

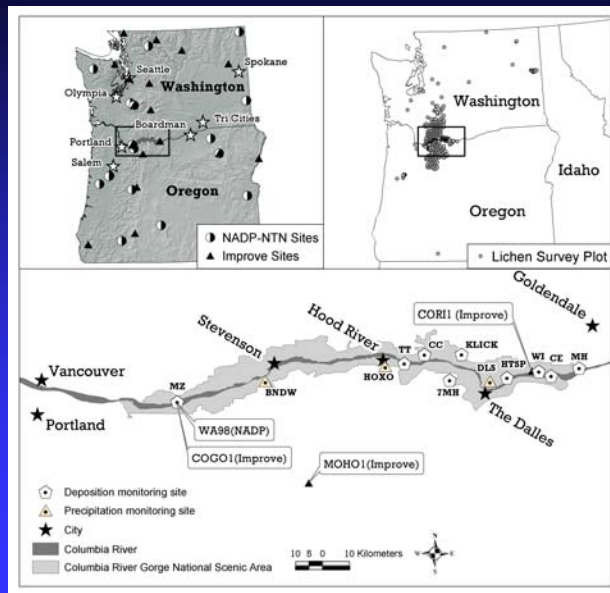
# Deposition of Nitrogen and Sulfur in the Columbia River Gorge National Scenic Area

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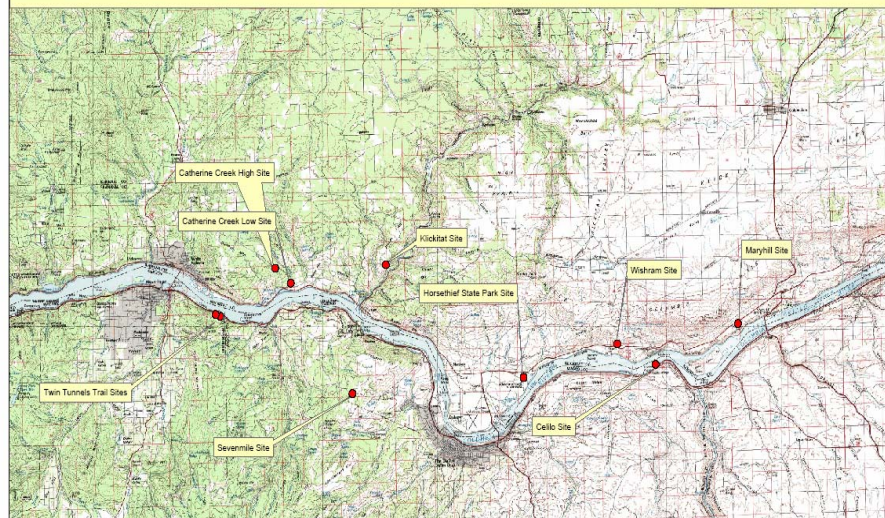
USDA Forest Service, Pacific Southwest Research  
Station, Riverside, California and Region 6 Air Program



## Study Area:



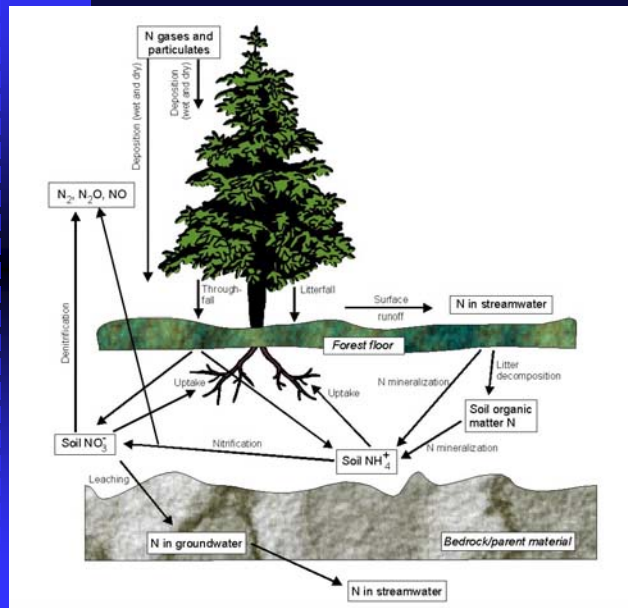
## Columbia River Gorge Fog Study Site Locations 2003-2004



### Initial Phase: Study Design

- Cloud & Fog Water samples collected at eleven sites
  - ◆ Sampled for NO<sub>3</sub>, NH<sub>4</sub>, SO<sub>4</sub>, & acidity
    - ◆ Sampled from late October thru February
  - ◆ From Maryhill to Twin Tunnels Trail plus Mt. Zion
  - ◆ Collected fog & cloud droplets, and rainwater
    - ◆ Three methods
      - Teflon filament collectors for fog and cloud droplets
      - Collected weekly bulk water samples for acidity (pH)
      - Used pine trees as collectors/scavengers (throughfall); bulk deposition also collected

## Forest Nitrogen Cycle



**Throughfall:**  
A common  
measure of  
atmospheric  
deposition

### Ion exchange resin throughfall collector;

(see Fenn & Poth, 2004; J. Env. Qual.  
33: 2007-2014, and  
[http://www.fs.fed.us/psw/topics/air\\_q  
uality/resin\\_collectors/index.shtml](http://www.fs.fed.us/psw/topics/air_quality/resin_collectors/index.shtml))



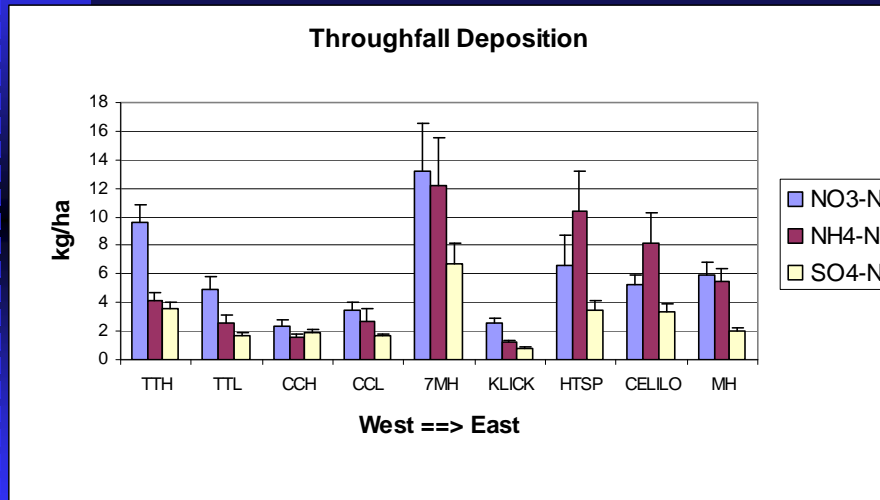


**Ion exchange resin columns and hardware used to fill and extract the columns**

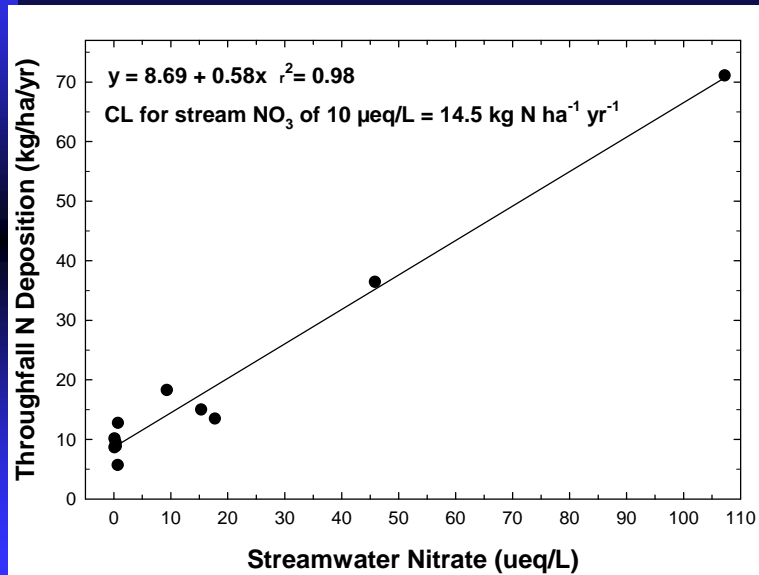




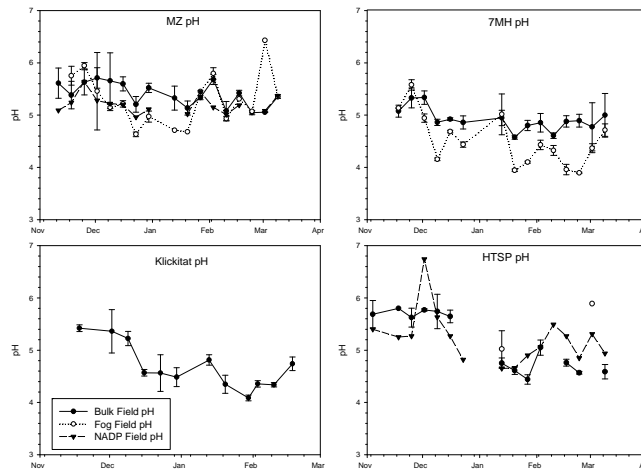
## Throughfall N Deposition During Winter 2004 in the Columbia River Gorge



**Empirical Throughfall CL for Mixed Conifer Forests in CA: 17.0 kg N ha<sup>-1</sup> yr<sup>-1</sup>**  
 (Based on literature and UNECE acceptable leaching value of 14.3 µeq L<sup>-1</sup>)

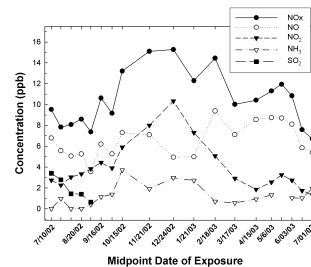


## pH of Precipitation and Fog Samples



## Concentrations of Gaseous N and S Pollutants (2 to 4 week averages from passive samplers): HTSP

- Concentrations indicative of a diluted urban plume & NH<sub>3</sub> from ag sources
- But high throughfall fluxes suggest that much of the deposition is in particulate form, plus fog & wet deposition
- But HNO<sub>3</sub> was not measured and may also be an important contributor from the western urban source area



## Summary of Initial Study Results

- Nitrogen deposition rates very high
  - ◆ More than double expected
    - ◆ 7MH comparable to N saturated sites in the US
- Acidity of the fog & cloud water samples -- characterized as extreme Seven day average fog samples as low as pH 3.7
  - ◆ Values for daily events presumably more extreme
  - ◆ Gorge rain pH 4.8 to 5.4
- These preliminary results suggest pollution levels with potential to impact cultural and natural resources
- Impacts of N deposition well documented for lichen communities

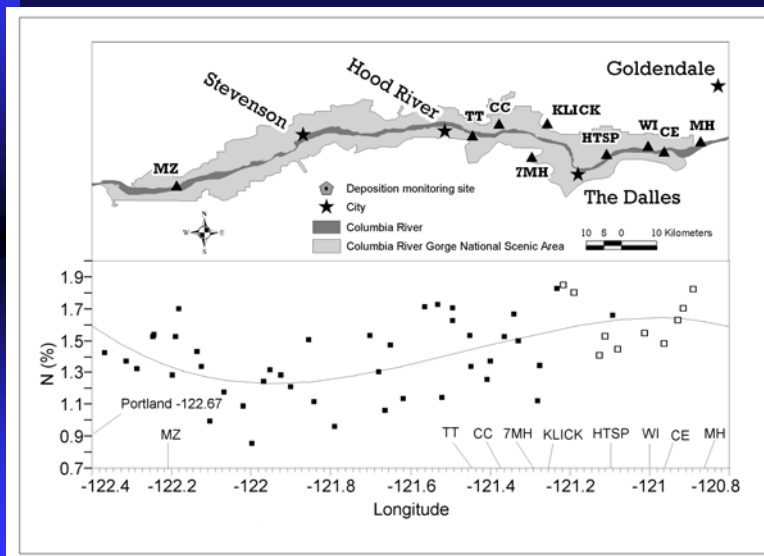
## Atm. Dep. (Sept. 2005 to May 2006) and Nutrient Status Indicators in the Columbia River Gorge

Site	Sp.	N dep	S dep	Fol N	Fol C:N	Fol N:P		Soil N	Soil C:N	Soil S
ME	PP	8.8	2.3	1.15	41.9	8.00		0.23	19.5	195
RR	PP	6.5	1.8	1.11	45.4	8.94		0.18	16.7	160
<b>7MH</b>	PP	5.9	1.7	<b>1.48</b>	<b>32.7</b>	<b>9.40</b>		<b>0.43</b>	17.3	<b>371</b>
TH	PP	1.8	1.5	1.22	41.5	8.08		0.20	17.6	166
Crit.	Val:			1.1		ca. 9			24	
7MH	DF	<b>10.1</b>	2.9	1.20	43.3	7.71		0.26	<b>18.0</b>	200
HC	DF	1.4	2.7	1.34	38.6	8.12		0.25	20.3	222
PC	DF	1.8	1.8	1.17	42.1	9.58		0.39	22.7	<b>358</b>
WR	DF	1.1	2.0	1.09	45.4	8.48		0.18	35.0	192
PM	DF	0.7	2.1					0.45	26.7	<b>371</b>

## Soil pH in the Columbia River Gorge

Site	Sp.	Hi Mean	Low Mean
7MH	PP	6.74	5.89
TT	PP	6.57	6.04
TH	PP	6.88	5.73
ME	PP	7.12	6.90
7MH	DF	6.98	6.66
PC	DF	6.49	6.17
PM	DF	5.49	5.03
HC	DF	6.68	6.42
WR	DF	6.14	5.21

## N concentrations in lichen tissue correspond with N deposition patterns



## Conclusions

- Nitrogen enrichment of ecosystem underway based on lichen data, and based on soil and foliar nutrient status indicators at 7MH
- Fog, dry and wet deposition inputs vary across the Gorge and inter-annually based on fog occurrence
- Agricultural N sources evident in eastern end of the Scenic Area; Fossil fuel emissions of N and S more evident to the west
- Deposition monitoring continues to determine longer term patterns and inputs
- Acidic fog and precipitation events occur, but no clear evidence of soil acidification in forested areas
- Greatest risk to forest health would be to yellow pine exposed to elevated ozone and N; plus S deposition