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Water-Quality and Suspended-Sediment Monitoring North Santiam River, Oregon

PNWS-AWWA Salem Conference, May 7, 2009

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U.S. Department of the Interior
U.S. Geological Survey

OVERVIEW

- Water-quality issues
- Project background
- Monitoring network
- Data and Analysis
- High-turbidity events
- Advantages of real-time monitoring

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Why Continuously Monitor Water Quality?

- Provide early-warning system for treatment facility operators
- Document exceedences of state standards
- Track recovery of landscape from disturbance
- Establish benchmark for future landscape perturbations
- Identify sediment source areas
- Monitor contaminant spillage migration
- Target areas for remedial action

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North Santiam River Basin

February 1996-

- 50- to 100-year flood events
- Landslides (216 in N Santiam Basin, 1 per 3 mi^2), debris flows, road/culvert failures, earthflows
- City of Salem forced to temporarily close water treatment plant and instituted several upgrades
- High turbidity and suspended sediment in Detroit Lake lasted for months

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North Santiam River Basin

Project Background – Environmental setting

- In Oregon most population uses and drinks surface water, which makes turbidity a treatment issue
- North Santiam Basin (690 mi^2) is the principle drinking water source for over 170,000 residents in the Salem area
- Two Reservoirs: Detroit and Big Cliff (436,000 and 2,430 acre-ft storage capacity at max pool elevation), with 100K and 18K kilowatt powerhouses, respectively
- Major sediment sources from landslides, debris flows, earthflows, road/culvert failures, clearcuts, glaciers

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North Santiam River Basin

Project Background

- Study began in Oct 98 in cooperation with the City of Salem, and to lesser extent USFS, and USACE
- Water-quality data (temp, sp cond, pH, DO, turbidity, and streamflow provided as real-time 30-minute data at up to 11 sites, totaling over 4 million values since Oct 1998
- Suspended-sediment samples collected, especially during storms
- Salem Water Treatment Plant- uses slow sand filtration with naturally occurring biological activity to clean drinking water

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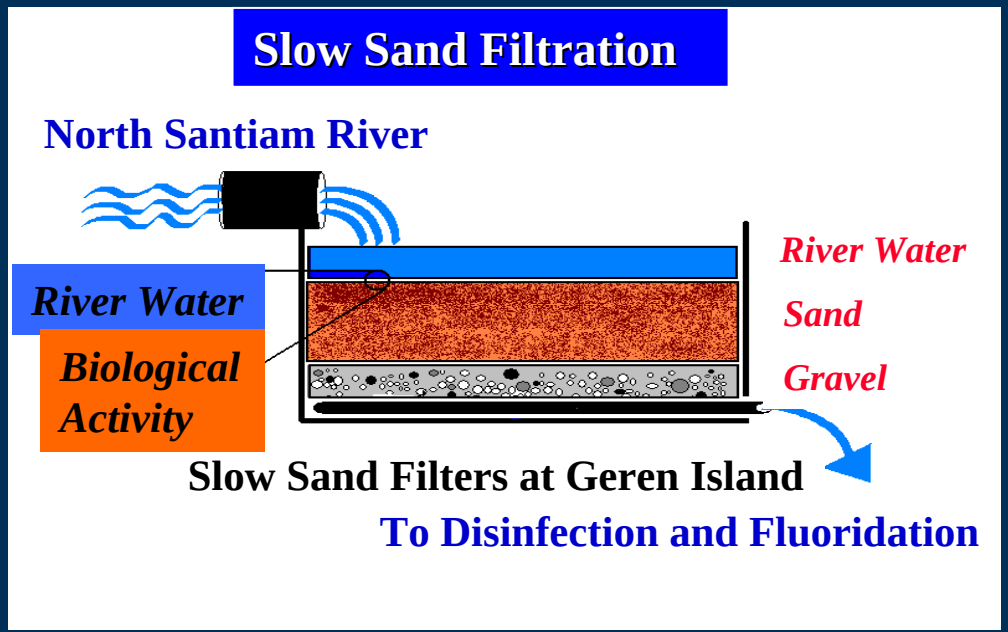

North Santiam River Basin Turbidity and Suspended-Sediment Study

Project Objectives:

1. Establish a real-time network of streamflow and water-quality stations to monitor short-term variability in turbidity.
2. Identify contribution of turbid water from tributaries entering Detroit Lake and North Santiam River upstream of WTP to monitor light attenuation and turbidity variation.
3. Establish long-term changes in suspended-sediment loads in major subbasins.
4. Establish correlations between turbidity and suspended-sediment concentration.
5. Develop statistical models to predict turbidity relative to geology, land use, and topographic features.

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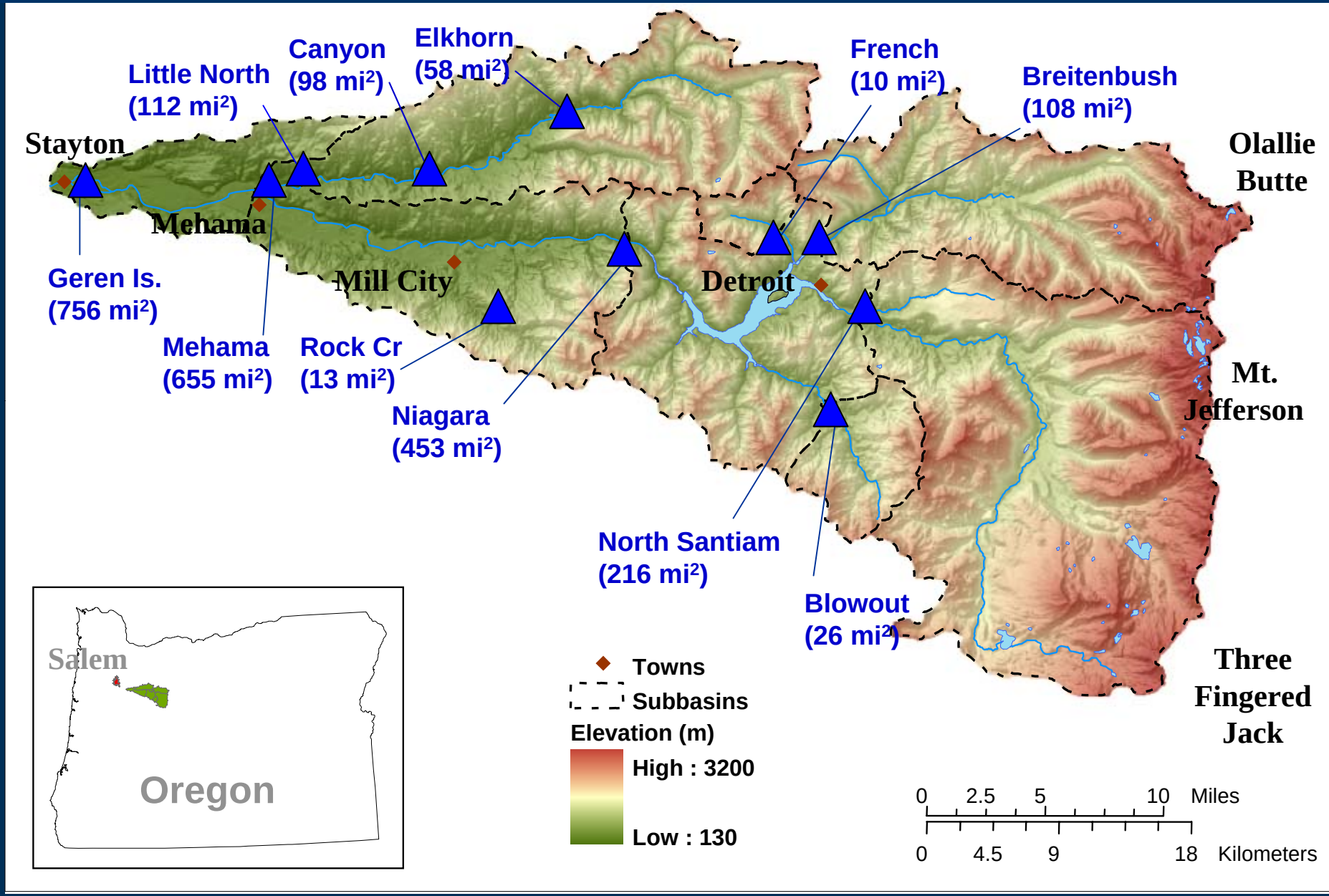
North Santiam River Basin



Environmental effects of high turbidity?

- Decrease light penetration = lower photosynthesis = limits aquatic plants and primary production
- No Plants = No Invertebrates
- No bugs = No Fish
- Sediment on fish gills & eggs = can’t breath or grow
- Aquatic predators can’t see prey.

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Other effects of high turbidity?

- ***Industrial***

  - Clog, scour , and damage pipes, machinery, and drinking-water system filters, making it costly to reduce turbidity

- ***Health***

  - Organic constituents may increase waterborne disease from bacteria, viruses, and protozoa.)

  - Organic pesticides may adsorb to turbidity-causing sediments

- ***Recreational***

  - Obscure potentially dangerous obstructions, such as boulders and logs from swimmers & boaters.

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Turbidity is one of the main culprits in treating drinking water

Natural Causes

- *Normal runoff, overland flow, some bank erosion*
- *Water turbulence from rain storms*
- *Wave action*
- *Seasonal turnovers (releases nutrients from sediment which increase phytoplankton production)*

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Turbidity is one of the main culprits in treating drinking water

Human Causes

- *Runoff from agricultural fields*
- *Runoff from clearcut lands after timber harvesting, road and culvert failures*
- *Wash from construction sites and urban areas*
- *Shoreline erosion from heavy boat traffic*
- *Dissolved nutrients released in treated wastewater*
- *Organics discharged by sewage treatment plants*

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Take home message: Turbidity changes can be widespread and persist

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The other water-quality parameters

Water Temp, Sp Cond, pH, DO

- *Important for viability of all aquatic life*
- *Important for industrial, commercial, agricultural, domestic and recreational uses*
- *Changes can be more important than actual values*
- *All can provide indicators of pollution and health of a water body*
- *Most effect taste, odor, distribution and plumbing lines*
- *What is normal in one stream may not be normal in another stream*

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The other water-quality parameters

- *Temperature effects aquatic habitats and ability of water to hold oxygen*
- *Specific Conductance measures the amount of dissolved material in water, distilled water=very low, seawater=high, can indicate some type of change*
- *pH effects acidity/basic, solubility and biological availability of nutrients, primary production, chlorine disinfection, on a log scale, high pH=algal growth*
- *Dissolved oxygen effects the vitality and diversity of aquatic species, low DO=eutrophication*

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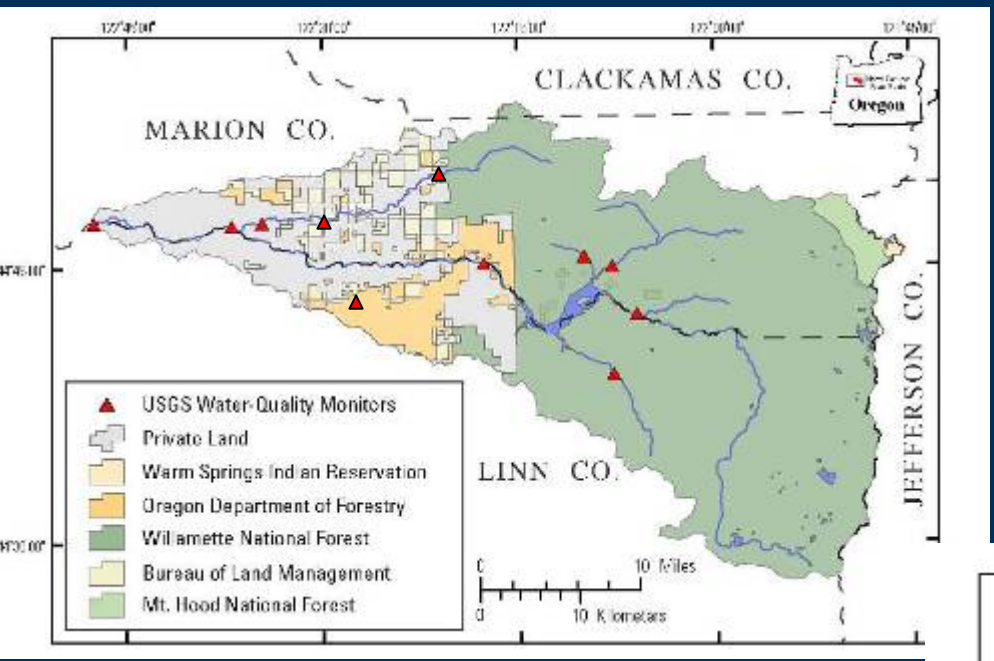
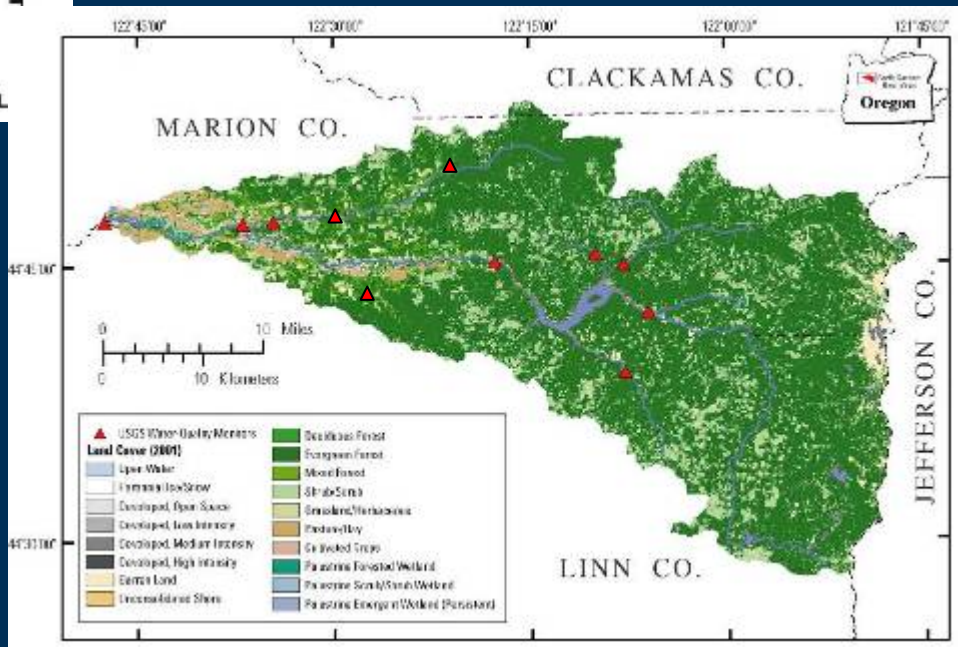
North Santiam River Basin
Land Ownership and Landcover





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Monitoring Site Selection

- **Data telemetry (real time)?**
- **Short or long-term installation?**
- **Security or vandalism concerns?**
- **Representativeness of watershed?**
  - Good mixing and depth
  - Inclement weather access
- **Sampling methods**
  - bridge, cableway, wading

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Monitoring Site Selection

- Existing USGS stream gages
  - Continuous and/or historic streamflow data
  - Infrastructure in place
  - Safety and accessibility issues previously addressed
  - Sampling methods comparable to stream-gaging
- North Santiam Project
  - 5 of 6 original water-quality sites were existing stream gages
  - 4 new SW / QW sites established
  - 1 QW only

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Water-Quality Sensor Selection

- Stand alone or multi-parameter (cost)
- Turbidity: nephelometric, optical backscatter
- DO: clark cell & optical, differ in maintenance
- pH: replaceable buffer solution within probe
- Range- high end, low end, broad range
- SDI-12 Communications, logging, telemetry
- Fouling- How much an issue, wiper or shutter
- Standards: Some instrument specific and agency defined

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Continuous In-Stream, Multi-Parameter, Water-Quality Instrument

- Water temperature
- pH
- Specific conductance
- Dissolved oxygen
- Fluorescence= Chlorophyll
- TURBIDITY

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Water-Quality Calibration and Standards

- 3-4 week schedule, use a backup datasonde as reference, calibrations done in field, with standards at stream temperature
- Turbidity= 0, 10 , 200, 800 FNU formazin primary standards (StablCal), field check with polymer standard
- pH= 4, 7, and 10 standards
- Specific Conductance= bracket expected values with three standards
- Cross-sectional sample readings important as check of station readings
- Standard preparation and cost

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Suspended-Sediment Sampling

- Depth-integrated samples, Eq-Width-Increment method
- Collected over range of flow and turbidity conditions
- Multiple samples during storms, duplicates for QA/QC
- Over 1000 samples collected since 1998

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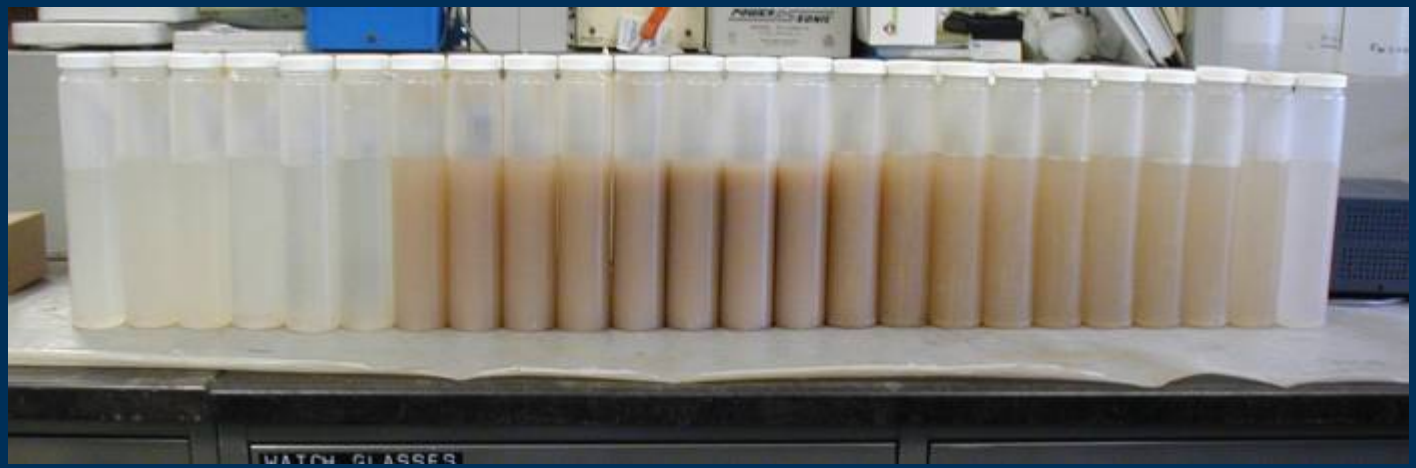
Suspended-Sediment Sampling

- Pumping samplers at three sites in upper basin
- Triggered by programmed turbidity threshold
- Point sample concentration must be compared to cross-sectional samples for possible correction
- Over 400 samples collected since 2003



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Take home message: sensors & sampling

- Be *consistent* with instrumentation and methods
  (lab & in-stream equipment are different)
- Readings and samples should be *representative* of water body and over the *whole range* of conditions

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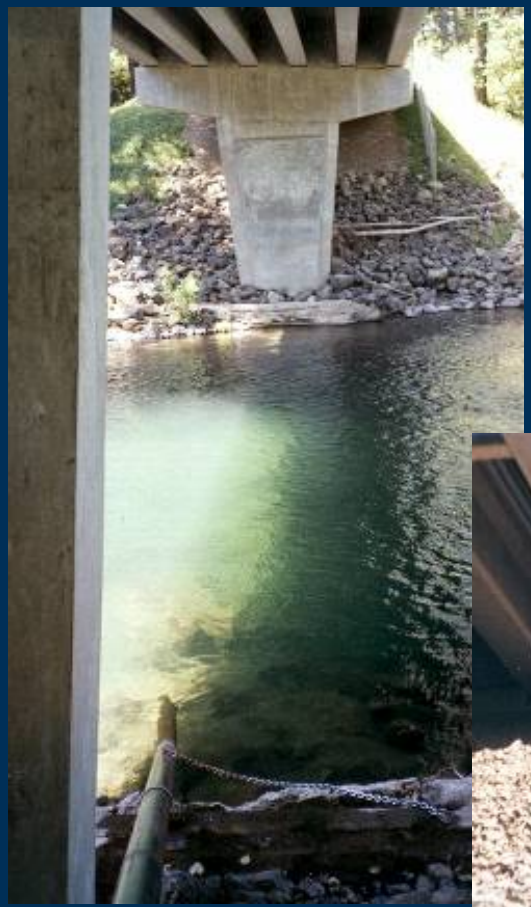
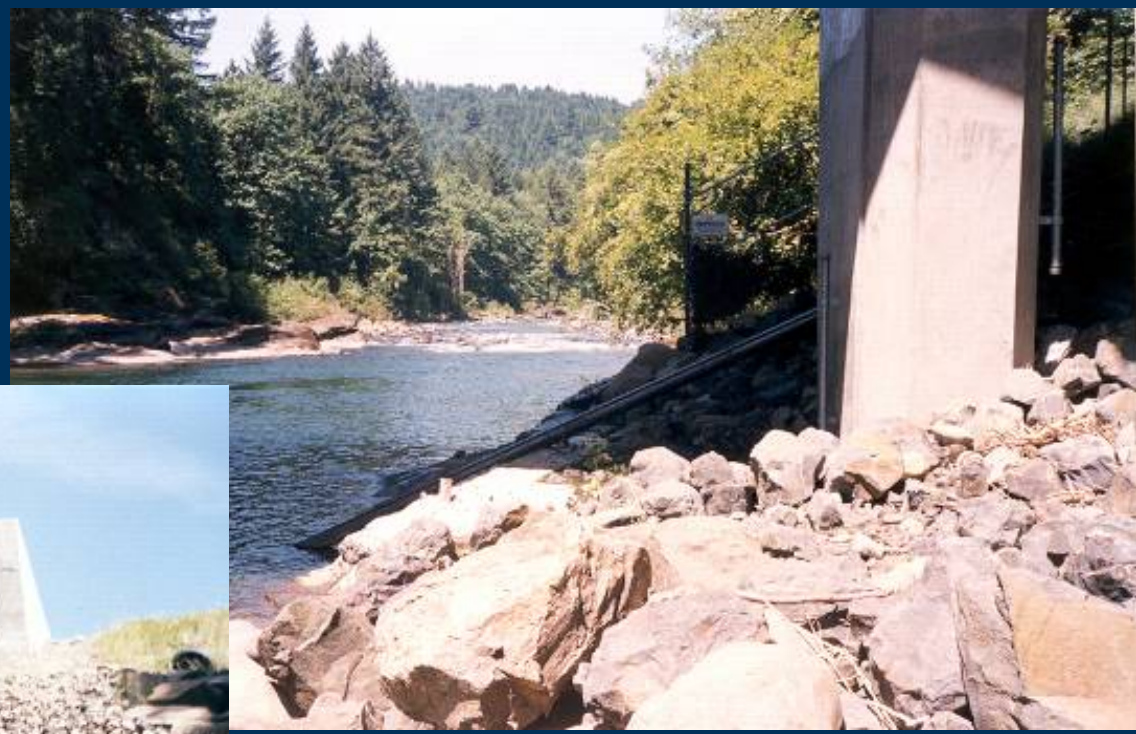
Typical Installation – 1 pipe each for stage and water quality- attached to concrete pier or gage house

Little North Santiam R monitoring site- major downstream tributary





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Blowout Creek monitoring site- inputs to Detroit Lake

Breitenbush River monitoring site- inputs to Detroit Lake

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Mehama monitoring site- most downstream on mainstem

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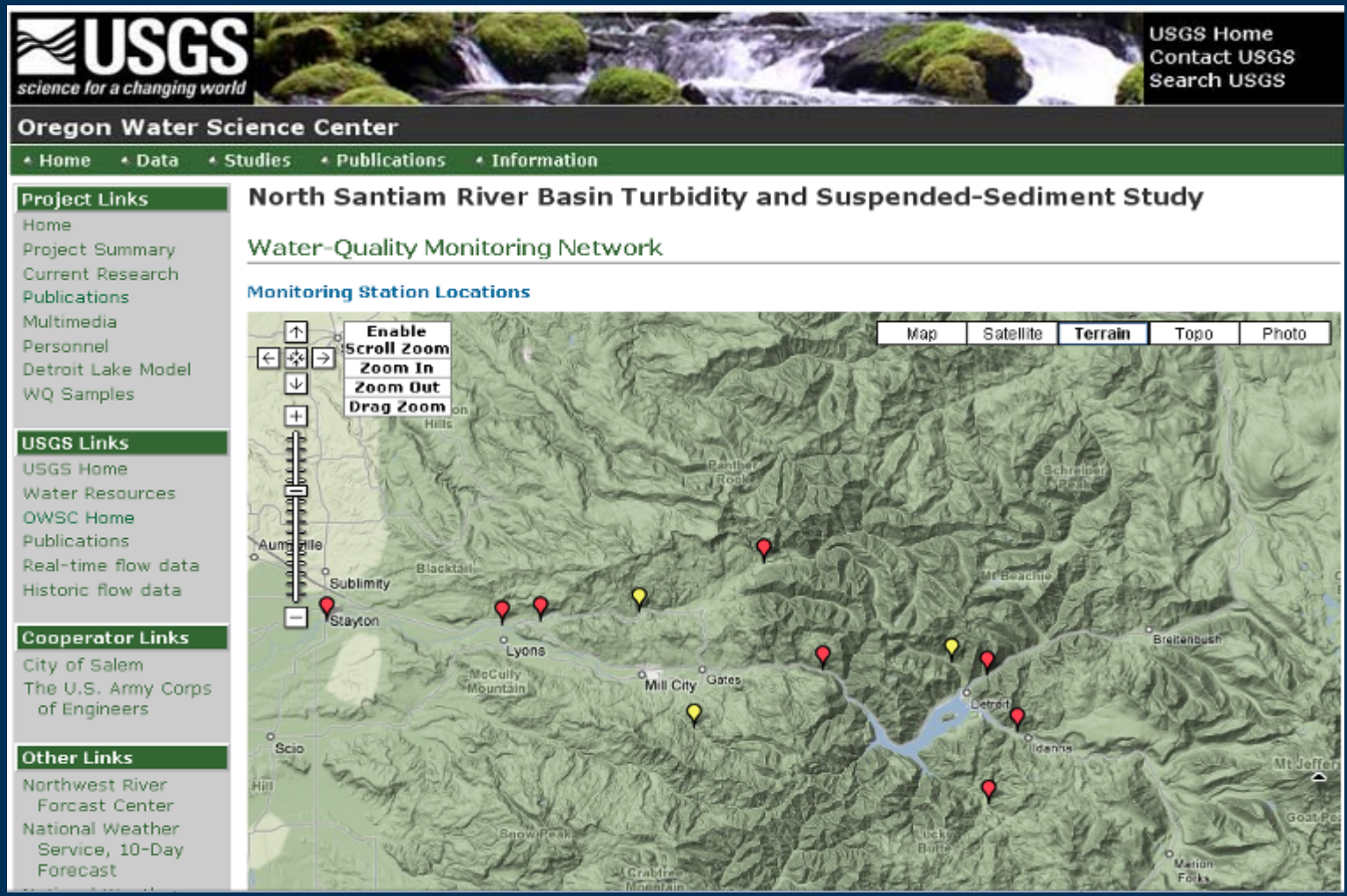
Project Website



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Project Website

Active Monitoring Stations

Parameter Definitions

Site and Status	Parameters	Plots	Tables
North Santiam River at Geren Island near Stayton, OR (444728122450000) *Data are downloaded and processed every 4 hours.*	WT, pH, SC, Tbdy, Prec	NWIS-Web Custom	Custom
North Santiam River at Mehama, OR (14183000) *Data are downloaded and processed every 4 hours.*	Q, S, WT, pH, SC, Tbdy	NWIS-Web Custom	Custom
Little North Santiam River Near Mehama, OR (14182500) *Data are downloaded and processed every 4 hours.*	Q, S, WT, pH, SC, Tbdy, DO/DO%	NWIS-Web Custom	stom
Little North Santiam River Above Evans Ck at Elkhorn, OR (14181900) *Data are downloaded and processed every 4 hours.*	Q, S, WT, pH, SC, Tbdy, DO/DO%	NWIS-Web Custom	Custom
North Santiam River at Niagara, OR (14181500) *Data are downloaded and processed every 4 hours.*	Q, S, WT, pH, SC, Tbdy	NWIS-Web Custom	Custom
Breitenbush River Above French Creek Near Detroit, OR (14179000) *Data are downloaded and processed every 4 hours.* *Parameters SC and pH no longer monitored.*	Q, S, WT, Tbdy	NWIS-Web Custom	Custom
North Santiam River Below Boulder Near Detroit, OR (14178000) *Data are downloaded and processed every 4 hours.* *Parameters SC and pH no longer monitored.*	Q, S, WT, Tbdy	NWIS-Web Custom	Custom
Blowout Creek Near Detroit, OR (14180300) *Data are downloaded and processed every 4 hours.* *Parameters SC and pH no longer monitored.*	Q, S, WT, Tbdy, Prec	NWIS-Web Custom	Custom

NWIS-Web Custom

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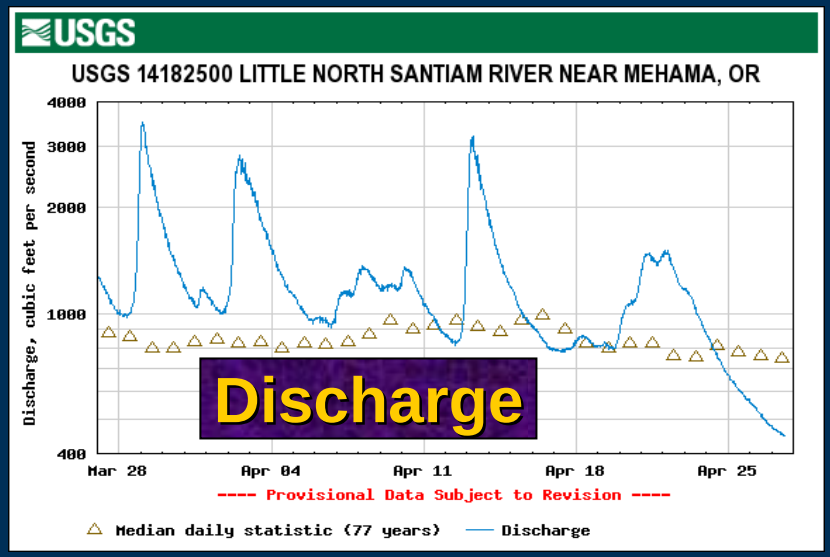
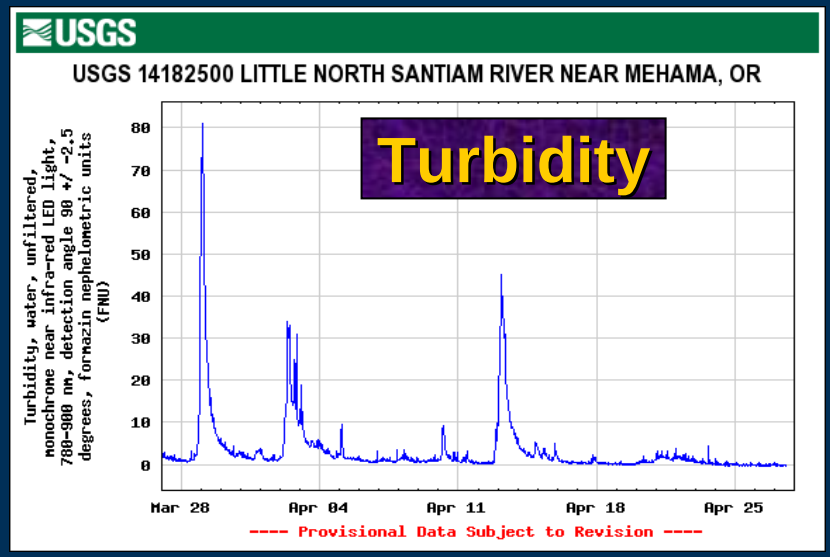
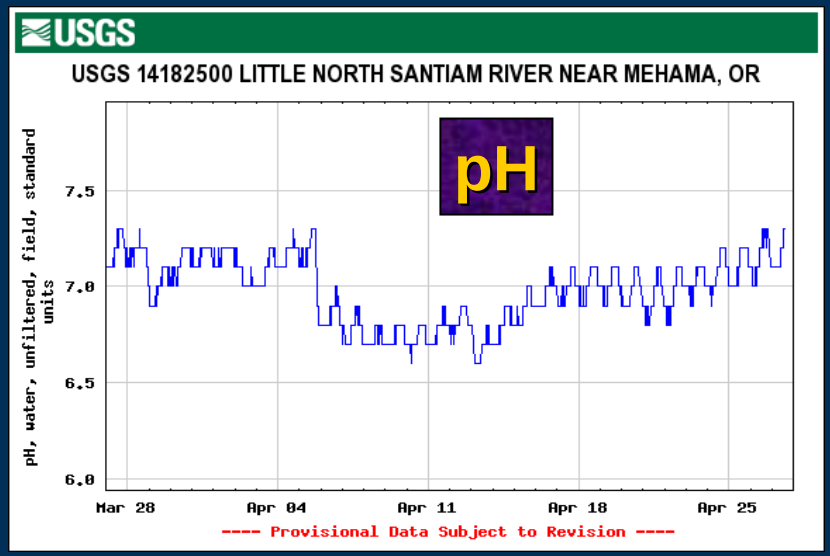
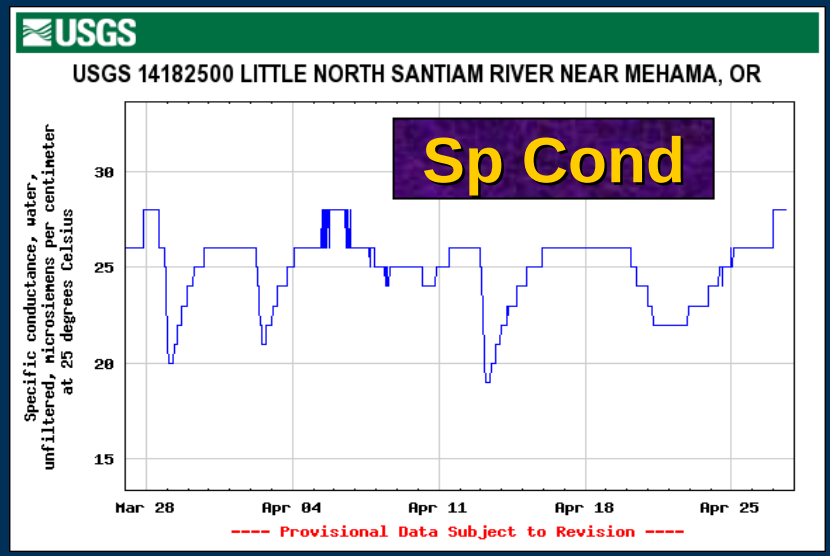
NWIS-Web (access to last 30 days only)









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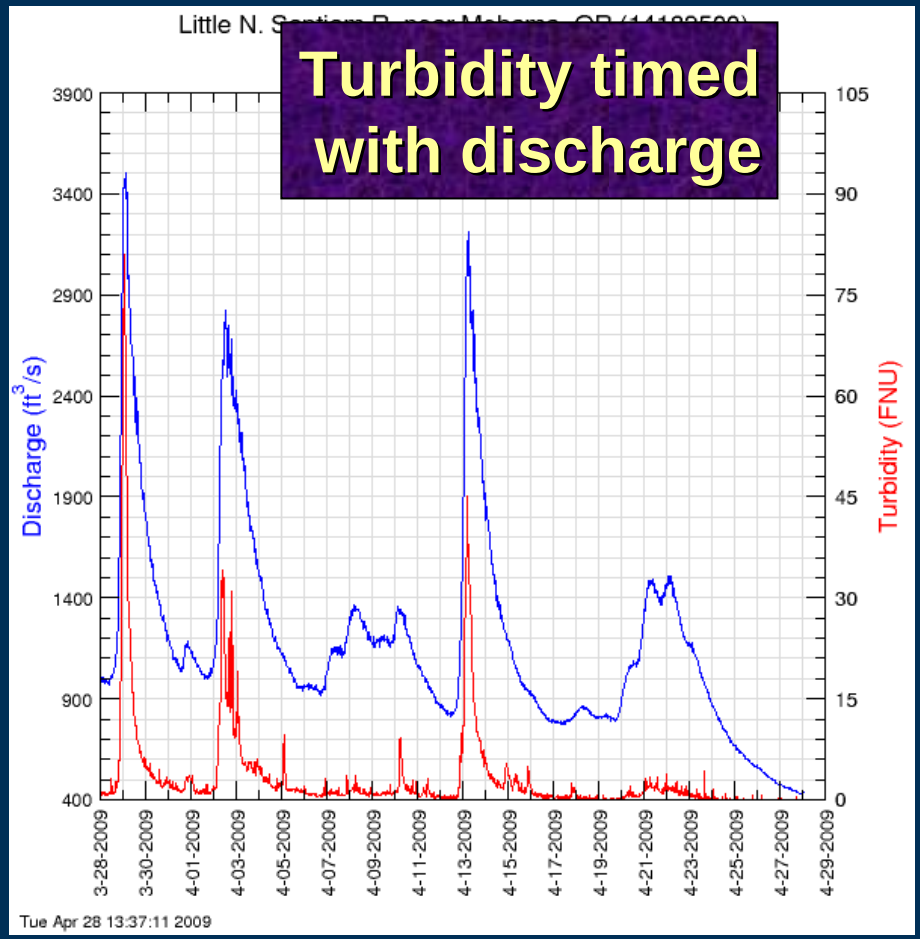
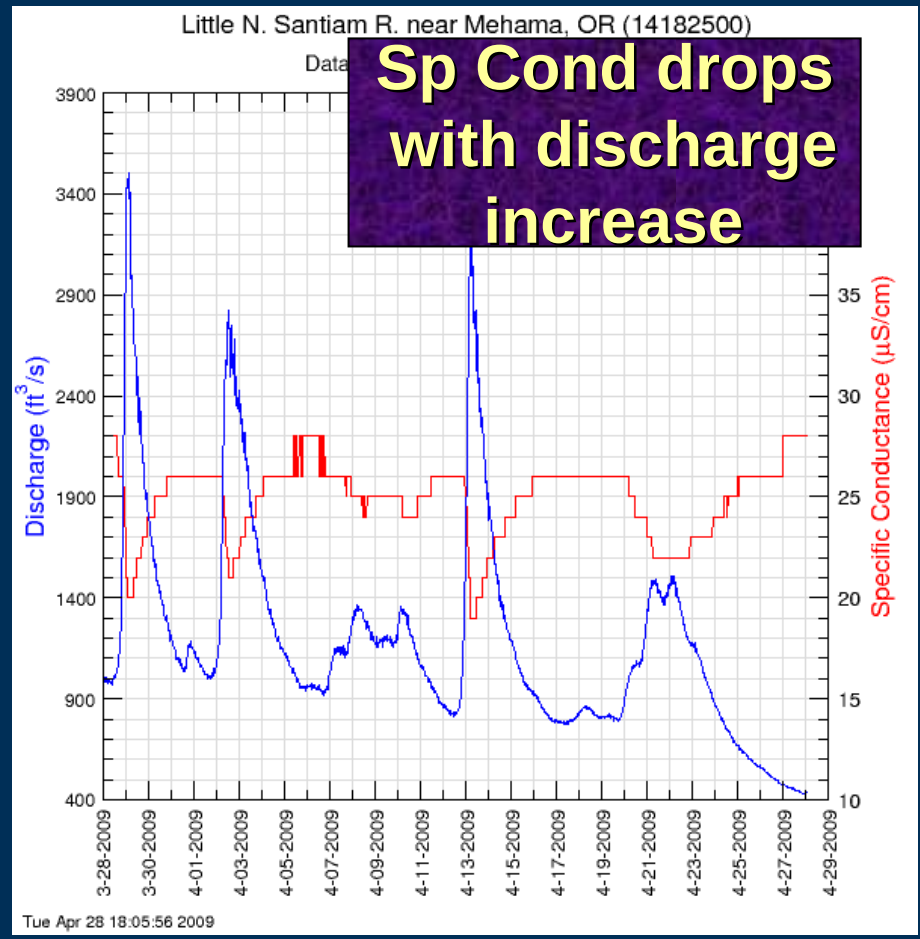
Custom Plots
(access to full period of record)





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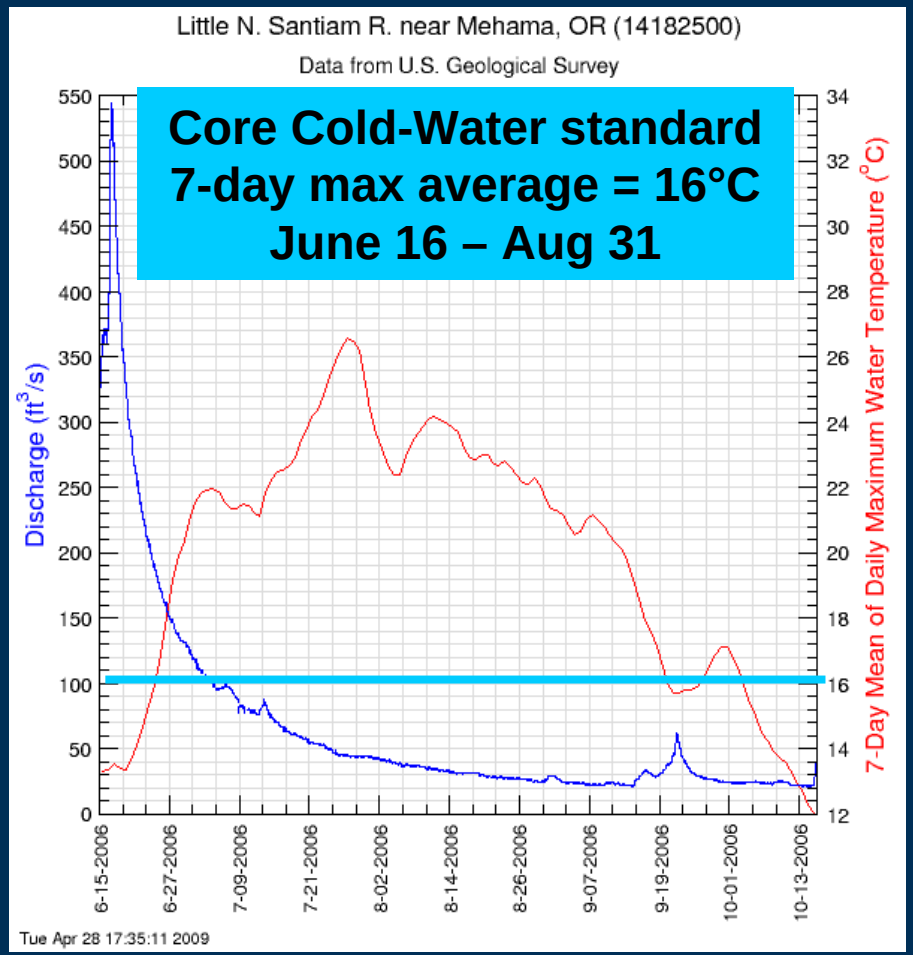
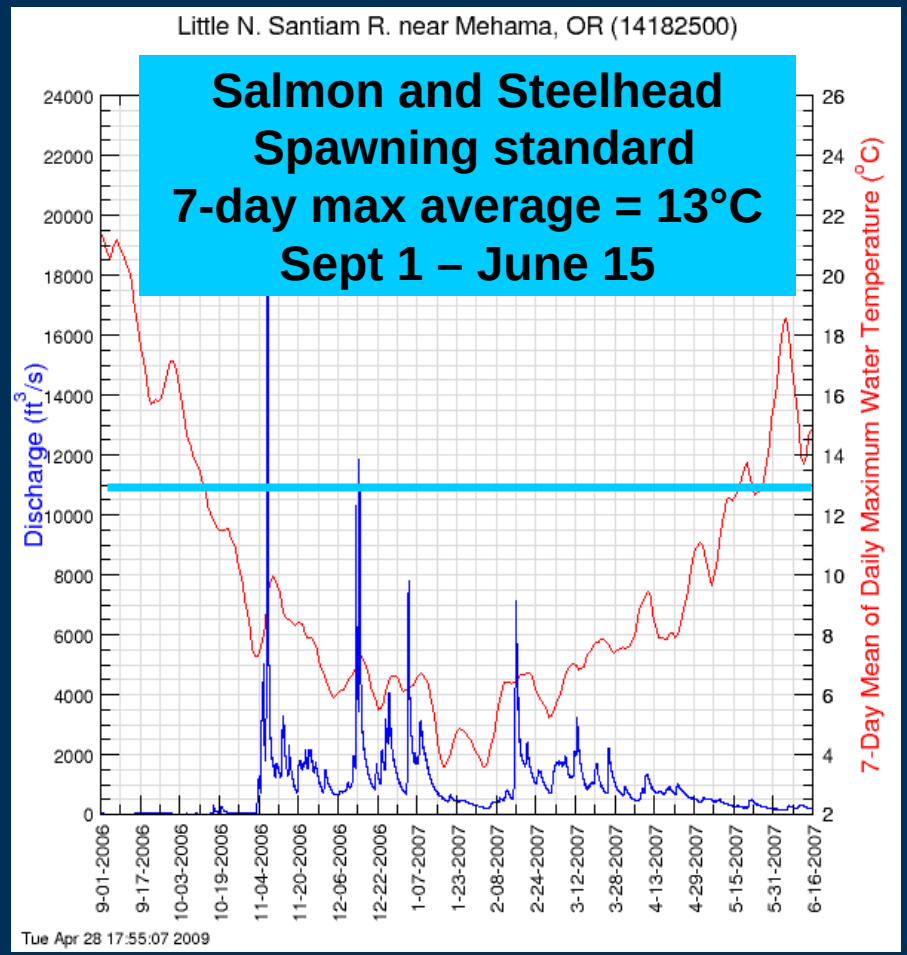
Custom Plots





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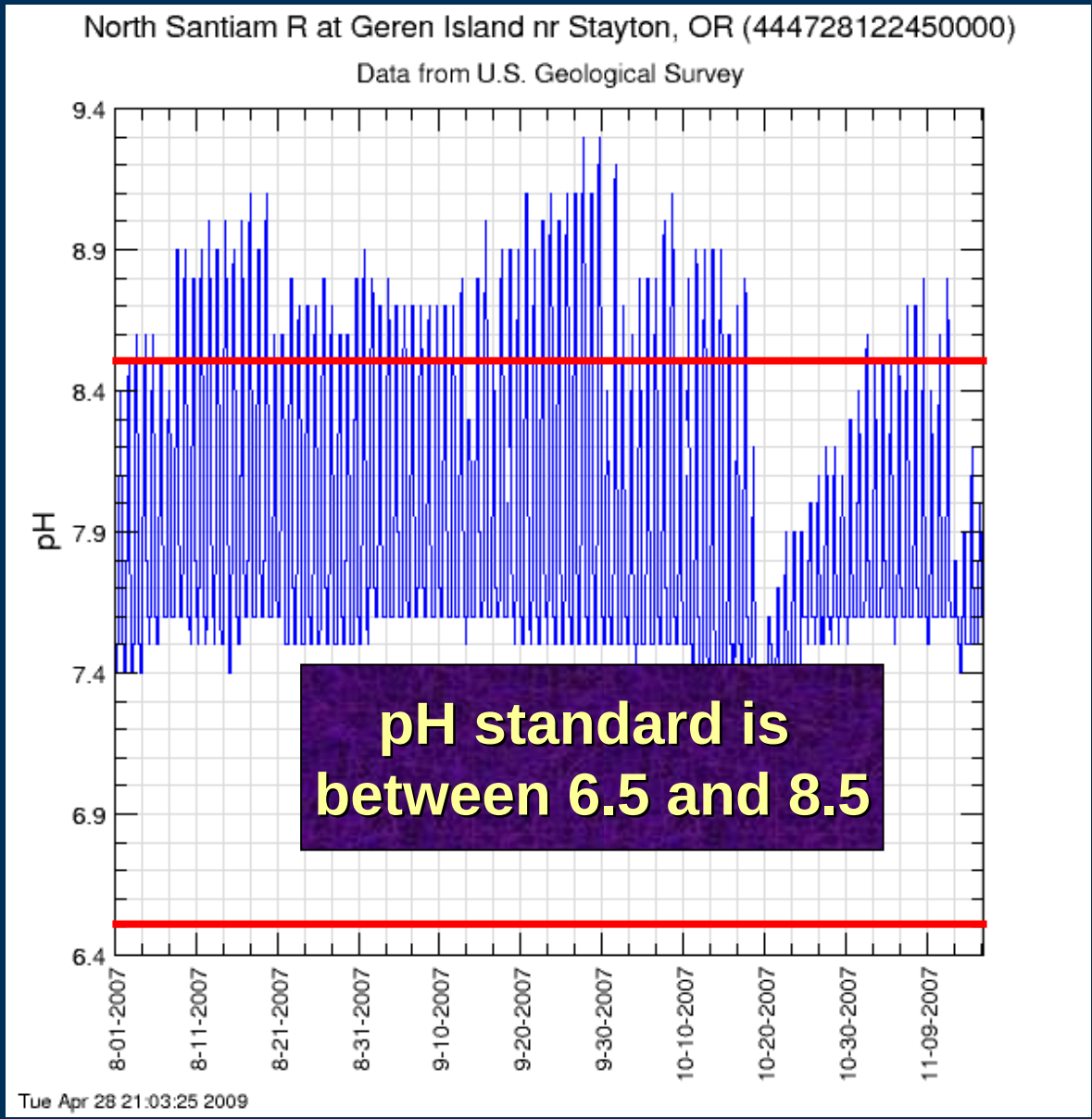

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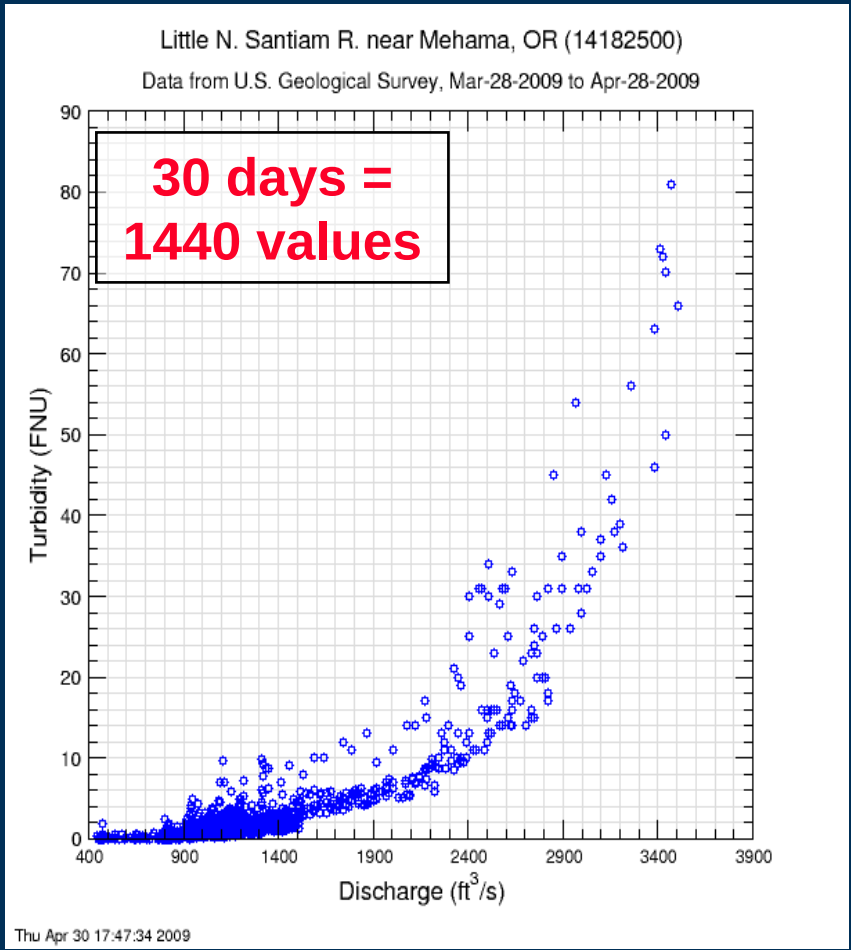
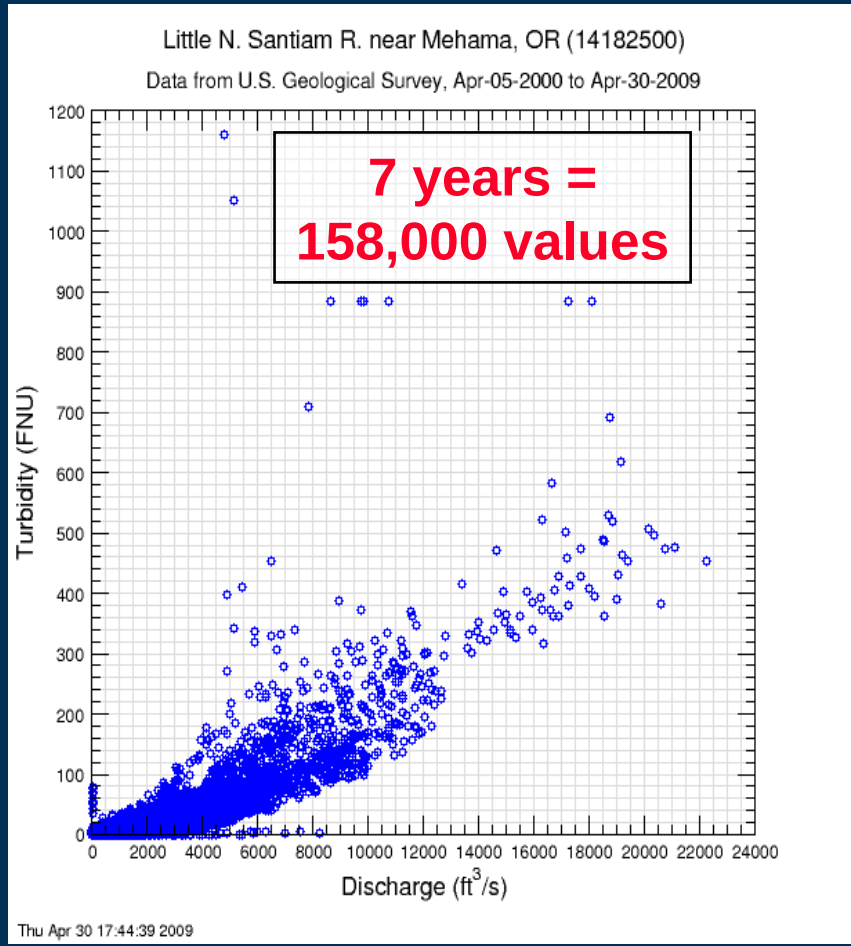
Custom Plots





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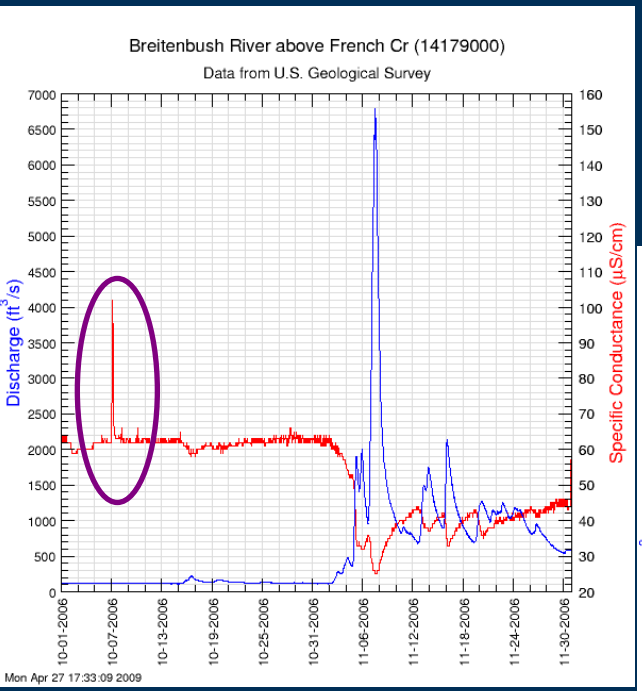
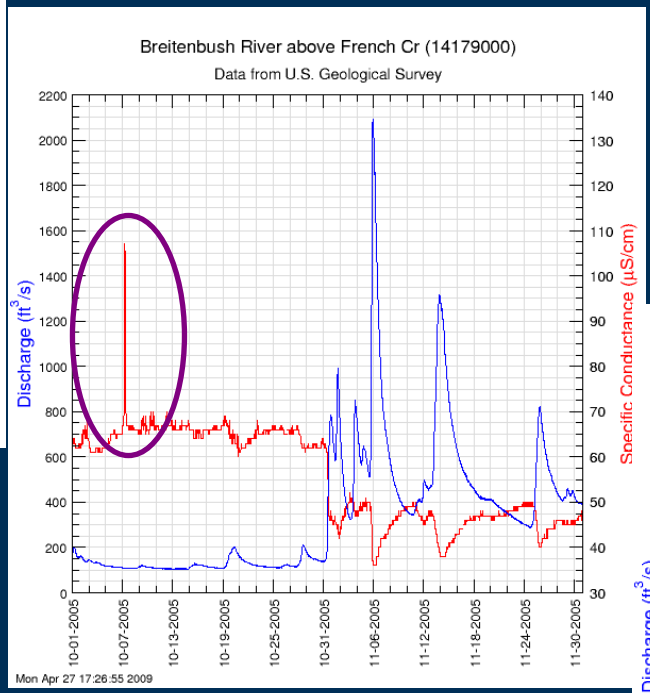
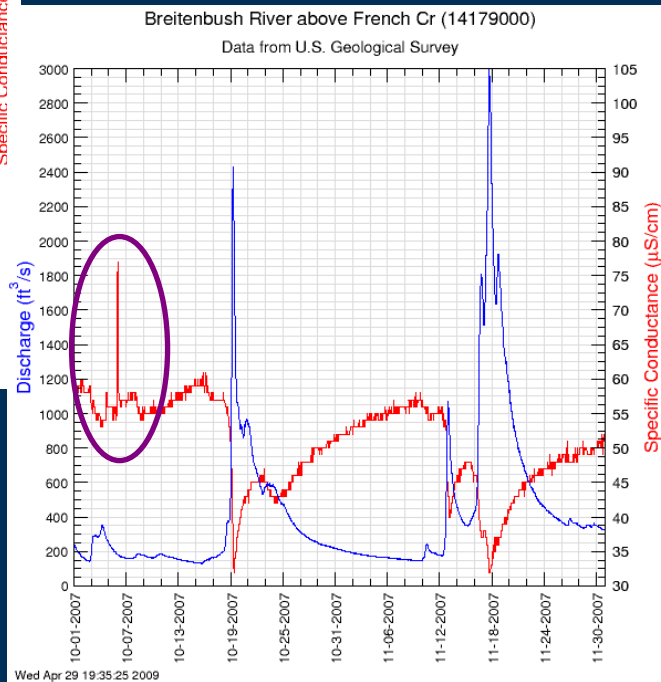
Specific Conductance spikes in Breitenbush River Oct 6-7, 2005, 2006, 2007







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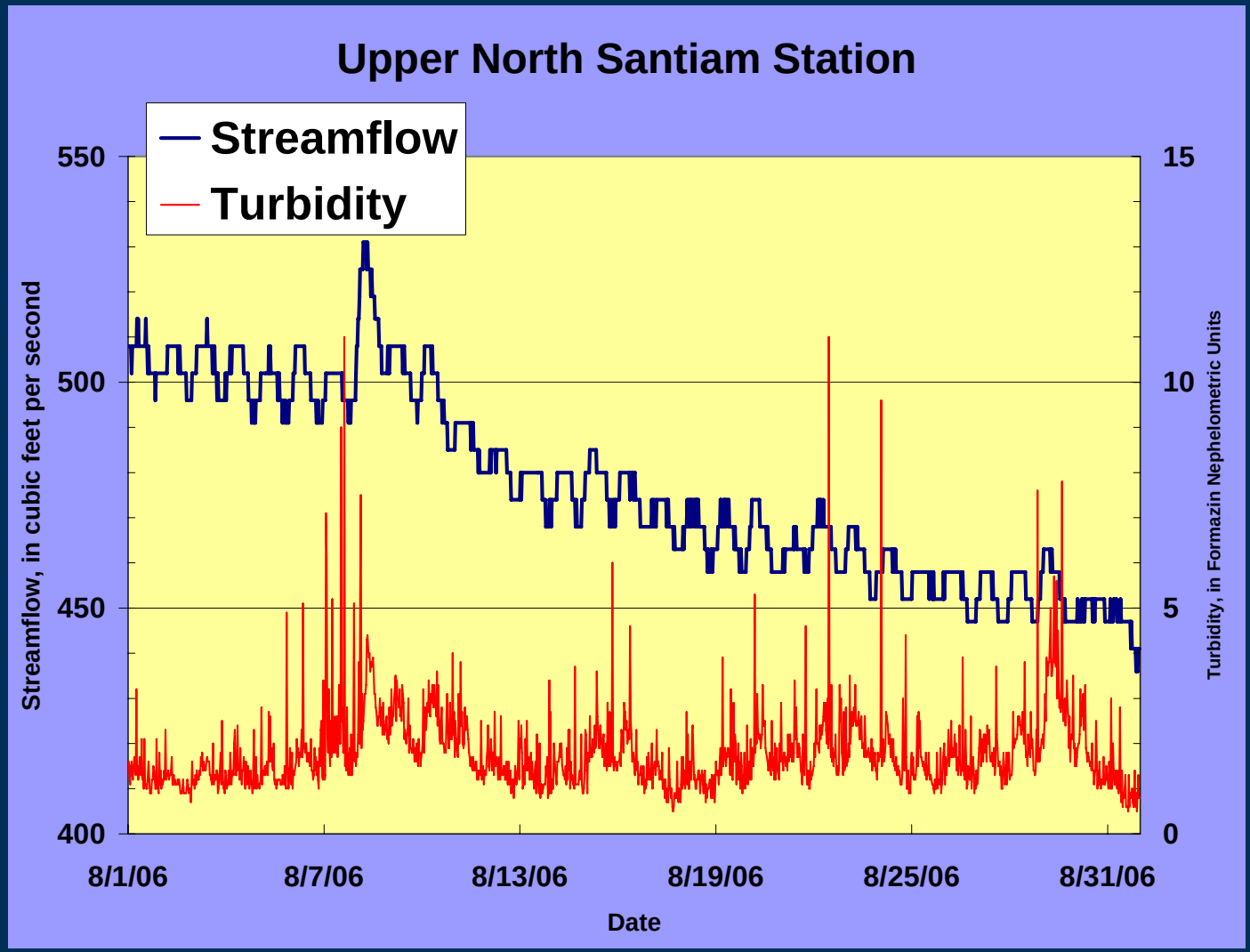
Diurnal fluctuations from glacial areas



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Data Analysis

CONTINUOUS TURBIDITY
and STREAMFLOW DATA
+
SAMPLE COLLECTION
and REGRESSION ANALYSIS
=
SUSPENDED-SEDIMENT
DISCHARGES, LOADS and YIELDS

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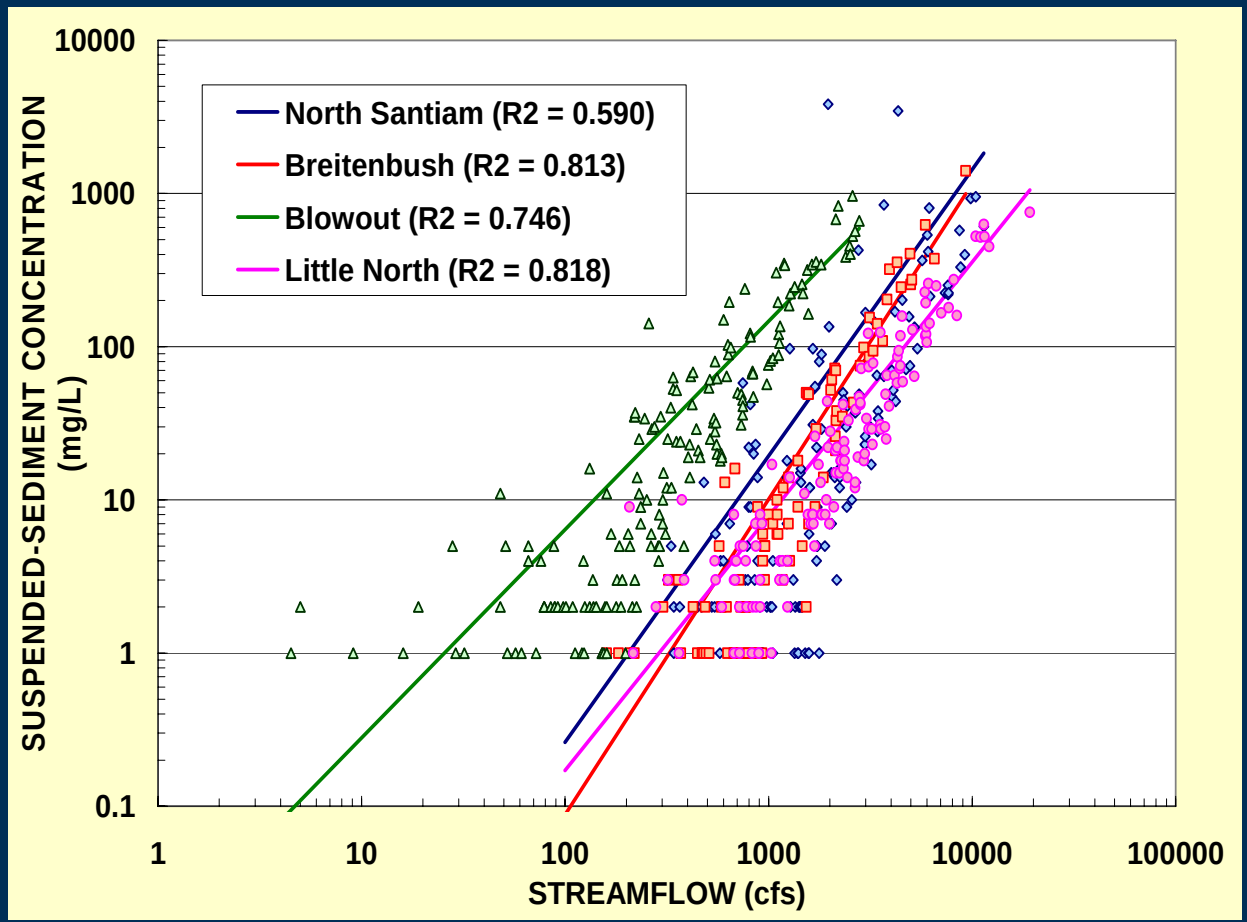
Regression Analysis

- **Streamflow vs. Suspended-Sediment Concentration**
- **R^2 = 0.590 to 0.818 (4 stations, 1998 - 2007)**



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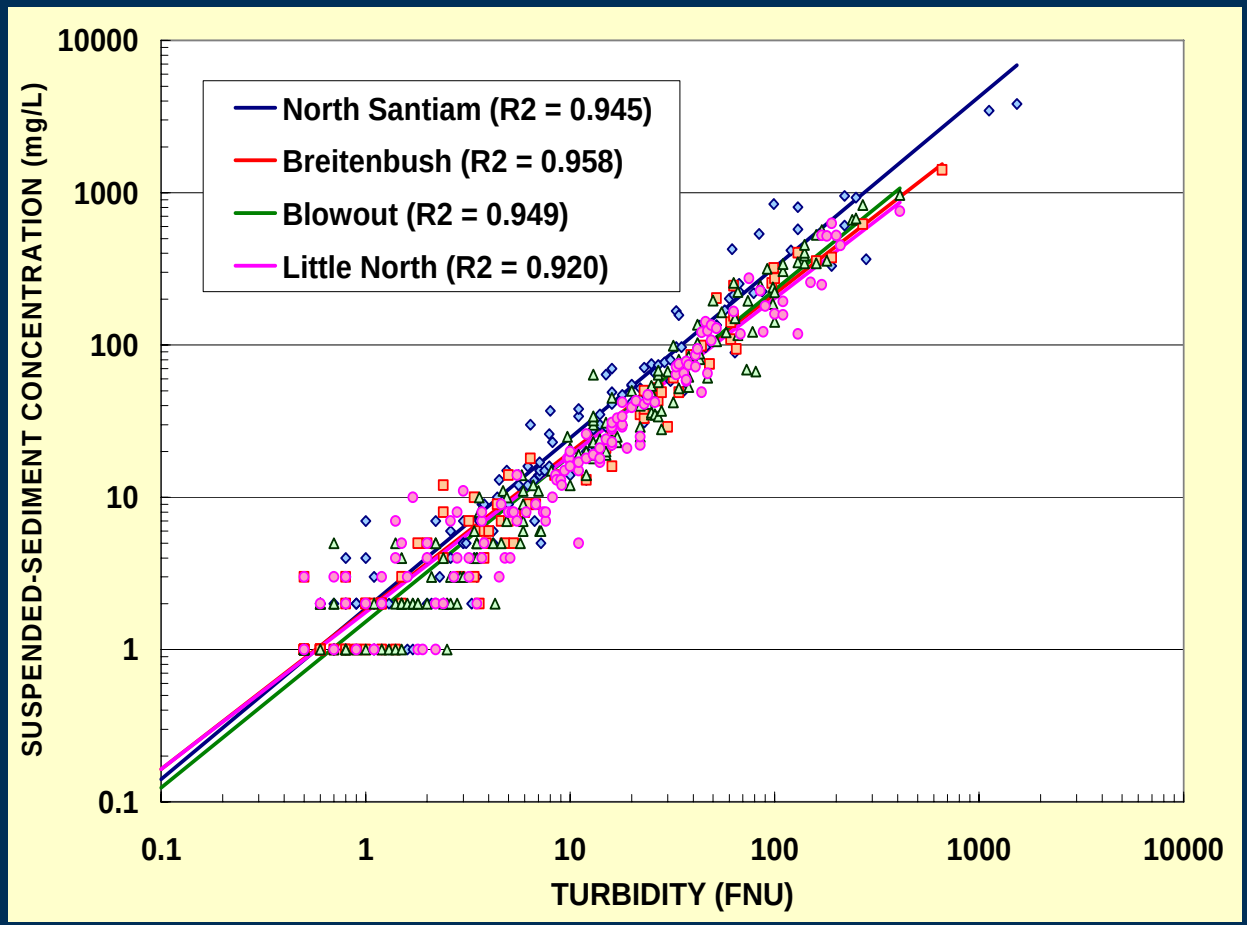
Regression Analysis

- Turbidity vs. Suspended-Sediment Concentration
- R^2 = 0.920 to 0.958 (4 stations, 1998 - 2007)



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Suspended-Sediment Load Calculation

- Start with 30-min values of streamflow and turbidity
- Convert 30-min values of turbidity to sediment concentration using regression equations
- Sediment load (tons/30 minutes) = streamflow (cfs) x concentration (mg/l) x conversion factor
- Daily sediment load = sum of 48 load values per day
- Annual sediment load = sum of 365 daily loads per year

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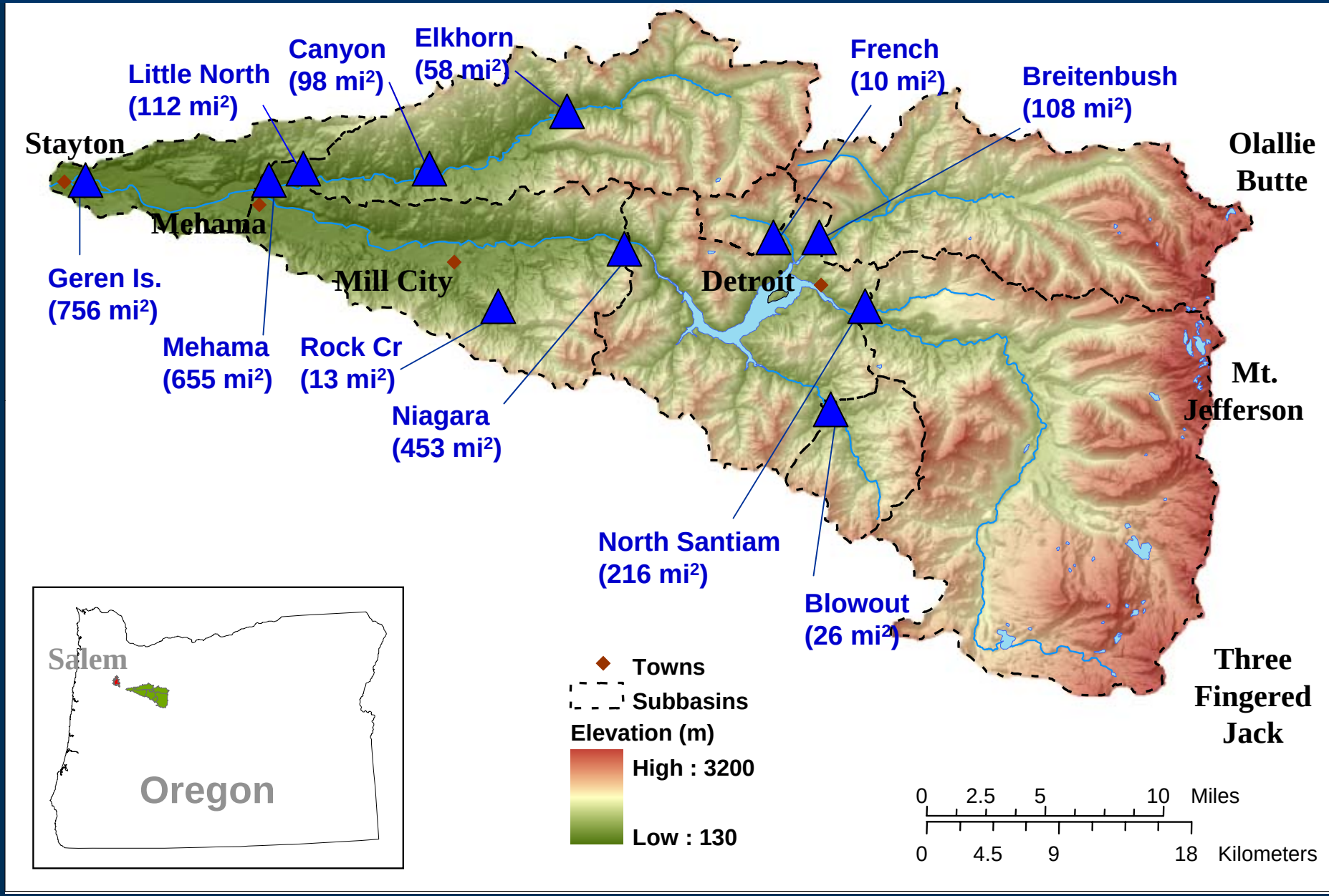
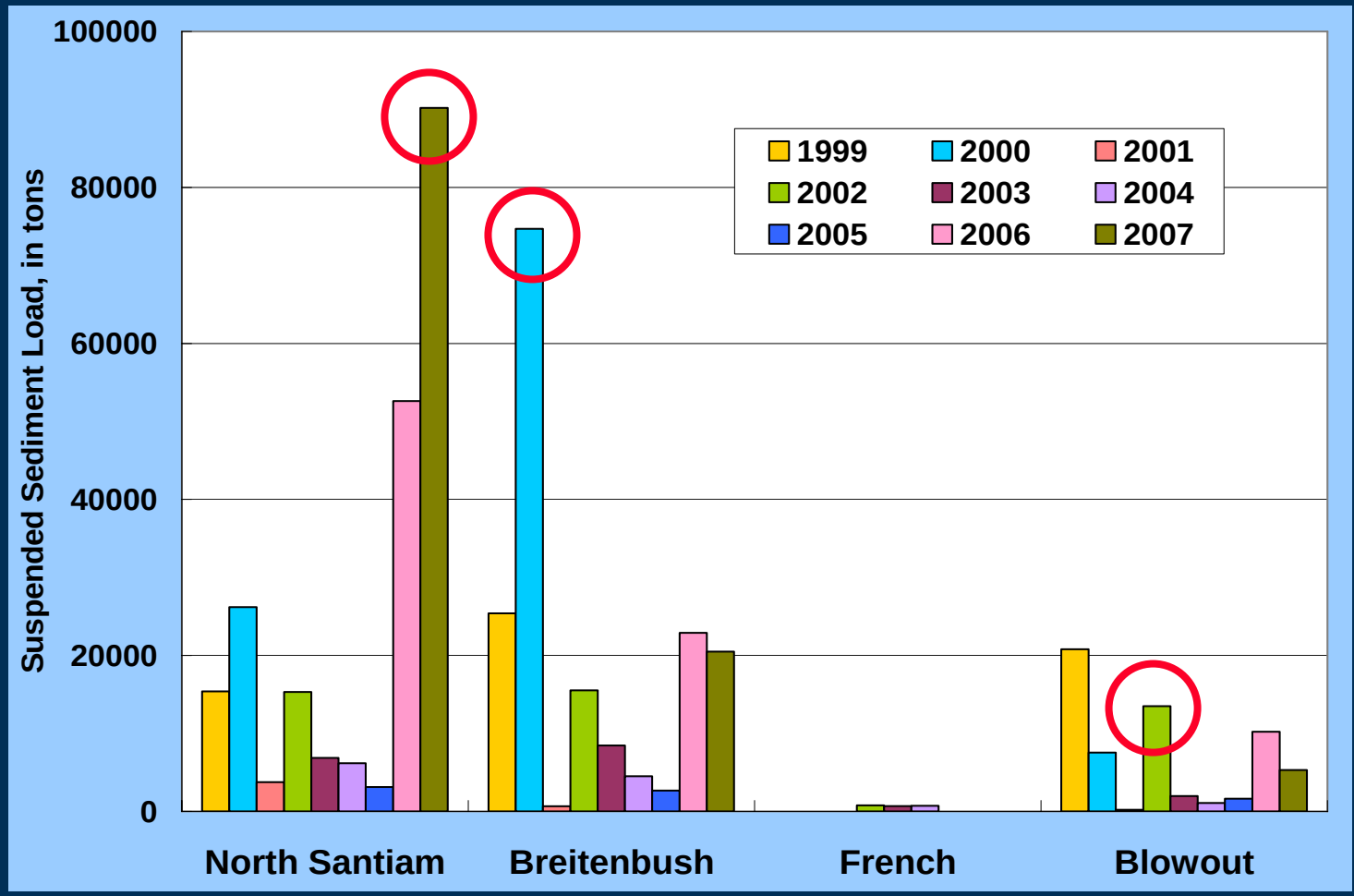
North Santiam River Basin



Annual Suspended-Sediment Loads
Upper Basin



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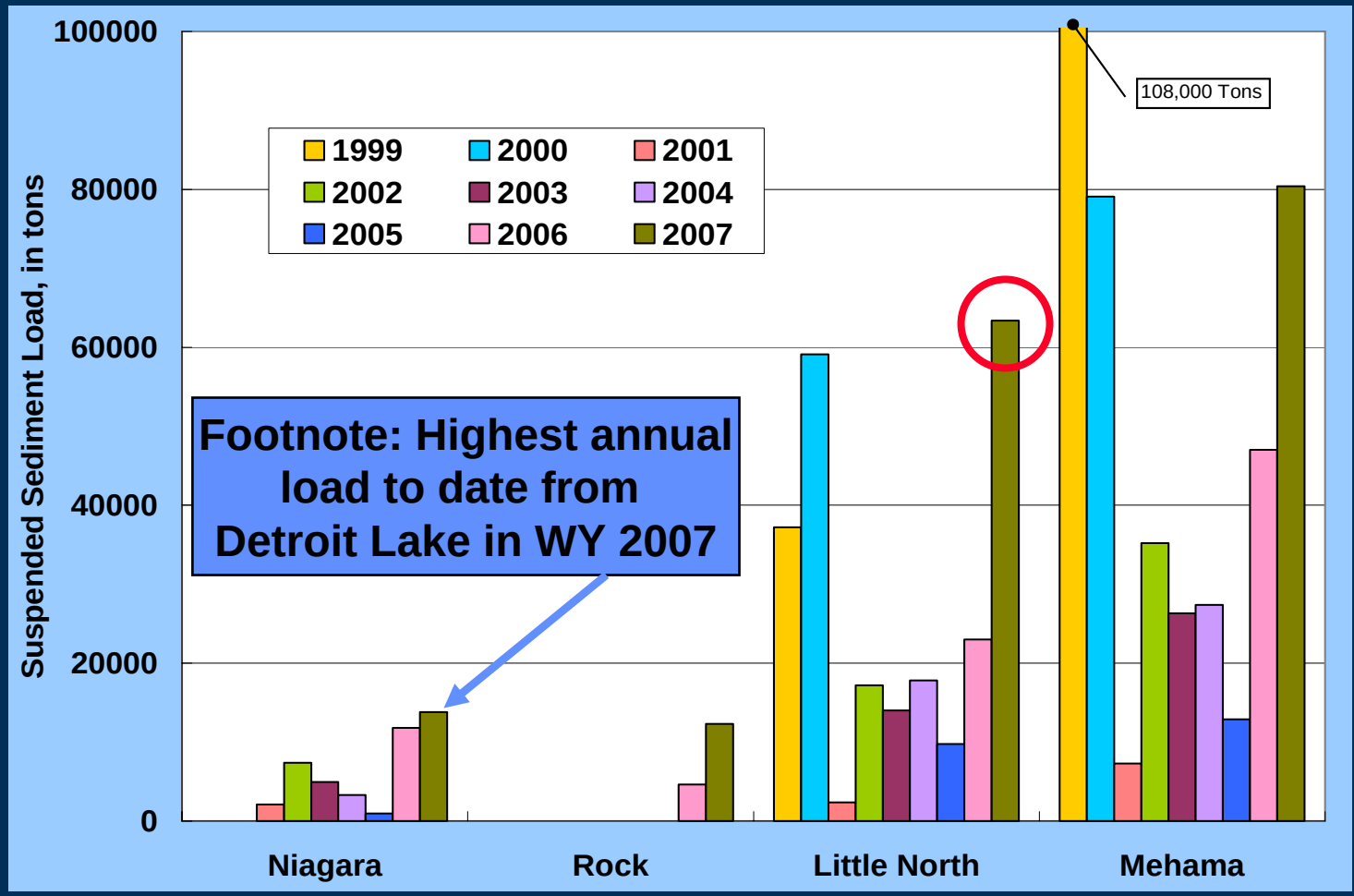
Annual Suspended-Sediment Loads
Lower Basin



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Breitenbush R- E Humbug Cr Landslide - Nov 99

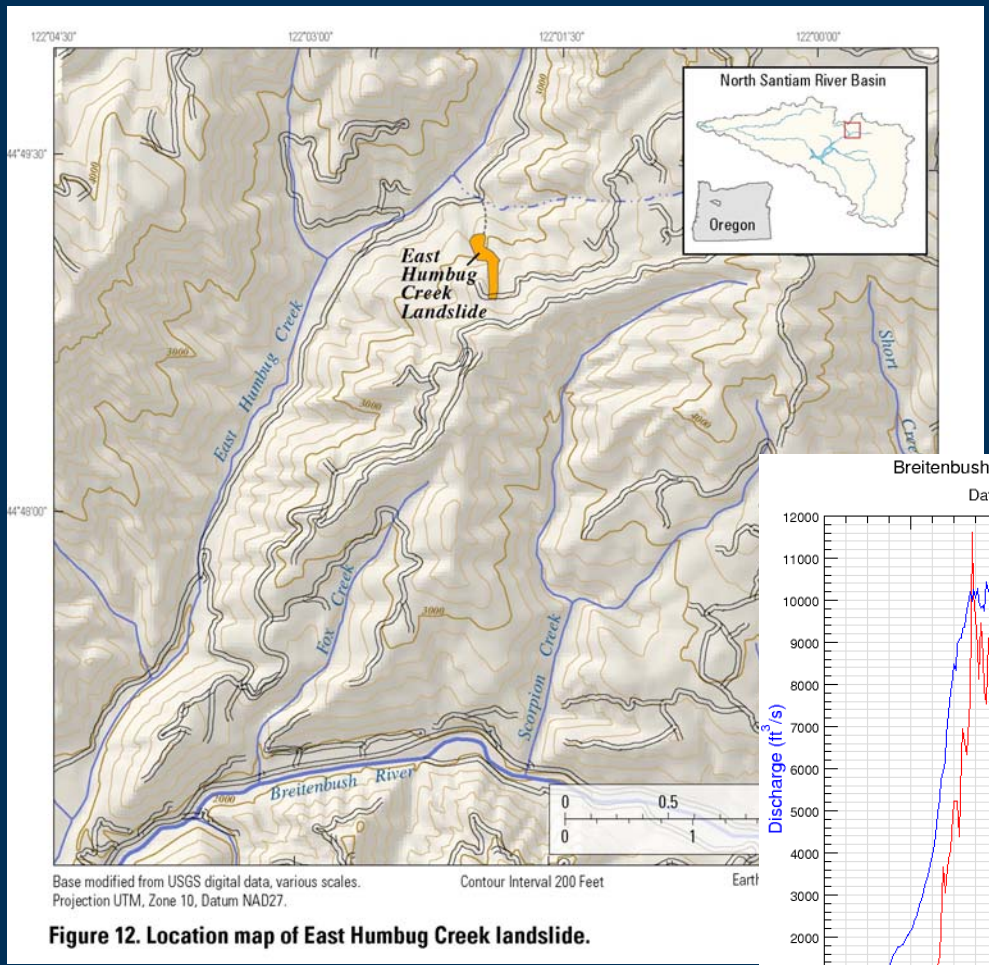
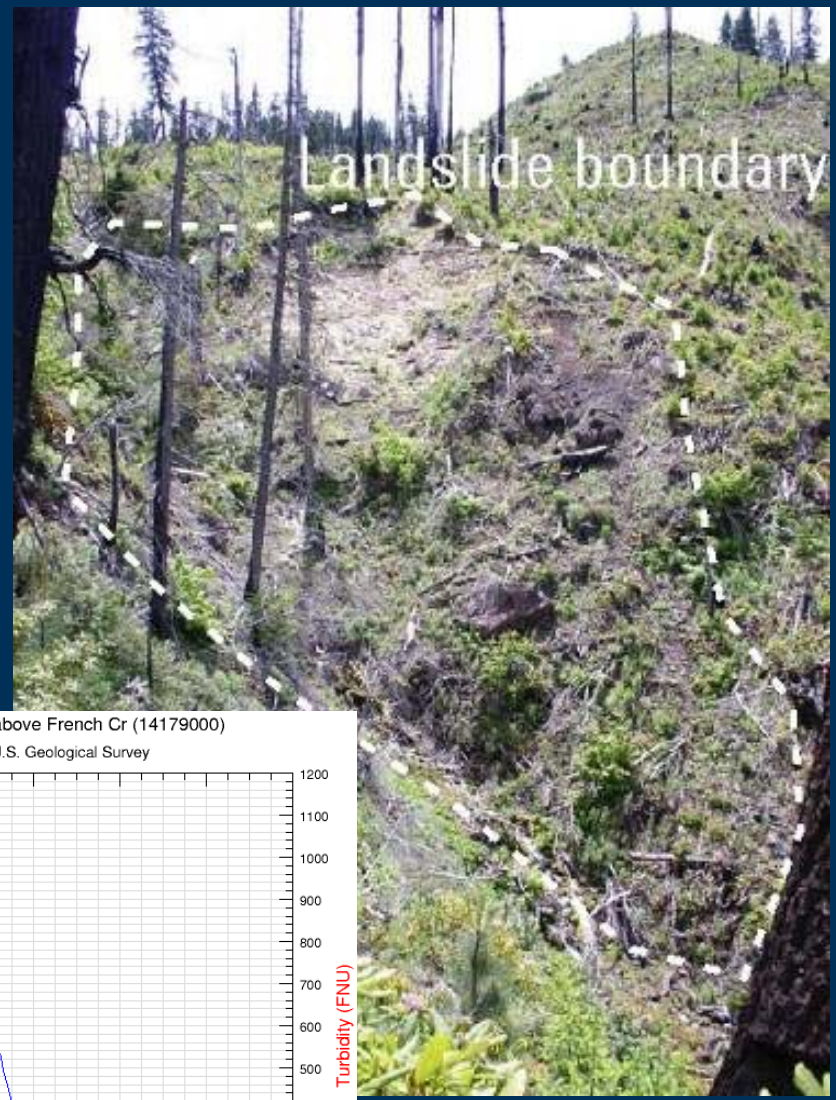
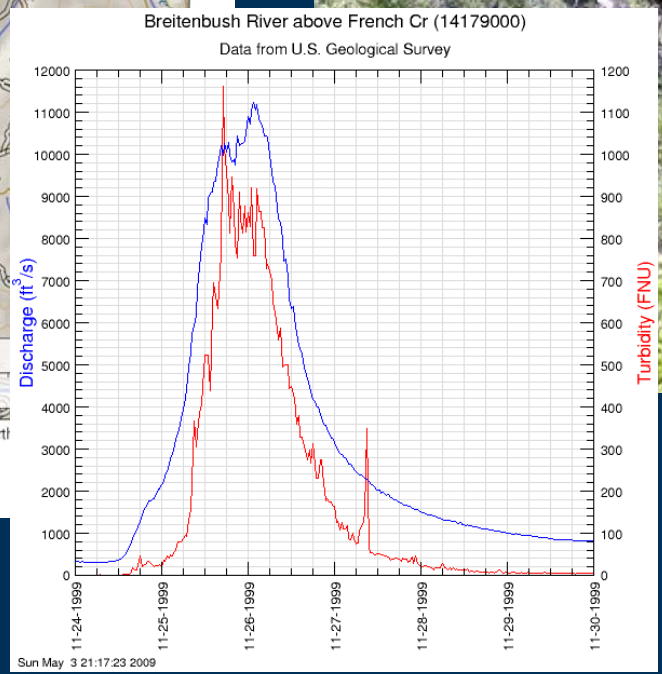


Figure 12. Location map of East Humbug Creek landslide.





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E Humbug Creek hillslope failure

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Blowout Basin- Ivy Cr Road Failure - Dec 01

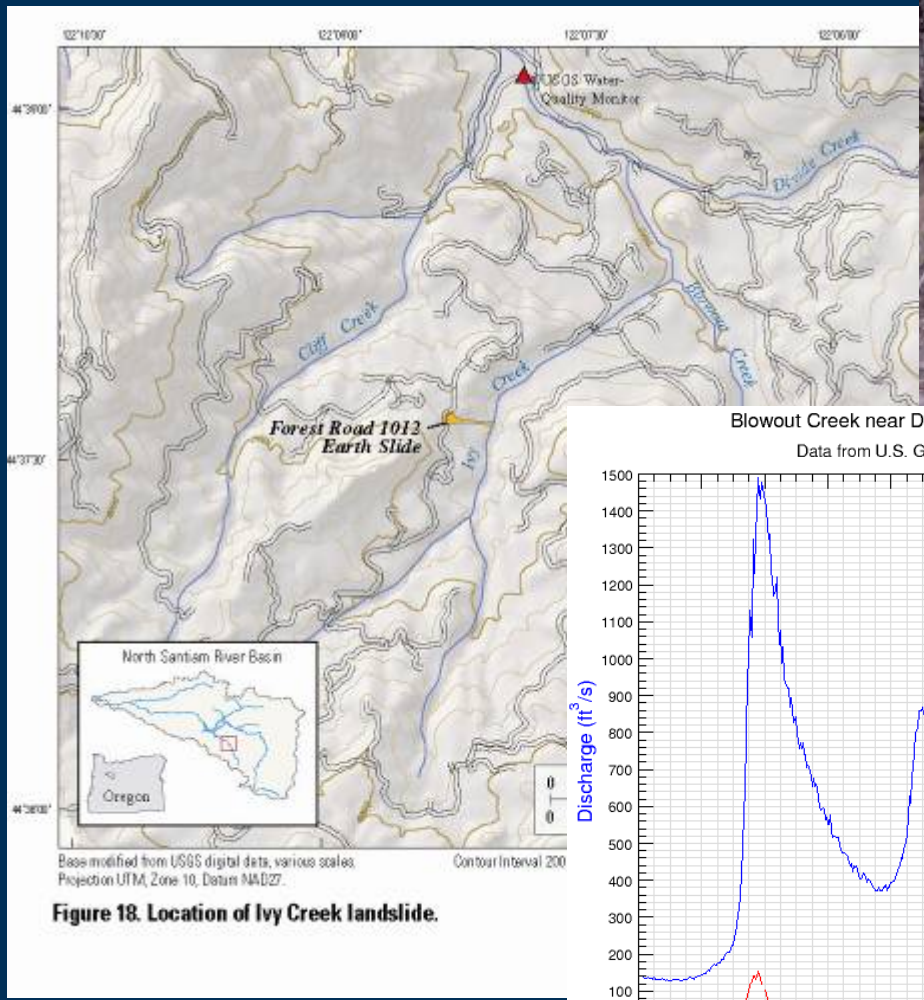
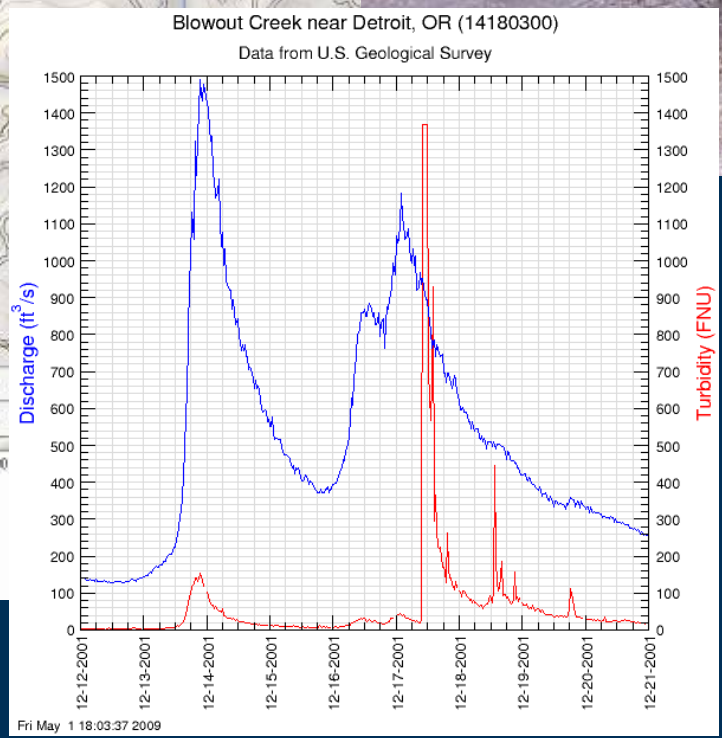


Figure 18. Location of Ivy Creek landslide.



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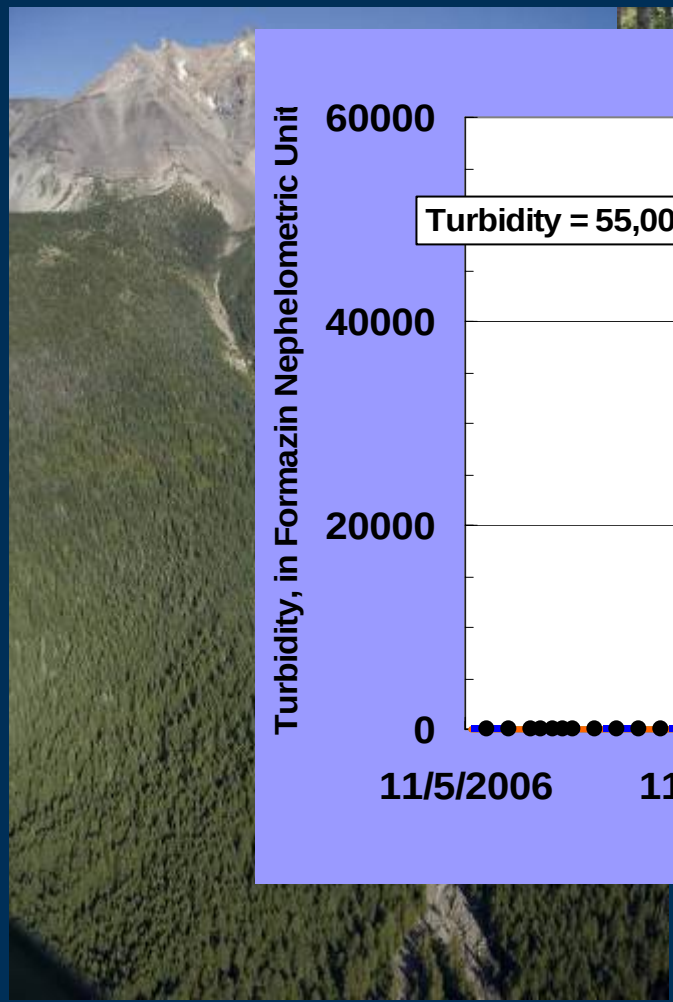
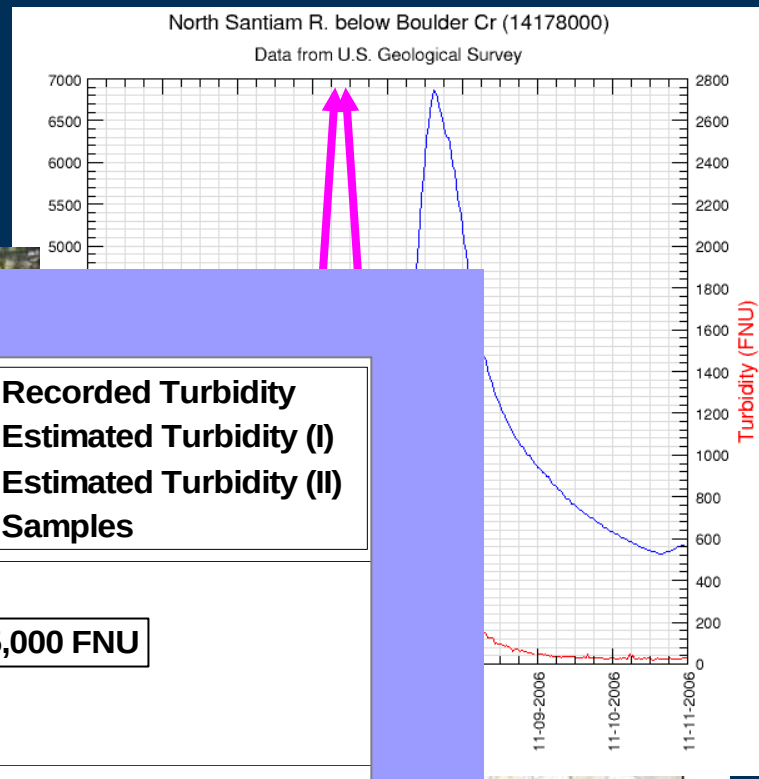
Milk Cr- N Santiam R Debris Flow – Nov 06





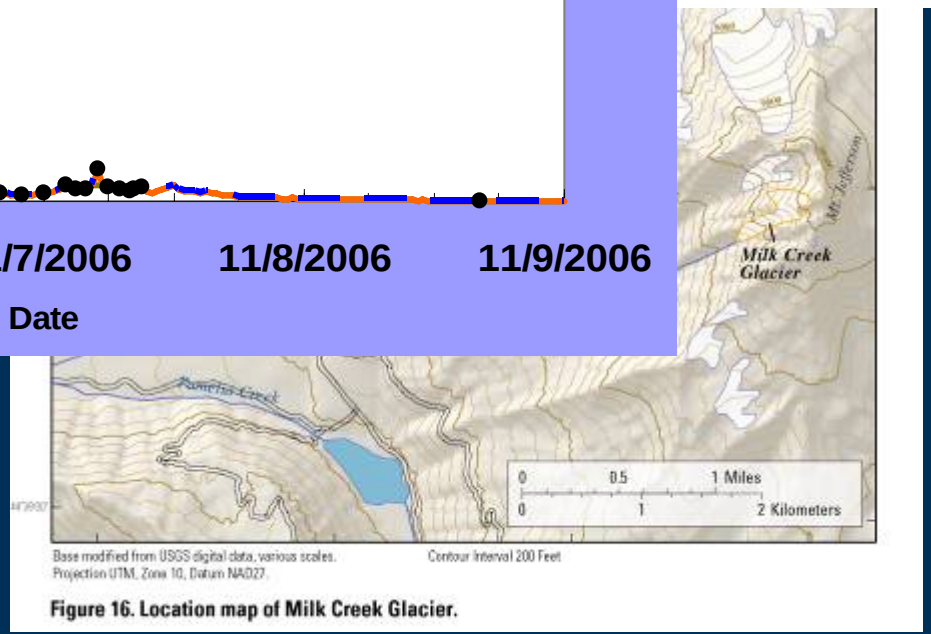


Figure 16. Location map of Milk Creek Glacier.

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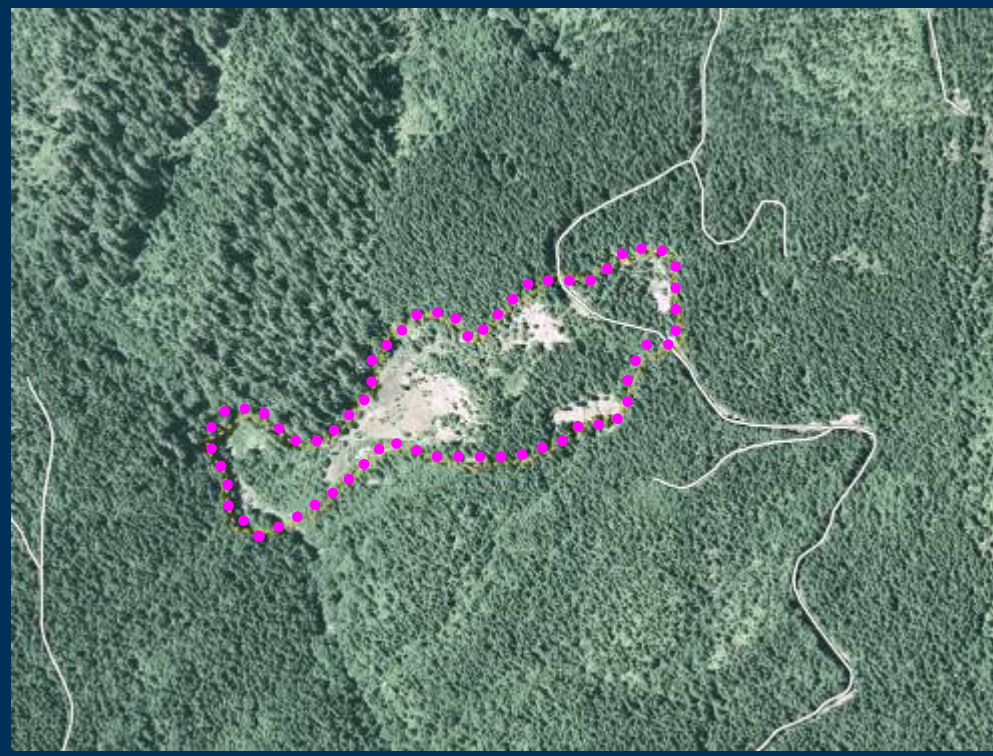
Little North Santiam River and Evans Creek Landslide – many dates



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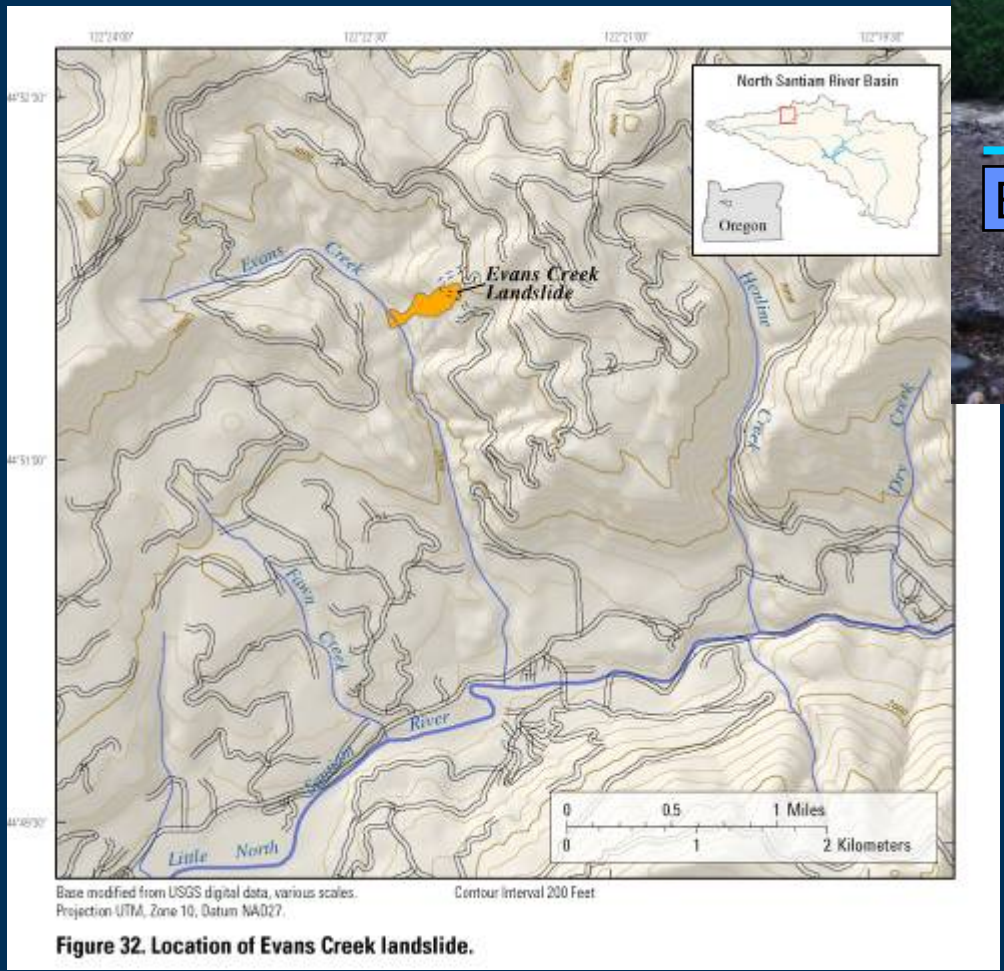
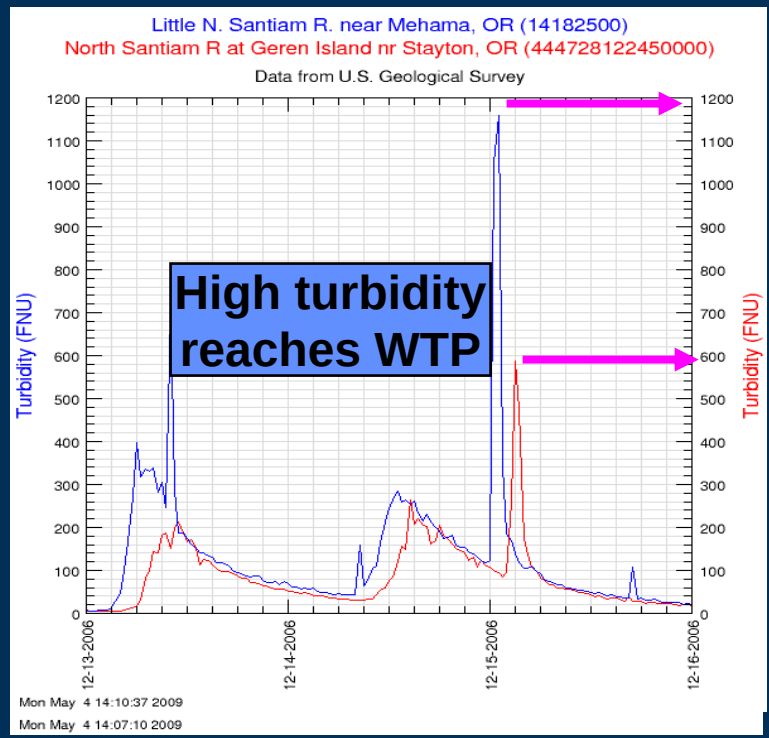
Evans Creek & Little North Santiam R- Dec 06



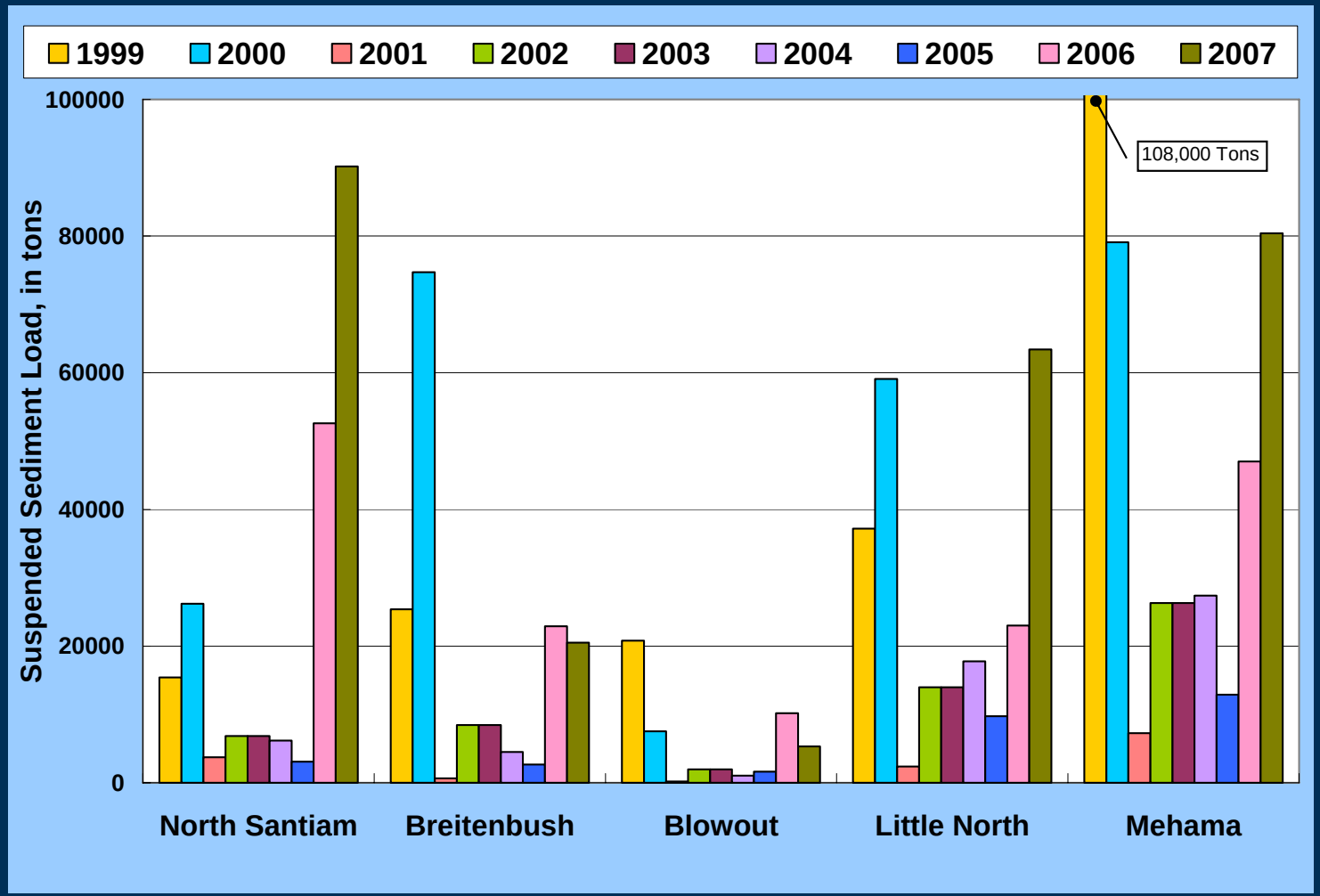
Base modified from USGS digital data, various scales. Contour Interval 200 Feet
Projection UTM, Zone 10, Datum NAD27.

Figure 32. Location of Evans Creek landslide.



USGS

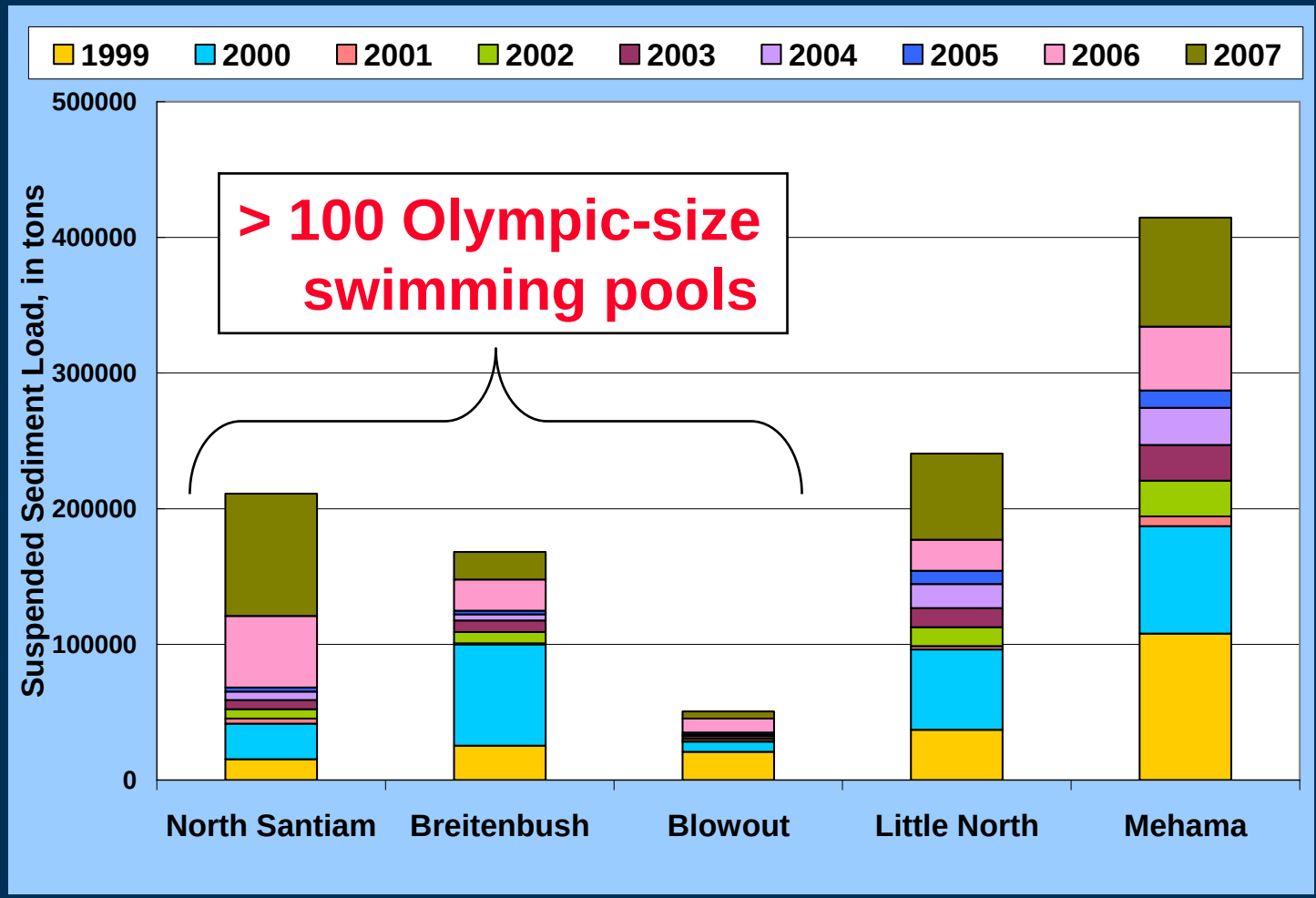
Annual Suspended-Sediment Loads



USGS

Sum of Annual Suspended-Sediment Loads

Water Years 1999-2007 (9 years)

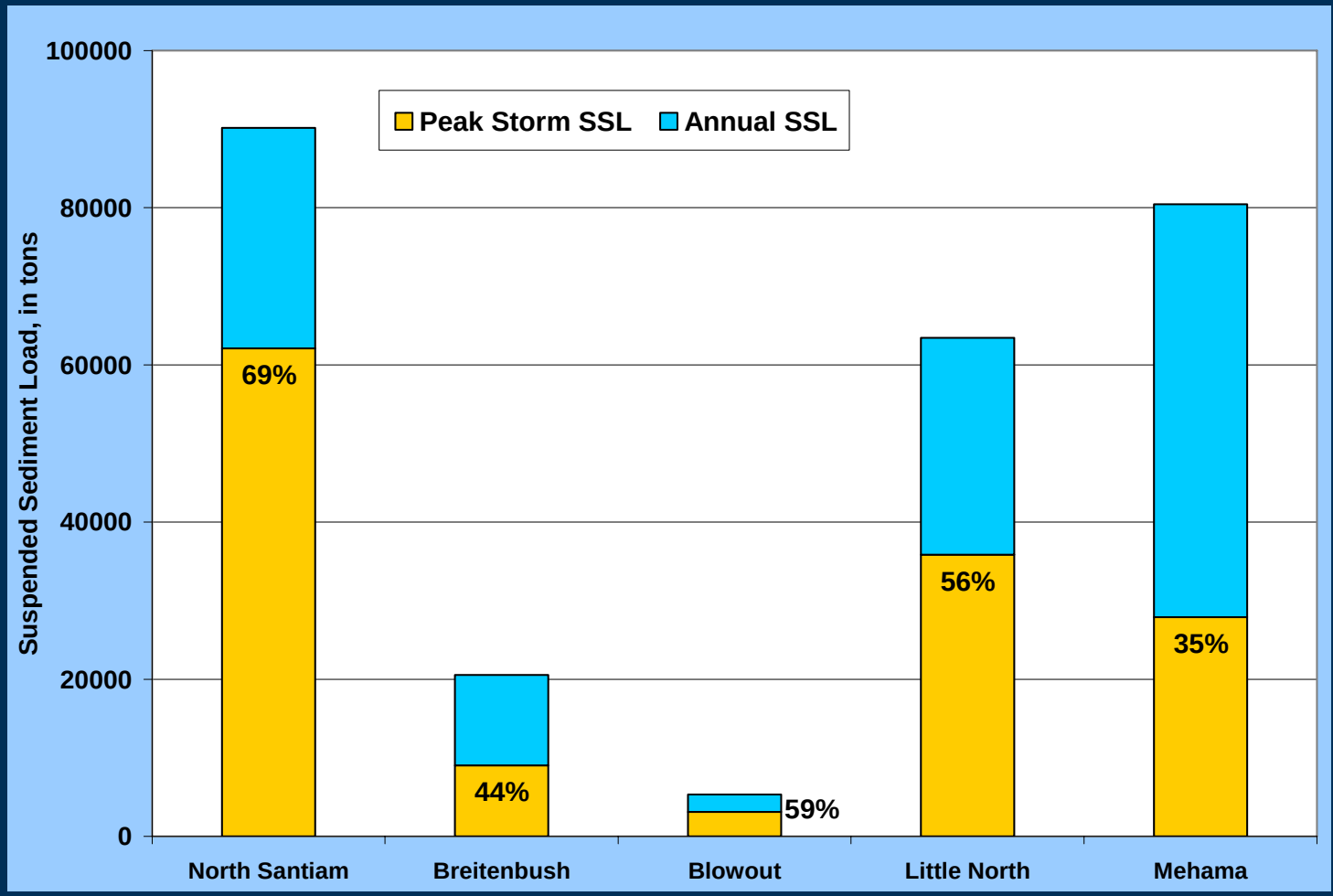


USGS

Take home message:

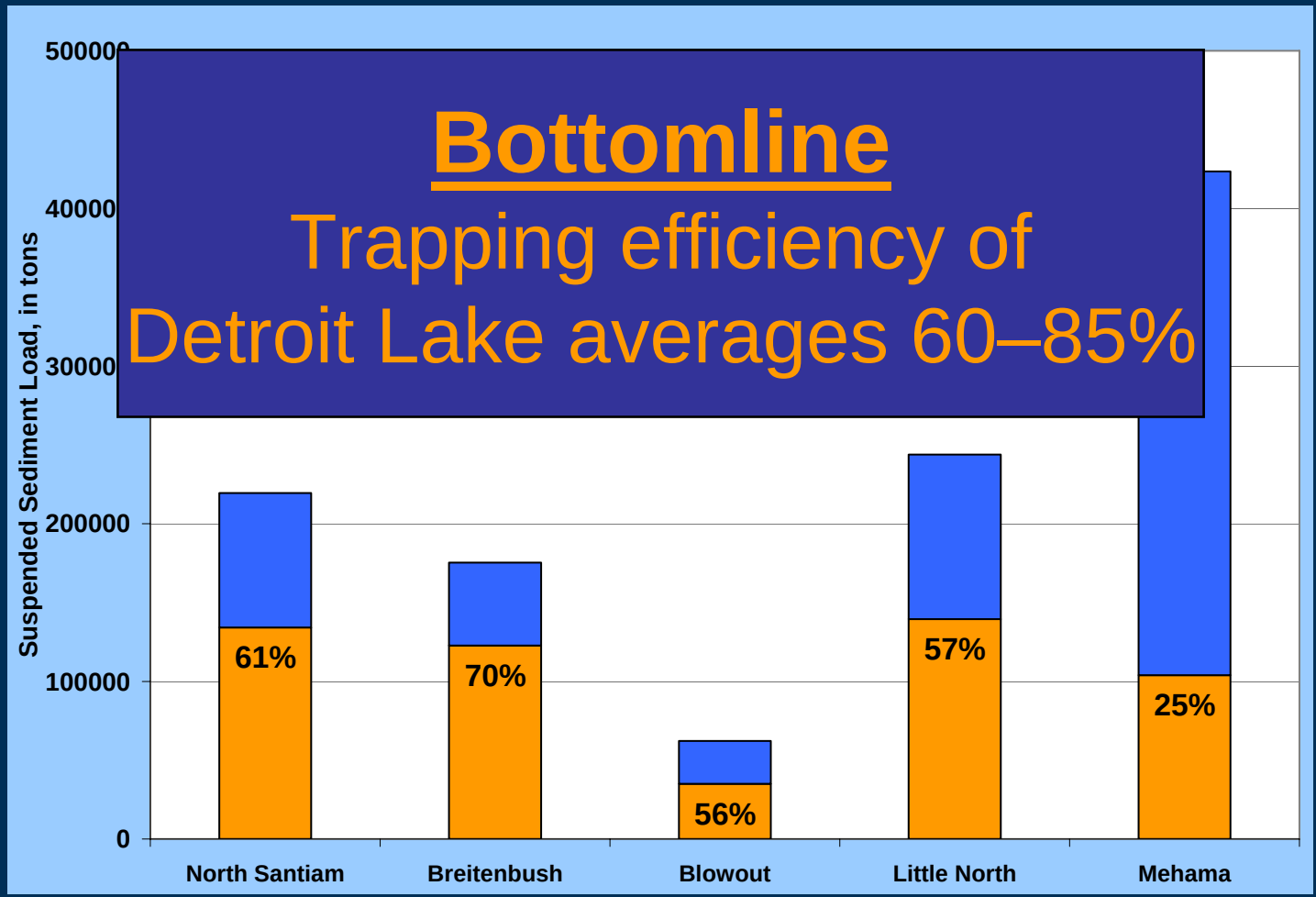
Storms move the most sediment

2007 Annual load and 3-day Storm load



USGS

Sum of Peak 3-Day Storm load
Water Years 1999-2007 (9 years)

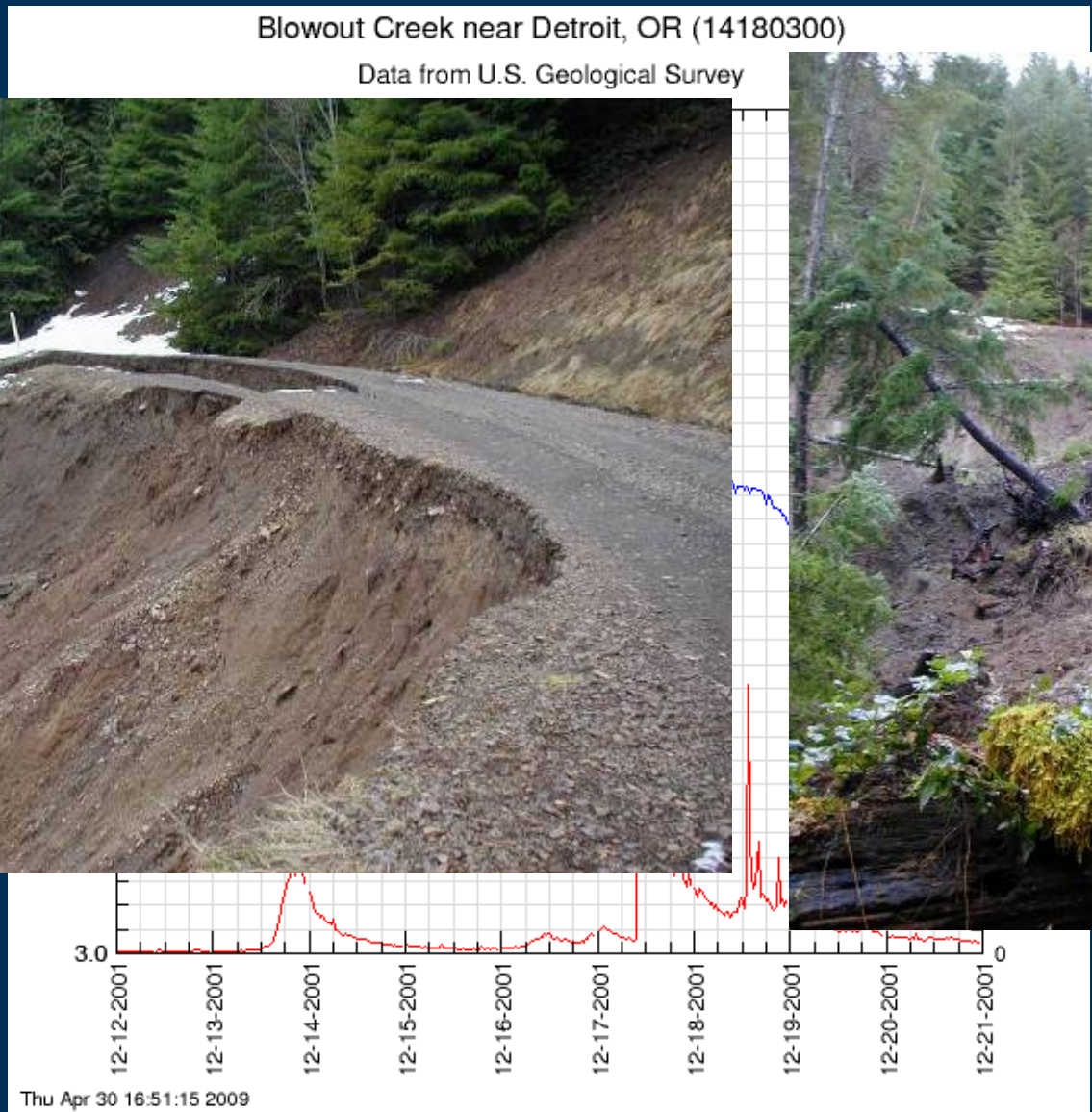


USGS

Advantages of Continuous Monitoring

Stage and Turbidity Events

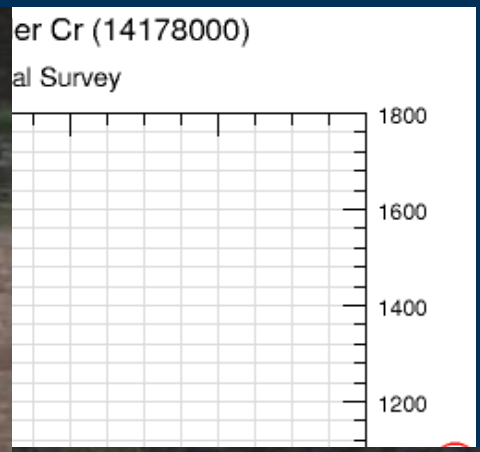
Blowout- Landslide December 17, 2001

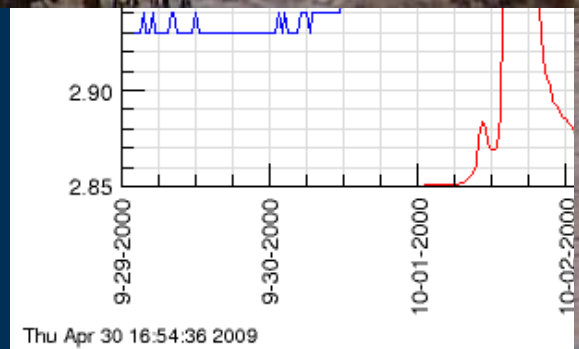


USGS

Take home message: Turbidity can be a better surrogate for sediment concentration than streamflow

N Santiam –Mt Jefferson event of Oct 1, 2000





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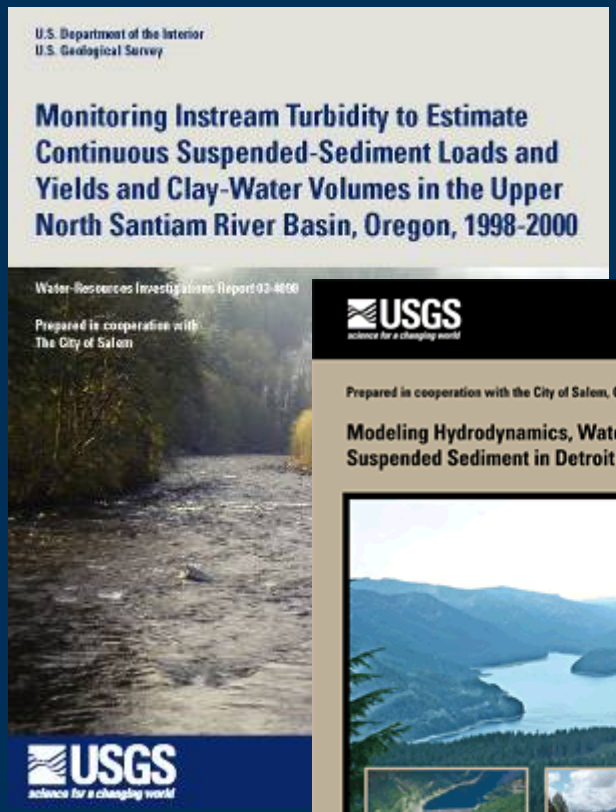
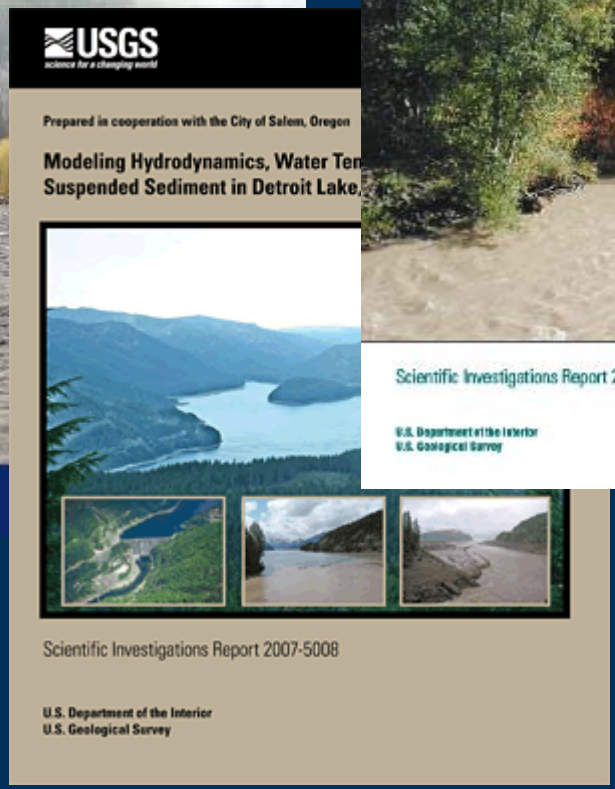
Salem Water Treatment Upgrades

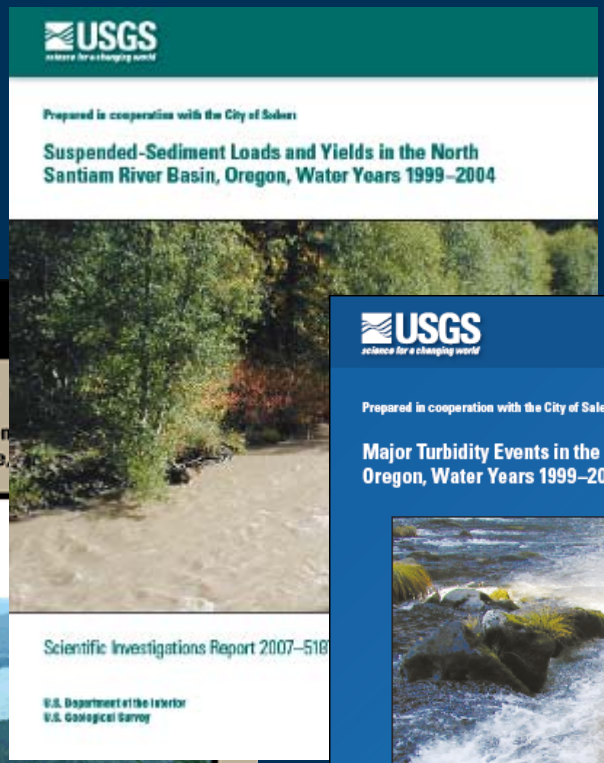
- ***Before 1996***: Two Slow Sand Filters & Infiltration Gallery. Max= 20 NTU for no more than 2 weeks
- ***1998:*** Added pretreatment, 3rd filter pond. Perimeter drains installed and connected to Caisson
- ***2000***: Added 4th filter pond. Perimeter drains installed and connected to Caisson
- ***2002***: Added Roughing Filter & pump station
- ***2003***: Aquifer water and Keizer intertie now used as emergency backup
- ***Upgrades***: Avoid shut down during prolonged high turbidity events. Max > 300 NTU, 20 NTU indefinite
- New system has not been tested to maximum level

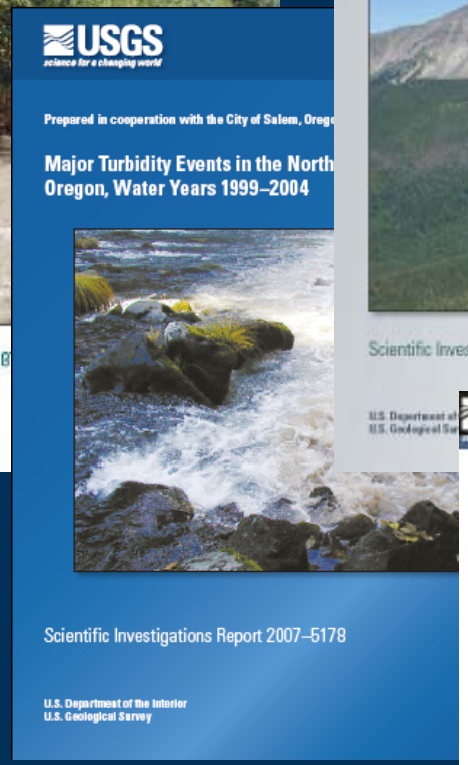
USGS

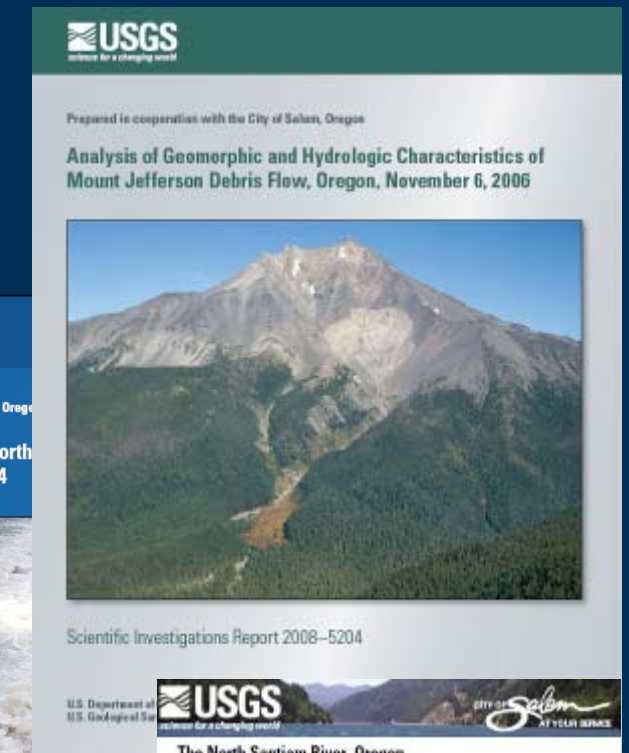
PUBLICATIONS











USGS http://or.water.usgs.gov/santiam

Future Work

- Analysis of fluvial sediment and turbidity from the North Santiam River Basin and Mount Jefferson Debris Flow, Oregon, 2006 (due October 2009)
- Analysis of LIDAR-derived sediment contribution from multiple landslide source areas in the Little North Santiam River (master thesis 2010)
- Water Quality in the North Santiam River Basin: A comparison of water year 2007 to the period of record (due December 2009)

USGS

QUESTIONS ?

USGS