Turbidity and suspended sediments after road improvements and forest harvest in streams of the TWS

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AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

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Key Points:
- Forestry can occur with limited inputs of fine sediment to streams
- Change thresholds provide a biological context to test results
- Turbidity and flow are not consistent predictors of suspended sediment

Supporting Information:
- Supporting Information S1

Suspended sediment and turbidity after road construction/improvement and forest harvest in streams of the Trask River Watershed Study, Oregon

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Trask River Watershed Study

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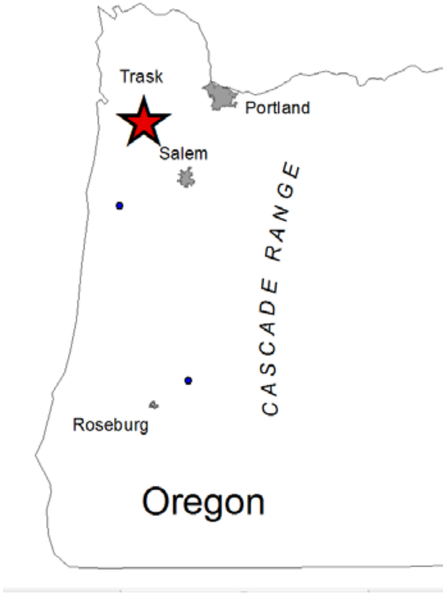
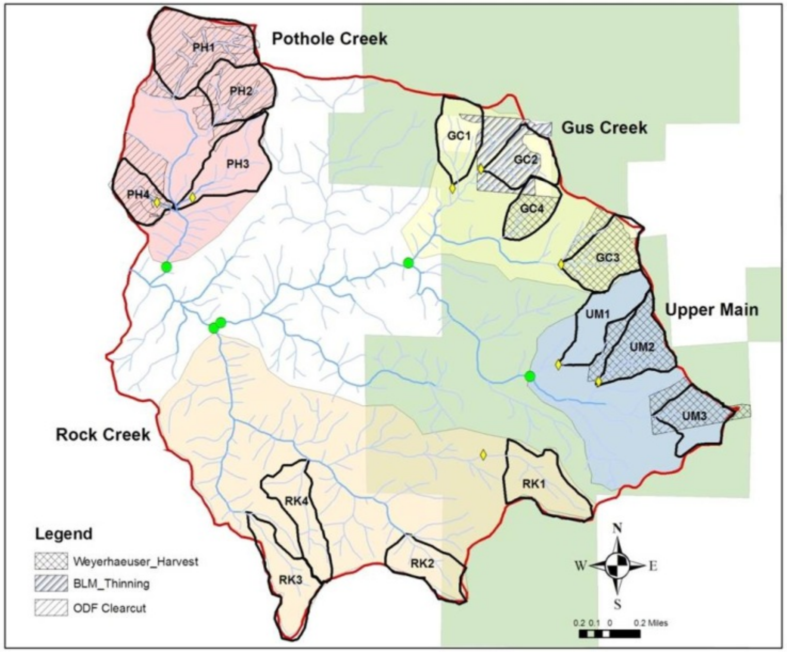
Dr. Ivan Arismendi, *OSU Fisheries and Wildlife*

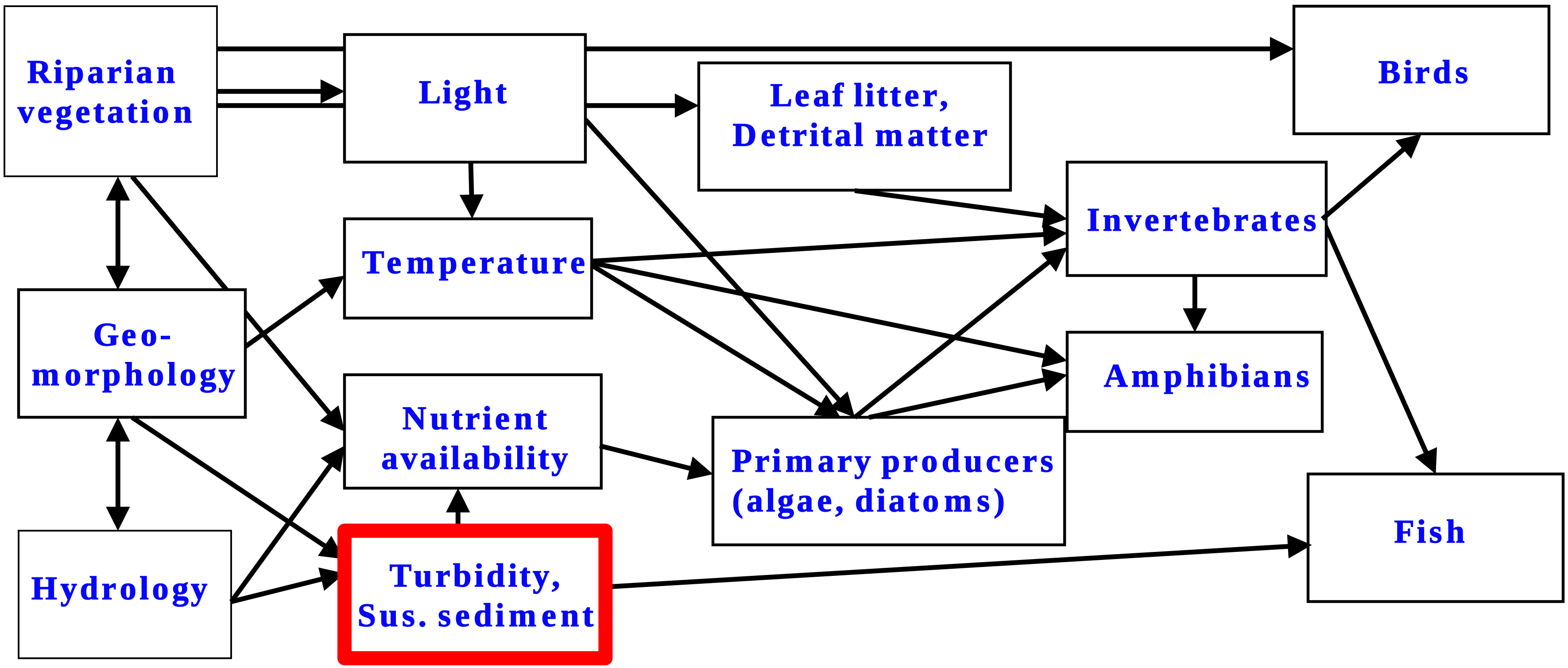
- The Trask Study takes a long term and multi-disciplinary approach to quantify the effects of forest harvest on the physical, chemical and biological characteristics of headwater streams



- The Trask Study design uses a nested paired watershed approach with both treatment and control basins. The reference watershed is left unharvested. Three treatment watersheds are harvested using contemporary best management practices (BMP)



Trask River Watershed Study





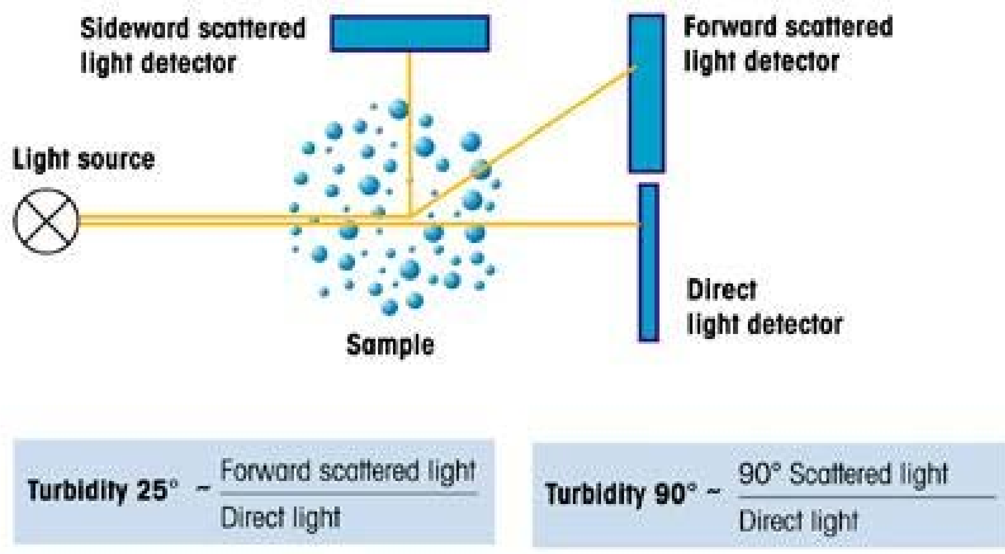


Turbidity

- Turbidity is the cloudiness of a fluid caused by suspended individual particles that are generally invisible to the naked eye

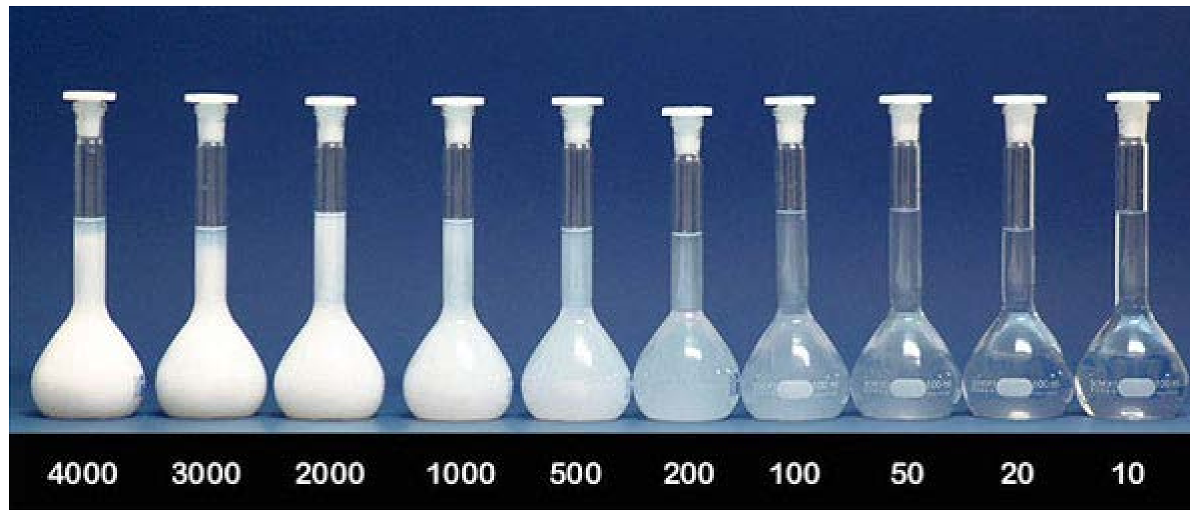
Turbidity measurements

- Nephelometric Turbidity Unit (**NTU**) measures scattered light at 90 degrees from the incident white light beam (EPA method 180.1)



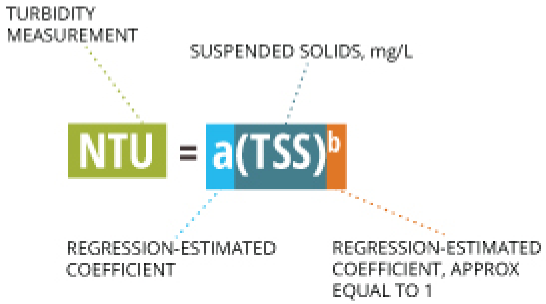
https://or.water.usgs.gov/grapher/fnu.html

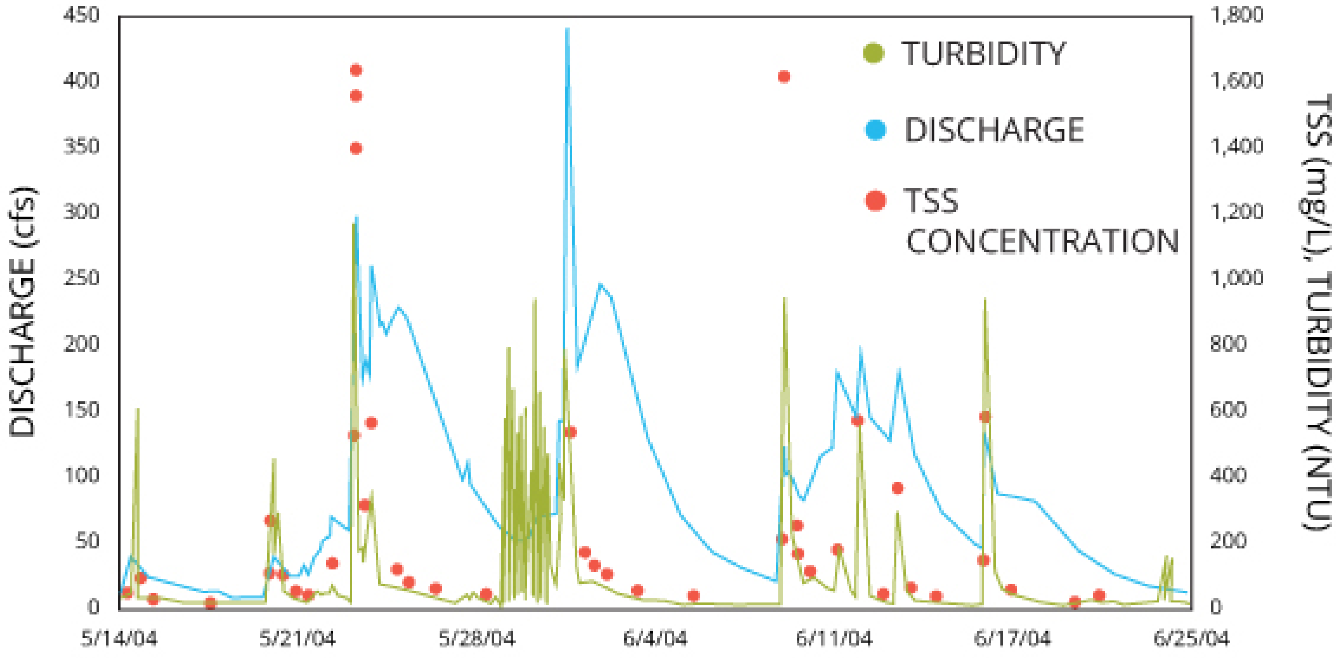
NTUs



250 100 50 25 10

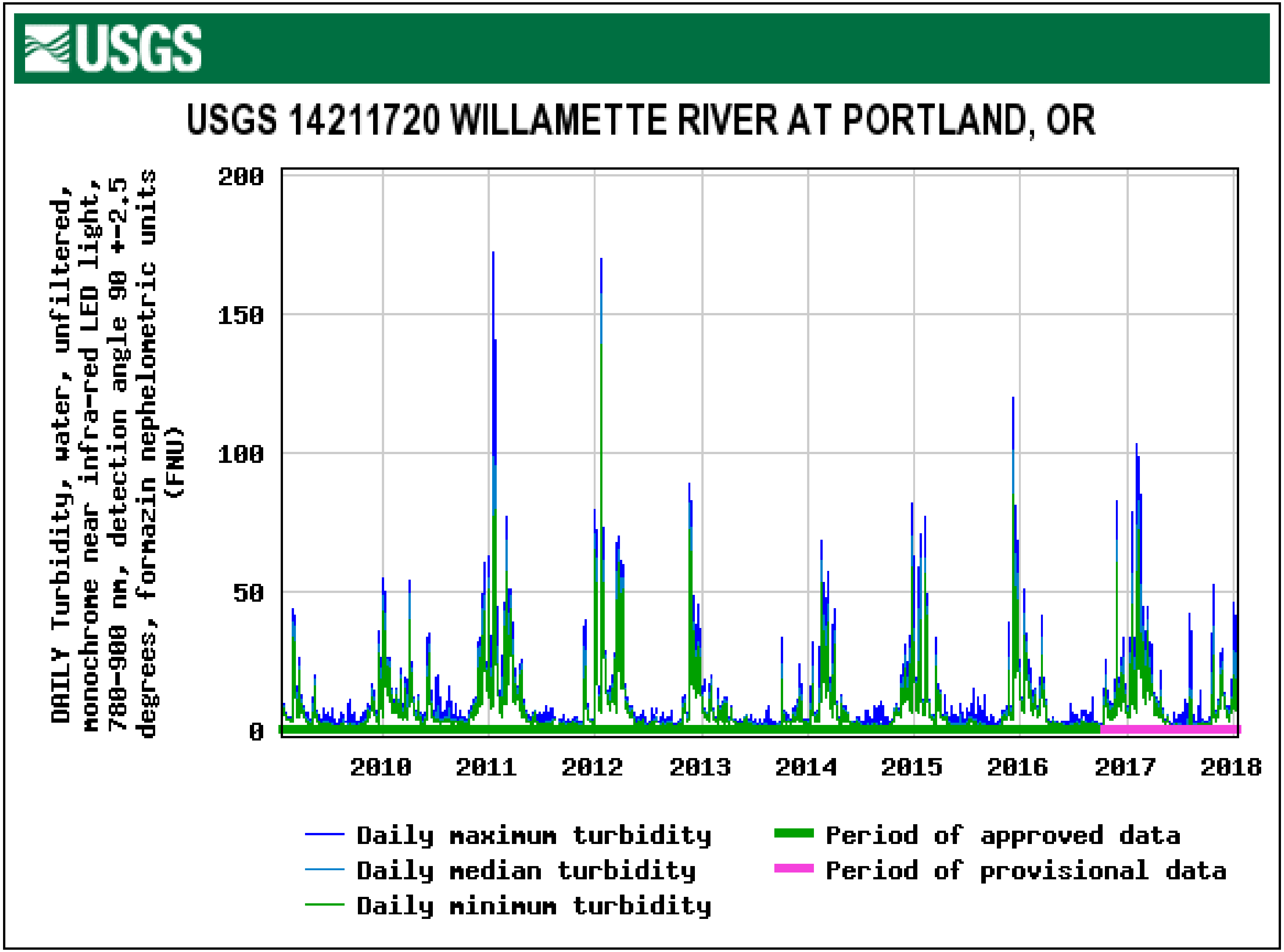
Turbidity & suspended sediments





http://www.fondriest.com/environmental-measurements/equipment/measuring-water-quality/turbidity-sensors-meters-and-methods/

Turbidity regimes



Impacts on freshwaters

Organism	Level of detection	Effects	Author
Stream function			
Photosynthetic efficiency	Addition: 6 g/L of clay (<0.5 mm diameter) for 3 days	Decrease in algal photosynthetic efficiency	Izaguirre et al. (2009)
Primary production (PP)	Turbidity = 5 NTU	Decline (3-13%)	Lloyd et al. (1987)
	Turbidity >25 NTU	Decline (13-50%)	Lloyd et al. (1987)
Primary producers			
Periphyton & macrophytes	Increase from 5 to 10 NTU	Decrease in periphyton biomass (chl a) and % cover of macrophytes	Parkhill and Gulliver (2002)
Algal community	Addition: 6 g/L of clay (<0.5 mm diameter)	Change in algal community composition	Izaguirre et al. (2009)

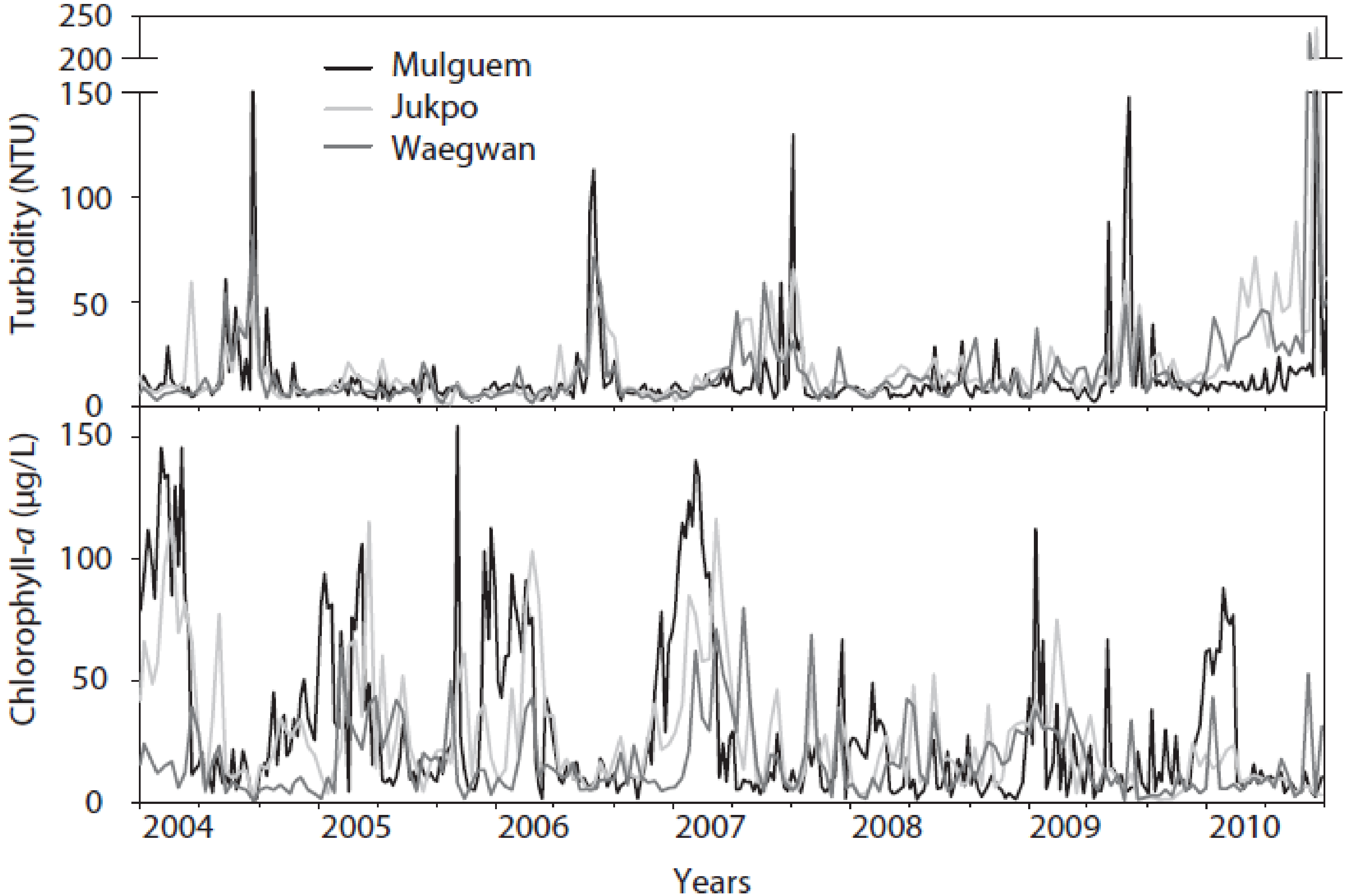


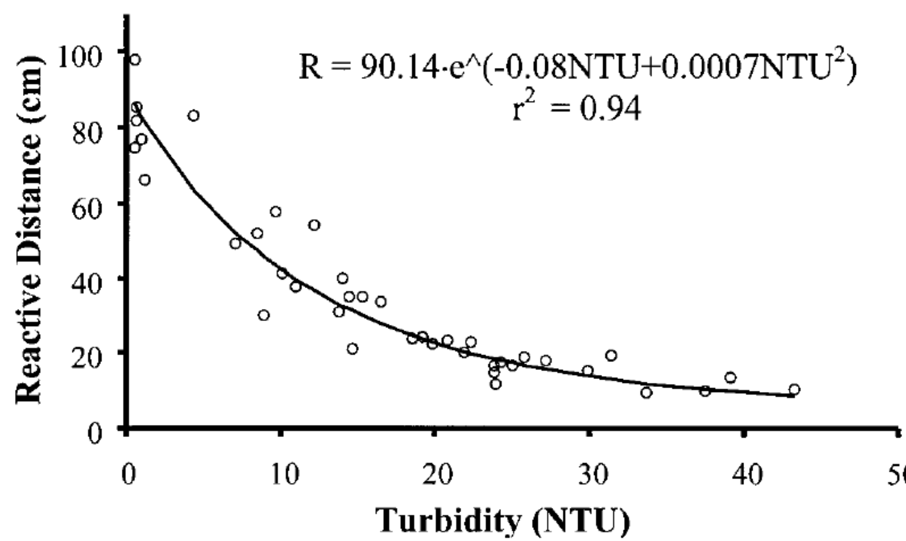
Fig. 5. Time series changes in turbidity and chlorophyll-a in the Nakdong River. NTU, nephelometric turbidity units.

Yoon Kim et al. (2011)

Fish				
	Coho Salmon	Turbidity >70 NTU	Avoidance of the zones with high turbidity	Bisson and Bilby (1982)
	Community	Turbidity >4000 NTU	Decreased prey consumption among species not adapted to highly turbid channels	Bonner and Wilde (2002)
	Cutthroat Trout and Coho Salmon	Turbidity >50 NTU, 100 NTU, and 400 NTU	Dramatic reduction of drift prey captures at 50 NTUs. Benthic feeding success of both species at 100 NTU was at least 70% of their feeding performance in clear water (i.e., 0 NTU), whereas neither species fed at 400 NTU	Harvey and White (2008)
	Rainbow Trout and Coho Salmon	Turbidity >22 NTU for 11 days	55% reduction of fry length and 45% reduction in weight	Sigler, Bjornn, and Everest (1984)
	Rainbow Trout	Turbidity >15 NTU and >30 NTU	Reactive distance 80% and 45% at 15 and 30 NTU, respectively, of normal reactive distances. No effect on pursuit speed.	Barrett et al. (1992)
	Rainbow Trout	Turbidity >60 NTU	Reactive distance changes from 30 to 10 cm during a 60 NTU pulse. Lower feeding during 60 NTU pulse.	Berg and Northcote (1985)

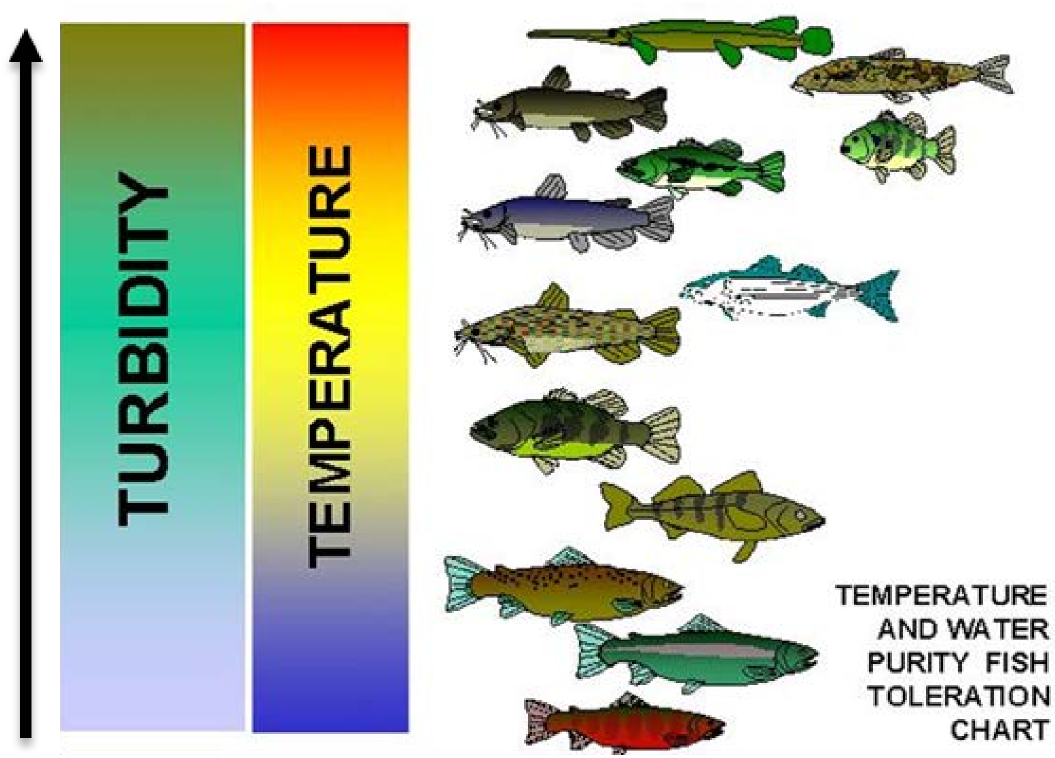
Effects of turbidity and fine sediments

- Fish: physical damage due to gill abrasion; diminished predatory abilities because of reduced reactive distance to prey



Sweka and Hartman (2001)

Environmental regimes and fish assemblages



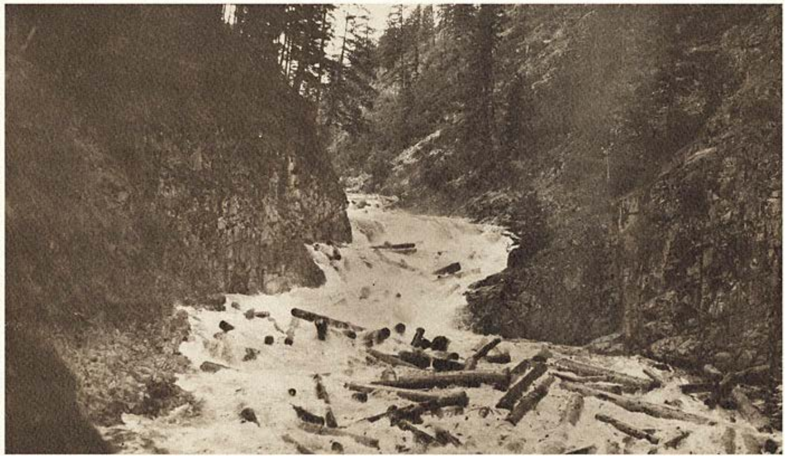
http://www.combat-fishing.com/streamecology.html

Historically, roads deliver fine sediments to streams affecting instream biota

- Increased fine sediment (<2mm) and turbidity from erosion of road surfaces (Brown and Krygier, 1971; Reid and Dunne, 1984; Bilby et al., 1989; Lane and Sheridan, 2002; Gomi et al., 2005)

- Increases in fine sediment and turbidity contributed to declines in populations and negative cascade effects at ecosystem level (Cederholm et al., 1981; Wood and Armitage, 1997; Henley et al., 2000)

Wind River, WA (1910)



http://www.ohs.org/education/oregonhistory/index.cfm

Do contemporary forest practices deliver fine sediments to streams?

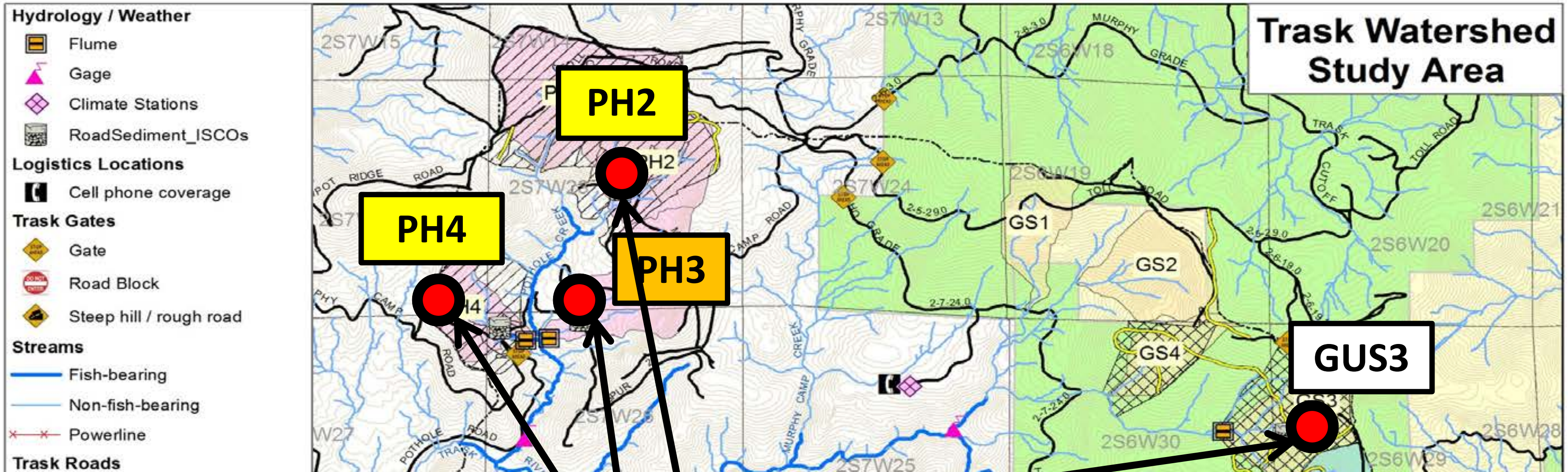
- Previous studies provide foundation for current forest practices designed to <u>minimize negative impacts</u>. But, we cannot make generalizations from previous studies

Trask Watershed Study, Pothole

Questions

Do contemporary forest practices increase turbidity and suspended sediment concentrations <u>at road crossings</u> in headwater streams?

Do turbidity and suspended sediment concentrations <u>respond consistently</u> across road crossings?



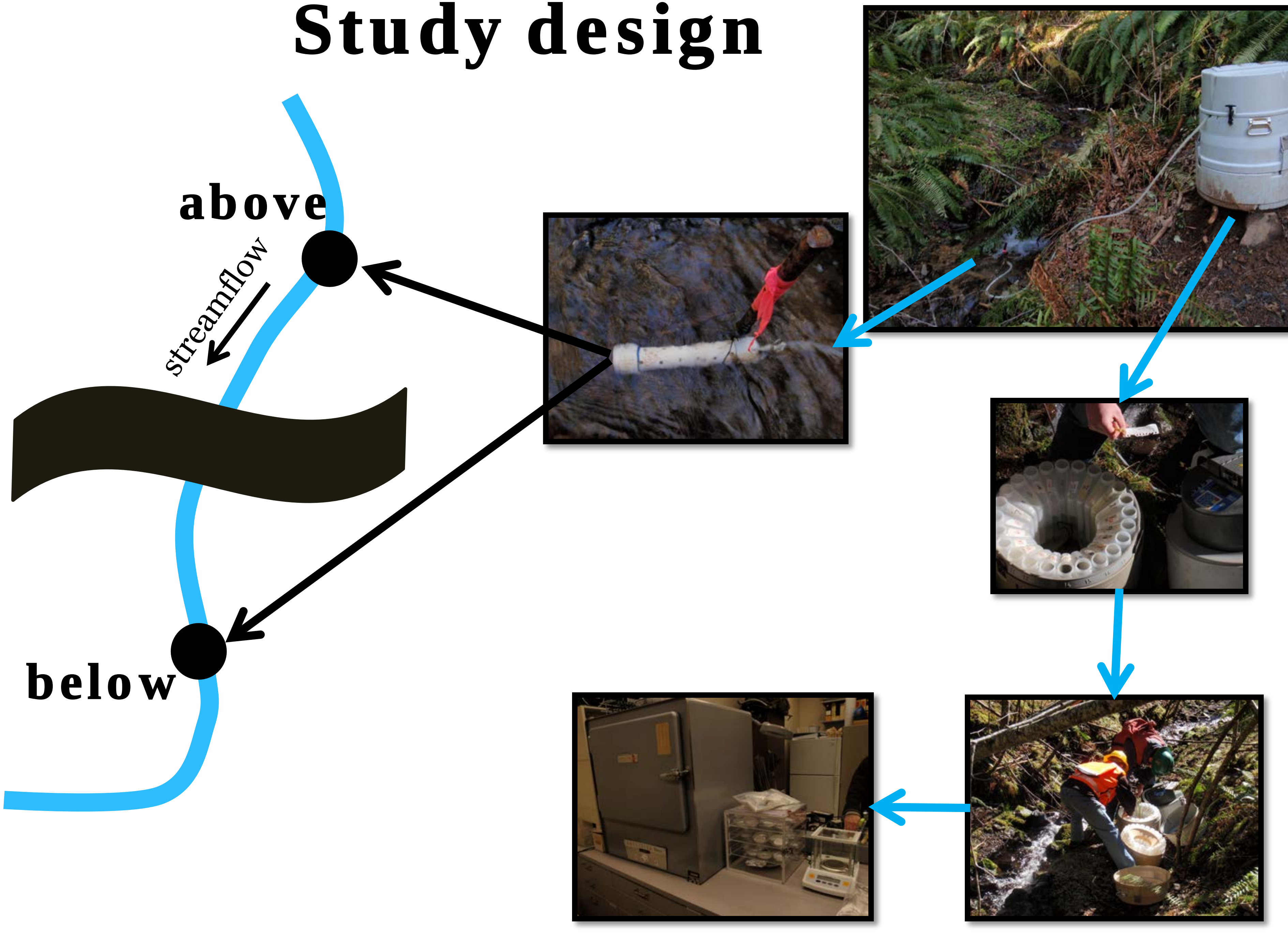
UM2 – 5.3 ha

re-surfaced (lift of rock) and re-constructed in 2007

PH3 – **reference road** (36 ha)

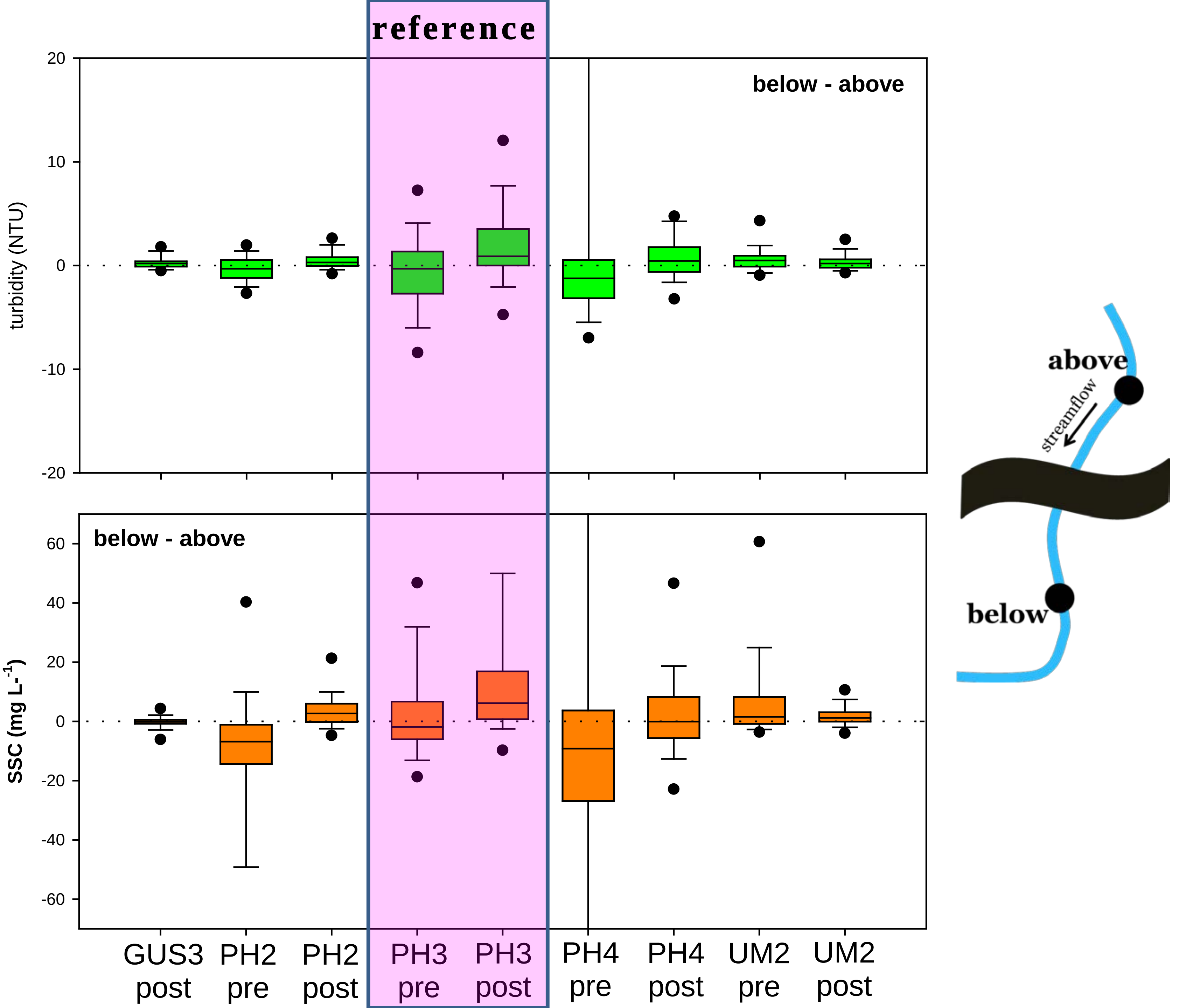
pre-existing road with no intervention (no harvest)

Study design



Timeline

PRE-road intervention	POST-road intervention	
old or non-existing road	road improvement	RI + forest harvest & hauling
before	**RI**	**RI+FH**
		
Jun 2010-Apr 2011	Jul 2011-Mar 2012	Jun 2012-Mar 2013



reference
below - above
turbidity (NTU)
20
10
0
-10
-20
below - above
SSC (mg L-1)
60
40
20
0
-20
-40
-60
GUS3 post
PH2 pre
PH2 post
PH3 pre
PH3 post
PH4 pre
PH4 post
UM2 pre
UM2 post
above
streamflow
below

Biological relevance?

Is below-above <= threshold "C"?

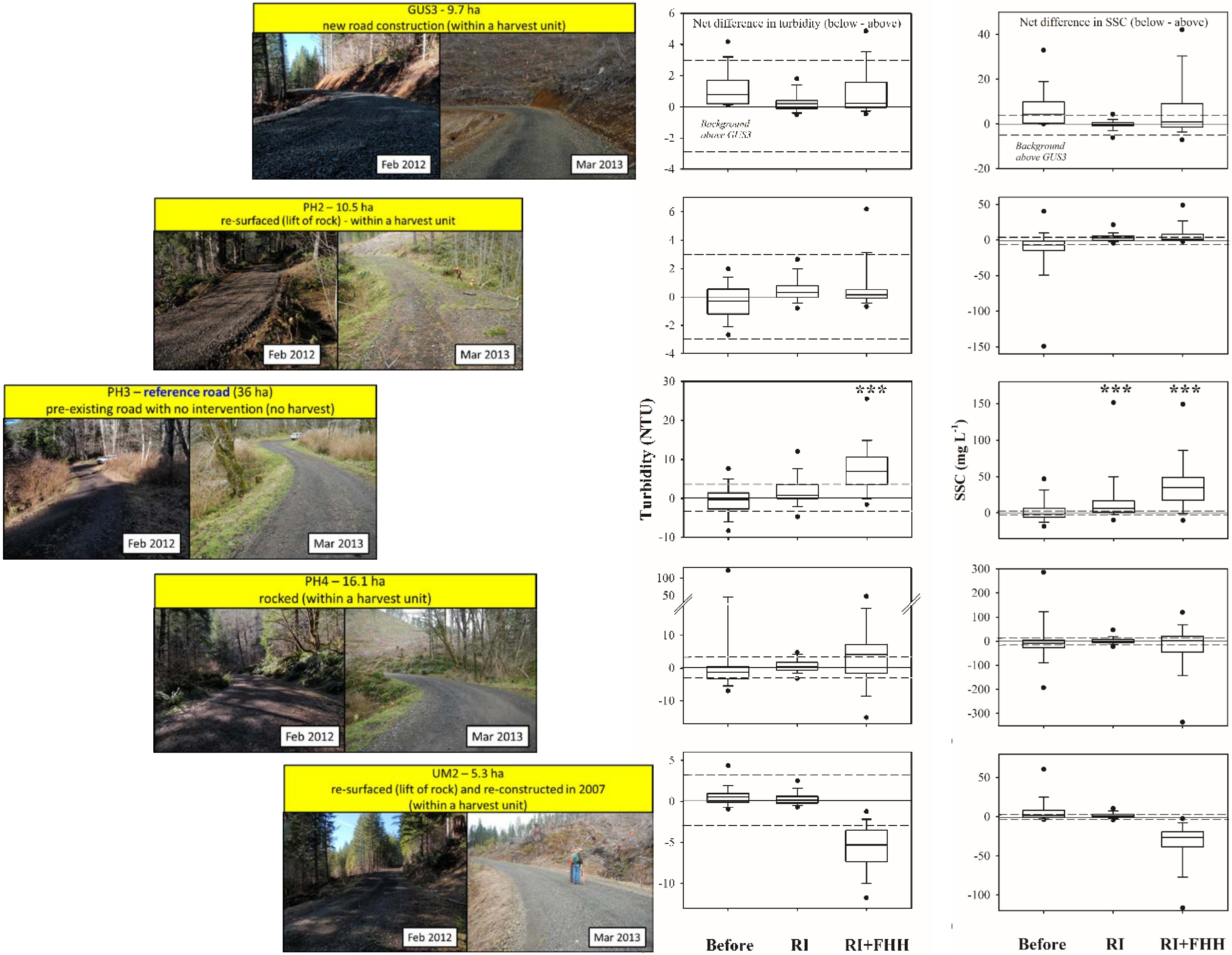
P-values

metric	time period	site (below-above)	C = 0.2	C = 1	C = 3	C = 5	C = 10
turbidity (NTU)	**before**	GUS3	NA	NA	NA	NA	NA
		PH2	1	1	1	1	1
		reference PH3[1]	0.973	1	1	1	1
		PH4	1	1	1	1	1
		UM2	0.002	1	1	1	1
	RI	GUS3	0.726	1	1	1	1
		PH2	< 0.001	1	1	1	1
		reference PH3[1]	< 0.001	0.068	1	1	1
		PH4	0.031	0.977	1	1	1
		UM2	0.296	1	1	1	1
	RI+FHH	GUS3	0.002	0.974	1	1	1
		PH2	0.287	1.000	1	1	1
		reference PH3[1]	< 0.001	< 0.001	< 0.001	< 0.001	1
		PH4	0.001	0.008	0.234	0.865	1
		UM2	1	1	1	1	1

Is below-above <= threshold "C"?

P-values

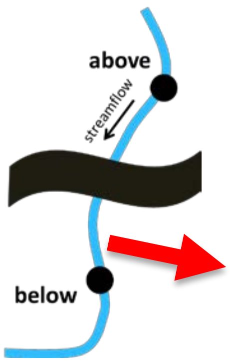
metric	time period	site (below-above)	C = 0.2	C = 1	C = 3	C = 5	C = 10
SSC (mg L^{-1})	**Before**	GUS3	NA	NA	NA	NA	NA
		PH2	1	1	1	1	1
		reference PH3[1]	0.697	0.846	0.974	0.997	1
		PH4	1	1	1	1	1
		UM2	< 0.001	0.005	0.363	0.923	1
	RI	GUS3	0.999	1	1	1	1
		PH2	< 0.001	< 0.001	0.617	1	1
		reference PH3[1]	< 0.001	< 0.001	< 0.001	< 0.001	0.819
		PH4	0.301	0.576	0.952	0.999	1
		UM2	0.000	0.049	1	1.000	1
	RI+FHH	GUS3	0.001	0.032	0.573	0.963	1
		PH2	< 0.001	< 0.001	0.336	0.981	1
		reference PH3[1]	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
		PH4	0.765	0.779	0.813	0.855	0.936
		UM2	1	1	1	1	1

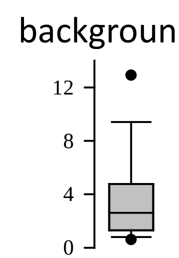


GUS3 - 9.7 ha
new road construction (within a harvest unit)
Feb 2012
Mar 2013
PH2 – 10.5 ha
re-surfaced (lift of rock) - within a harvest unit
Feb 2012
Mar 2013
PH3 – reference road (36 ha)
pre-existing road with no intervention (no harvest)
Feb 2012
Mar 2013
PH4 – 16.1 ha
rocked (within a harvest unit)
Feb 2012
Mar 2013
UM2 – 5.3 ha
re-surfaced (lift of rock) and re-constructed in 2007
(within a harvest unit)
Feb 2012
Mar 2013
Net difference in turbidity (below - above)
Background above GUS3
Net difference in SSC (below - above)
Background above GUS3
Turbidity (NTU)
SSC (mg L-1)
***
***
***
Before
RI
RI+FHH
Before
RI
RI+FHH

turbidity at PH3 – reference road

no forest management





Take home messages

- <u>Minimal increases</u> in sediment influx from road crossings in these forested streams under contemporary forest harvest
- <u>Local disturbances</u> can be very important to fine sediment influx in headwater streams
- Future regulations may consider the <u>natural variability</u> of sediment influx to streams within and among watersheds
- Multifaceted metrics of fine sediment influx <u>regimes</u> may be more informative than single central tendency statistics

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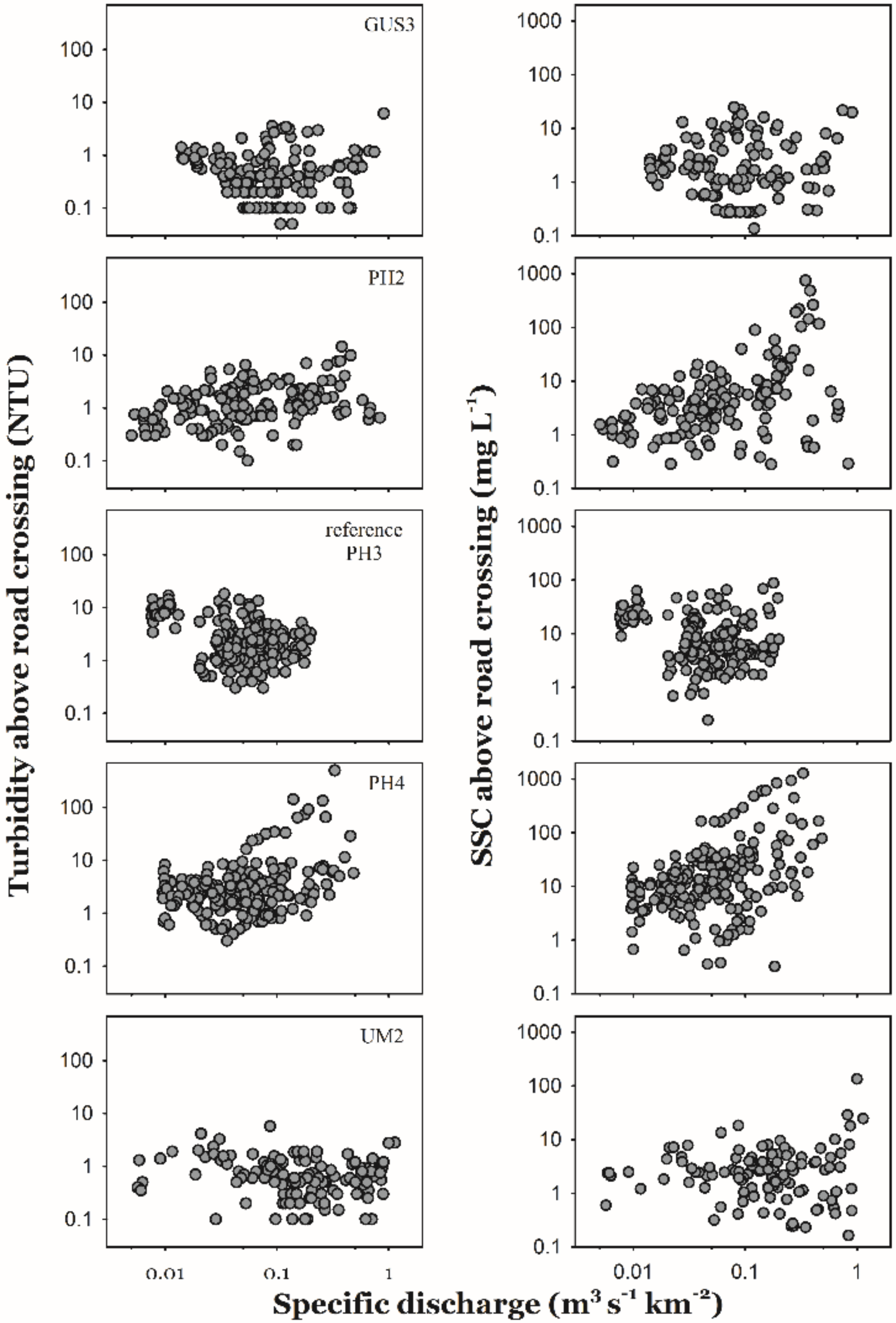
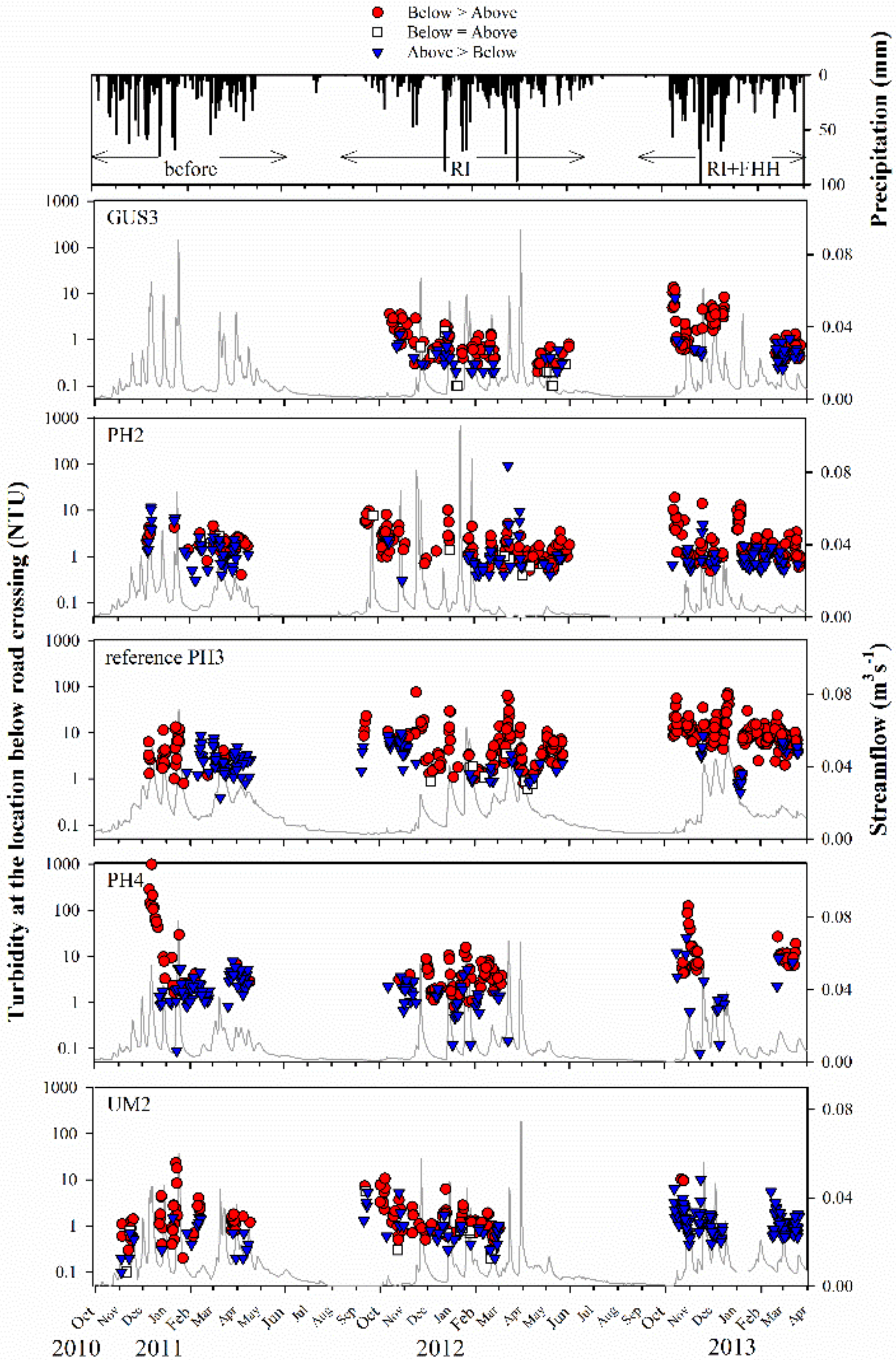

GUS3
PH2
reference
PH3
PH4
UM2
Turbidity above road crossing (NTU)
SSC above road crossing (mg L-1)
Specific discharge (m3 s-1 km-2)
0.01
0.1
1
0.1
1
10
100
1000



Below > Above
Below = Above
Above > Below
Precipitation (mm)
before
RI
RI+FHH
GUS3
PH2
reference PH3
PH4
UM2
Turbidity at the location below road crossing (NTU)
Streamflow (m3 s-1)
2010
2011
2012
2013