Hydroecological assessment process to evaluate effects of water management on hydrologic variability in streams

Linking Hydrological Change and Ecological Response in Streams and Rivers of the Eastern U.S. Herndon, VA February 2005

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Partnership:

- New Jersey Dept. of Environmental Protection (NJDEP)
- USGS WRD West Trenton, NJ
- USGS BRD Fort Collins, CO

Technical advisory committee

19 members

7 Divisions in NJDEP (WS, SWM, WMM, WPC, LUP, WP, ESC)

Philadelphia Academy of Natural Sciences

Pinelands Commission

USGS WRD

USGS BRD

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Purpose

Develop method to establish environmental flow standards

- sustain or restore aquatic communities -

- sustain or restore stream integrity -

- Guiding criteria -
  - Applicable to all water programs
  - Not require site specific studies/data collection
  - Use NJ NAWQA study results
  - “Scientifically” defensible

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Overview

1. New Jersey project - purpose and participants
2. Technical advisory committee's "search"
   - Evaluated 3 environmental flow methods
   - Overview stream ecology – concepts & theories
   - Natural flow regime paradigm
3. Hydrologic indices
   - Stream classification
   - Flow components
4. Hydroecological Integrity Assessment Process (HIP)
   - Classifying NJ streams
   - Significant indices
   - Application software

Instream Flows for Riverine Stewardship

(Instream Flow Council 2002)

29 Assessment tools (#)

- Standard setting (10)
- Incremental (12)
- Monitoring/diagnostic (7)

Environmental flow assessment methods

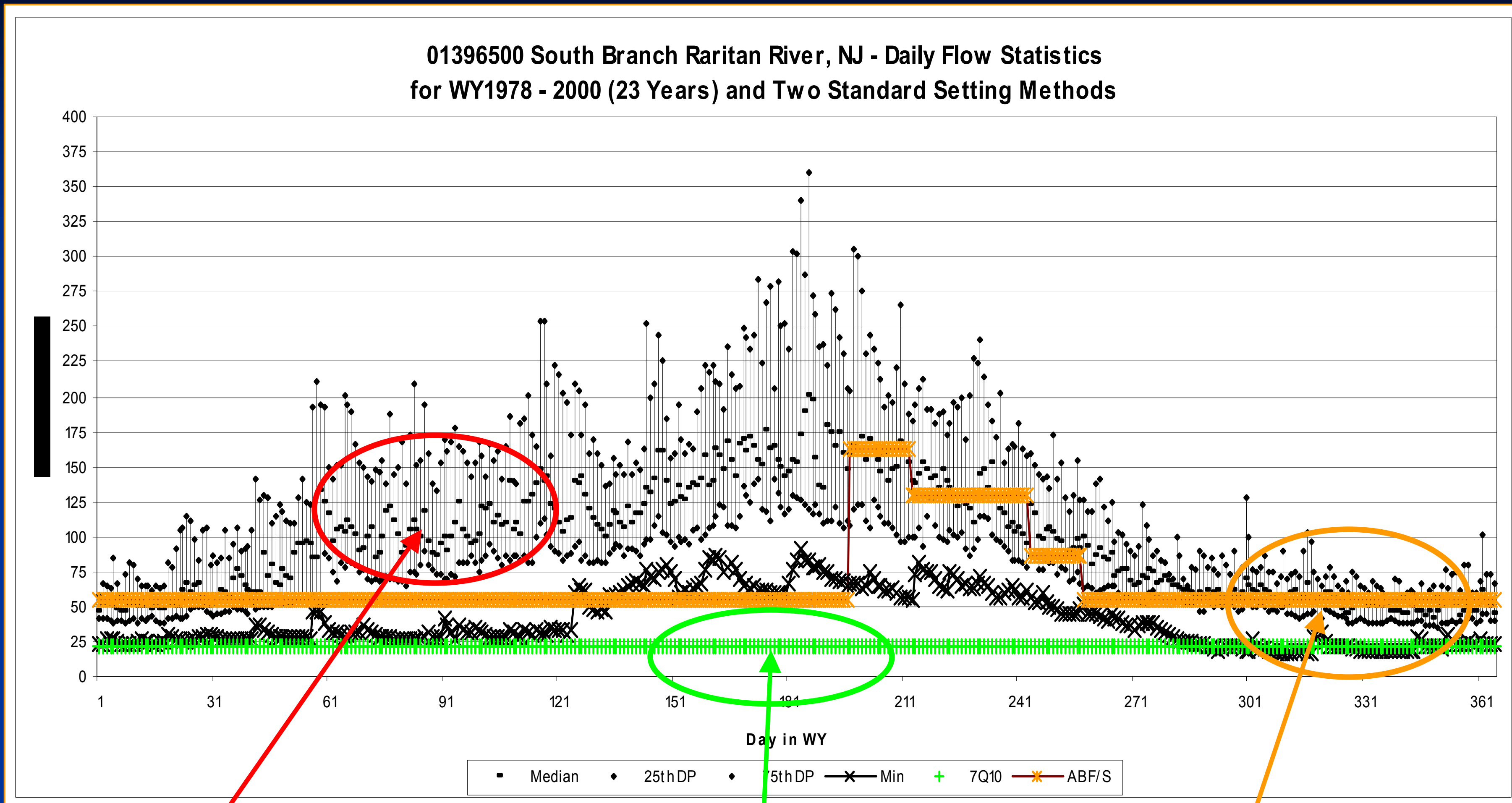
(Tharme 2003)

207 Assessment tools (#) ?

- Hydrological (61)
- Hydraulic rating (22)
- Habitat simulation (58)
- Holistic (16)
- Combination-type (37)
- Other (13)

TAC compared 3 assessment methods:

- 7Q10 – current NJ standard
- Aquatic base flow *(Larson 1981)*
- Indicators of hydrologic alteration *(Richter 1996)*



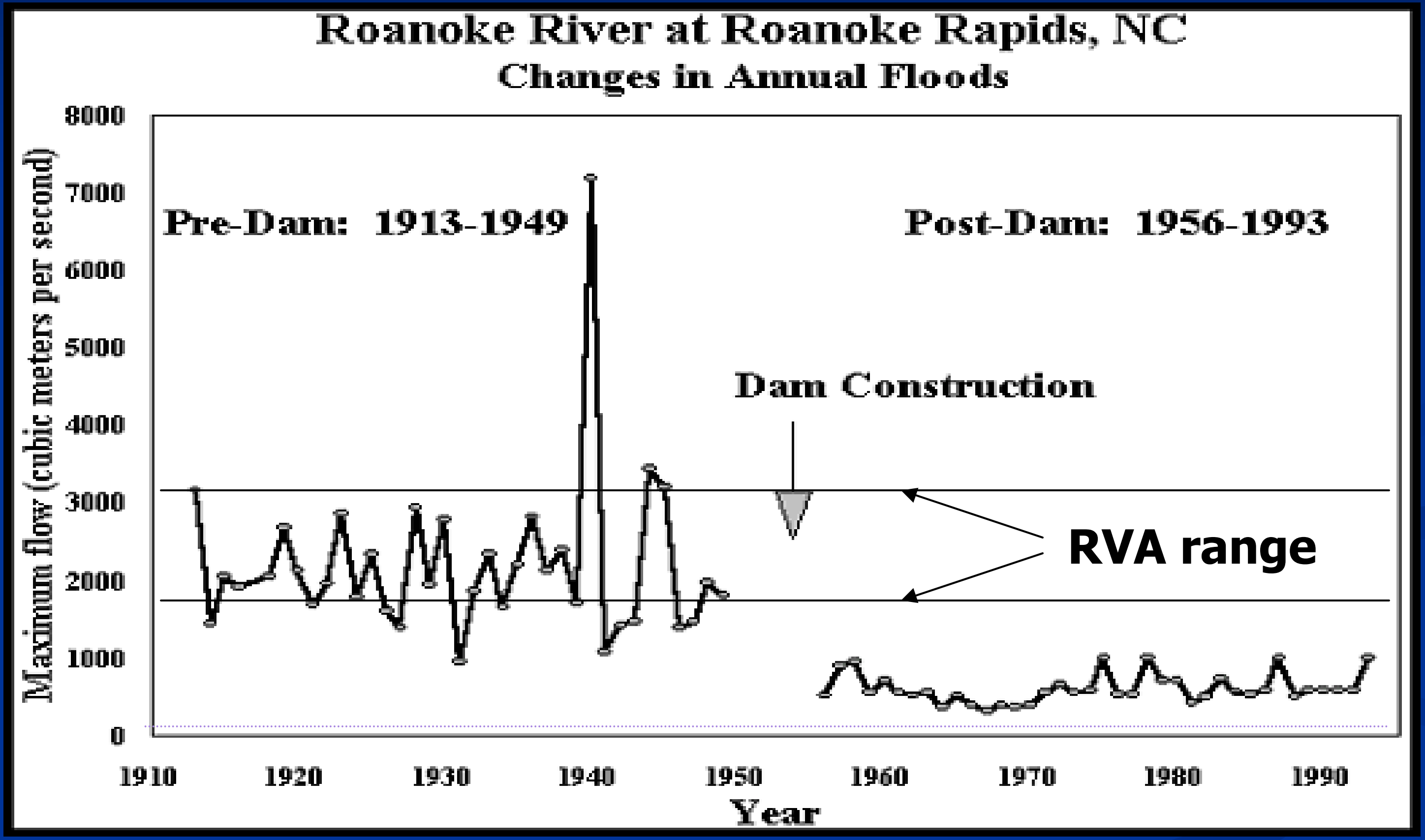
Range of daily variability
75/25 percentile

7Q10 standard

Aquatic base flow standard
(Larson 1981)

IHA/RVA - range of variability targets

(Richter et al. 1996)



- RVA range 75/25 percentile (or +/- 1 sd)

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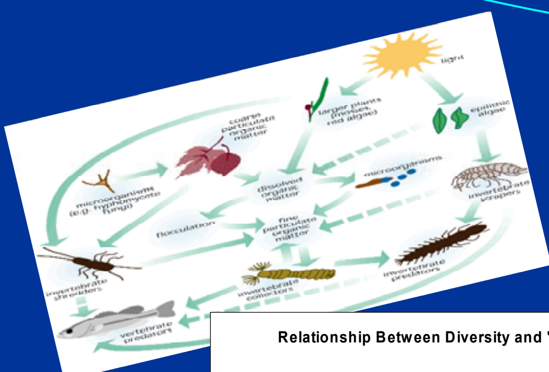
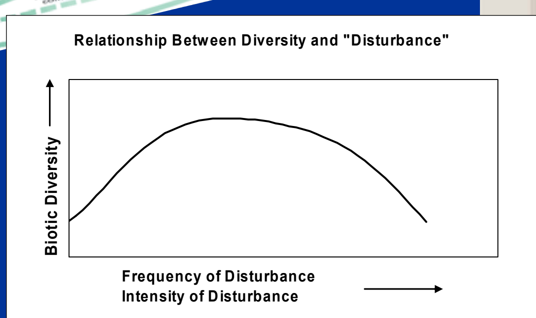
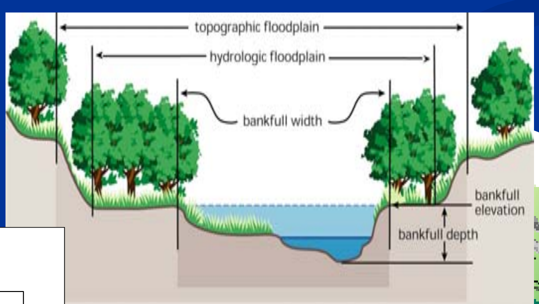
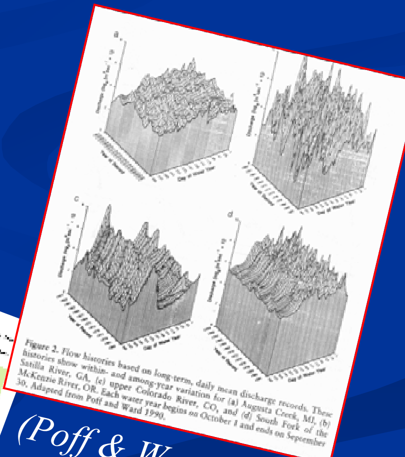
Natural flow regime paradigm

- River continuum concept *(Vannote 1980)*
- Flood pulse concept *(Bayley 1991)*
- Hierarchical, multi-scale *(Frissell 1986)*
- Network dynamics hypothesis *(Benda et al. 2004)*
- *Intermediate-disturbance hypothesis (Ward & Stanford 1983)*



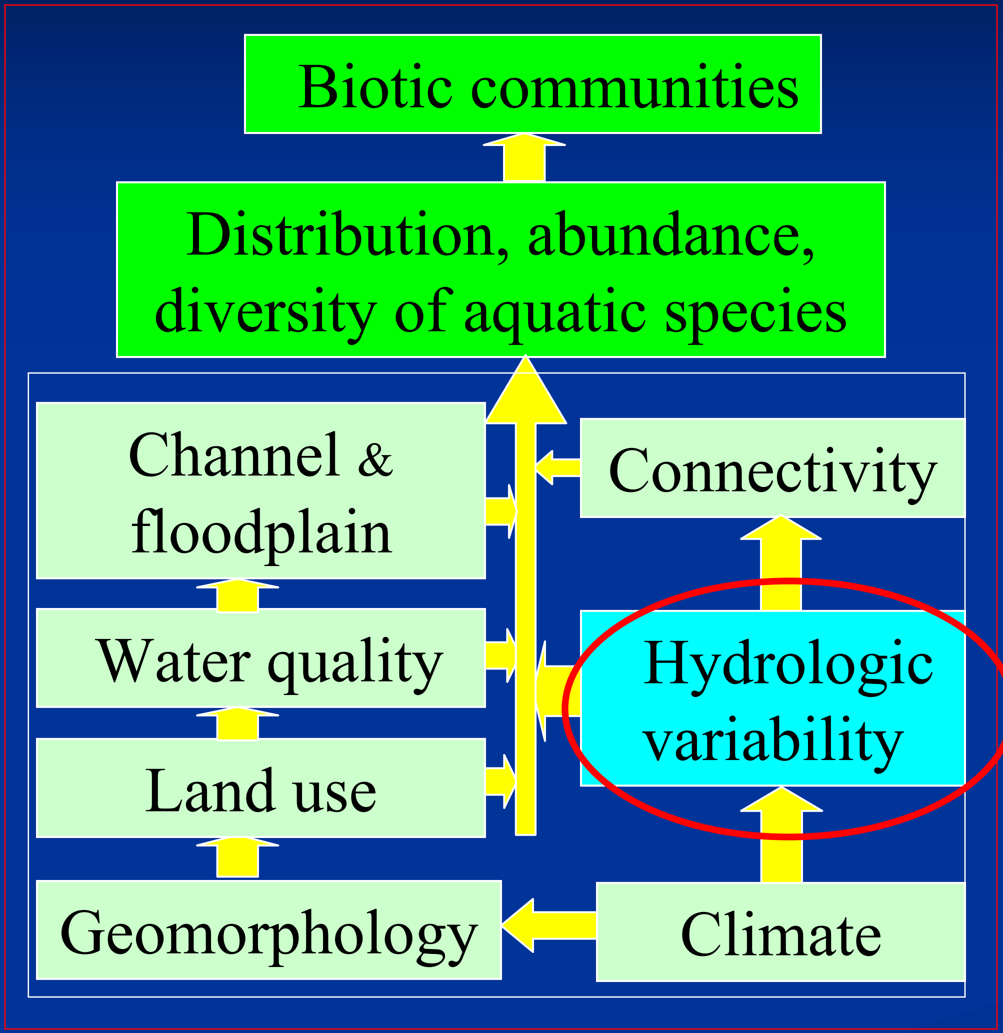


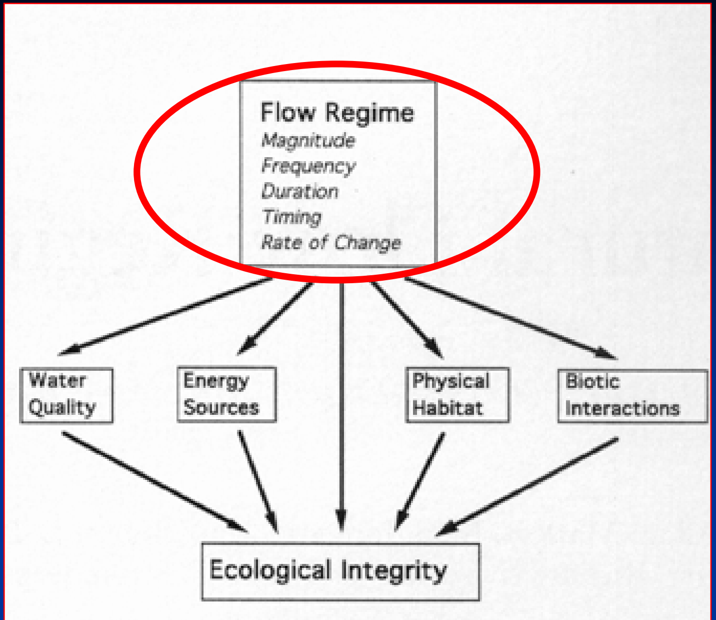




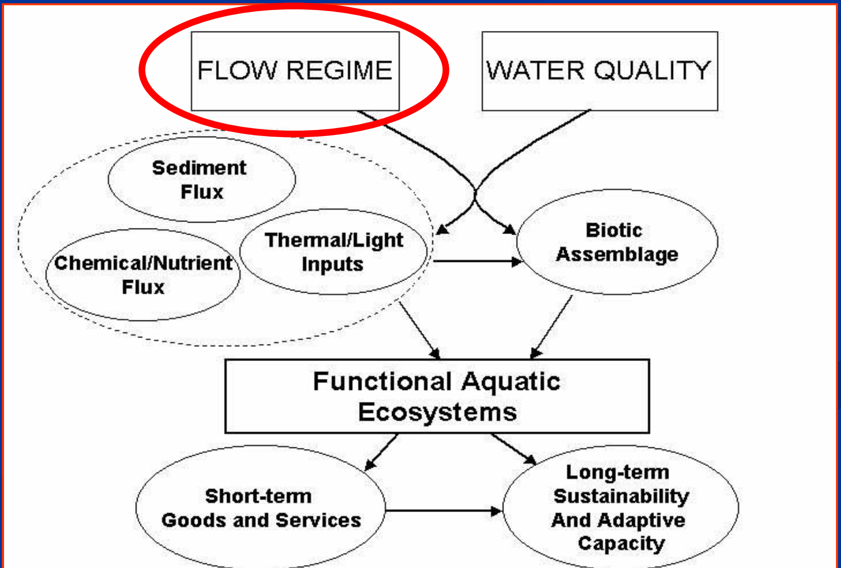
(Poff & Ward 1990)

Conceptual views of stream ecosystem





(Poff et al. 1997)



(Baron et al. 2002)

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Premise #1 – Recognize flow/response relationships and hydrologic indices

Examples

Author	Indices	Biota/Variables
Clausen & Biggs 1997	34	Periphyton, invert. diversity
Puckridge et al. 1998	23	Fish biology
Horwitz 1978	2	Fish diversity patterns
Kennen & Ayers 2002 (NJ)	3	Fish, invert., algal
Poff & Ward 1989	11	Comm. structure/processes
Richter 1997	33	Diversity & integrity
Poff & Allan 1995	8	Fish assemblages
Keller & Swanson 1979	Stats	Woody debris
Leopold 1964	Stats	Sediment
Jowett 1990	7	Periphyton, invert., fish

etc,
etc….

So?

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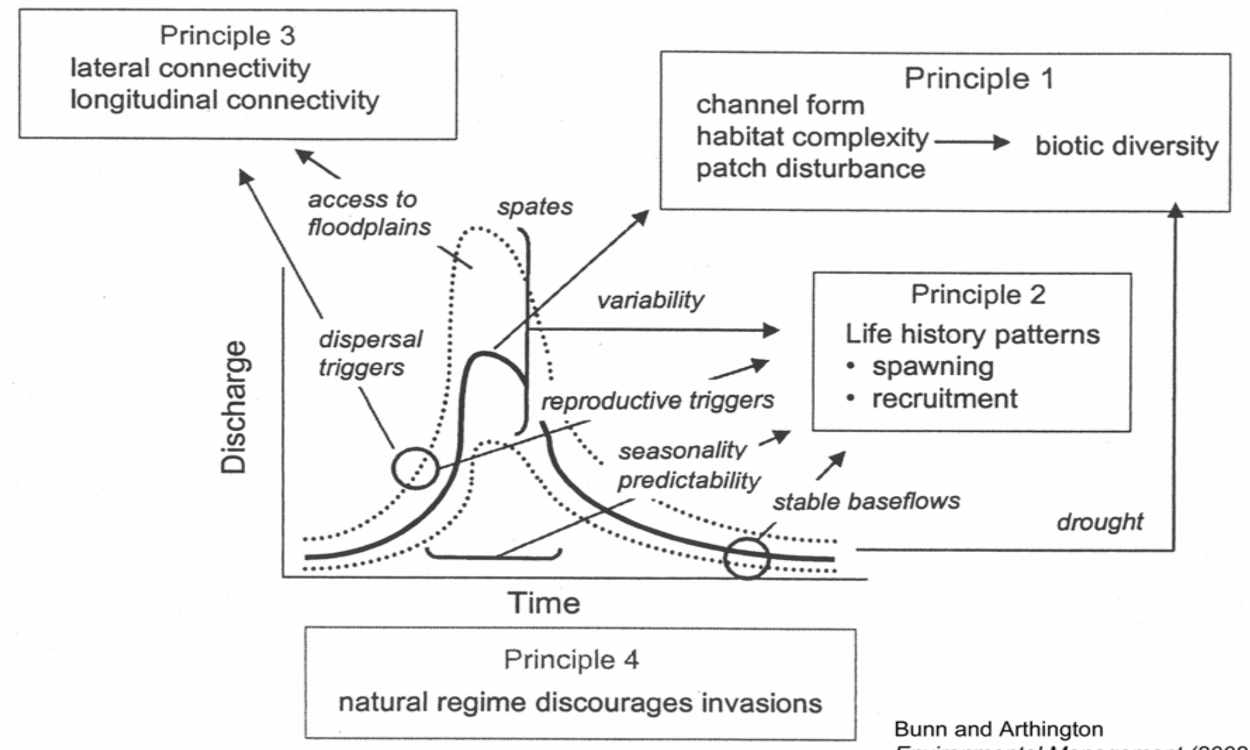
Aquatic biodiversity and natural flow regimes

"The ecological integrity of river ecosystems depends on their natural dynamic character."



Bunn and Arthington
Environmental Management (2002)

Premise #2 - Quantify the natural flow regime?

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Approach - *Poff & Ward 1989* - *Can. J. Fish. Aquat. Sci. Vol. 46.*

Objectives:

- Characterize streamflow variability & predictability
- Assess hydrologic similarity using 11 indices
- Assess hydrologic patterns & community patterns

- 78 US streams
- 11 pre-selected summary hydrologic indices
- Nine stream types based on:
  - Overall flow predictability
  - Flood frequency
  - Flood predictability
  - Intermittency

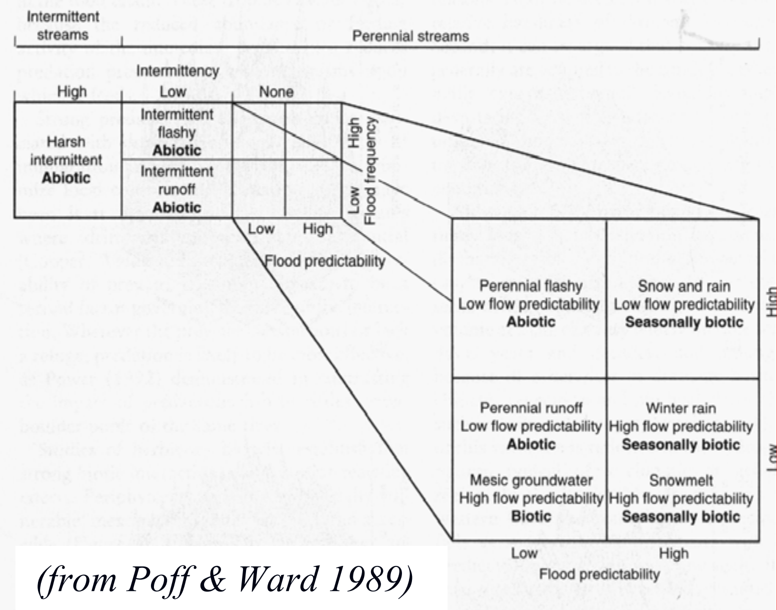

FIGURE 11.7 Conceptual model of nine stream types based on several temporal measures of discharge regi degree of intermittency is the first classification variable. For streams of low intermittency and for perennial s flood frequency provides additional separation. For perennial streams, flood predictability also must be con Names ('winter rain') are indicative of environmental conditions resulting in hydrographs of a particular clas tional descriptions (abiotic, seasonally biotic) are Poff and Ward's (1989) predictions of the relative contr to community structure of abiotic and biotic processes for each stream type.

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Olden & Poff 2003

River Research and Applications

"Redundancy and the Choice of Hydrologic Indices for Characterizing Streamflow Regimes"

- Evaluated 171 hydrologic indices using 420 streams (U.S. gages)
  - Addresses index redundancy
  - Identifies nine components of flow regime
  - Identifies "significant" indices for 6 stream types, e.g., snowmelt, snow and rain, perennial flashy etc.

Synthesis of important hydroecolgical information

To characterize the Natural flow regime use:

- Non-redundant indices
- 10 attributes of flow regime (more?)
- Stream type (class) specific indices
- A baseline daily flow period of record

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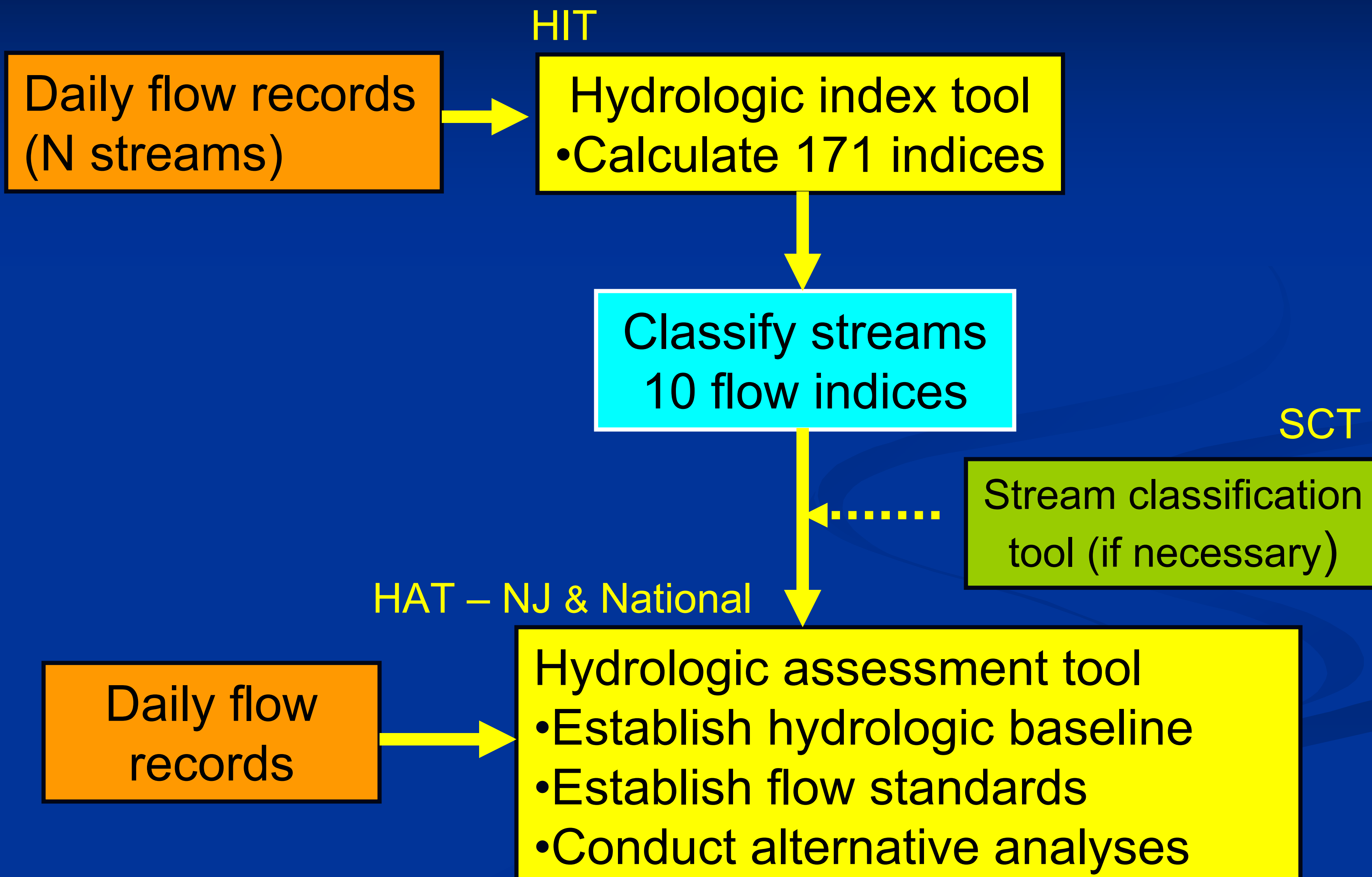
Hydroecological Integrity Assessment Process - HIP



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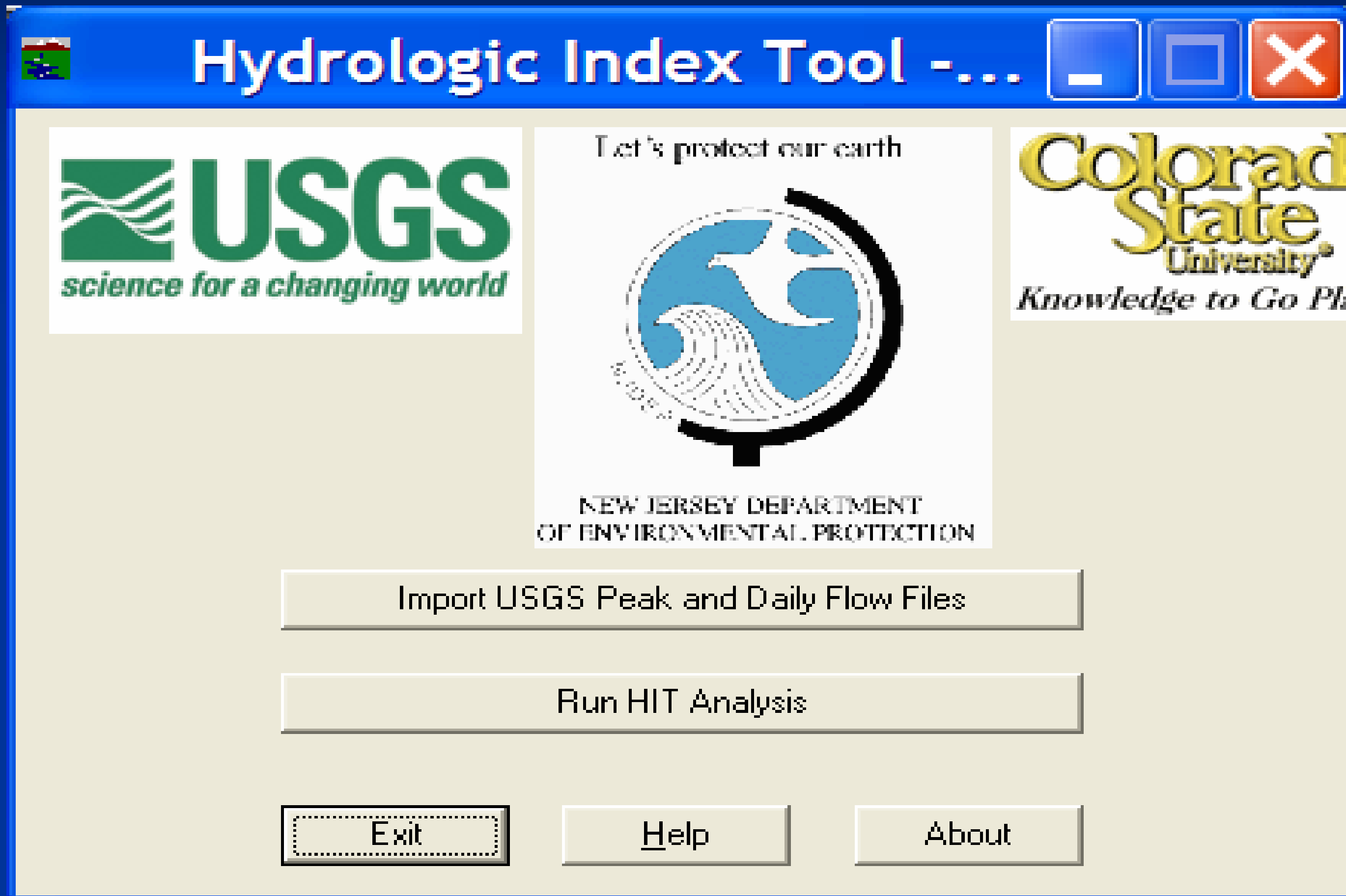
HIT Program – calculates 171 indices



General approach taken for NJ

USGS daily stream flow data

HIP Analysis of 94 Network Stations

Compare output with published records (validate)

Creation of 171 indices for all 94 streams

Cluster analysis –to form hydrologic classification of New Jersey streams

PCA identifies significant hydrologic variables for ten components of the flow regime

Ten Flow Components

MAGNITUDE
- Average
- High
- Low

FREQUENCY
- Low
- High

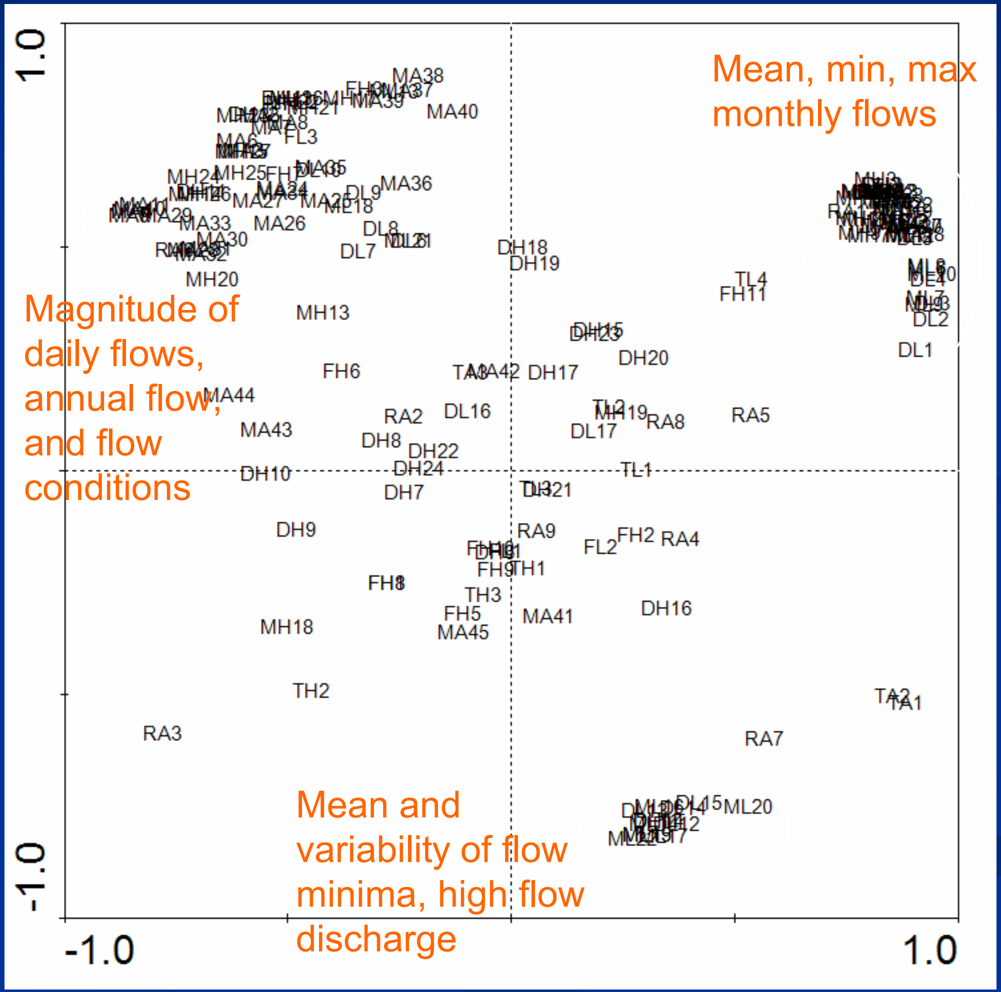
DURATION
- Low
- High

TIMING
- Low
- High

RATE OF CHANGE

Principal Components Analysis

- Principal components analysis I suggested some redundancy among indices.
- These groups represent indices that account for the majority of the variation.
- Some are relatively independent.



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Hydrological indices – significant principle components for NJ streams

NJ classification – 89 streams – 4 stream types

Ten Flow Components	Stream Type A	Stream Type B	Stream Type C
Mag Ave	MA18, MA 39, MA26, MA37	MA9, MA15, MA33, MA32	MA24, MA11, MA43, MA40
Mag Low	ML6, ML13, ML16	ML20, ML4, ML21, ML16	ML3, ML19, ML20, ML3
Mag High	MH5, MH16, MH20, MH18	MH24, MH4, MH18, MH26	MH14,MH17, MH12, MH13
Freq Low	FL3, FL1	FL3, FL2, FL1	FL1, FL3, FL2
Freq high	FH4, FH3, FH1, FH9	FH4, FH10, FH1	FH7, FH3, FH4, FH11
Dur Low	DL4, DL12, DL16, DL6	DL15, DL1, DL16, DL12	DL16,DL14, DL5, DL9
Dur High	DH2, DH13, DH20, DH8	DH12, DH2, DH20, DH24	DH11, DH14, DH1, DH9

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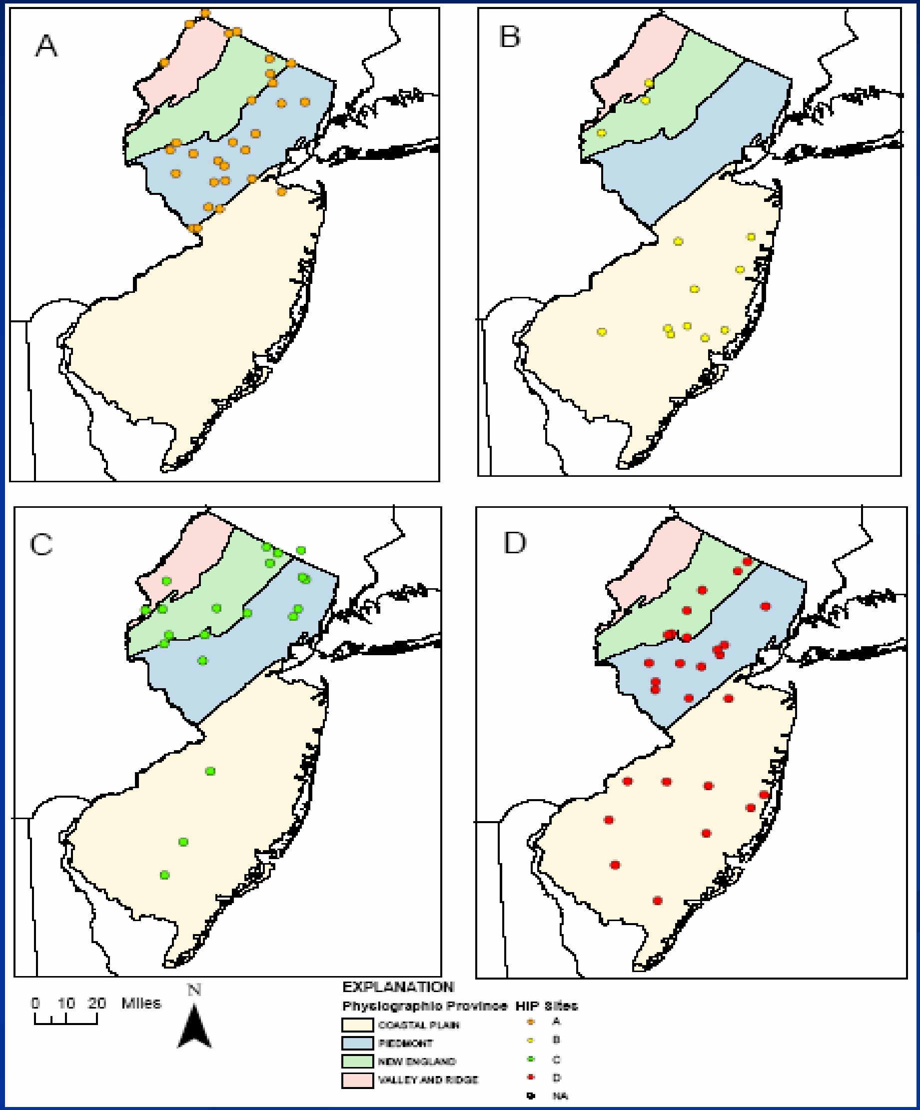
Distribution of four NJ stream types

- Consistent across multiple analyses
- Group B – stable, high base flow, GW supported
- Group D – small streams, low base flow, flashy
- Groups A & C – intermediate, but not GW supported



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Distinctive characteristics of NJ stream types

Low ← **Skewness of Daily Flows** → High

*(MA5 - Dimensionless)

<u>*Stable*</u>	B (1.25)	C (1.62)	A (1.74)	D (2.09)	<u>*Flashy*</u>

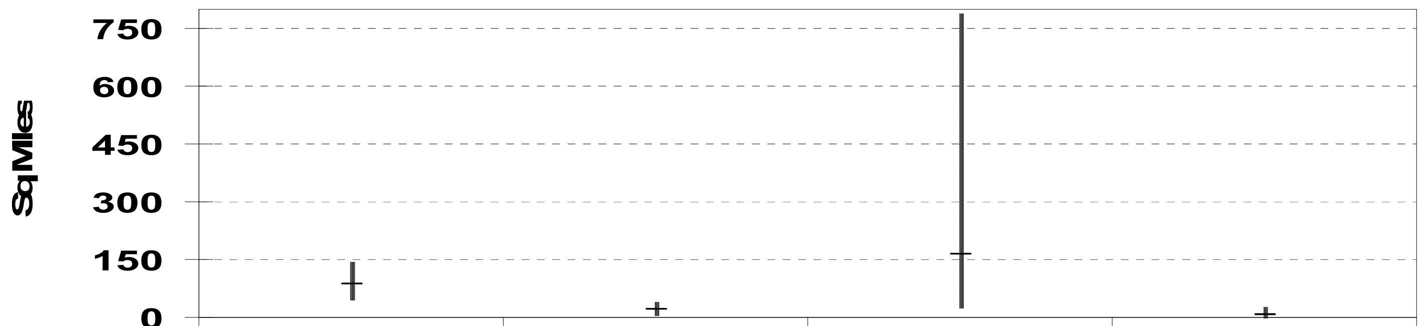
*(mean value)

Low ← **Frequency Low Flow Events** → High

*(FL3 - events/yr)

<u>*High Base Flow*</u>	B (0.0)	C (0.7)	A (1.3)	D (2.8)	<u>*Low Base Flow*</u>

Drainage area for Stream Types A, B, C, and D



	B	C	A	D
max	141	37	786	23
min	47	8	25	1
— mean	86	21	165	6

Stream Type

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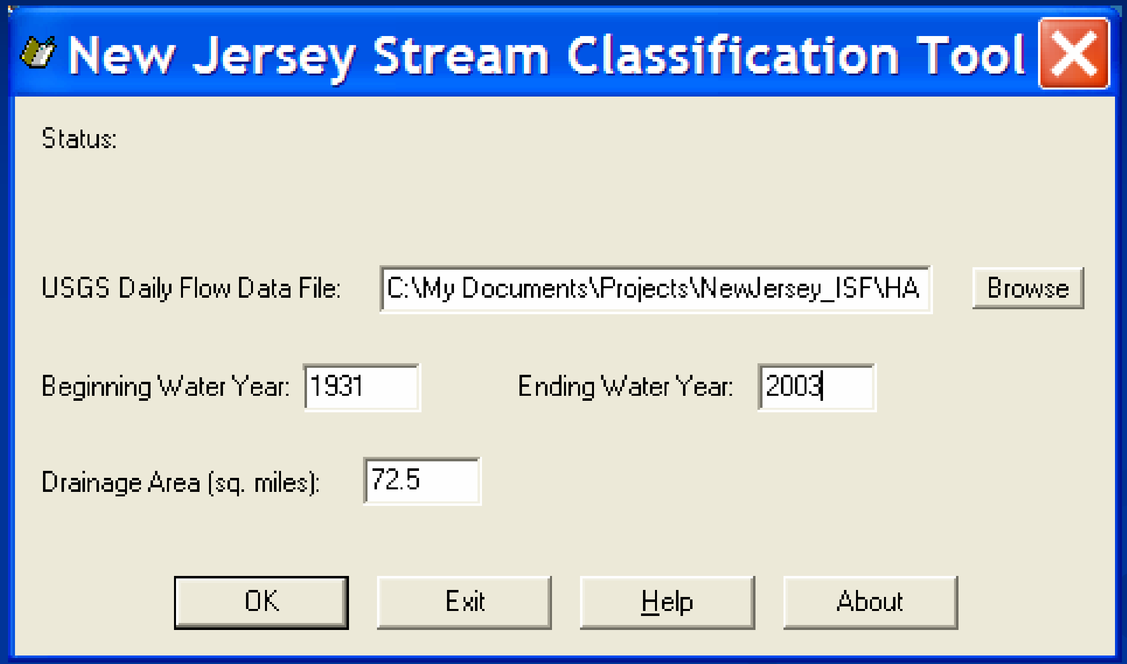
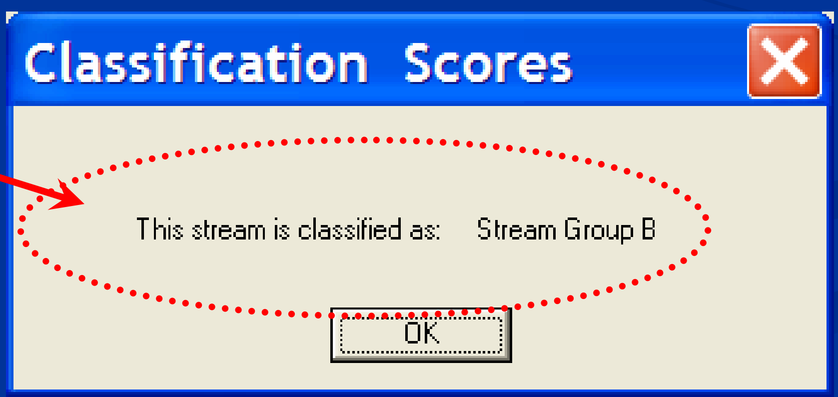
NJ Stream Classification Tool - assigns streams type

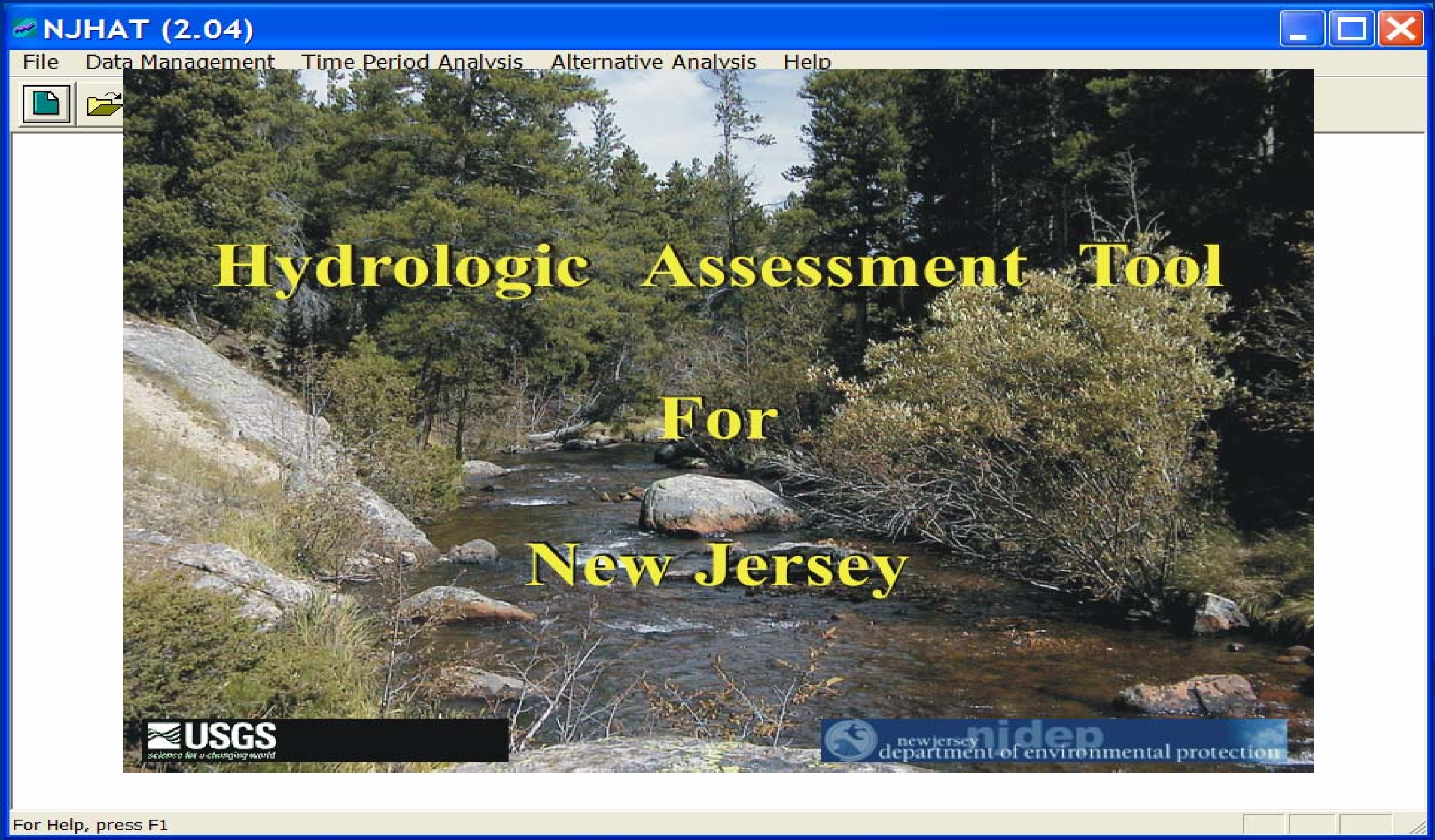


Answer

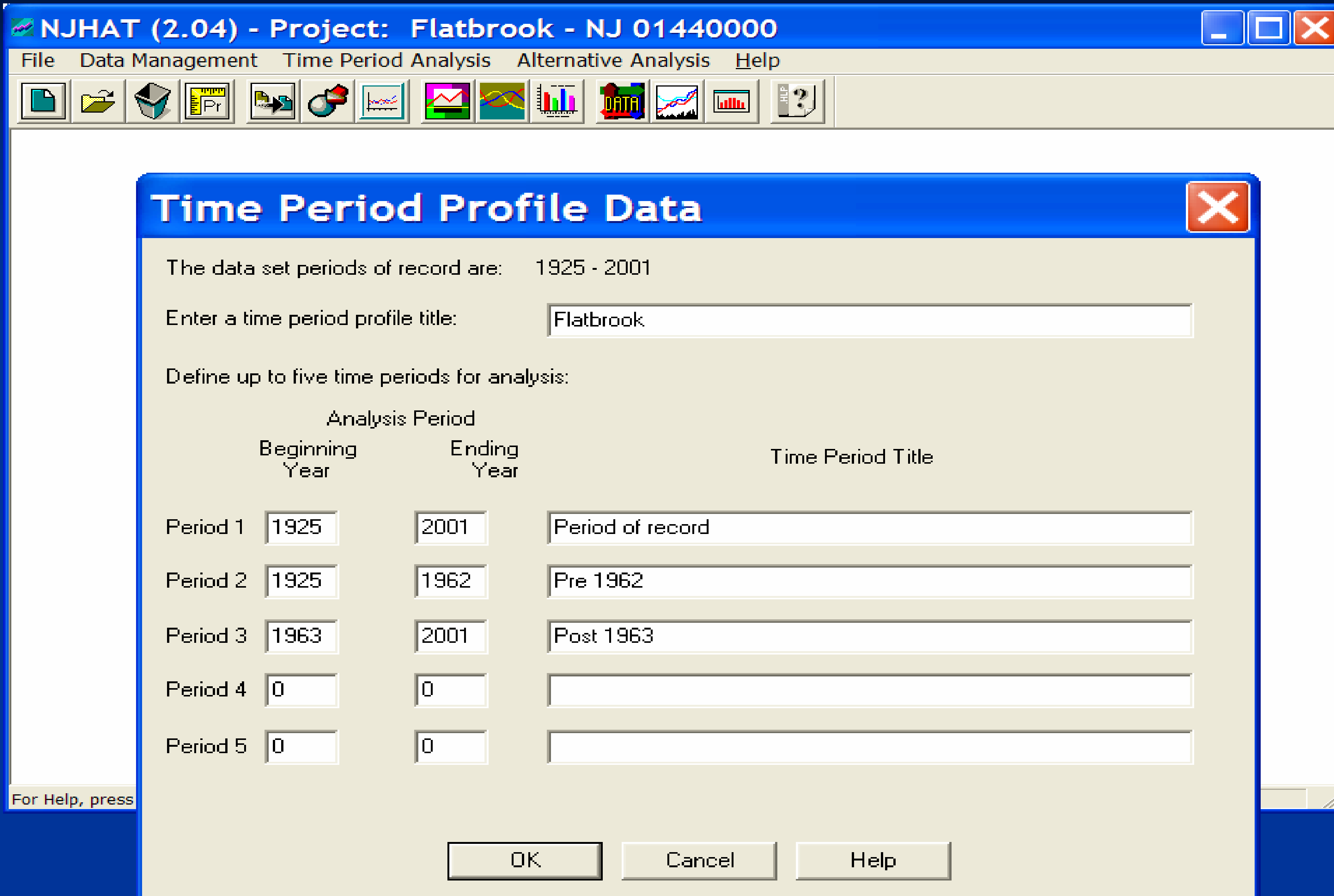


NJHAT - hydrologic assessment tool

- Establish hydrologic baseline
- Establish standards (10 to 171 indices)
- Conduct alternative analyses



Baseline hydrologic period



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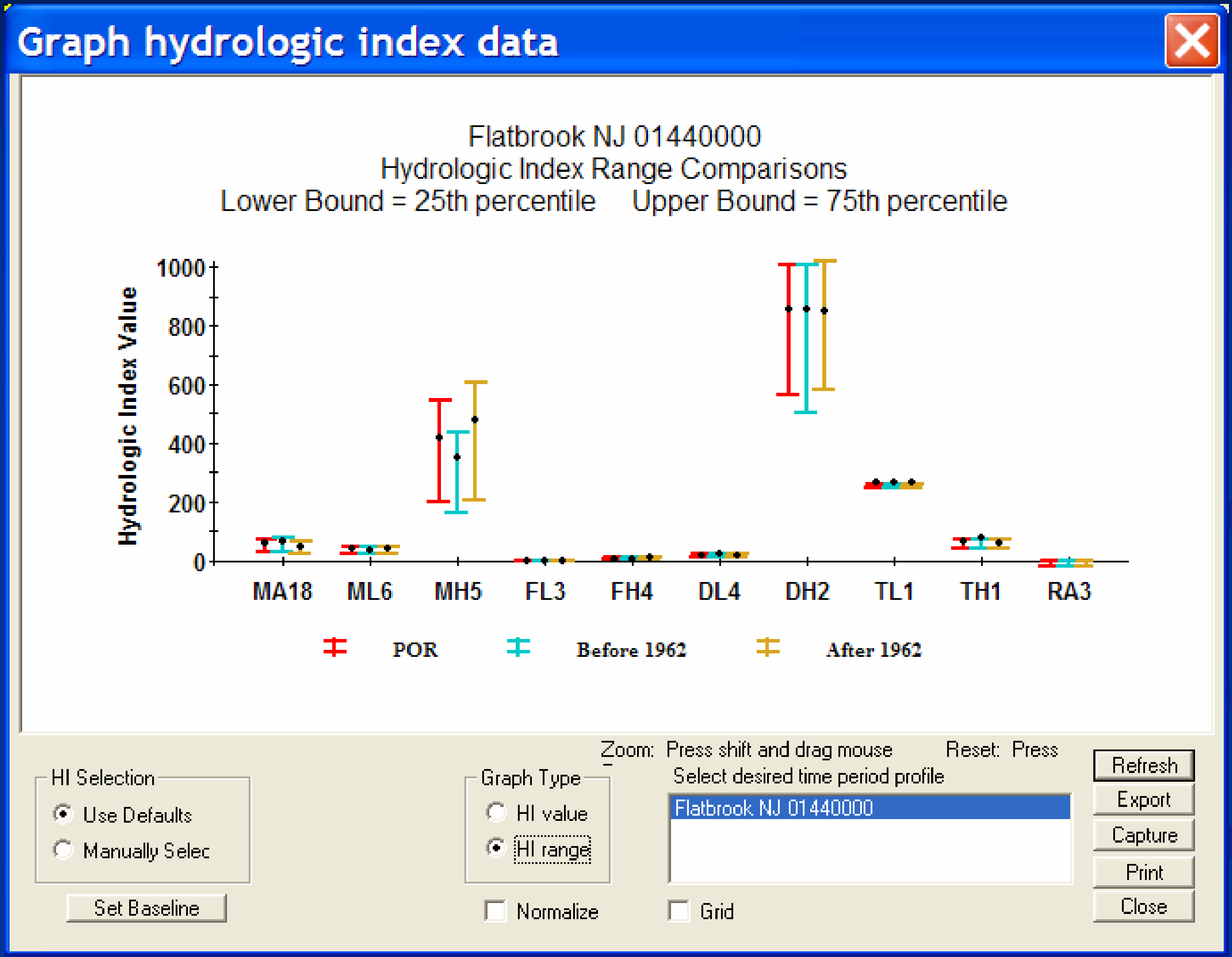
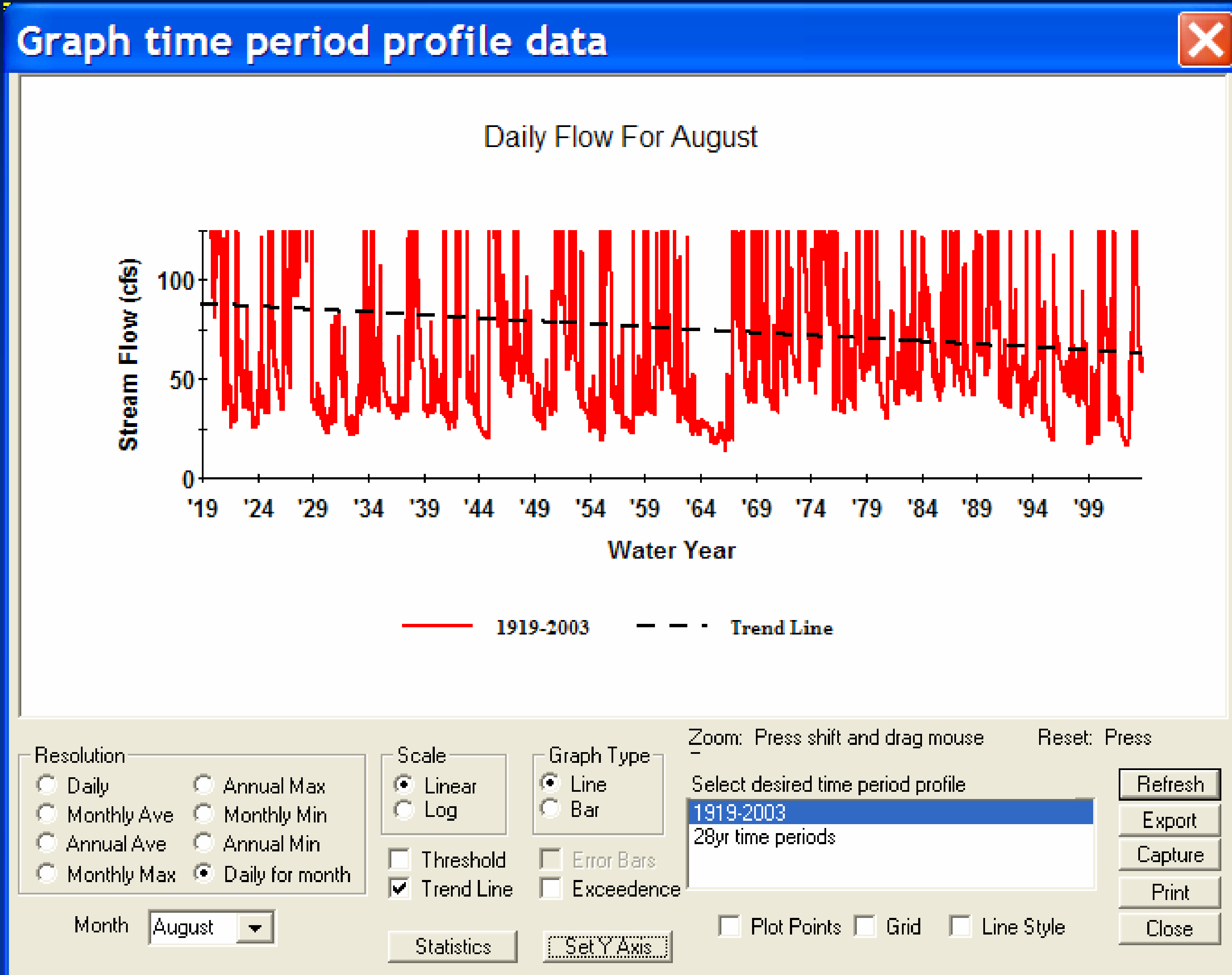
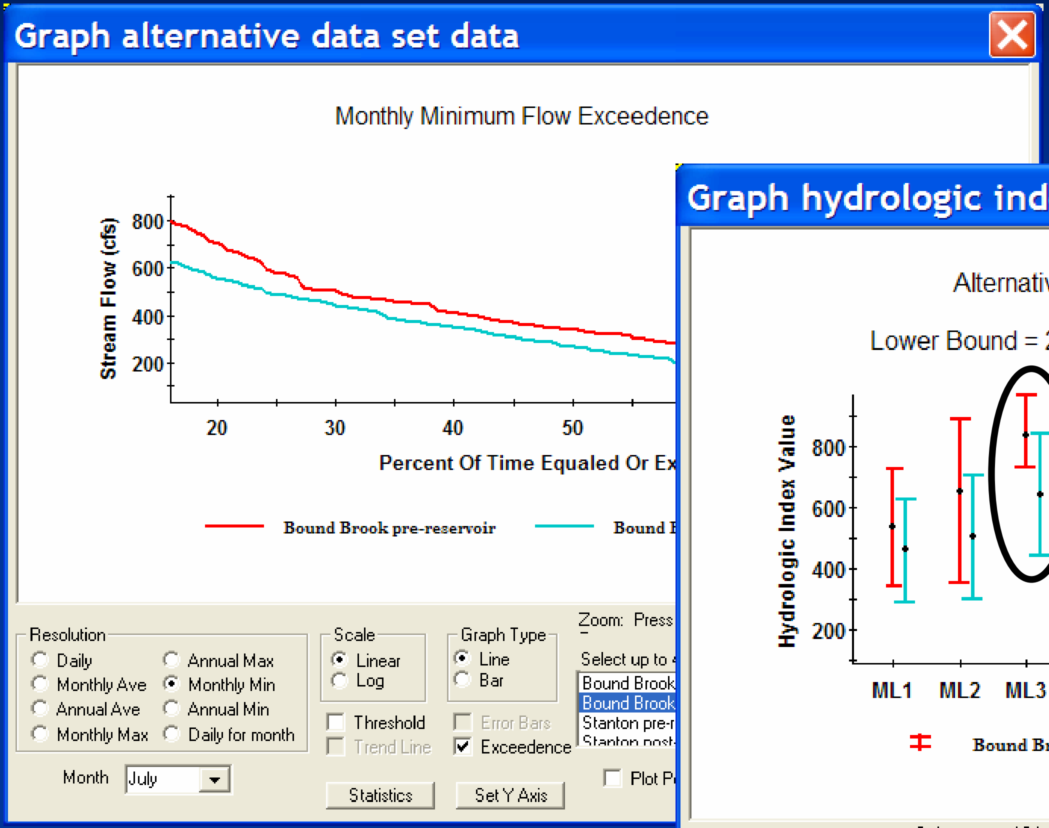
Establish standards

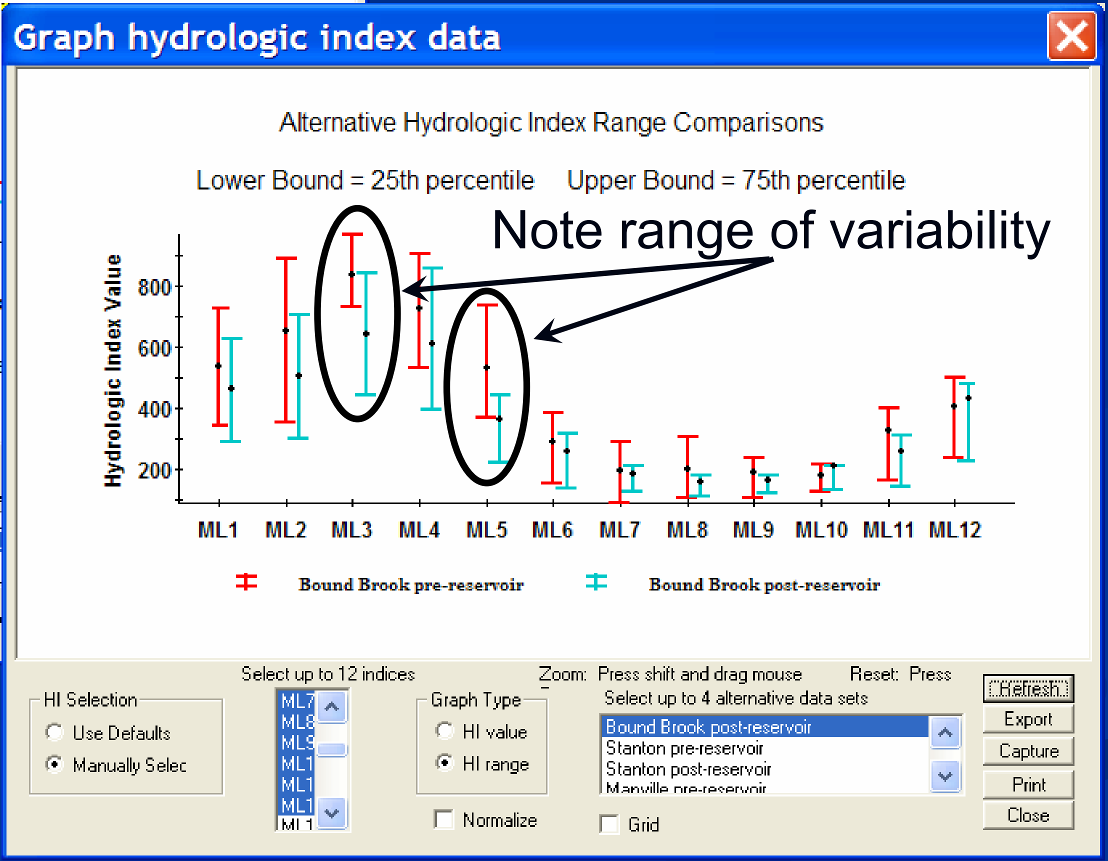


Trend analysis for Bound Brook, NJ



Alterative analyses – before and after a reservoir





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Issues to consider

- Standard setting – always 75-25 percentile?
  - 60-40 percentile? 90-10 percentile?? "must define management goal"
- Median "same" – range increases or decreases?
- Baseline determination – process?
- Simulating daily & peak flow records?

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Contributors:

THANKS!

- Steve Nieswand (WRD - NJ)
- LeRoy Poff (CO State University)
- Brain Cade (BRD - FORT)
- Dave Hamilton (BRD - FORT)
- TAC Members

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