# Consideration of Non-Stationary Sediment Dynamics in Watershed Based Plans

*2nd Annual Watershed Health Indicators and Data Science Symposium* **Sacramento, CA Thursday June 29, 2017**

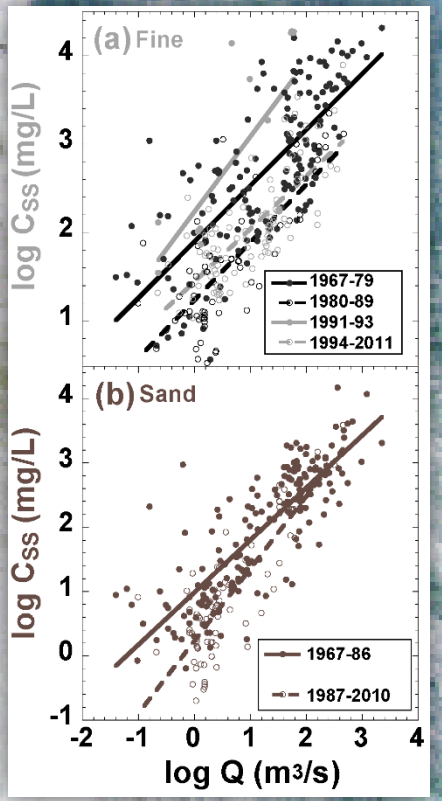


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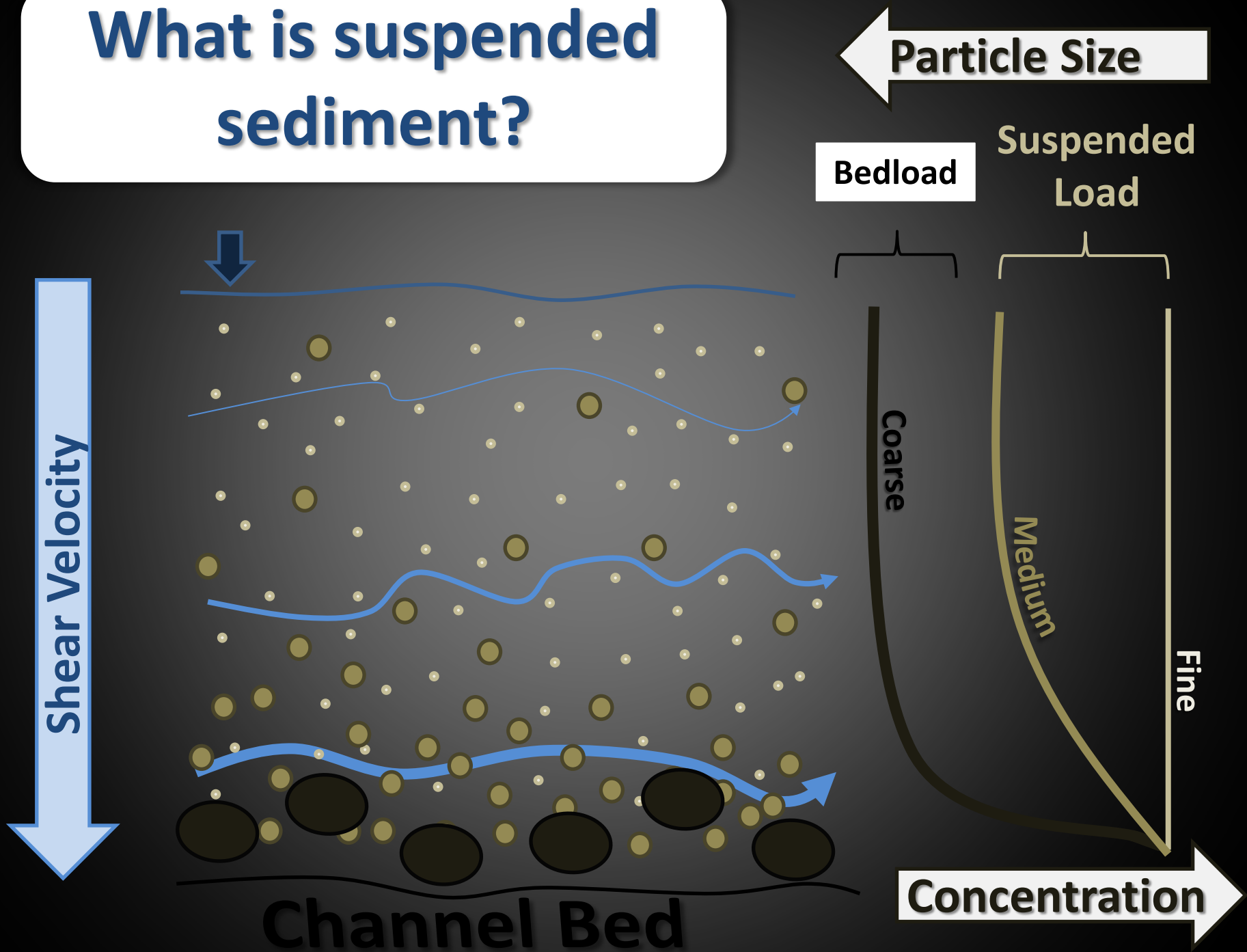
Image: Monterey County Water Resources Agency

# Fine River Sediment

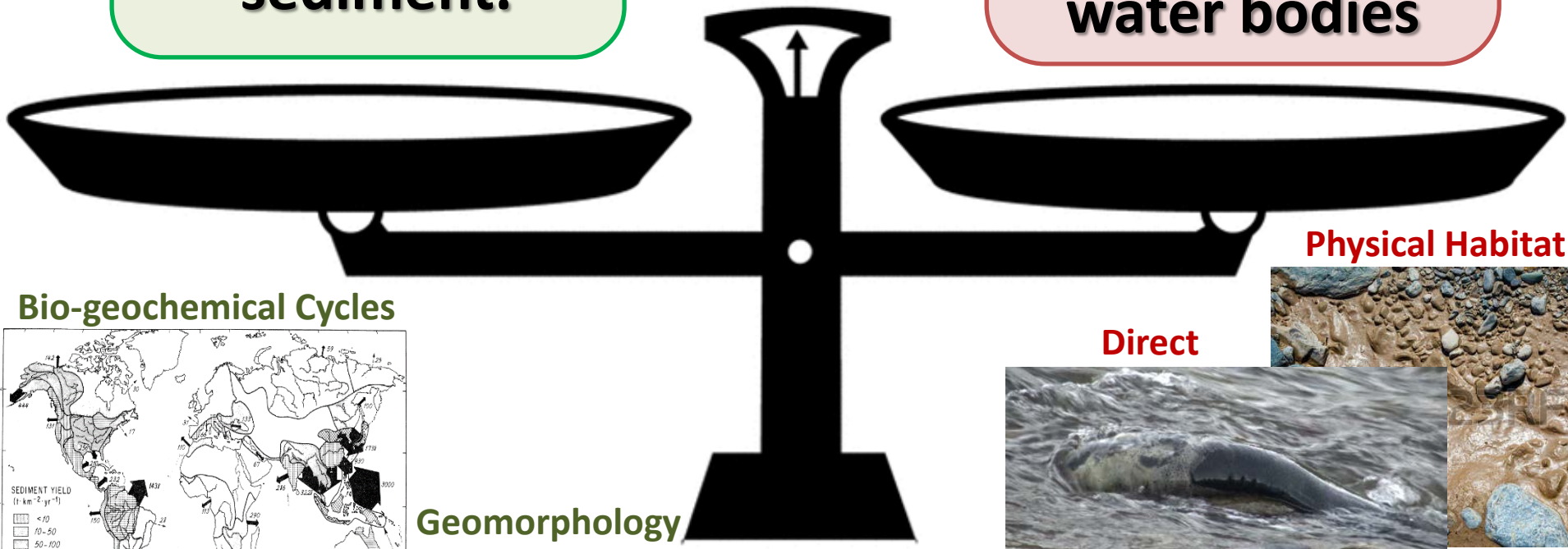
- **Master Variable**
- **Natural Variability** in abundance often spans orders of magnitude within and between systems
- ***Non-Stationary*** (time dependent) dynamics can sabotage ‘snapshot’ based plans
- **Suggestions**

# What is suspended sediment?



**All natural water bodies transport sediment.**

**Sediment is the most prevalent impairment of water bodies**



## Bio-geochemical Cycles




## Geomorphology

Image: A. Gray

## Physical Habitat

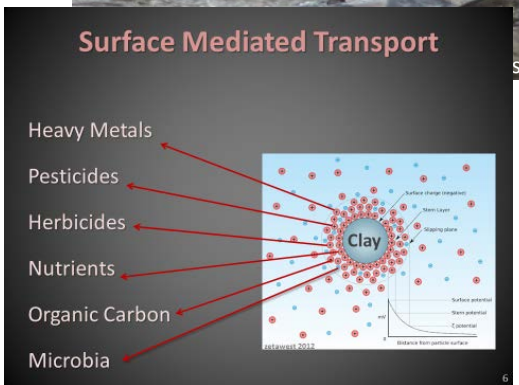


## Direct



shutterstock

## Surface Mediated Transport




1. **Milliman and Meade** (1983)

# Spatially Divergent Demands

## Coastal

- Wetland accretion
  - SLR
- Legacy sediments contaminated[1]

**‘Clean’ Sediment as Resource**


Sacramento-San Joaquin Watershed
*from: CA DFW*

## Interior

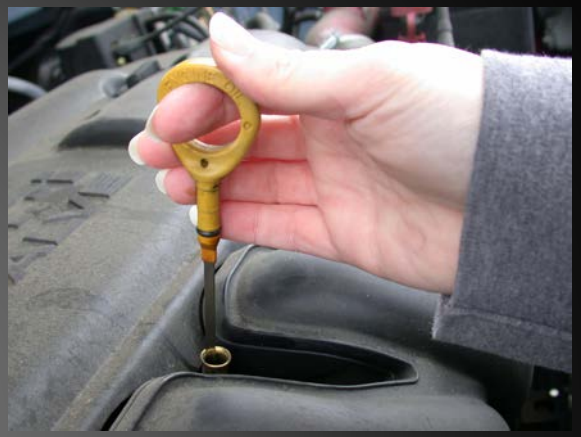
- Source restructuring[2]
  - Damming
  - Agriculture
- Habitat
- Human use

**Sediment as Contaminant**

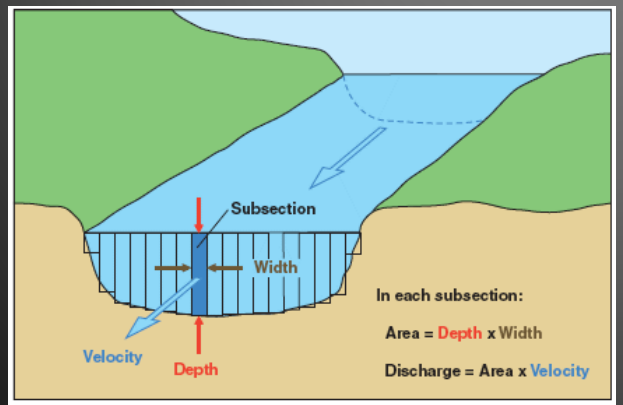
1. Schoelhamer et al. (2007)
2. McKee et al. (2013)

# Fluvial Suspended Sediment Monitoring

- Ambient Characterization

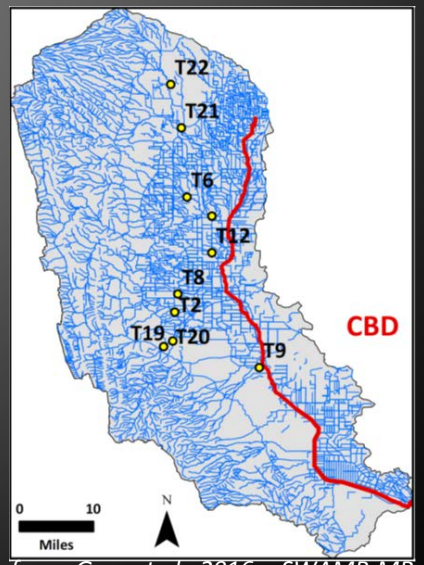


- Dynamical/Flux-Based



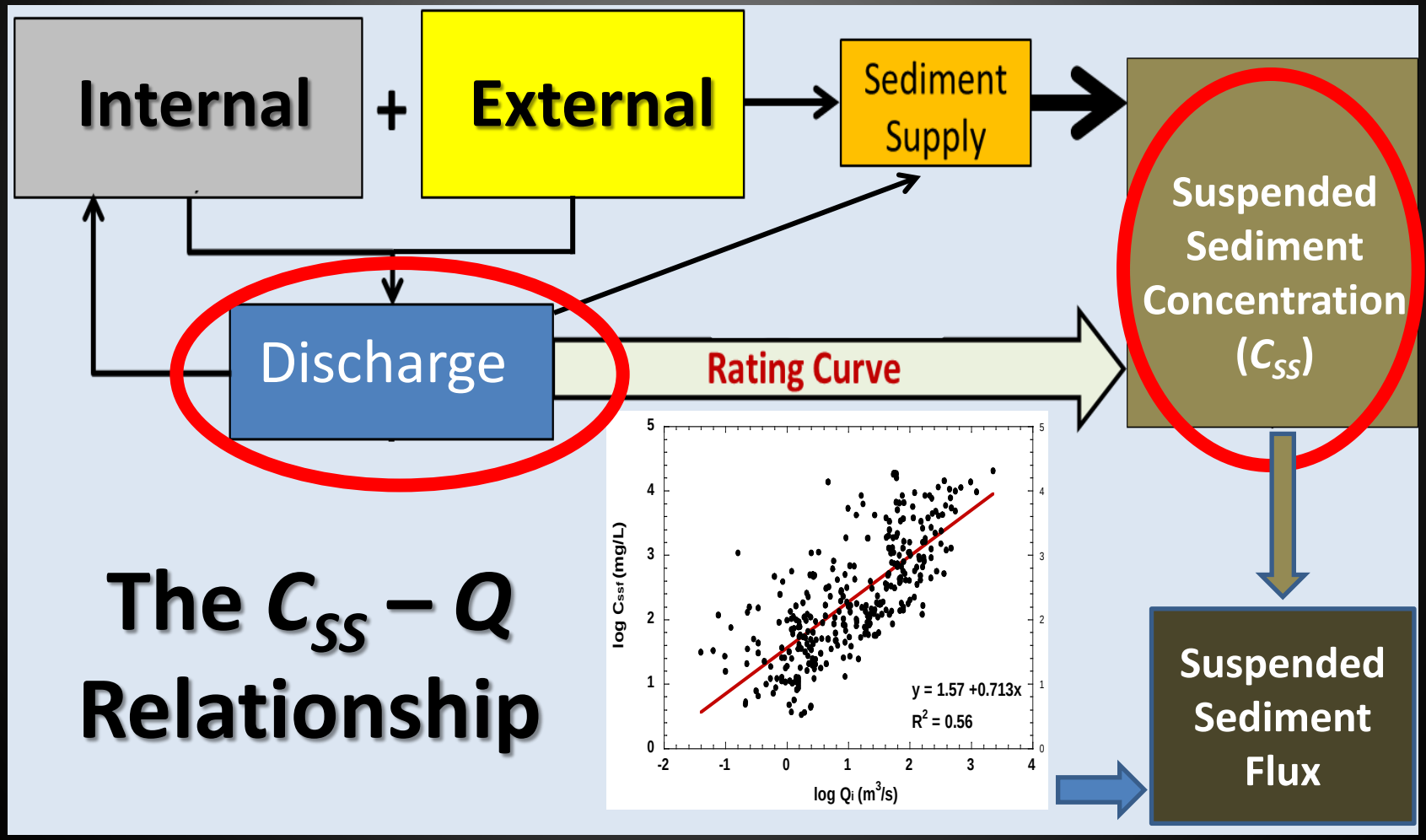

Current-meter discharge measurements are made by determining the discharge in each subsection of a channel cross section and summing the subsection discharges to obtain a total discharge.

*USGS*

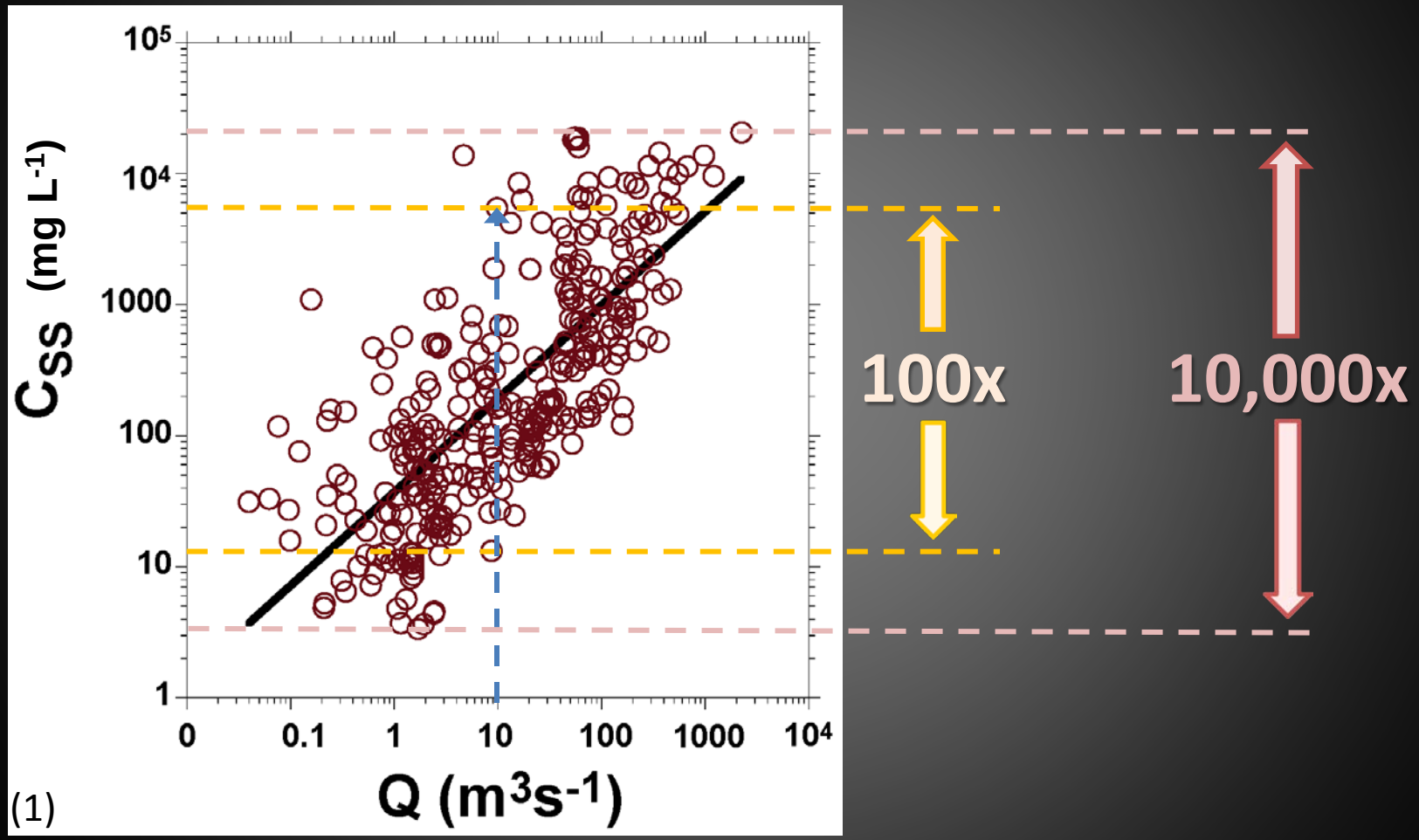



*from: Gray et al., 2016a: SWAMP-MR-RB5-2016-0002*

# Suspended Sediment Dynamics



# High Variability




1. Lower Salinas River fine suspended sediment

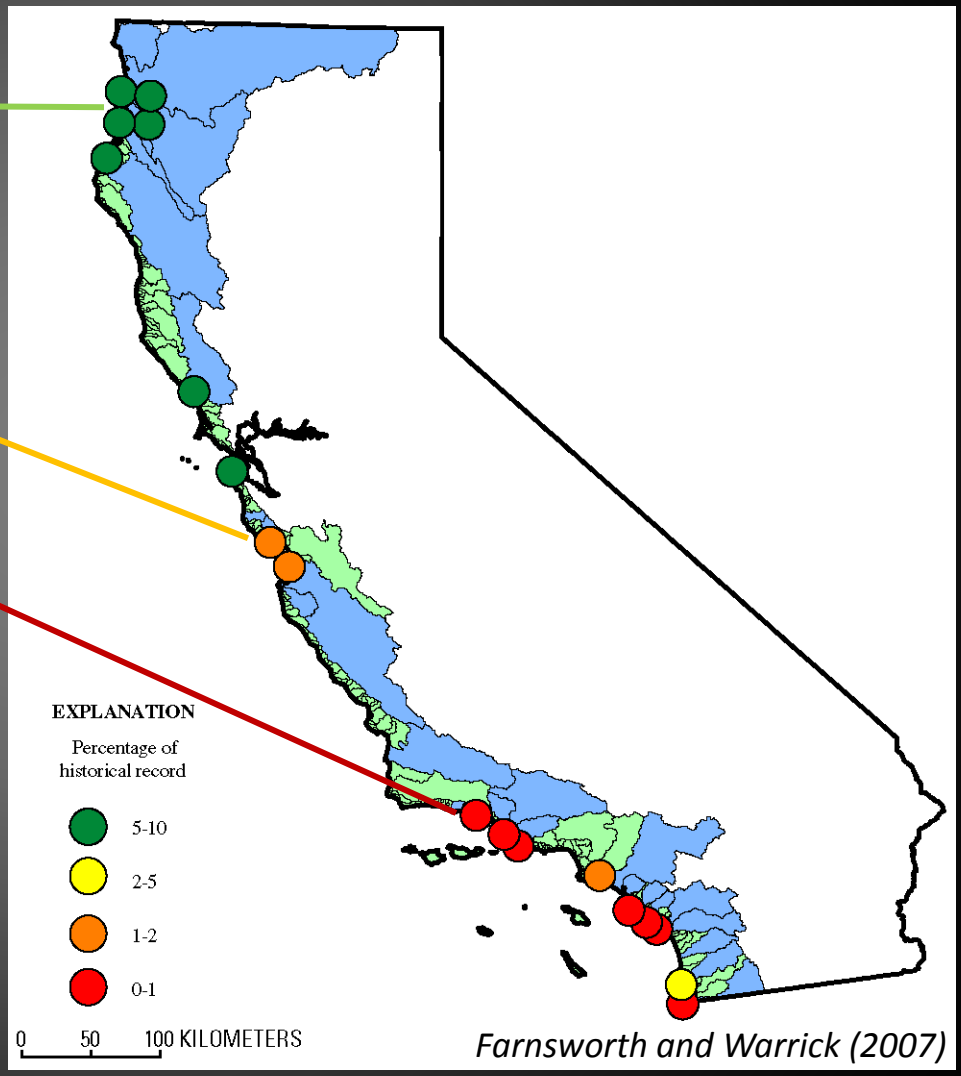
# Episodic Sediment Flux

90% of Sediment flux from n% of hydrologic record

5-10%

1-2%

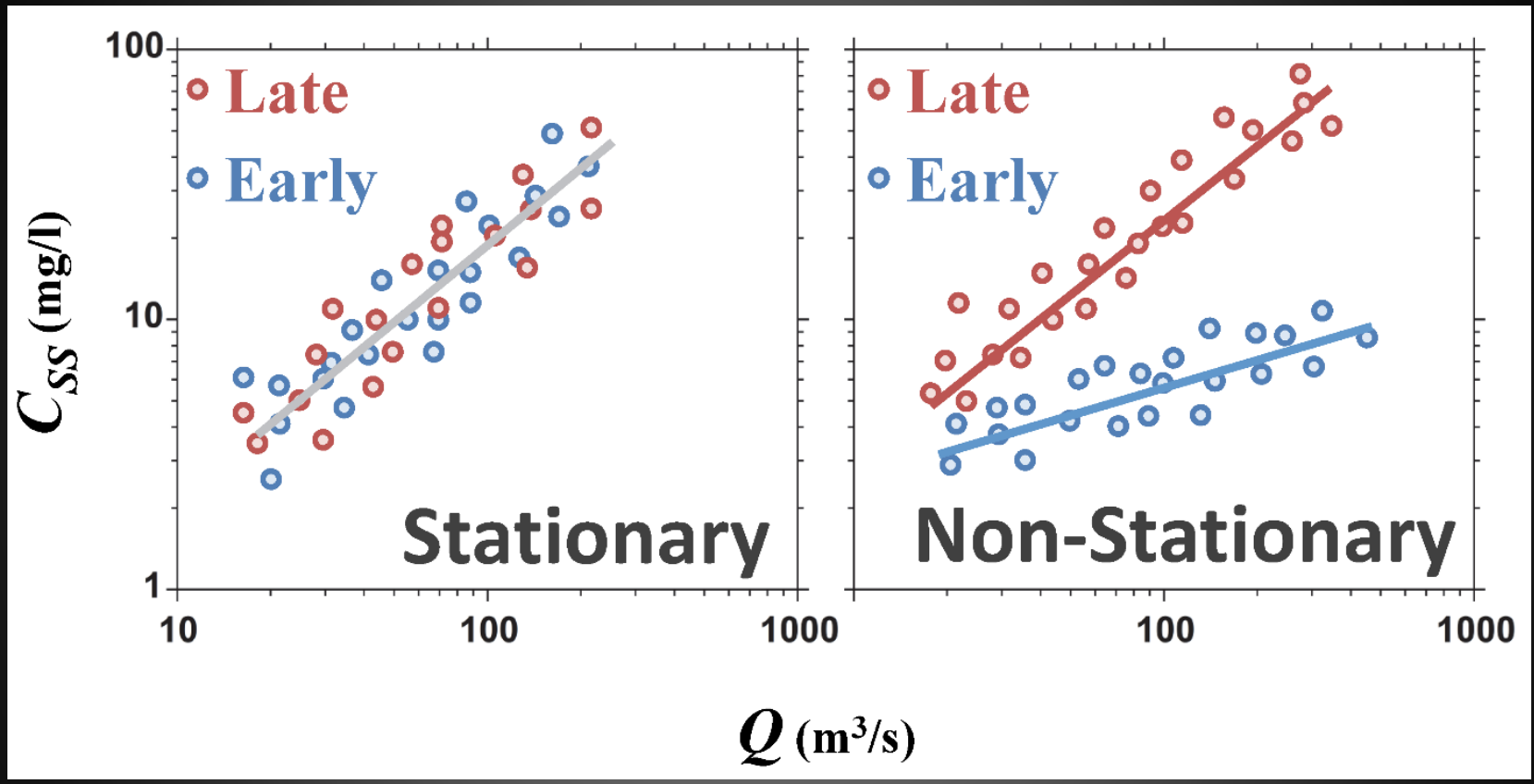
0-1%




*Farnsworth and Warrick (2007)*

Dominated by rare, high magnitude events

# Time Dependent Behavior




**Found across a wide range of temporal scales**

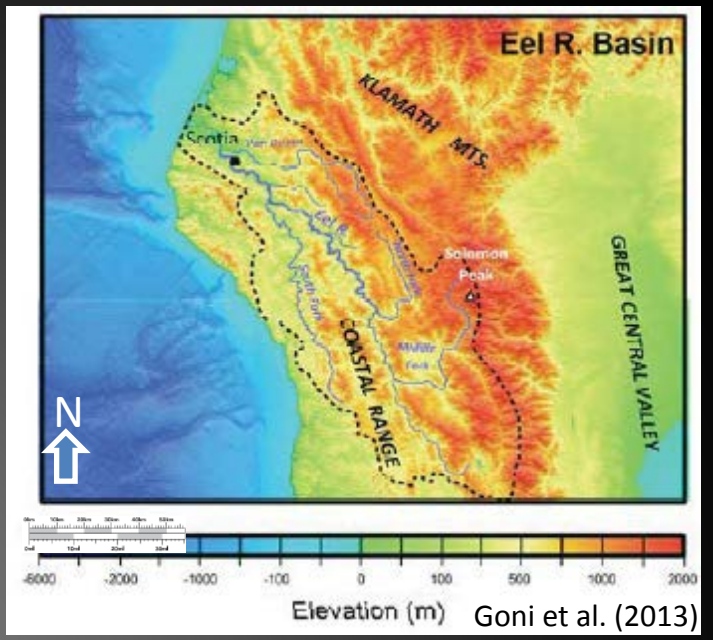
✓ ***Event to Interdecadal***

# Flood Disturbance/ Recovery

## *Eel River Christmas Flood*

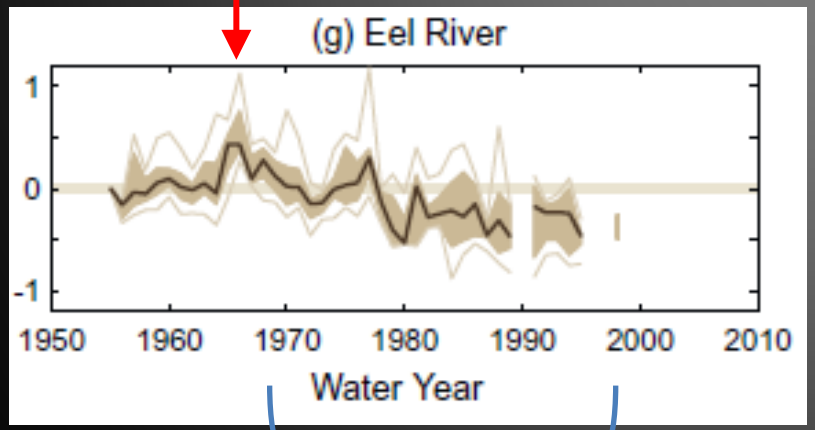
***December, 1964***

***~ 200 year recurrence interval***



Goni et al. (2013)

Supply Augmentation



Warrick et al. (2013)

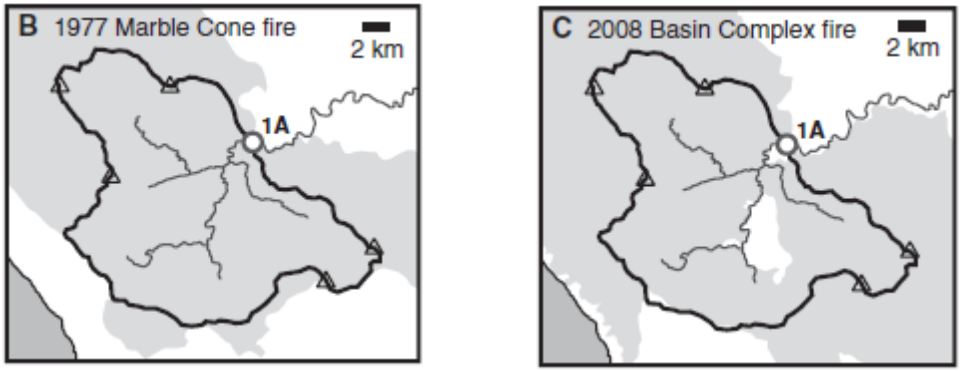
System Rebound

**Decreasing temporal trend in $C_{SS}$-$Q$ relationship at the Interdecadal Scale**

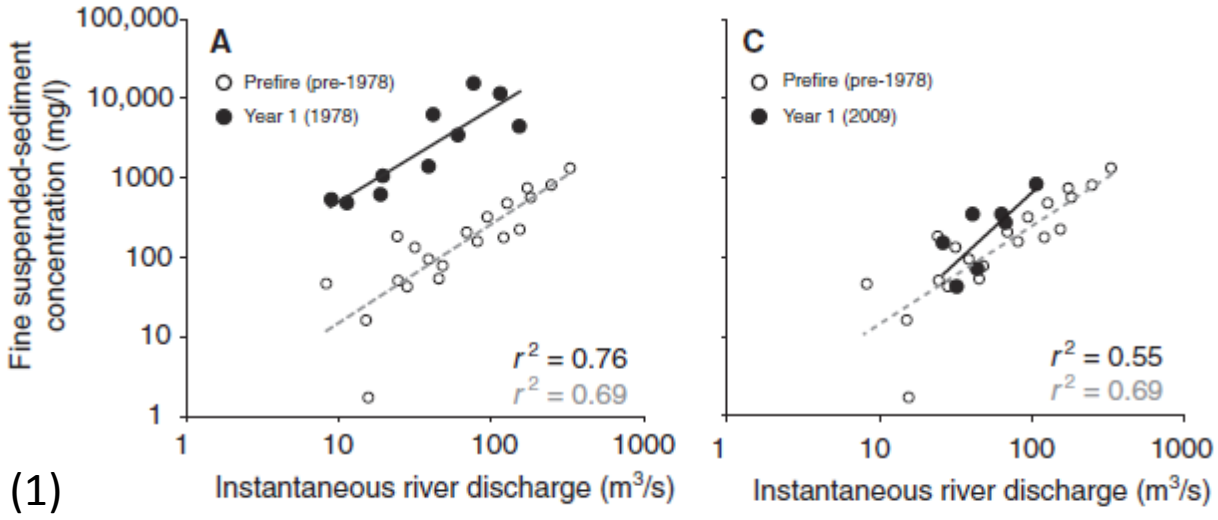
# Wildfire-Storm Event Sequencing

**Arroyo Seco burned completely in**

**1977 & 2008**




*1977 Marble Cone* *2008 Basin Complex*




(1)

## Suspended Sediment Response

Post 1977 100x pre-fire

Post 2008 2x pre-fire

**Event Scale**

**Disturbance**

**Interannual Scale**

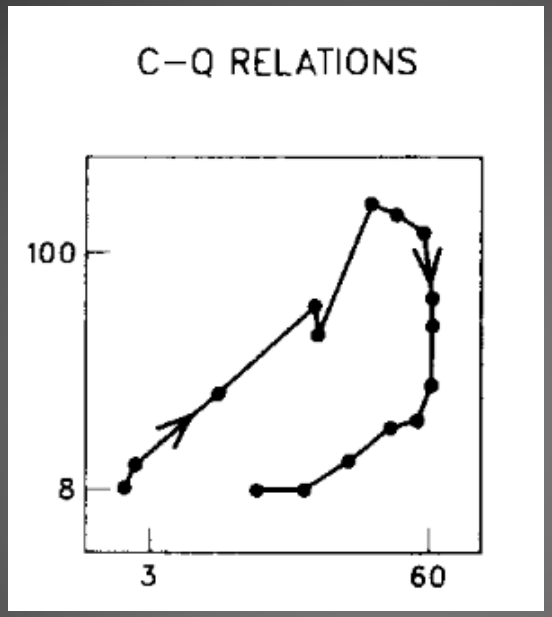
**Supply Recovery**

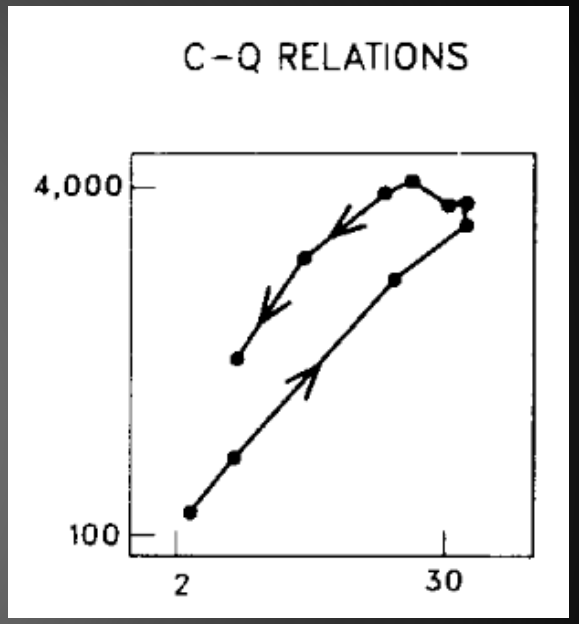
**Conditioned by Rainfall Intensity**

1. Warrick et al. (2012)

# Event Scale Non-Stationarities

## Hysteresis




$C_{SS}$ (mg/L)

$Q$ ($m^3s^{-1}$)

(1)

## Hydrologic Regime

- Baseflow
- Stormflow
- Reservoir Release



1. Williams (1989)

# Hydroclimate & Humans

Event to Interannual

Temporal Scale

Interdecadal

## Loading/Flushing Regimes

Drought/Low Flow

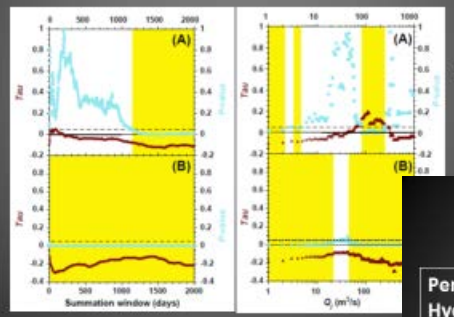
Event magnitude/timing

Fines

Threshold Supply Suppression

Sand

General Supply Suppression



Fines

Supply Maintenance Flushing Flows

Sand

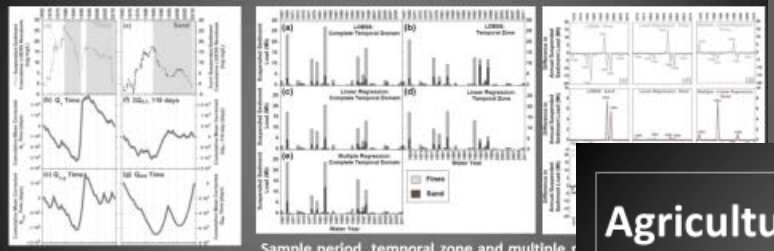
Gray et al. (2014)

Decadal

## Persistent Hydro-Climatic Cycles

Persistent Patterns in Hydrologic Conditions

Sediment flux comparisons



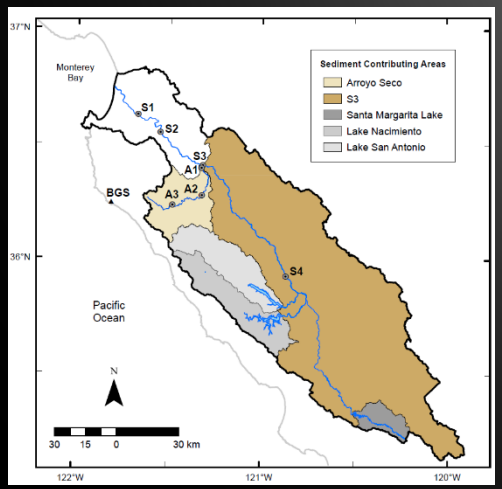
Sample period, temporal zone and multiple hydrologic conditions.

Fine controls are complex – flushing flows dominate.

Sand controls simple and consistent until the mid

Gray et al. (2015a,b)

## Salinas River




## Agriculture

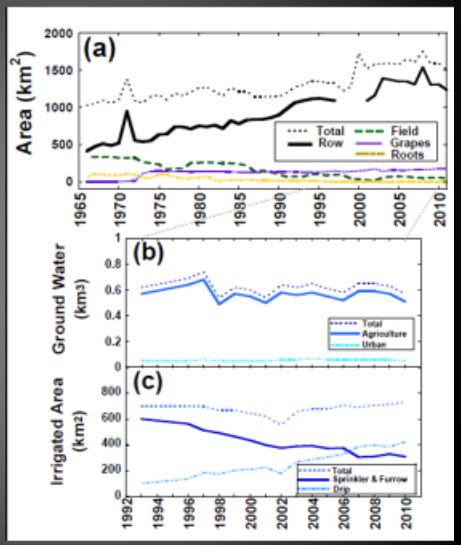
Salinas River Watershed

~50% increase in crop area from 1965-2011.

**Drip irrigation**

- Introduced in 1960s.
- Expanded rapidly from 1990 to present

Gray et al. (2016a)

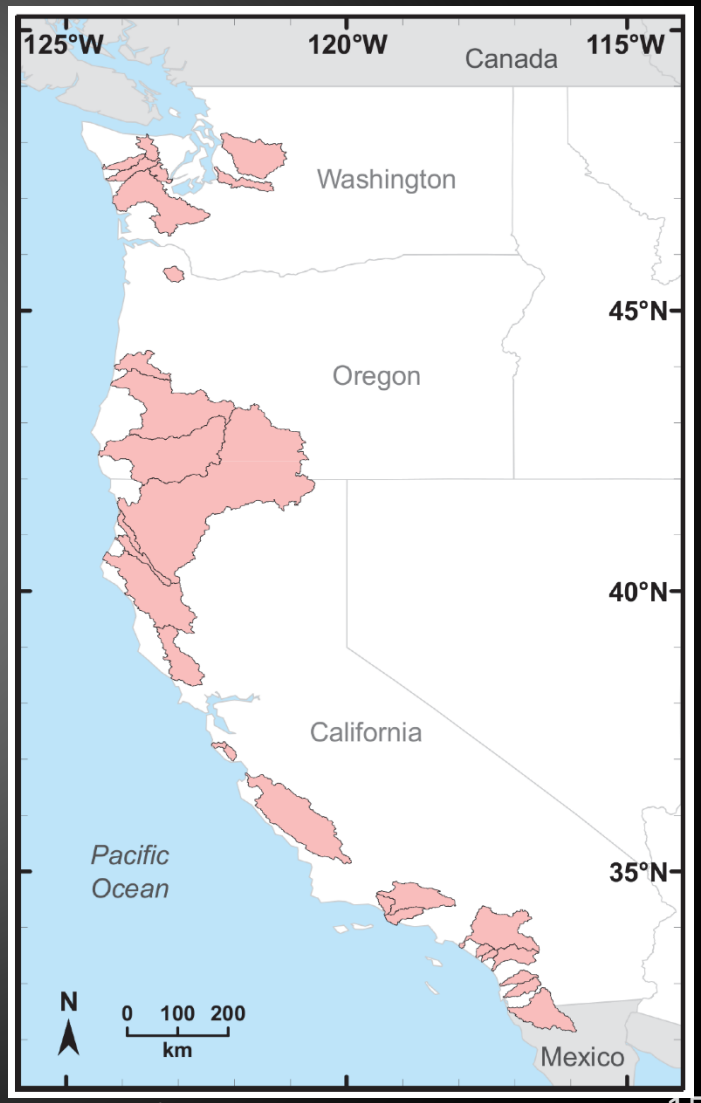


# Variability Rich, Data Poor

Only 23 of 250+ watersheds have 10+ year suspended sediment data sets

- Short duration
- Sporadic, low resolution
- ‘Effective’ flood events missed

Almost no sediment composition/ associated contaminant data




Gray et al., *in prep.*

# Automated $C_{SS}$-$Q$ Sampling

ISCO

Sediment Intake

Acoustic-Doppler Flow Meter

image: A. Gray

Data Logger


image: A. Gray

Turbidity Meter

Pressure Transducer

Fine sediment (D < 63 µm) well mixed, and carry most of contaminant load

# Sediment Associated Contaminant Dynamics

- *Very, very few studies ever conducted*[1]

  Requirements[2]

  - SS dynamics
  - Contaminant analysis

  → LARGE samples (10 – $10^3$ liters)

  → High volume processing for SS (i.e. large or continuous flow centrifuges)

*Scientific Methods Inc.*

- We know very little about the transport dynamics of sediment associated contaminants through fluvial systems.

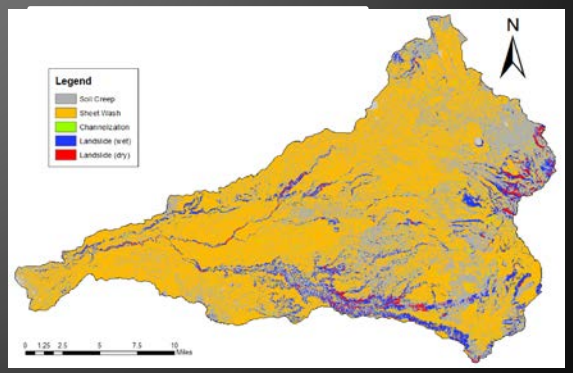
1. LeBlanc et al. (2004) 2. Conn et al. (2016)

# Sediment Provenance[1]

| Characterize Source/SS | | Mixing Model |
|---|---|---|
| • Trace elements[2] | → | Geology |
| • Contaminants[3] | → | Land use |
| • Fallout Radionuclides[4,5] | → | Erosion/Transport |

Image: USGS


Image: A Gray




from: Henkle et al., 2016, SWAMP-MR-RB5-2016-0003

1. Haddadchi et al. (2013) 2. Collins et al. (1998) 3. LeBlanc et al. (2004) 4. Smith et al. (2012) 5. Olley et al. (2013)

# The Future of Sediment Management Requires Rethinking Sediment Monitoring

## Watershed Based Plans

Beyond reach scale & distributed 'snapshot' requirements

- **Dynamical/Flux-based monitoring**
  - Associated contaminant dynamics
- **Emergent technologies**
  - Remote sensing, high resolution surveys, sediment fingerprinting
- **Explicit consideration of time**


Hatch

# Thank You!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