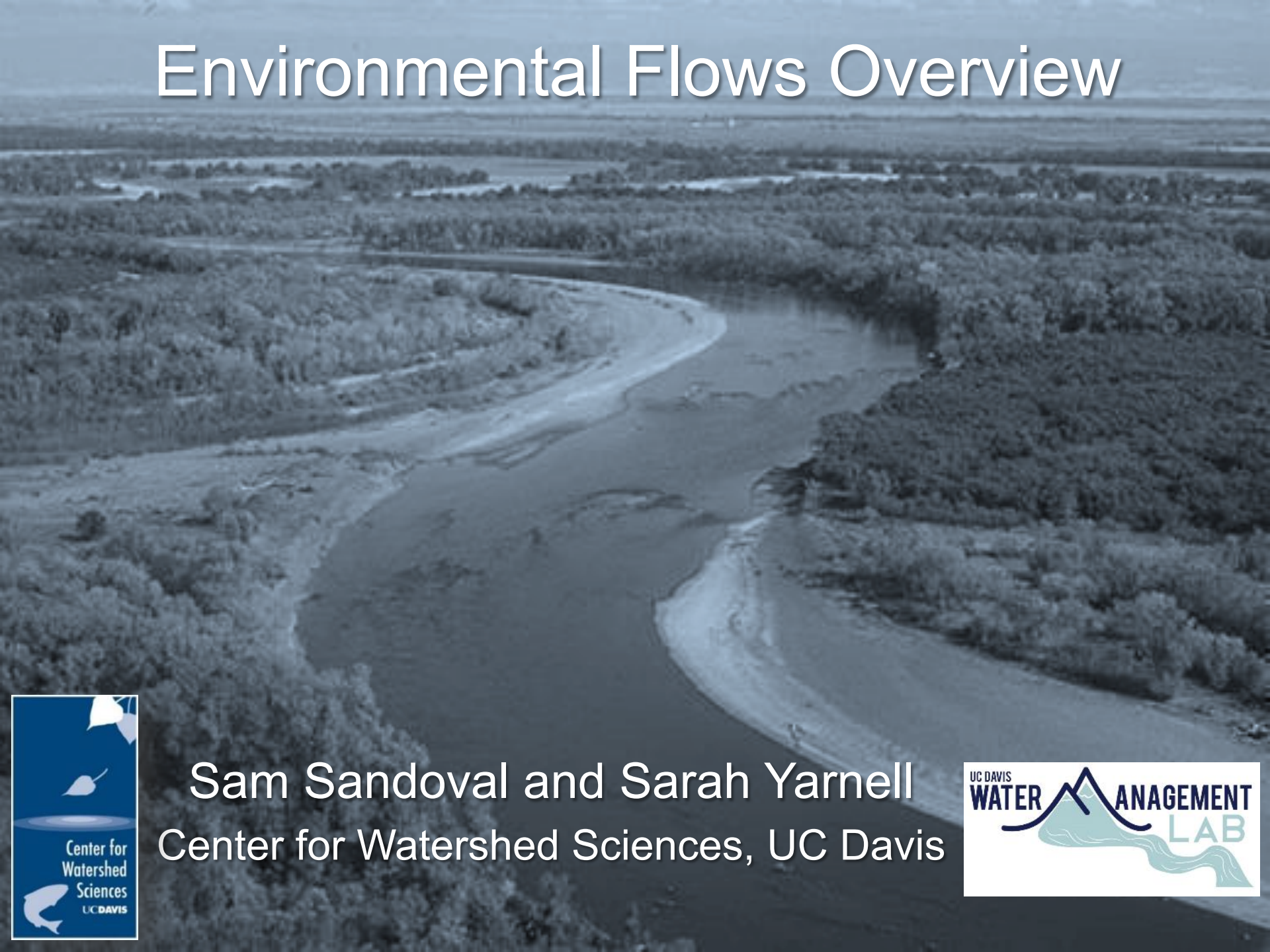
Environmental Flows Overview



Sam Sandoval and Sarah Yarnell
Center for Watershed Sciences, UC Davis

Presentation Outline

- What are Environmental Flows?
- History of E-flows in CA
- E-flows methods
- Policy and Implementation in CA
- Seminar Schedule

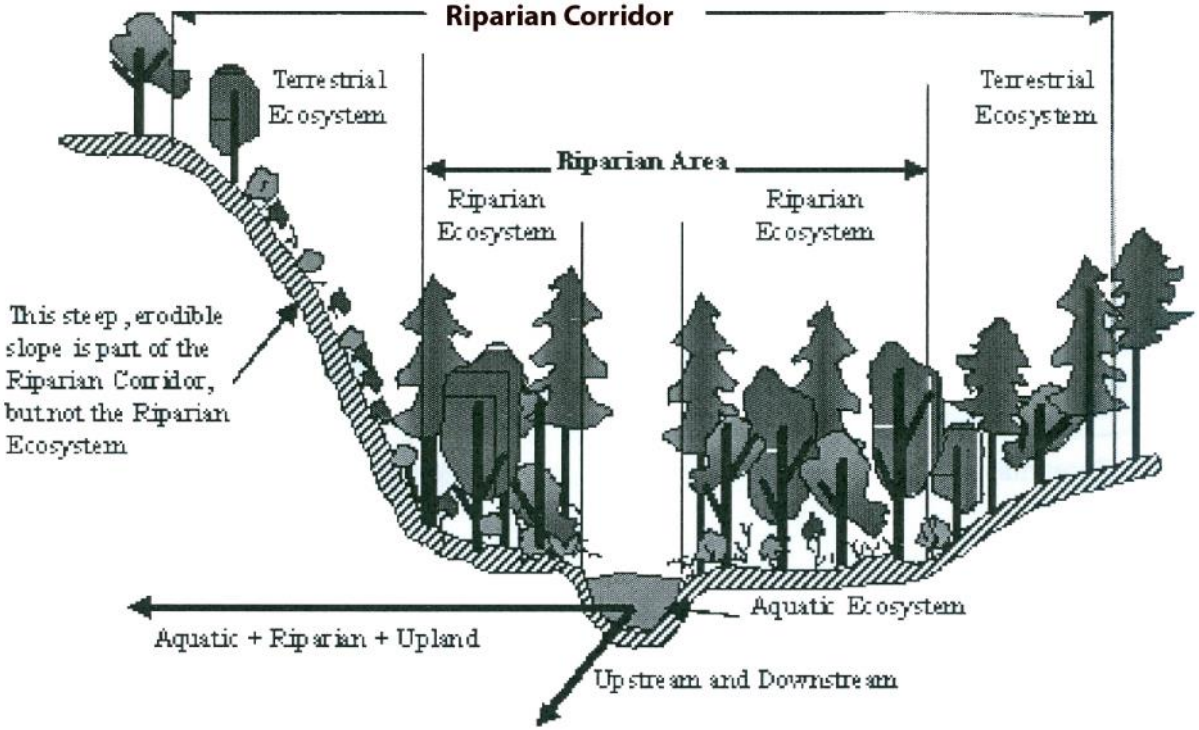
Environmental Flows

- What do we mean by: “Environmental Flows”?

Environmental Flows

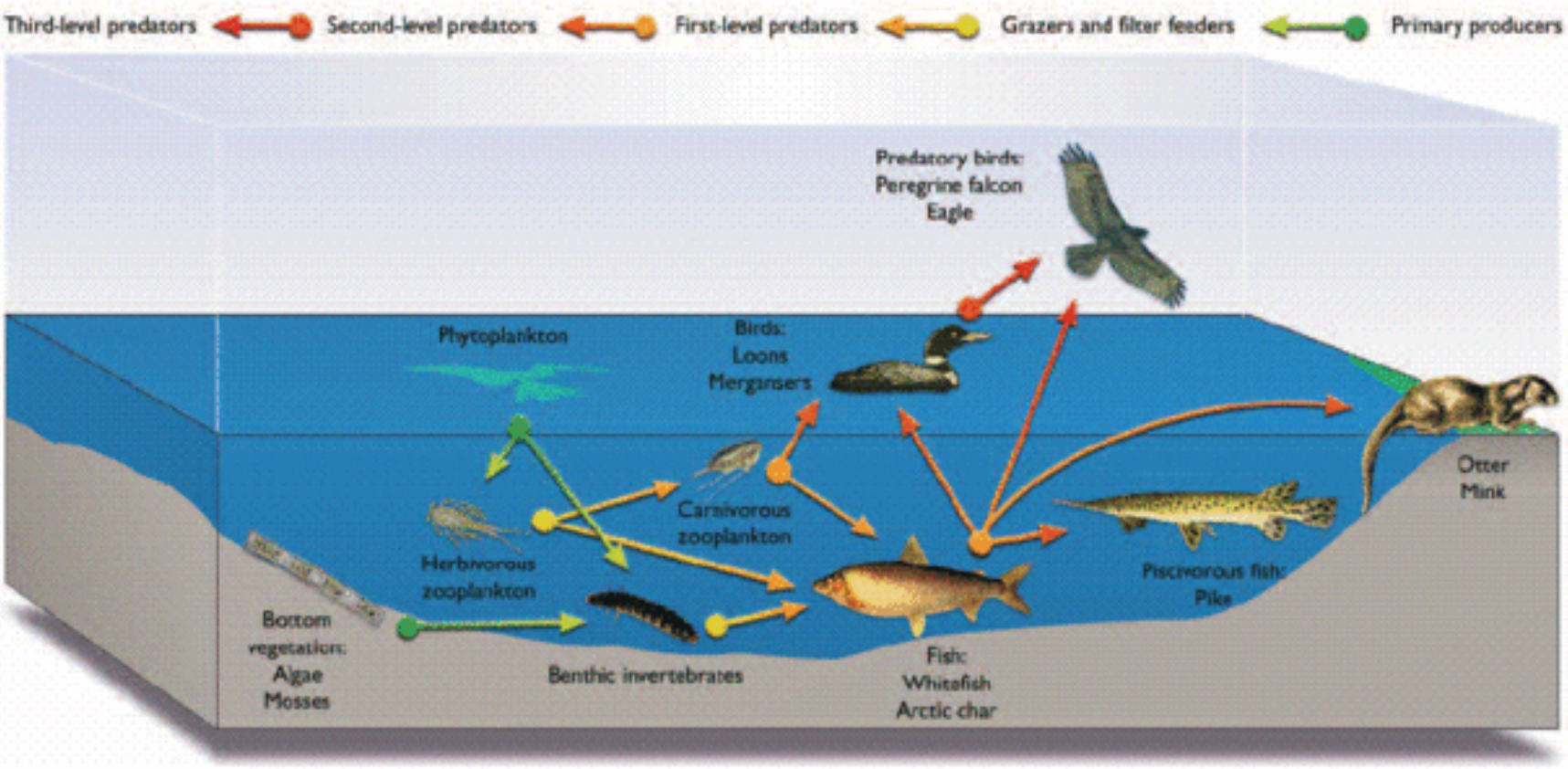
Ecosystem: community of living organisms and nonliving components that interact as a system

- Aquatic
- Riparian
- Terrestrial



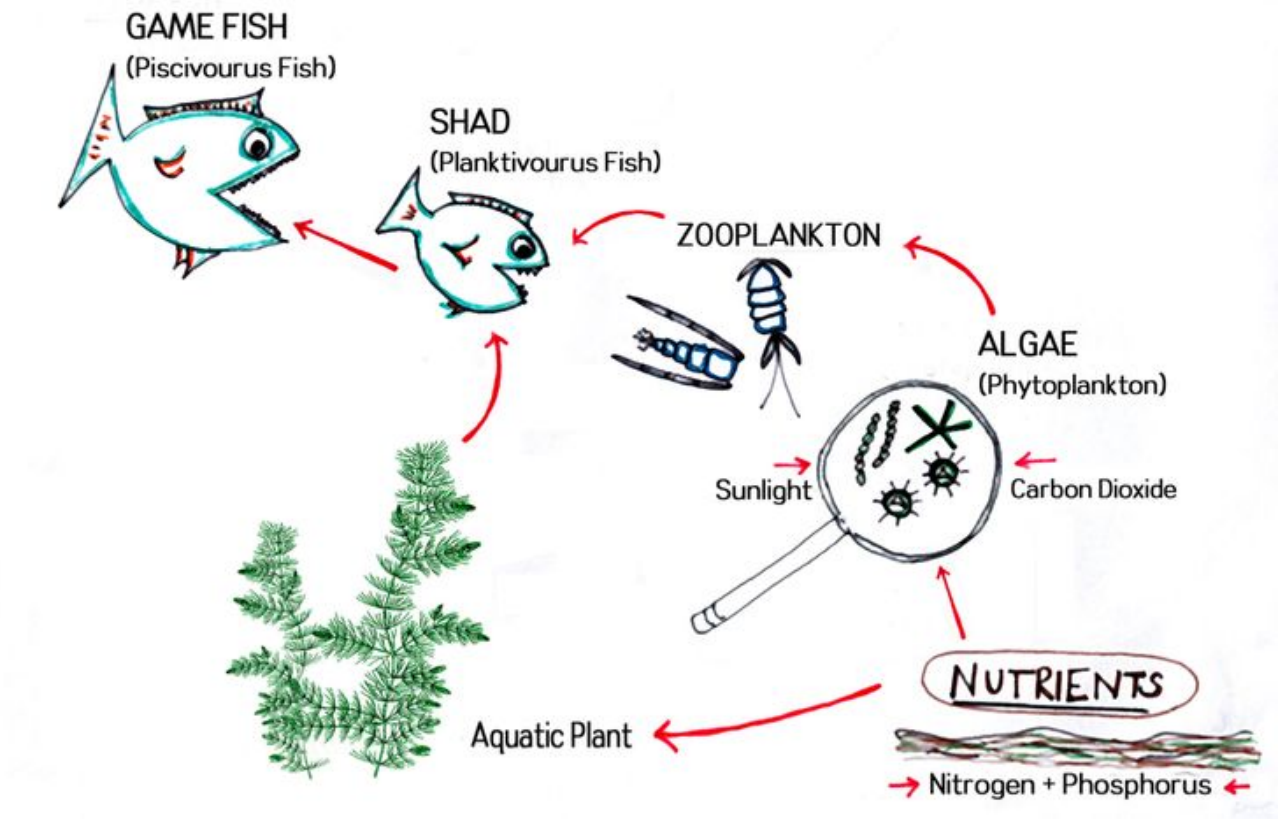
Environmental Flows

- Aquatic Ecosystem



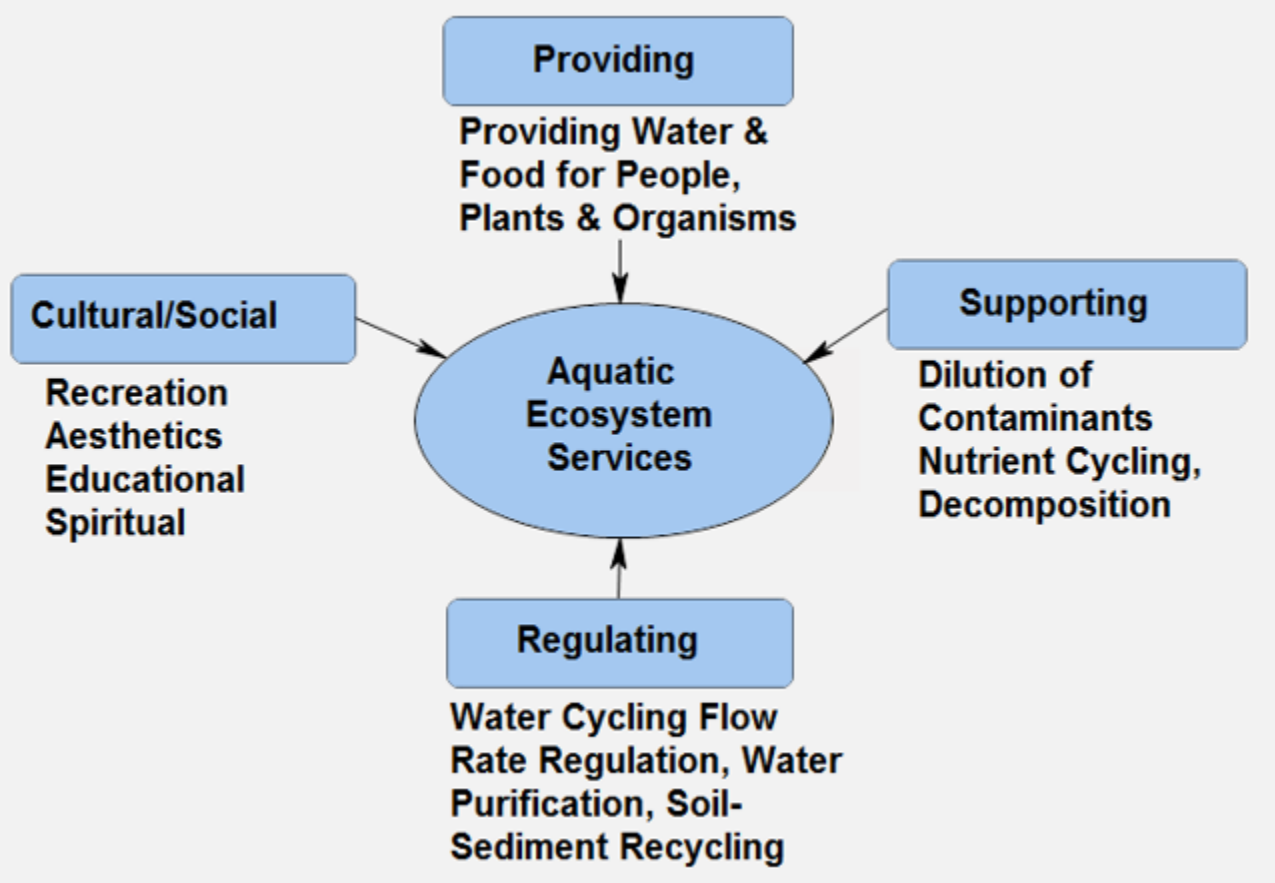
Environmental Flows

- Aquatic Ecosystem: Food Chain



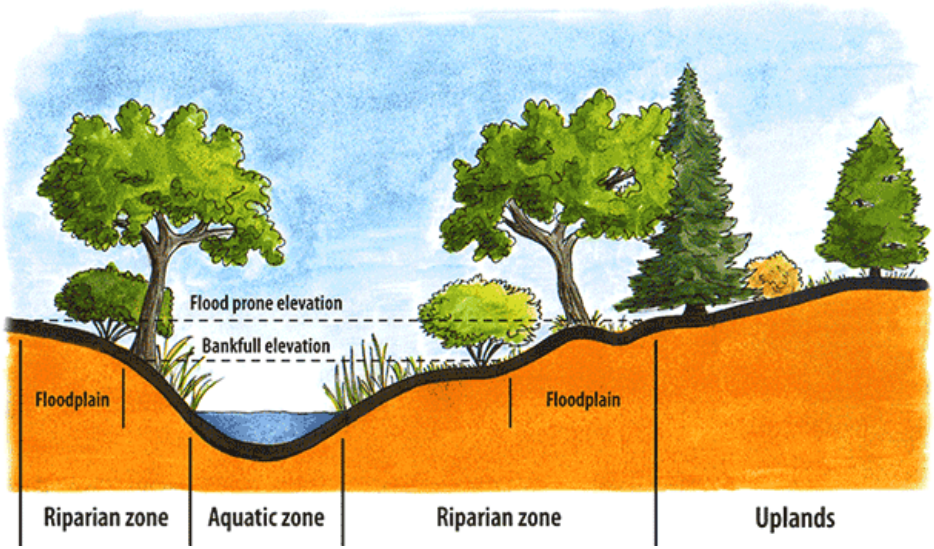
Environmental Flows

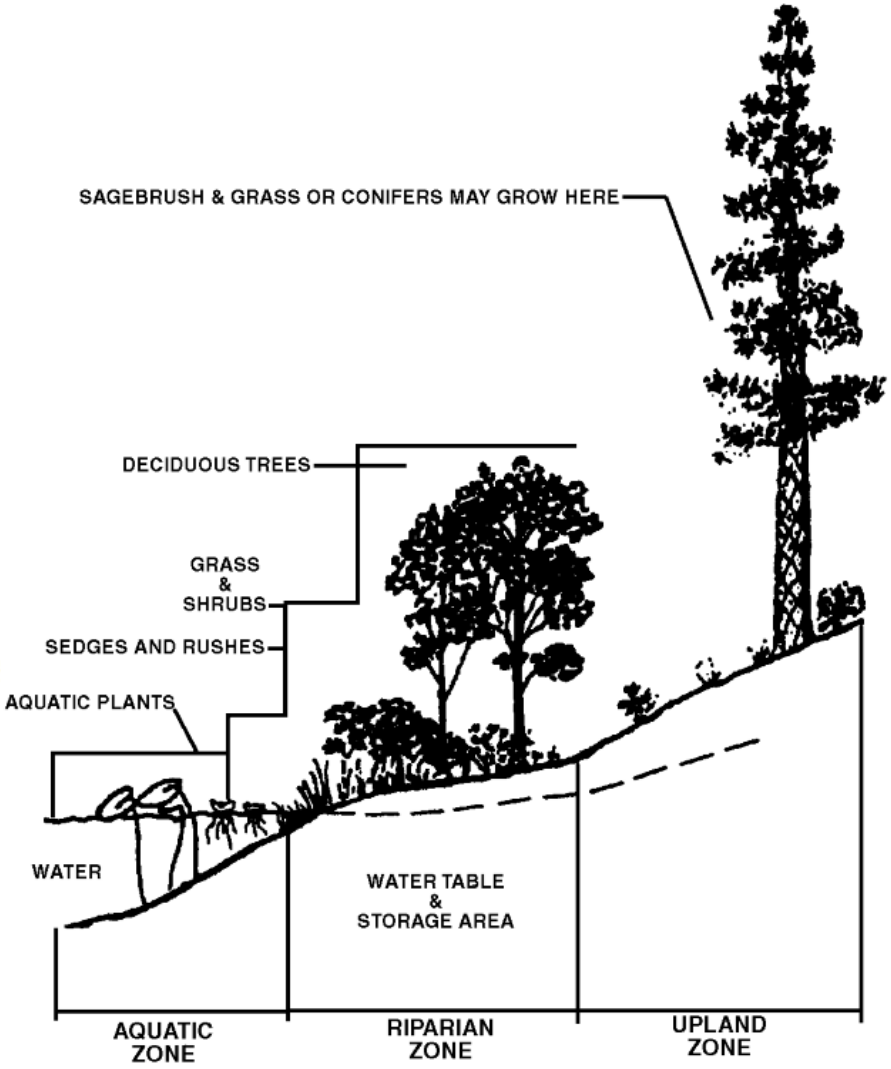
- Aquatic Ecosystem: Ecosystem Services



Environmental Flows

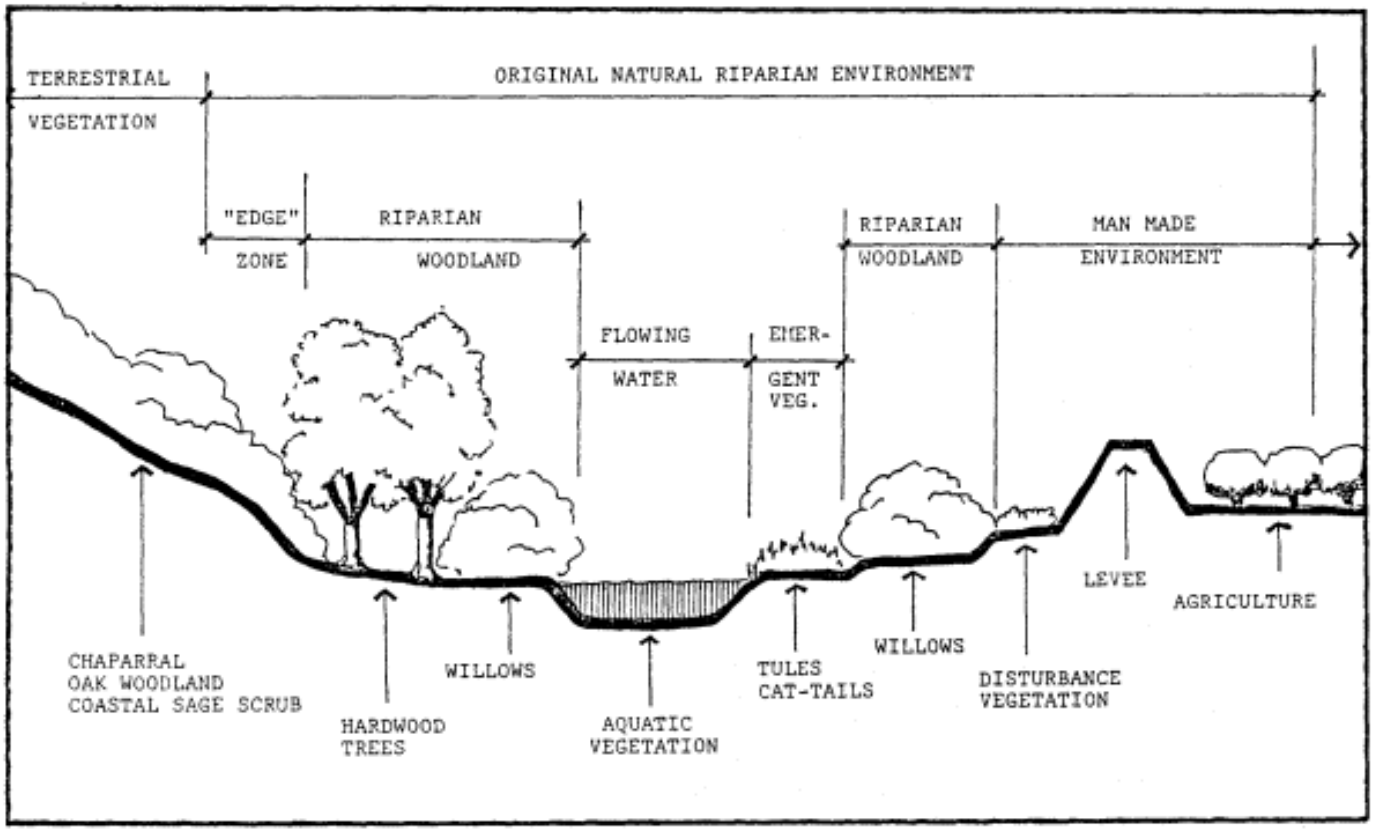
- Riparian Ecosystem





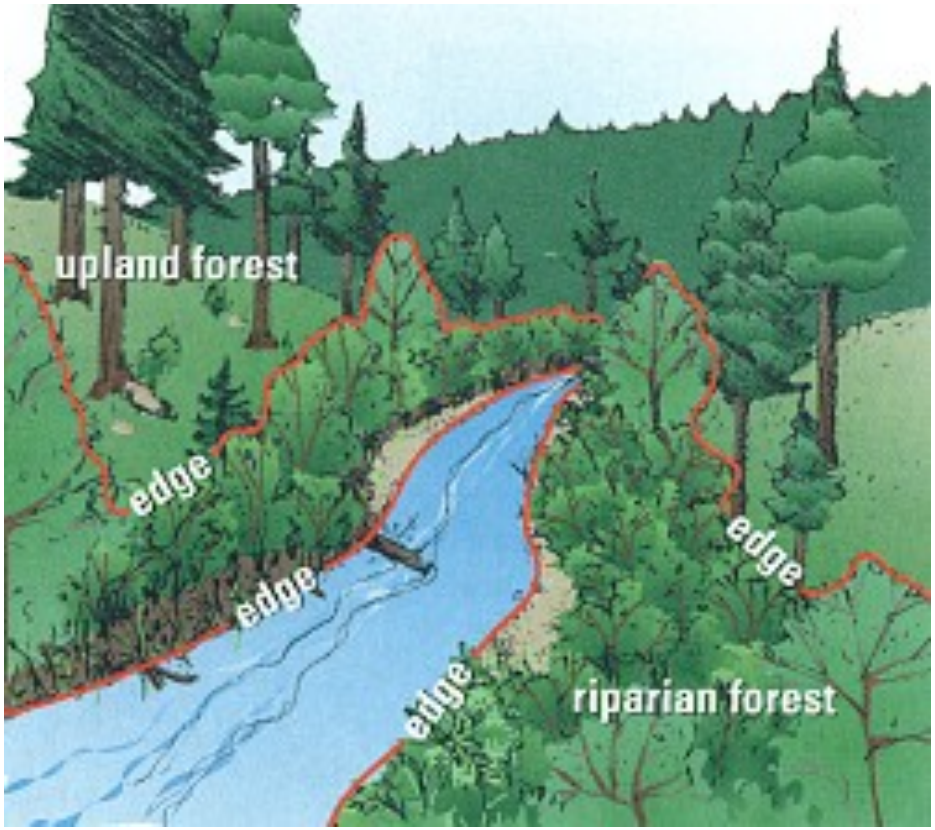
Environmental Flows

- Riparian Ecosystem



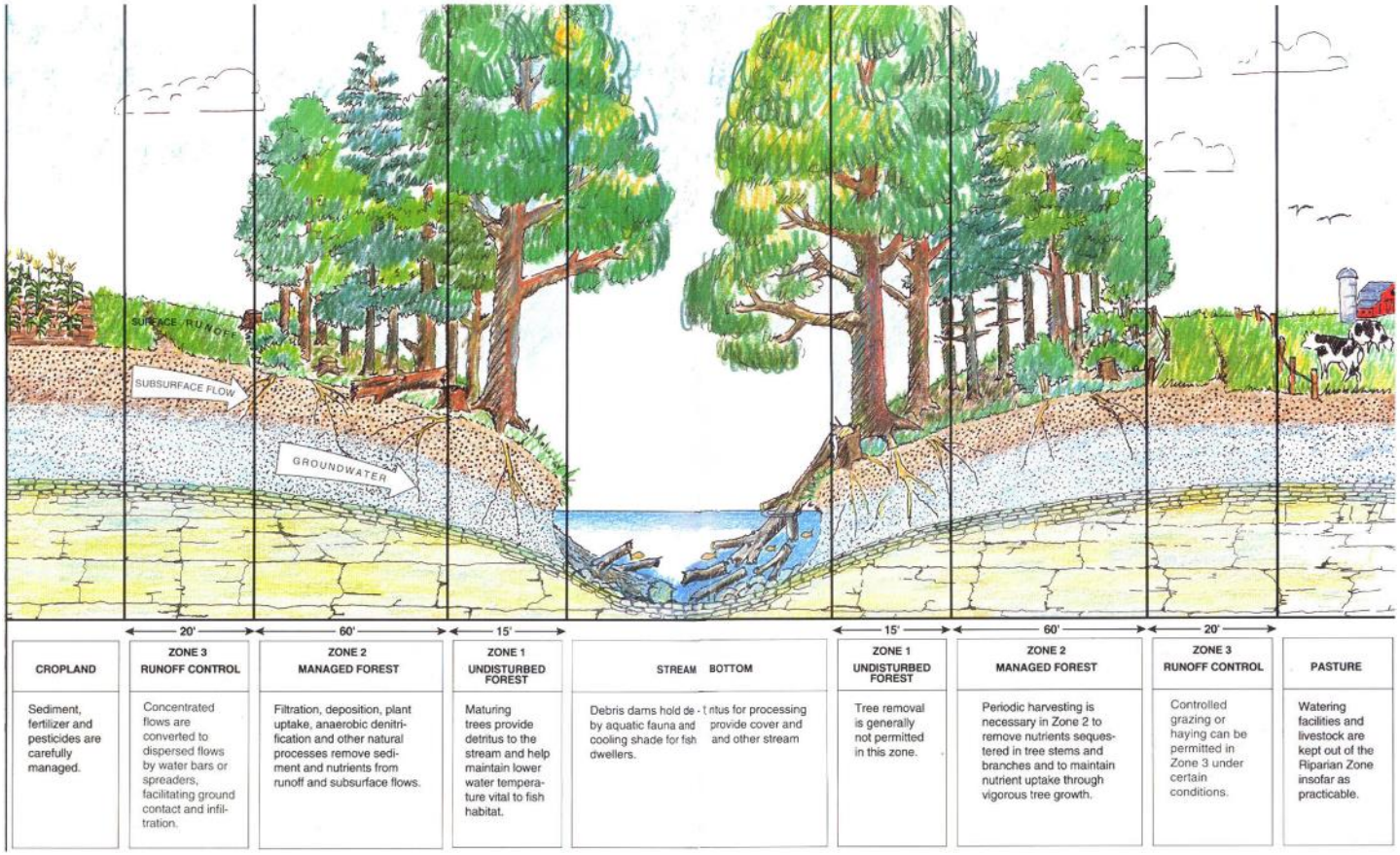
Environmental Flows

- Riparian Ecosystem



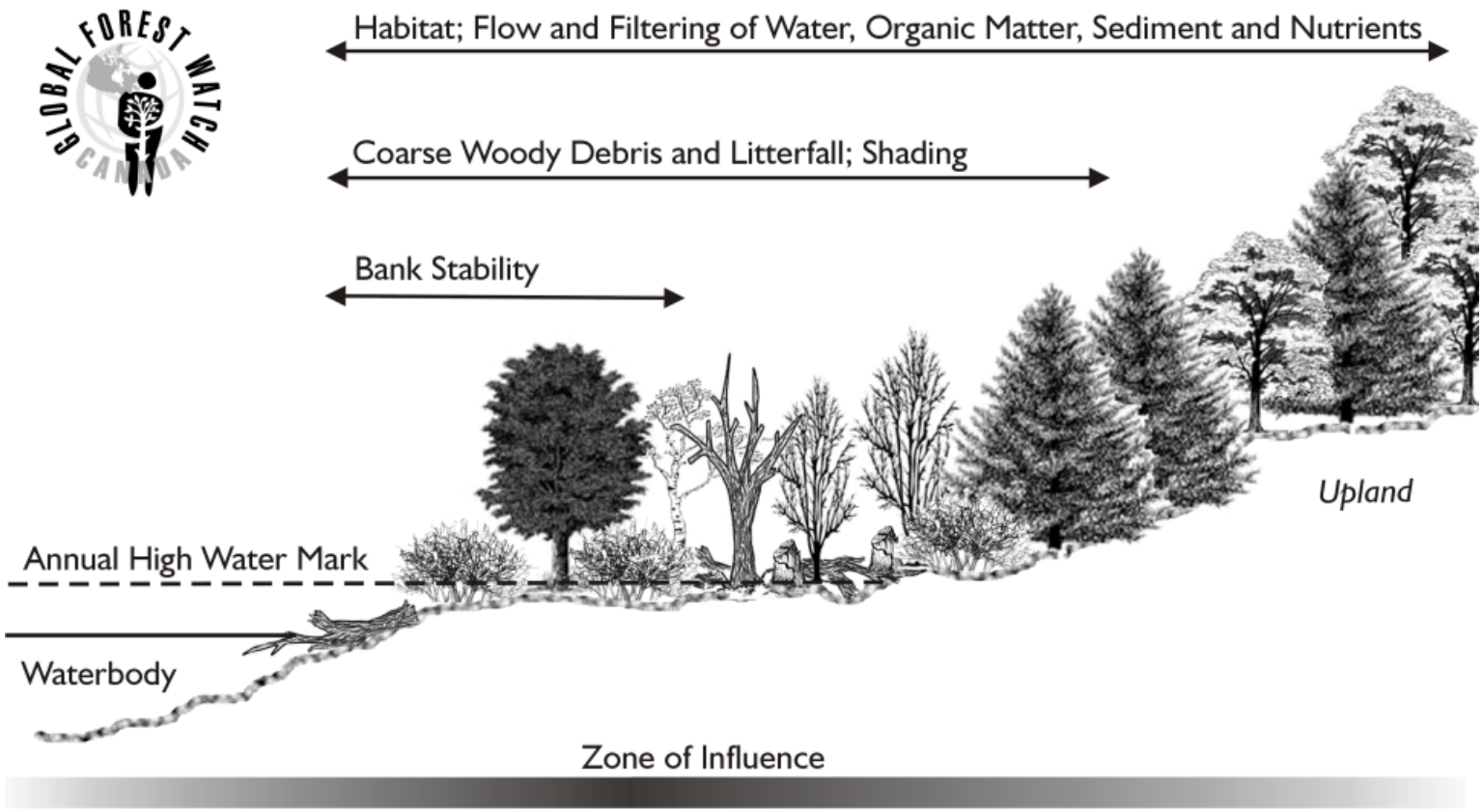
Environmental Flows

- Riparian Ecosystem



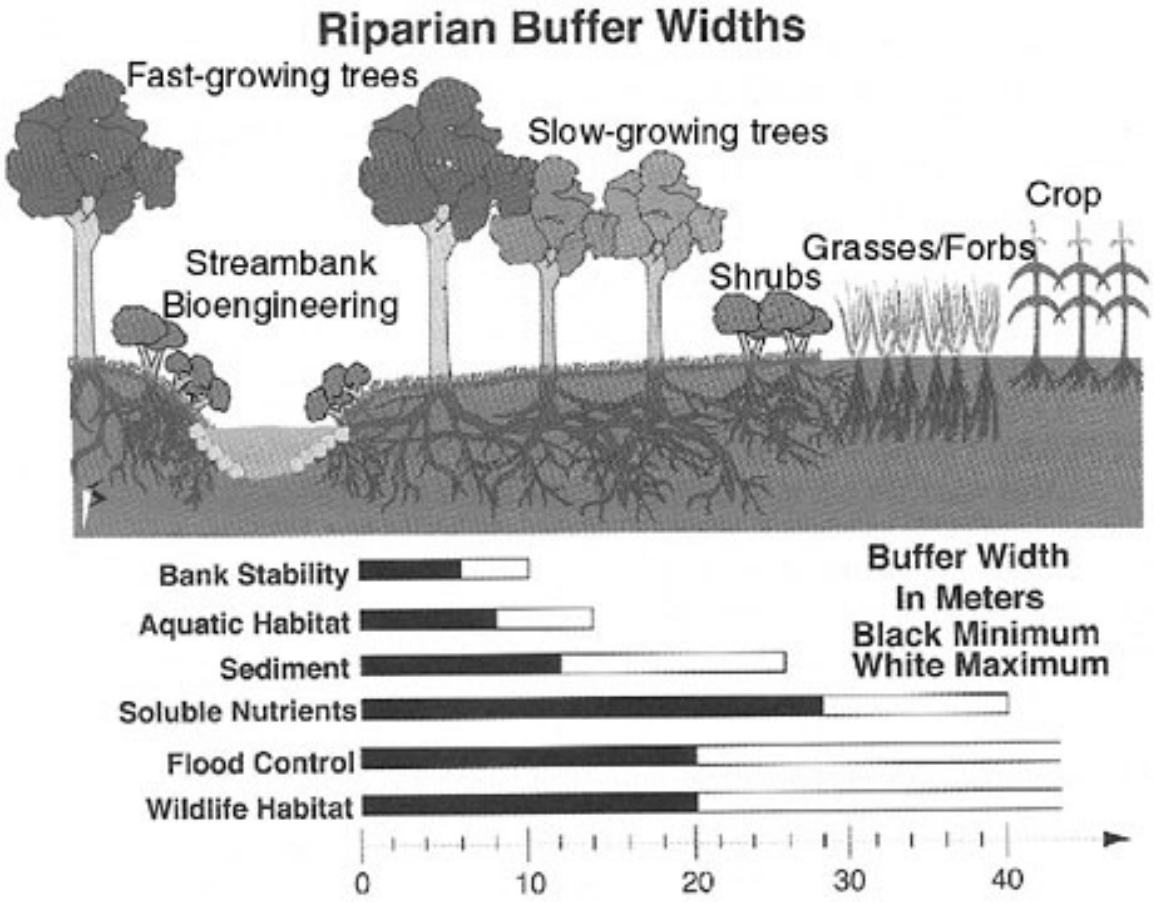
Environmental Flows

- Riparian Ecosystem: Services



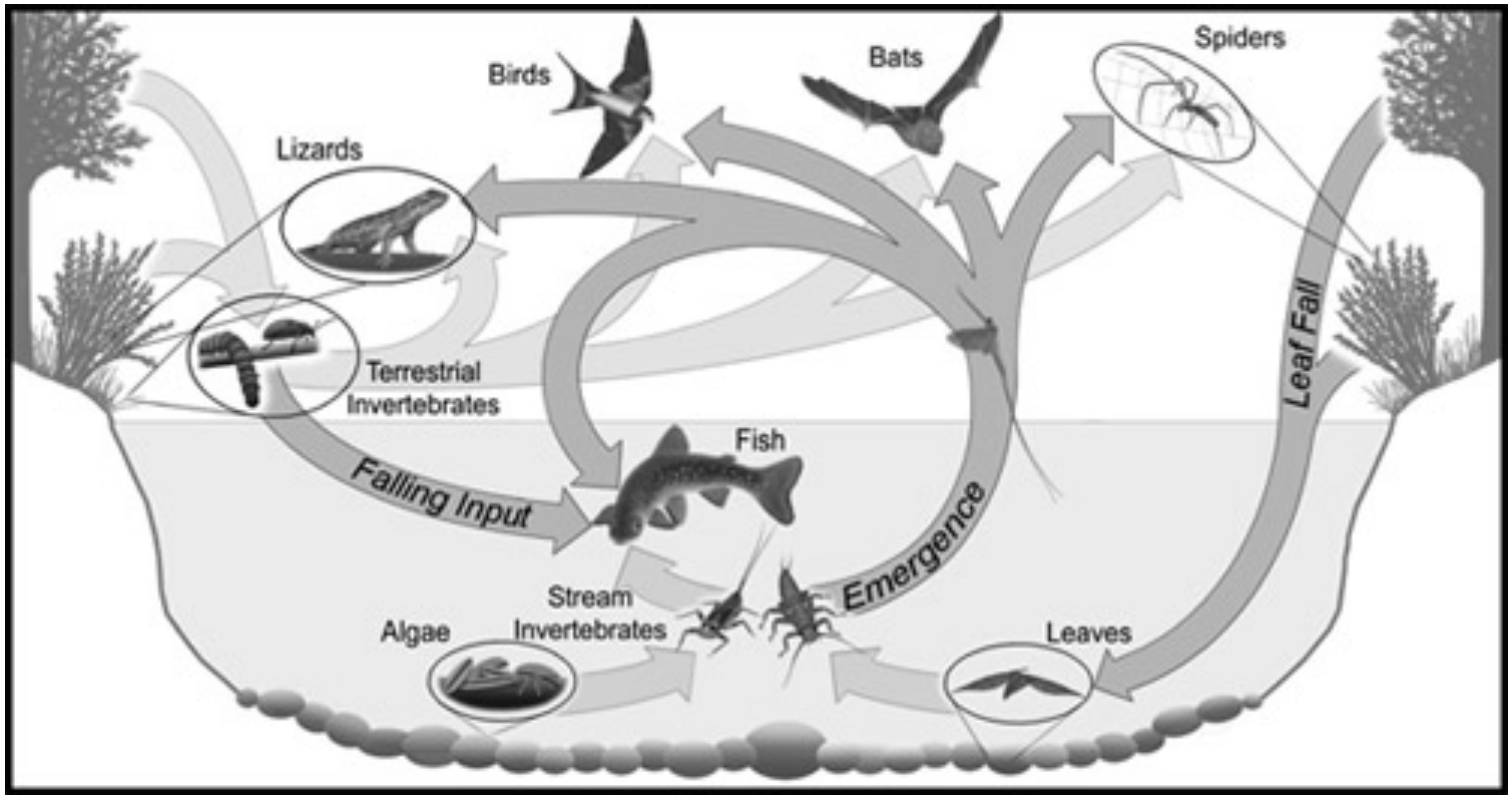
Environmental Flows

- Riparian Ecosystem: Services



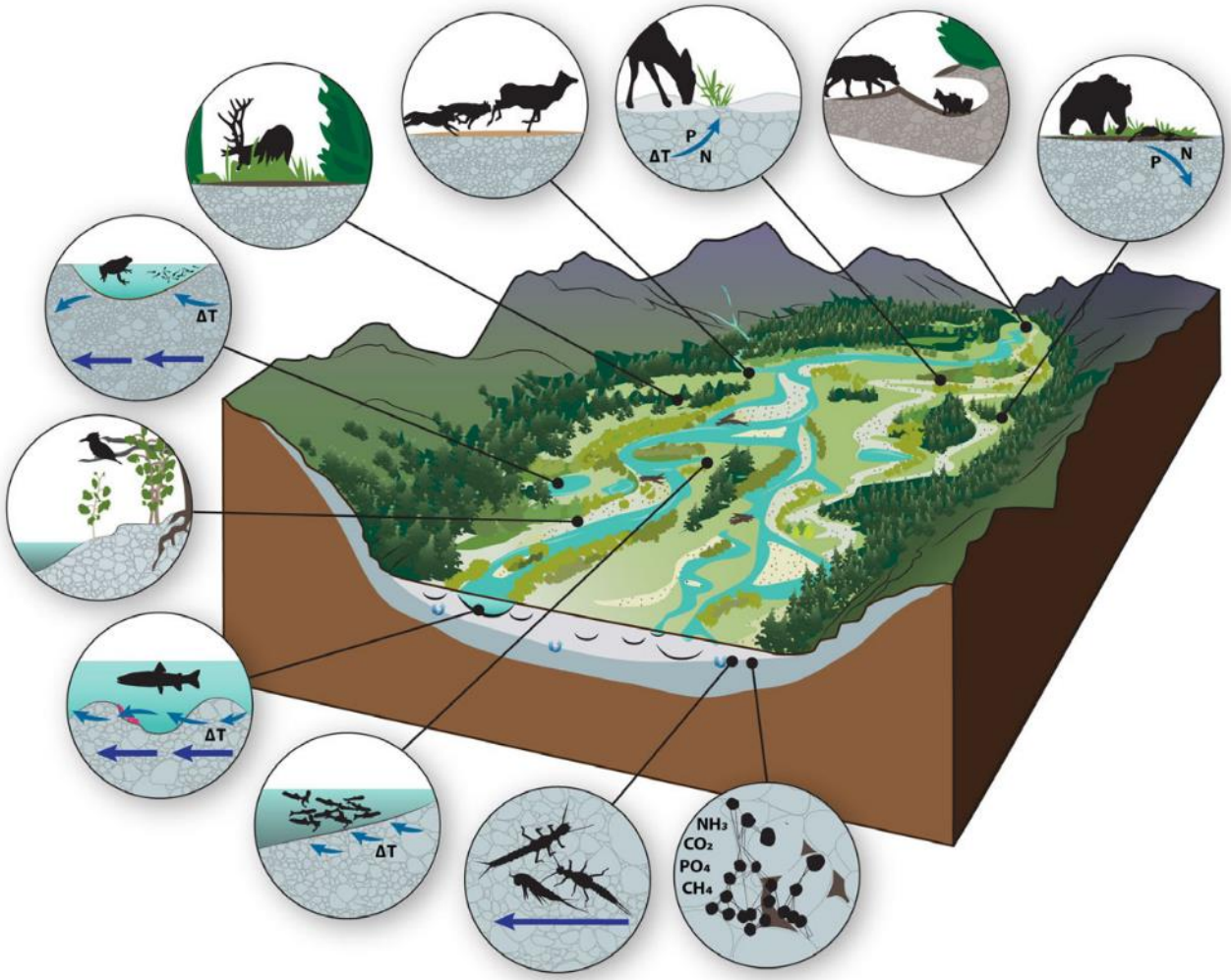
Environmental Flows

- Aquatic and Riparian Ecosystems



Environmental Flows

- Terrestrial Ecosystem



Environmental **Flows**

- Quantity
- Quality
- Geomorphology

Environmental **Flows**

Flow Regime

the variability in its discharge throughout the year due to P, T, ET, and basin characteristics

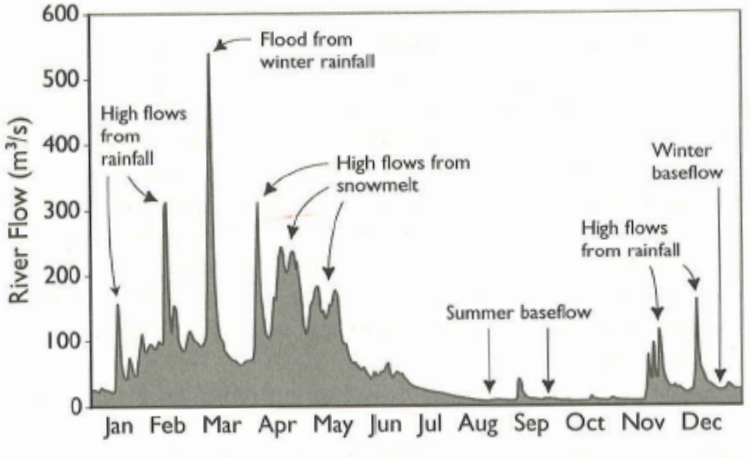
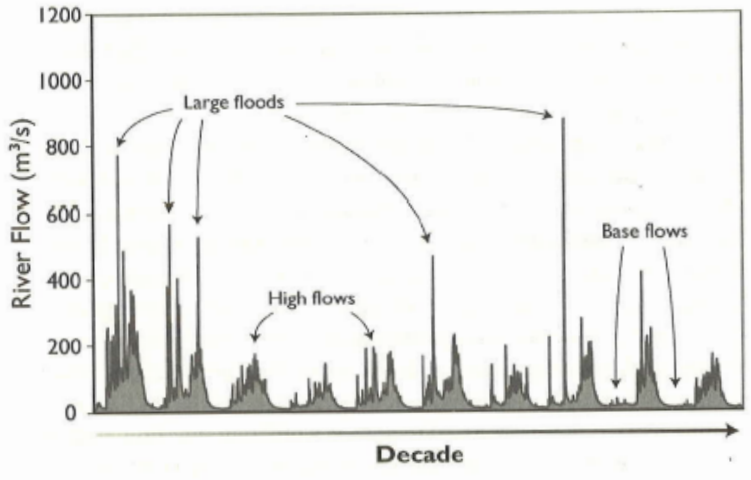


FIGURE 2-3. Annual Hydrograph from the Trinity River in Northern California.



Environmental **Flows**

Quantity ~ Flow regime:

- Magnitude
- Frequency
- Timing
- Duration
- Rate of Change

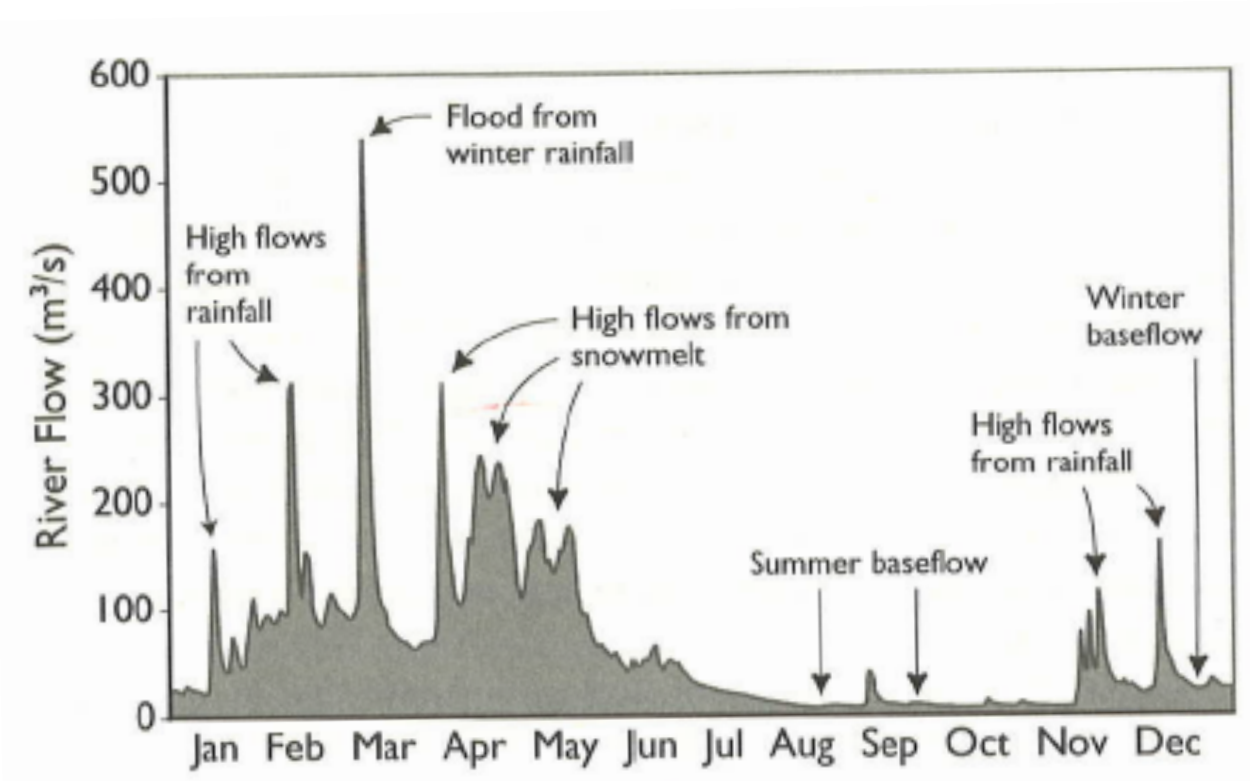
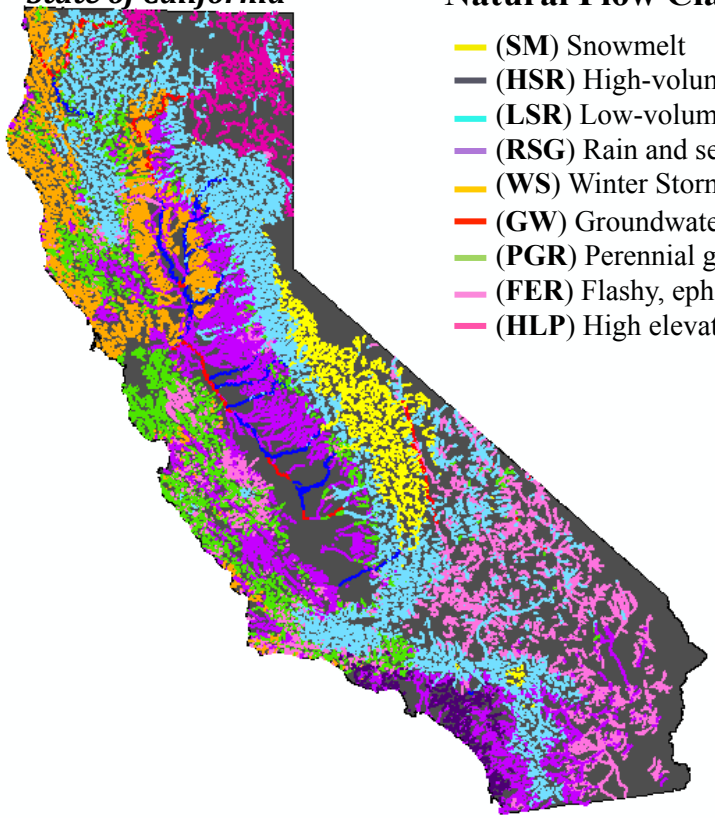


FIGURE 2-3. Annual Hydrograph from the Trinity River in Northern California.

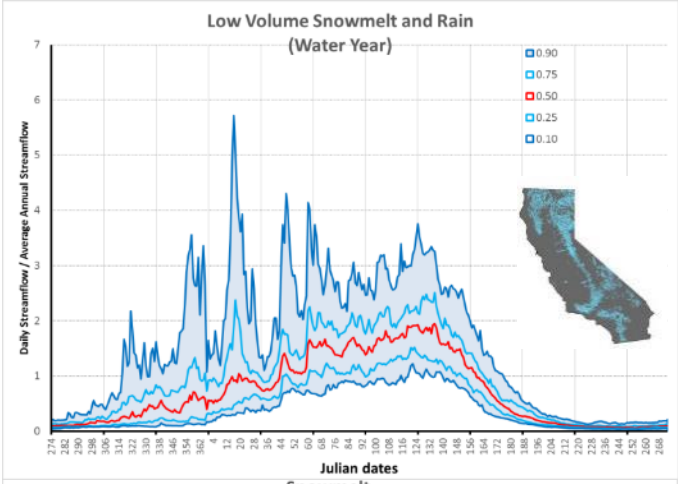
Hydrologic Classification for California

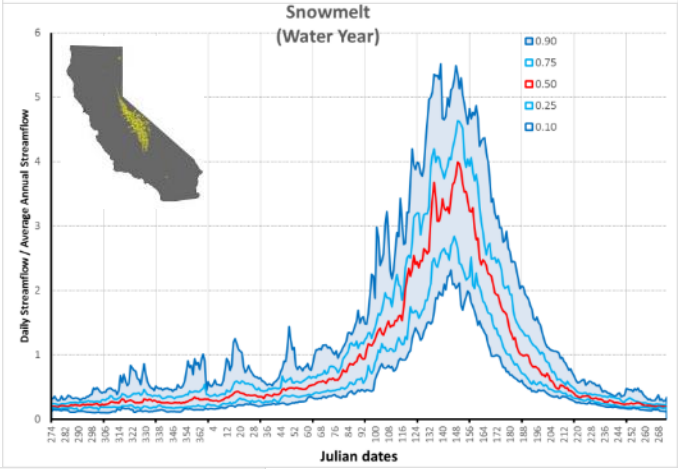
State of California

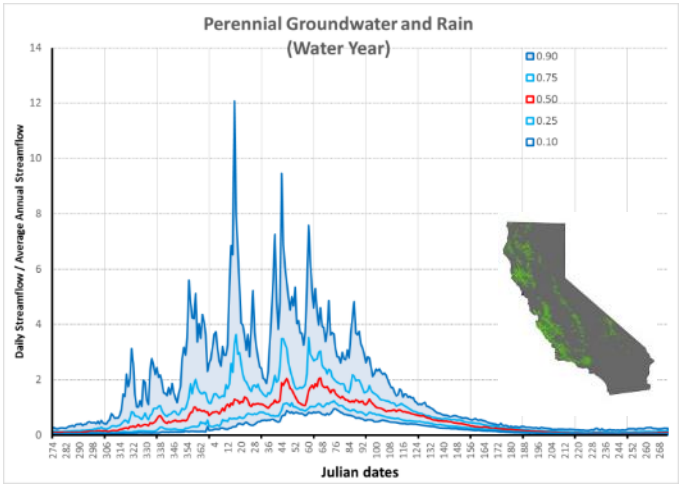


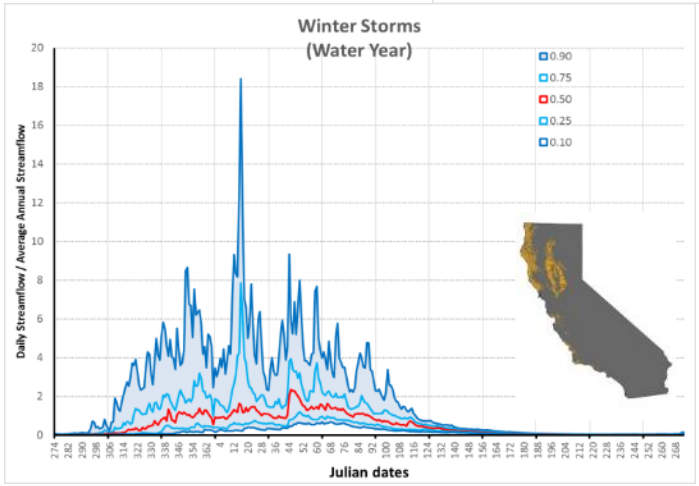
Natural Flow Class

- (**SM**) Snowmelt
- (**HSR**) High-volume snowmelt and rain
- (**LSR**) Low-volume snowmelt and rain
- (**RSG**) Rain and seasonal groundwater
- (**WS**) Winter Storms
- (**GW**) Groundwater
- (**PGR**) Perennial groundwater and rain
- (**FER**) Flashy, ephemeral rain
- (**HLP**) High elevation & low precipitation





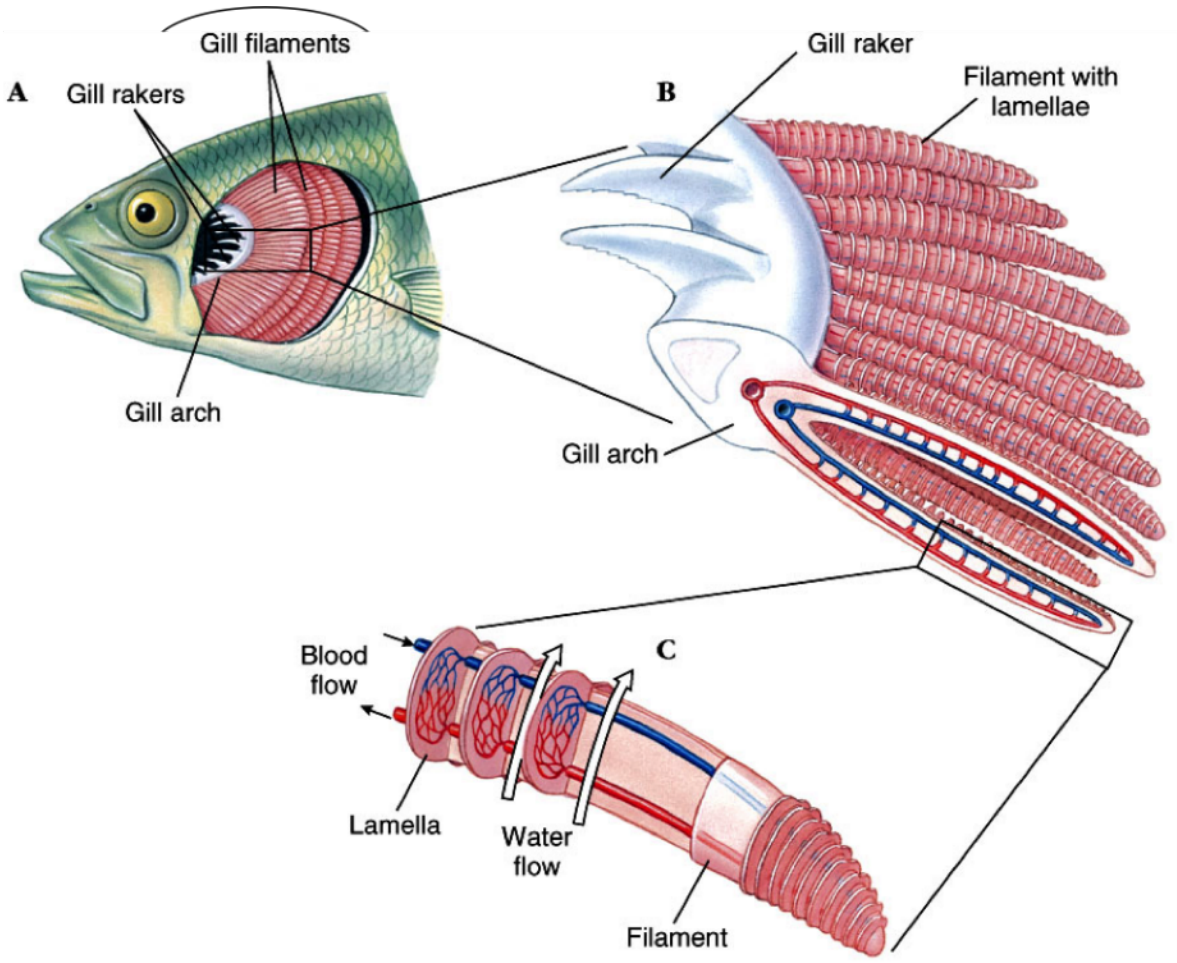




Environmental **Flows**

Quality

- Dissolved Oxygen
- Suspended Solids
- Temperature
- Rate of Change



Environmental **Flows**

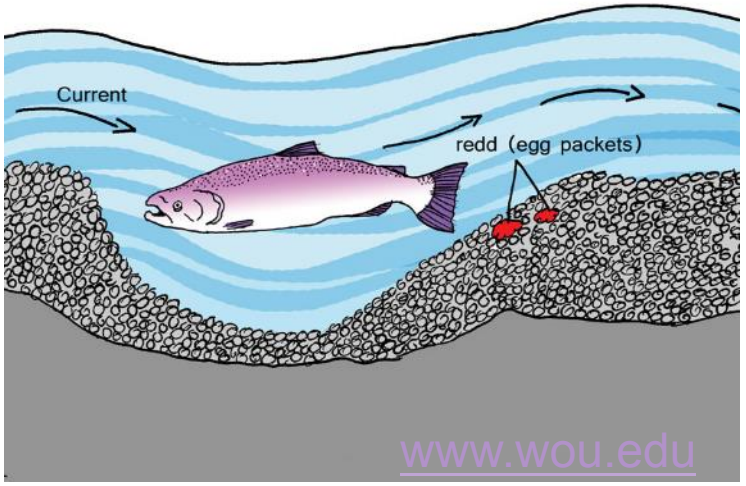
Quality: *Dissolved Oxygen*

- Hypoxia
- Decrease Fertilization
- Delay Embryo development
- Reduce size at time of hatching
- Decrease food consumption
- Reduce growth
- Increase exposure to contaminants

Environmental **Flows**

Quality: *Suspended Solids*

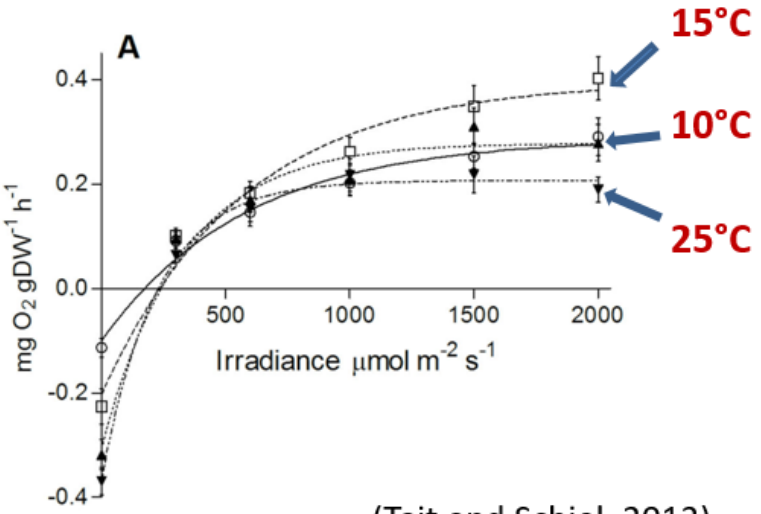
- Lower penetration of light
- Vector of nutrients and contaminants
- Abrasive effect – physical damage
- Scour Benthic Invertebrates over the channel bed
- Clog feeding structure
- Causes stress, suppress immune system, increase diseases
- Reduce development and survival of eggs



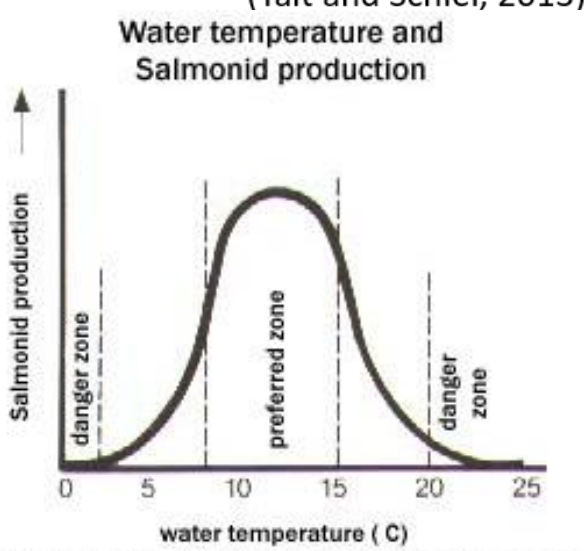
Environmental Flows

Quality: *Temperature*

- Higher respiration rates
- Change rate of embryo development
- Reduce feeding and growth rate
- Decreases tolerance to hypoxia
- Accelerates life cycle of parasites
- Shortens incubation time of bacteria in fish
- Immunosuppression in fish



(Tait and Schiel, 2013)



References: Everest, F.H.; Harr, D.H. 1982. Influence of forest and rangeland management on anadromous fish habitat in Western North America.

Environmental Flows

Geomorphology

- Sediment composition
- Sediment transport & deposition
- River structure

Channel type

- Headwater
- Alluvial fan
- Upland uniform
- Cascade / step-pool
- Pool-riffle
- Plane-bed
- Anastomosing
- Large uniform boulder
- Large meandering sand

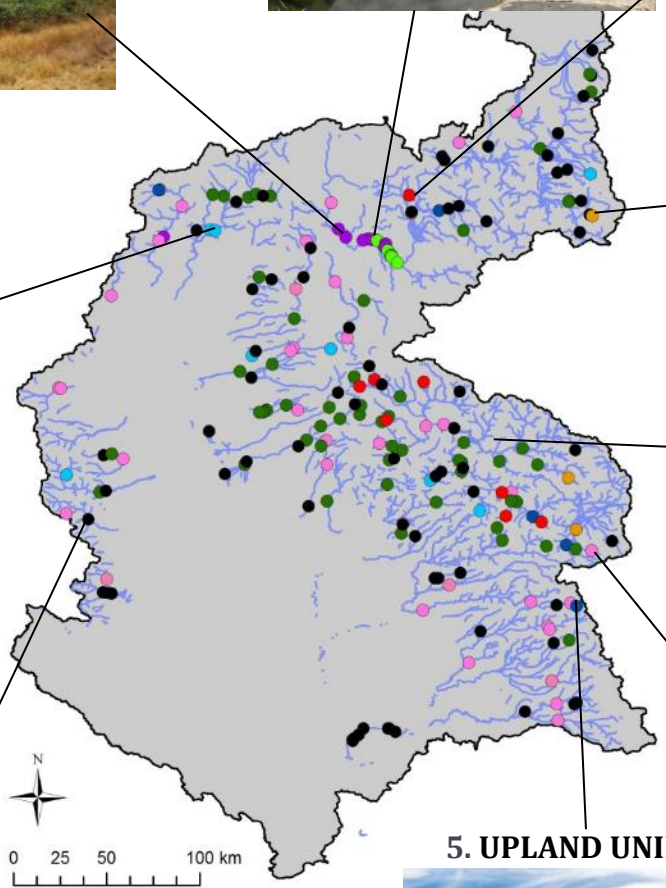
9. LARGE UNIFORM BOULDER

1. ALLUVIAL FAN

8. LARGE MEANDERING SAND

4. ANASTOMOSING

7. HEADWATER



2. POOL-RIFFLE

6. CASCADE/STEP-POOL

3. PLANE BED

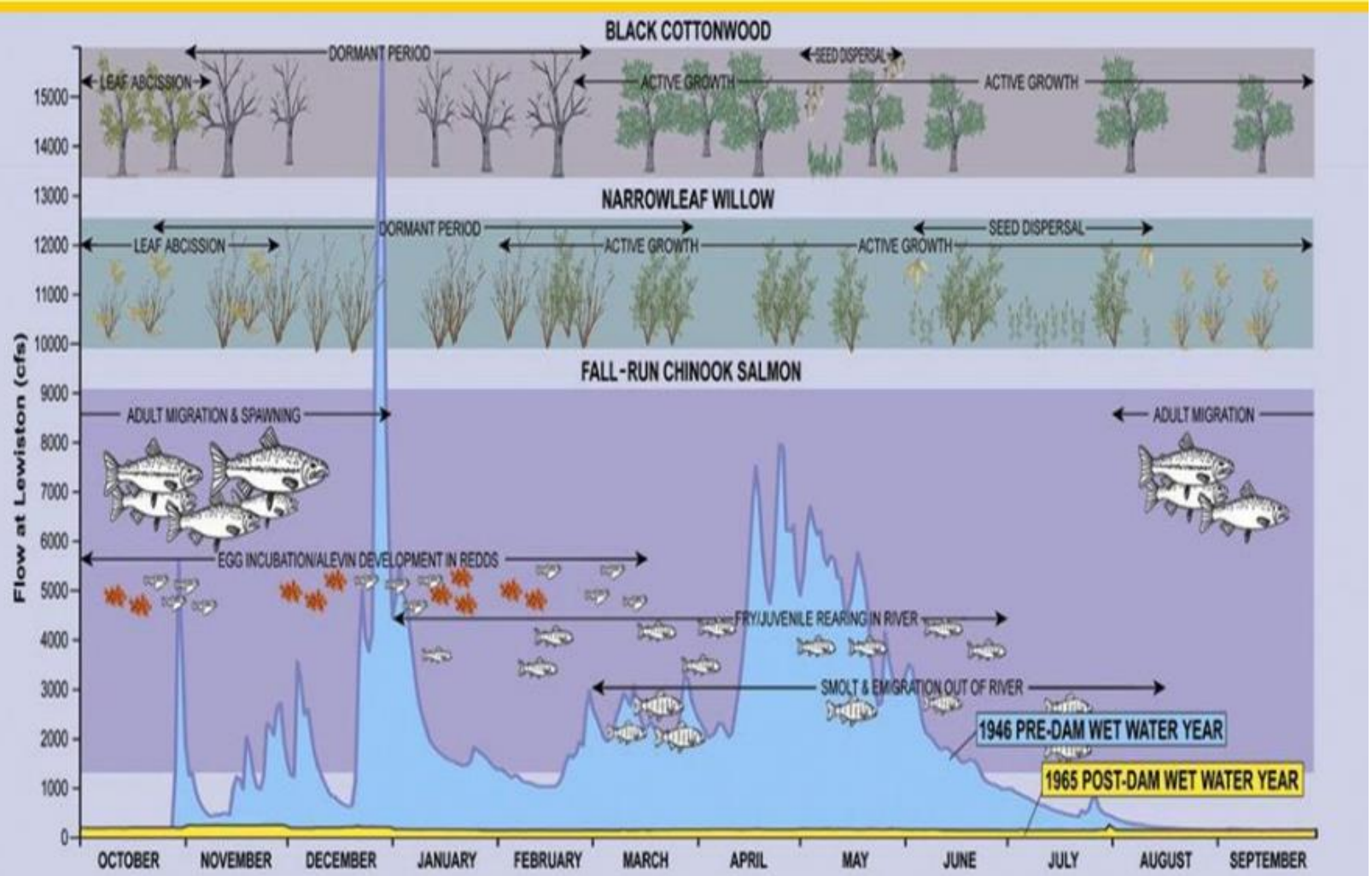
5. UPLAND UNIFORM

Geomorphic variability of LSR

Environmental Flows

Healthy ecosystems have evolved in response to natural flow variations.

TRINITY RIVER, CALIFORNIA, USA

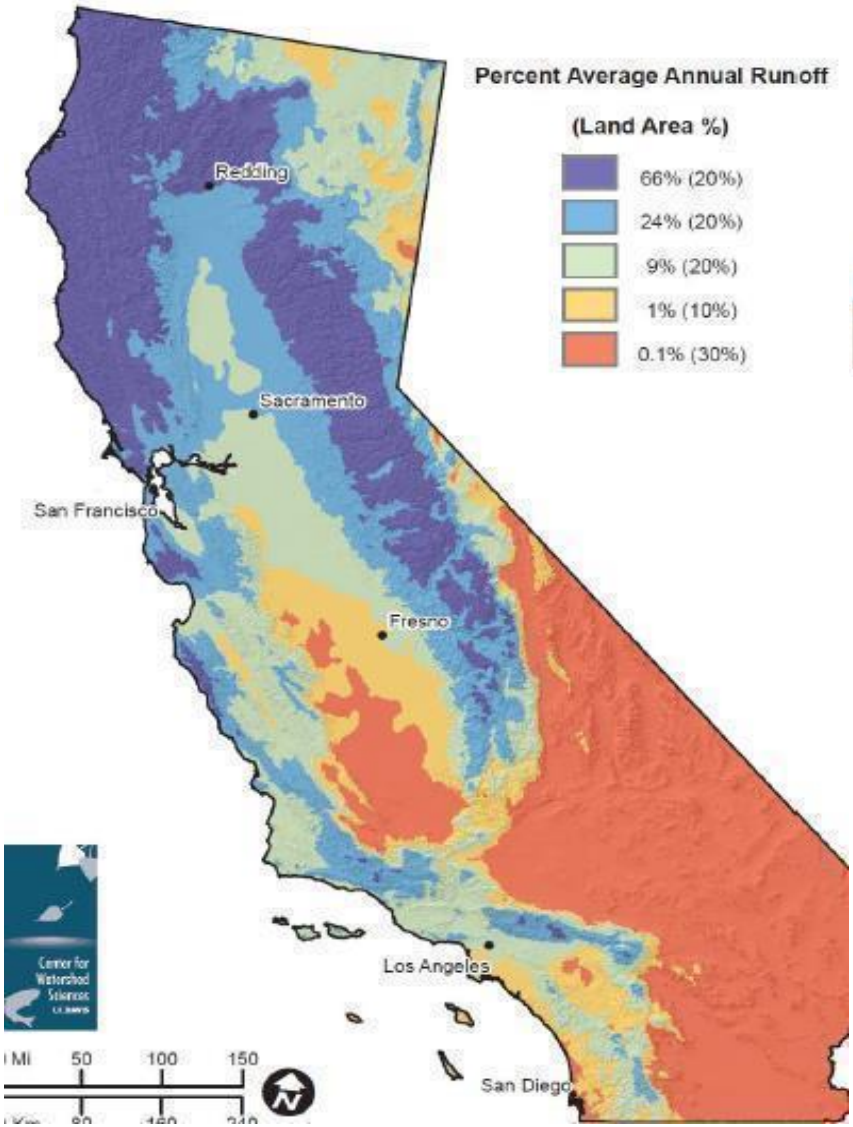


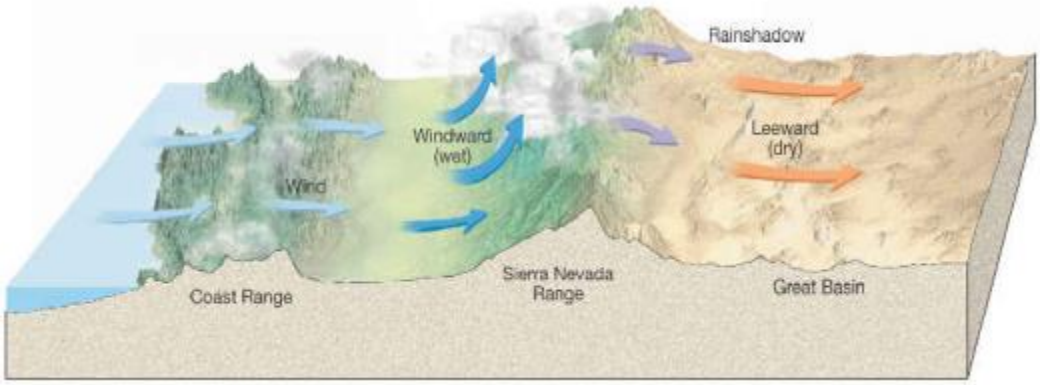
Environmental Flows

What do we mean by “Environmental Flows”?

- **Environment**: mostly aquatic & riparian, also terrestrial
- **Flows**
  Quantity: Flow regime – magnitude
  Frequency, timing, duration, rate of change
  Quality: DO, T, SS,
  Geomorphology: Sediment composition, transport, and river structure
- that support the environment and human activities

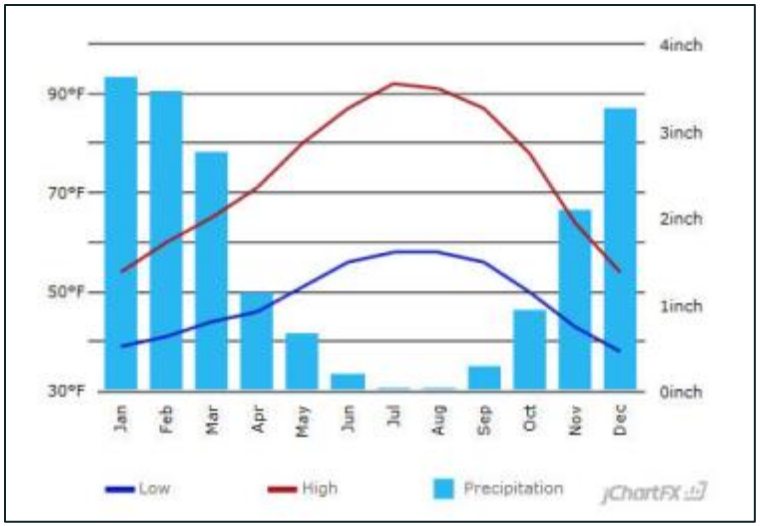
California Geography and Climate



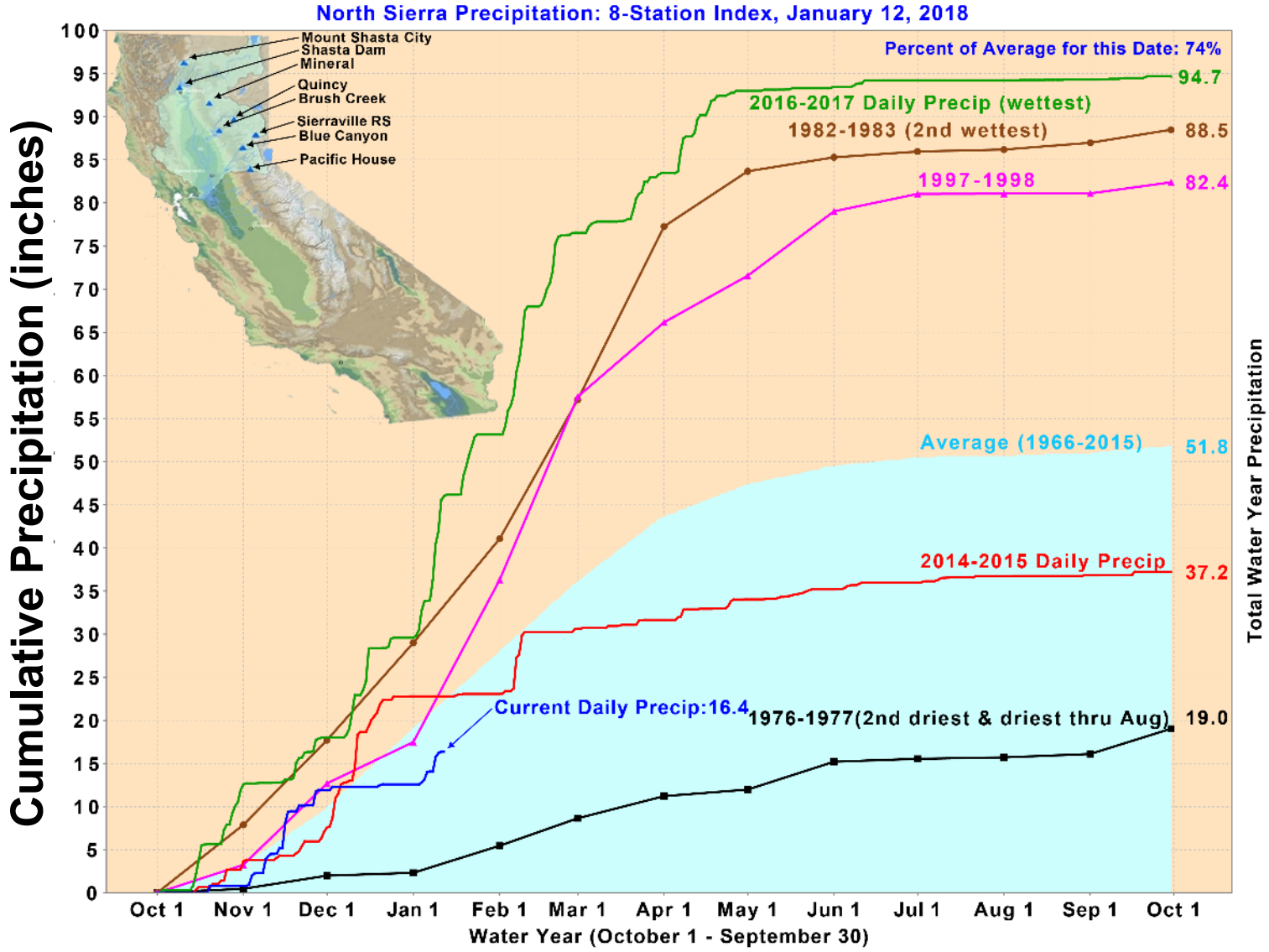


Geoscience.com

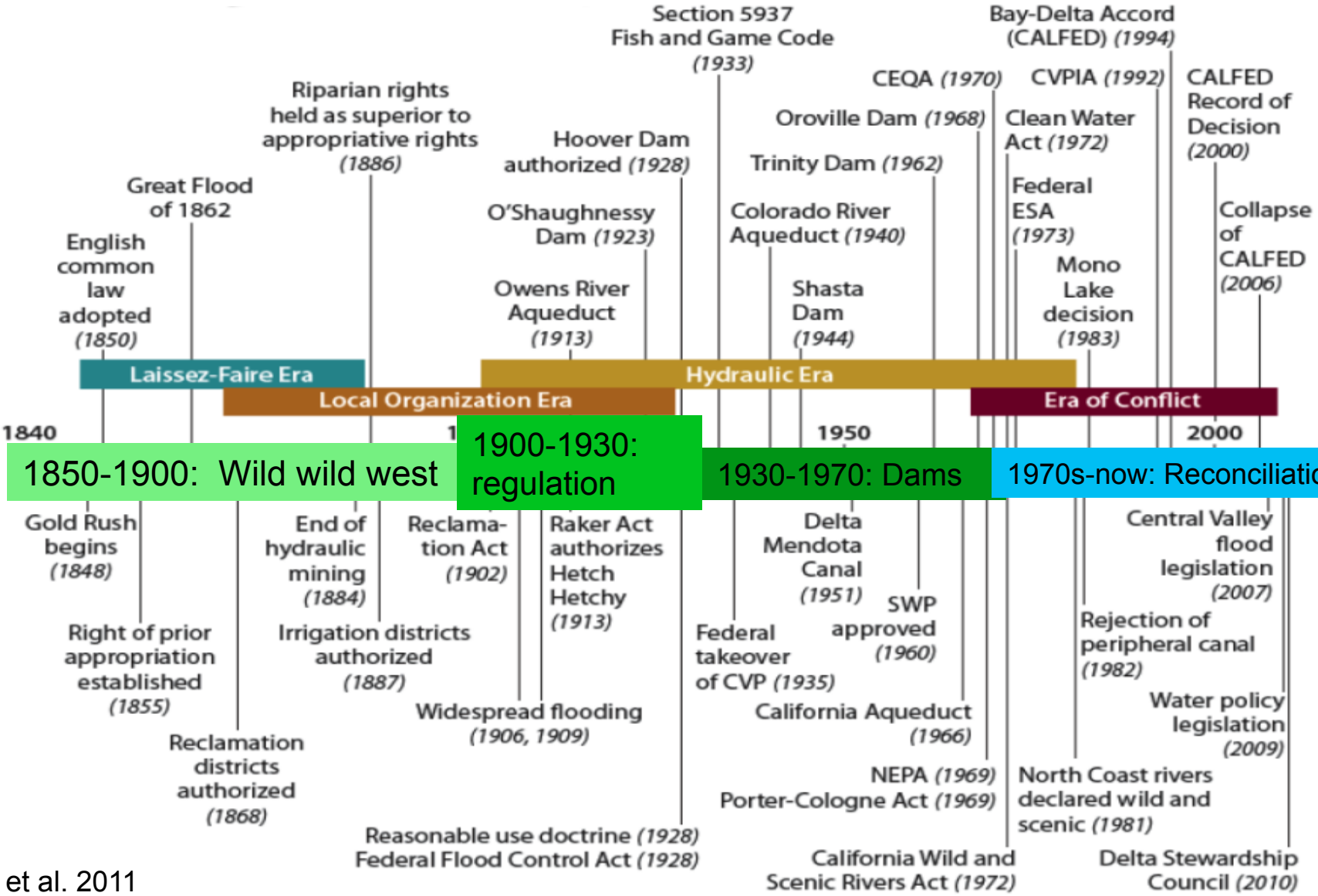
Sacramento, California



California's Climate: Extremes



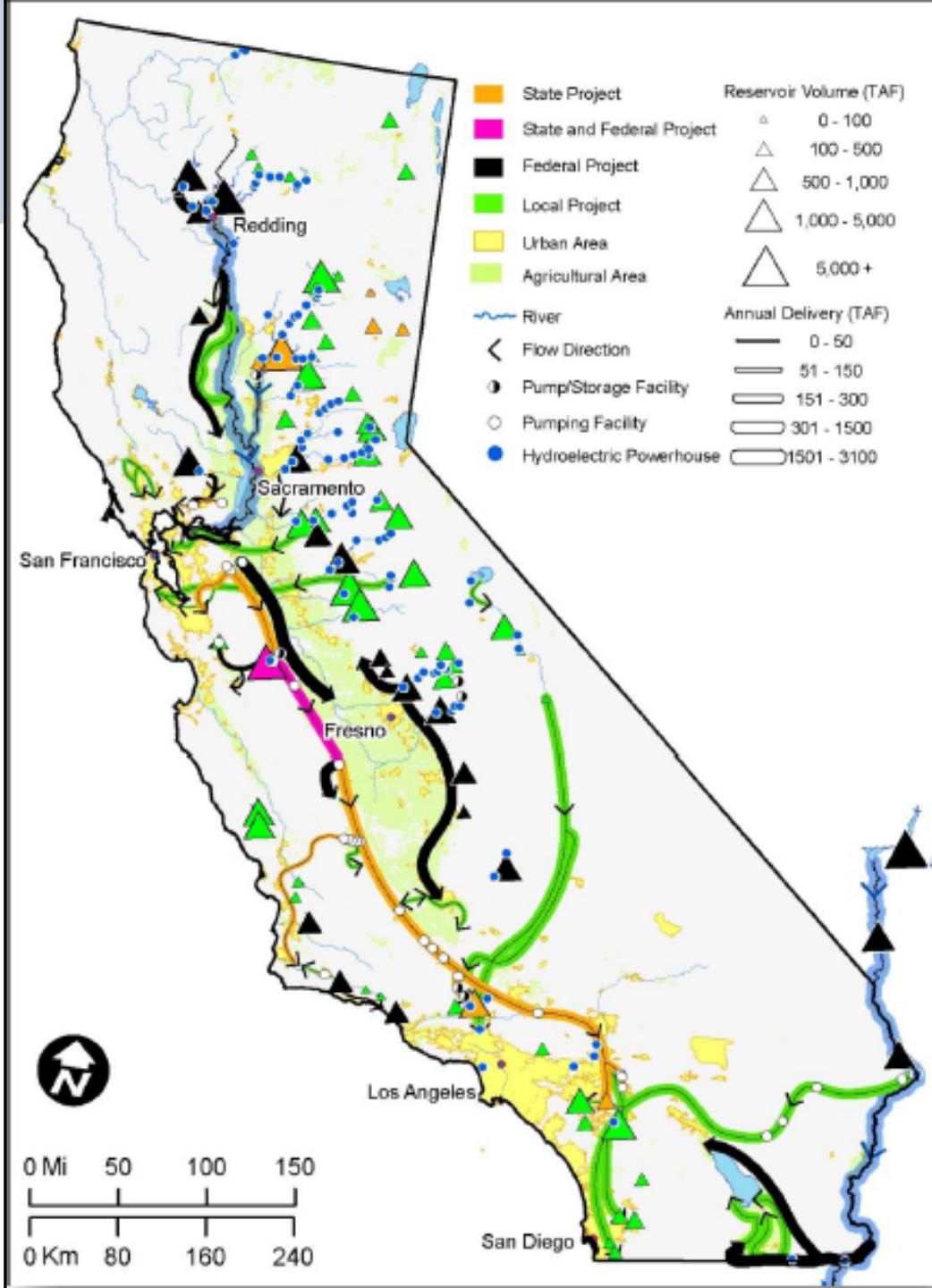
History of Water Management in CA



Hanak et al. 2011

Hydrologic Alteration

- Supply → North
- Demand → South
- Over 1500 dams
- SWP: >700 miles of aqueducts deliver 2.5 MAF
- CVP: 500 miles of aqueducts deliver 7 MAF

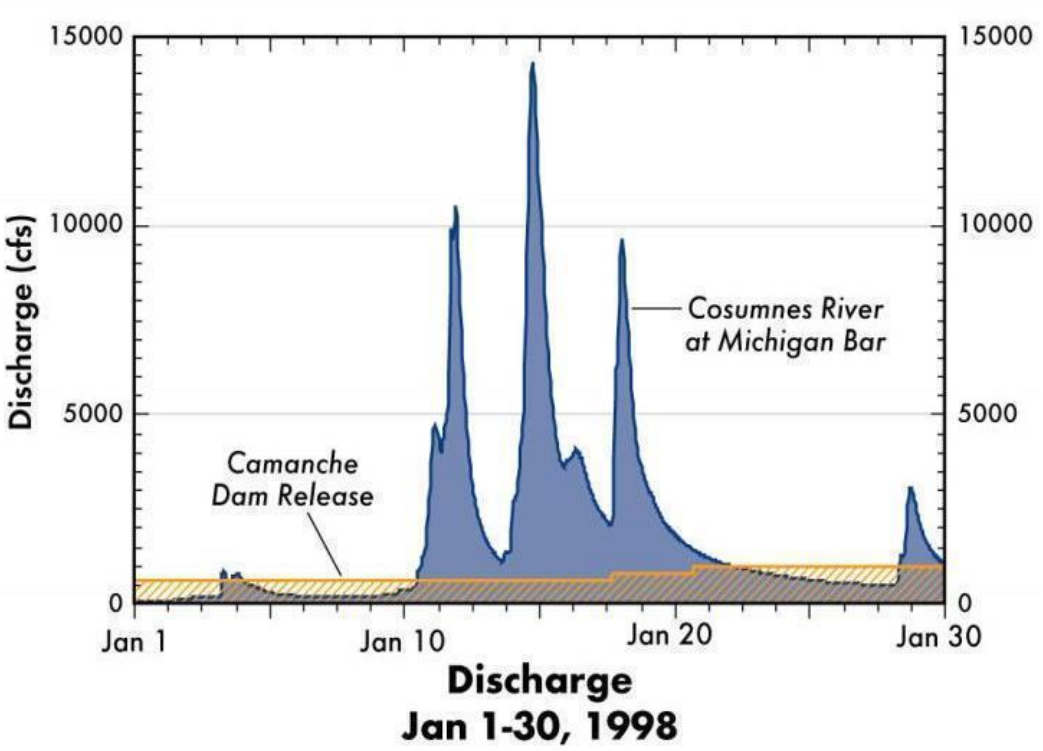


Changes from Water Development

- Fundamentally altered flow regime
  - Lower winter flows
  - Few flood events
  - Higher summer flows
  - Disconnect river from floodplain
  - Reduced sediment transport
  - Channel morphology more static
  - Biotic Repercussions

- Competing water uses
  - Water supply, hydropower, flood control, recreation, environmental protection

The Greatest Impact: Loss of Hydrologic Variability



- Homogenization of flows
- Loss of flows sufficient to transport sediment, support riparian recruitment
- Pattern of flows often in conflict with life history strategies
- Loss of or minimization of disturbance events

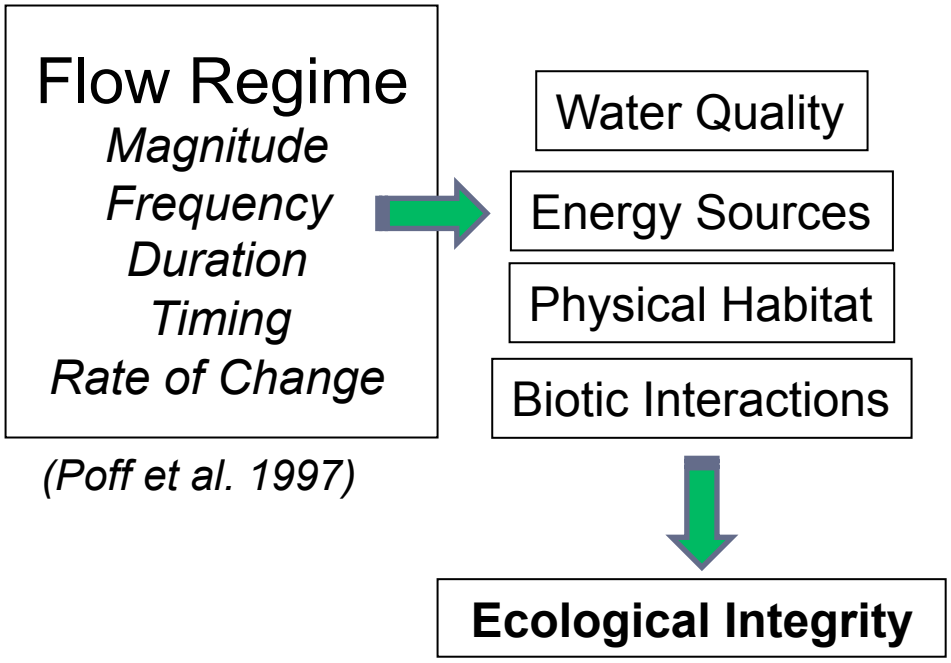
How can we reduce the impacts of dams on river ecosystems?

"Clearly half of the peak discharge will not move half of the sediment, half of the migration motivational flow will not move half of the fish, and half of an overbank flow will not inundate half of the floodplain"

-Poff et al. 1997

Environmental Flow Methods

Natural Flow Regime Paradigm



(Poff et al. 1997)

- Native aquatic species are adapted to the natural stream flows under which they evolved (Naiman et al. 2008)
- Flow variability is a primary driver in ecosystem processes

➢ Therefore, aspects of the natural flow regime should be preserved to support native species

Environmental Flow Methods

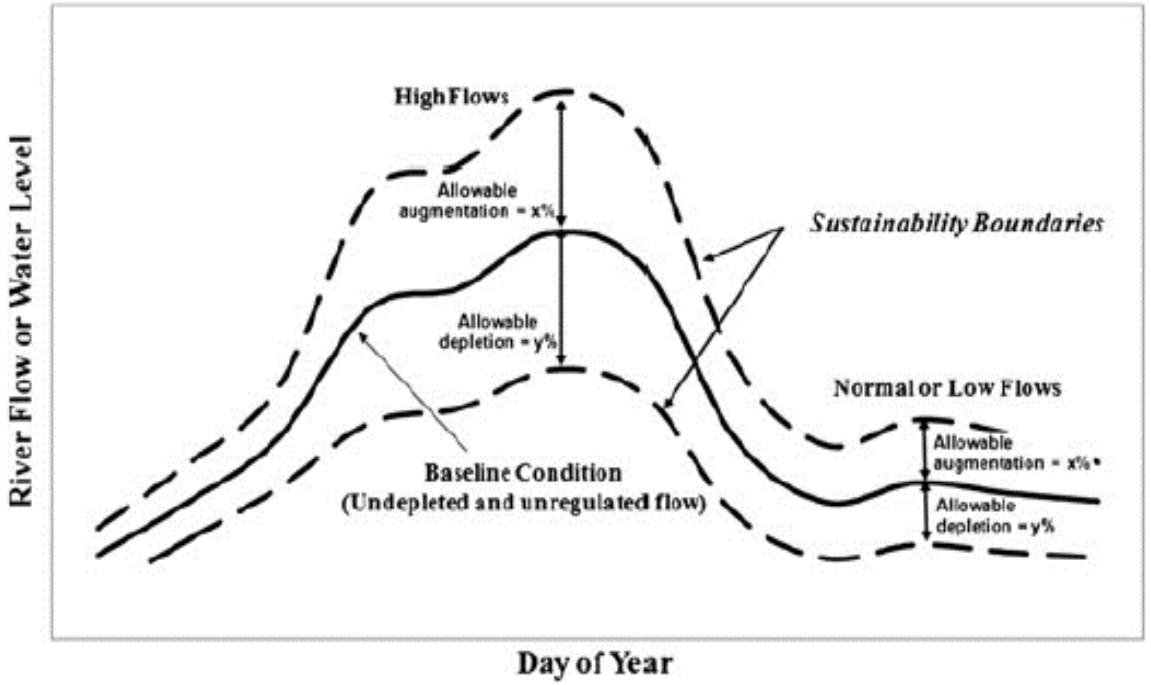
By 2002, Over 200 methods and broader frameworks existed to assess water requirements and support flow management (Tharme 2003)

- **Hydrological**
- **Hydraulic rating**
- **Habitat simulation**
- **Holistic methods**

DeSabla powerhouse
Butte Creek

Environmental Flow Methods

- **Hydrological** – single index, rule-of-thumb, look-up table approaches
  - e.g. Montana Method *(Tennant 1976)*, Downscaled Flow Regime *(Hall et al. 2011),* Set Percentage of Flow *(Richter et al. 2013)*



Presumptive Standard – Richter et al. 2013

Environmental Flow Methods

- **Hydraulic rating** – quantification of instream hydraulic habitat for target species, started as wetted area assessments but typically now used within habitat simulation models
- **Habitat simulation** – using hydraulic rating methods, outputs habitat metrics for target species such as weighted usable area (WUA) or habitat availability in 1D, 2D and 3D modeling space
  - e.g. PHABSIM, IFIM *(Bovee 1986),* Regional IFIM (*Denslinger et al. 1998)*

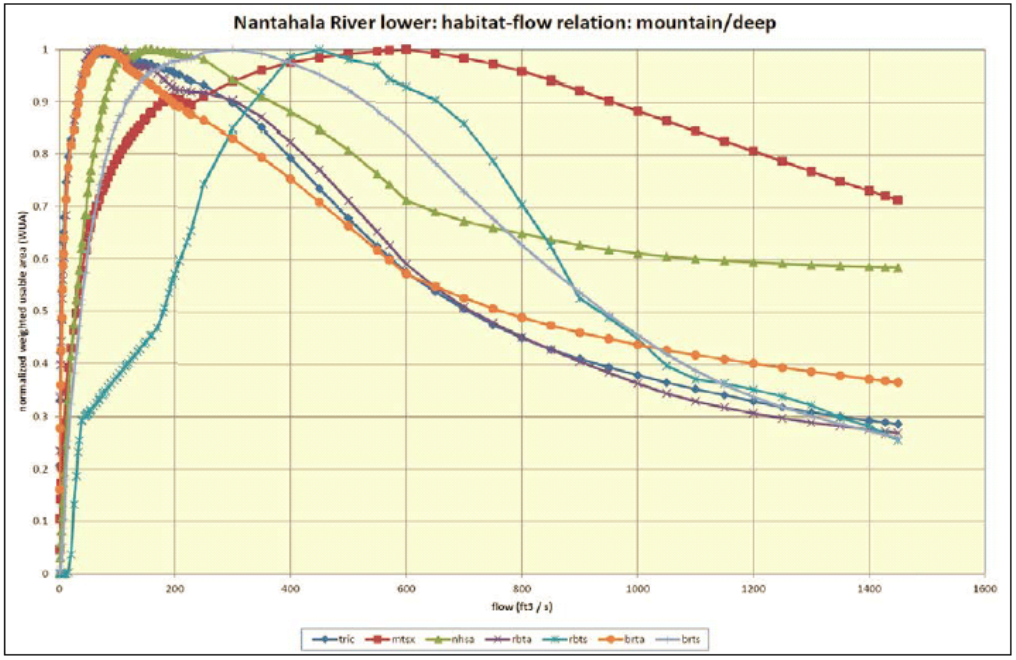
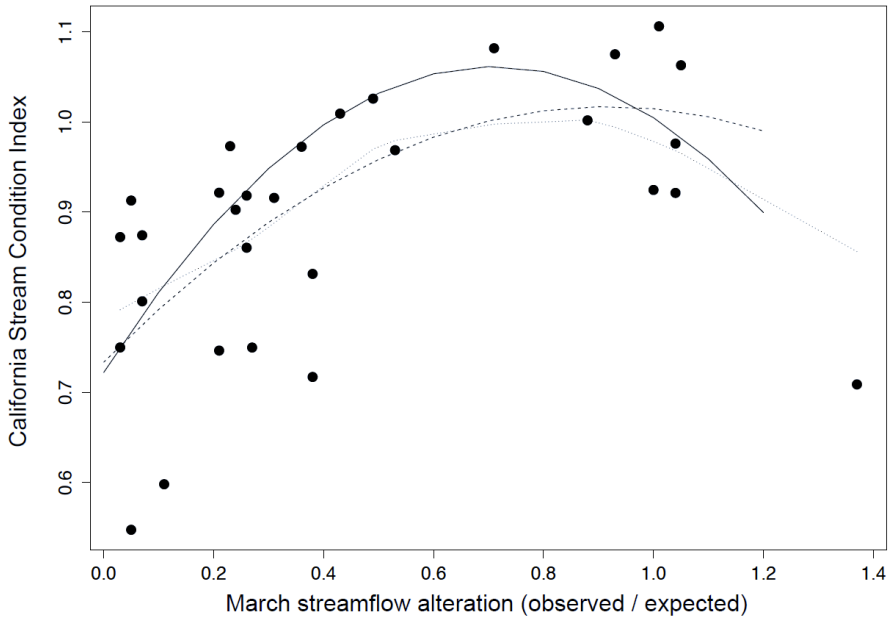


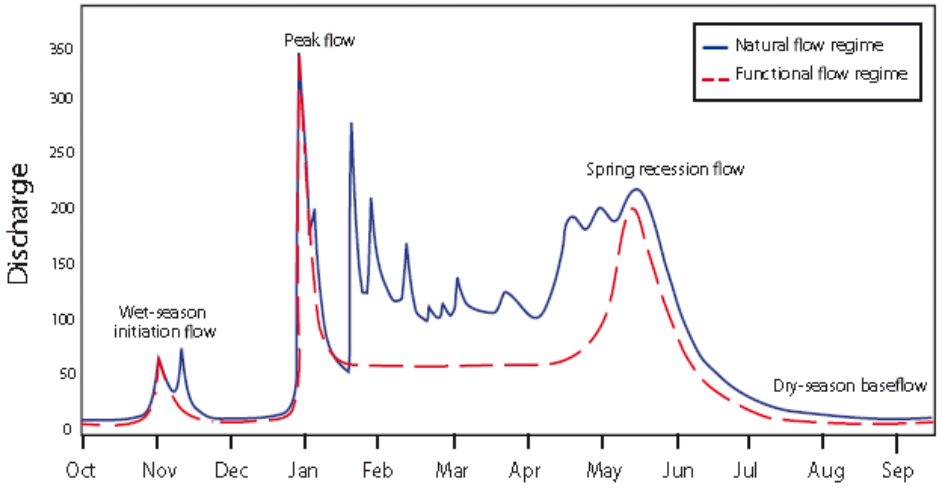
Figure 3. Example of WUA habitat-discharge relation (mountain-deep species/life stages) output from PHABSIM modeling.

Environmental Flow Methods

- **Holistic methods** – ecosystem approaches, hydrologic regime linked to quantitative ecological responses
  - e.g. DRIFT *(King et al. 2003)*, ELOHA *(Poff et al. 2010)*, PROBFLO *(Dickens et al. 2015)*, Functional Flows *(Yarnell et al. 2015)*



ELOHA -Carlisle et al. 2015



Functional Flows - Yarnell et al. 2015

ELOHA Framework

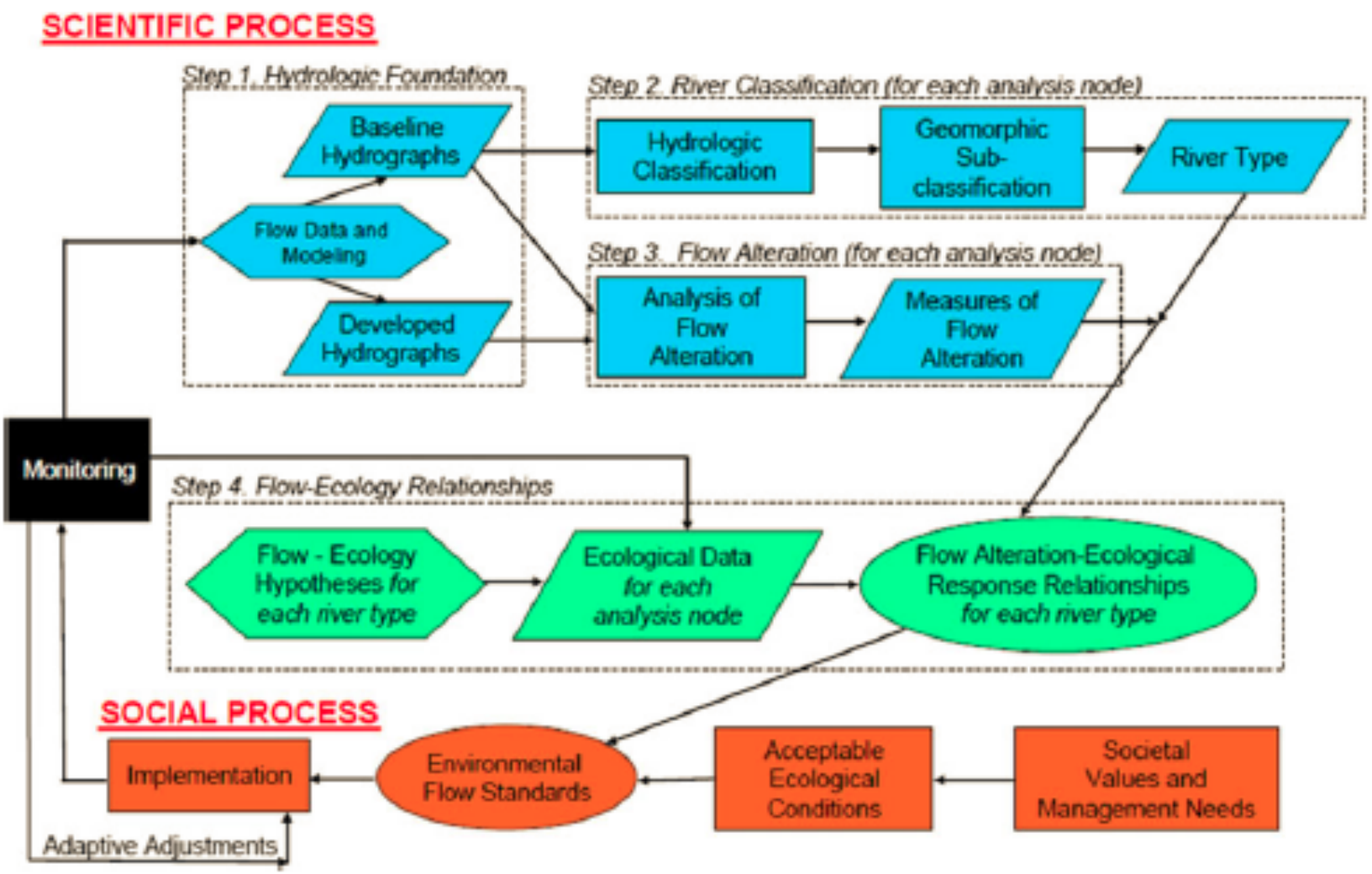
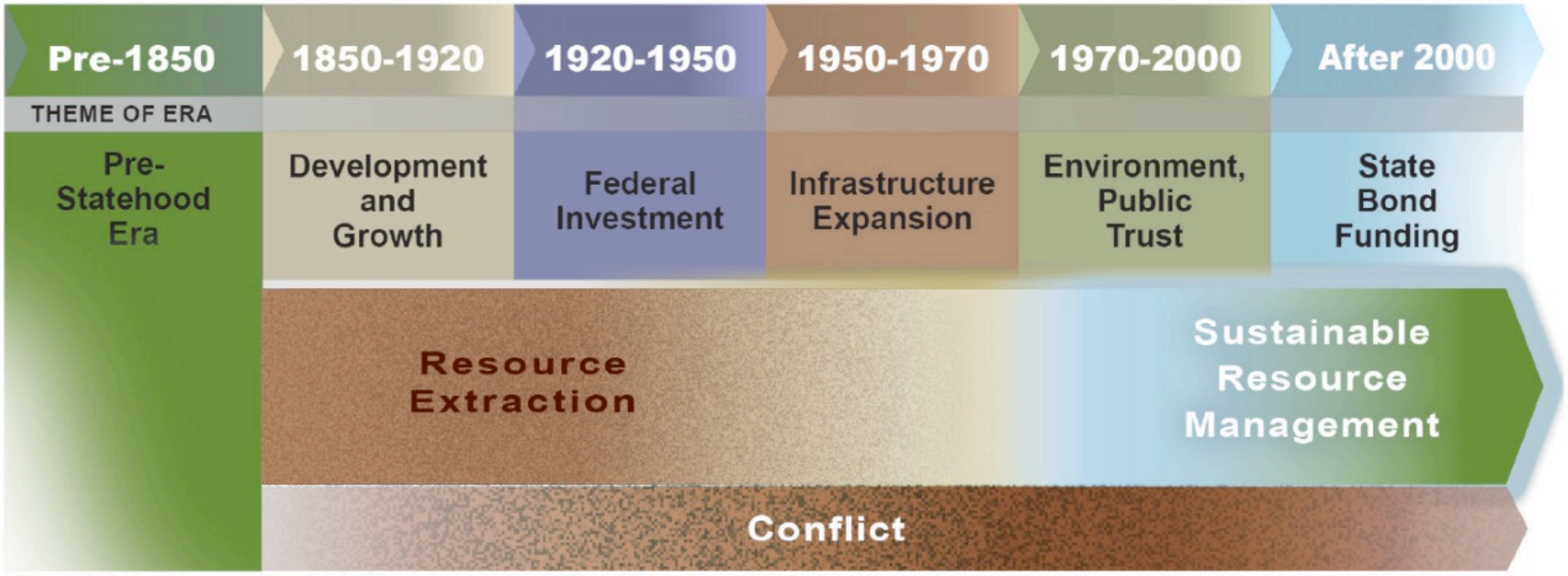


Fig. 1 The ELOHA framework (taken directly from Poff and others 2010)

Implementation and Policy



2013 CA Water Action Plan

Federal Policy

- **ESA** – following passage of the California Endangered Species Act (CESA) in 1970, Congress followed suit in 1973 by passing the federal Endangered Species Act (ESA) to protect rare plants and animals.
- **Public Trust Doctrine** – requires the state to hold in trust designated resources for the benefit of the people. Traditionally, applied to commerce and fishing in navigable waters, but its uses were expanded in CA in 1971 to include fish, wildlife, habitat and recreation.

Federal Policy

- 20 federal agencies including:
  - Army Corp
  - Bureau Land Mgmt
  - Env Protiection Agency
  - Fed Energy Reg Comm
  - US Fish & Wildlife Srvc
  - US Forest Srvc
  - US Geological Survey
  - Natnl Oceanic Atmsp Agy
  - Natnl Marine Fisheries
  - Natnl Park Srvc

- FERC – hydropower relicensing
- BLM, USFS – largest landholders, manage water resources
- USFWS, NMFS – ESA enforcement
- Army Corp – dam owner

FERC relicensing

"The public must retain control of the great waterways. It is essential that any permit to obstruct them for reasons and on conditions that seem good at the moment should be subject to revision when changed conditions demand."

(*President Theodore Roosevelt, 1908*)

Common Environmental Goals for Hydropower Reform

- Higher Instream Flows
- **Flow schedule mimics natural flow regime**
- Improved water temperatures
- Upstream/Downstream fish passage
- Increased recreational opportunities, public access

State Policy

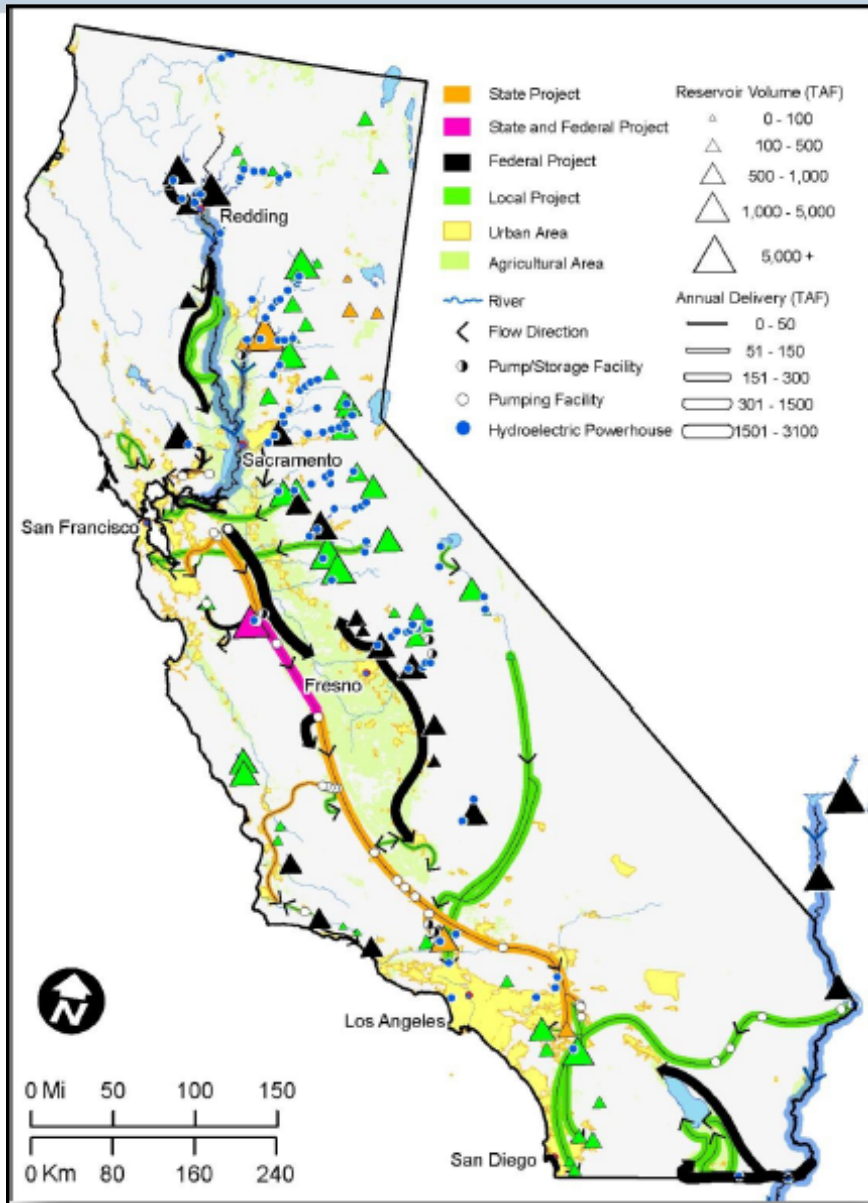
- 29 state agencies including:
  - Dept Water Resources
  - State Water Resouces Control Board
  - CA Coastal Commission
  - CA Dept Fish & Wildlife
  - CA Energy Comission
  - Cal EPA
- DWR – operates State Water Project; responsible for overall water supply planning
- SWRCB – integrates water rights and water quality; responsible for overall water quality planning and protecting water resources (9 RWQCBs)
- CDFW – restoration of adequate instream flows a priority for instream flows program

Local Policy

- Tribes – overlap both state and federal
- Over 600 local water and irrigation districts
- Over 2000 local special districts (e.g. resource conservation district, reclamation district
- 48 Integrated Regional Water Mmgmt (IRWM)

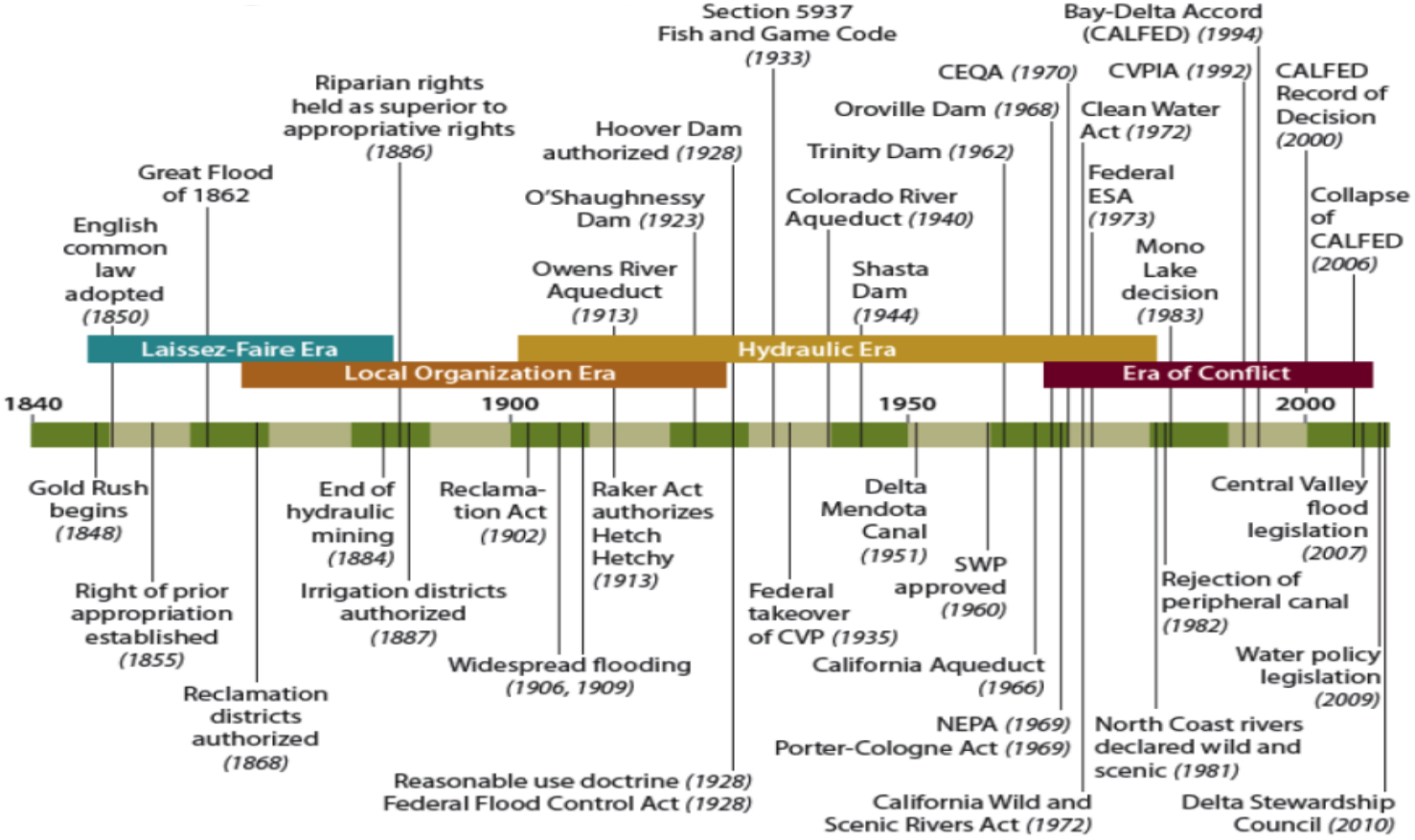
Environmental Flows in CA

- Complex Landscape



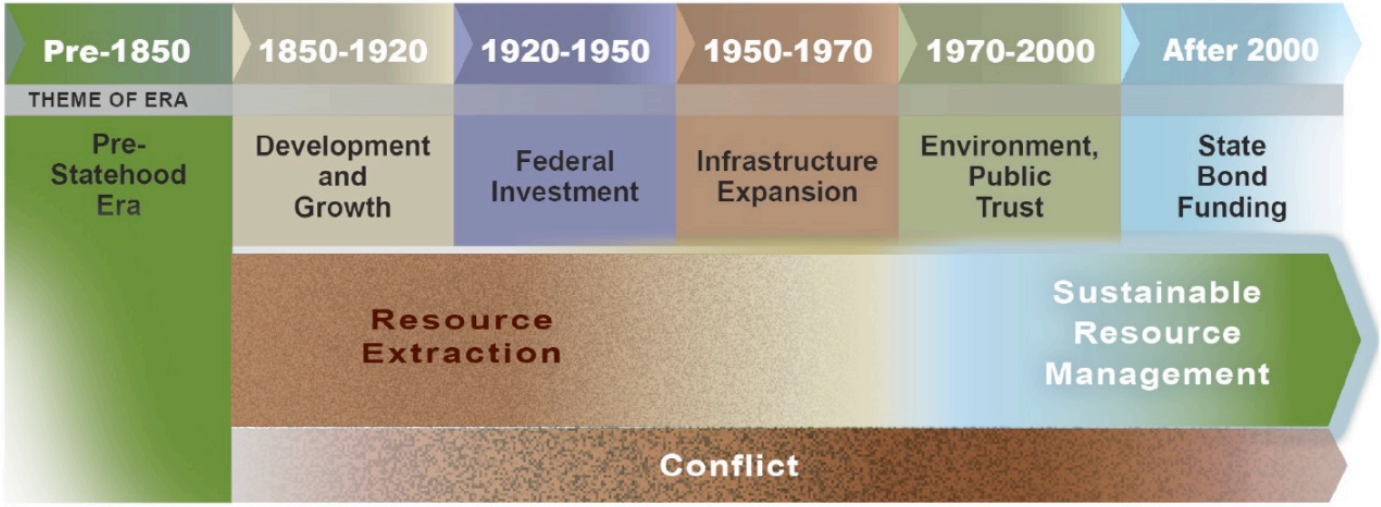
Environmental Flows in CA

- Complex Landscape
- Complex History



Environmental Flows in CA

- Complex Landscape
- Complex History
- Complex Policy and Regulations



Winter Seminar Outline

- Science of Environmental Flows
  - Jan 24: Ecohydrology, Dr. Greg Pasternack
  - Jan 31: Fish and Flows, Dr. Peter Moyle
  - Feb 7: Flow-Ecology, Dr. Eric Stein
- Policy on Environmental Flows
  - Feb 14: Water Markets, Panel
  - Feb 21: Lessons from FERC, Panel
  - Feb 28: Cannabis, Panel
  - Mar 7: CA Case Studies, Panel
  - Mar 14: CA Prospects, Panel