

VELMA model green infrastructure applications for reducing 6PPD-quinone concentrations in Puget Sound urban streams

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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

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

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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

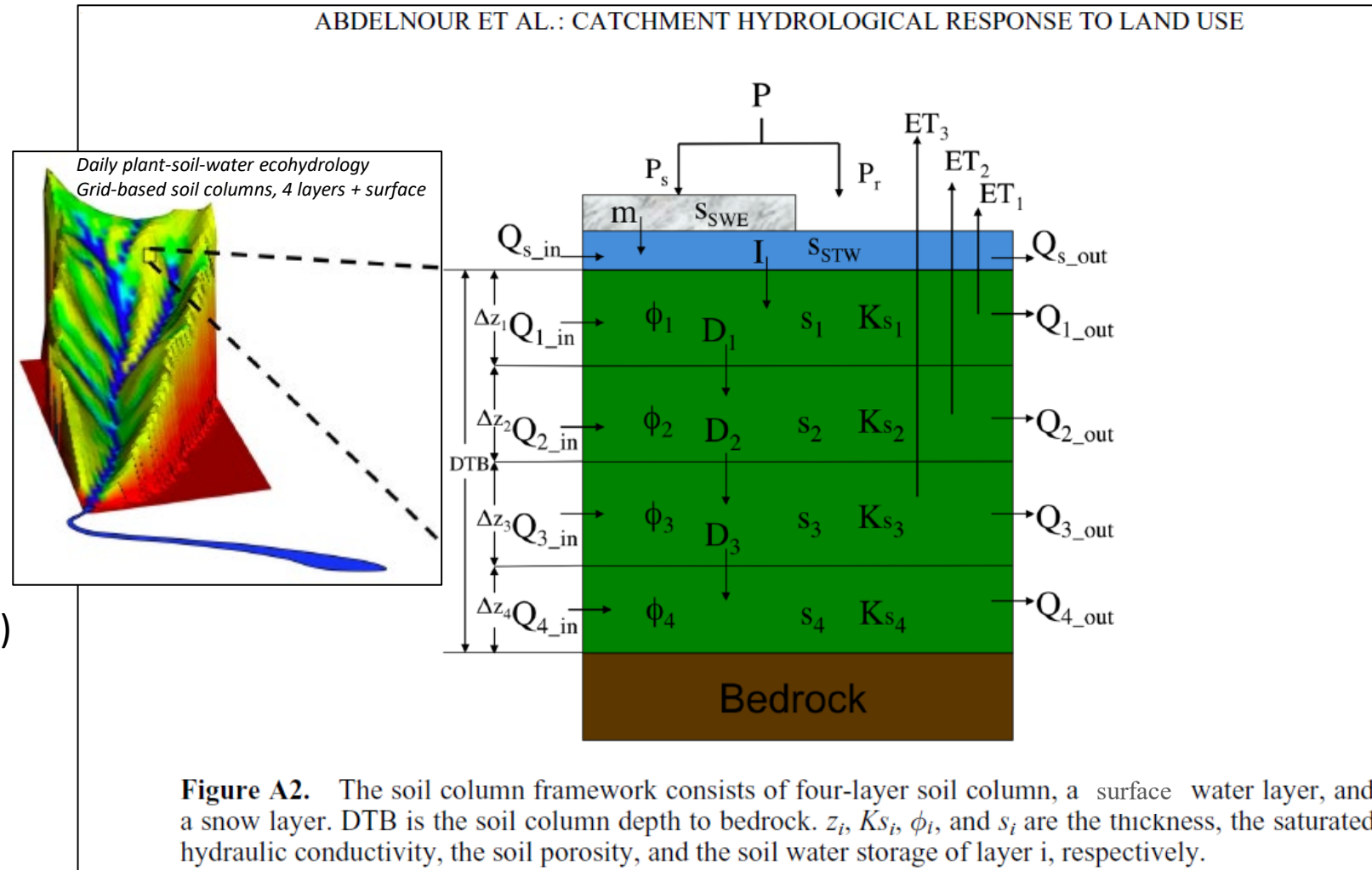


Bioswale
Longfellow Creek Watershed
West Seattle, WA

VELMA: Grid-based Urban Fate and Transport

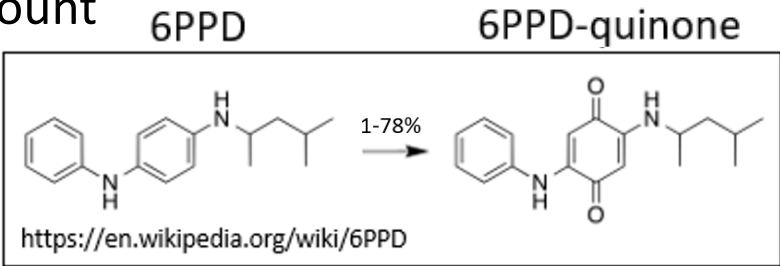
Water & Chemical Transport

- Daily precipitation and runoff
- Surface layer perviousness (0-1)
- Stormwater System
 - Spatially-explicit roads, curbs, drains, pipes
 - Transfers: curb to drain to pipe to stream...
- Soil matrix (5 or 10-meter grid)
 - Vertical and lateral flow (see figure)
 - Contaminant & nutrient transport, decomposition, sorption, desorption, aqueous/solid phase mass balance



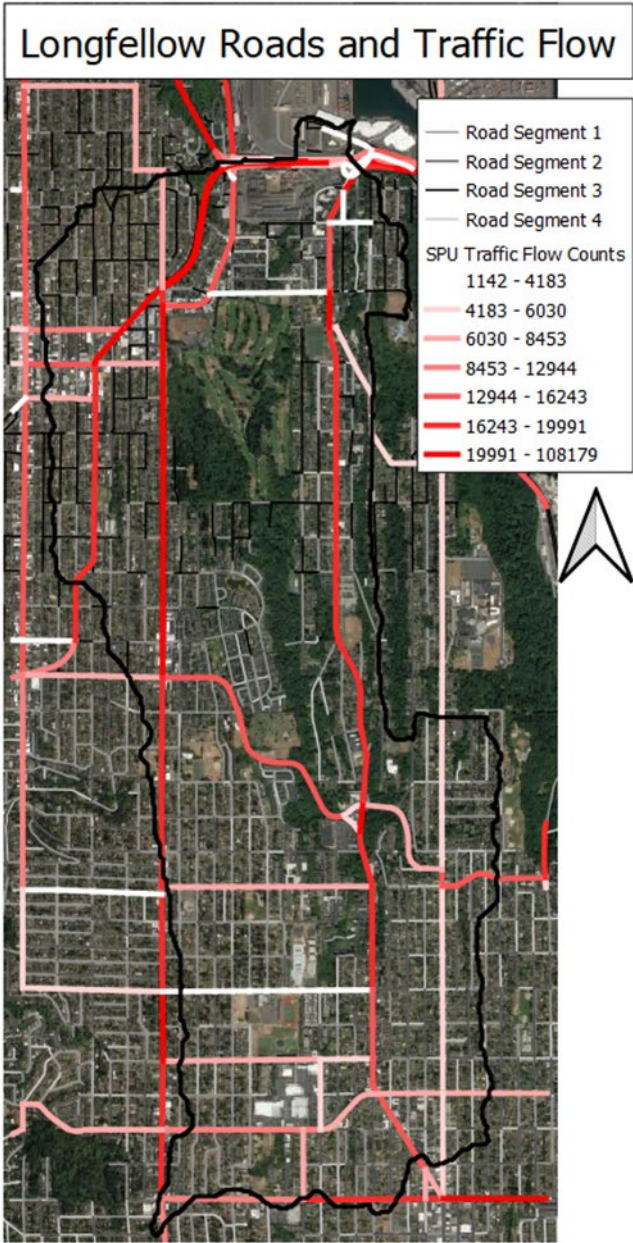
VELMA 6PPD calibration setup

- 6PPD deposition, degradation to 6PPD-quinone
 - 6PPD location, timing, amount
 - Fraction to 6PPD-quinone



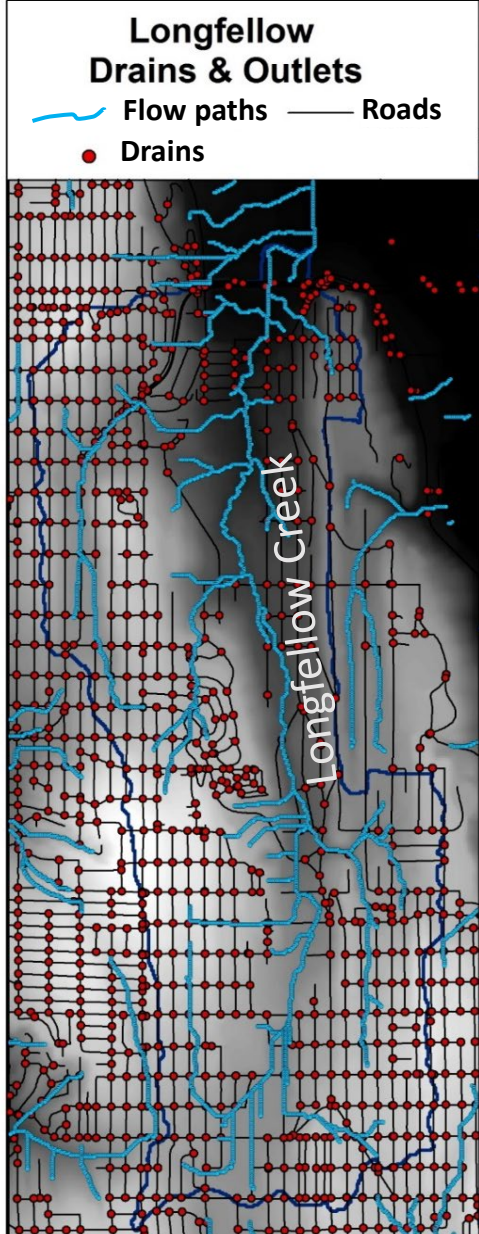
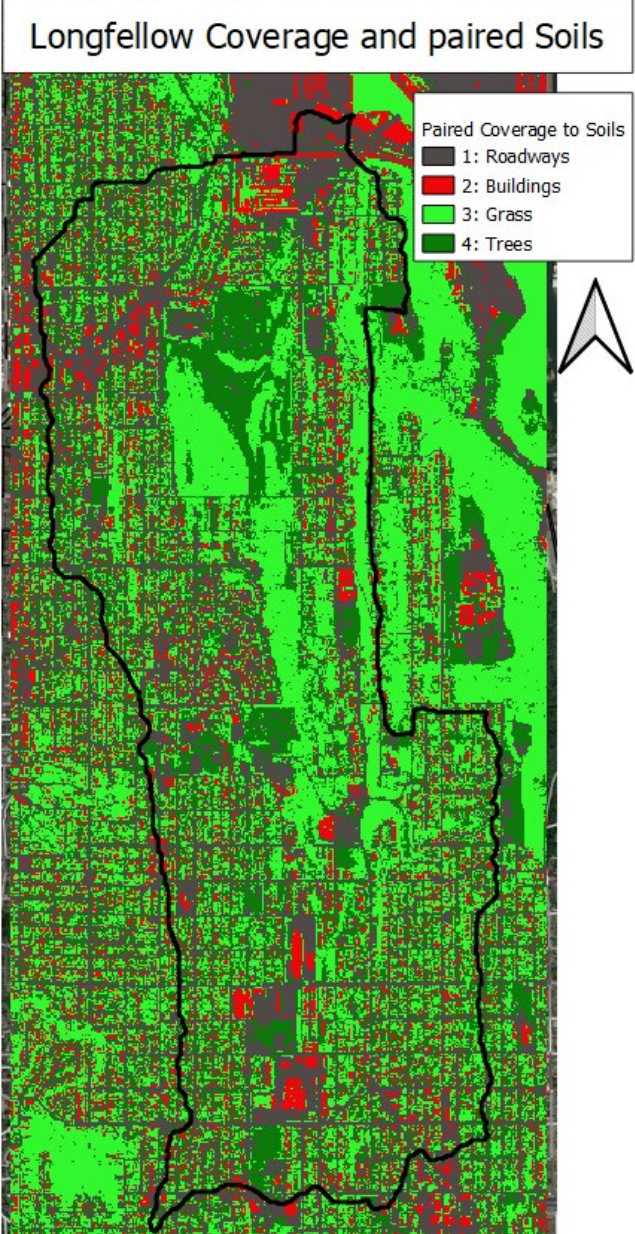
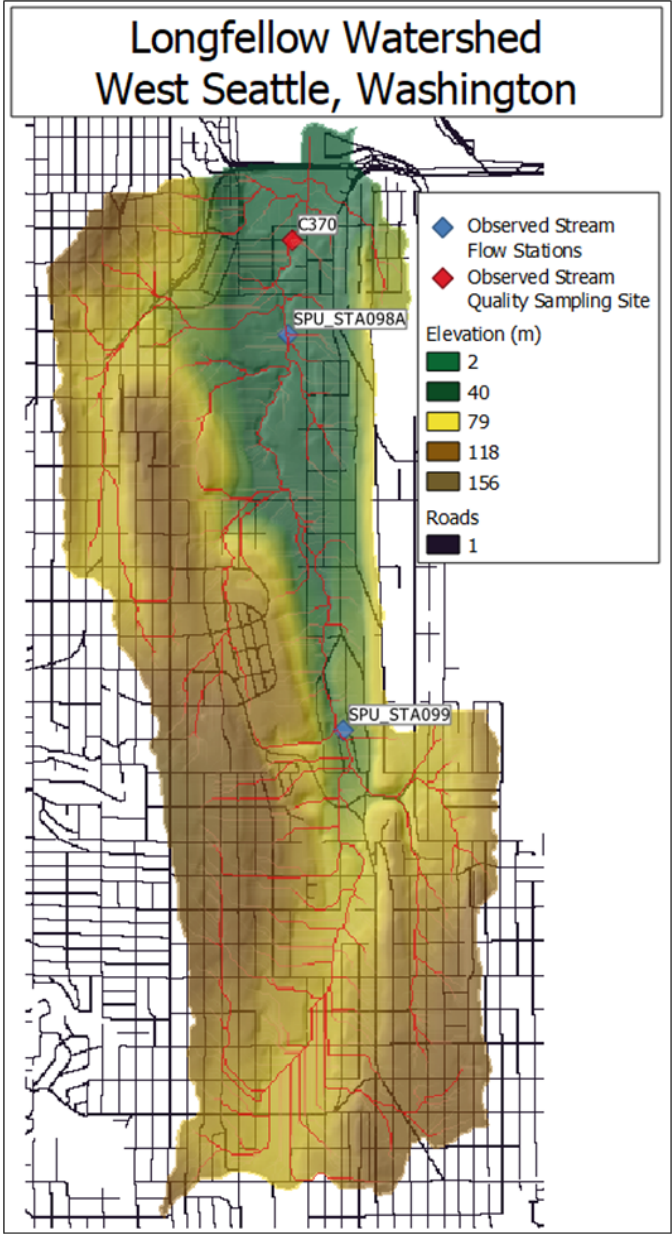
- Parameters: 6PPD fate and transport

Group	Item	Parameter		
contaminant	RoadDepo_6PPD	setMolarSolubilityCoefficient	*	0.000158
contaminant	RoadDepo_6PPD	setChemMaxDecay	*	0.2207475
contaminant	RoadDepo_6PPD	logKocSlope		NA
contaminant	RoadDepo_6PPD	uniqueSequenceId		1
contaminant	RoadDepo_6PPD	uniqueId		1
contaminant	RoadDepo_6PPD	Koc	*	11000
contaminant	RoadDepo_6PPD	logKocIntercept		NA
contaminant	RoadDepo_6PPD	setMolarMass	*	268.404
contaminant	RoadDepo_6PPD	logKow	*	3.6
contaminant	RoadDepo_6PPD	setDecompositionFactorMode		NONE
contaminant	RoadDepo_6PPD	modelClass		OrganicContaminantModel
contaminant	RoadDepo_6PPD	uniqueName		RoadDepo_6PPD
contaminant	RoadDepo_6PPD	directKocSpecification		true



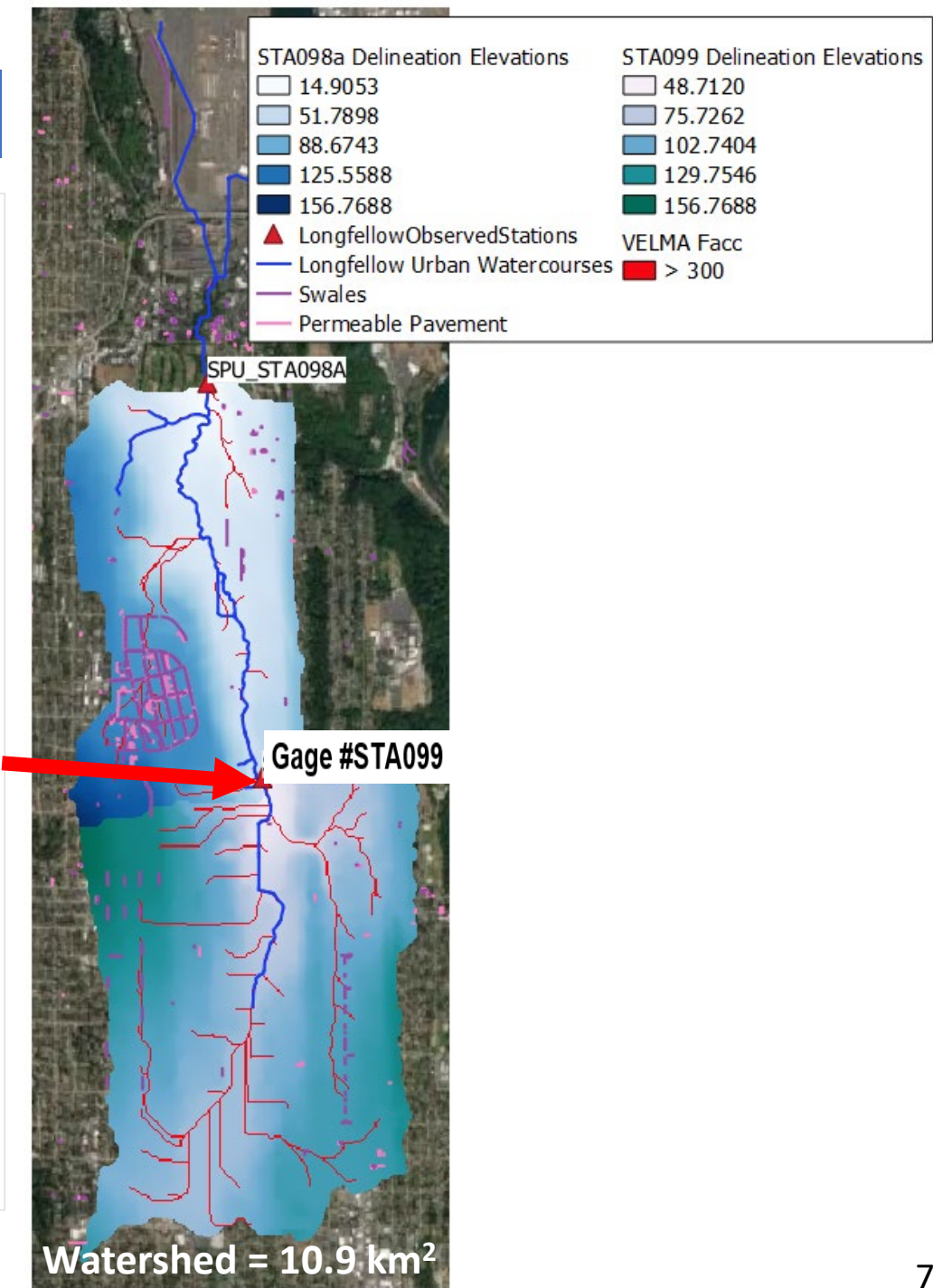
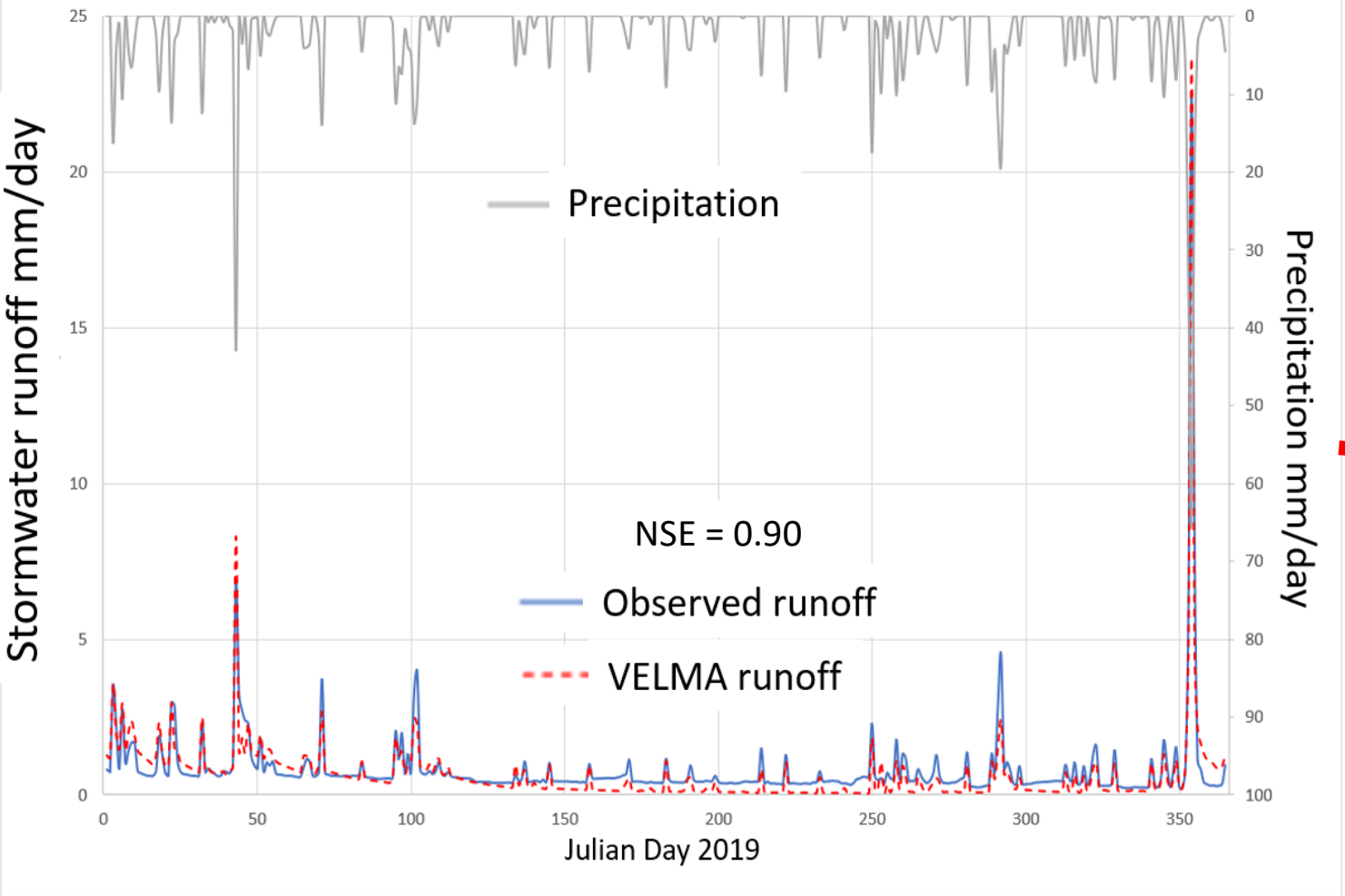
*From EPA CompTox Database <https://comptox.epa.gov/dashboard>

VELMA Urban Setup: Major Spatial Components



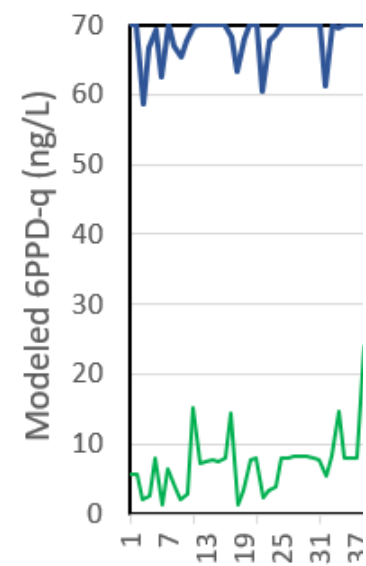
VELMA urban stormwater runoff performance tests

Longfellow Creek Stream **Gage #STA099**, Year = 2019

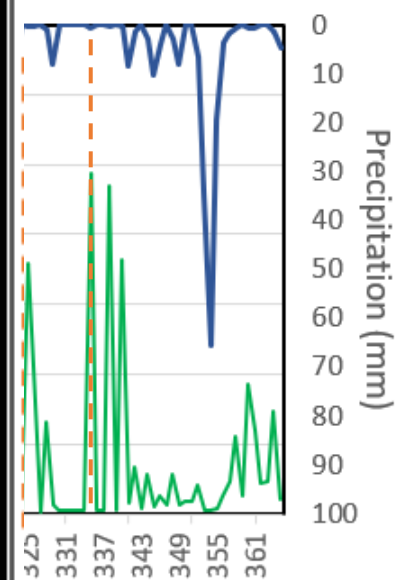


Long

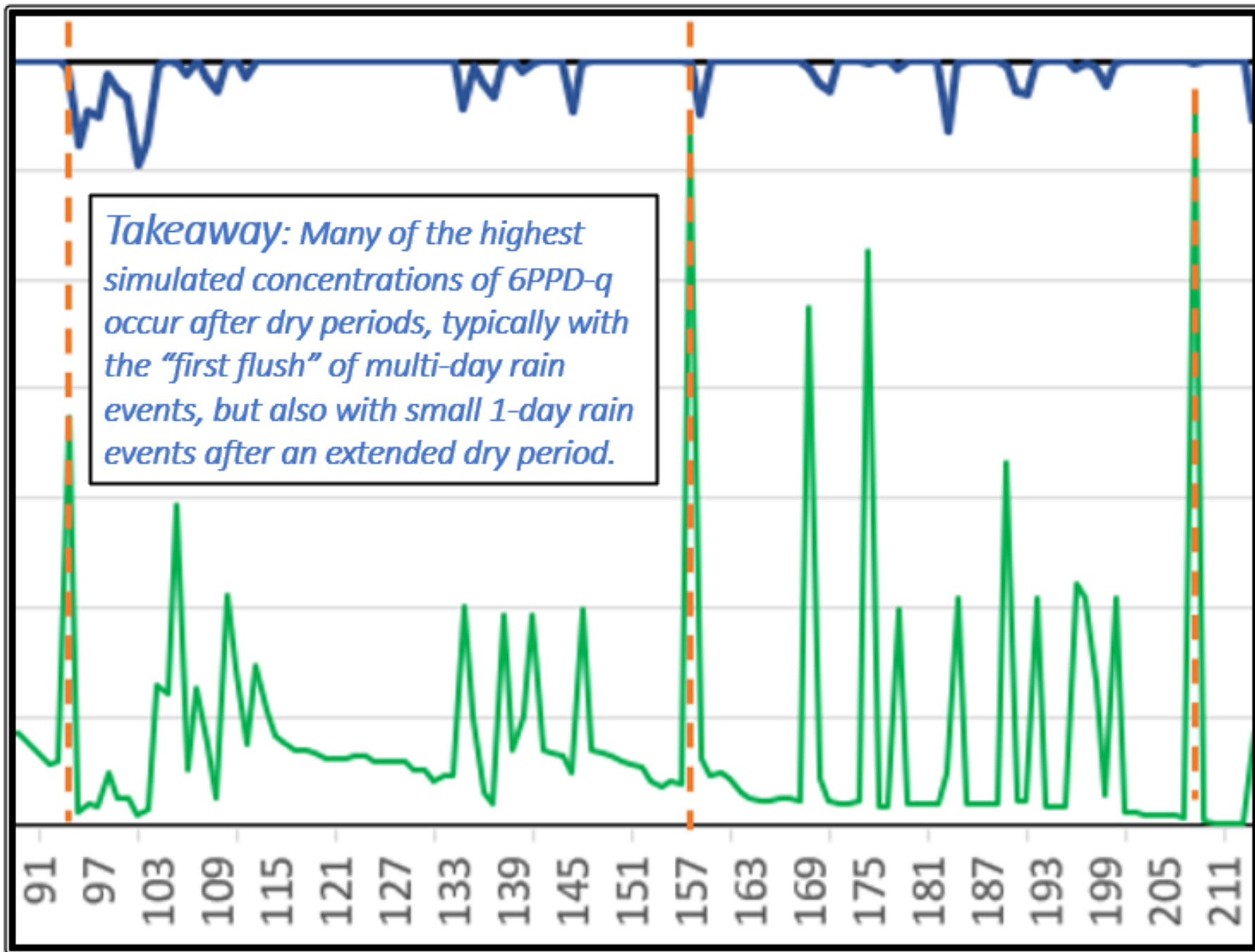
tions



Takeaway: Many of the highest simulated concentrations of 6PPD-q occur after dry periods, typically with the “first flush” of multi-day rain events, but also with small 1-day rain events after an extended dry period.

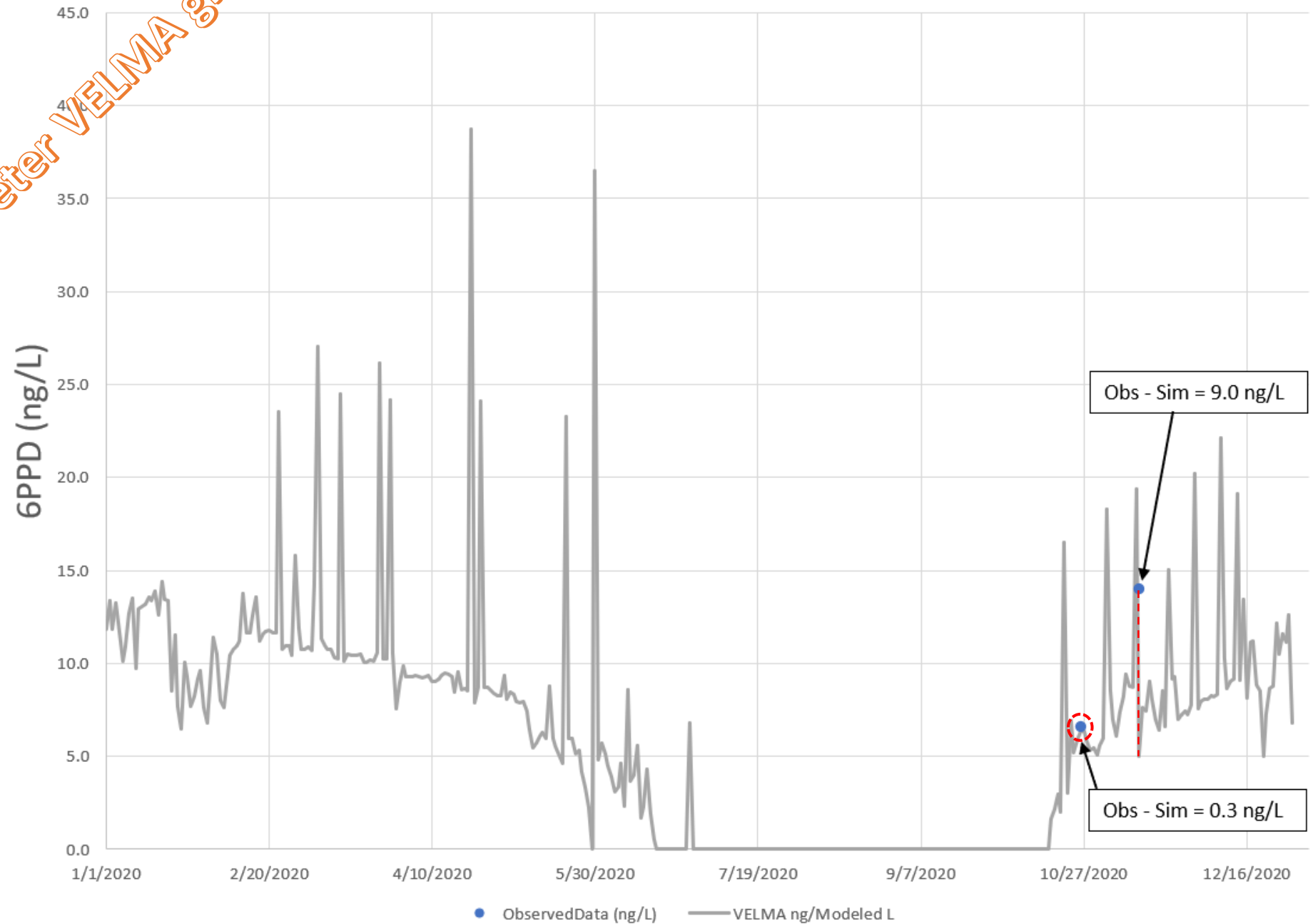


No observed
but VELMA
observed 2



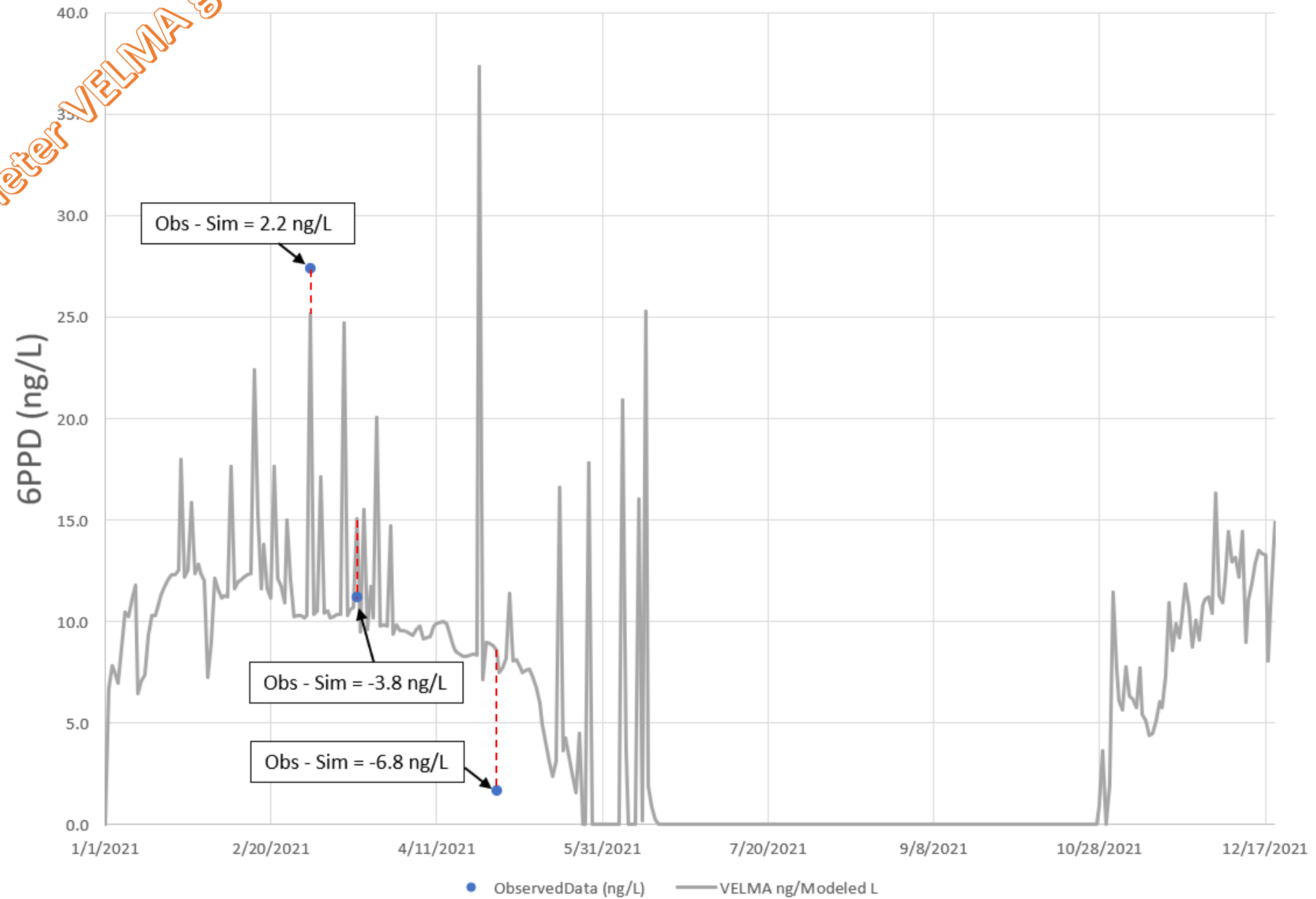
UPDATE: 5-meter VELMA grid

Longfellow Creek 6PPD-q at Grab Sample Location

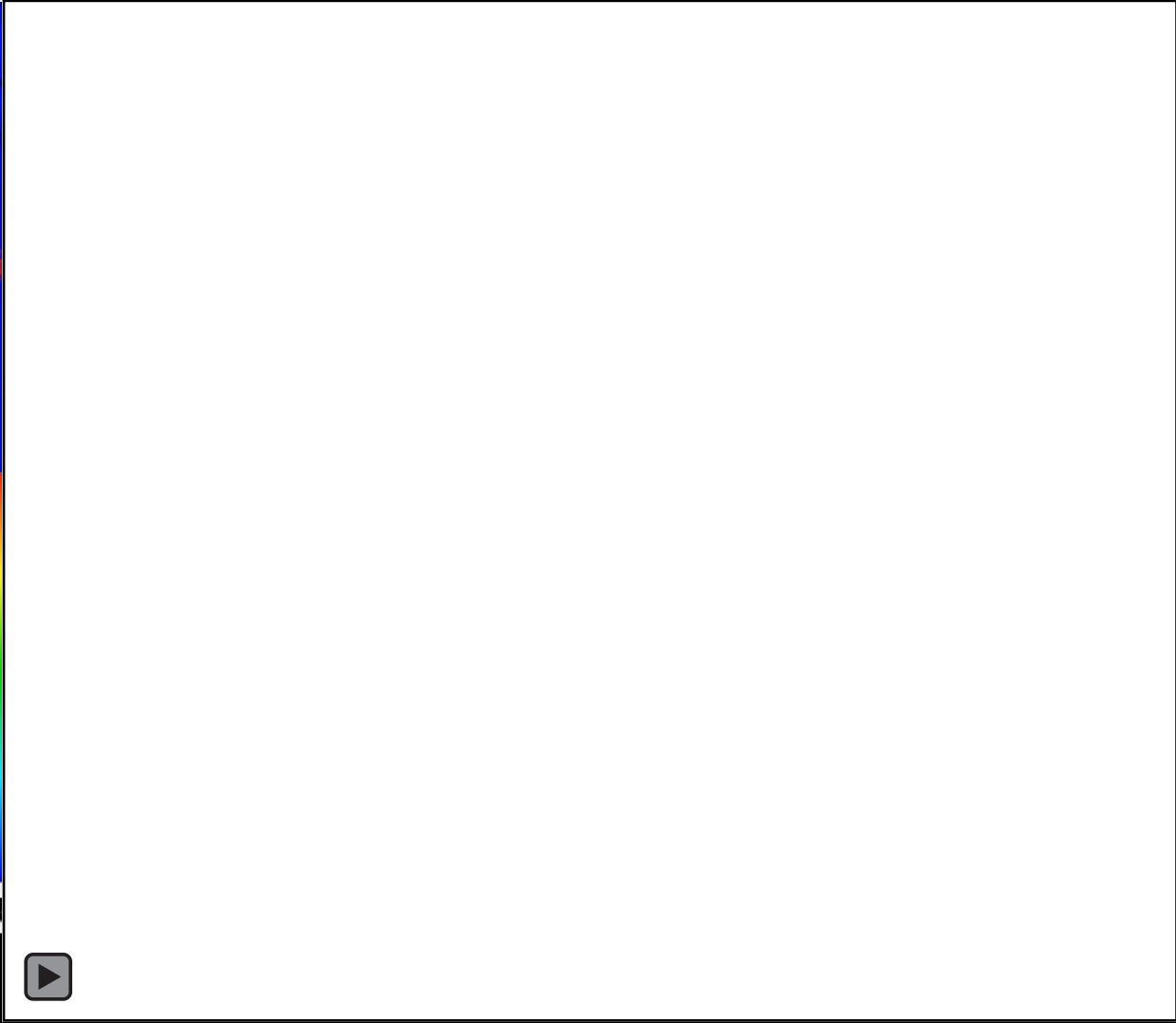


UPDATE: 5-meter VELMA grid

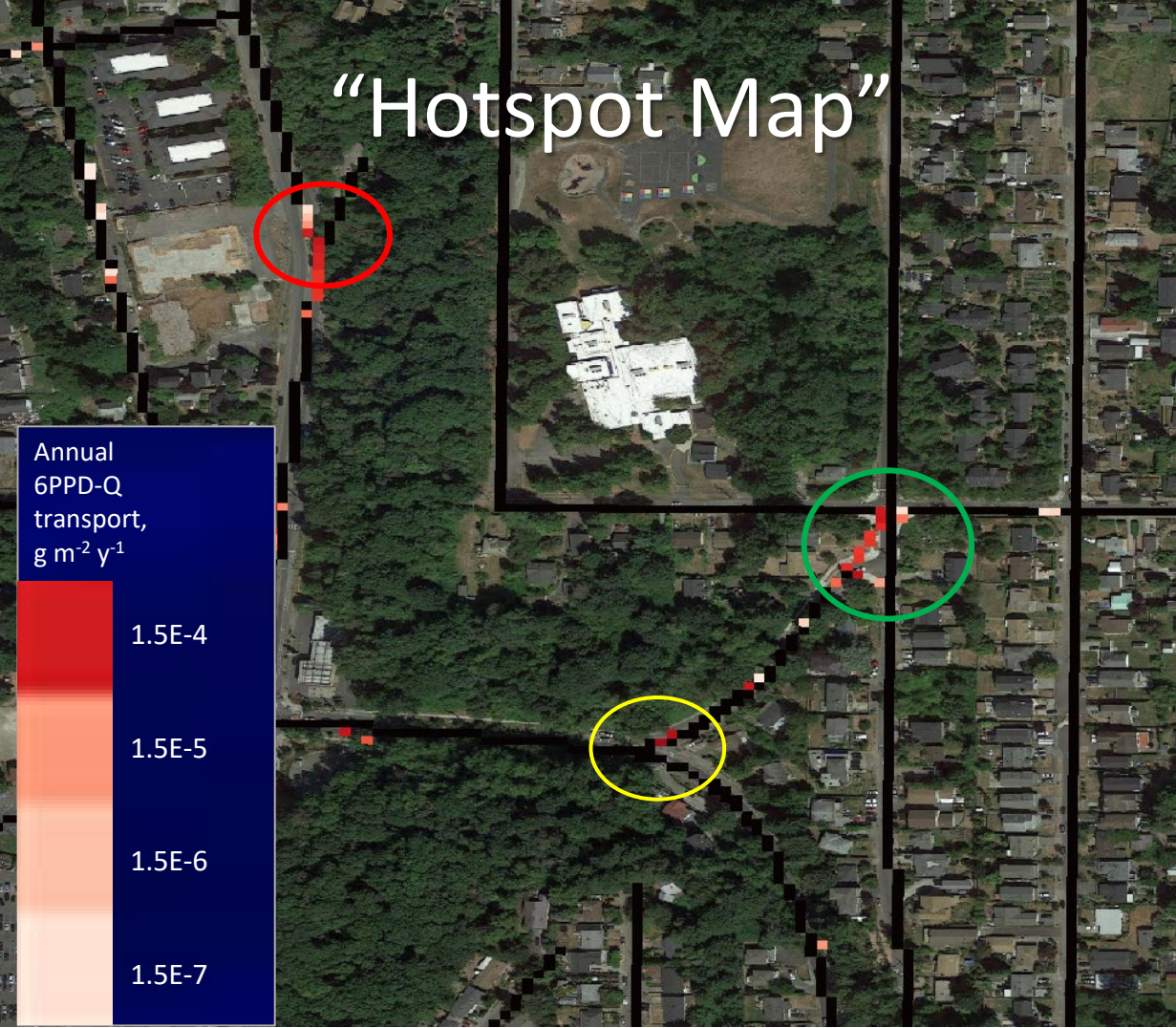
Longfellow Creek 6PPD-q at Grab Sample Location



Daily 6PPD-Q Surface Transfers (g m⁻² d⁻¹)

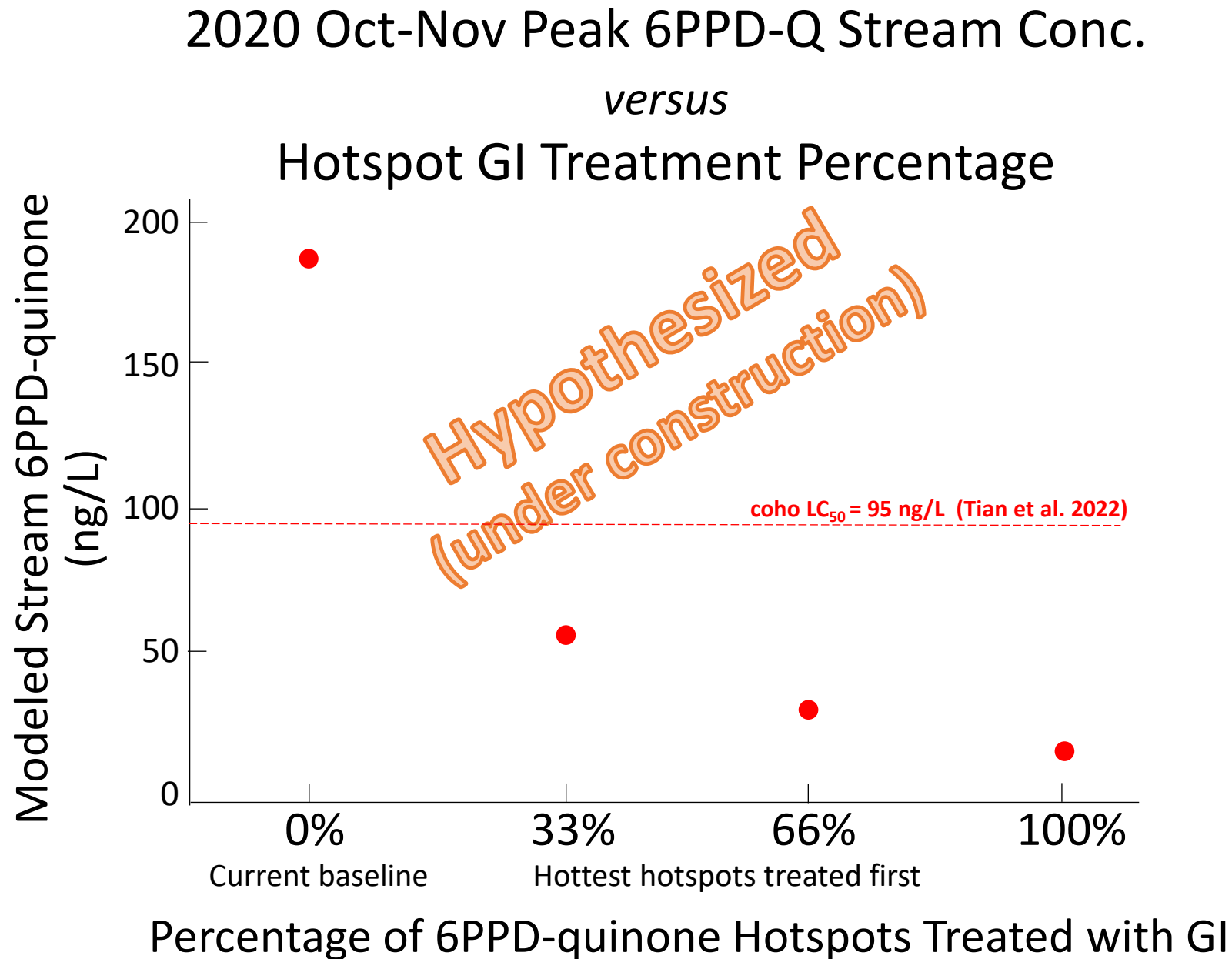


2020 Annual 6PPD-Q Surface Transfers (g m⁻² y⁻¹)



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

Simulated effects of hotspot GI treatments on stream 6PPD-quinone ng/L





Summary

- **Model performance:** Though modeled stream 6PPD-Q concentrations are consistent with limited available stream data, confident use of VELMA for informing GI best practices awaits more extensive performance tests.
- **New findings:** VELMA can identify 6PPD-Q hotspots at fine scales (5m) for prioritizing watershed-scale GI treatment placement, type, and amounts required to lower coho mortality.
- **Next steps:**
 - Complete Longfellow Creek VELMA hotspot analysis (slide 10)
 - More testing in more urban watersheds: Miller, Thornton, Pipers, Taylor (high coho prespawn mortality in all).
 - Coordination & integration of data and modeling across multiple scales (plots → whole watershed).
 - Progress on these steps will continue to depend on collaboration of modelers with empirical researchers, community and tribal watershed managers, and state and federal decision makers.
- **Important unanswered modeling questions/uncertainties:**
 - Spatial and temporal 6PPD deposition patterns?
 - 6PPD rates of conversion to 6PPD-Q?
 - 6PPD-Q half-life?
 - Optimal GI soil treatments to maximize contaminant retention and decay?

Project Collaborators – Thank you!

- EPA-ORD VELMA Team: Jonathan Halama (Spatial Synergy Solutions), Bob McKane, Vivian Phan, Allen Brookes, Kevin Djang (Inoventures)
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- City of Normandy Park: Amanda Leon