EPA United States Environmental Protection Agency

Multipollutant Reduction Simulation of BMPs with VELMA

Bob McKane, Jonathan Halama, Allen Brookes, Kevin Djang*, Vivian Phan

U.S. Environmental Protection Agency, Pacific Ecological Systems Division, Corvallis, OR
*Inoventure Inc, Corvallis, OR

Region 10 Virtual Nutrients Technical Roundtable

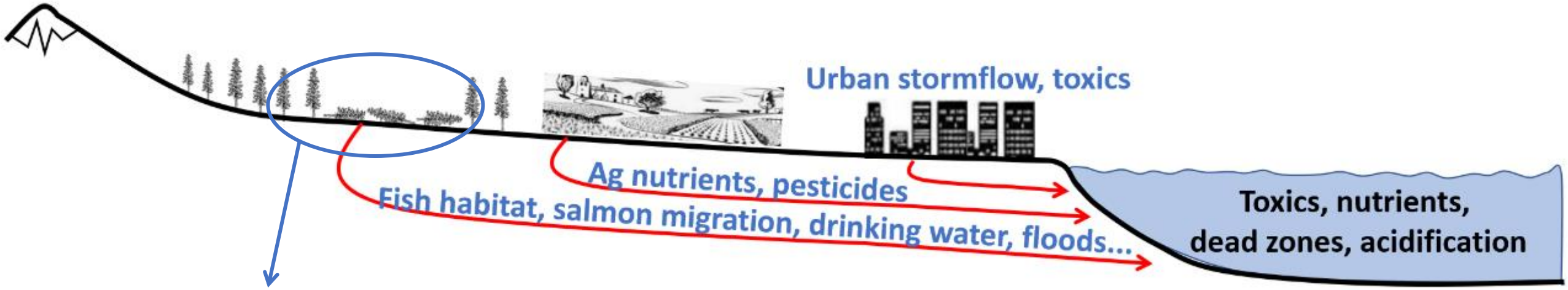
May 3, 2022

Outline

1. Multi-scale pollutant modeling & decision support
2. Urban stormwater contaminants
3. Nutrients
4. Stream flow, temperature, velocity, salmon habitat

Key Goal

Help local planners visualize how effects of their decisions will propagate downstream with far reaching benefits and tradeoffs for terrestrial and marine ecosystem services



Local Watershed Restoration Case Study Example

Nisqually Community Forest

Salmon Habitat Restoration

Local benefits

Basin-scale benefits

Puget Sound Integrated Terrestrial-Marine Modeling Framework

VELMA

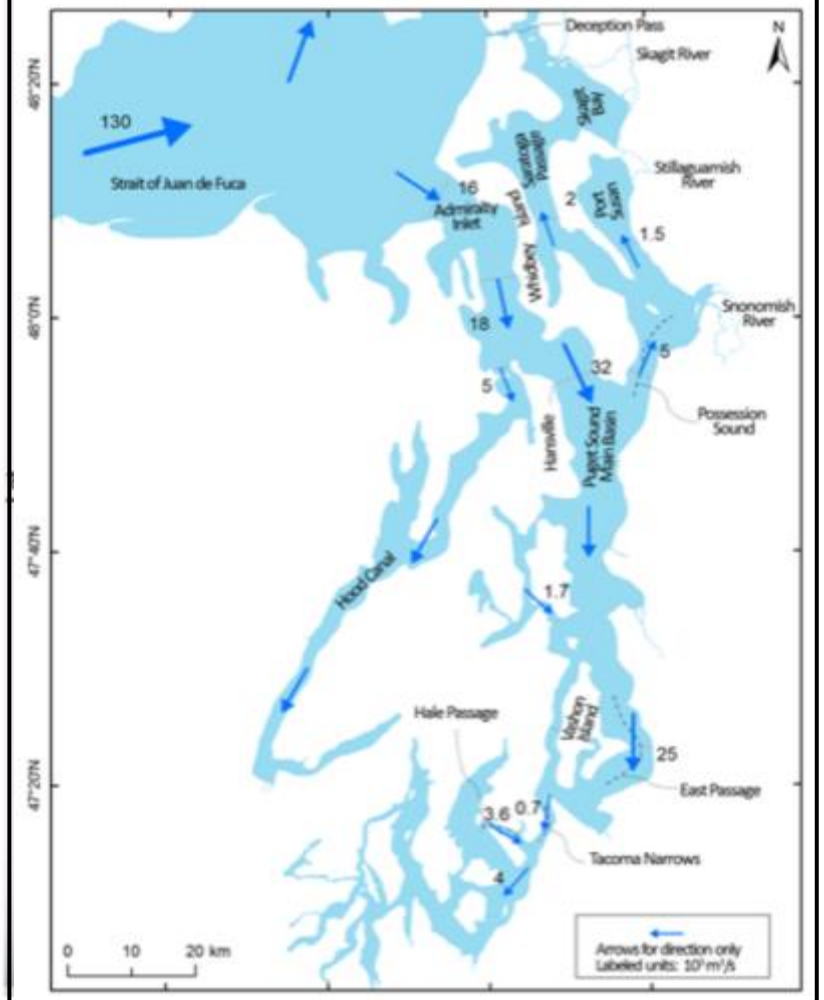
Stormwater Green Infrastructure, Nutrient Mgmt, Clean Rivers, Salmon Habitat Improvement

EPA/UW

Freshwater, Nutrients, Toxics

Salish Sea Model

Tidal Inflow

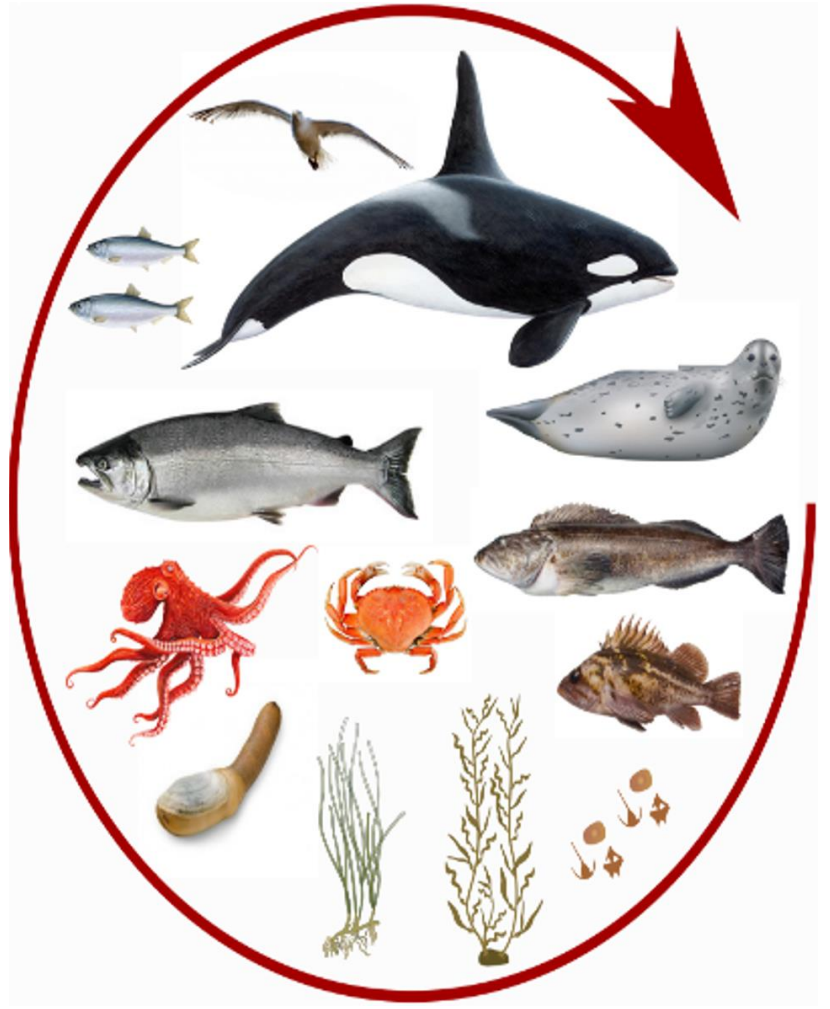


UW/PNNL/ECY

Nutrients, Toxics, Temp, pH, Salinity

Atlantis Model

Marine Food Web, Toxics in Fish



NOAA / LLTK

Outline

1. Multi-scale pollutant modeling & decision support
2. Urban stormwater contaminants (Region 10 RARE FY20-22)
3. Nutrients
4. Stream flow, temperature, velocity, salmon habitat

What's killing the coho?

A decades-long mystery solved

The Seattle Times

Stormwater pollution in Puget Sound streams killing coho before they can spawn

October 18, 2017

1 of 2 | *Coho salmon, including females full of eggs, are dying before they can spawn in Puget Sound streams polluted with stormwater runoff. (NOAA Fisheries)*

Science **Tian et al. 2021**

REPORTS

6PPD-quinone

Cite as: Z. Tian *et al.*, *Science* 10.1126/science.abd6951 (2020).

A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon

Zhenyu Tian[1,2], Haoqi Zhao[3], Katherine T. Peter[1,2], Melissa Gonzalez[1,2], Jill Wetzel[4], Christopher Wu[1,2], Ximin Hu[3], Jasmine Prat[4], Emma Mudrock[4], Rachel Hettinger[1,2], Allan E. Cortina[1,2], Rajshree Ghosh Biswas[5], Flávio Vinicius Crizóstomo Kock[5], Ronald Soong[5], Amy Jenne[5], Bowen Du[6], Fan Hou[3], Huan He[3], Rachel Lundeen[1,2], Alicia Gilbreath[7], Rebecca Sutton[7], Nathaniel L. Scholz[8], Jay W. Davis[9], Michael C. Dodd[3], Andre Simpson[5], Jenifer K. McIntyre[4], Edward P. Kolodziej[1,2,3*]

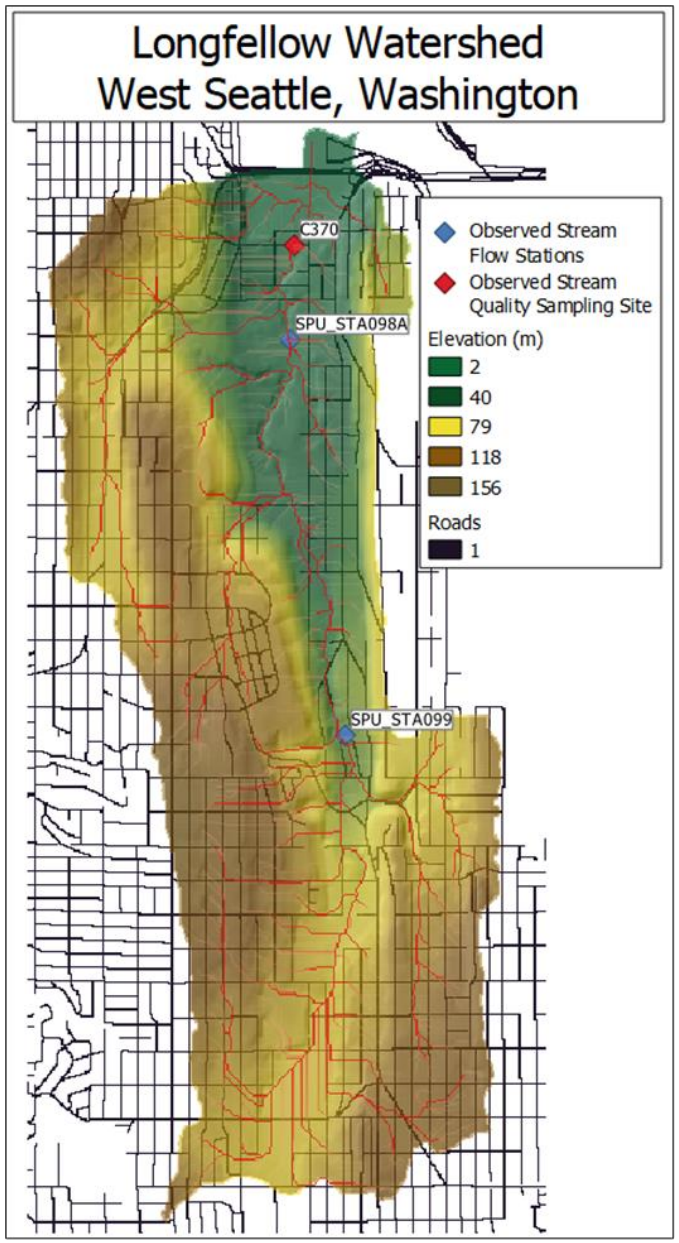
VELMA Ecohydrology Model

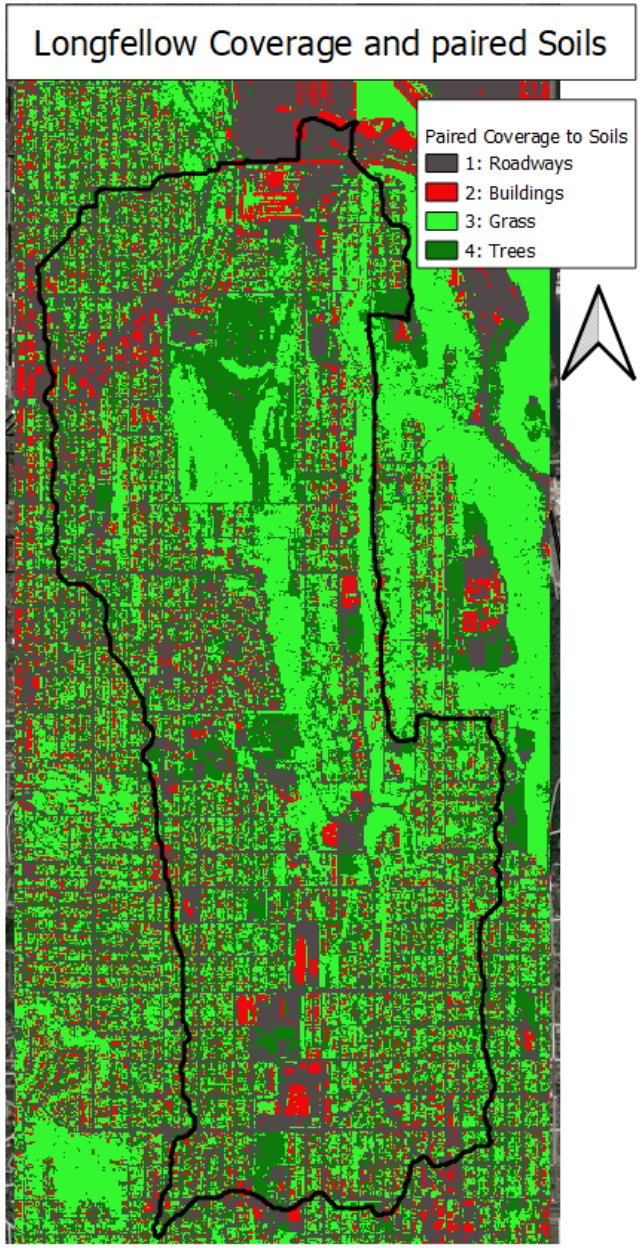
- **Estimate**: Contaminant Fate and Transport in Urban and Rural Watersheds: Organics, Nutrients, Metals
- **Inform**: Green Infrastructure Options for Reducing Toxic Chemicals in Stormwater
- **Support**: Clean Water Act, Endangered Species Act, National Pollutant Discharge Elimination System, H.R.4266-Clean Water Through Green Infrastructure Act

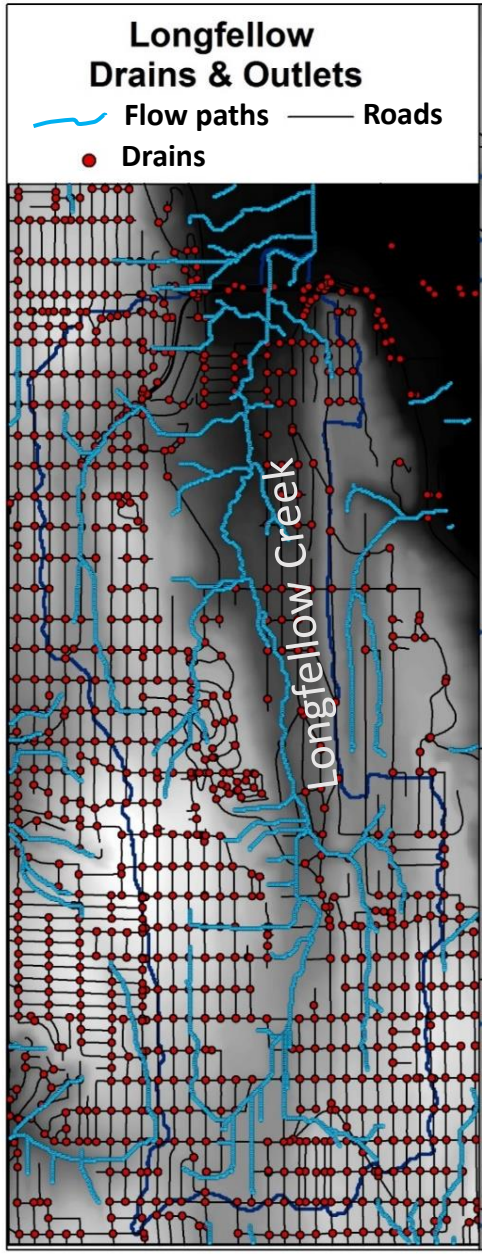
Bioswale
Longfellow Creek Watershed
West Seattle, WA

US EPA Office of Research and Development
Center for Public Health and Environmental Assessment, Pacific Ecological Systems Division

VELMA Urban Setup: Major Spatial Components

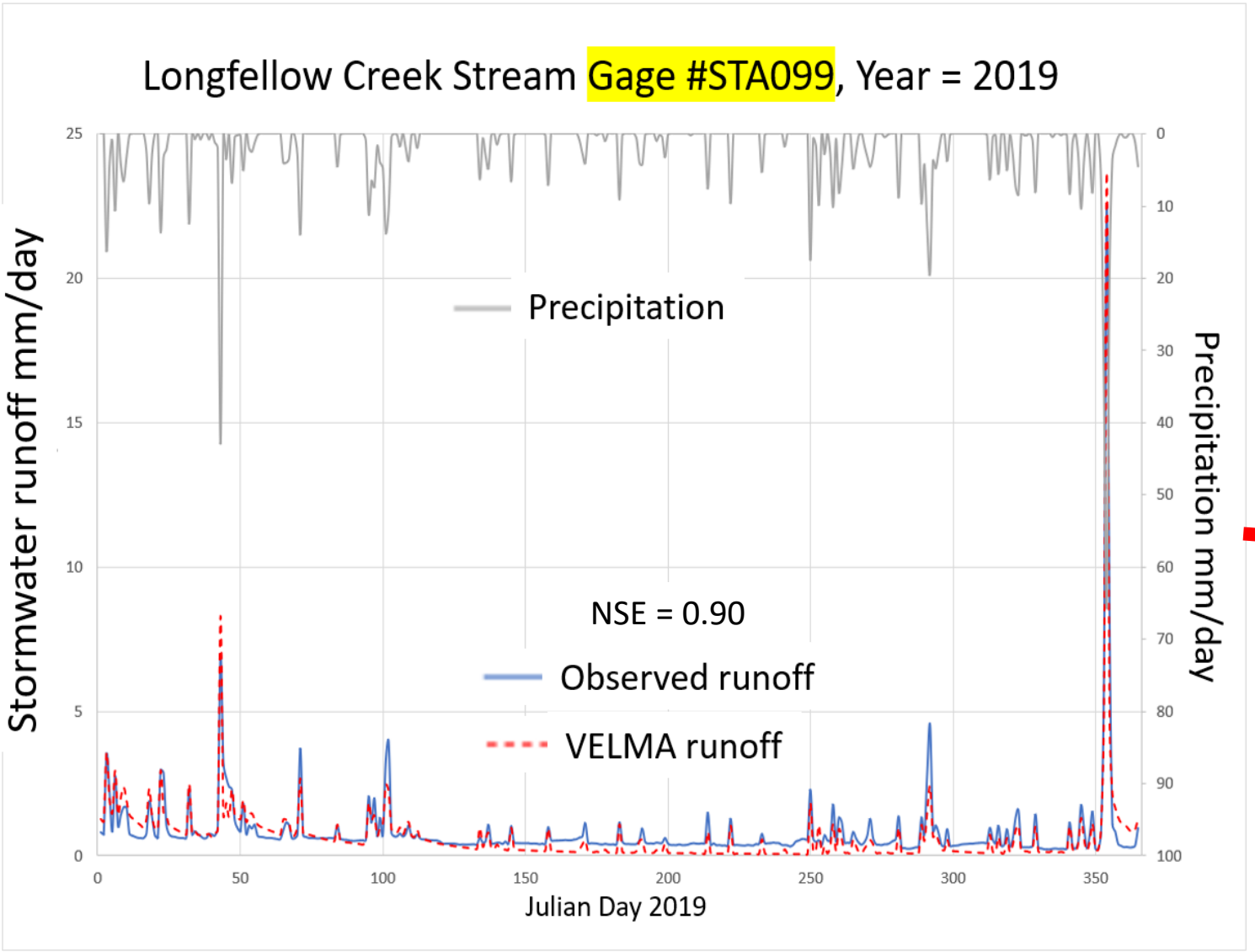


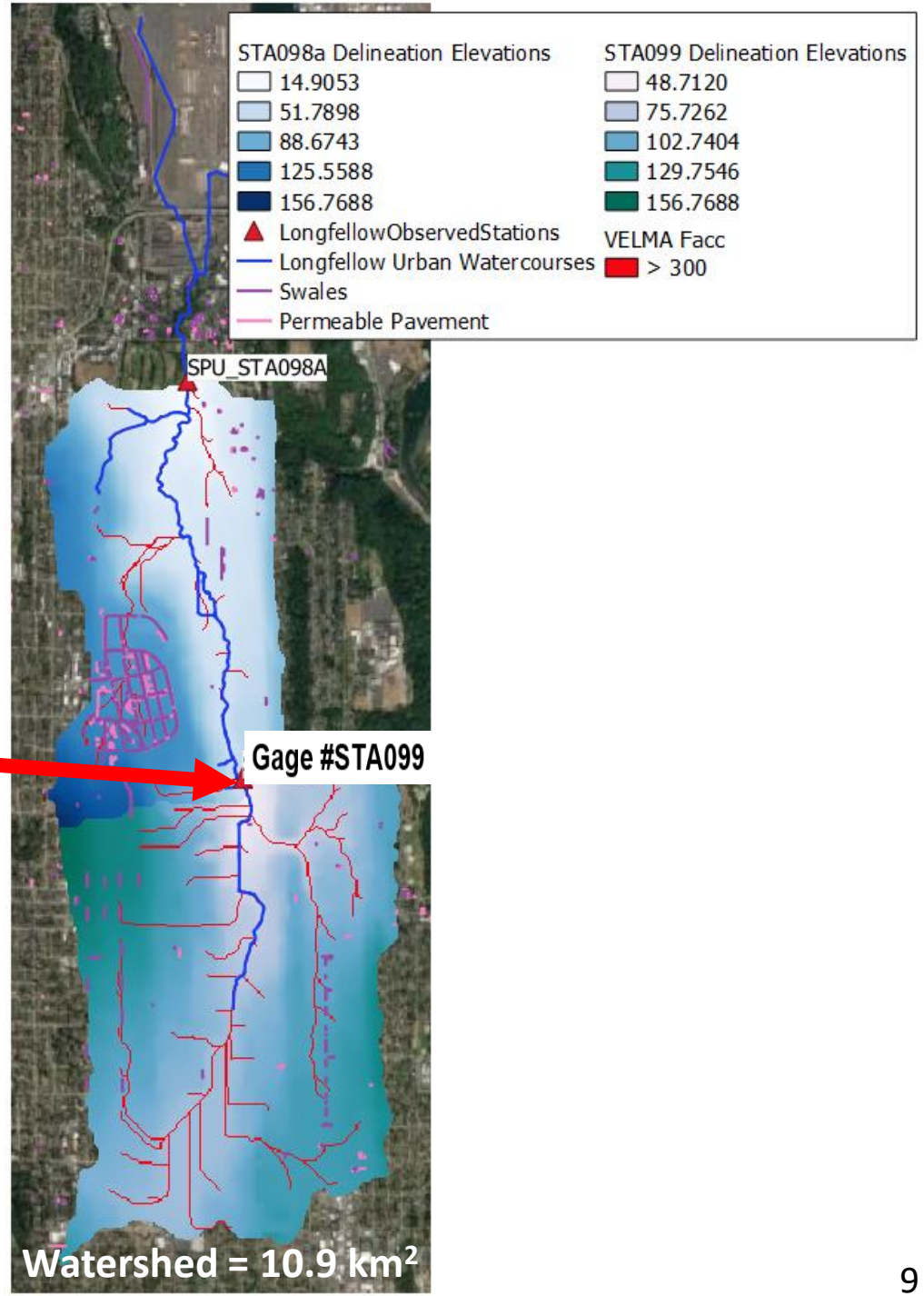




EMCON 2020 10-meter VELMA grid results (McKane, Halama et al. 2020)

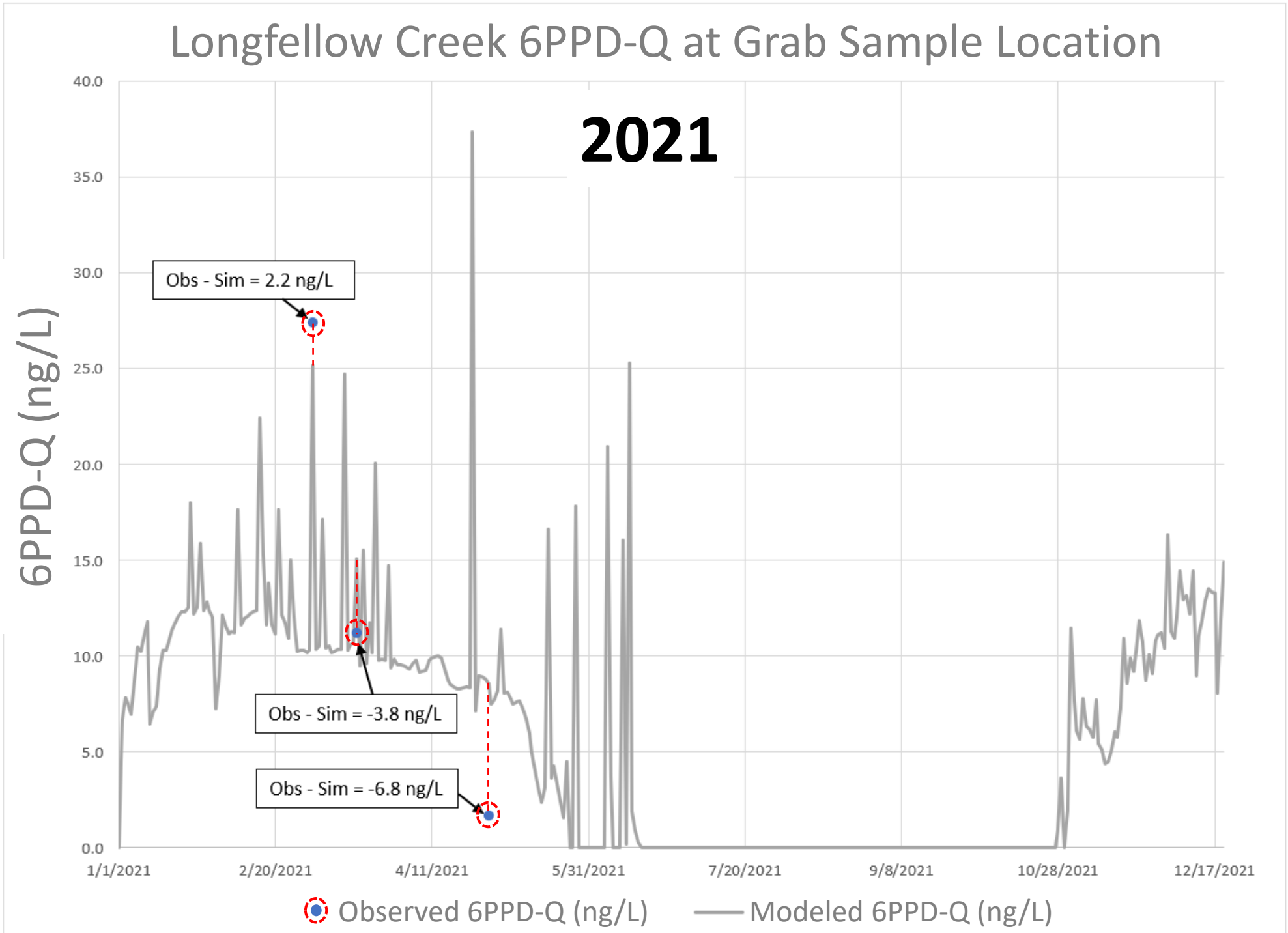
VELMA urban stormwater runoff performance tests



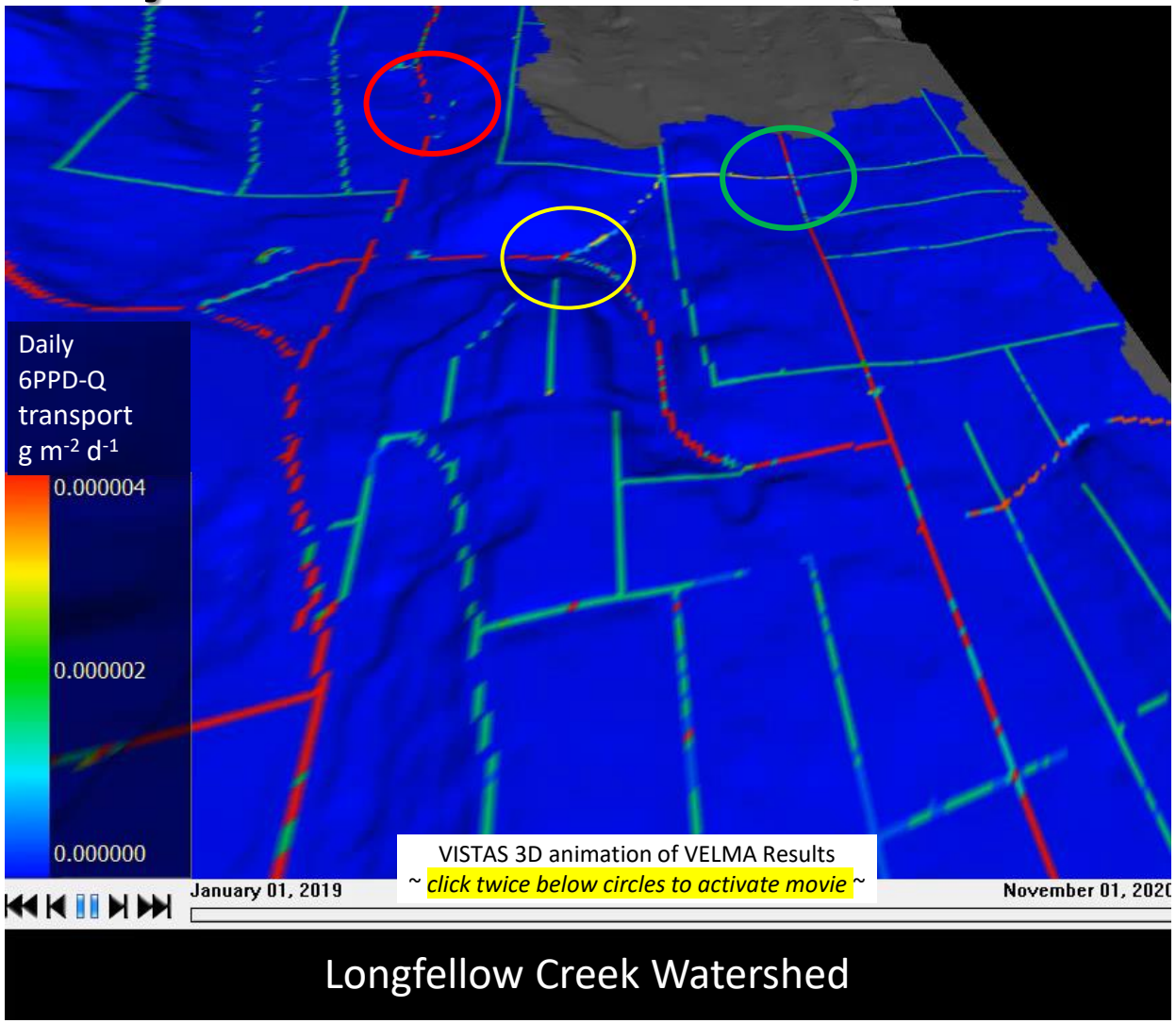


Halama, McKane et al 2022

Longfellow Creek 6PPD-Q at Grab Sample Location

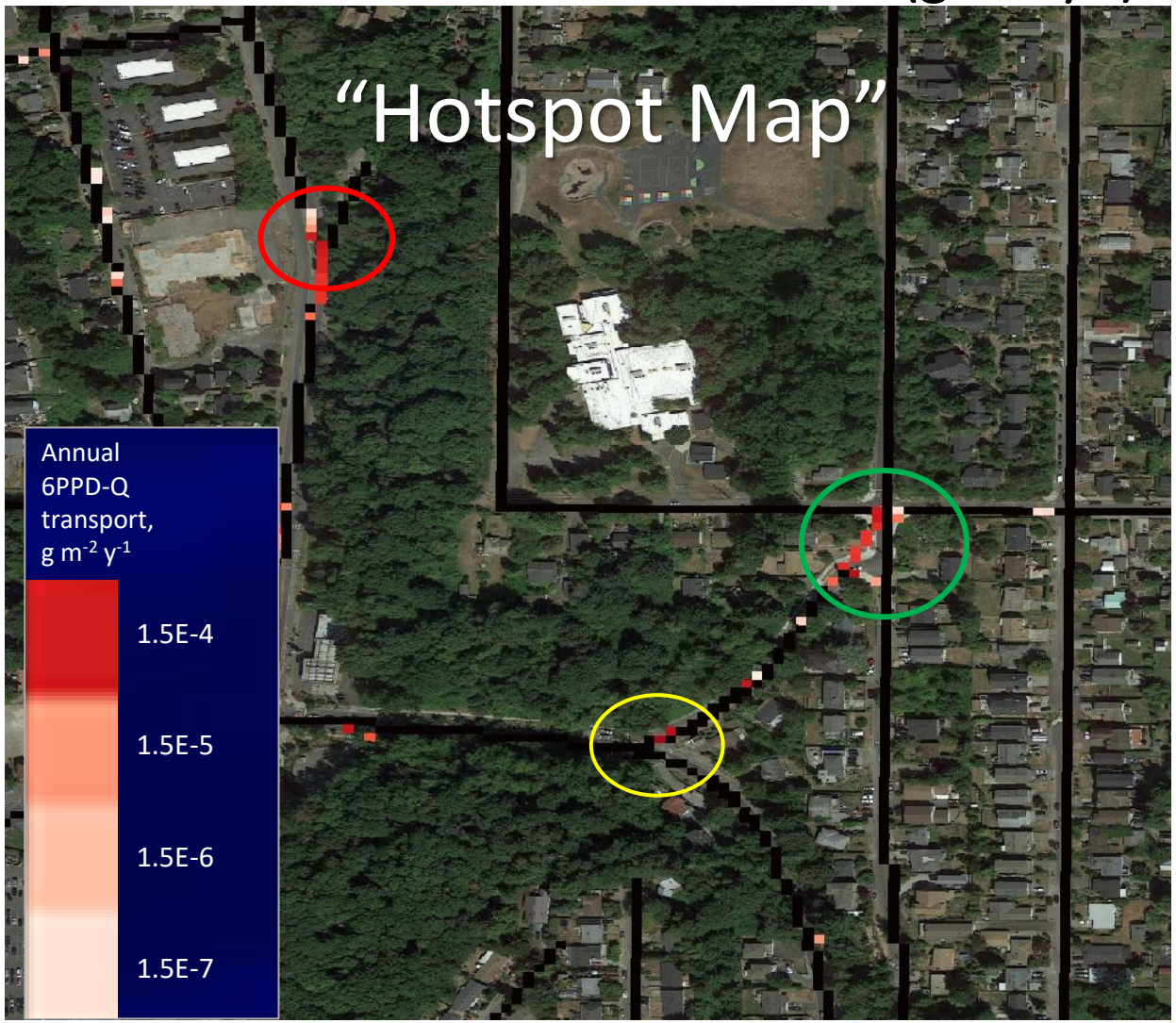

Longfellow Creek 6PPD-Q at Grab Sample Location
2021
6PPD-Q (ng/L)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Obs - Sim = 2.2 ng/L
Obs - Sim = -3.8 ng/L
Obs - Sim = -6.8 ng/L
1/1/2021
2/20/2021
4/11/2021
5/31/2021
7/20/2021
9/8/2021
10/28/2021
12/17/2021
Observed 6PPD-Q (ng/L)
Modeled 6PPD-Q (ng/L)

Daily 6PPD-Q Surface Transfers (g m^{-2} d^{-1})



Longfellow Creek Watershed

2020 Annual 6PPD-Q Surface Transfers (g m^{-2} y^{-1})

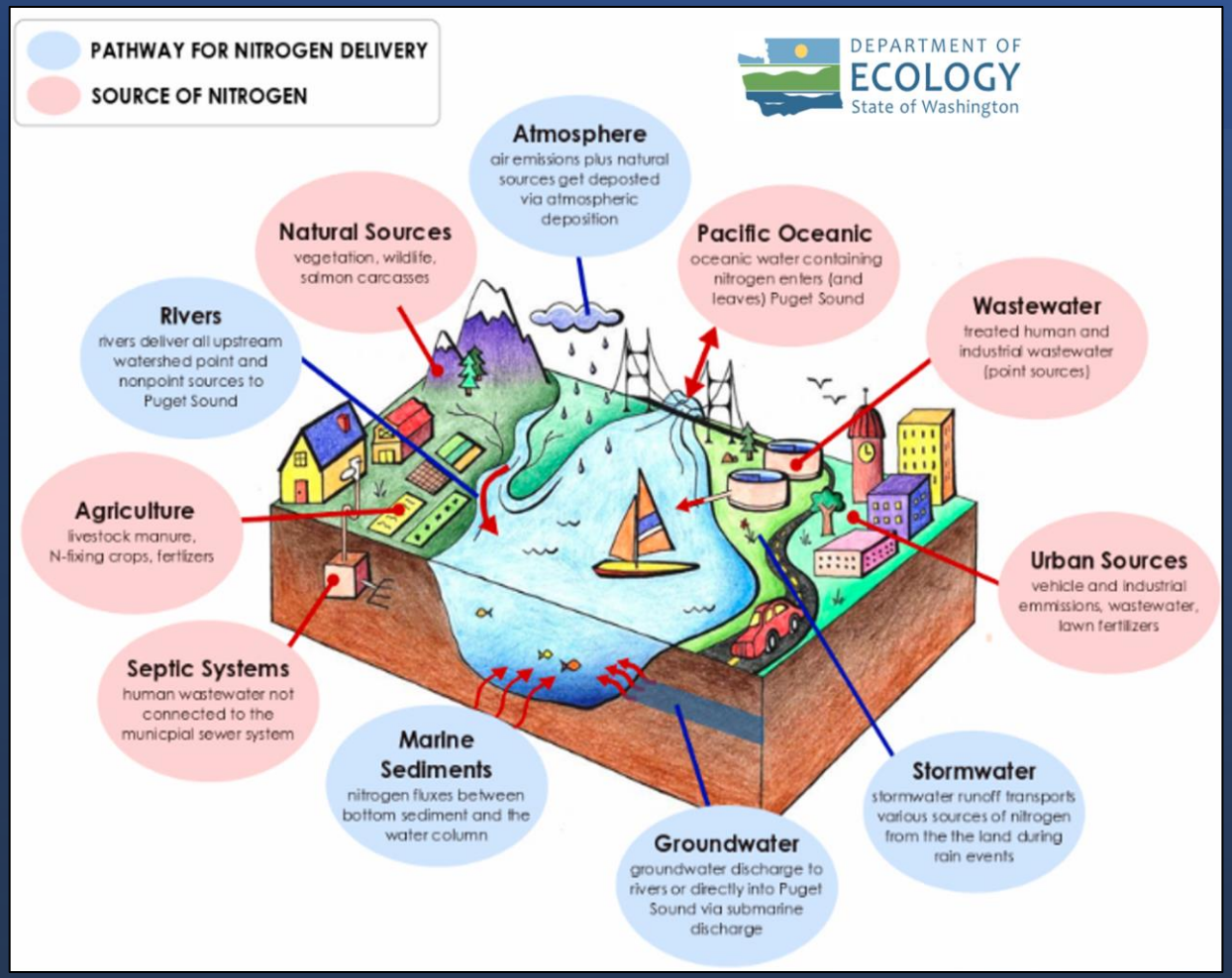


NOTE: 6PPD-Q Annual sums are ~100x larger than daily values

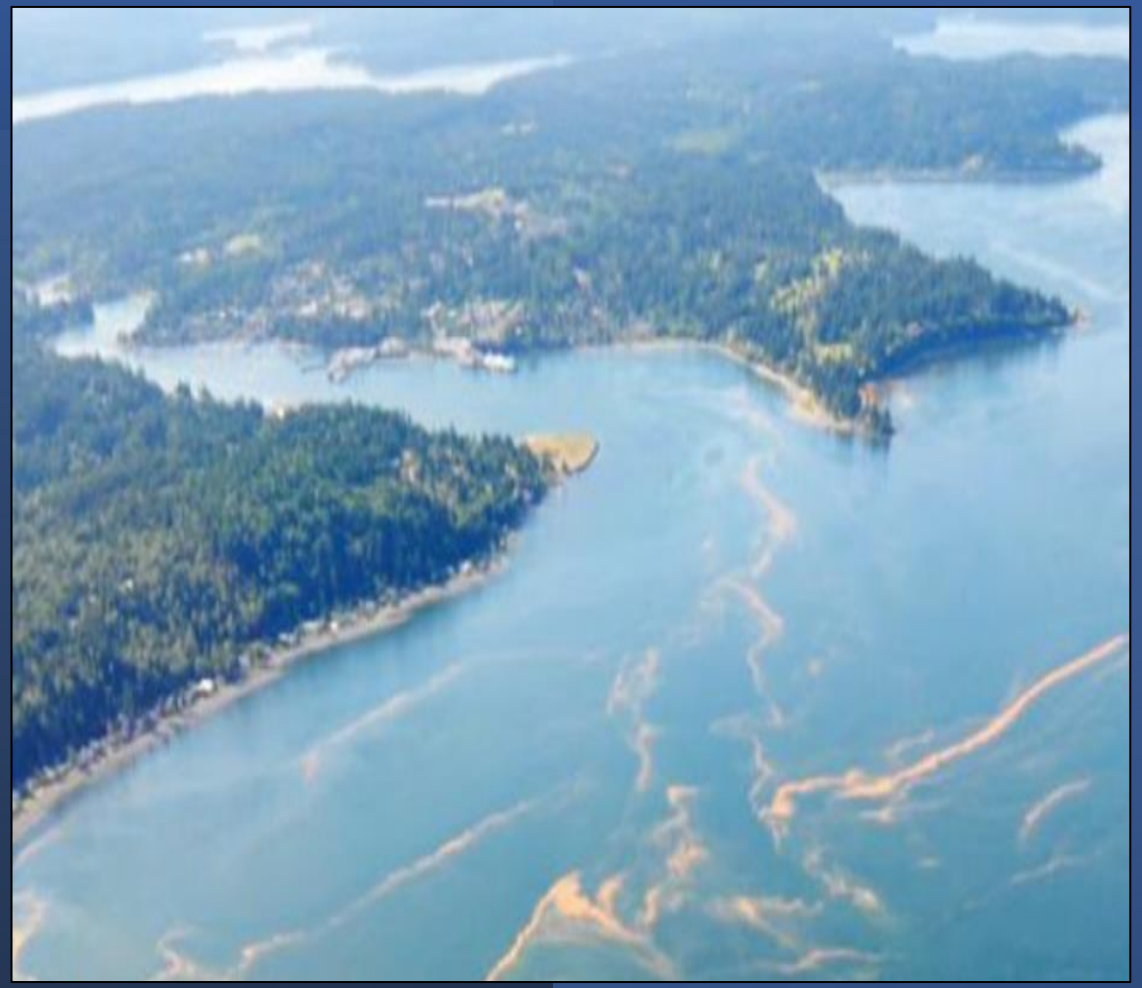
Outline

1. Multi-scale pollutant modeling & decision support
2. Urban stormwater contaminants
3. Nutrients (ORD FY23-26 proposal: McKane, Compton, Detenbeck)
4. Stream flow, temperature, velocity, salmon habitat

Terrestrial nitrogen sources to Puget Sound are many…

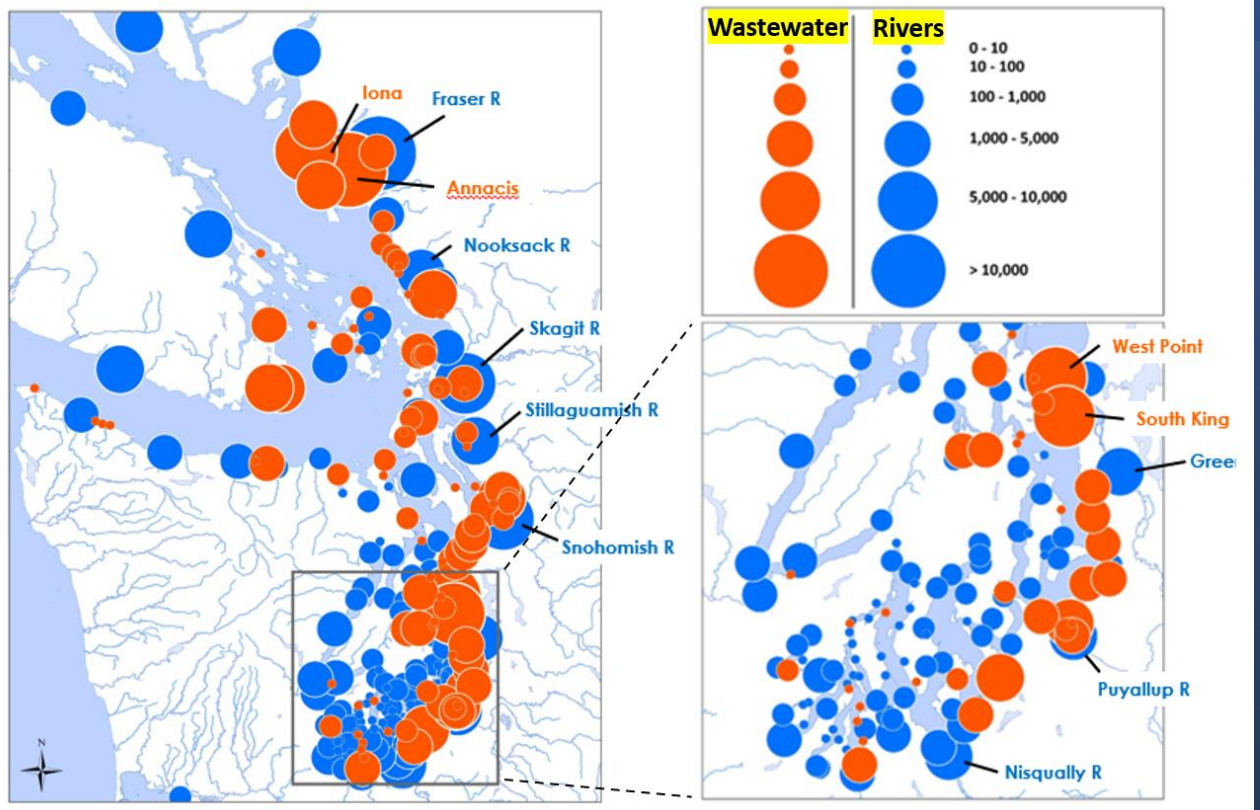


As are effects on water quality, food web, human health, economy…



DEPARTMENT OF ECOLOGY
State of Washington

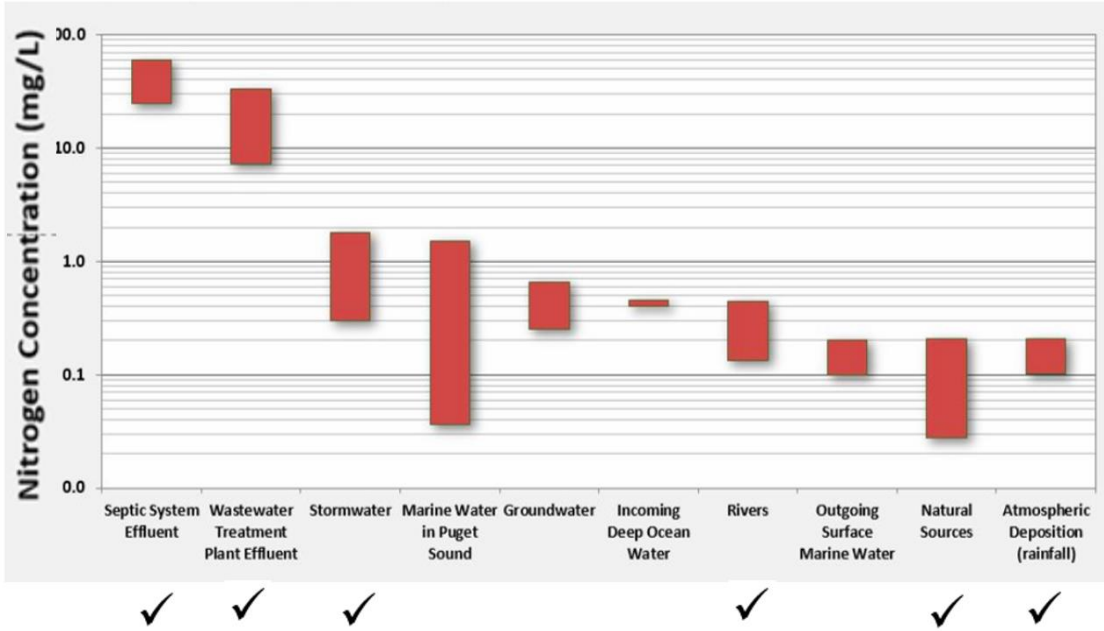
Terrestrial Inorganic Nitrogen Loads (kg/day) Entering Puget Sound, 1997-2017 Annual Average



DEPARTMENT OF ECOLOGY
State of Washington

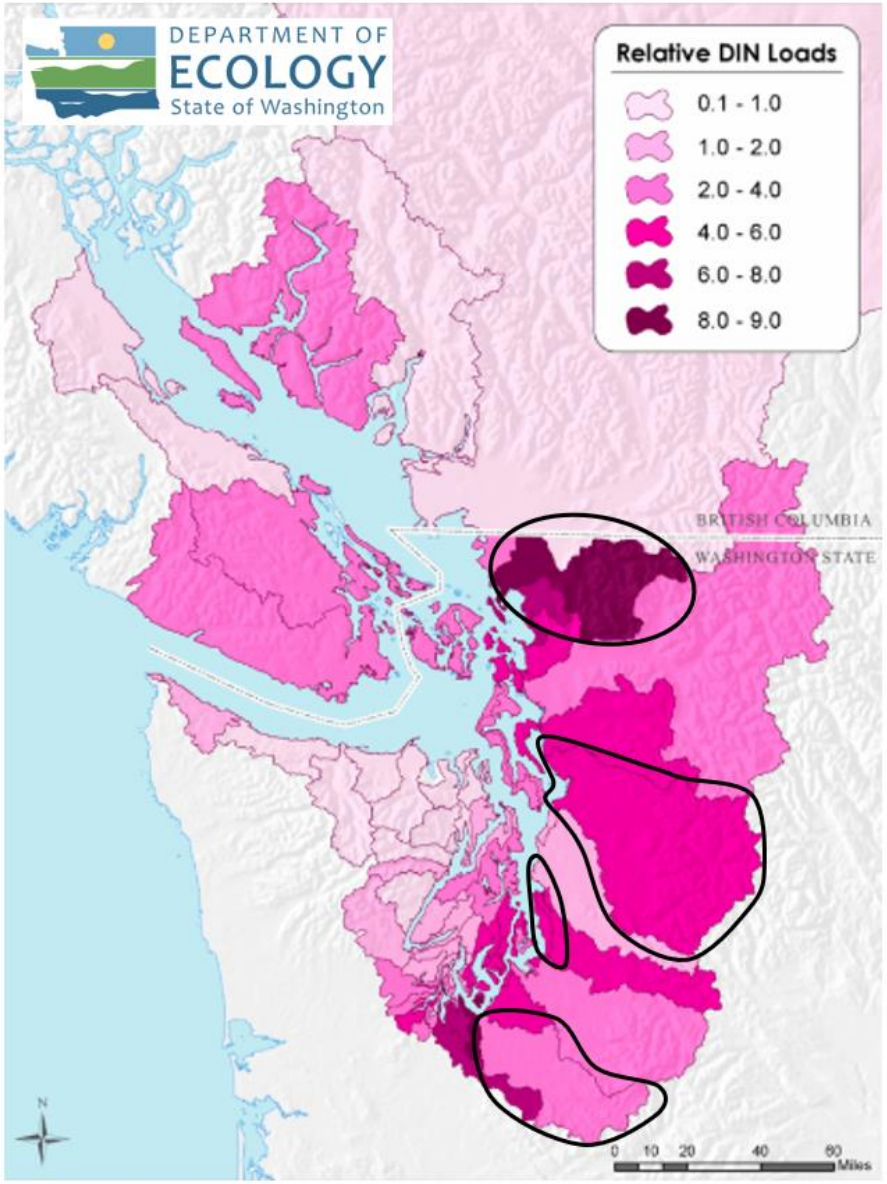
Puget Sound Point and Nonpoint Nitrogen Sources

https://www.arcgis.com/apps/MapSeries/index.html?appid=907dd54271f44aa0b1f08efd7efc4e30



✓ = Nitrogen sources VELMA can model

Prioritizing initial subbasin N load VELMA simulations



Source: Mohamedali et al., 2011

"River loads contribute the second largest local input of inorganic nitrogen to Puget Sound (after wastewater loading). There are about 13 major rivers that discharge to Puget Sound."
https://www.arcgis.com/apps/MapSeries/index.html?appid=907dd54271f44aa0b1f08efd7efc4e30

Nooksack River N Loads

- Main sources: ag, CAFO, N dep

Annual DIN load (kg/day)	4,175
Summer DIN load (kg/day)	1,065

Snohomish River N Loads

- Main sources: ag, urban, alder

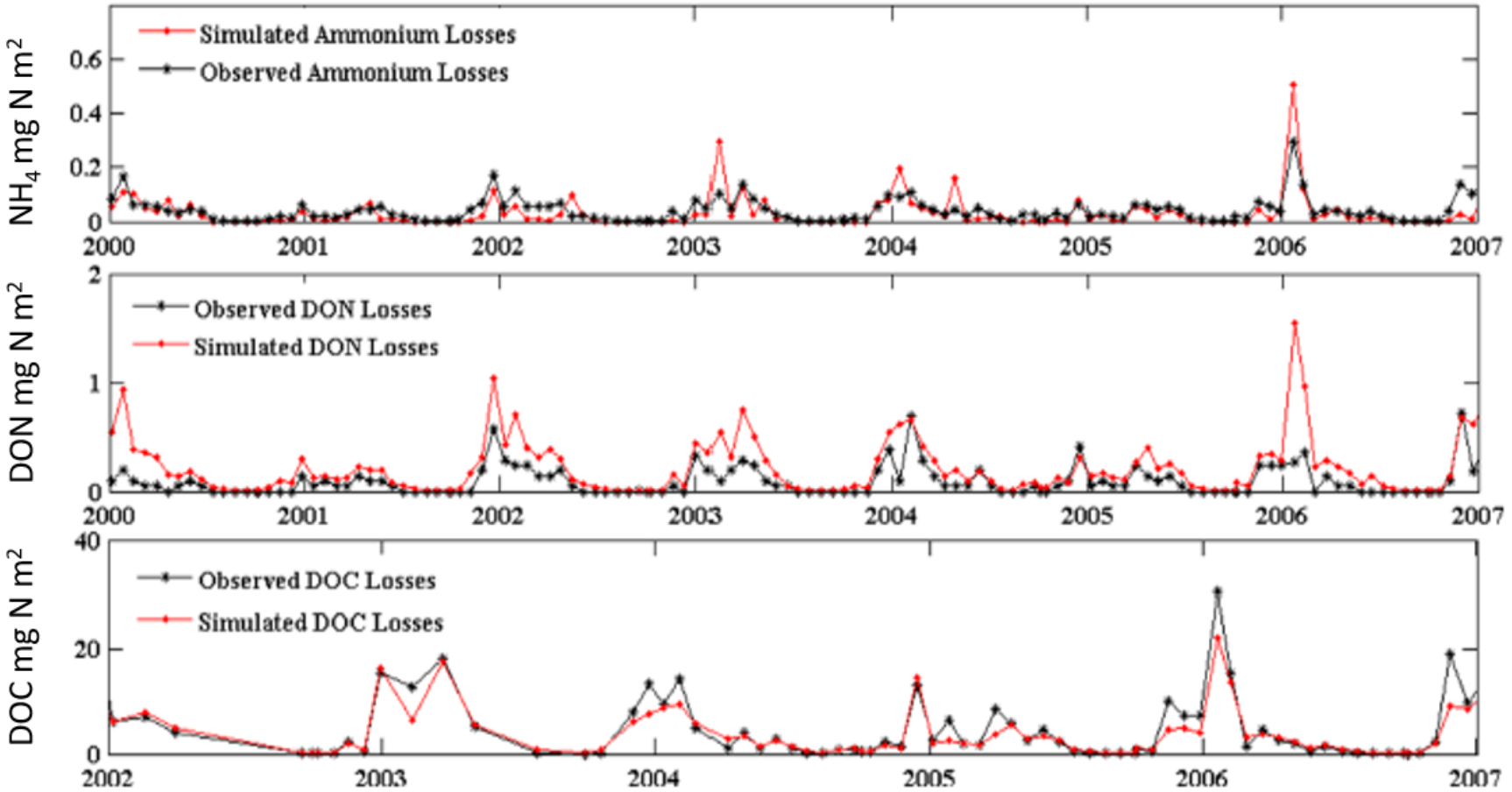
Annual DIN load (kg/day)	5,945
Summer DIN load (kg/day)	1,600

Nisqually River N Loads

- Main sources: septic, alder

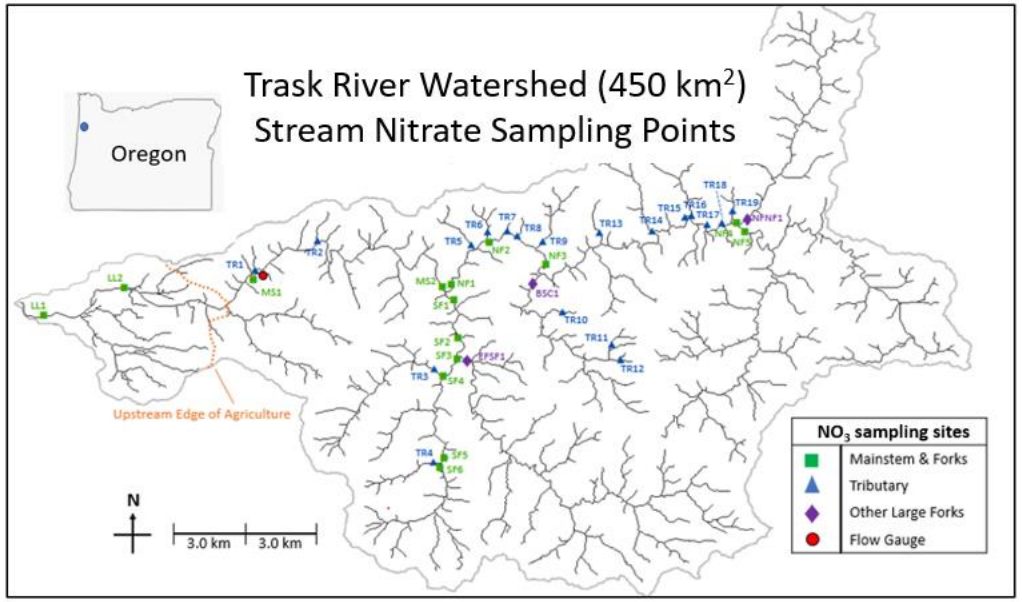
Annual DIN load (kg/day)	1,425
Summer DIN load (kg/day)	440

VELMA simulated stream nutrient loadings during forest recovery

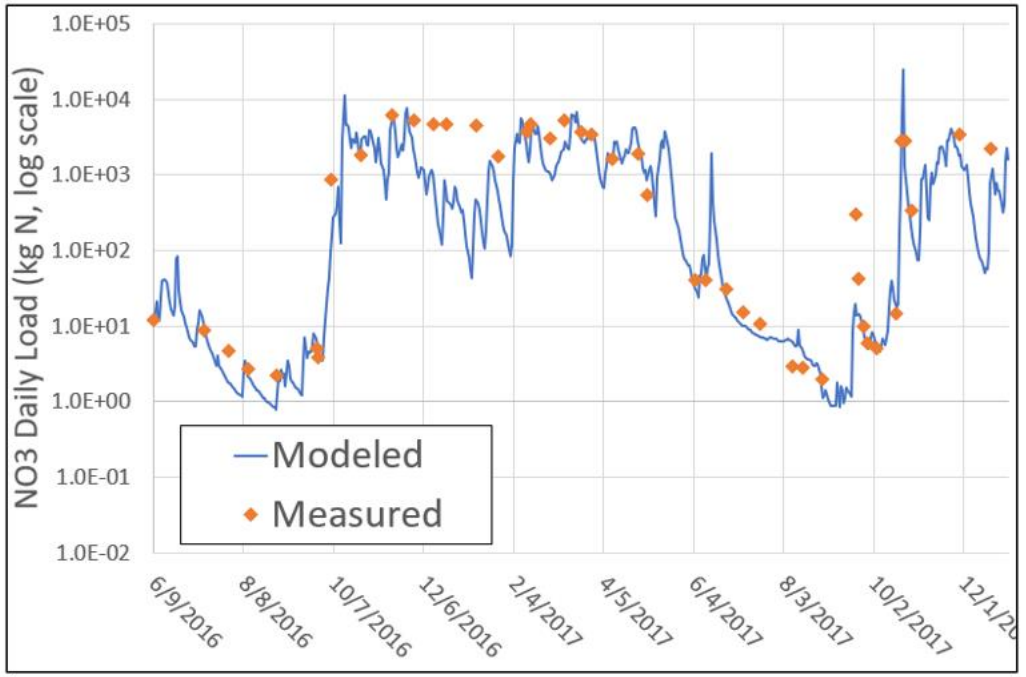


Abdelnour et al. 2013

Red alder along Trask River



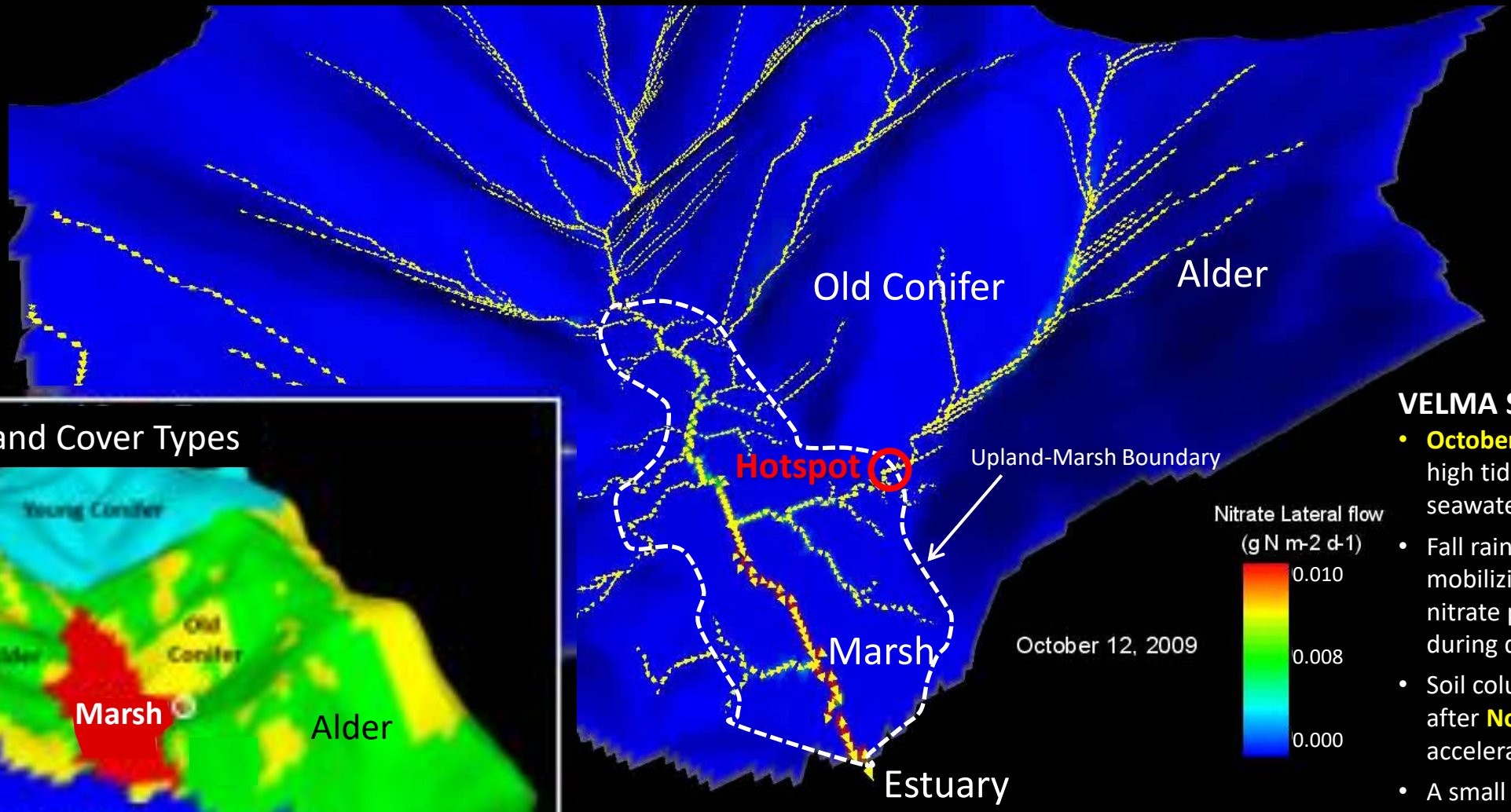
- VELMA nitrate results for the Trask River generated using publicly available data described in the VELMA Overview section (includes alder spatial coverage)
- Measured stream nitrate data are based on synoptic stream sampling protocols for the dates shown



Source: Darryl Marois, in preparation – Do not cite

VELMA animation: upland sources & flow paths by which nitrate is flushed to an Oregon salt marsh

- Nitrate flux arrow size and background color indicate direction and amount of nitrate flushed per day -



ANIMATION – wiggle mouse over image to display start

Animation best viewed in Normal View first, then Slide Show

VELMA SUMMARY

- **October 18** overtopping high tide adds N-rich seawater to marsh.
- Fall rains pick up **October 27**, mobilizing the alder soil nitrate pool that built up during dry summer months.
- Soil column fully saturates after **November 7**, accelerating nitrate flushing.
- A small patch of old Douglas fir just below the alder helps buffer the nitrate hotspot at the marsh edge.

McKane et al. in prep

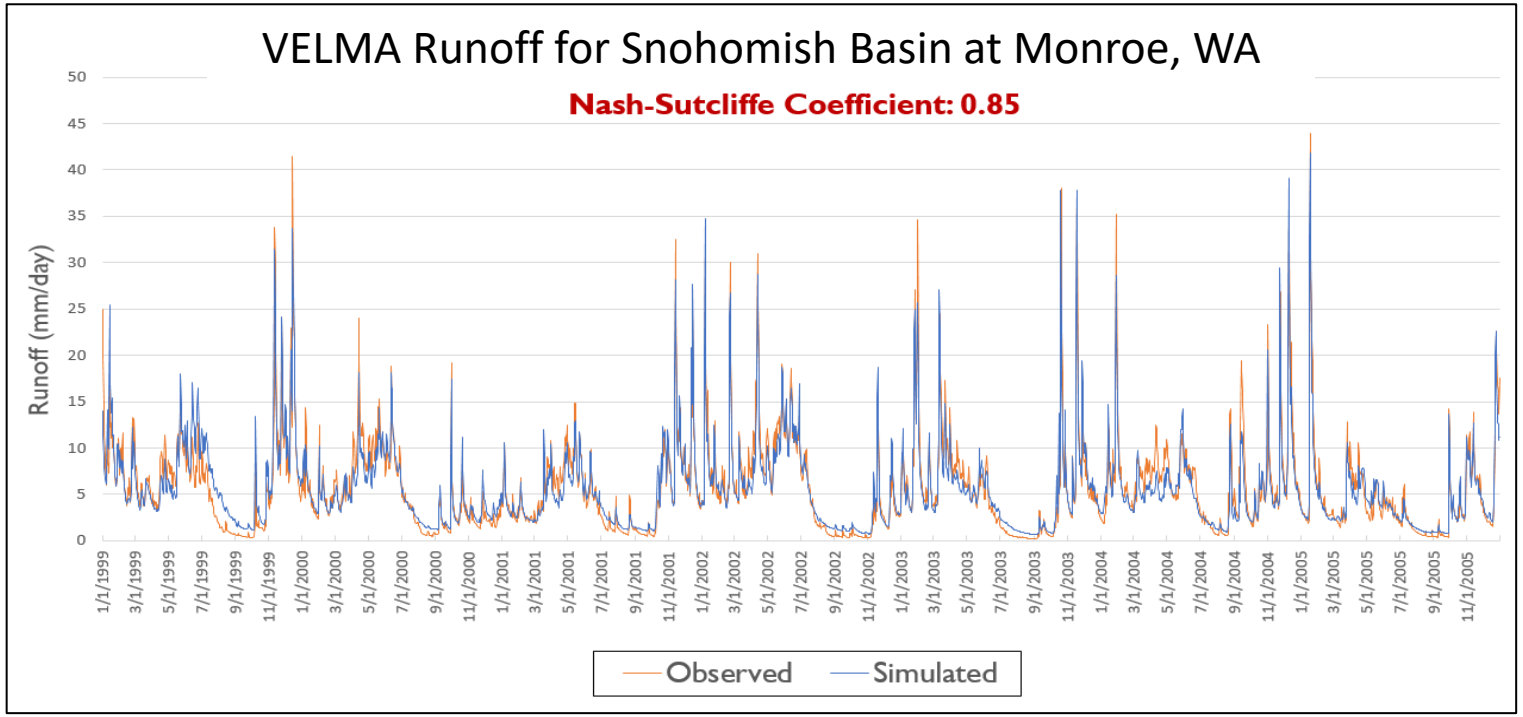
Outline

1. Multi-scale pollutant modeling & decision support
2. Urban stormwater contaminants
3. Nutrients
4. Stream flow, temperature, velocity, salmon habitat
   (ORD StRAP3 + StRAP4 proposed research)

Accurate water quality and stream habitat modeling depends on accurate streamflow modeling

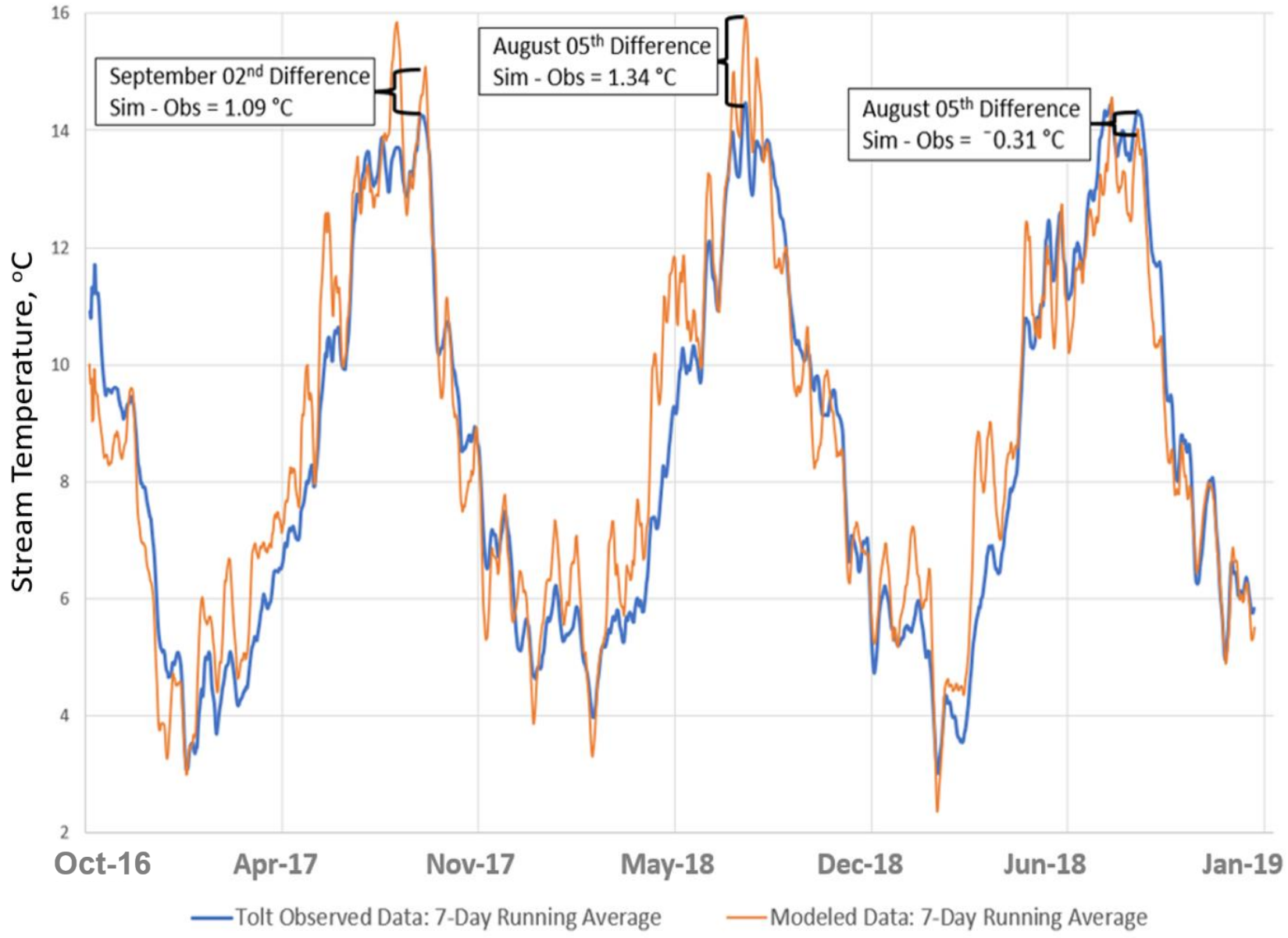
- **WATER QUALITY:** VELMA simulates hillslope flushing dynamics, enabling accurate simulation of nutrient & contaminant loads and identification of hotspots for remediation (preceding sections).
- **LOW SUMMER FLOWS:** VELMA simulation of short rotation forestry on summer low flows & impacts on salmon habitat quality can be found here. Slides included.
- **STREAM TEMPERATURE:** When linked with Penumbra, VELMA accurately simulates effects of riparian and upland shading on stream mainstem and cold-water refuges.
- **STREAM VELOCITY:** VELMA streamflow predictions can be used to drive HEC-RAS-2D to model stream velocities for floodplain salmon habitat restoration assessments
- **STREAM SEDIMENTS:** In progress

Snohomish Basin Streamflow



Stream Temperature – North Fork Tolt River

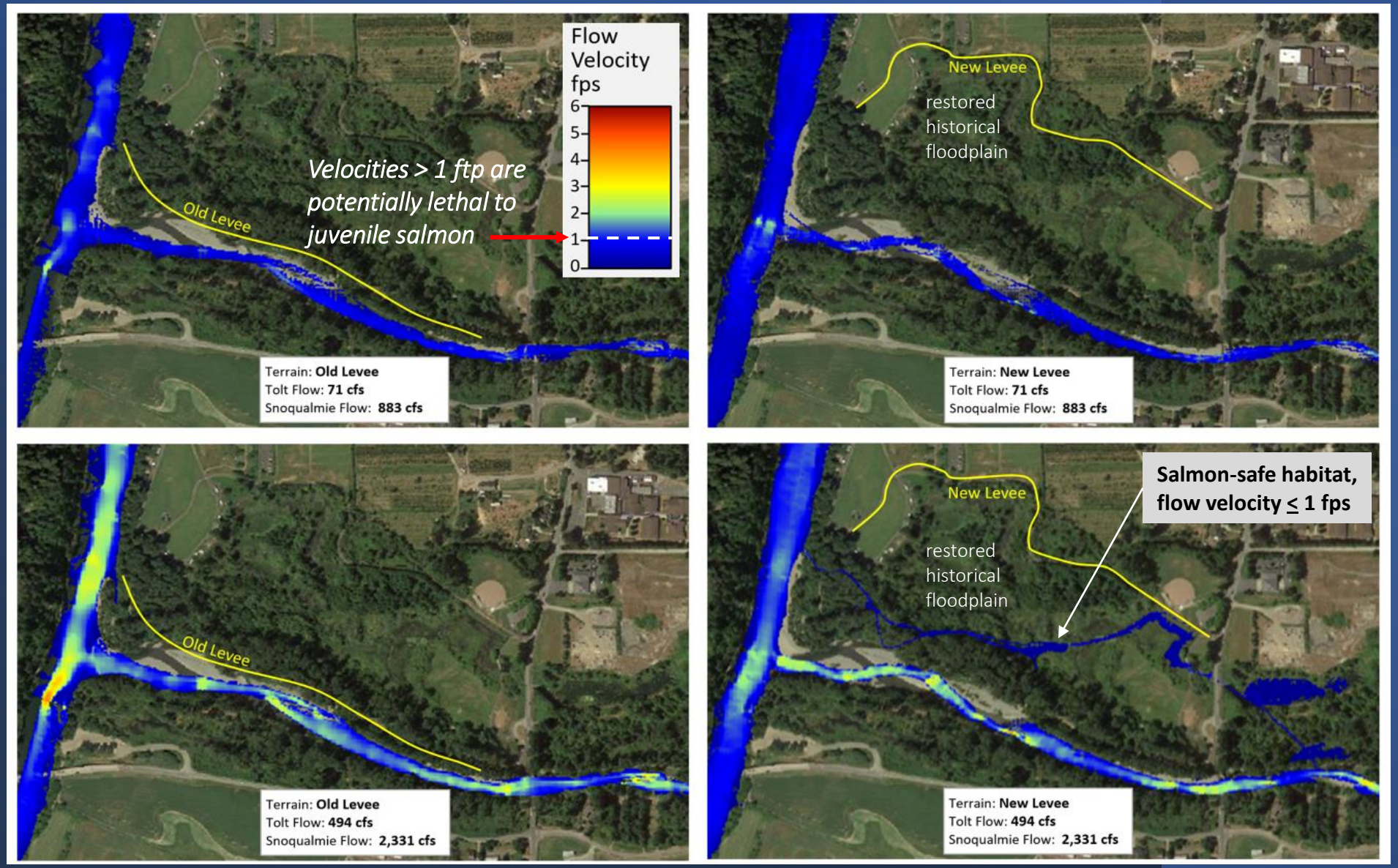
Observed vs. VELMA-Penumbra 7-day Running Average



VELMA flow data → HEC-RAS2D flow velocity

Tolt River Floodplain, WA

Slide courtesy of Brian Cluer, NOAA



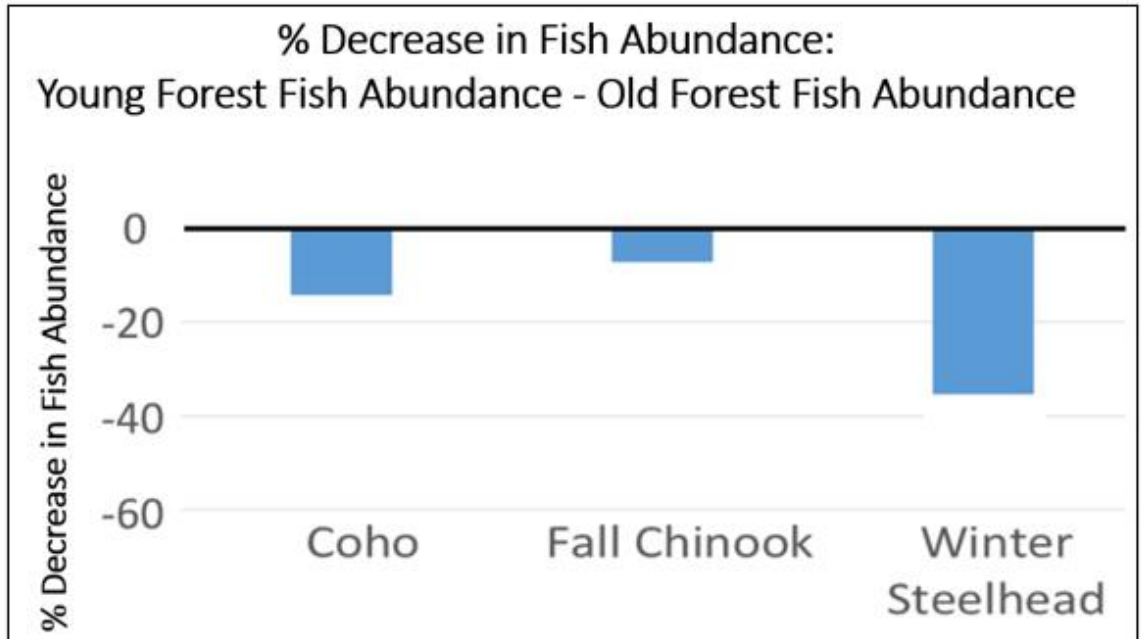
Linking Models for Salmon Recovery Planning

VELMA: Peak & Low Flow*

VELMA: Large Woody Debris

Penumbra: Stream Temperature

EDT: Fish Habitat



These results do not yet include harvest effects on stream temperature, sediments, velocity, or CWD

Thanks!

mckane.bob@epa.gov

Nitrogen remediation scenarios – Key questions

- **For treated sewage**, to what extent can WWTP upgrades for inland communities reduce N loads to freshwater streams? How will those upgrades translate to reduced N loads to Puget Sound?
- **For onsite sewage systems**, to what extent can septic system upgrades reduce N loads to freshwater streams? How will those upgrades translate to improvements in terrestrial and marine water quality?
- **For managed rural and urban land use practices**, to what extent can reductions in nutrient fertilization and increases in green infrastructure (riparian buffers, rain gardens, bioswales, etc.) reduce terrestrial nitrogen loads?
- **For natural nitrogen sources**, to what extent can riparian management options reduce biological inputs of N to streams? Options considered will include riparian cover type conversion of N-fixing alder to coniferous and/or non-N-fixing hardwood species, especially on primary flow paths.