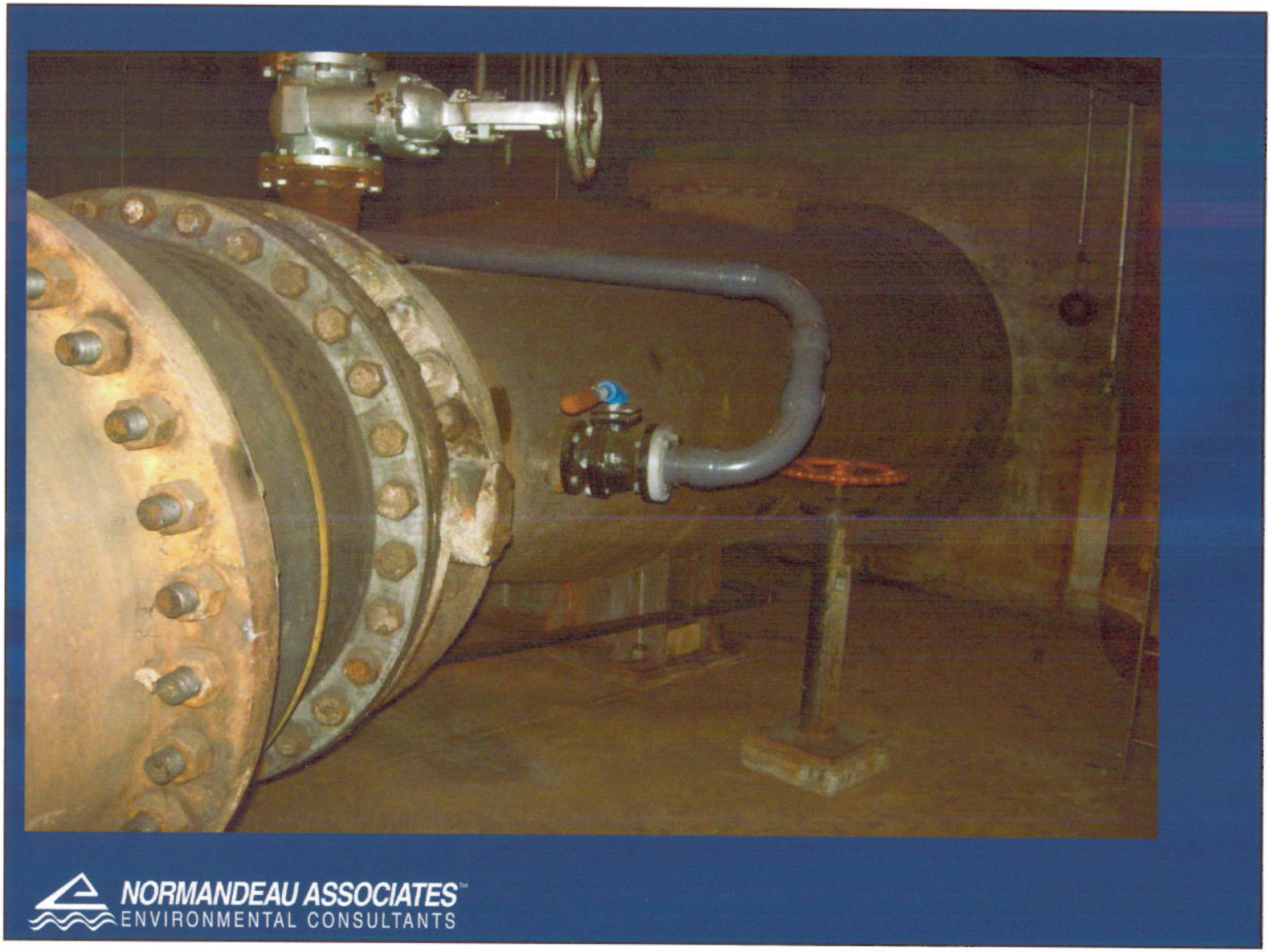
RIS or Non-RIS Fish	Long-Term (1974-2005) Trends in Electrofishing CPUE		
Common Name	Ambient Zone	Mixing Zone	Thermal Zone
Alewife	Stable	Not Present	Not Present
Am. shad	Not Present	Not Present	Not Present
Atl. Salmon smolts	Not Present	Not Present	Not Present
Pumpkinseed	Stable	Decreasing	Decreasing
Largemouth Bass	Stable	Stable	Stable
Smallmouth Bass	Stable	Stable	Stable
Yellow Perch	Stable	Stable	Stable
Fallfish	Stable	Stable	Stable
White Sucker	Stable	Stable	Stable
Introduced Assemblage[2]	Stable	Stable	Stable

[1]Decreasing or increasing trends were significant if Kendall Tau statistic was significant with $p<0.05$

[2]Introduced Assemblage includes bluegill, rock bass and black crappie.

Completed Merrimack 316(a) Studies: Conclusions

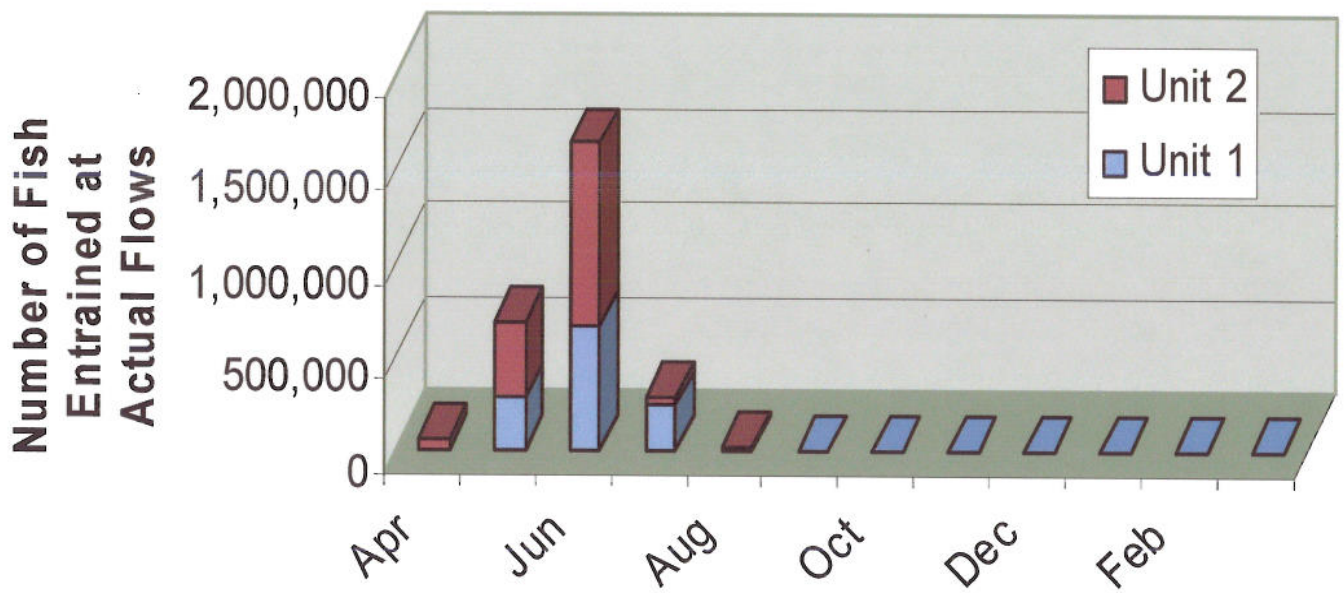
- 1972 – 2005 studies demonstrate that present thermal regime is protective of Balanced Indigenous Populations in Merrimack River
- Adequate zone of passage for migratory species
- RIS are not excluded from use of any significant portion of habitat (seasonally less than 4%)
- RIS show stable or increasing trends in abundance (except for pumpkinseed, which is being replaced by introduced species (bluegill) of similar life history)



NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

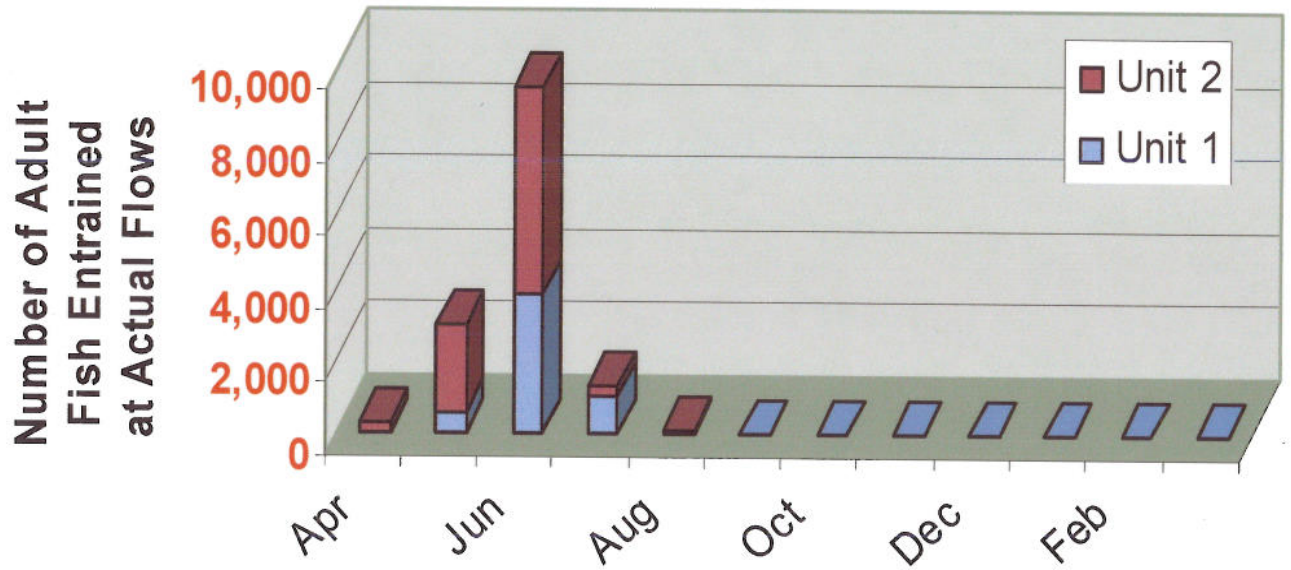
NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

Completed Merrimack 316(b) Studies: Entrainment Abundance

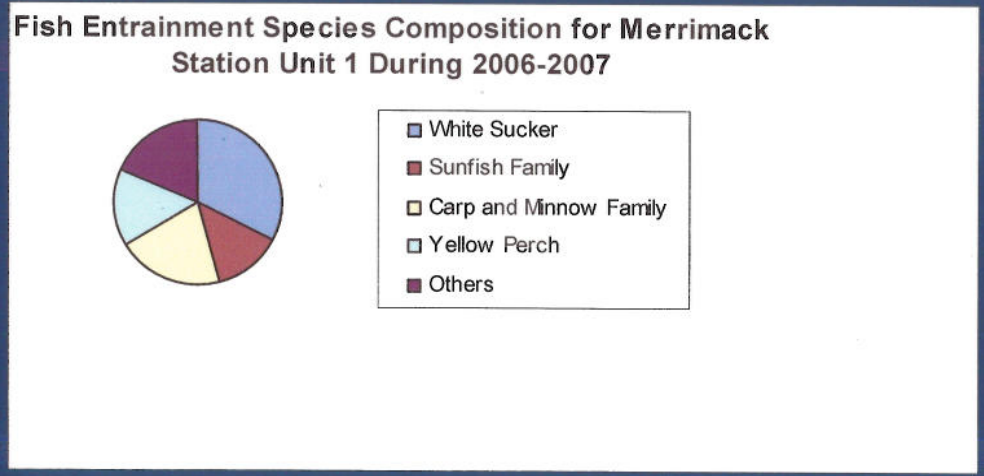


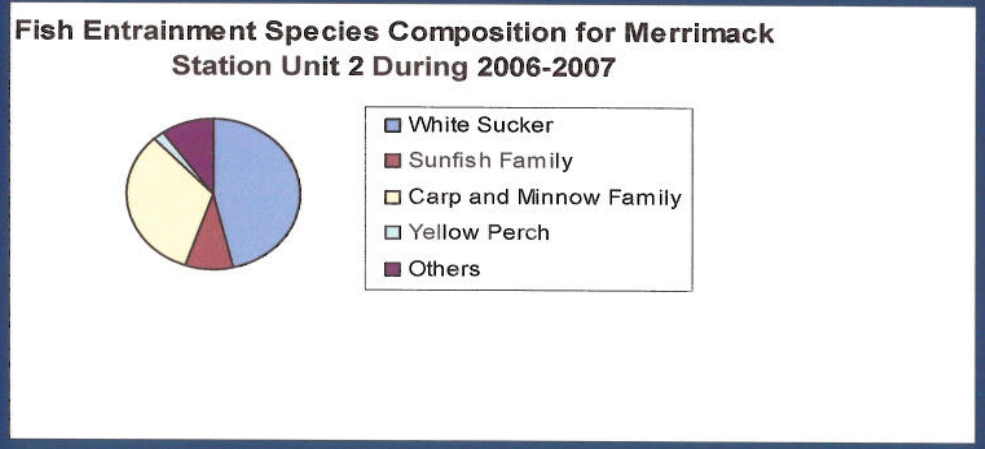
Completed Merrimack 316(b) Studies: Entrainment Abundance

Monthly Average Adult Equivalent Entrainment for Merrimack Station Unit 1 and Unit 2



Completed Merrimack 316(b) Studies: Entrainment Abundance



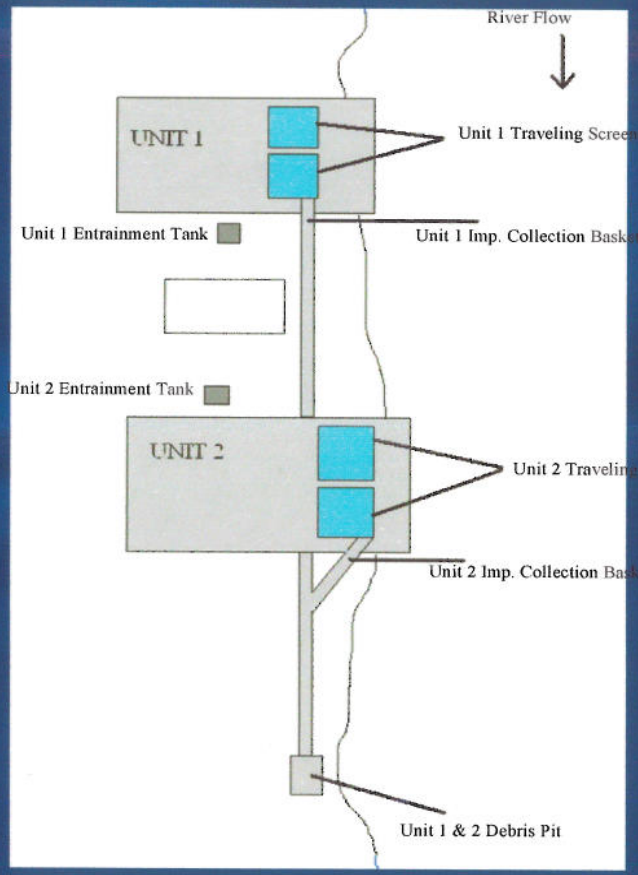


Completed Merrimack 316(b) Studies: Impingement Abundance






- Impingement Abundance 2005-2007
  - Impingement Survival



NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

Merrimack Station Unit 1
Impingement Collection Basket

NORMANDEAU ASSOCIATES℠
ENVIRONMENTAL CONSULTANTS

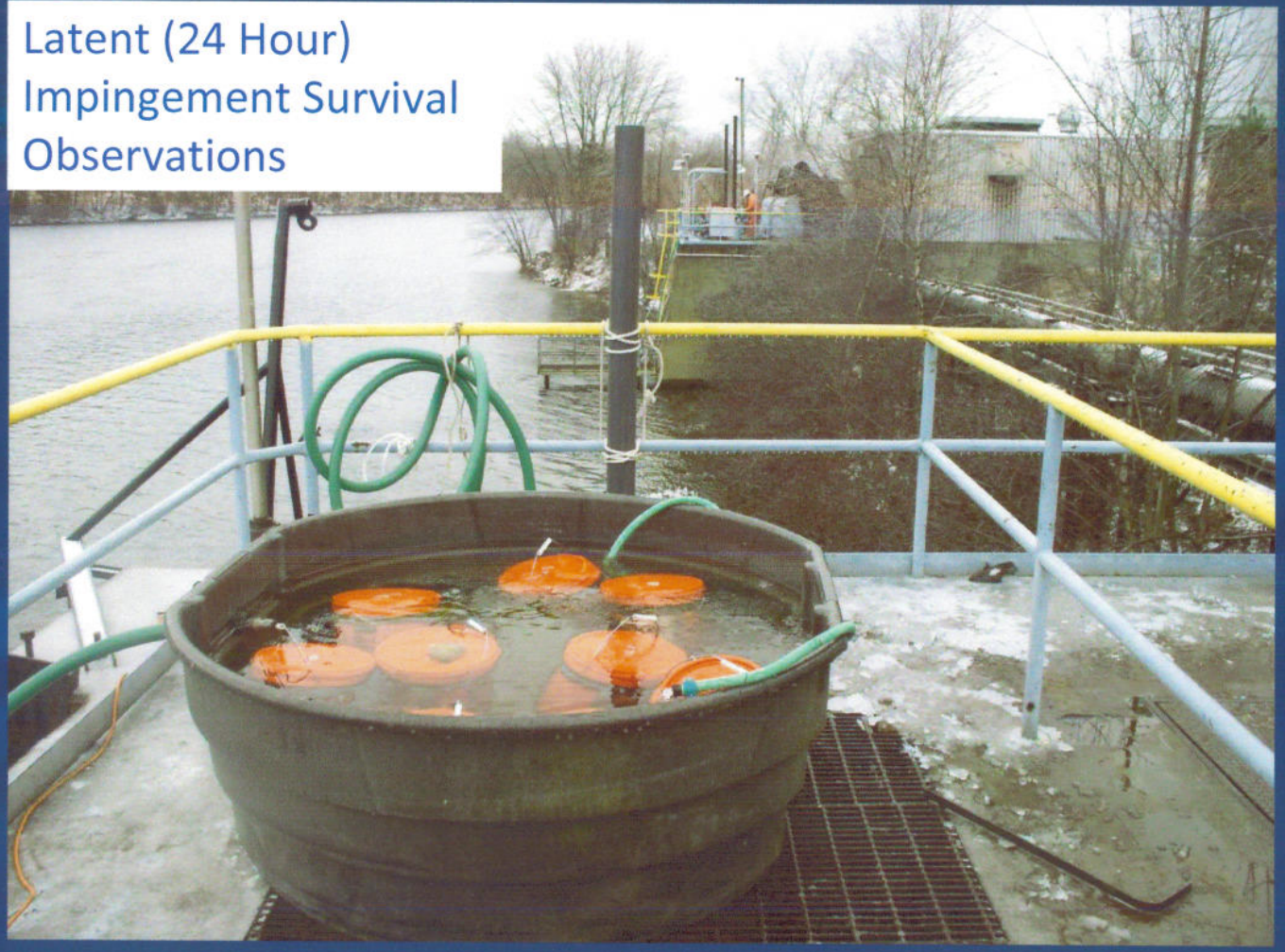





Collecting an Impingement Survival Sample from Unit 1 of Merrimack Station, January 2007

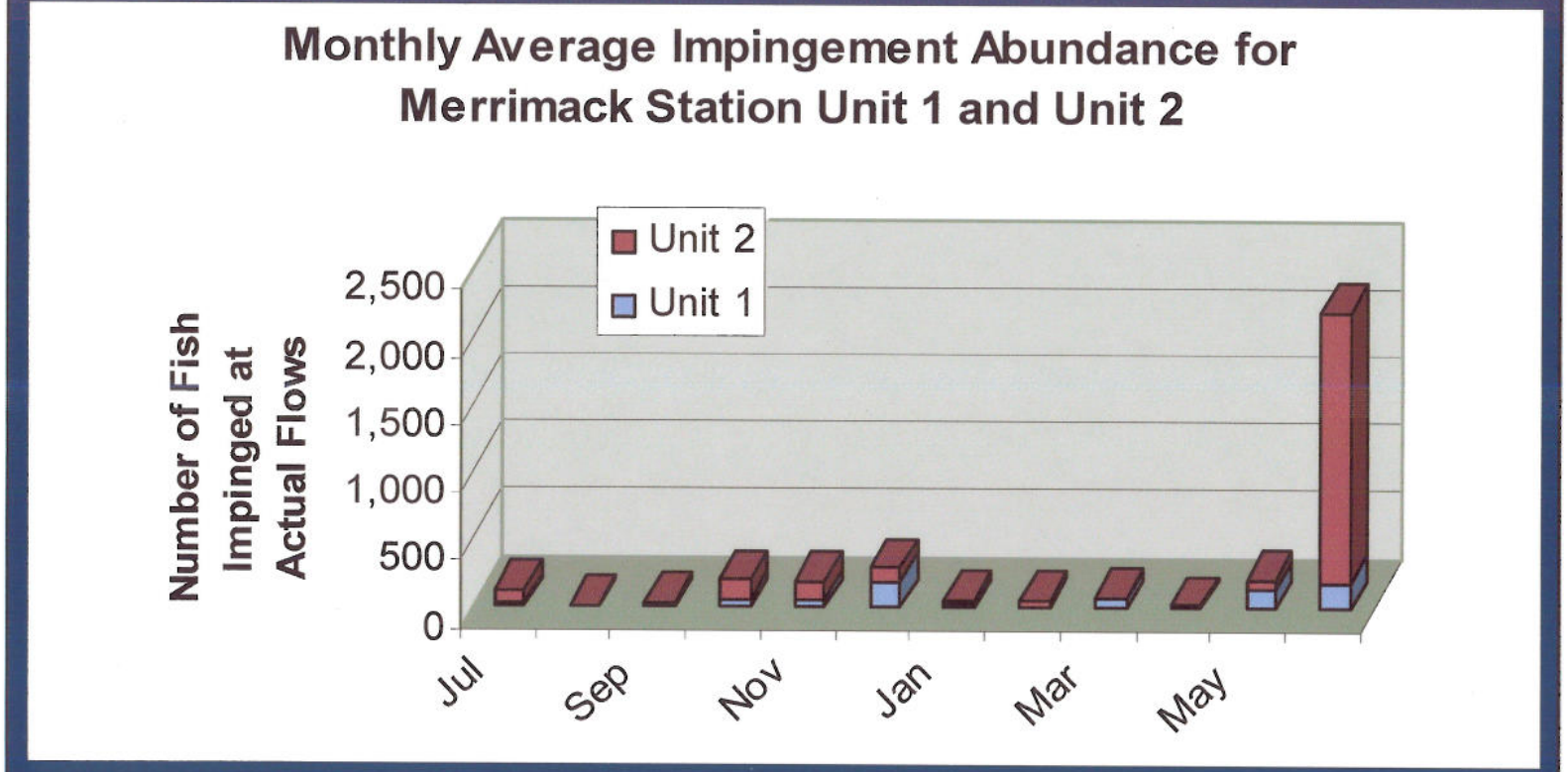
NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

Latent (24 Hour) Impingement Survival Observations



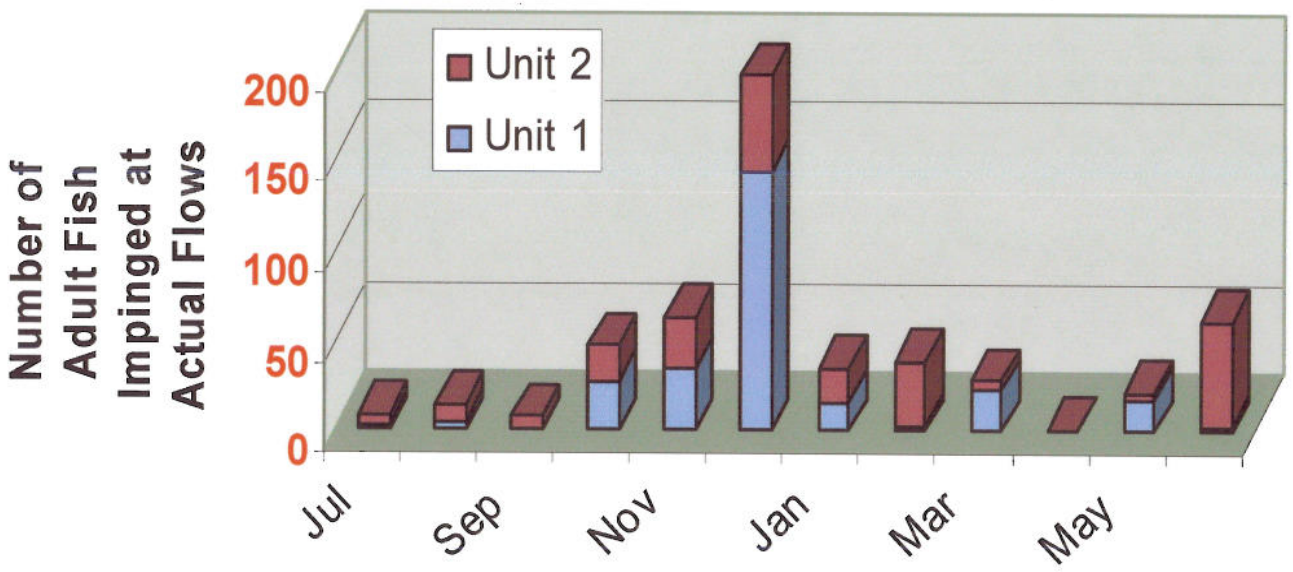
NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

Completed Merrimack 316(b) Studies: Entrainment Abundance



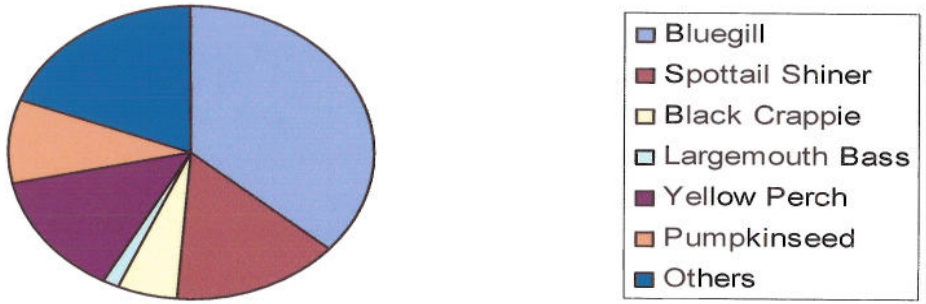
Completed Merrimack 316(b) Studies: Impingement Abundance

Monthly Average Adult Equivalent Impingement for Merrimack Station Unit 1 and Unit 2

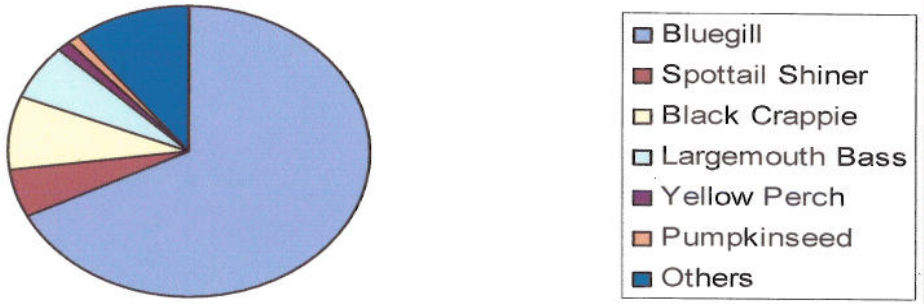


Completed Merrimack 316(b) Studies: Impingement Abundance

Fish Impingement Species Composition for Merrimack Station Unit 1 During 2005-2007



Fish Impingement Species Composition for Merrimack Station Unit 2 During 2005-2007



Completed Merrimack 316(b) Studies: Conclusions






Total Impingement and Entrainment Mortality of Merrimack Station On Adult Equivalent Fish Populations

Vulnerable to Impingement Mortality at Design Flow

1,329	U1
3,574	U2
4,903	Both

Avoid Impingement Due to Flow Reductions

325	U1
573	U2
898	Both

Survive Impingement if Returned to the River

543	U1
1,374	U2
1,918	Both

Survive "Natural" Mortality to Adult Equivalent Age

247	U1
160	U2
407	Both

Impingement Mortality

461	U1
1,627	U2
2,087	Both

Die From Impingement Before Adult Equivalent Age

124	U1
122	U2
246	Both

Total AE Impingement and Entrainment Mortality of Merrimack Station

5,507	U1
8,800	U2
14,307	Both

Vulnerable to Entrainment Mortality at Design Flow

1,677,802	U1
1,787,008	U2
3,464,810	Both

Initial Entrainment Mortality

1,289,515	U1
1,587,018	U2
2,876,533	Both

Die From Impingement Before Adult Equivalent Age

5,383	U1
8,678	U2
14,061	Both

Avoid Entrainment Due to Flow Reductions

388,287	U1
199,990	U2
588,278	Both

Survive Entrainment if Returned to the River (Assumed Zero)

0	U1
0	U2
0	Both

Survive "Natural" Mortality to Adult Equivalent Age

1,621	U1
1,094	U2
2,714	Both

NORMANDEAU ASSOCIATES™
ENVIRONMENTAL CONSULTANTS

Completed Merrimack 316(b) Studies: Conclusions

- Magnitude of Station's annual entrainment and impingement losses are small compared to other plants with similarly sized intakes
- Installation and operation of upgraded fish return system would further reduce impingement mortality
- Timing of spring maintenance outages would also contribute to further reduced entrainment and impingement mortality

Supplemental Merrimack 316(a) Studies (2008)

- Hooksett Dam water temperatures
- Objective is to continuously observe and record mixed water temperature data at Station A0 during all months of 2008
  - Station A0
  - Continuous recording of tailrace water temperatures beginning in December 2007
  - Possible compliance location due to complete mixing and year round access

Supplemental Merrimack 316(a) Studies (2008)

- Yellow perch and white sucker age and growth
  - Objective is to examine local fish populations for sub-lethal effects on age structure, growth rates, fecundity, condition, and parasite burden.
  - There is no empirical evidence of harm to BIP from Station's thermal discharge based on population level studies conducted for past 40 years.
  - Spring and Fall sampling in Garvins, Hooksett, and Amoskeag Pools targeting these two fish species.

Supplemental Merrimack 316(b) Studies (2008)

- White sucker larval entrainment survival
- Objective is to quantify whole system entrainment survival at end of cooling canal (S0) compared to intake.
  - Observed white sucker larval entrainment at Merrimack Station represented 55% to 74% of the total during the spring months of 2006 and 2007.
  - Literature reports white sucker entrainment survival of 88% to 98% at discharge temperatures of 26°C to 36°C.

Supplemental Merrimack 316(b) Studies (2008)

- White sucker larval transport and flux in Hooksett Pool
  - Objective is to determine if entrainment may be having adverse environmental impact (AEI) on white sucker population of Hooksett pool by building model of flux of larvae into and through pool for comparison with observed entrainment mortality
  - White sucker may enter Hooksett Pool from Garvins Pool or from tributaries (Soucook R., Suncook R., Bow Bog Brook) and exit pool downstream through Hooksett Dam
  - Goal of model is to quantify flux and put entrainment mortality in perspective with source populations

Supplemental Merrimack NPDES Studies (2008)

- Merrimack River Ambient pH
- Objective is to analyze June 2002 – May 2007 hourly pH data from intake water to make case for conforming permit to observed ambient river conditions
  - Existing NPDES permit states Merrimack Station discharge pH shall not be lower than NH State water quality standards of 6.5 SU
  - However upstream ambient pH at the intake often are lower than 6.5 SU