Watershed Modeling Workshop Summary

Last Updated: January 4, 2023

Overview

The PSEMP Modeling Work Group and Puget Sound Institute as part of The Science of Puget Sound Water Quality project co-hosted a Watershed Modeling workshop on December 12, 2022. The workshop began with an overview of some current watershed models and regional decision support tools relevant to nutrient management, including the following:

Model *Direct Link to 10-Minute Overview*	Presenter	Learn More
Hood Canal Landscape Assessment and Prioritization (LAP) Tool	**Scott Brewer** *Hood Canal Coordinating Council*	Learn More
VELMA	**Bob McKane** *Environmental Protection Agency*	Learn More
SPARROW	**Dan Wise** *U.S. Geological Survey*	Learn More *Results for the Pacific*
Stormwater Heatmap	**Christian Nilson** *Geosyntec*	Learn More
WQBE (Water Quality Benefits Evaluation)	**Jeff Burkey** *King County*	Learn More
BasinScout	**Nick Osman** *The Freshwater Trust*	Learn More

The discussion then turned to considering future scenarios and drivers in the use of these tools. For example, future climate change, and land cover predictions such as Puget Sound Institute's Land Cover Change Model, Envision, and scenario planning processes such as the Puget Sound Partnership's Future Scenarios project. **Some considerations that were raised for downscaled climate change model projections as inputs to other models include:**

- Start with a bottom-up approach to assessing impacts and sensitivity on any model that these inputs might have
- Always consider a range of climate change projections
- Consider whether to use dynamical or statistical downscaling at the outset because the historical and climate change datasets need to be consistent. Currently, no study has systematically compared the two downscaling methods to clarify when to use one or the other
- Guillaume Mauger also recommended Snover et al. (2013) as a resource that formalizes the approach to using climate change projections

Experts then reflected on knowledge gaps and shared inputs that could potentially benefit from collaborative improvements in the region, including:

- Compile/integrate higher resolution land cover classifications versus aggregate cover types like high-density urban data
- Develop detailed agricultural nitrogen budgets*
- Expand septic system data*
- Compile/integrate data on small and local constructed stormwater facilities (e.g., detention, infiltration) into the hydrologic models
- Expand monitoring for urban contaminants like 6PPD-Q and PCBs that end up in the food web
- Strengthen evaluations of the impacts of population growth, land use change, and climate change
- Strengthen projections and connections to biological impacts and indicators

*As part of the Puget Sound Nutrient Source Reduction project, SPARROW is planning to refine data sets for several nonpoint nutrient sources that we generally have lower confidence in, including population using septic tanks, farm fertilizer, and livestock waste.

This workshop was intended to be the beginning of a discussion on the models presented, which are a subset of the tools developed and available in the Puget Sound region. We hope to continue and expand engagement on the topic through follow-up PSEMP Modeling Work Group meetings. In the meantime, please share other regional models, tools, and future inputs for consideration through the Modeling Compendium Contribution Form.

Materials

Here are direct links to the materials for the *Watershed Modeling* workshop:

- Slides
- Full video
- Highlight video
- Chat

A recap for each workshop in The Science of Puget Sound Water Quality workshop series is available on our website. The recaps include a summary, highlight video, full recording, chat, and slides. The videos from the workshop series are also available directly via this YouTube playlist.

Note: for the full presentation slides and full video of resulting discussion please see the links above. Below are some highlights from the presentations, followed by a summary of questions and key discussion points.

Highlights

Discussion

- Stefano asked the presenters how much confidence we have in the delineation between alder and non-alder forest, particularly given the significance to nutrients?
    - Dan Wise shared that he is pretty confident in this for SPARROW because it is input for from the LEMMA (Landscape Ecology, Modeling, Mapping, and Analysis) group at Oregon State University, which uses 30 m raster to estimate the basal density of alder trees which is a strong predictor of nitrogen load. This data is updated annually, which is more refined than most inputs
    - Bob McKane reiterated that LEMMA is a great data source. He also highlighted that nitrogen from alders can improve primary productivity in streams and benefit salmon, so we have to be careful about how we frame and think about the problem. While alders may be feeding nitrogen into the estuary, it is probably dwarfed by other sources for most marine locations
        - VELMA used this data to analyze the land cover effects of alder on nitrate loads along the Trask River (appendix; see slide 21 for additional detail)
    - Gordon Holtgrieve added that nutrient concentrations in Puget Sound streams are generally pretty low, typically below 0.5 mg/L and rarely above 1 mg/L
- Alan Chapman asked will existing models project whether stream flow changes associated with climate change be mediated effectively by natural infrastructure improvements?
    - Bob McKane shared that young forest managed on short rotations consume 2 to 3 times more water than an older forest, which can reduce summer flows, particularly during critical spawning times in August, September and early October. VELMA has been working with tribes, including the Nisqually Indian Tribe, to analyze alternatives to this industrial forest approach. For example, the Nisqually Indian Tribe is using long rotations of about 80 years, which uses about half as much water. They are catalyzing the community more broadly to adopt these practices
- Dan Wise highlighted that it would be great to further refine the phosphorus inputs. SPARROW currently estimates geological phosphorous based on course geospatial data to start with. Secondly, since the raising of cattle is a significant source in some areas, it is important to accurately delineate where cattle are allowed to graze. Dan shared examples where the delineation of grazing can be improved in Puget Sound, pointing out that this input to SPARROW is planned for refinement in the region
- Gordon Holtgrieve shared that he has been measuring atmospheric deposition using ^{17}O isotope, which is a pretty sensitive method. He noted that he can hardly see the presence of this source in most waters. Additionally, atmospheric deposition only appears to be a meaningful source when rivers are dominated by snowmelt and at the time of the year when the freshet occurs. He asked the presenters if that was consistent with what they were seeing in the models.

Discussion Questions

1. What are the key inputs or knowledge gap that would be valuable to refine for models/tools in the region?
2. Which shared inputs could potentially benefit from collaborative improvements?
3. What other regional models, tools, and inputs would you highlight?

    - Dan Wise noted they see a similar pattern in SPARROW; where there is a signal from atmospheric deposition lower in the watershed, but it gets swamped by point sources like agriculture and urban runoff by the time it gets to the mouth of the rivers
- Ken Pierce noted that he was struck by the fact that all these models use land cover and sometimes land cover change but only the Stormwater Heatmap even attempts to use high resolution data mapping actual cover versus mixed cover "types" like high-density urban
    - Philip Murphy highlighted that LandTrndr data provides historic harvest info, and covers Puget Sound
    - Ken Pierce shared that LandTrendr, LCC, CCAP are not great for mapping urban land cover change. For example, they suggest impervious land cover is decreasing, when observations consistently show it is increasing
- Aaron Clark asked if the Seattle data predicting 'effective impervious area' instead? i.e. incorporating GSI that offsets impervious especially in redevelopment?
    - Ken Pierce followed up to say it is potentially mapping maturing urban tree canopy that makes it seem like impervious surface is reducing as a byproduct
    - Curtis DeGasperi added could vegetation overhanging roads be an important urban process that is not considered in these models?
    - Ken Pierce highlighted Coen et al.(2017) and shared that the Washington Department of Fish & Wildlife is starting to produce land cover maps that try to capture trees over the road and in the future trees over buildings
- Jeff Burke added there is multiple data sources being used to develop the hydrologic landscape in these models and there are different errors associated with each of those inputs. For example, geology is highly variable and a big driver for runoff. Whereas impervious surface is generally high resolution and pretty accurate. Areas that are highly disturbed and more impacted are likely less accurate. Additionally, any linear feature is hard to present as a raster
- Jonathan Halama shared some additional context for VELMA in the chat including that roads and buildings are forced, then the trees are overlaid using tree LiDAR dataset, and the remaining is considered grass or open space. He also shared that some urban watersheds have 1-5 m resolution, the model accounts for stormwater, etc.
- Christian Nilsen shared that anecdotally, a lot of the national datasets like the National Land Cover Database has more error in our region so need to be refined for use here. For example, our tree canopy is a lot thicker than where they were developed and calibrated. Furthermore, any classes that have tree canopy carry this challenge for example roadside vegetation
- Curtis DeGasperi reflected that it may be potentially helpful to have more information on existing stormwater infrastructure (e.g., detention, infiltration) that would allow some modeling of the flow changes caused by existing infrastructure. He added that the region does not seem to have the data that would allow the inclusion in the hydrological and other models of many smaller/local constructed facilities that have been built across the region
- Lynn Schneider asked how the massive die off of Doug Fir trees over the past few years is being incorporated into updates of the models
    - Jeff Burkey shared that in King County developed urban landscape has a greater impact on stormwater and nutrient runoff, so the Water Quality Benefits Evaluation assumes trees are static and has not focused on differentiating the types of trees and their change, but could develop that functionality in future

- Shuhui Dui asked how much monitoring data is available to calibrate/verify the proposed models and if we need to put in more resources to collect site-specific data for model development.
    - Lynn Schneider followed up to ask if we need more data for on-site sewage systems, particularly given the different nutrient reduction capabilities between tanks, drain fields, and complex on-site treatment systems
    - Bob McKane advocated for more monitoring for urban contaminants to get a better handle on the deposition and legacy pools, particularly for contaminants like 6PPD-Q and PCBs that are ending up in the food web. Furthermore, while there is some detailed information on these a readily accessible map would be valuable
    - Jeff Burkey reflected that King County is lucky to be pretty data-rich, but it is hard to extrapolate from these well studied areas to other areas in the Sound. Finally, Jeff highlighted that it can be difficult to understand the role and impacts that lake dynamics within the watersheds are having, because it is easier to monitor what is coming in as opposed to what is coming out and these systems dynamics need their own specific consideration

Resources

Additional watershed models, decision support tools, and inputs shared

- Ecology's Puget Sound Watershed Characterization Project
- National Water Model (overview from Brian Cosgrove)
- Distributed Hydrology Social Vegetation Model (DHSVM) | Ning Sun at Pacific Northwest National Laboratory
- Variable Infiltration Capacity Macroscale Hydrologic Model (VIC) | Bart Nijssen at the University of Washington
- Structure for Unifying Multiple Modeling Alternatives (SUMMA) | Bart Nijssen at the University of Washington and Martyn Clark at the University Corporation for Atmospheric Research
- First Street Foundation
- Hydrological Engineering Center's River Analysis System (HEC-RAS) and Flood Damage Reduction Analysis (HEC-FDA)
- HAZUS
- LandTrndr
- Coastal Change Analysis Program (CCAP)

Please share other regional models, tools, and future inputs for consideration through the Modeling Compendium Contribution Form.

Additionally shared

- Magel, C. L., & Francis, T. B. (2022). Evaluating ecosystem-based management alternatives for the Puget Sound, U.S.A. social-ecological system using qualitative watershed models. *Frontiers in Marine Science*, *9*. Available at: https://www.frontiersin.org/articles/10.3389/fmars.2022.1012019

- Cohen, W. B., Healey, S. P., Yang, Z., Stehman, S. V., Brewer, C. K., Brooks, E. B., Gorelick, N., Huang, C., Hughes, M. J., Kennedy, R. E., Loveland, T. R., Moisen, G. G., Schroeder, T. A., Vogelmann, J. E., Woodcock, C. E., Yang, L., & Zhu, Z. (2017). How Similar Are Forest Disturbance Maps Derived from Different Landsat Time Series Algorithms? *Forests*, *8*(4), Article 4. Available at: https://doi.org/10.3390/f8040098

Referenced in the presentations

- Snover, A. K., Mantua, N. J., Littel, J. S., Alexander, M. A., Mcclure, M. M., & Nye, J. (2013). Choosing and Using Climate-Change Scenarios for Ecological-Impact Assessments and Conservation Decisions. *Conservation Biology*, *27*(6), 1147–1157. Available at: https://doi.org/10.1111/cobi.12163

VELMA (Visualizing Ecosystem Land Management Assessments)

- Heris, M. P., Foks, N. L., Bagstad, K. J., Troy, A., & Ancona, Z. H. (2020). A rasterized building footprint dataset for the United States. *Scientific Data*, *7*, 207. Available at: https://doi.org/10.1038/s41597-020-0542-3
- Lin, J., Compton, J. E., Clark, C., Bittman, S., Schwede, D., Homann, P. S., Kiffney, P., Hooper, D., Bahr, G., & Baron, J. S. (2020). Key Components and Contrasts in the Nitrogen Budget Across a U.S.-Canadian Transboundary Watershed. *Journal of Geophysical Research: Biogeosciences*, *125*(9). Available at: https://doi.org/10.1029/2019JG005577
- McKane, R., Brookes, A., Djang, K., Stieglitz, M., Abdelnour, A., Pan, F., Halama, J., Pettus, P. B., & Phillips, D. (2014). *Visualizing Ecosystem Land Management Assessments (VELMA) v. 2.0: User manual and technical documentation* (Technical Report L-PESD-30840-QP-1–2). US Environmental Protection Agency, National Health and Environmental Effects Research Laboratory. Available at: https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/7307080
- Abdelnour, A., B. McKane, R., Stieglitz, M., Pan, F., & Cheng, Y. (2013). Effects of harvest on carbon and nitrogen dynamics in a Pacific Northwest forest catchment. *Water Resources Research*, *49*(3), 1292–1313. Available at: https://doi.org/10.1029/2012WR012994

SPARROW (Spatially Referenced Regression on Watershed Attributes)

- Ator, S., Schwarz, G. E., Sekellick, A. J., & Bhatt, G. (2022). Predicting Near-Term Effects of Climate Change on Nitrogen Transport to Chesapeake Bay. *JAWRA Journal of the American Water Resources Association*, *58*(4), 578–596. Available at: https://doi.org/10.1111/1752-1688.13017
- Roland, V. L., Garcia, A. M., Saad, D. A., Ator, S. W., Robertson, D., & Schwarz, G. (2022). Quantifying regional effects of best management practices on nutrient losses from agricultural lands. *Journal of Soil and Water Conservation*, *77*(1), 15–29. Available at: https://doi.org/10.2489/jswc.2022.00162
- Wise, D. (2021). *Using Regional Watershed Data to Assess Water-Quality Impairment in the Pacific Drainages of the United States* (Scientific Investigations Report No. 2021–5087; Scientific Investigations Report). U.S. Geological Survey. Available at: https://doi.org/10.3133/sir20215087

- Miller, M. P., Capel, P. D., García, A. M., & Ator, S. W. (2020). Response of Nitrogen Loading to the Chesapeake Bay to Source Reduction and Land Use Change Scenarios: A SPARROW-Informed Analysis. *JAWRA Journal of the American Water Resources Association*, *56*(1), 100–112. Available at: https://doi.org/10.1111/1752-1688.12807

WQBE (Water Quality Benefits Evaluation)

- King County. 2022. Water Quality Benefits Evaluation – Phase 2 Watershed Model Configuration approach for Hydrology and Water Quality Simulation Technical Memorandum. Prepared by Paradigm Environmental. Seattle, WA. Available at: https://your.kingcounty.gov/dnrp/library/2022/kcr3369/kcr3369.pdf
- King County. 2022. Water Quality Benefits Evaluation – Phase 2 Watershed Model Hydrology Calibration Technical Memorandum. Prepared by Paradigm Environmental. Seattle, WA. Available at: https://your.kingcounty.gov/dnrp/library/2022/kcr3367/kcr3367.pdf
- King County. 2022. Water Quality Benefits Evaluation – Phase 2 Watershed Model Water Quality Calibration Technical Memorandum. Prepared by Paradigm Environmental. Seattle, WA. Available at: https://your.kingcounty.gov/dnrp/library/2022/kcr3368/kcr3368.pdf

Follow-up Questions

- Michael Connor: It seems that livestock population is quite variable depending on the economy. How accurately are livestock tracked and updated
    - Dan Wise kindly followed up offline to share that, "Most SPARROW models for U.S. watersheds rely on livestock data that is collected at five-year intervals by the U.S. Dept. of Agriculture and reported at the county level. Therefore, not only is it temporally course, but spatially course as well. For the SPARROW models we are developing for the Puget Sound, however, we have more refined livestock estimates both temporally and spatially. The WA Dept of Agriculture tracks cattle numbers at individual dairies and feedlots annually."

Engaging in the workshop series

Our region is navigating complex and challenging decisions on how best to manage nitrogen, dissolved oxygen, and the potential impacts on the key habitats and species of the Salish Sea. The University of Washington Puget Sound Institute is supporting a series of scientific workshops to help address technical uncertainties, advance modeling, and refine monitoring to improve our understanding of nutrients and broader water quality in the Salish Sea. Learn more about upcoming workshops or review the recordings and presentation materials from previous workshops.

Continue the discussion

- If you have not already, please join the listserv to receive periodic updates about Puget Sound Institute's program to foster regional water quality science, including information about upcoming workshops
- Join us for the follow up workshops to dig into these technical uncertainties
- Reach out to Stefano Mazzilli (mazzilli@uw.edu) and Marielle Larson (marlars@uw.edu) if you:

- Are interested in contributing or helping with one of the upcoming workshops or modeling and monitoring analyses
- Want to recommend another expert, program, or study for us to connect with to help advance the research
- Have additional ideas or questions