Role of landuse and BMPs in reducing the effect of extreme magnitude events on sediment and pollutant transport

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EPA RESEARCH FORUM: Extreme Event Impacts on Air Quality and Water Quality with a Changing Global Climate
February 27, 2013

Collaborators

- Daniel Wren
  - USDA-ARS, National Sedimentation Lab
    - Oxford, MS
- Rob Wheatcroft and Kris Richardson (Student)
  - Oregon State U., College of Earth, Ocean, and Atmospheric Sciences
- Francisco Guerrero-Bolaño (Student)
  - Oregon State University, College of Forestry

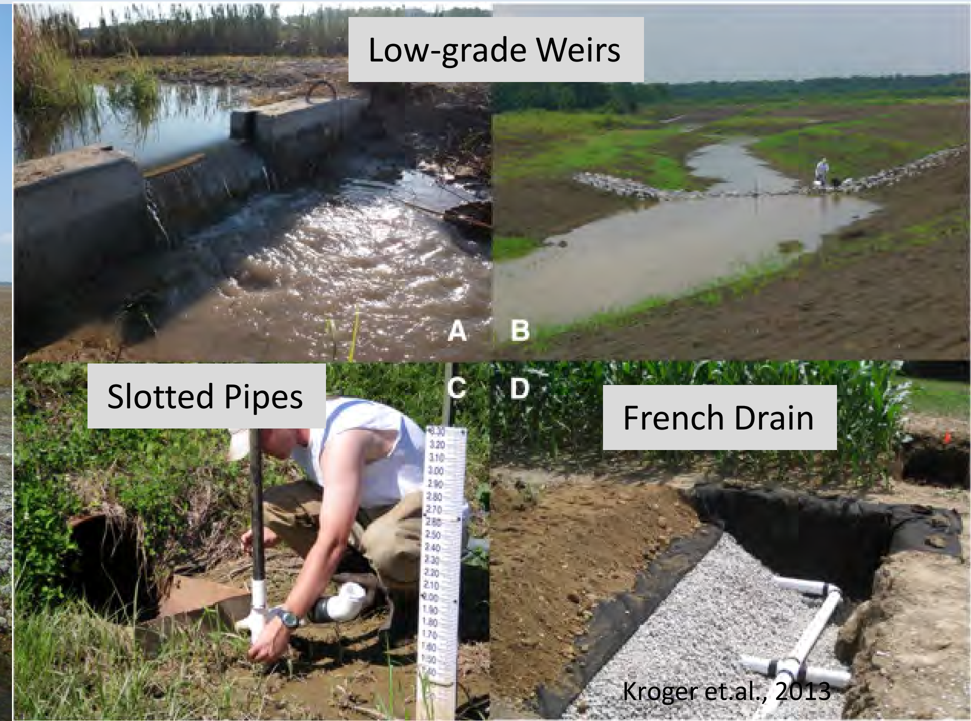
Introduction

- Suspended sediment is a major non-point source pollutant of surface waters
- Best management practices (BMPs) and current landuse decisions may not be sufficient to protect water quality
  - Loss of efficiency at high storm intensities
  - Climate change is expected to increase the magnitude of storm events
- Interactions among BMPs, land management, land use change, and water quality as storm events change in magnitude are unknown

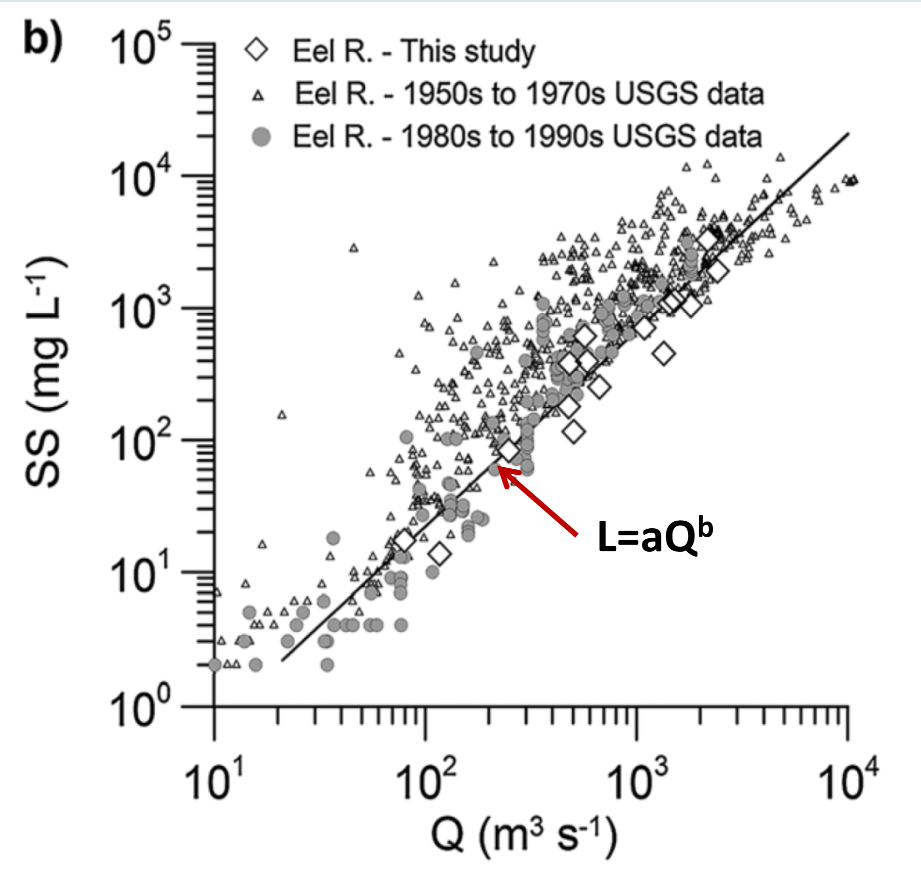

Riparian Zones
Google earth


Filter Strips
http://www.virginiaplaces.org/chesbay/savethebay.html

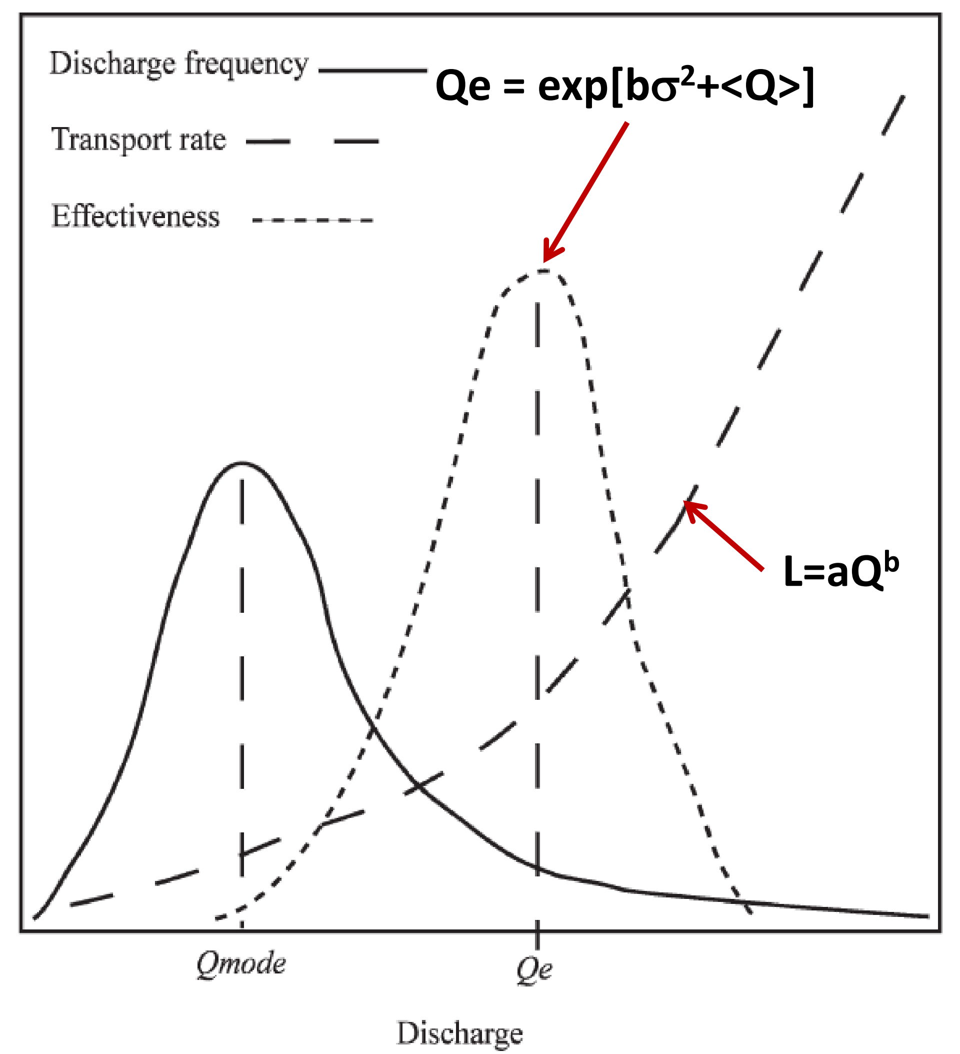

Flashboard Risers
http://blogs.nicholas.duke.edu/nicolecarlozo/a-few-more-memories/


Low-grade Weirs
A
B
Slotted Pipes
C
D
French Drain
Kroger et.al., 2013

Conceptual Model

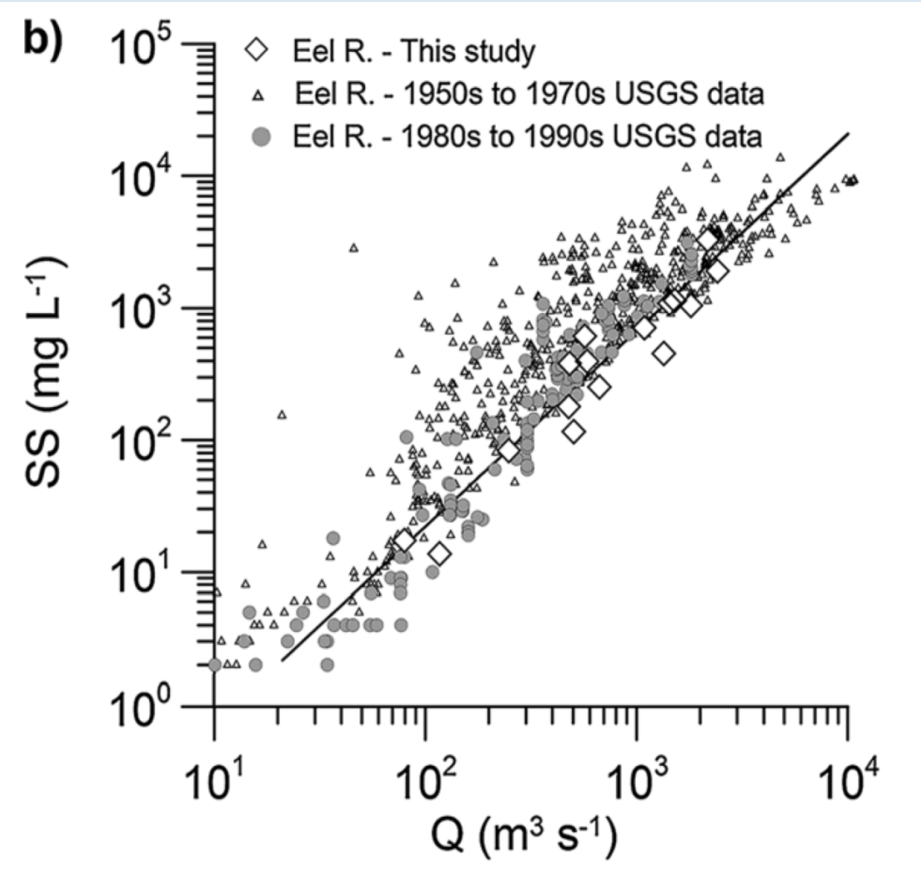


Goni et al., 2013

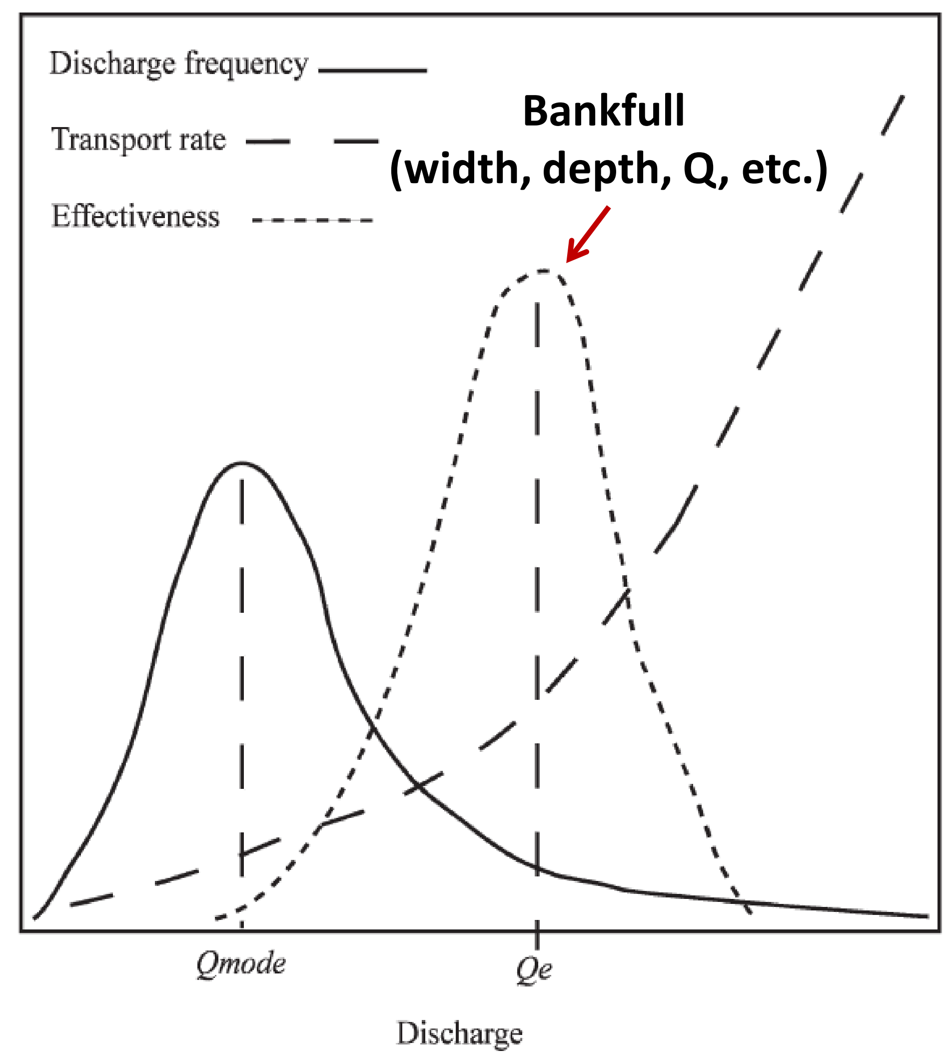


Wheatcroft et al., 2010

Conceptual Model

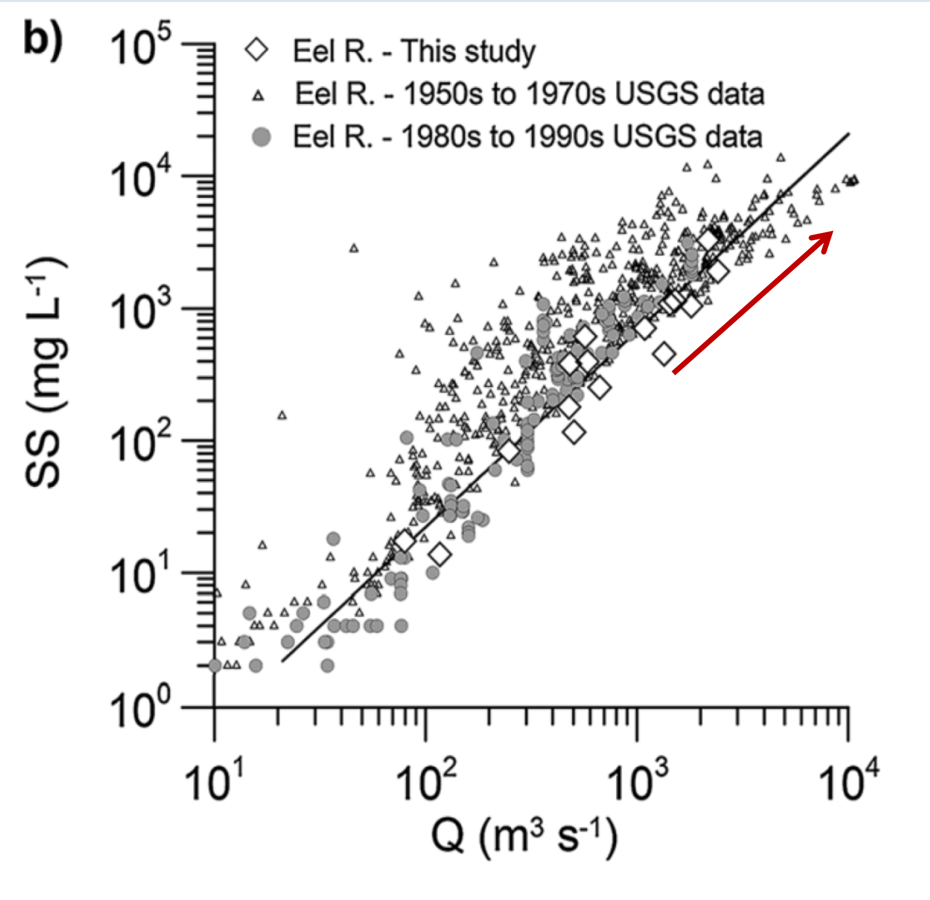


Goni et al., 2013

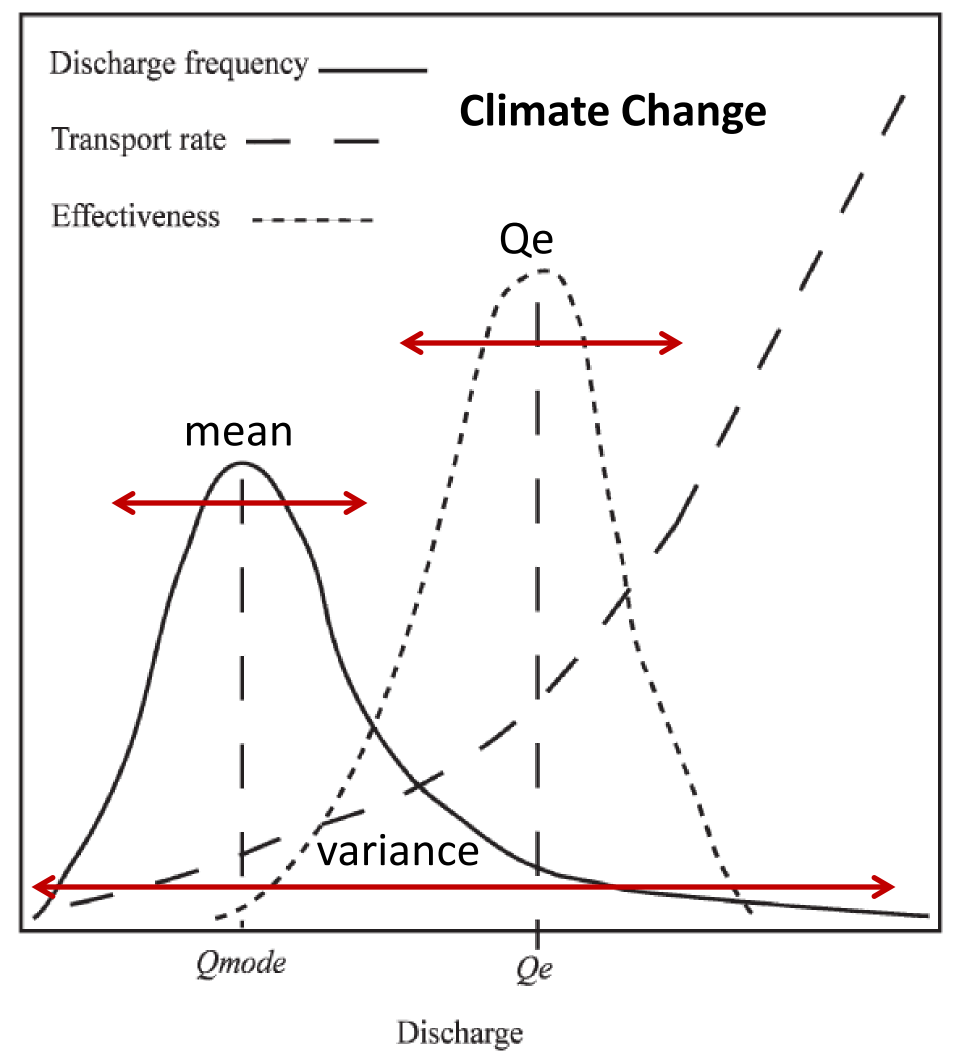


Wheatcroft et al., 2010

Conceptual Model

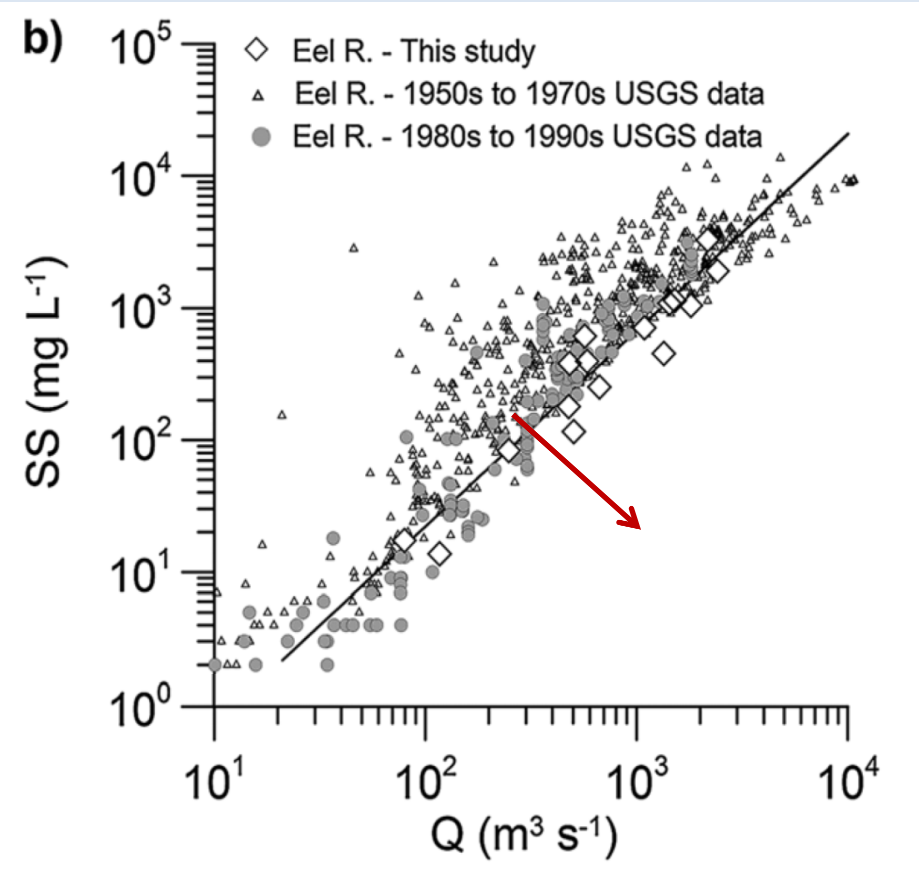


Goni et al., 2013

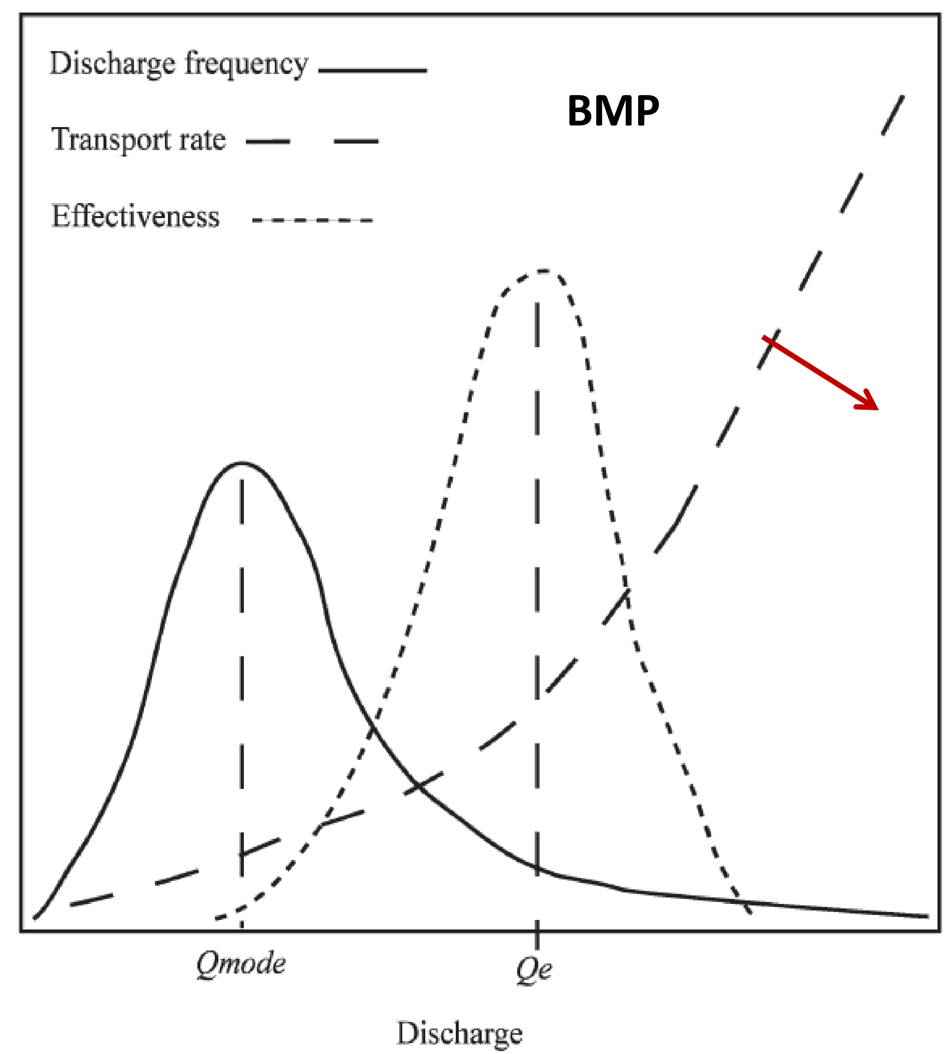


Wheatcroft et al., 2010

Conceptual Model



Goni et al., 2013



Wheatcroft et al., 2010

Hypothesis

- **Central hypothesis:**

The efficiency of BMPs at reducing sediment and pollutant yield will decrease with increasing storm magnitude.

- BMPs typically tested and designed under climate forcing from relatively small events
  - Therefore less effective against large events.

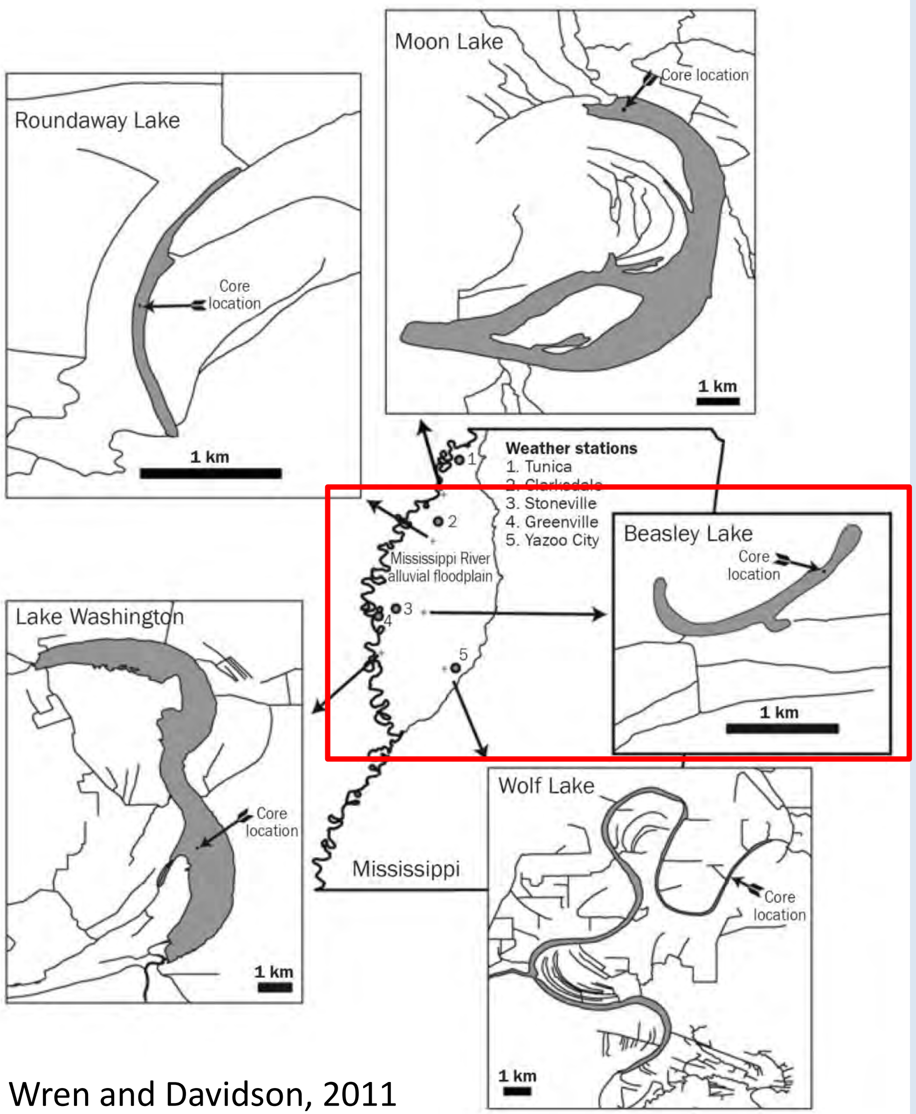
Objectives

- **Objective #1: Fine scale changes**
  – Determine the capacity of BMPs to reduce large event caused delivery of sediment in lakes with small watersheds
- **Objective #2: Large scale changes**
  – Determine the role that BMP development and landuse decisions have had on event associated sedimentation rates in a lake with a large watershed

Objective #1

- Objective #1. Determine the capacity of BMPs to reduce large event caused delivery of sediment in lakes with small watersheds in the Mississippi Alluvial Valley (MAV).

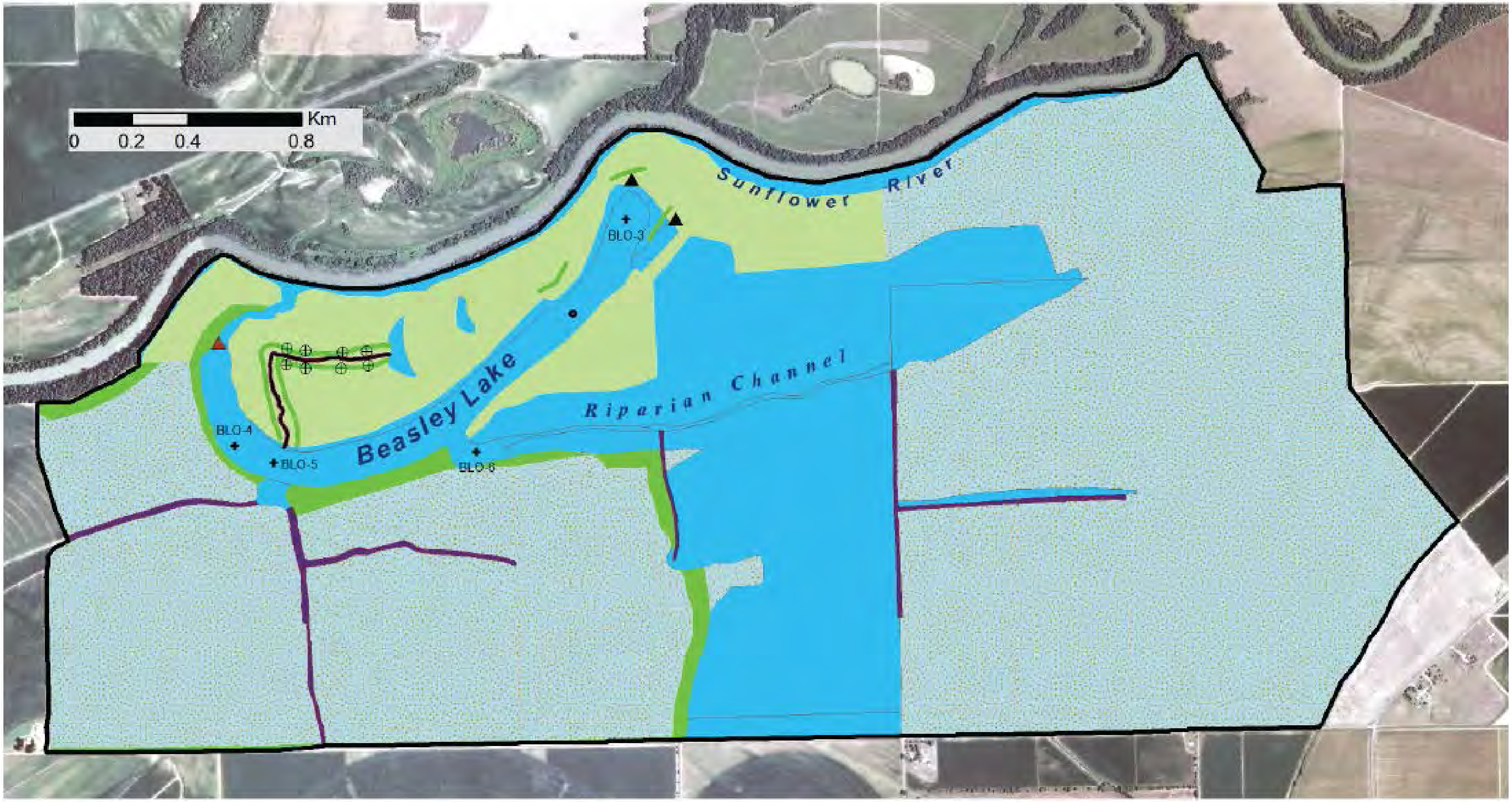
Beasley Lake



Wren and Davidson, 2011

- 9 km^2 watershed
- Agricultural - 67% row crops
- Big Sunflower River watershed
- BMPs – installed in 1994-96
  - Slotted board risers
  - Slotted inlets
  - Fescue and switchgrass buffers
  - Row crop cover was decreased from 79% to 67%

Kinlock Rd
Horne Rd
Beasley Lake
Dement Rd
Abney Rd
Floyd Smith Rd
© 2013 Google
Google earth
Imagery Date: 11/12/2012
33°23'45.56" N 90°40'15.14" W elev 109 ft
Eye alt 16985 ft



Beasley Lake Watershed, Sunflower County, Mississippi

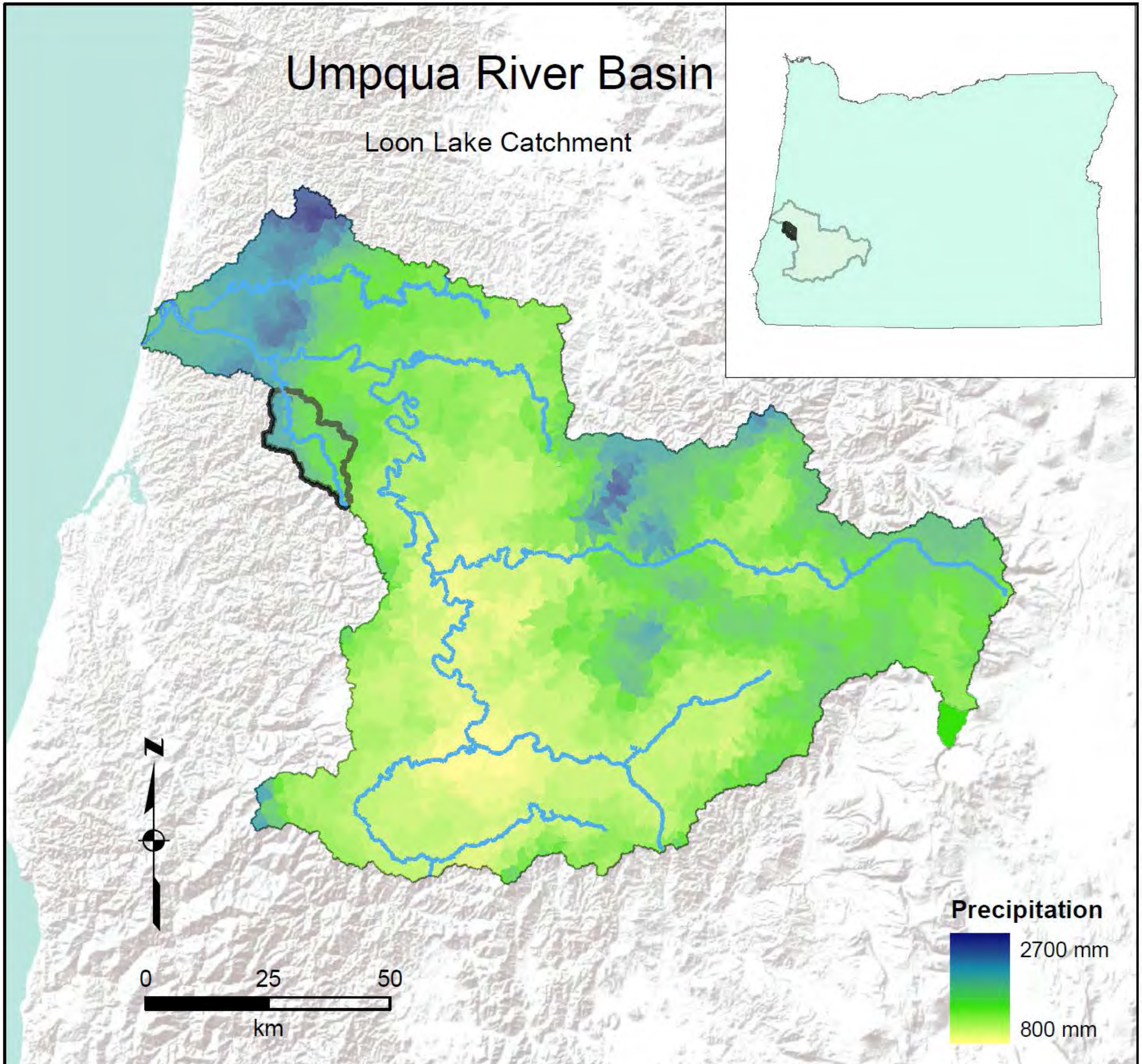
+	2011 cores		Sediment Retention Pond		WATER
•	2008 Core		Crops	▲	Slotted risers
▲	Beasley Lake Outlet		CRP	⊕	Slotted pipes
	Ditches		Buffer		Beasley Lake Watershed

Objective #2

- Objective#2. Determine the role that BMP development and landuse decisions have had on event associated sedimentation rates in a lake with a large watershed.

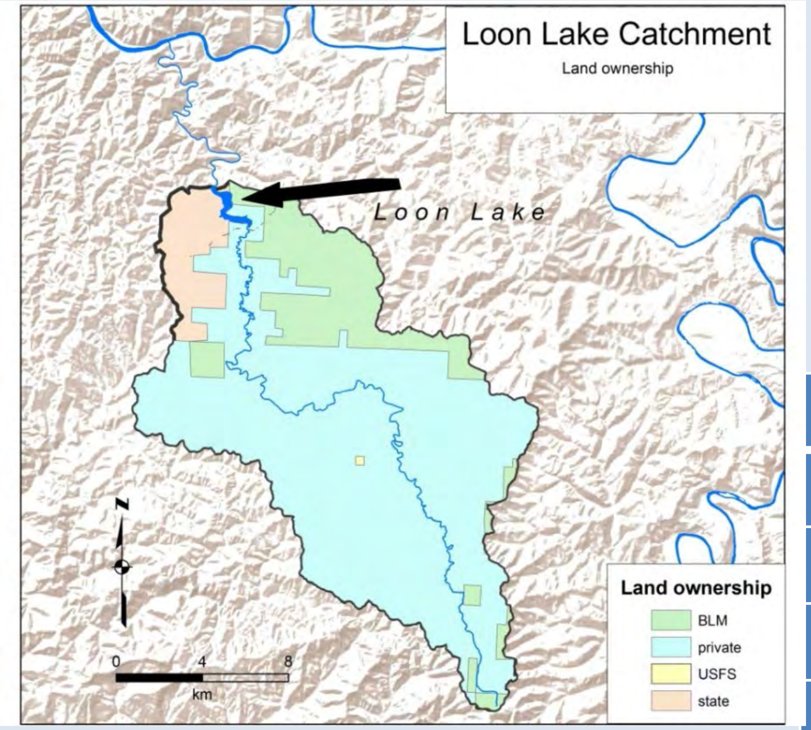
OR Forest Practices Act

- Established 1974-75
- Regulated forest harvesting
  - Riparian management zones
  - Special management of mass wasting prone areas
  - Rules for road building and abandonment
  - Harvesting operations
  - Etc.



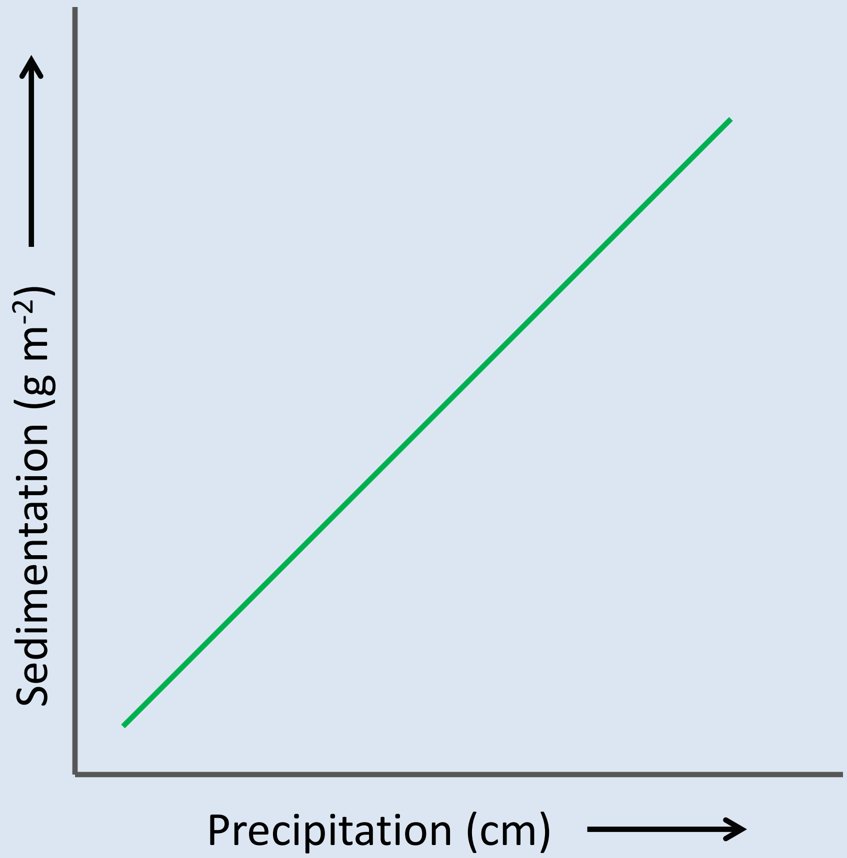
Umpqua River Basin
Loon Lake Catchment
N
0
25
50
km
Precipitation
2700 mm
800 mm

Loon Lake



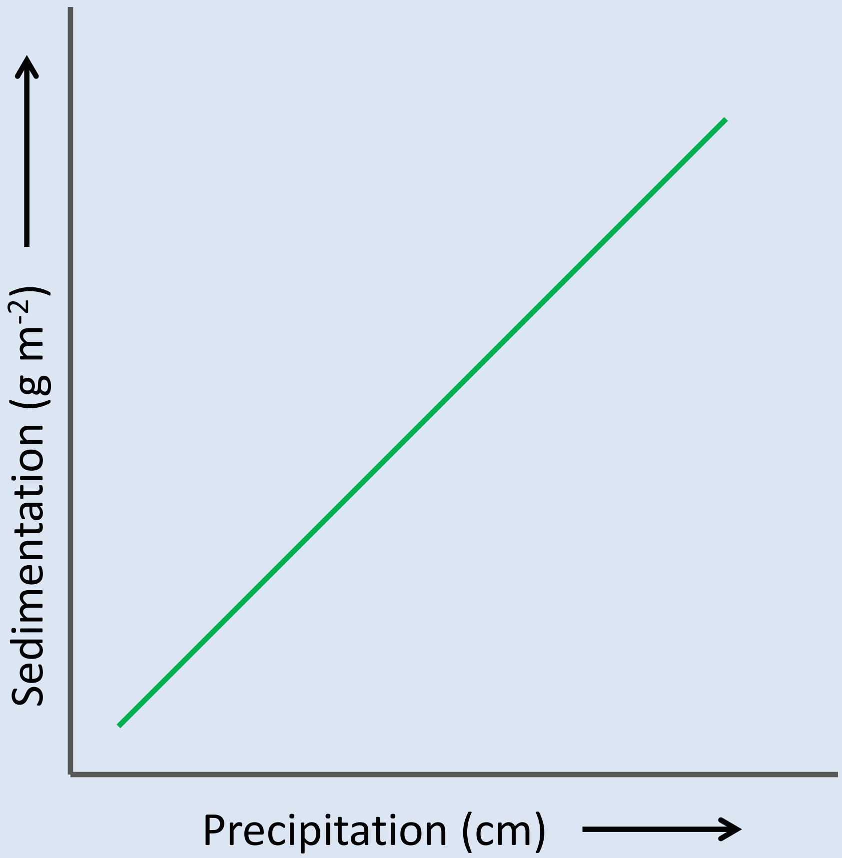
Loon Lake basin area	**230 km^2**
Loon Lake area	1.19 km^2
Lake depth, maximum	30 m
Lake depth, average	16.3 m
Land ownership of catchment	
Private	74.8%
BLM	17.7%
State	7.4%
USFS	0.1%

Approach: “Rating Curve”



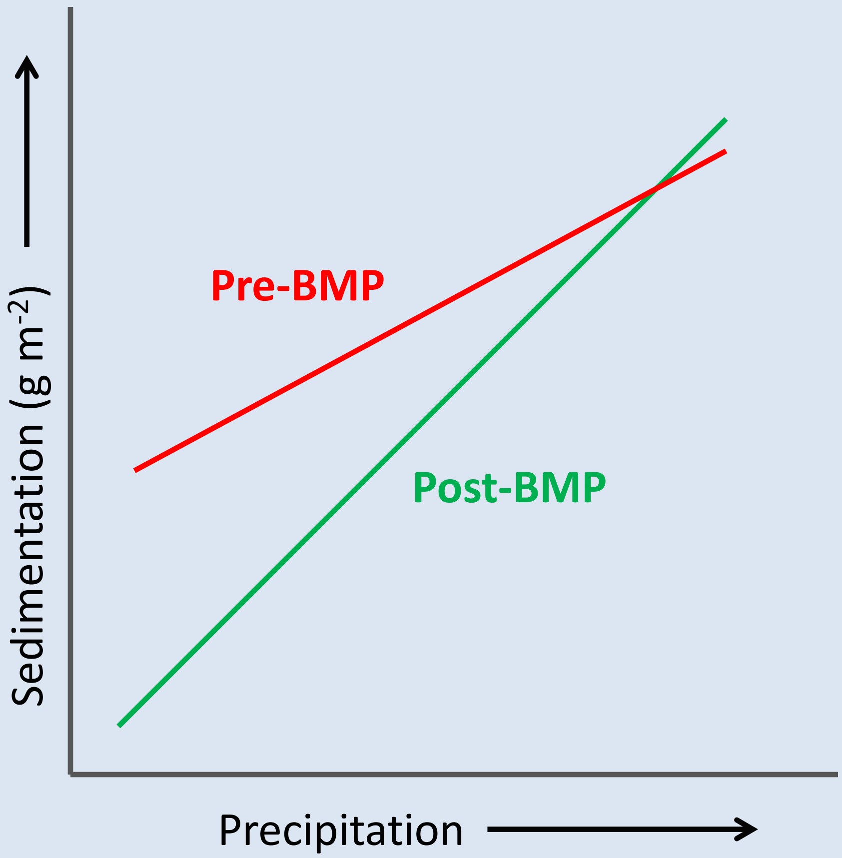
- Sedimentation
  - Cores collected from lakes
  - Mass of sediment per area
- Precipitation
  - Nearby weather stations
  - Interpolated (PRISM)

Approach: “Rating Curve”



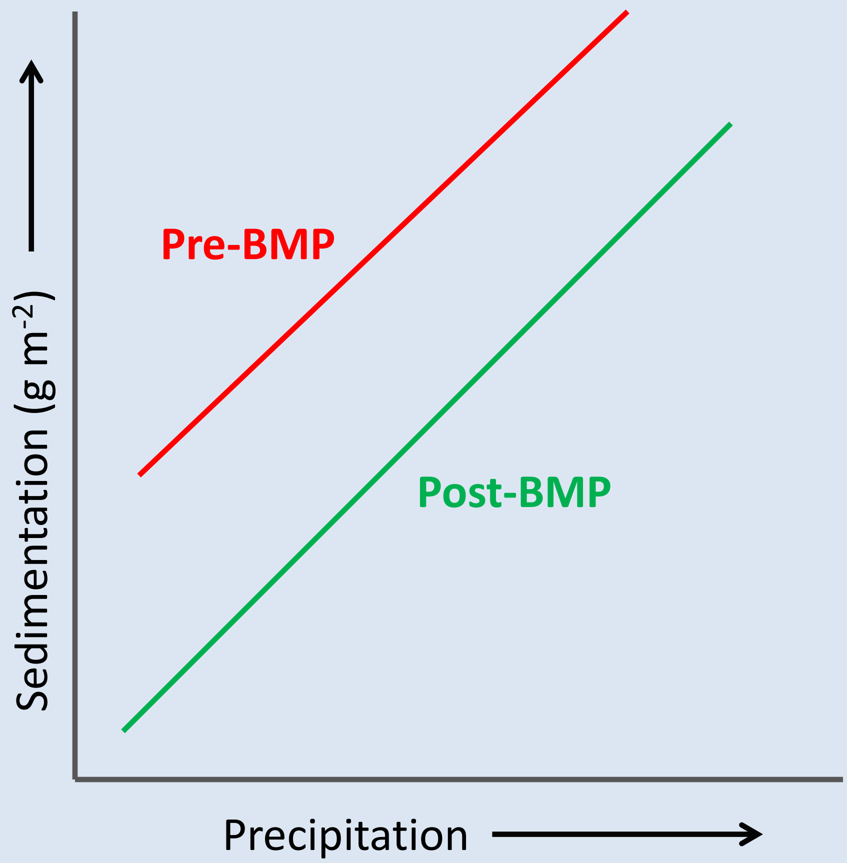
- Units
  - Event (hopefully)
  - Annual (probably)
- Develop Rating curve
  - Pre- and Post-BMP
  - Pre- and Post-FPA

Approach: "Rating Curve"



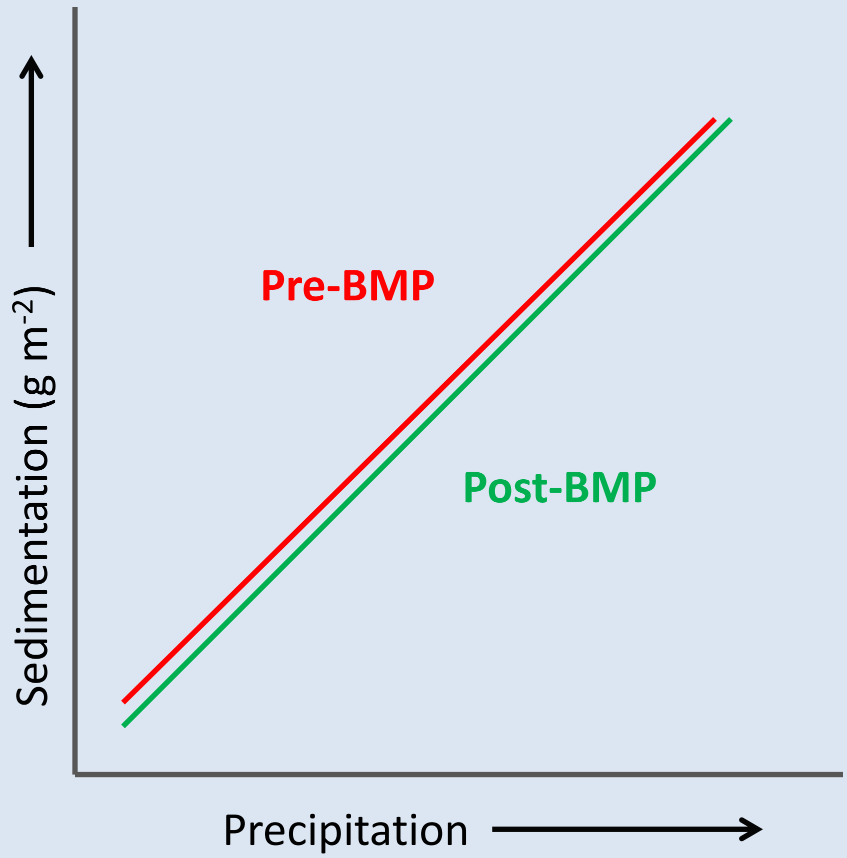
- Support for our Hypothesis
  - BMPs effective at low degrees of forcing
  - Not effective during high magnitude events

Approach: “Rating Curve”



- BMPs effective at all event magnitudes

Approach: “Rating Curve”



- BMPs not effective at reducing sedimentation during any sized event
  - Legacy sediment in steam channels
  - Channel erosion
  - Other…

Approach: Core Chronology

- CAT Scan
- Gamma density
- Magnetic susceptibility

- Line scan (visible)

- $^{210}Pb_{ex}$ and ^{137}Cs
- Total Pb (as a marker of the use of leaded fuel)

Approach: Event Discrimination

- CAT Scan
- Particle Size Distribution
  – Events should appear as “couplets” of layers with a fine layer over a coarse layer (as long as the source has coarse and fine particles)
- Organic Geochemistry
  – Elemental - C, N, S, and P
  – Stoichiometry - C:N:P:S
  – Stable isotopes - $\delta^{13}C$ and $\delta^{15}N$
  – CuO oxidation products (lignin, cutin, non-vascular plant products, etc.)

Approach: Watershed Characterization

- Climate
  - Nearby weather stations
  - PRISM data (Monthly: 1895-Present)
    - Parameter-elevation Regressions on Independent Slopes Model
- Landuse
  - Historical timber harvesting
    - Watershed data 1971-present
    - County level data Pre-1971
  - Road building
  - BMPs and FPA
- Disturbance
  - Fire (1930s-present)

Approach: Effects of CC

- Rating Curve (Pre- and Post-BMP/FPA)
  - With landuse, harvesting rates, road building, etc.
- Historical Distribution of Forcing
  - With and without BMP/FPA
- Predicted Climate
  - Downscaled GCM data
    - CMIP3
    - Three different climate scenarios
      - SRES A2 (higher emissions path)
      - SRES A1B (middle emissions path)
      - SRES B1 (lower emissions path).

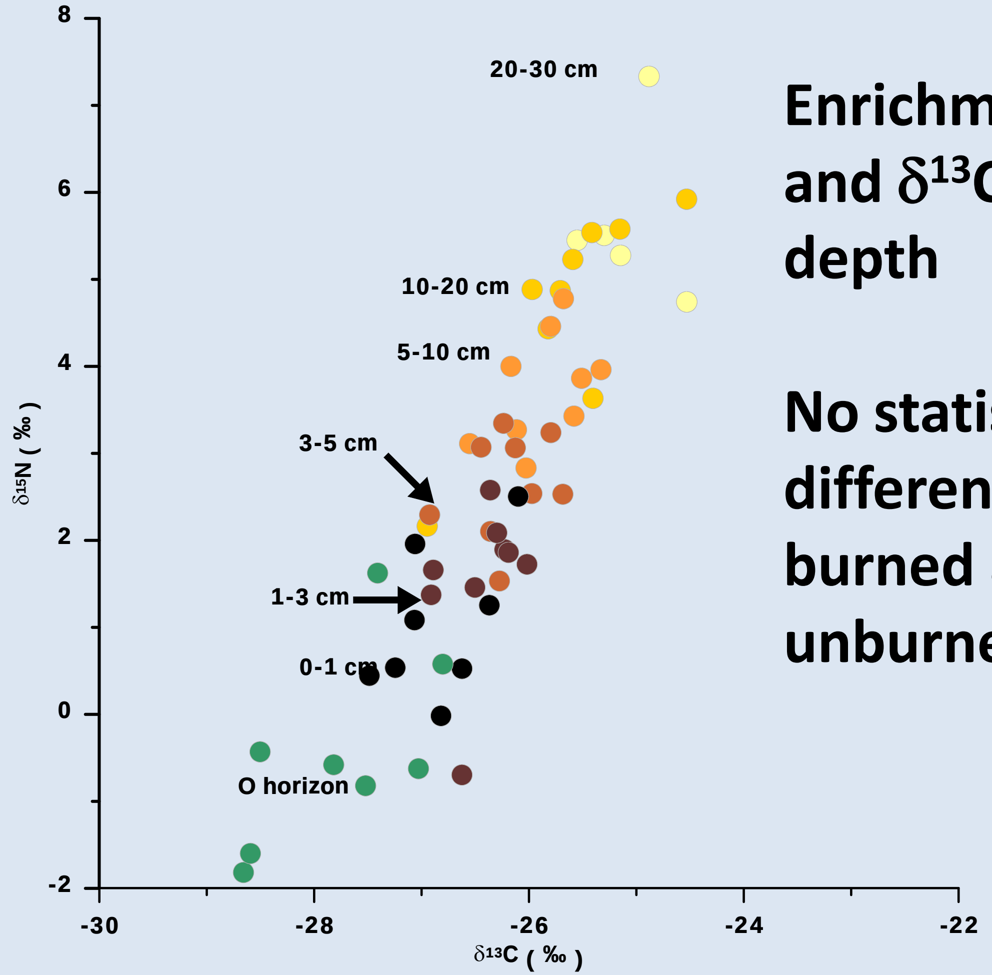
Approach: Mobilization and Transport

- Do mobilization and transport of material change as a result of BMPs, event magnitude, landuse (e.g. road building, forest harvesting, crop harvesting), disturbance (e.g. fire, drought), etc. ?
  - Elemental - C, N, S, and P
  - Stoichiometry - C:N:P:S
  - Stable isotopes - $\delta^{13}C$ and $\delta^{15}N$
  - CuO oxidation products (lignin, cutin, non-vascular plant products, etc.)

  - End-members
    - Soils – hillslope, near channel, road ditches, etc.
    - Sediments – toes of landslides, in-channel sediment, etc.

Stable isotopic signature of Soil Organic Matter in a recently burned chaparral watershed in C. CA

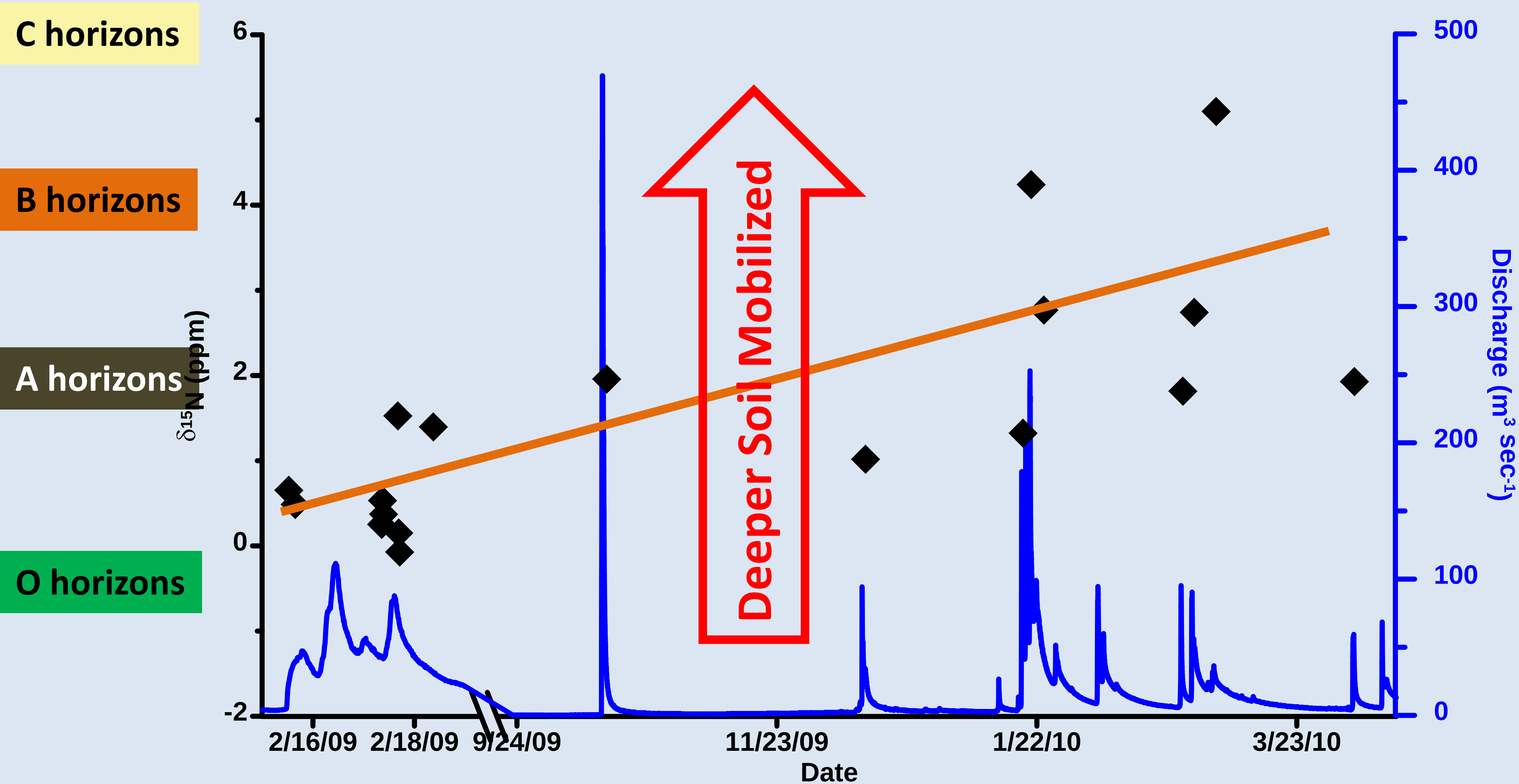
Soils sampled post-fire (11/2008) from burned and unburned locations



Enrichment of $\delta^{15}N$ and $\delta^{13}C$ with depth

No statistical difference between burned and unburned areas

Post-fire $\delta^{15}N$ composition of Total POM



Multiple Linear Regression

Total $\delta^{15}N$ = f(cumulative Q since fire) $p<0.001$ $R^2=0.528$

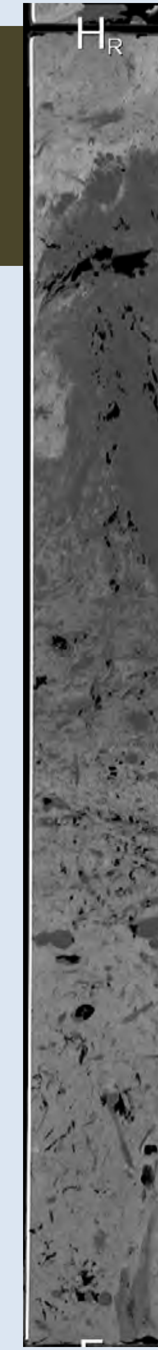
Status: Beasley Lake Core

- Water Depth: 168 cm
- Coring Device: Specialty Devices Vibecore
- Length: 169 cm
- Diameter: 4"

- 169-338 samples (1-0.5cm sub-sampling interval)

Status: Beasley Lake - CAT Scan

- Completed (last week)
  - OSU Vet School
- Show many features that will help interpret the core
  - Flood layers?
  - Mixing?



Status: Beasley Lake

- ± Month
  - Gamma density, magnetic susceptibility, line scanning, sub-sampling
- End of Spring
  - Total C, N, and S
- End of Summer
  - Stable and Radiogenic Isotopes
  - Particle Size
  - Total Pb
- End of Fall
  - CuO oxidation products
- Fall/Winter
  - End-member Sampling

Status: Loon Lake Core

- Specific plan for coring:
  - April 2013: Reconnaissance cruise by small boat to conduct depth sounding and extract surface sediment sample cores with a small gravity corer
  - August 2013: Extract surface and long cores from deepest basin (30m). Operations will be conducted from a 3mX3m coring barge with winch and generator capabilities.
- Long core options:
  - UWITECH percussion piston corer – 2 m drives up to ~20 m total (preferred)
  - Kasten corer - ~2-1/2 m depth only (still enough to capture at least the last 200 years)
- Surface core options:
  - If not turbid, diving crew with small piston corer
  - If not with divers, a slow Bothner gravity corer

Status: Loon Lake

- End of Summer
  - CAT scan, Gamma density, magnetic susceptibility, line scanning, sub-sampling
  - Total C, N, and S
  - End-member sampling
- End of Fall
  - Stable and Radiogenic Isotopes
  - Particle Size
  - Total Pb
- End of Winter/Spring 2014
  - CuO oxidation products
- Fall 2013 – Spring 2015
  - Storm sampling Umpqua River or Coast Range Rivers

Questions

Source: U.S. Geological Survey, 1978. View looking north.

[redacted]

Approach: Event Discrimination

- OM in flood layers = terrestrial (allochthonous)
  - Low C and N
  - High C:N
  - And depleted $\delta^{13}C$
  - High lignin, lower non-vascular plant products
- OM in nonevent layers = aquatic (autochthonous)
  - High C and N
  - Low C:N
  - And enriched $\delta^{13}C$
  - Low lignin, higher non-vascular plant products

Approach: Extrapolation to Larger Area (Loon Lake)

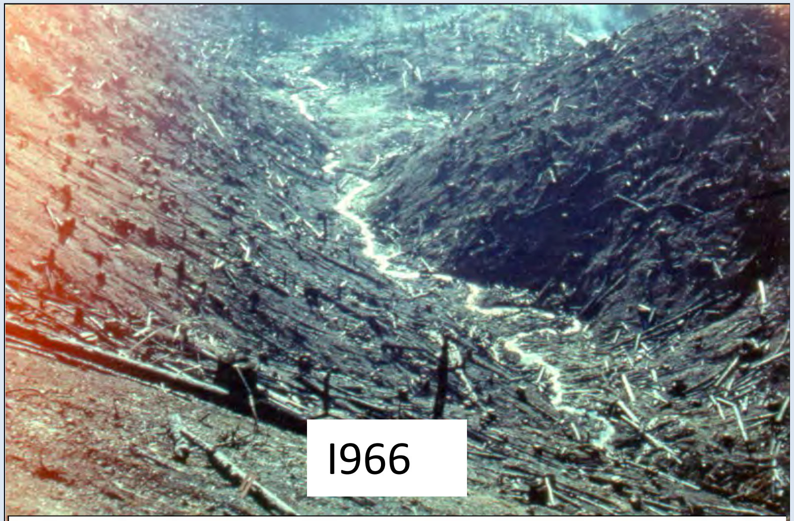
- Sediment and Carbon
  - Relate to TSS and POC in nearby Coast Range Rivers (Alsea, Trask, others)
    - Sample and Data archive (2007-2011)
  - Relate to Sedimentation in Estuary (and on Shelf)
- Nitrogen and Phosphorus
  - Relate to TN and TP in nearby Coast Range Rivers (Alsea, Trask, others)
    - OR DEQ and USGS data
    - Sample and data archive (2007-2011)
    - Additional samples during large events

Connection to Other Work

- Alsea Watershed Study
  - Historical and Contemporary Practices
- Trask River Watershed Study
  - Contemporary Practices
- Land-Estuary-Ocean Connections

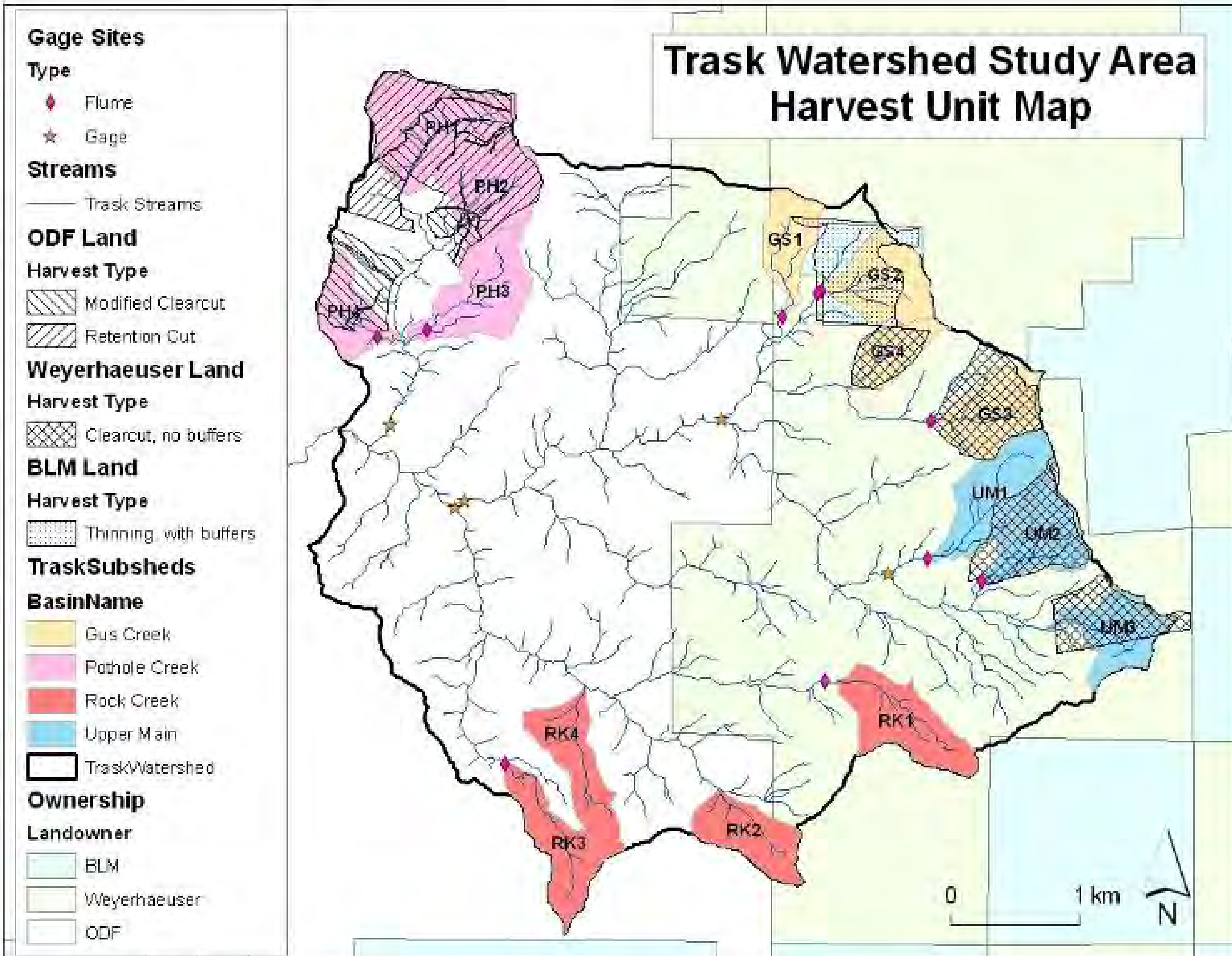
Alsea Watershed Revisited – Assessing Contemporary Management Impacts

- 1966 - large increase in sediment and temp. and decrease in DO conc. without buffer and slope protection
- 2009 – minimal exposure of bare mineral soil, RMA left on fish streams and roads managed – no large changes in WQ?



Trask River Watershed Study

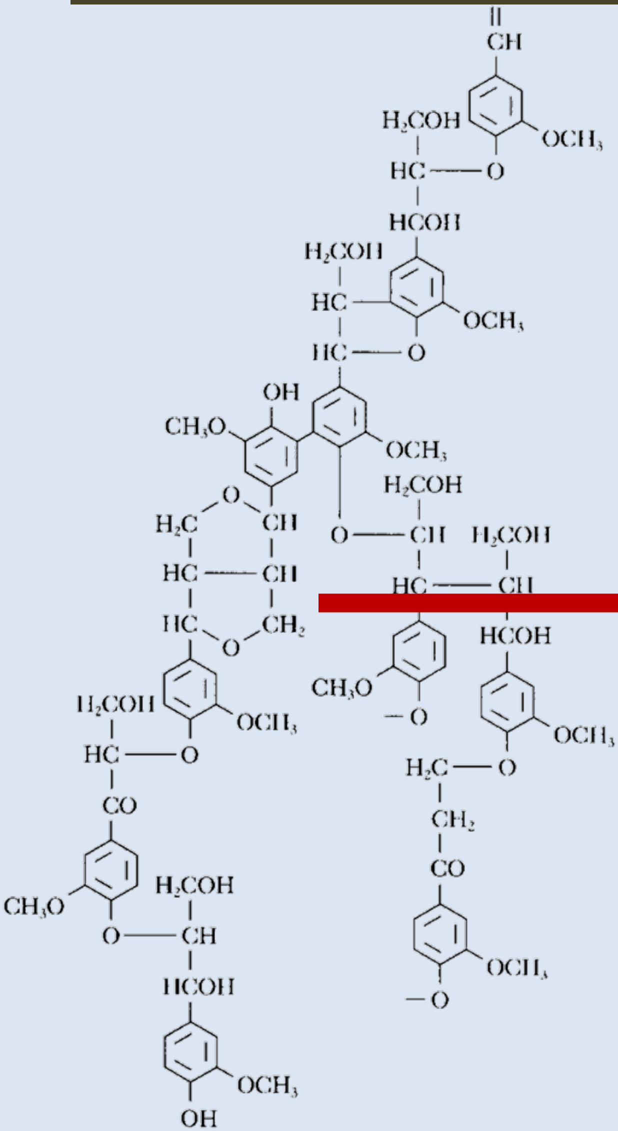
Dr. Sherri Johnson, *PNW Research, USFS*
Dr. Bob Bilby, *Weyerhaeuser Company*
Liz Dent, *Oregon Dept of Forestry*
Maryanne Reiter, *Weyerhaeuser Company*
Dr. Judy Li, *OSU Fisheries and Wildlife*
Dr. Jason Dunham, *USGS FRESC*
Dr. Michael Adams, *USGS FRESC*
Dr. Joan Hagar, *USGS FRESC*
Dr. Arne Skaugset, *OSU College of Forestry*
Doug Bateman, *OSU College of Forestry*
Linda Ashkenas, *OSU Fisheries and Wildlife*
Nate Chelgren, *USGS FRESC*
Bill Gerth, *OSU Fisheries and Wildlife*
Janel Sobota, *OSU Fisheries and Wildlife*
Amy Simmons, *OSU College of Forestry*
Alex Irving, *OSU College of Forestry*
Dr. Jeremy Groom, *Oregon Dept of Forestry*
Brooke Penaluna, *OSU Fisheries and Wildlife*
Dr. Ivan Arismendi, *OSU Fisheries and Wildlife*

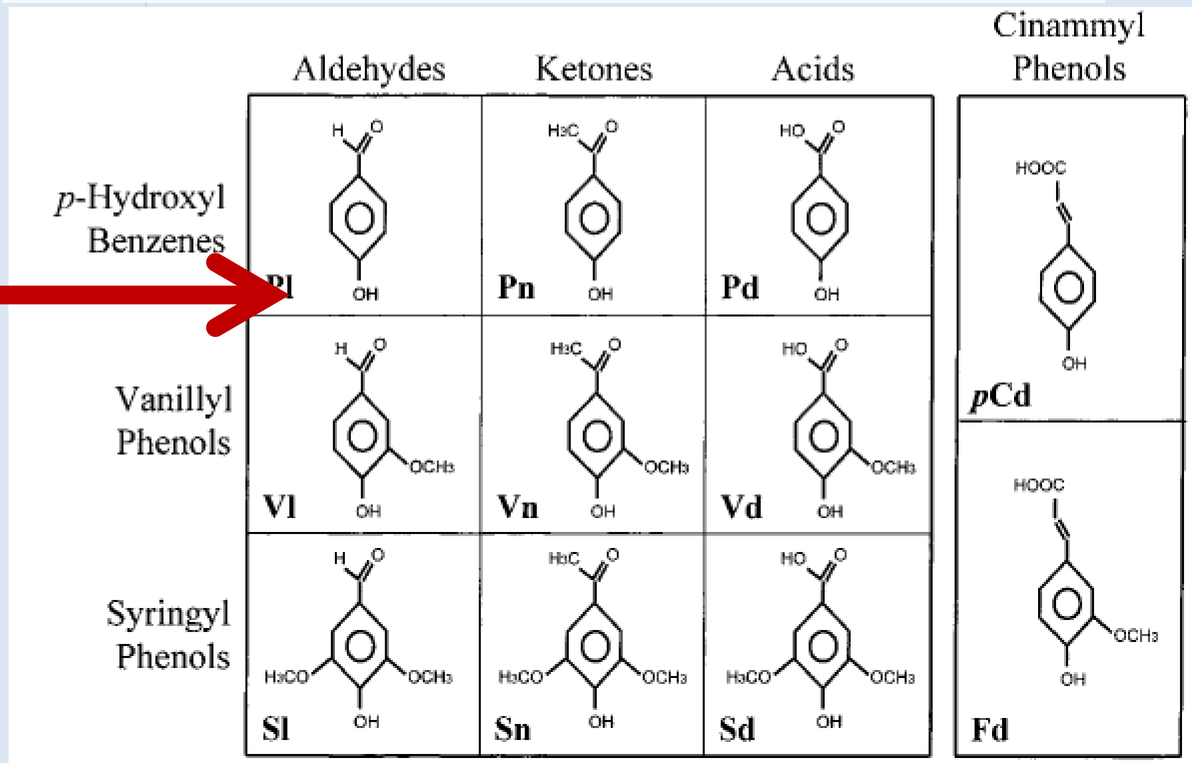

Trask Watershed Study Area
Harvest Unit Map
Gage Sites
Type
Flume
Gage
Streams
Trask Streams
ODF Land
Harvest Type
Modified Clearcut
Retention Cut
Weyerhaeuser Land
Harvest Type
Clearcut, no buffers
BLM Land
Harvest Type
Thinning, with buffers
TraskSubsheds
BasinName
Gus Creek
Pothole Creek
Rock Creek
Upper Main
TraskWatershed
Ownership
Landowner
BLM
Weyerhaeuser
ODF
PH1
PH2
PH3
PH4
GS1
GS2
GS3
GS4
UM1
UM2
UM3
RK1
RK2
RK3
RK4
0
1 km
N

Approach

Method:
CuO oxide oxidation

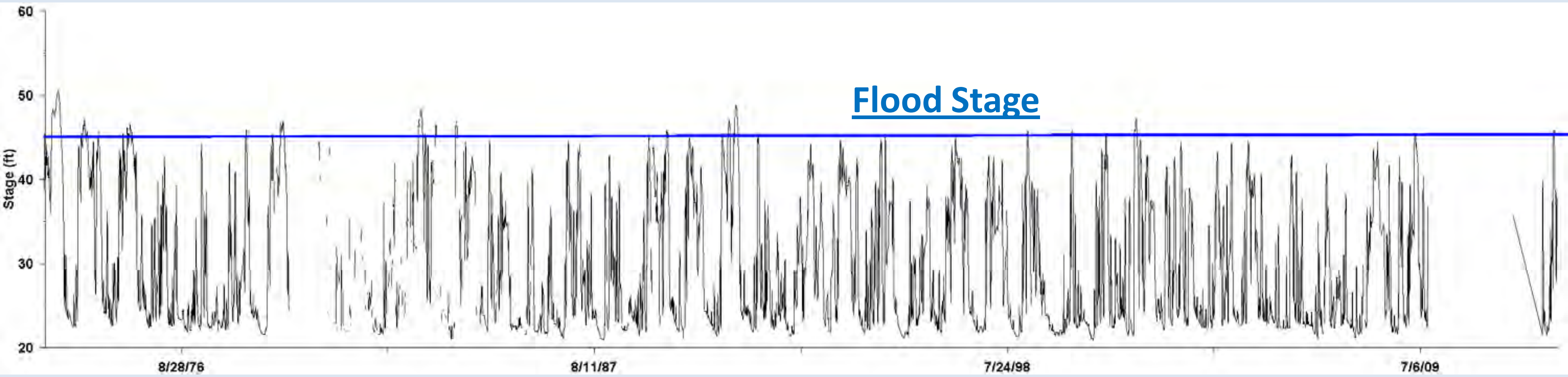
COP determinations made with GC/MS after hydrolysis of OM





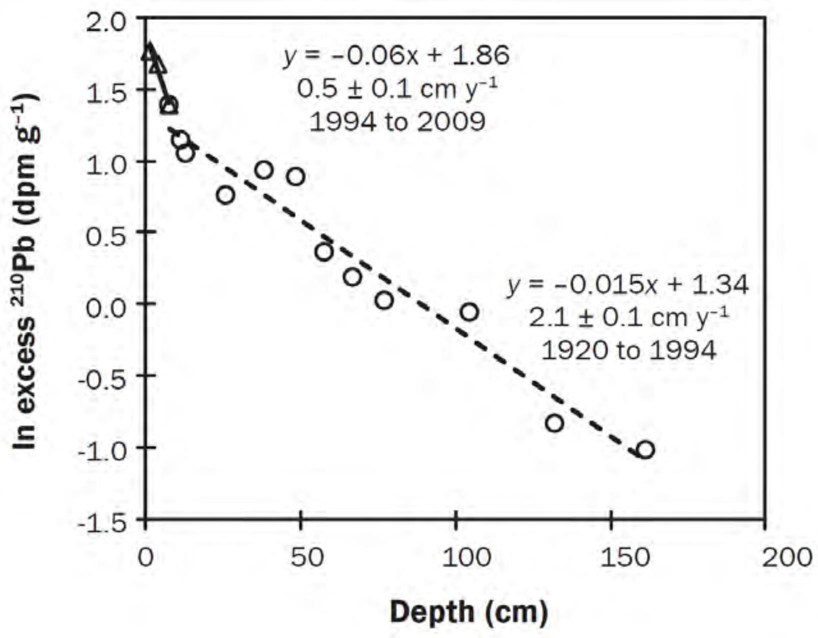
From Goni and Thomas, 2000

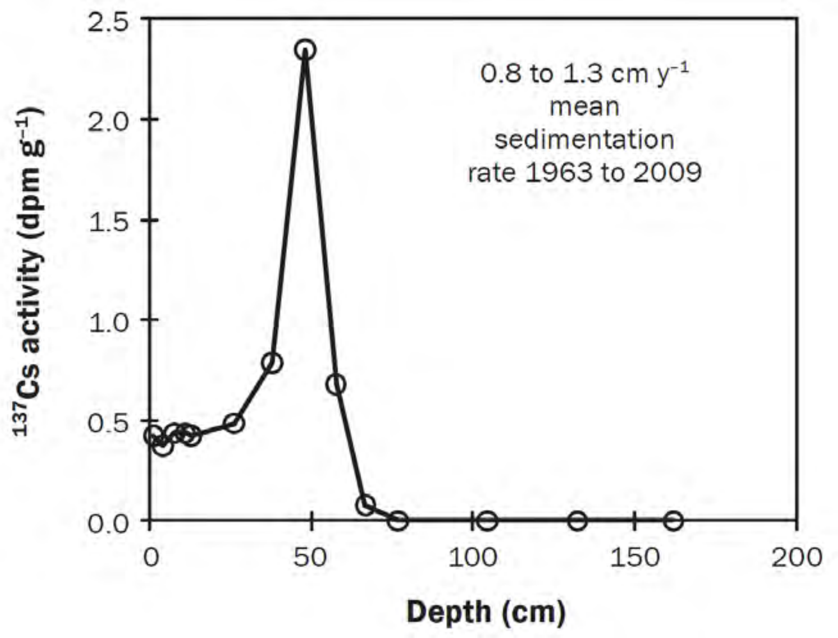
- Big Sunflower River
- @ Anguilla, MS
  - Reaches Flood Stage at least 17 times in last 30 years
- Sediment will have a different geochemical signature

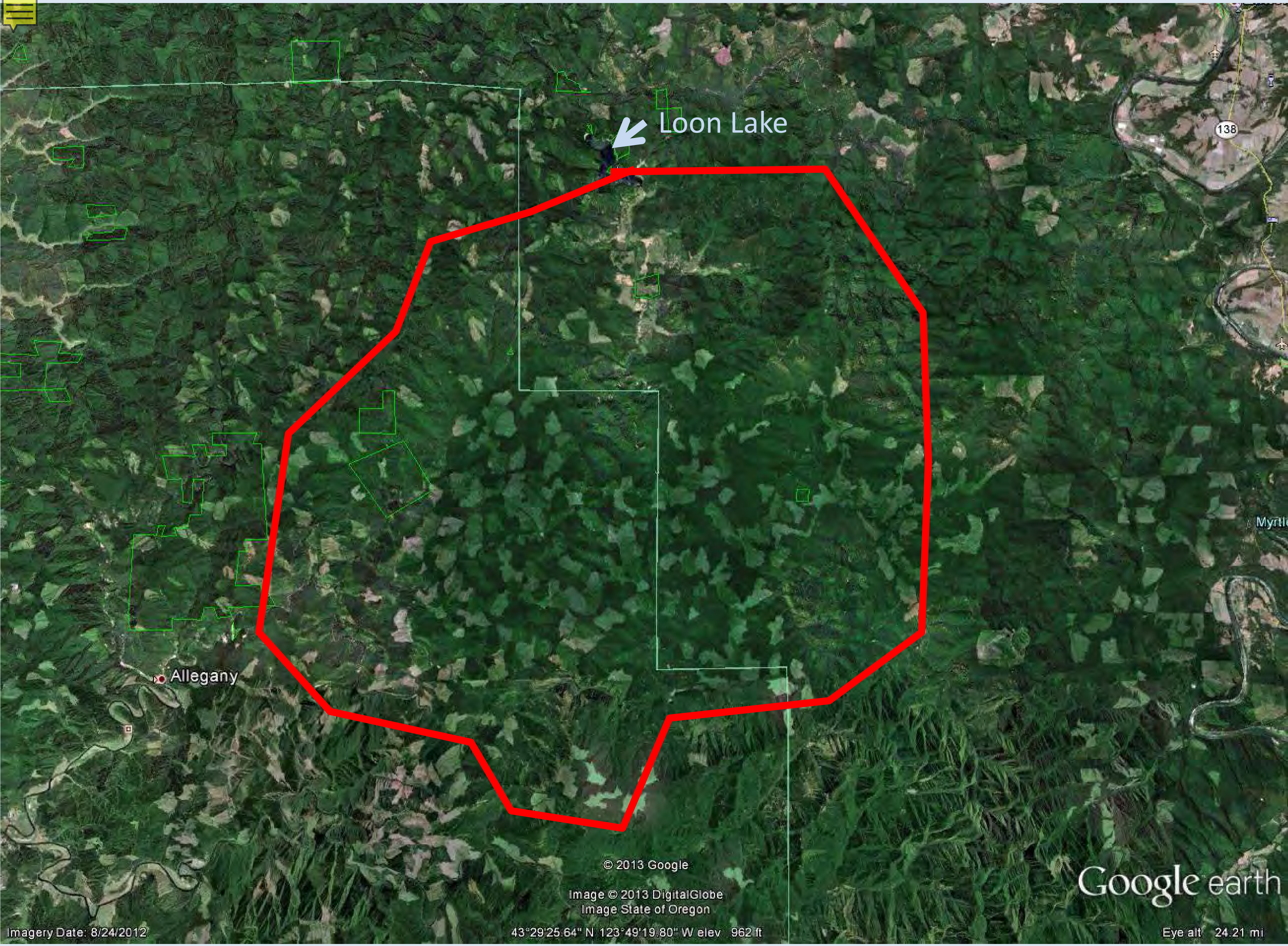


Beasley Lake

- Pre-BMPs 2.1cm yr^{-1}
- Post-BMPs 0.5cm yr^{-1}
  - Not a very long record (1994-2009)
  - # large magnitude events low



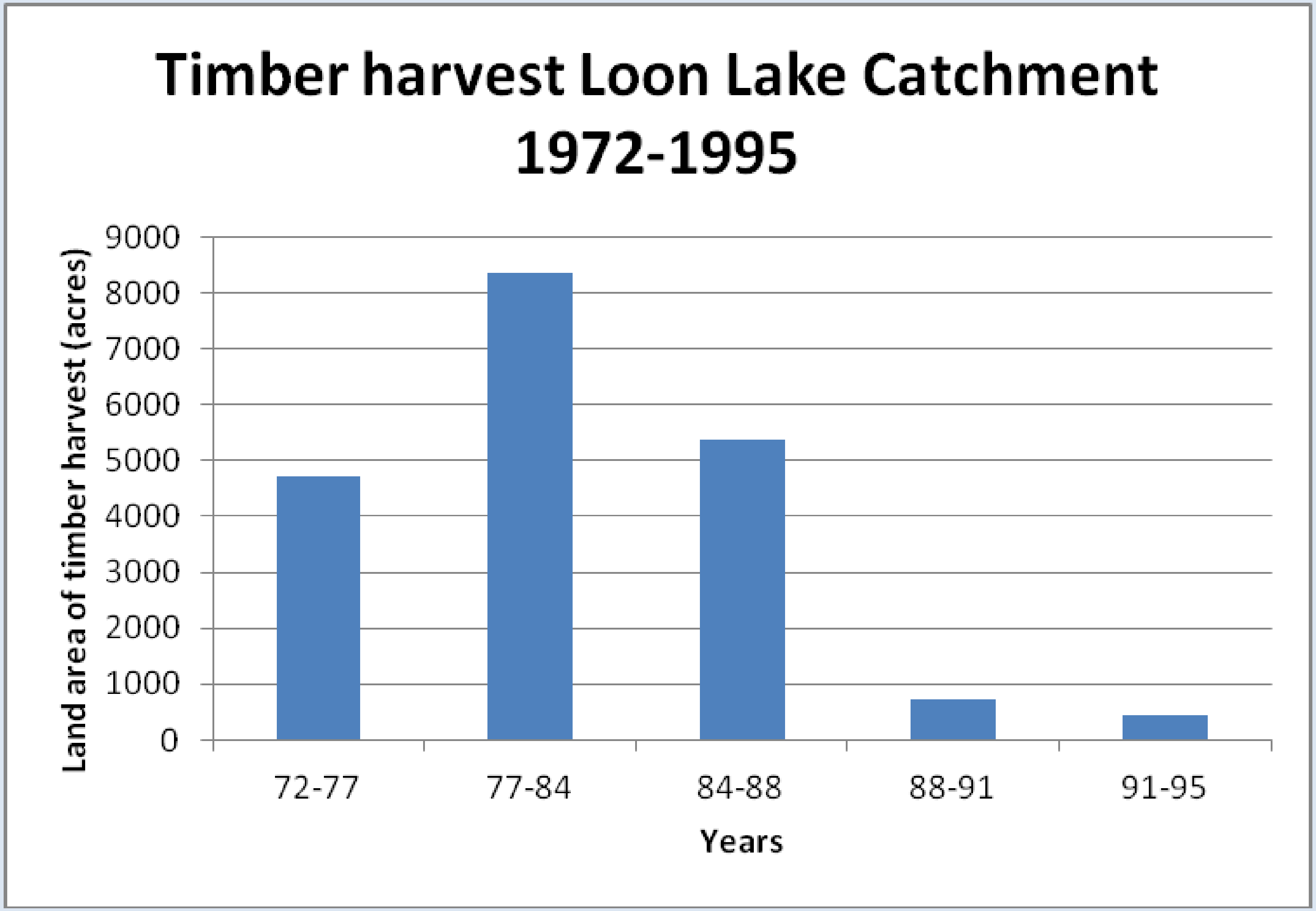




Loon Lake
138
Myrtle
Allegany
© 2013 Google
Image © 2013 DigitalGlobe
Image State of Oregon
Google earth
Imagery Date: 8/24/2012
43°29'25.64" N 123°49'19.80" W elev 962 ft
Eye alt 24.21 mi



Loon Lake – Timber Harvest



Loon Lake

- Geologic Setting
  - Tyee Formation: micaceous, feldspathic, lithic, or arkosic marine **sandstone** and micaceous carbonaceous **siltstone**
  - Yamhill Formation: marine **siltstone** and thin interbeds of arkosic, glauconitic, and basaltic **sandstone**
  - Tuffaceous **siltstone** and **sandstone** (minor component)