Environmental Flows

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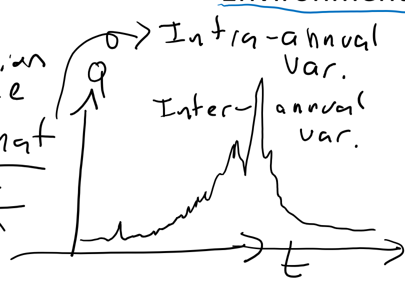
- Flow Regime?

Water in Rivers / Fluctuation in time

Flow in River that change in time



- Natural Flow Regime?

Flow Regime w/o Human Intervention

→ Template for Restoration/Conserv.

Stremflows + GW

- Environmental Flows vs Instream flows?

+ Humans / Only the env.

Environment?

Riparian → Area along the River

Freshwater + Wetlands → What live in the River

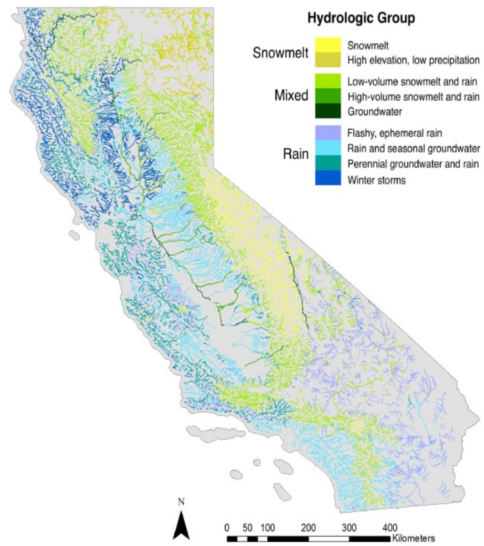
Terrestrial → live on the land

Flows?

Quantity, Quality, habitat, conectivity

Environmental Flows

- Natural Flow Regime
- Environmental Flows
- Instream Flows
  - ✓Relevant Ecosystems
  - ✓Characteristics
- Methods for determining Instream flows
  - ✓Examples

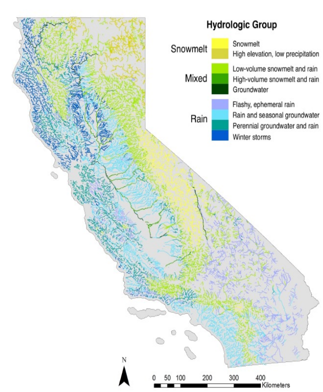


Natural Flow Regime

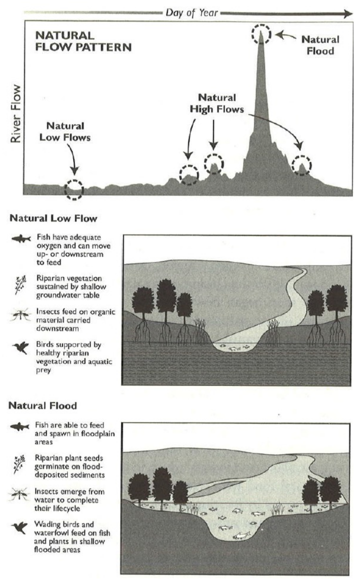
- *<u>Flow</u>* is the "the maestro that orchestrates pattern and process in rivers"
- *<u>Natural Flow Regime</u>* captures the seasonal and inter-annual flow variability, as well as the magnitude, timing and frequency of different flow conditions
- Natural Flow Regime *<u>maintained the entire panoply of species</u>*
- The Natural Flow Regime has considerable *<u>influence over water quality, food supply and interaction among species</u>*. (*Poff et al. 1997*)

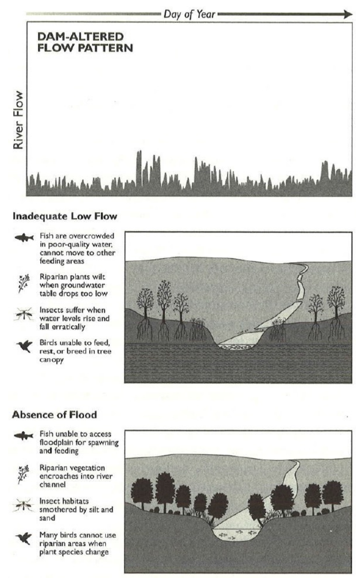
Assumptions:

- In the absence of sufficient understanding of river ecosystem drivers and requirements, mimicking the natural hydrology to which species are adapted will intrinsically provide the greatest ecological benefit even if the driving mechanisms at work are not explicitly understood
- The natural flow regime offers a time-tested recipe for river restoration and protection. The needs of all river species are met over the course of seasons, years, decades and centuries by the natural variations of the river flow.

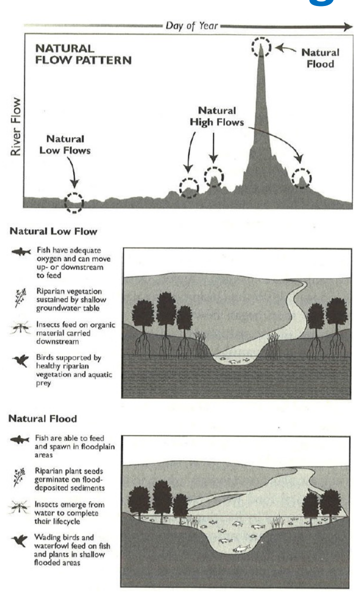


Natural Flow Regime





Natural Flow Regime



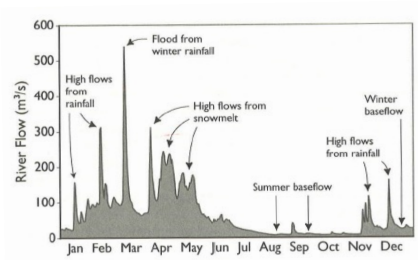
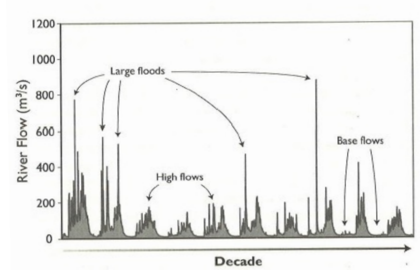
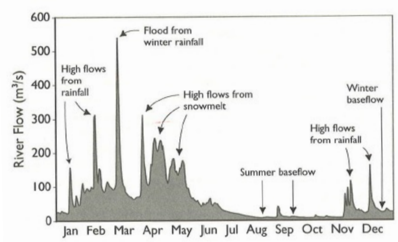


FIGURE 2-3. Annual Hydrograph from the Trinity River in Northern California.



Natural Flow Regime



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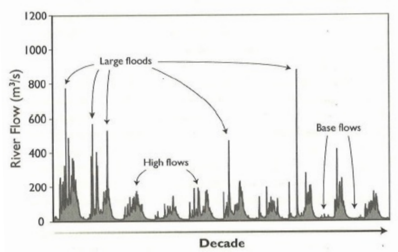


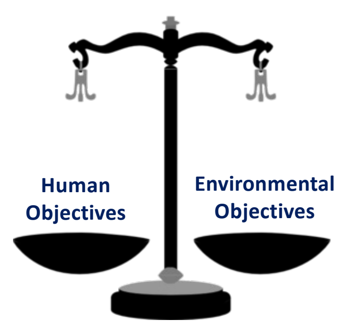
BOX 2-1 Ecological Functions Performed by Different River Flow Levels

Flow Level	*Ecological Roles*
Low (base) flows	Normal level: • Provide adequate habitat space for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living in saturated sediments) Drought level: • Enable recruitment of certain floodplain plants • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
Higher flows	• Shape physical character of river channel including pools, riffles • Determine size of streambed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation • Maintain suitable salinity conditions in estuaries
Large floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g., insects) • Enable fish to spawn on floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive, introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

Environmental Flows

"**A flow regime (quantity, quality and timing) to <u>sustain natural river functions and services</u> <u>while meeting human water demands</u>**" (*Poff et al. 1997*)

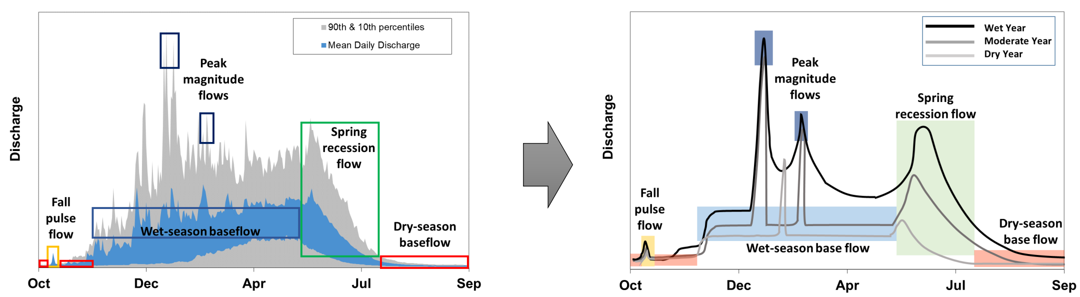
- The **flow regime** is a primary determinant of the structure and function of river ecosystems
- Hydrologic alteration by human activities has impaired river ecosystems on a global scale
- A (**naturally) variable flow regime**, rather than a **minimum flow**, is needed
- Current scientific understanding and pilot releases support re-design of systems operation to provide environmental flows



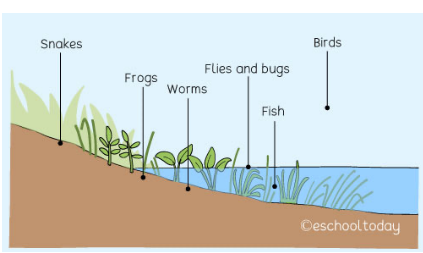
Instream Flows

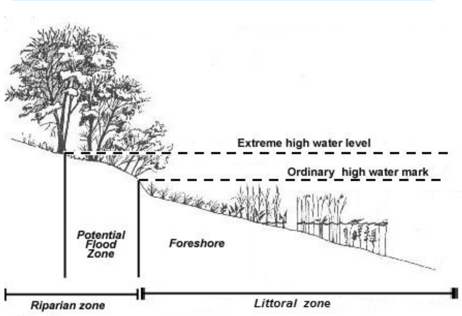
"A defined *__flow regime__*, associated physical habitat, connectivity and water quality able to sustain ecosystem functions for protecting or restoring freshwater and riparian ecosystems"

A **__flow regime__** refers to water: magnitude, timing, seasonality and inter-annual variability



Relevant Ecosystems - Instream





Freshwater Ecosystems
(What lives in the river)

- Mammals (e.g. Beavers)
- Aquatic Flora
- Fish communities
- Phytoplankton, Zooplankton
- Invertebrates (Benthic Macroinv.)

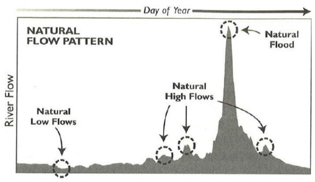
Riparian Ecosystems
(What lives along the river)

- Plant Communities
- Invertebrates/ Reptiles/Amphibians
- Birds

Terrestrial Ecosystems
(What lives around the river)

- Mammals
- Primary producers
- Forest

Instream Flows



Quantity
(Seasonal and Inter-annual Variability)

- **Magnitude (cfs, cms)**
- **Timing (date)**
- **Frequency (# of events per year/decade)**
- **Duration (# of days)**
- **Rate of Change**

Quality
(Adequate along the river corridor)

- Temperature, PH
- TSS, DO, BOD
- Metals, salinity

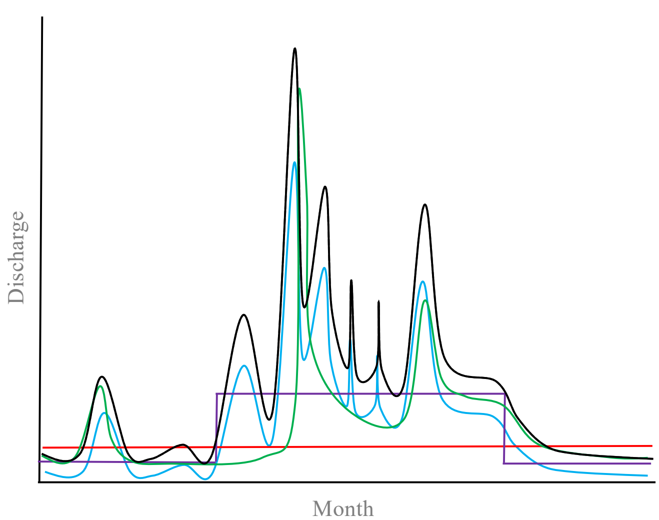
Habitat
(Diverse throughout the network)

- Channel forms, river types and network var.
- Sediment transport and composition
- Coarse woody habitat

Connectivity
(All directions)

- Longitudinal
- Transversal
- Surface Water and Groundwater

Instream Flows, a very short history



Natural flow regime
Minimum flows *(Tennant 1976)*
Seasonally varying minimum flows
Natural flows paradigm *(Poff et al. 1997)*
Percent of flow (POF) *(Richter et al. 2012)*
Functional flows *(Escobar-Arias & Pasternack 2010, Yarnell et al. 2015; Lane et al. 2017)*

But what is 'functional'? In heavily constrained systems, we really want to know ***the adequate water needed to sustain critical ecosystem functions***

Methods for determining Instream Flows

Hydrology-Based
- Statistical methods
- Determine ecologically-significant flow components
- Mimic flow components to sustain desired functions
- e.g. Tenant, IHA, **Functional Flows**

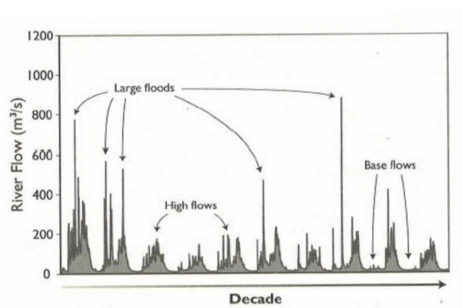
~~**Hydraulic Rating**~~
- ~~Use basic hydraulic parameters as surrogate for biotic habitat requirements~~
- ~~Output optimal minimum flow or fixed habitat reduction~~
- ~~e.g. *Wetted Perimeter*`~~

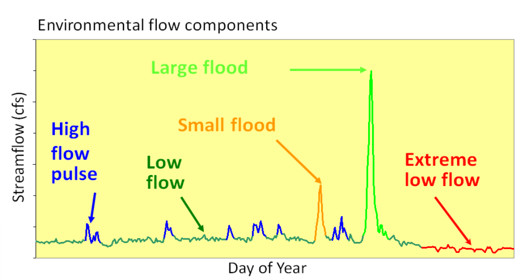
Habitat Simulation
- Link flow, hydraulics, and biological response (HSCs)
- Output quantity and suitability of physical habitat for different flow regimes
- Focus on target species
- e.g. PHabSIM, HEC-EFM, **Flow Form Function (FFF)**

Holistic
- Whole ecosystem focus
- Expert-defined ecologically significant flow events
- Bottom-up or Top-down
- e.g. **Building Block Method**, Benchmarking Method

Hydrology-Based Methods

Statistical methods to determine ecologically-significant flow components

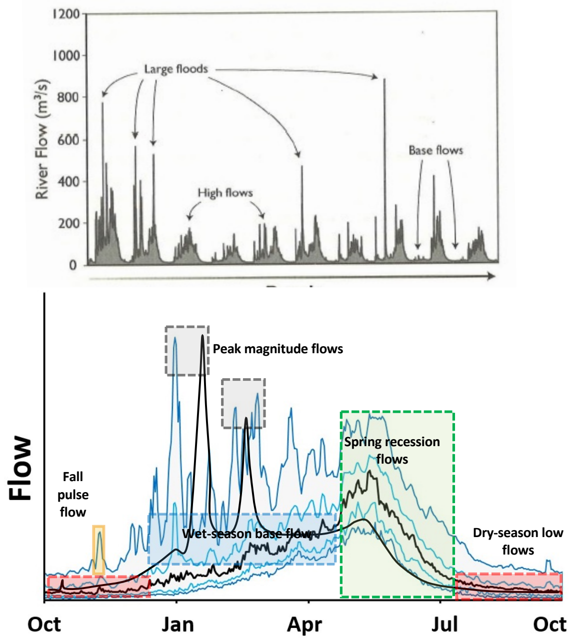


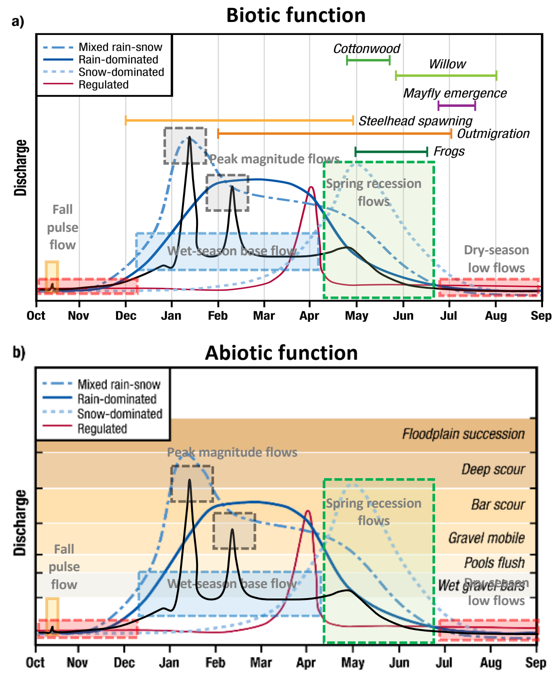


For each :
- magnitude
- frequency
- duration
- timing
- rate of change

Objective: mimic flow components that sustain desired env. functions
Advantages: simple, rapid, visual, inexpensive, use available data , whole ecosystem focused
Disadvantages: lacking/limited direct ecological/physical links, constrained to rivers/sites with streamflow data

e.g. Functional Flow Approach





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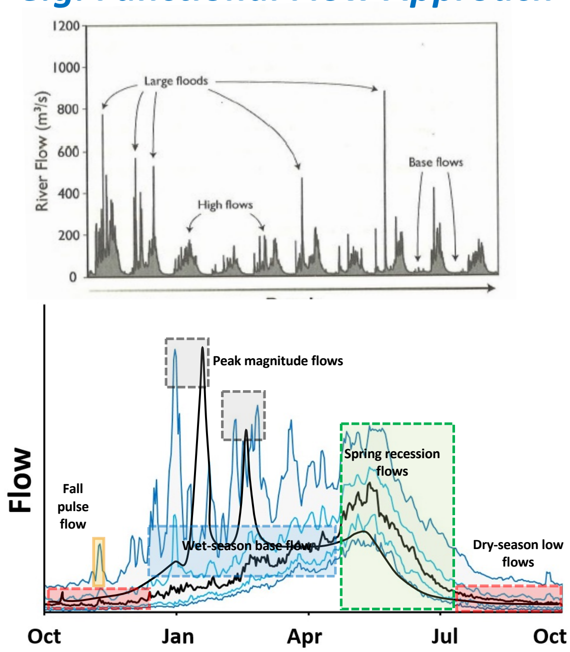


Flow Component	Flow Characteristic
Fall pulse flow	Magnitude (cfs)
	Timing (date)
	Duration (days)
Wet-season base flow	Magnitude (cfs)
	Timing (date)
	Duration (days)
Peak flow	Magnitude (cfs)
	Duration (days)
	Frequency
Spring recession flow	Magnitude (cfs)
	Timing (date)
	Duration (days)
	Rate of change (%)
Dry-season base flow	Magnitude (cfs)
	Timing (date)
	Duration (days)

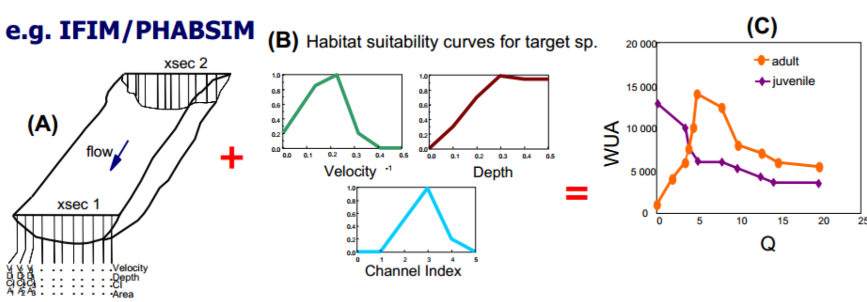
Hydraulic Rating Methods

Use hydraulic parameters as surrogate for habitat requirements to determine flows

Objective: Provide the adequate streamflow to create sufficient habitat conditions
Advantages: Physically based
Disadvantages: simplistic, site-specific, lack links between hydraulic parameters and biological responses

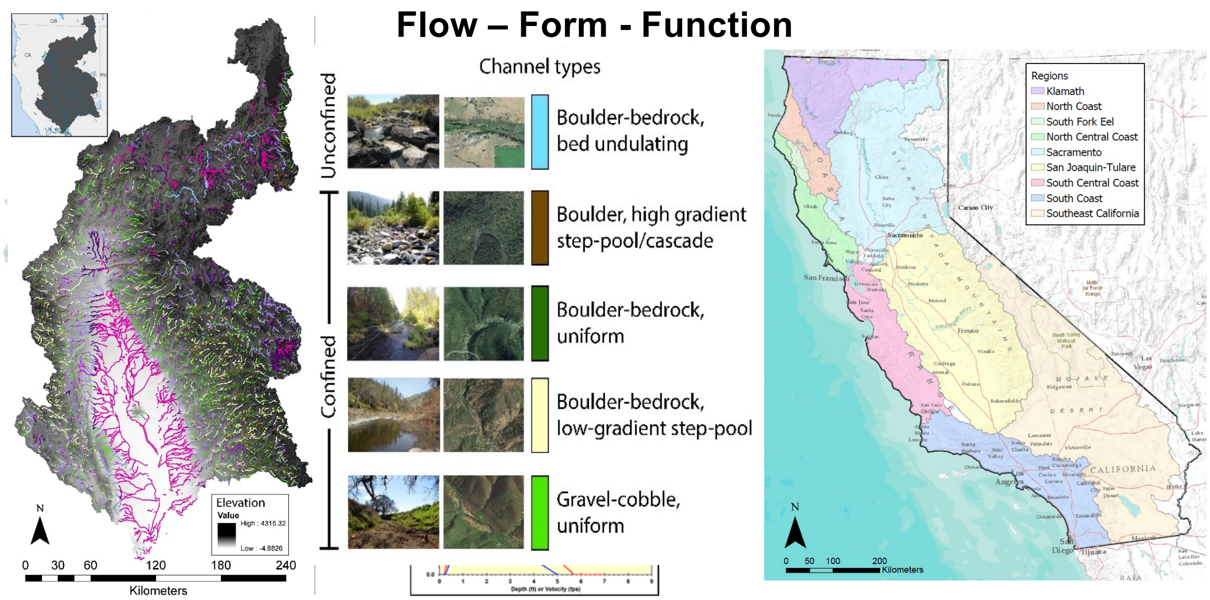
Habitat Simulation

Relates flow regime with quantity and suitability of physical habitat for targeted species



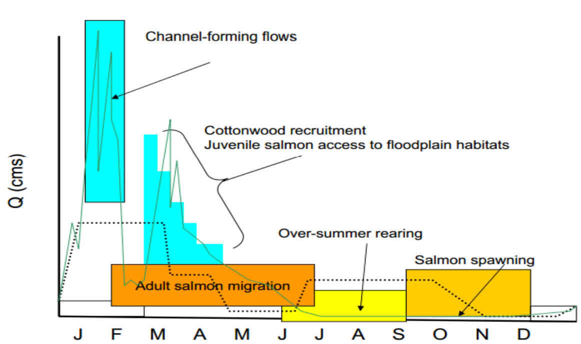
Objective: Provide the flow regime to sustain hydraulic conditions for specified habitat suitability/area for target species/life-stage
Advantages: Relate hydrology, hydraulics, and biological response, scenarios for different biota, mechanistic, spatially distributed
Disadvantages: target species focus, resource intensive, local scale

e.g. Flow – Form - Function



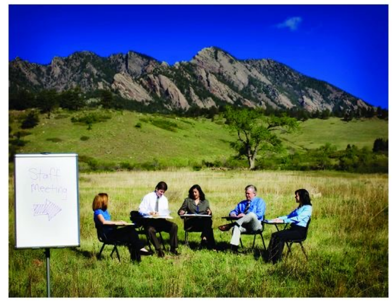
Holistic

Use multidisciplinary expert knowledge to sustain ecologically-significant flow components



Objective: Provide flows to sustain desired environmental objectives
Advantages: Whole ecosystem focused, explicit flow- physical/ecological response links, large scale, usable w/ range of data availability
Disadvantages: relies on expert judgment, resource/time intensive, not spatially distributed

e.g. Building Block Method



- Expert based – ***Bottom-up Approach*** at environmental control points (gage stations)
- Includes social component
- Depends on data

- Phase approach
  - **Preparation for workshop**: Stakeholder consultation, desktop and field studies, geomorphological reach analysis, river habitat integrity and social services, objectives for river future conditions, assessment of river importance & ecological condition, hydrological and hydraulic analysis
  - **Multidisciplinary workshop**, construction of modified flow regime to identify ecological essential flow features on a month-by-month basis, element-by-element for maintenance and drought years based on the best available scientific data
  - Links e-flow requirements with water resources development through **scenario modeling & hydrologic analysis**
- **Method to define E-flows. Usually for Restoration**

e.g. Building Block Method (BBM)

Flow motivation forms

Flow motivation forms for drought

FLOW MOTIVATION FORMS

Geomorphology	Rodrigo de la Garza

Month: February	Low flow Drought

Discharge: m^3 / sec	Depth: m	Average velocity: m /s
0.40	0.42	0.08

Reasons for recommending this flow:

- With the recommended velocity we can avoid sediment depositions, and bank erosion

Consequences of not providing this flow:

- Sediment deposition on the river bed. - Cloudiness - Decrease the water quality

e.g. Building Block Method (BBM)

Ecological Management Class (EMC)

PES: C

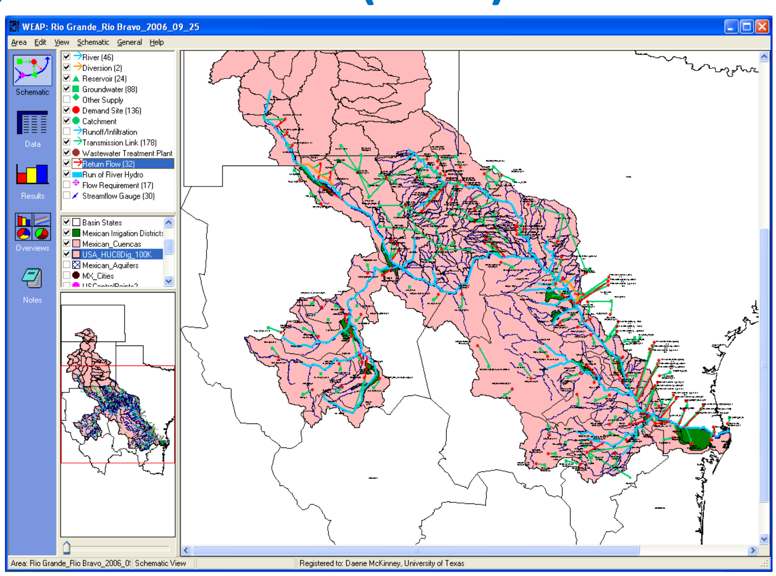
Discipline	EMC	Motivations	Objectives	Indicators
Fish	B	10 native species, the historical assemblage was 16. Recover Scatomyzon (Indicator fish are tied to high water volume, clean bottoms, and gross particulate.	Maintain the fish diversity.	:*Cycleptus*, *Scartomyzon*, *Rhinichthys*, *Macrhybopsis*, *Ictiobus*, *Carpiodes*. *Recovery of:* *Scartomyzon*,
Invertebrates	B/C	Maintain the actual class. Maintain the seasonality of flows	To Maintain some habitat for the indicator species (reefs)	Simulidae
Vegetation	B/C	Exotic species in the site (relation native/exotics).	To reduce the exotic species in the site (relation native/exotics).	Seedlings of *Salix*
Geomorphology	B/C	The channel is relatively stable.	To maintain the river channel	

Recommended environmental flows

	EMC	Drought m^3/s		Maintenance m^3/s	
		Low	High	Low	High
Geomorphology	B/C				
Discharge		0.4	0.7	2.25	7.2
Depth		0.42	0.8	1.15	1.92
Velocity		0.08	0.1	0.14	0.2
Fish	B				
Discharge		0.65	1.3	1.3	9
Depth		0.7	1	1	2.5
Velocity		0.10	0.13	0.13	0.25
Invertebrates/Veg	B/C				
Discharge		0.65	4	4	9
Depth		0.7	1.5	1.5	2.5
Velocity		0.10	0.17	0.17	0.25

e.g. Building Block Method (BBM)

- River Basin Specific Tool
- Broad Spatial Coverage
  - Elephant Butte to Gulf
- Allows Scenario Analysis
- Useful to Project Partners
- Capable of
  - Prioritized Water Allocation
  - Link to Groundwater
  - Rainfall-Runoff Hydrology
  - Economic Calculations
  - Links to Water Quality
- Flows
  - 21 Tributary Inflows
  - 22 Incremental Flows
  - TCEQ Naturalized Flows
- 23 Reservoirs
  - 2 International
  - 15 in Mexico
  - 6 in US
- Groundwater
  - Included on both sides



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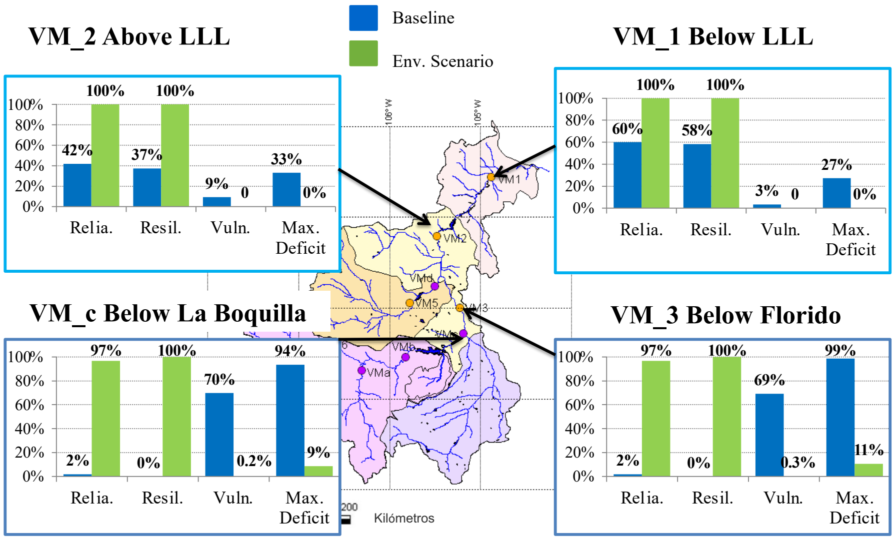
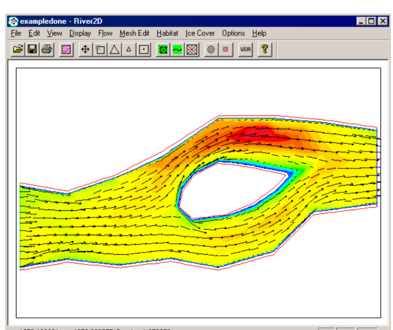


Head to head comparison

	Ecosystem	Cost	Data Intensive	Expert Reliant	Scale	Physically Based	Spatially Distributed
Hydrology Based	Whole	moderate	moderate	moderate	Large	No	Yes
Hydraulic Rating	Simplistic/Lack	High	High	moderate	Small	Yes	Yes
Habitat Simulation	Certain Species	High	High	High	Small	Yes	Yes
Holistic	Whole	High	Moderate	High	Large	Yes/No	No



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Agriculture and Natural Resources

Thank you

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