# Defining Instream Flow Standards Using Best Professional Judgment

*The Connecticut Experience*

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**with assistance from**
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**and CT DEP Scientific-Technical Advisory Committee**

‘…shall promulgate regulations establishing instantaneous minimum flow standards and regulations for all stocked river and stream systems. Such instantaneous minimum flow standards and regulations which the commissioner finds are reasonably necessary to keep a sufficient flow of water to protect and safely maintain the fish placed therein by him pursuant to his stocking program’

*Connecticut’s Former Instream Flow Legislation*

'…shall: (1) apply to **all river and stream systems** within this state; (2) **preserve and protect the natural aquatic life**, including anadromous fish, contained within such waters; (3) preserve and protect the natural and stocked wildlife dependent upon the flow of such water; (4) promote and protect the usage of such water for public recreation; (5) **be based**, to the maximum extent practicable, **on natural variation of flows** and water levels **while providing for the needs and requirements of public health**, flood control, industry, public utilities, water supply, public safety, agriculture and other lawful uses of such waters; and (6) be **based on the best available science**'

*Connecticut Public Act 0514 , Adopted in 2005*

Established December of 2005

**Commissioner's Advisory Group**

**Scientific – Technical Workgroup**

**Policy – Implementation Workgroup**

Scientific- Technical Workgroup Includes:

*2 water suppliers, 3 academics, 1 professional engineer, 1 USGS staff, 1 NGO staff, 1 non-profit consultant, and support from Connecticut DEP staff*

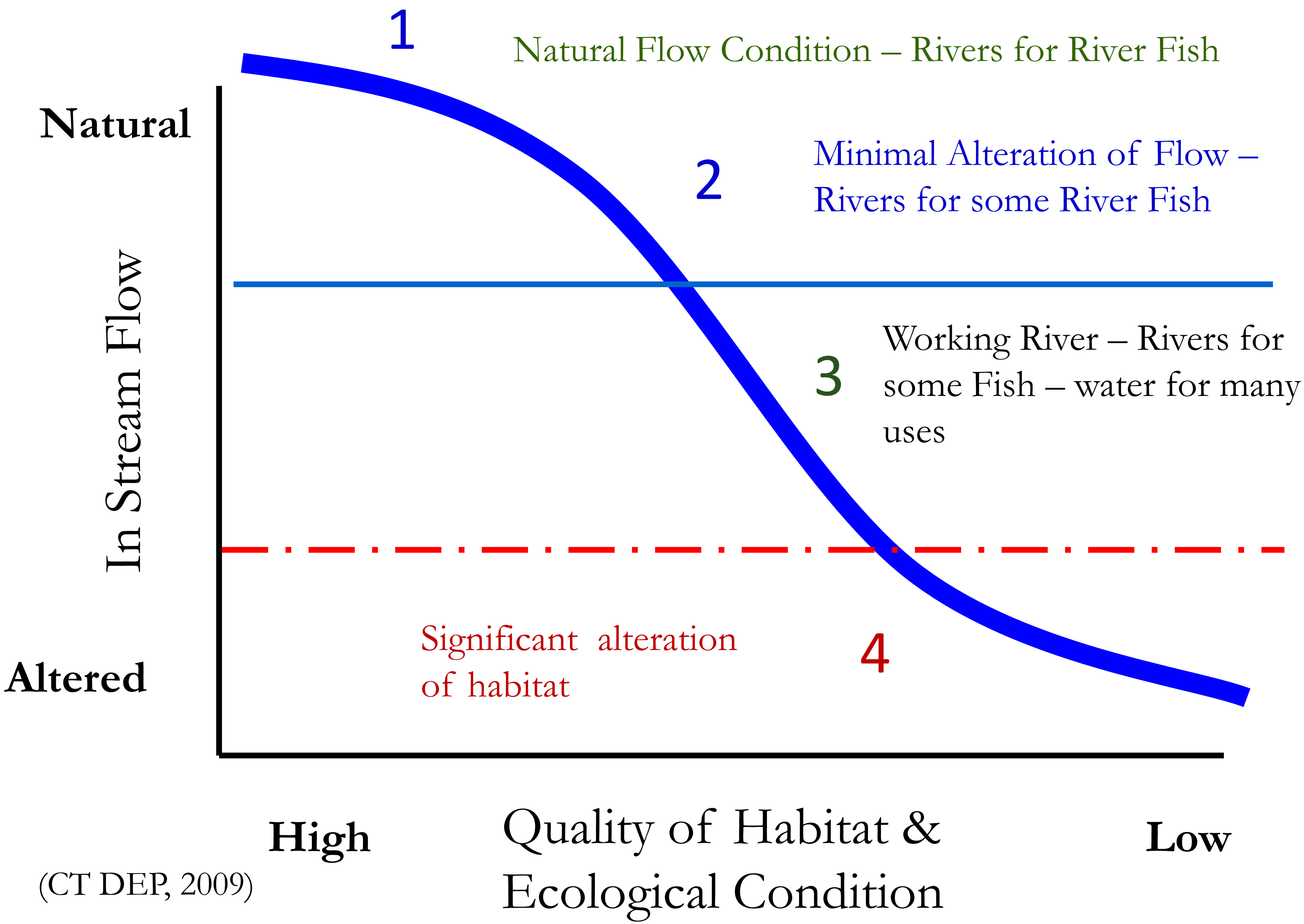
**Scientific-Technical Workgroup Approach:**

- Connecticut DEP set agenda and facilitated; workgroup members work to arrive at consensus
- No funding at outset, with initial deadline of 1 year (end of 2006)
- Met for almost three years, approximately 15 meetings
- Initial focus on state of science in Connecticut and Eastern U.S. & models for developing standards (including early ELOHA concepts)

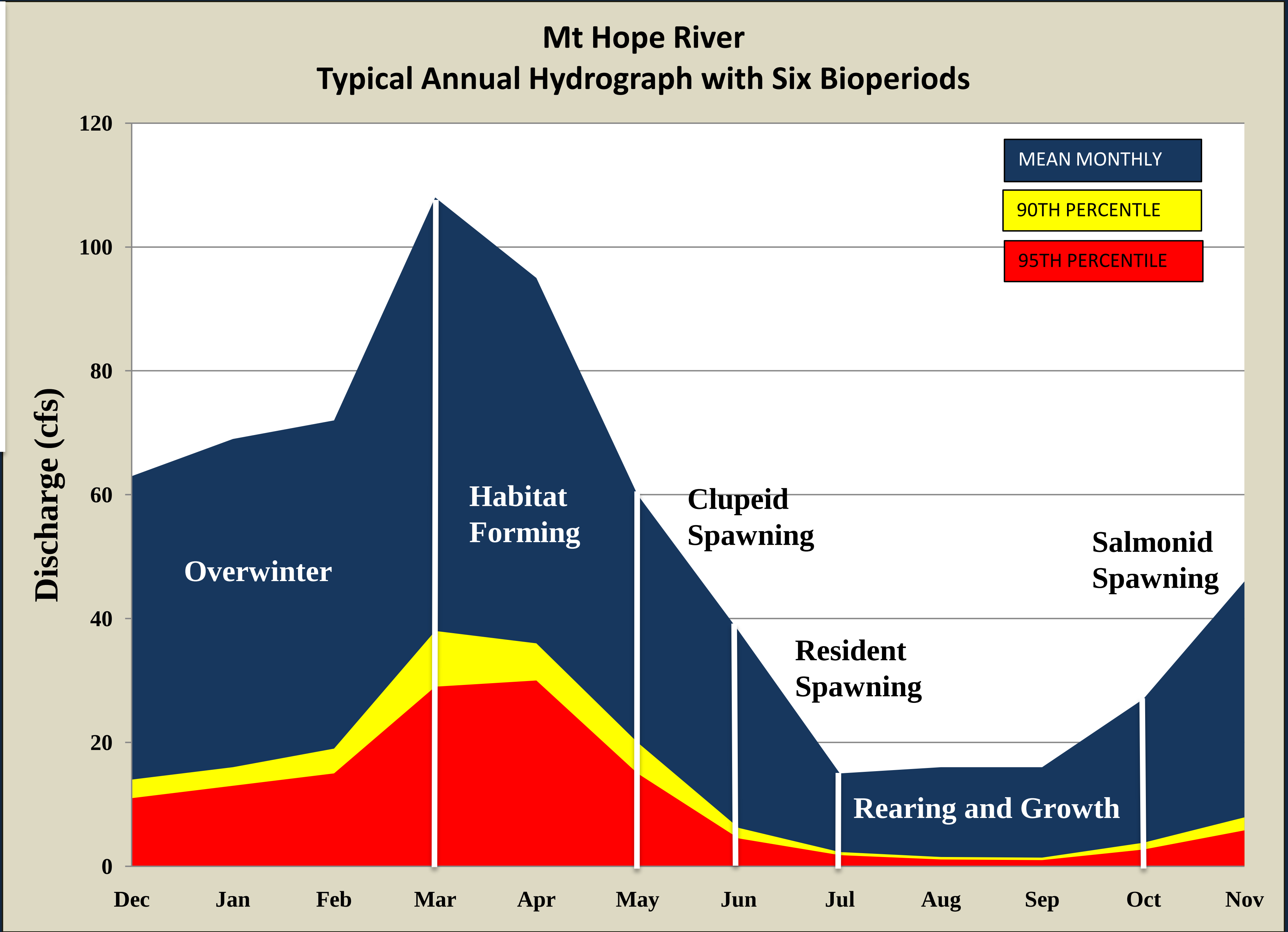
Made recommendations, within constraints, on:

  - overall regulatory structure & scientific foundation (narrative standards, class system, bioperiods)
  - use of USGS simulation of "unimpacted" hydrology at ungaged sites
  - division between direct withdrawal & reservoir release standards
  - quantitative direct withdrawal standard options
  - quantitative reservoir release standard options
  - flow alteration criteria using IHA statistics (*recommendation not accepted to date)*

# Proposed Stream Flow Classification




(CT DEP, 2009)

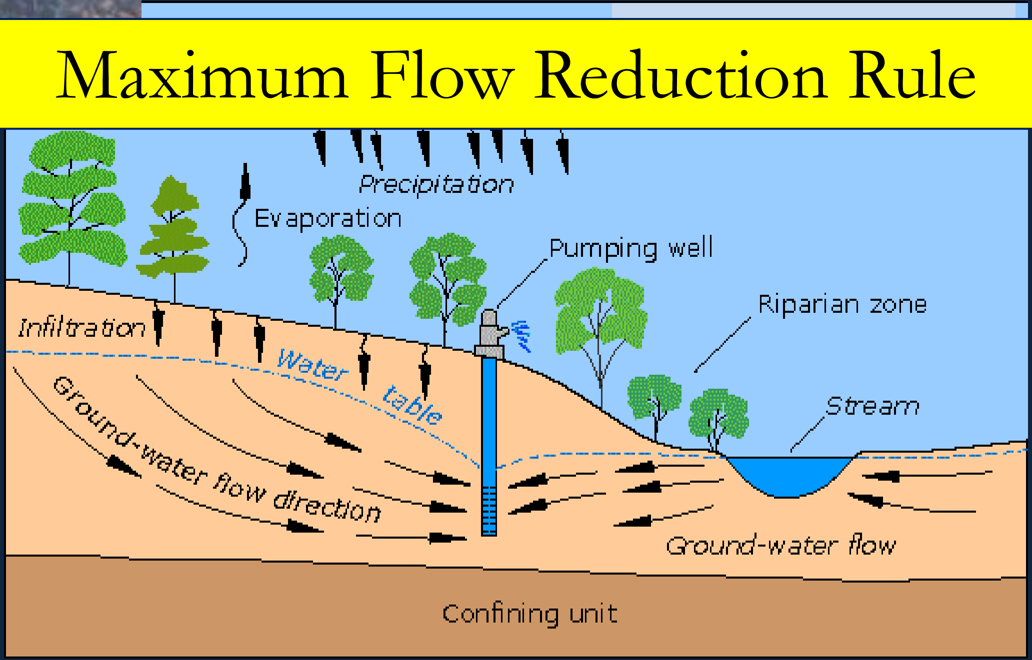

Mt Hope River
Typical Annual Hydrograph with Six Bioperiods
MEAN MONTHLY
90TH PERCENTILE
95TH PERCENTILE
Discharge (cfs)
120
100
80
60
40
20
0
Overwinter
Habitat Forming
Clupeid Spawning
Resident Spawning
Rearing and Growth
Salmonid Spawning
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

## Minimum Flow Release Rule

Source - NOAA

- Discussion was easier when we focused on form of implementation
- Unique situation: no withdrawal from "wastewater discharge" rivers

## Maximum Flow Reduction Rule




Source - USGS

- Narrative & presumptive standards for each of 3 river "classes"
- Site specific "off-ramp" through water compact agreements

# Literature Review: Filling a Gap in Connecticut Instream Flow Science

- **Freeman and Marcinek (2006)**

  "Fish Assemblage Response to Water Withdrawals and Water Supply Reservoirs in Piedmont Streams"

  - Used by Advisory Committee in absence of state-specific relationships
  - Example of a well-written scientific paper that appeals to water managers

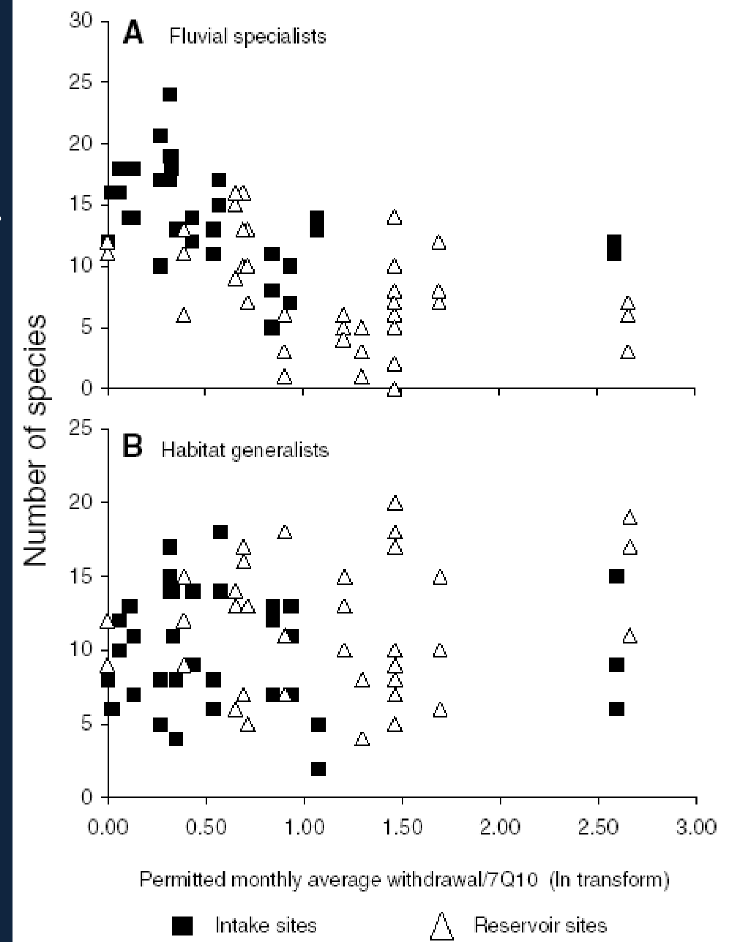
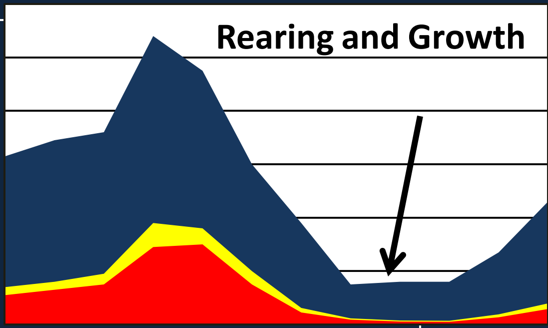



**Figure 5.** Richness estimates for fluvial specialist (**A**) and habitat generalist (**B**) fishes plotted in relation to withdrawal index at intake and reservoir sites, data for all years.

- **Acreman et al (2006)**
  - UK effort to define risk-based abstraction standards based on "best available scientific information and expert opinion" for WFD

# Presumptive Direct Withdrawal Standard




- In order to protect natural variation in flows, operate diversions such that
  - Class 1 – max alteration is .05 x Q99
  - Class 2 – max alteration is .25 x Q99 x F
  - Class 3 – max alteration is .50 x Q99 x F
  - Class 4 – existing practice

**F = Q99 for the bioperiod /Q99 for Rearing and Growth bioperiod**

**- allowing for greater amounts of water to be removed for human use during bioperiods when flow is typically higher than during Rearing and Growth bioperiod**

**F varies from 1 to 4, allowing for additional water in wet months**

Implementation Considerations:

- Model impact of well pumping on stream depletion
- Look at diversion impact **individually then cumulatively**

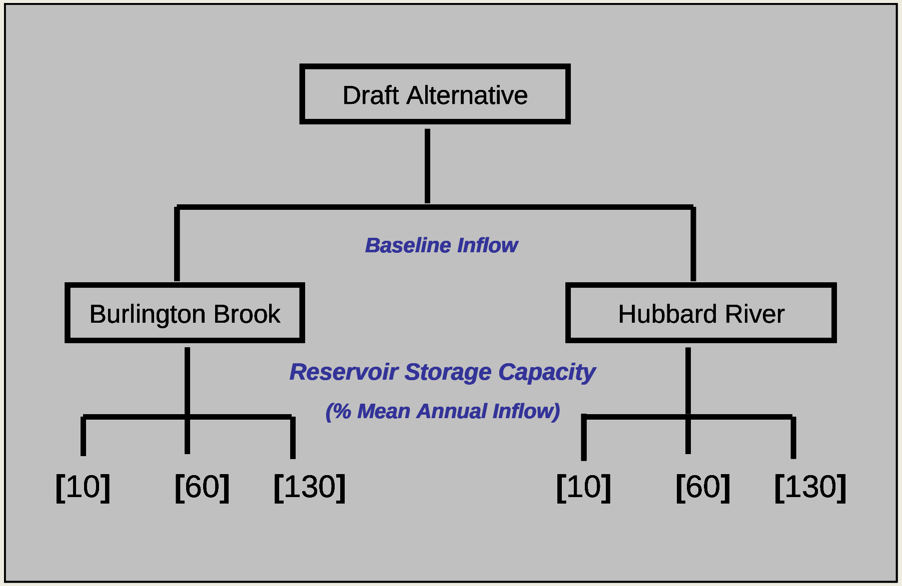
# Draft Class 1 Reservoir Release Rule: Run of River

# Draft Class 2 Reservoir Release Rule: 75% on inflow on daily time step

# Draft Class 3 Reservoir Release Rule: Modeling

1. Watershed Characteristics
2. Reservoir Storage Ratio

| Basin Characteristics | Burlington Brook | Hubbard River |
|---|---|---|
| Watershed Size (sqm) | 4.1 | 19.9 |
| Stratified Drift (%) | 33.2 | 0 |
| Glacial Til (%) | 31.1 | 100 |
| Thick Glacial Til (%) | 40.6 | 0 |
| Q99 (cfs) | 0.65 | 0.56 |
| 7Q10 (cfs) | 0.57 | 0.47 |
| Q5 (cfs) | 26 | 476 |



# Balancing Between Ecological and Human Needs & Using "Best Available Science"

## WEAP Model Simulation and Analysis

### Two Outputs: Safe Yield and Daily Reservoir Release

*Key Ecological Stats*- modification of Olden & Poff (2003)

- Monthly Means, Medians
- Baseflow index
- High flow duration & magnitude
- Low and high flow pulse count
- Date of minimum streamflow
- Variability in reversals
- Flow frequency statistics

*Table 4 Thresholds of hydrological alteration to meet GES*

| | | | |
|---|---|---|---|
| **Low Flows 2000 statistics**<br>mean January flow ($m^3s^{-1}$)<br>mean April flow ($m^3s^{-1}$)<br>mean July flow ($m^3s^{-1}$)<br>mean October flow ($m^3s^{-1}$)<br>$Q_{95}$ ($m^3s^{-1}$)<br>$Q_5$ ($m^3s^{-1}$)<br>BFI | **Low risk of failing GES if alteration less than 40% in all statistics** | **Medium risk of failing GES if alteration greater than 40 but less than 80% in any statistic** | **High risk of failing GES if alteration greater than 80% in any statistic** |

**Acreman et al (2007)-**Guidance on Env. Flow Releases from Impoundments to Implement Water Framework Directive

# Policy Testing: Bioperiod Adaptive Release Approach

| Bioperiod | Months | Subsistence Flow<br>*Flow that occurs infrequently* | Base Flow<br>*Typical flows in most conditions* | Wet Period Flow<br>*Occassional high flow periods* |
|---|---|---|---|---|
| Overwinter | Dec-Feb | Dec-Feb Q98 | Dec-Feb Q90 | Dec-Feb Q75 |
| Habitat forming | Mar-Apr | Mar-Apr Q98 | Mar-Apr Q90 | Mar-Apr Q75 |
| Clupeid spawning | May | May Q98 | May Q90 | May Q75 |
| Resident spawning | June | June Q95 | June Q75 | June Q50 |
| Rearing and growth | July-Oct | Jul-Oct Q90 | Jul-Oct Q75 | Jul-Oct Q50 |
| Salmonid spawning | Nov | Nov Q90 | Nov Q75 | Nov Q50 |

- Resulted from iterative examination of over 25 release “policies”
- Uses release “bins” that provide variability in releases based on antecedent conditions
- “Triggers” of antecedent flow relative to long term, estimated unregulated flows in the bioperiod are used to define what bin you are in
- Actual release quantities are exceedence flow values that allow for release that reflect local, natural hydrology
- Time frame for changes in releases based on triggers can be as short as implementation allows (generally used 2 weeks)
- Trying to arrive at implementable, local hydrology-based, limited infrastructure changes, eco & safe yield protection

# Balance Between Ecological and Human Needs

## Draft Reservoir Release Rule:

### Interpreting the Balance: Flow Protection & Yield

| | Reference with Demand (.64) | Augmented Consant .2 cfsm (.543) | BAR2b1 (.528) | BAR% (.44) | BAR2g (.415) | BAR2c (.413) | BAR2b (.408) | BAR2b2 (.393) | BAR3b (.39) | BAR2a (.378) | BAR2d (.378) | BAR3c (.375) | BAR2f (Q85) (.320) | BAR1 (.313) | BAR2 (.308) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAFE YIELD | 0.640 | 0.543 | 0.528 | 0.440 | 0.415 | 0.413 | 0.408 | 0.393 | 0.390 | 0.378 | 0.378 | 0.375 | 0.320 | 0.313 | 0.308 |
| *Monthly Flow Statistics: Non-parametric* | | | | | | | | | | | | | | | |
| October | -100.0 | -70.4 | -51.9 | -34.8 | -48.1 | -74.1 | -51.9 | -51.9 | -51.9 | -51.9 | -51.9 | -55.6 | -63.0 | -51.9 | -51.9 |
| November | -100.0 | -84.2 | -32.7 | -47.1 | -46.5 | -70.3 | -32.7 | -32.7 | -32.7 | -32.7 | -32.7 | -64.4 | -52.5 | -32.7 | -32.7 |
| December | -100.0 | -86.7 | -53.3 | -50.5 | -33.3 | -63.3 | -53.3 | -53.3 | -53.3 | -53.3 | -31.7 | -63.3 | -45.0 | -31.7 | -31.7 |
| January | -100.0 | -85.5 | -49.1 | -54.5 | -45.5 | -60.0 | -49.1 | -49.1 | -49.1 | -49.1 | -25.5 | -60.0 | -40.0 | -25.5 | -25.5 |
| February | -100.0 | -87.2 | -55.2 | -52.0 | -39.2 | -48.0 | -54.4 | -50.4 | -50.4 | -44.8 | -34.4 | -34.4 | -47.2 | -32.8 | -32.8 |
| March | -56.4 | -50.0 | -52.7 | -43.6 | -41.8 | -41.8 | -49.1 | -47.3 | -47.5 | -46.4 | -32.7 | -34.3 | -40.9 | -32.7 | -32.7 |
| April | -47.7 | -41.4 | -50.9 | -35.9 | -29.1 | -32.7 | -32.7 | -32.7 | -32.7 | -32.7 | -32.7 | -32.7 | -32.3 | -32.7 | -32.7 |
| May | -79.7 | -68.9 | -51.4 | -43.2 | -32.4 | -59.5 | -51.4 | -51.4 | -51.4 | -51.4 | -29.7 | -48.0 | -41.9 | -29.7 | -29.7 |
| June | -100.0 | -75.8 | -24.2 | -40.9 | -21.2 | -57.6 | -24.2 | -24.2 | -25.2 | -24.2 | -24.2 | -51.5 | -42.4 | -24.2 | -24.2 |
| July | -100.0 | -66.7 | -45.8 | -23.3 | -41.7 | -70.8 | -45.8 | -45.8 | -45.8 | -45.8 | -45.8 | -50.0 | -58.3 | -45.8 | -45.8 |
| August | -100.0 | -55.6 | -27.8 | -21.1 | -38.9 | -61.1 | -27.8 | -27.8 | -27.8 | -27.8 | -27.8 | -33.3 | -44.4 | -27.8 | -27.8 |
| September | -100.0 | -55.6 | -27.8 | -33.3 | -44.4 | -61.1 | -27.8 | -27.8 | -27.8 | -27.8 | -27.8 | -33.3 | -44.4 | -27.8 | -27.8 |

**Risk to Good Ecological Status**

| | | |
|---|---|---|
| (red) | ≥ (-) 80% | High Risk |
| (orange) | (-) 40 to (-) 80 | Moderate Risk |
| (yellow) | < (-) 40% | Low Risk |
| *Acreman, 2007* | | |

# Summary of Flow Release Rule

- Trigger for dry period/wet period is Bioperiod Q25
- Up to 26 times a year, operators will be required to evaluate whether to make a “dry” flow or “wet” flow release
- Many times, there will be no change in previous flow release (always can release more)

**MULTI-LEVEL RELEASE RULE**

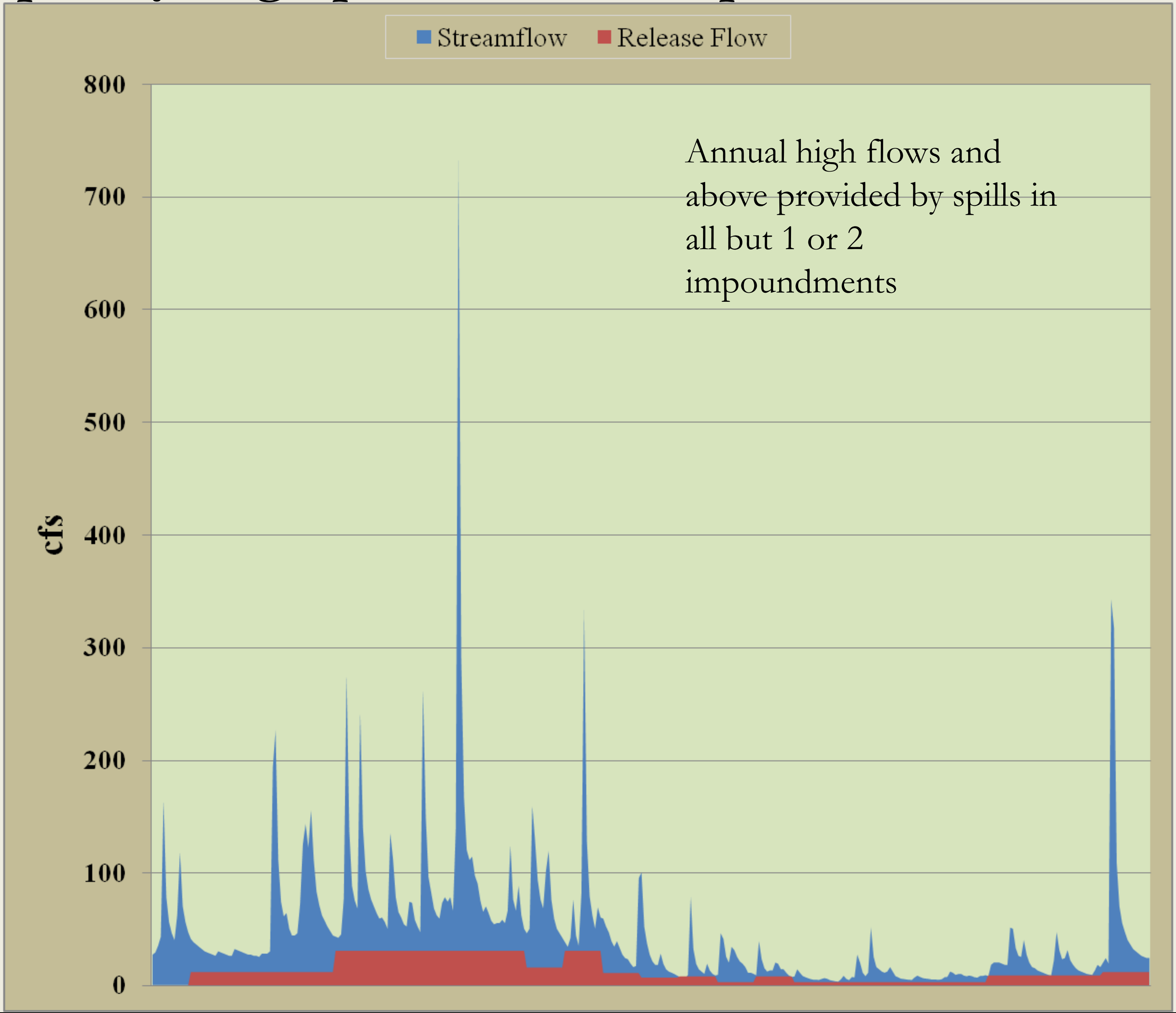
| Bioperiod | Effective Date | Minimum Required Release | |
|---|---|---|---|
| | | Anteceedent 14d Period Dry | Anteceedent 14d Period Wet |
| Overwinter | Dec 1 - Feb 28 | Bioperiod Q95 | Bioperiod Q75 |
| Habitat Forming | Mar 1 - Apr 30 | Bioperiod Q95 | Bioperiod Q75 |
| Cluepeid Spawning | May 1 - May 30 | Bioperiod Q95 | Bioperiod Q75 |
| Resident Spawning | Jun 1 - Jun 30 | Bioperiod Q90 | Bioperiod Q75 |
| Rearing and Growth | Jul 1 - Oct 31 | Bioperiod Q80 | Bioperiod Q50 |
| Salmonid Spawning | Nov 1 - Nov 30 | Bioperiod Q90 | Bioperiod Q75 |

# Flow Release Drought Triggers

- Effective when new release requirements start
- Based on individual water supply plan trigger

| Water Supply Plan Trigger | Reduction in Required Release | |
|---|---|---|
| | Rearing and Growth Bioperiod | All Other Bioperiods |
| Advisory | None | 50% |
| Watch | 50% | 50% |
| Warning | 75% | 75% |
| Emergency | none | none |

# Sample Hydrograph from Presumptive Release Rule



# Results to Date:

• Regulation proposed on October 13th with modifications to Advisory Group recommendations & long implementation time frame

• Initial reaction from water suppliers & municipalities is differing levels of opposition, but not on scientific grounds– focus on cost & complexity

• Room for compromise remains (e.g. additional flexibility in direct withdrawal requirements, especially during non-drought periods)

• Will likely be a visible, political stage of the process – but water supplier involvement & communication throughout improve odds of implementation

• Could be worse, given this regulation may result in the largest total reallocation of water back to the environment in U.S. history

# Connecticut Specific Flow-Ecology Relationships: Impact on Regulations?

Table 5. Effect size of Withdrawal Index (WI) on fish assemblage metrics which included WI in competing models. Effect size is based on a generalized linear regression model which included WI, intercept, and a scale term in the model. The WI value of 0 indicates no withdrawal.

| | Withdrawal Index (WI) | | | |
|---|---|---|---|---|
| | 0 | 10 | 50 | 100 |
| **Flow-related guilds** | | | | |
| % Fluvial dependent | 28 | 25 | 18 | 12 |
| % Macrohabitat generalist | 10 | 12 | 25 | 64 |
| **Thermal guilds** | | | | |
| % Warmwater | 16 | 17 | 25 | 40 |
| **Trophic guilds** | | | | |
| % Benthic Invertivore | 27 | 24 | 17 | 11 |
| % Non-Tolerant Gen Feeder | 12 | 13 | 17 | 26 |
| **Tolerance** | | | | |
| % Tolerant | 58 | 59 | 65 | 73 |
| **Indicater species/family** | | | | |
| % White sucker | 17 | 16 | 14 | 12 |
| % Centrarchidae | 6 | 8 | 17 | 51 |

WI = maximum permitted withdrawal rate/ estimated 7Q10

- Vokoun & Kanno (UConn, 2009) use similar approach to Freeman & Marcinek (2006)
- Different response variables, different patterns of response - yet still an effect
- Unclear how CT DEP proposes to use these results, may assist flexibility in withdrawal standard

## Lessons Learned:

- Flow standards can be defined through a “best professional judgment” approach that may be both implementable and protective

- The technical workgroup approach takes time, but not necessarily money

- If time can be built in ahead of time, development of local “regional flow-ecology science” may be practical & incorporated into the process

- The ability to simulate (by time of implementation) daily, unregulated hydrology at ungaged sites eliminates significant controversy

- The threshold for acceptable science may not be as difficult to achieve as the threshold of acceptable public & private implementation cost

- Balancing done primarily as part of science-technical committee work given lack of alternative -- may be value in a clearer separation of tasks