

15th WASHINGTON HYDROGEOLOGY SYMPOSIUM

May 11-14, 2026 | Hotel Murano | Tacoma, WA

PROGRAM *AND* ABSTRACTS

WASHINGTON HYDROGEOLOGY SYMPOSIUM

| Hotel Murano
| Tacoma, Washington
May 11-14, 2026

www.wahgs.org

SCHEDULE OVERVIEW

DATE	ACTIVITY
MONDAY May 11	<p>Field Trip 1: Woodland Creek and Hawks Prairie Groundwater Recharge Site Visits (8:00 AM - 5:00 PM)</p> <p>Field Trip 2: Doolin Rogers Geology Boat Tour (2:30pm - 6:00pm)</p>
TUESDAY May 12	<p>First Day of Symposium</p> <p>Opening Session / Keynote Talk</p> <p>Platform Presentations</p> <p>Exhibits</p> <p>Lunch Provided</p> <p>Poster Session and Reception (early evening)</p>
WEDNESDAY May 13	<p>Second Day of Symposium</p> <p>Keynote Talk</p> <p>Platform Presentations</p> <p>Lunch Provided</p> <p>Exhibits and Posters</p>
THURSDAY May 14	<p>Workshop 1: Water Rights, Ecology, and Best Practices - A Day of Hands-On Water Rights Analysis with an Ecology Water Master (8:00 AM - 4:00 PM)</p> <p>Workshop 2: Python Applications in Hydrogeology (8:00 AM - 5:00 PM)</p> <p>Workshop 3: AI Applications with Environmental Data (8:00 AM - 5:00 PM)</p>

2026 WELCOME

15th WASHINGTON HYDROGEOLOGY SYMPOSIUM

May 11-14, 2026 | Hotel Murano | Tacoma, WA

Welcome to the 15th Washington Hydrogeology Symposium, returning in 2026 to the Hotel Murano, Tacoma Washington! We are excited to bring together professionals from industry, government, academia, and Tribal Nations to discuss work in hydrogeology and related fields. The Symposium is an excellent venue for learning about the work of others and sharing experiences, as we look to advance the state of the practice.

Technical program – The technical program consists of sixteen technical sessions split across two tracks over two days. A poster session will be combined with a reception and refreshments on Tuesday evening for a great opportunity to engage poster presenters, sponsors/exhibitors, and colleagues. Technical sessions cover a wide variety of topics, including **streamflow restoration, recharge estimation, groundwater usage, contaminant hydrology, remediation, emerging contaminants, tools/methods, climate trends, geologic carbon sequestration, and more**. There is something for everyone!

Keynote speakers – We are pleased to hear from distinguished keynote speakers, Steven P Loheide II, PhD and Ms. Melanie Redding. Dr. Loheide comes to us as the 2026 Darcy Distinguished Lecturer in Groundwater Science and professor of Water Resources Engineering in *Civil and Environmental Engineering, Geological Engineering, Freshwater and Marine Sciences and Water Resource Management* at the University of Wisconsin – Madison. As an ecohydrologist, Dr. Loheide’s research focuses on the interactions between ecological and hydrological processes in natural and built systems with special attention to the role of groundwater.

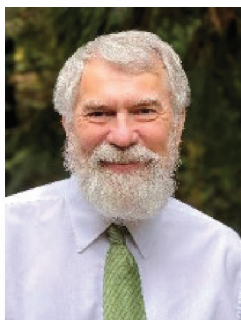
Ms. Redding is a licensed hydrogeologist and has worked for the Washington State Department of Ecology for 35 years working in water resources, water quality, and conducting groundwater research. She and her co-presenter Chris Neumiller were also part of the inaugural effort to launch the first Symposium on the Hydrogeology of Washington State. Their efforts, and those of many other Ecology hydrogeologists, helped lay the groundwork for this successful event.

Field trips and workshops – We are excited to offer two field trips this year on Monday, May 11. We have a special event this year with the return of the Puget Sound Coastal Geology Charter Cruise. This event is even more special in that we were able to coerce the original tour guide, Dr. Kathy Goetz Troost, into reprising her role as tour host. On Thursday, May 14, we will offer four one-day workshops on the topics of water law/water resources, hydrogeologic modeling with Python/FloPy, and environmental applications of artificial intelligence.

Exhibitors and Passport Program – Please spend some time visiting our exhibitors, who offer a variety of solutions for state-of-the-art field methods, sample analysis, data collection, water treatment, and more. We encourage you to visit each exhibitor and participate in our Passport Program for an opportunity to win prizes! We would especially like to thank our sponsors for their generosity, which helps ensure the long-term success of the Symposium.

Nadine Romero Scholarships – The Symposium is proud to award scholarships to undergraduate and graduate students as they continue their study and practice of hydrogeology, and to promote the development of new professionals in our field. We look forward to announcing this year’s winners!

On behalf of the entire 15th Washington Hydrogeology Symposium Steering Committee, I want to thank you for attending and taking advantage of the technical sessions, field trips, workshops, exhibitors, and networking opportunities. Our intent is that your time at the Symposium not only benefit you, but will serve to further advance and inspire the work in your organization and the hydrogeology community in the Northwest.



Sincerely,
Christopher Martin
Washington State Department of Ecology
2026 Washington Hydrogeology Symposium Chair

TABLE OF CONTENTS

2026 WELCOME	i
TABLE OF CONTENTS.....	ii
GENERAL INFORMATION.....	iii-iv
STEERING COMMITTEE.....	v
SCHEDULE AT A GLANCE	2-6
KEYNOTE SPEAKERS	
Dr. Stephen Loheide - Tuesday morning keynote	7-8
Melanie Redding - Wednesday morning keynote	9-10
ORAL ABSTRACTS	12-76
POSTER ABSTRACTS.....	77-91
FIELD TRIPS	93-94
WORKSHOPS.....	95-96
PRESENTER INDEX	98-103
EXHIBITORS.....	104
SPONSORS	Back cover

Nadine L. Romero Student Scholarships

The biannual Nadine L. Romero Student Scholarship recognizes students who have demonstrated exceptional academic achievements, are making valuable contributions to the hydrogeology and university communities, and have significant potential as future professional hydrogeologists. Scholarship recipients will be announced at the Symposium and on the Symposium website.

GENERAL INFORMATION

Symposium Registration Booth and Registration Hours

The Washington Hydrogeology Symposium Registration Booth is located outside the Rotunda at the Hotel Murano. Staff will be available to provide assistance and information throughout the Symposium.

Tuesday, May 12: 7:30 AM–6:00 PM

Wednesday, May 13: 8:00 AM–4:40 PM

Thursday, May 14: 7:30 AM– 5:00 PM

Name Badges

Please wear your name badge. It is your entrance ticket to Symposium activities including sessions, breaks, lunches, and the Tuesday Poster Reception.

Symposium Sessions

Symposium sessions and Thursday workshops will be held at the Hotel Murano in the Rotunda.

Presenters

Presenters in oral sessions should arrive at assigned presentation rooms at least 15 minutes before the session start time to load files onto the laptop provided. An audio-visual operator will be available if assistance is needed. Poster presenters may set up their poster any time on Tuesday morning or during the morning breaks at 9:15 and 10:50 AM. It is important that all posters be in place by the end of the afternoon break at 2:50 PM. Plan to be available at your poster during the Tuesday Poster Session and Reception from 4:30-6:30 PM. You may leave your poster up until the end of the afternoon break on Wednesday at 2:05 PM.

Meals and Refreshments

Breakfast and lunch are provided on Tuesday and Wednesday, and a light breakfast will be provided Thursday morning before workshops begin. If you made a special meal request (vegetarian or other), please note that the buffets each day will offer options to meet most dietary requirements. Morning coffee will be provided each day, and beverages and snacks will be available during breaks.

Poster Session and Reception

We hope you will join us at the Symposium Poster Session and Reception on Tuesday from 4:30-6:30 PM. View the 2026 posters, visit our sponsors and exhibitors, and enjoy food and beverages while networking with colleagues.

Sponsors / Exhibits

Sponsors and exhibitors showcasing their latest products and services will be available throughout the day on Tuesday and Wednesday through the afternoon break.

2026 Passport Book Contest

Your passport book lists all our 2026 Sponsors and Exhibitors. Get your passport stamped as you visit each exhibitor table. Those who visit every table and turn in a completed passport at the registration desk are entered into our prize drawings, including a grand prize. *Must be present to win.*

GENERAL INFORMATION

Internet Access

Complimentary internet access is available in all meeting rooms, the Hotel Murano, and the hotel restaurant without restriction. Access information will be provided at the registration desk.

Questions can be answered by hotel front desk staff or Symposium staff at the Registration Booth.

Important Phone Numbers

Hotel Murano 253.238.8000 | Visit Tacoma, Pierce County 253.284.2354 | Emergencies: Dial 911

STEERING COMMITTEE

15th Washington Hydrogeology Symposium

Christopher Martin	Washington State Department of Ecology, Chair
Stephen Breen	U.S. Geological Survey, Vice-Chair
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Sarah Dunn	U.S. Geological Survey, Committee
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Frederick Day-Lewis	Pacific Northwest National Laboratory, Committee
Shuhui Dun	Pierce County, Committee
Kevin Hansen	Thurston County Water Planning, Committee
Derek Holom	Geosyntec, Committee
Chelsea Jefferson	Washington State Department of Ecology, Committee
Jeff Johnson	Washington State Department of Health, Committee
Amber Nguyen	Pacific Northwest National Laboratory, Committee
Evan Paul	AESGEO, Committee
Jason Shira	Aspect Consulting, Committee
Danielle Squeochs	Yakima Tribe, Committee
Kurt Walker	Washington State Department of Ecology, Committee
Delphine Appriou	Pacific Northwest National Laboratory, Committee

Cindy Pepler	UW Conference Management
Katherine McCulley	University of Washington conferencemanagement.uw.edu

Schedule At-a-Glance

Tuesday

pages 2-3

Wednesday

pages 4-5

Thursday

page 6

Tuesday, May 12, 2026		
7:30 AM	Registration Check-In Open Coffee Exhibits	
8:00 AM	Welcome/Opening Remarks and Keynote Speaker	
	Keynote: Trees are Groundwater Stakeholders Too Dr. Steven Loheide, <i>University of Wisconsin - Madison, 2026 Darcy Lecturer</i>	
9:15 AM	Refreshment Break Exhibits Posters	
9:30 AM	Session 1A: General Hydrogeology 1	Session 1B: GW and SW Interaction
SESSION 1	Groundwater-Induced Slope Instability on the Tsawwassen Peninsula Steve Graham, <i>S. Graham Engineering and Geology Inc.</i>	Evaluating the hydrologic impacts of site development requires an accurate understanding of both surface and subsurface conditions Scott Kindred, <i>Kindred Hydro, Inc.</i>
	A New Approach to Deep-Well Infiltration Testing and Design: Case Study in Seattle, WA Blake Lytle-Goldstein, <i>Haley & Aldrich, Inc.</i>	Field Methodology for Monitoring Surface Water and Groundwater Interactions in Agricultural Settings Sarah Faubion, <i>GIT, Associated Earth Sciences, Inc.</i>
	Hydrologic State Shifts Across the Volcanic Cascade Range Alex Simpson, <i>University of Oregon</i>	Evaluating the accuracy of base-flow estimation techniques in catchments across Oregon and Washington Ana-Turi Maher, <i>USGS</i>
	Groundwater Recharge and Water Budget Assessment for San Juan County, Washington Elise Wright, <i>Washington Water Science Center</i>	Design Considerations and Implementation Techniques for In Situ Applications of Modified Clay for PFAS Sequestration Mike Mazzaresse, <i>AST Environmental, Inc.</i>
10:50 AM	Refreshment Break Exhibits Posters	
11:00 AM	Session 2A: General Hydrogeology 2	Session 2B: Environmental Contamination
SESSION 2	Sampling results for WSDA's Regional Groundwater Quality Monitoring Program Emily Oberhoffer, <i>Washington State Department of Agriculture</i>	Colloidal Silica Gels for Blocking Vertical Flow in Long-Screened Wells Katherine Muller, <i>Pacific Northwest National Laboratory</i>
	Integrating Field Testing, Groundwater Flow Modeling, and Nitrate Tracer Evidence to Inform Indirect Groundwater Recharge Design Luke Mioduszewski, <i>AESI</i>	Wood Waste-Related Contamination at VCP Sites in Western Washington Frank Winslow, <i>WA State Department of Ecology</i>
	Statistical Characterization of Groundwater Composition Christian Johnson, <i>Pacific Northwest National Laboratory</i>	When 2D Is Not Enough: Three-Dimensional and Boundary-Condition Controls on Groundwater Flooding and Salinity in Diked Coastal Lowlands Xuehang Song, <i>Pacific Northwest National Laboratory</i>
	Groundwater, Surface Water, and Precipitation at the Olympic Peninsula Eugene Freeman, <i>Department of Ecology</i>	Transitional Zone Monitoring Approaches at Marine and Riverfront Cleanup Sites in the Pacific Northwest Brett Beaulieu, <i>Floyd Snider</i>
12:30 PM	Lunch	
1:30 PM	Session 3A: Models and Modelling 1	Session 3B: Risk Assessment
SESSION 3	ARTi3D: A New Software Package for Reactive Transport Modeling Deviyani Gurung, <i>Anchor QEA</i>	From Conflict to Collaboration: Safeguarding Redmond's Urban Aquifer Amanda Balzer, <i>Redmond Public Works</i>
	The Distributed Drawdown Function: An Analytical Tool for Estimating Effects of Pumping Adjacent to Complex Stream Networks Jessica Rogers, <i>S.S. Papadopoulos & Associates</i>	Supporting Agricultural Producers in Groundwater Protection: A Suite of Nutrient Management Tools Adam Peterson, <i>Washington State Department of Agriculture</i>
	The Whatcom Groundwater Model: Status and Planned Refinements of the Groundwater/Stream-Depletion Management Tool Gilbert Barth, <i>S.S. Papadopoulos & Associates</i>	Integrated Hydrogeologic Investigations, Groundwater Modeling and Decision Support Tool Development in the Livermore Valley Basin Aaron Lewis, <i>PE, PG, EKI Environment & Water, Inc.</i>
	Recent Developments in Streamflow Forecasting with the Baseflow Separation Model Christopher Konrad, <i>WaterInform</i>	Aquifer Storage and Recovery in Washington State – Is It Working? Ben Lee, <i>Landau Associates, Inc.</i>
2:50 PM	Refreshment Break Exhibits Posters	

Tuesday, May 12, 2026		
3:00 PM	Session 4A: Models and Modelling 2	
SESSION 4	An introduction to NHM-Assist: A tool for visualizing and evaluating the USGS National Hydrologic Model Matthew Barker, <i>USGS</i>	
	Methods for modifying the USGS Geospatial Fabric for a regional recharge modeling application, Oregon, USA Adel Haj, <i>USGS</i>	
	Ensemble methods for parameter estimation and uncertainty quantification for a watershed model Andrew Long, <i>USGS</i>	
4:30 PM - 6:30 PM	Poster Session & Reception	
POSTER SESSION	Analysis of the Pilot Infiltration Test Method and Correlation between the Vertical Saturated Hydraulic Conductivity and Grain-Size Distribution of Normally and Glacially Consolidated Sediments in Western Washington Lam Nguyen, <i>Associated Earth Sciences, Inc.</i>	Characterizing Bedrock Topography Using Electrical Resistivity Tomography to Constrain Aquifer Geometry for Groundwater Modeling in a Glaciated Puget Lowland Setting Joseph Natale, <i>Associated Earth Sciences, Inc.</i>
	Washington State's Geothermal Energy Collaborative Process Alexandra Shin, <i>WA Dept of Natural Resources</i>	Water Temperature Dynamics in the Quillayute River Basin, Washington, 2021 – 2023 Chad Opatz, <i>USGS Washington Water Science Center</i>
	Characterizing Subsurface Stratigraphy through Petrographic Analysis, Radiocarbon Dating, and Geochemical Methods, Orting Plateau, East Pierce County, Washington. Collin Marshall, <i>Associated Earth Sciences, Inc.</i>	Using complimentary surficial geophysical techniques to assess the effectiveness of channel spanning engineered log jams to increase floodplain connectivity and groundwater storage on the South Fork Nooksack River, Northwest WA Jake Peckenpaugh, <i>Western Washington University</i>
	The Geomorphology and Hydrology of Pre-Restoration West Fork Teanaway River, Kittitas County, WA Maggie Egan, <i>Central Washington University</i>	Spring Revival: Quantifying Managed Aquifer Recharge on the Toppenish Alluvial Fan Using Stratigraphy and Hydrochemistry Sam Dossa, <i>Central Washington University</i>
	Experiments on the Use of H2O2 to Control DBPs in Aquifer Recharge Water Julian Howe, <i>Central Washington University</i>	Storm drain StreamStats: Integrating stormwater infrastructure into web-based watershed delineation tool Sarah Dunn, <i>USGS</i>
	PFAS Monitoring in East Selah, Spokane, and the West Plains Jacob Carnes, <i>Washington State Dept. of Ecology</i>	Yakima Training Center Per- and Polyfluoroalkyl Substances (PFAS) Remedial Investigation Time Critical Removal Actions - Installation of Residential Whole-Home Point-of-Entry-Treatment (POET) Systems, Yakima, WA Audra Balson, <i>PG, ECC</i> ; Michael Brown, <i>USAEC</i>
	Microplastics (MP) in Drinking Water Linked with Colorectal Cancer Across Urban-Rural Counties of Maryland Millen Singh, <i>Landon School</i>	Tracing Groundwater Movements and Mixing with Stable Isotopes at the Taneum Managed Aquifer Recharge Site Adriana Pacheco Garcia, <i>Central Washington University</i>
	An Evaluation and Update of Guemes Island Groundwater Conditions Leland Fuhrig, <i>USGS</i>	

Wednesday, May 13, 2026	
7:00 AM	Symposium Committee Steering Breakfast
7:30 AM	Registration Check-In Open Coffee Exhibits
8:00 AM	Welcome and Keynote Speaker
	Keynote: Tales from the first Symposium on the Hydrogeology of Washington State Melanie Redding and Chris Neumiller, <i>Washington State Department of Ecology</i>
9:00 AM	Refreshment Break Exhibits Posters
9:15 AM	Session 5A: Geochemistry Session 5B: Water Resources 1
SESSION 5	Geochemical Controls on Arsenic Attenuation in a Tidal Estuary: Insights from Field Data and Reactive Transport Modeling Brad Bessinger, <i>GSI Water Solutions</i>
	Groundwater chemistry in the Columbia River Basalt Group aquifer Lee Florea, <i>Washington Geological Survey</i>
	Late Pleistocene high-volume, regional recharge to the Columbia River Basalt groundwater system of eastern Oregon and WA Hank Johnson, <i>USGS</i>
	Integrating Site-Specific Geochemistry and Reactive Transport Modeling to Support Post-closure Care Decisions at a Municipal Landfill Grace Weatherford, <i>Anchor QEA</i>
10:35 AM	Refreshment Break Exhibits Posters
10:45 AM	Session 6A: Stable Isotopes Session 6B: Water Resources 2
SESSION 6	Cosmogenic Isotopes of Halogens in the Cascades of Washington Lee Florea, <i>Washington Geological Survey</i>
	Inferring spatial and temporal qualities of groundwater recharge sources using water stable isotopes in the Klamath River Basin, Oregon Alysa M. Yoder, <i>USGS</i>
	Identifying Anthropogenic Contributions to Saline Groundwater Using Sulfate CSIA and Geochemical Inverse Modeling Brad Bessinger, <i>GSI Water Solutions</i>
	Stable Isotopes as a Tool for Deciphering Hydrogeologic Relationships in the Yakima River Basin Carey Gazis, <i>Central Washington University</i>
12:15 PM	Lunch

Wednesday, May 13, 2026		
1:30 PM	Session 7A: Climate	Session 7B: Hydrostratigraphy
SESSION 7	Climate Model Effects on Stormwater Facility Size Within WWHM Jade Cooley, <i>Thurston County</i> ; Joe Brascher, <i>Clear Creek Solutions</i>	Hydrogeologic framework and groundwater chemistry near the Yakima Training Center, Washington Jackson Mitchell, <i>U.S. Geological Survey</i>
	Which Climate Model Should You Choose? A Brief Guide to Why “It Depends” Jade Cooley, <i>Thurston County</i>	A Hydrogeologic Model of the Duwamish River Valley utilizing Leapfrog Works Mackenzie Mills, <i>Washington Water Science Center, United States Geological Survey</i>
	Open-Loop Ground Source Heat Pumps – Hydrogeology and Modeling Sarah Weeks, <i>Landau Associates, Inc.</i>	New Hydrostratigraphic Interpretations of a Portion of the Black Diamond Quadrangle Gustaf Carlson, <i>Associated Earth Sciences, Inc.</i>
2:30 PM	Refreshment Break Exhibits Posters Passport Contest Prize Drawing	
2:40 PM	Session 8A: PFAS	Session 8B: AI and Machine Learning
SESSION 8	Assessing and Modeling PFASs Leaching to Groundwater Pathway John Stults, <i>CDM Smith</i>	Leverage data assimilation and machine learning to improve the forecast of reservoir water temperature and thermal release Zeli Tan, <i>Pacific Northwest National Laboratory</i>
	Integrated Geophysical Characterization of PFAS Transport Pathways in the Columbia River Basalt Group Greg Byer, <i>Arcadis, Army</i>	AI-Enabled Decision Support for Groundwater–Surface Water Systems to Protect Drinking Water and Reduce Public Health Risk in the Pacific Northwest Ishita Srivastava, <i>University of California, Berkeley</i>
	Yakima Training Center Per- and Polyfluoroalkyl Substances (PFAS) Remedial Investigation Time Critical Removal Actions - Installation of Residential Whole-Home Point-of-Entry-Treatment (POET) Systems, Yakima, WA Audra Balson, <i>PG, ECC</i>	Groundwater-Level Mapping and Monitoring Network Evaluation Using Diffusion Models Xuehang Song, <i>Pacific Northwest National Laboratory</i>
	PFAS in the Greater Lake Washington Watershed: Assessment of the Groundwater Pathway Diane Escobedo, <i>Washington State Department of Ecology</i>	Large Language Model (LLM)-Assisted Access to Subsurface and Contamination Information Rebecka Iveson, <i>Pacific Northwest National Laboratory</i>
4:00 PM	Panel Q&A	
4:30 PM	Symposium Presentations Adjourn Workshops on Thursday	

Thursday, May 14, 2026	
8:00 AM - 4:00 PM	WS 1: Water Rights, Ecology, and Best Practices – A Day of Hands-On Water Right Analysis with an Ecology Water Master
	Workshop Presenters: Kellie Gillingham, <i>Washington State Department of Ecology</i>
8:00 AM - 5:00 PM	WS 2: Python Applications in Hydrogeology
	Workshop Presenter: Christian Langevin, <i>U.S. Geological Survey</i>
8:00 AM - 5:00 PM	WS 3: AI Applications with Environmental Data
	Workshop Presenters: Anurag Acharya, Research Scientist, <i>PNNL</i> Xuehang Song, Earth Scientist, <i>PNNL</i> Anastasia Bernat, Data Scientist, <i>PNNL</i> Hongfei Hou, Software Engineer, <i>PNNL</i> Theresa Pham, Data Scientist, <i>PNNL</i> Jason Hou, Chief Data Scientist, <i>PNNL</i> Maruti Mudunuru, Earth Scientist, <i>PNNL</i>



Dr. Stephen P Loheide II

*Professor, Water Resources Engineering in Civil and Environmental Engineering, Geological Engineering, Freshwater and Marine Sciences, Water Resource Management
University of Wisconsin, Madison, WI. 2026 Darcy Lecturer*

“Trees are Groundwater Stakeholders Too”

Groundwater dependent ecosystems depend on groundwater to thrive. Groundwater dependent ecosystems include wetlands and riparian forests that border streams and are well recognized in arid regions where lush vegetation may only exist where shallow groundwater is accessible to plant roots. However, in humid, temperate regions it’s often assumed that forests do not rely on groundwater because precipitation is typically sufficient to meet the plant water demand. We tested this assumption by quantifying groundwater’s influence on tree growth and transpiration in northern humid forests with sandy soils. Time-series of groundwater levels show that groundwater levels fall during the daylight hours when transpiration occurs and recover during nighttime periods in some of the observation wells we monitored. We used these diurnal groundwater fluctuations to quantify groundwater consumption and found that northern Wisconsin’s forests consume groundwater when and where it is within 3m of the land surface. Furthermore, we analyzed tree growth response by coring trees and measuring annual tree ring increments. We found that trees in regions with shallow groundwater had up to twice as much growth as indicated by tree rings compared to regions where groundwater was deeper than 5m. Finally, we employed remote sensing techniques that compared vegetation indices during wet and dry periods and mapped the degree of groundwater influence across the study area. Counter to conventional wisdom, this research demonstrates that shallow groundwater subsidizes evapotranspiration even in humid forests and enhances forest productivity. Recognition of forests as groundwater users is important in guiding sustainable water and forest management decisions in the region.

KEYNOTE SPEAKER

Tuesday, 9:00 AM

Dr. Steven Loheide is the Distinguished Professor of Water Resources Engineering in Civil and Environmental Engineering, Geological Engineering, Freshwater and Marine Sciences and Water Resource Management at the University of Wisconsin – Madison. He received his BS in Environmental Chemistry and Geology from the University of Northern Iowa (1999), MS in Geology from Indiana University (2001), and PhD in Hydrogeology from Stanford University (2006). As an ecohydrologist, Loheide’s research focuses on the interactions between ecological and hydrological processes in natural and built systems with special attention to the role of groundwater. His approaches use a combination of field data, remote sensing, and numerical modeling to understand the feedback between vegetation patterning, plant water use, soil moisture availability, groundwater regimes, stream-aquifer interactions, and agricultural and urban water management. This work is focused on improving the scientific basis for stream, floodplain, meadow, and wetland restoration efforts; quantifying the provisioning of hydrologic ecosystem services under current and future scenarios; and evaluating interactions among groundwater and urban, agricultural, and natural environments.

Melanie Redding and Chris Neumiller

Washington State Department of Ecology

“Tales from the first Symposium on the Hydrogeology of Washington State: How it got started, mistakes that we made, and what we did to help ensure a successful future for this event.”

Melanie Redding and Chris Neumiller are longtime employees of the Washington State Department of Ecology and were fortunate to be good friends and fellow hydrogeologists with Nadine Romero. Nadine was the brainchild and force behind the start of the Symposium on the Hydrogeology of Washington State over 30 years ago. Sadly, Nadine isn't here to share how this landmark symposium came about, but Melanie and Chris have many good memories – and a few battle scars – that they are happy to share. They consider themselves fortunate to have been involved in the origins of this longtime event, and are encouraged that the Symposium continues to be valuable to the hydrogeologic community.

Melanie is a licensed hydrogeologist and has worked for the Washington State Department of Ecology for 35 years working in water resources, water quality, and conducting groundwater research.

Chris is a licensed hydrogeologist with the Washington State Department of Ecology, where she has worked for 36 years in cleanup site management and clean water studies before moving into data management. Chris is the data manager for Ecology's Environmental Information Management System (EIM).

Melanie and Chris were part of the inaugural effort to launch the first Symposium on the Hydrogeology of Washington State. Their efforts, and those of many other Ecology hydrogeologists, helped lay the groundwork for this successful event.

KEYNOTE SPEAKER

Wednesday, 8:00 AM



Pictured here are Melanie Redding (left) and Nadine Romero (right), taken on a Hood Canal field trip during the 2007 Symposium.

Oral Abstracts

pages 12-80

Poster Abstracts

pages 81-95

Groundwater-Induced Slope Instability on the Tsawwassen Peninsula

Presenting/Author: Steve Graham, *S. Graham Engineering and Geology Inc.*

The Tsawwassen Peninsula is comprised of a large mound of glacially-compacted sand with minor silt that stands about 100 feet amsl at the subject site. The Peninsula was an island until progradation of the Fraser River delta connected it to the mainland. Basal erosion by the Salish Sea at its base created deep slopes along most of its shoreline that have attracted development of expensive homes in both Point Roberts and Tsawwassen BC along the bluff to avail of scenic vistas. The setback of homes from the bluff has been a tradeoff between slope stability and the quality of the viewscape. However the latter criterion has tended to be dominant in the determination of the appropriate setbacks as the views are apparent but the slope stability risk has been misunderstood.

The subject site lies on the northern bluff of the upland portion of the Peninsula on the land of the Tsawwassen First Nation (TFN). The TFN obtained legal control of the former Tsawwassen Indian Reserve in 2009, and thereby jurisdiction of the Stahaken subdivision which had been developed in 1987 under a land lease from the Federal government that extends to 2092. The TFN began biennial monitoring of the bluff at Stahaken in 2010.

A review of monitoring reports and site investigations for residents revealed that the northern bluff is eroding in an episodic manner at an average rate of 3.5 to 4 inches per year. In the 38 years since development in 1987 it has eroded about 12 feet and has now reached the boundaries of many of the subdivision properties along the top of the bluff. Mitigation is difficult as access is limited because the houses were placed close together in order to maximize lot sales along the crest of the bluff.

Most of the bluff zone on the Tsawwassen Peninsula experiences slope instability. The major mechanism in Point Roberts is erosion at the base of the bluff by wave action, which leads to rotational slope failures; however groundwater-induced failure by loss of soil strength is also prevalent. This has been mitigated by French drains in several places. There is minimal wave erosion on the Canadian side due to shore armoring and extended causeways to offshore port facilities. The primary erosion mechanism there is groundwater flow along the surface of the overconsolidated silty sand till (locally known as hardpan), which has low permeability. Groundwater issues from springs and seeps along the wall of the bluff at somewhat regular intervals and thoroughly wets the soil. As the hardpan has low cohesion, it loses its strength when wet and unconfined, and fails by sloughing with runouts typically 50 to 100 in length. These failure events are usually associated with large storms occurring about 8 to 10 years apart.

Mitigation methods that have been locally effective include drainage and installation of mesh over coco mats (or similar) that are fixed with soil nails. These installations have an expected life of about 25 years, so long-term maintenance will be required.

A New Approach to Deep-Well Infiltration Testing and Design: Case Study in Seattle, WA

Presenting: Blake Lytle-Goldstein, *Haley & Aldrich, Inc.*

Authors: Blake Lytle-Goldstein, Aaron Galletly, Roy Jensen, *Haley & Aldrich, Inc.*

Deep-well infiltration is a potential tool for managing stormwater at dense urban sites with limited surface area. At the Lakeside School project in Seattle, Washington, we evaluated the feasibility and design parameters for deep infiltration wells discharging to advance outwash soils using a testing and analysis framework adapted from Kindred Hydro's 2022 Flexible Infiltration Test Methods for Evaluating Infiltration Feasibility. This case study illustrates how that methodology can be applied to characterize unsaturated hydraulic performance of deep, heterogeneous glacial outwash units and designing deep infiltration wells.

Three sonic borings were advanced to depths of 60 to 80 ft to identify the depth and thickness of fill, glacial till, and advance outwash units. Two borings were completed as 2 in. diameter test wells with 20 ft screened intervals in the advance outwash at depths of 40 to 60 ft and 60 to 80 ft, respectively. No groundwater was observed in any exploration or during testing, confirming unsaturated conditions within the screened intervals. Constant head and falling head deep infiltration tests were conducted using approximately 10 gallons per minute of applied flow, with pressure transducers logging water levels at one-minute intervals.

Using the Constant-Rate Single-Borehole Permeameter (CSSBP) equations and correction framework developed by Kindred Hydro (2022), bulk saturated hydraulic conductivities were back-calculated from steady-state flow and head data, resulting in bulk hydraulic conductivities of about 8 to 12 ft per day for the advance outwash. Application of a composite correction factor of 0.6, accounting for recharge behavior, potential clogging, and long-term performance, yielded design hydraulic conductivity of approximately 5 to 7 ft per day.

The infiltration system design utilized two deep infiltration wells, each consisting of a 12-inch diameter pipe to 35 ft depth to transmit water into a 36-inch diameter gravel column completed in the advance outwash to depths of approximately 72 ft. Each well was equipped with a 2-inch piezometer to monitor water levels within the completed well. Infiltration wells were designed with a capacity of approximately 50 GPM per well. Following the design and construction of the deep infiltration wells, Haley & Aldrich performed confirmatory testing of the completed wells to verify performance.

The presentation will describe the design and confirmation testing program, the practical implementation of the Kindred Hydro CSSBP-based method, and how the resulting design rates were translated into Western Washington Hydrologic Model (WWHM) inputs using head-dependent rating tables.

Hydrologic State Shifts Across the Volcanic Cascade Range

Presenting: Alex Simpson, *University of Oregon*

Authors: Alex Simpson, Leif Karlstrom, *University of Oregon*

Young volcanic landscapes are highly permeable, resulting in large, productive aquifers in humid regions. These aquifers are vital water resources, sustaining summer streamflow and providing crucial cold water refugia. In Karlstrom et al. (2025), we showed that the hydrology of volcanic landscapes changes dramatically as they age, transitioning from a large, regional aquifer system to shallow hillslope aquifers over 2-7 Ma. This relationship was established in the Central Oregon Cascades, a portion of the Cascade Range dominated by distributed, mafic volcanism. We expect this relationship to hold in other similar parts of the Cascades (and ocean islands), but this has not yet been explored. Although the suite of data examined in Karlstrom et al. isn't available everywhere, hydrographs are common and we have found that the state shift appears in recession exponent variation as a function of bedrock age in the Central Oregon Cascades. We plan to extend this across the Cascade arc, and in doing so assimilate other relevant data such as SNOTEL and PRISM climate data, known bedrock ages, and maps of known lava units. This will allow us to calculate aquifer transmissivities and dynamic storage, as well as quantify heterogeneity of the groundwater system. With this regional generalization we aim to test how translatable the state shift found in Central Oregon is across the entire US Cascade Range.

Groundwater Recharge and Water Budget Assessment for San Juan County, Washington

Presenting: Elise Wright, *Washington Water Science Center*

Authors: Elise Wright, Andrew Long, Wendy Welch, *Washington Water Science Center*

Due to its island setting, San Juan County, Washington, relies almost entirely on precipitation to sustain its freshwater resources. These resources are further constrained by a rain shadow effect from the Olympic Mountains to the south and Vancouver Island to the west, as well as by the islands' steep terrain, bedrock geology, small catchments, and extensive shorelines. Together, these conditions result in lower rainfall, limited groundwater recharge and storage, high runoff, and an increased risk of seawater intrusion. To assess the groundwater system and inform future water management strategies, estimates of groundwater recharge and water use were quantified and compiled into an updated groundwater budget for San Juan County. Using the U.S. Geological Survey's Soil-Water-Balance (SWB) model, average groundwater recharge from precipitation was estimated to be 3.55 inches per year for 2011–2020. This SWB model updates earlier recharge estimates with more current data and a bias correction process. A water use analysis for the county found that groundwater supplied 54.2 percent of water use withdrawals, fresh surface water 45.3 percent, and seawater (through desalination) 0.5 percent. The updated groundwater budget, recharge estimates, and water use analysis provide a foundation for understanding groundwater availability and will assist water managers in planning for current and future water needs on the islands.

Sampling results for WSDA's Regional Groundwater Quality Monitoring Program

Presenting: Emily Oberhoffer, *Washington State Department of Agriculture*

Authors: Emily Oberhoffer, Jaclyn Hancock, *Washington State Department of Agriculture*

In 2023, WSDA acquired funding from the state legislature to begin a Regional Groundwater Quality Monitoring Program. The primary goal of the new program is to determine the presence and concentration of pesticides in aquifers in Washington State in agriculturally dense regions. To meet this goal, samples are collected from private drinking water wells to be analyzed for pesticides, nitrate, general water chemistry, and stable isotopes.

Sampling regions were established using Ecology's nitrate priority areas and percentage of area in agricultural production in each region. Regions with over 30% agricultural production were selected to be included in sampling design. WSDA partnered with Washington State University (WSU) to create a sampling design for each region to determine the number of wells required to obtain a statistically representative dataset with good geographic coverage. Sampling was completed in the first study region, the Pasco Basin in Franklin County in fall 2025. Well logs were obtained for all potential sampling locations and permissions were gained via a door-to-door campaign. Throughout Pasco Basin 471 houses were visited to obtain 149 permissions. Samples were collected from 149 wells and sent to two different laboratories for analysis. Pacific Agricultural Laboratory in Oregon analyzed pesticide and herbicide samples and the Department of Geological Sciences at Central Washington University (CWU) analyzed nutrients, isotopes and general water chemistry. Local partnerships with the Franklin Conservation District (FCD) and Benton Franklin Health District (BFHD) enabled enhanced outreach and resources for study participants. Of the 149 wells sampled, 24 locations had positive pesticide detections. Pesticide concentrations were compared to EPA human health benchmarks. Each positive detection was less than 5% of the human health benchmark. There were 85 wells (57% of sampling locations) with nitrate detections above the maximum contaminant level of 10mg/L. Through this project partnership, BFHD provided countertop reverse osmosis filters to homeowners who qualified through Department of Health's (DOH) alternative drinking water program. In partnership with CWU, an analytical report will be generated to explore relationships between nitrate detections, well characteristics, land use, and isotopes. In the coming year, WSDA will expand this program to additional monitoring regions to provide groundwater quality data to study participants and local partners.

Integrating Field Testing, Groundwater Flow Modeling, and Nitrate Tracer Evidence to Inform Indirect Groundwater Recharge Design

Presenting: Luke Mioduszewski, *AESI*

Authors: Luke Mioduszewski, Curtis Koger, Lam Nguyen, Lara Koger, Gus Carlson, Stan Thompson, *AESI*

The Tehaleh Employment Based Planned Community (EBPC) occupies approximately 4,700 acres on the Bonney Lake Plateau in eastern Pierce County, Washington, and has a long history of treated wastewater discharge to the subsurface. Earlier work documented the increase of nitrate when the drainfield was operating as a LOSS and subsequent decline of the nitrate plume associated with progressive improvements in wastewater treatment. The nitrate tracer provided important constraints on groundwater travel times and plume behavior. Current planning efforts focus on implementation of a Surface Spreading Basin (SSB) for indirect groundwater recharge using highly treated reclaimed water, supported by extensive pilot testing, site investigation, and groundwater flow and transport modeling.

Recent investigations significantly refine the hydrogeologic conceptual model of the site. Subsurface data indicate a thick, heterogeneous sequence of Olympia Formation deposits characterized by laterally discontinuous fine-grained interbeds that locally perch recharging groundwater, resulting in a complex pathway within the unsaturated zone prior to entry into the Plateau Aquifer. To directly evaluate infiltration performance and subsurface response, a multi-phase SSB Pilot Program was conducted that included installation and testing of deep underground injection control (UIC) wells and associated monitoring wells. Long-term testing demonstrated that pea gravel-filled UIC wells can reliably transmit high infiltration rates under sustained conditions, supporting design-scale infiltration.

Aquifer testing and site-wide subsurface characterization indicate significant lateral heterogeneity within the Plateau Aquifer, consistent with a buried alluvial valley system. Hydraulic conductivity is highest along the inferred valley axis north of the SSB and decreases substantially to the south, exerting strong control on groundwater gradients, mounding, and plume migration. These features were incorporated into a groundwater flow model used to simulate combined reclaimed water and stormwater infiltration under future full buildout conditions. Model results indicate that groundwater mounding remains well below ground surface and does not adversely affect slope stability or downgradient seepage conditions.

Nitrate was evaluated as a conservative tracer to further constrain time-of-travel and dilution behavior. Observed trends support an approximate one-year travel time through the thick unsaturated zone and an additional year of transport through the aquifer to an alternate point of compliance (APOC) at the downgradient property boundary. Groundwater transport simulations indicate that, given the travel distance and relatively limited volume of intervening groundwater, dilution between the SSB and the APOC is limited. This understanding has been explicitly incorporated into project planning, with treatment objectives established to be protective of

quality at the APOC. Nitrate tracer behavior shows that groundwater flow downgradient of the SSB turns westward and flows through deltaic deposits ultimately recharging the Alluvial aquifer of the Puyallup River valley. The strong westerly gradient documented by the nitrate plume is consistent with long-term water quality monitoring at Canyonfalls Creek where nitrate concentrations have remained unchanged over 30 years of data collection. The nitrate data, groundwater flow information and particle tracking indicate the proposed recharge will maintain beneficial uses for downgradient water resources.

Statistical Characterization of Groundwater Composition

Presenting: Christian Johnson, *Pacific Northwest National Laboratory*

Authors: Christian Johnson, Ivani Patel, Elsa Cordova, Mariah Doughman, Jim Szecsody, Christopher Thompson, Alex Kugler, Carolyn Pearce, Hilary Emerson, *Pacific Northwest National Laboratory*

Remedy design for effective in situ groundwater contamination cleanup requires an understanding of multiple factors, including the subsurface hydrology (possibly interacting with surface waters), the geologic context over the relevant spatial extent, potentially the microbial populations, the nature of contaminant interactions with the porous media, and the groundwater geochemistry. Where adequate spatial and temporal data are available this latter aspect of the composition of key constituents in groundwater can be assessed with a statistical evaluation. This assessment will provide an understanding of the variation of groundwater composition across a site, as well as a solid justification for a representative groundwater formulation. Knowing an appropriate representation of groundwater allows practitioners to conduct site-specific treatability testing to identify treatment technologies that are most likely to be successful.

Synthetic groundwater that represents the properties of site groundwater can be useful in laboratory testing for multiple reasons. Synthetic groundwater for treatability studies has the advantage of providing controlled conditions to assess the impacts and interactions between treatment technology performance and key parameters (e.g., pH, alkalinity, contaminant, etc.). The use of synthetic groundwater also facilitates consistency and reproducibility of experiments. Additionally, synthetic groundwater has cost and practical benefits including ease of preparation, availability of adequate volumes, and straightforward disposal—compared to actual groundwater, which requires field collection, transportation, more complicated/costly disposal, and for which adequate volumes may not be available.

With these advantages in mind, a holistic evaluation of spatial and temporal aqueous geochemistry data from the U.S. Department of Energy Hanford Site in southeastern Washington state was used to develop a technically defensible synthetic groundwater formulation for the site. Cluster analysis and principal component analysis were used to assess key chemical constituents and the spatial distribution of data for the clusters. The analysis resulted in potential representative synthetic groundwater formulations that could be used in current and future laboratory treatment tests for the Hanford Site. This technically defensible and statistically sound approach to determining the representative groundwater formulation provides a solid basis for understanding treatability testing results, comparability of results from multiple studies, and interpreting implications for site remediation applications. This presentation will describe the rationale and the methods for conducting this statistical analysis to determine groundwater composition.

Groundwater, Surface Water, and Precipitation at the Olympic Peninsula

Presenting/Author: Eugene Freeman, *Department of Ecology*

Seasonal Variation in precipitation is compared to water-level at a surface water gage station and an adjacent groundwater monitoring well for a site near the confluence of the Queets and Clearwater Rivers for the years 2021 to 2023. The water levels in the groundwater well and at the surface water gage demonstrate hydraulic connection. Measured parameters are also correlated with the Ocean Nino Index to assess how El Nino Southern Oscillation trends relate to water-level patterns. The resulting patterns indicate that precipitation can amplify the rise or decline of water-level in the groundwater well relative to river stage based on precipitation timing.

ARTi3D: A New Software Package for Reactive Transport Modeling

Presenting: Deviyani Gurung, *AnchorQEA*

Authors: Deviyani Gurung, Dimitri Vlassopoulos, *AnchorQEA*; Olivier Atteia, *Institut Polytechnique de Bordeaux*

We present a new graphic user interface (GUI) developed to facilitate pre- and postprocessing of 3-dimensional spatially and temporally complex groundwater models with a particular focus on effective simulation of real-world groundwater quality problems. The application schedules and monitors numerical simulations using model input files defined by a Qt-based graphical user interface. The GUI enables users to construct models by defining scalar settings and spatiotemporally distributed parameters on structured and unstructured grids, including rectangular, radial, and Voronoi-based discretizations. Spatiotemporal parameter matrices can be imported as numerical arrays from existing model input files or generated in the application by rasterization of vector GIS features (vector-to-grid projection) or geostatistical interpolation (kriging). After successful model run completion, the model results can be analyzed through multiple types of visualizations across spatial and temporal dimensions and exported to formats such as VTK.

The GUI's intuitive workflow for model building includes seamless support for widely used flow and transport codes such as MODFLOW-2000, MODFLOW-USG, MT3DMS, and PHT3D as well as the new multiphase reactive transport simulator MuFlowRT. This new simulator couples OpenFOAM for multiphase flow with PHREEQC-3 for geochemical reactions, enabling advanced representation of coupled physical and chemical processes. ARTi3D also provides integrated access to PEST for model calibration, sensitivity analysis, and uncertainty quantification, along with comprehensive visualization tools for examining model results in both spatial and temporal dimensions. Through its structured and transparent workflow, ARTi3D facilitates the construction and evaluation of reactive transport models across a wide range of hydrogeologic and environmental applications. The GUI is specifically dedicated to simulate large 3D problems to provide accurate transport simulations. This includes heat transport, unsaturated and multiphase transport, allowing gas injection and/or gas migration through diffusion. This presentation introduces the ARTi3D platform and demonstrates the capabilities of the GUI and MuFlowRT simulator through representative application examples.

The Distributed Drawdown Function: An Analytical Tool for Estimating Effects of Pumping Adjacent to Complex Stream Networks

Presenting: Jessica Rogers, *S.S. Papadopoulos & Associates*

Authors: Jessica Rogers, Michael Ou, Lucy Sandoe, Doug Hayes, Gilbert Barth, *S.S. Papadopoulos & Associates*

Quantifying streamflow depletion is a critical component of riparian resource management; however, direct measurements are not available and thus depletion must be estimated. Analytical models are generally rapid and cost-effective but are limited by assumptions including, typically, oversimplified stream geometry. Numerical models require considerably more data and intensive computation to improve upon analytical estimates. To help bridge this gap, SSP&A has developed the Distributed Drawdown Function (DDF), an analytical tool designed to efficiently estimate groundwater drawdown and stream depletion caused by pumping near complex, meandering stream networks. DDF extends the Theis solution by discretizing stream networks into multiple nodes and applying the principle of superposition to enforce constant-head boundary conditions along meandering stream geometries. The tool solves a system of linear equations to determine the leakage rate at each stream node that results in zero drawdown at the stream boundary. DDF output includes time series and contours of drawdown as well as time series of estimated stream depletion. This talk will introduce the theory behind the DDF and demonstrate how DDF reproduces traditional analytical drawdown and stream depletion results for directly comparable linear boundary conditions and accurately captures spatial variations for real-world stream networks with arbitrary geometry. An example will be shown for the use of DDF within user friendly map-based interfaces which facilitate the construction of pumping scenarios and visualize spatial and time series outputs. However, DDF is scheduled to also be freely available to the public as a standalone command line tool. DDF offers water resource managers a rapid and accessible method to assess pumping effects on connected surface waters.

The Whatcom Groundwater Model: Status and Planned Refinements of the Groundwater/Stream-Depletion Management Tool

Presenting: Gilbert Barth, S.S. Papadopulos & Associates

Authors: Gilbert Barth, S.S. Papadopulos & Associates; Jessica Rogers, Jay Chennault, AESI

The Whatcom Groundwater Model (WGM) was constructed using the latest available data on geologic structure, monthly precipitation, flow, and pumping stresses. It was calibrated using a combination of water levels, stream flows and hydrogeologic constraints. Model predictions provide estimates of management alternative benefits. Following development and initial calibration, the WGM has been used to estimate impacts of surface water and groundwater management alternatives in the vicinity of the Lower Nooksack River, including the Lynden, Everson, Nooksack, and Sumas areas. Targeted improvements for the management alternatives include groundwater levels, stream depletion timing, and maintaining or improving seasonal low flows. Several different shallow pumping conversion scenarios have been simulated, including converting direct surface water diversions to shallow aquifer pumping, converting both shallow Sumas aquifer pumping and direct surface water withdrawals to pumping from a deeper aquifer, and moving shallow aquifer pumping and direct surface water withdrawals outside a half mile stream buffer. Conversion scenario results indicate increased seasonal low flows. Other scenarios evaluated Aquifer Storage Recovery (ASR) and wetland enhancements. The ASR scenario assessed potential for using wet season surface water supply to augment declining groundwater levels and improve late season base flows. Wetland enhancement explored capturing wet season flows and releasing during the dry season. The WGM continues to adopt new information as it becomes available to improve predictive capabilities of water management impacts, groundwater levels, and stream depletions. Ongoing field data collection efforts will be used to evaluate aspects of the WGM's predictive capabilities, review elements of the underlying conceptual model and identify potential refinements. Taken as a whole, these efforts demonstrate WGM capabilities, opportunities to explore alternatives, and possibly refine predictive capabilities.

Recent Developments in Streamflow Forecasting with the Baseflow Separation Model

Presenting/Author: Christopher Konrad, *WaterInform*

Baseflow is the reliable component of streamflow that can be expected in the absence of increasing runoff from rain storms or snowmelt. Baseflow maintains water availability in rivers and streams during drought making extreme low flows more predictable than extreme high flows. The Baseflow Separation (BFS) model is an open-source model that can be used to forecast streamflow during dry periods with no or decreasing snowmelt at more than 7,000 gaged sites across the US with real-time streamflow as of 2026. In the BFS model, streamflow is generated through three processes (baseflow, surface flow, direct runoff) using spatially aggregated parameters conceptually representing basin geometry and groundwater hydraulics. The model was originally developed as a set of functions in the statistical programming language R. Recent updates to BFS include a Python version of the model, model re-calibration, and the launch of a new web site providing streamflow forecasts. Re-calibration was aimed at improving BFS performance at sites where streamflow recession is highly non-linear including both non-perennial sites and sites where groundwater maintains steady low flows. BFS re-calibration exploited "equifinality", or different sets of parameters providing equivalent model performance, by setting physically-based bounds on parameter that still allowed calibration to converging on well-performing parameters sets. Non-stationarity of baseflow at sites where snowmelt has advanced earlier in the Spring due to the warming climate or where deforestation due to wildfire has increased snow accumulation limits the accuracy of streamflow forecasts from BFS. At these sites, however, the model can be easily re-calibrated using a recent period representative of current patterns of streamflow recession and baseflow.

An introduction to NHM-Assist: A tool for visualizing and evaluating the USGS National Hydrologic Model

Presenting: Matthew Barker, *USGS, WA Water Science Center*

Authors: Matthew Barker, Adel Haj, *USGS, WA Water Science Center*; Parker Norton, *USGS, Dakota Water Science Center*; James McCreight, *UCAR CPAESS*; Luka Ludden, *USGS, WIM Contractor*; Amelia Snyder, *USGS, WMA – Integrated Modeling and Prediction Division*

NHM-Assist is a software package comprised of Jupyter notebooks and supporting Python scripts for evaluating, running and interpreting regional models from the U.S. Geological Survey's (USGS) National Hydrologic Model (NHM). Further, NHM-Assist adapts legacy USGS hydrologic models and pywatershed to make these products and data broadly accessible to the greater modeling community. We demonstrate how to use the NHM-Assist software to visualize the underlying geospatial fabric of the hydrologic models, display NHM subdomain parameter values on interactive maps and plots, run the NHM subdomain model using pywatershed to create output and visualizations for user-specified variables, and display simulated and observed streamflow for model gages on interactive plots. All visualizations are saved locally in .html format for easy sharing and convenient display in a web browser. NHM-Assist is suitable for users with varying Python experience, and we anticipate advanced users will be able to easily adapt the package to their specific needs.

Methods for modifying the USGS Geospatial Fabric for a regional recharge modeling application, Oregon, USA

Presenting: Adel Haj, U.S. Geological Survey

Authors: Adele Haj, Matthew Barker, Andrew Bock, U.S. Geological Survey

The Geospatial Fabric (GF) is a dataset of hydrographic features and spatial data designed for use within the National Hydrologic Model (NHM), a product of the United States Geological Survey (USGS). The NHM is a watershed model that covers the conterminous United States (CONUS), Hawaii, Alaska, and most major river basins that flow from Canada. The Oregon Hydrologic Model is a regional watershed model built from the GF and designed primarily for estimating groundwater recharge. Two Python workflows have been developed to modify the GF (version 2) to improve upland and lowland landscape discretization for model construction and parameter estimation. The first workflow generates a contour line for hydrologic response units (HRUs) associated with vast, arid lowlands separating the lowland from the upland portion of each HRU. The second workflow identifies a contour line for HRUs associated with high-elevation peaks that approximate the snow line and separates the snow-covered summits from areas of lower elevation. These workflows provide more precise landscape discretization of upland and lowland features and spatial data in the GF that will improve spatial distribution and recharge estimates from the regional watershed model. These workflows are consistent with current GF methodologies and approaches, are integrated with current USGS GF fabrication pipelines, and can be used to modify any watershed domain in the GF (version2).

Ensemble methods for parameter estimation and uncertainty quantification for a watershed model

Presenting: Andrew Long, *USGS*

Authors: Andrew Long, Michael Fienen, Adel Haj, Matthew Barker, *USGS*; Katherine Markovich, *University of New Mexico*

Parameter estimation, or history matching, of a watershed model at the scale of the continental U.S. is challenging, due in part to data sparsity that leads to multiple potential parameter combinations that can produce similar model outputs. The standard method traditionally used for the National Hydrologic Model (NHM) uses a stepwise parameter estimation approach. In the stepwise approach, different subsets of parameters are each estimated during different parameter estimation steps by assuming that selected observation subsets are causally connected to appropriate parameters. A major limitation of this approach is that it does not include uncertainty quantification.

To test an alternative method, we applied an ensemble-based parameter estimation process that concurrently quantifies uncertainty and tested this on three selected watersheds within the NHM. With the ensemble method, parameter estimation and nonlinear uncertainty quantification are performed within a single, efficient process. Uncertainty quantification is produced for the history-matching period, validation period, and any forecasted modeling periods. We demonstrate that the ensemble method allows for the same causal connections among selected parameter subsets and associated observation subsets as are implemented in the stepwise approach, but within a single combined step, thus eliminating the computational cost of the stepwise process. Overall, the ensemble method performed similarly to the stepwise approach in regard to model fit—worse in some areas, better in others—largely based on observation weighting decisions. Although model fit was similar, we argue that the ensemble method is superior due to its efficiency and built-in uncertainty analysis.

Evaluating the hydrologic impacts of site development requires an accurate understanding of both surface and subsurface conditions

Presenting/Author: Scott Kindred, *Kindred Hydro, Inc.*

Permitting agencies and communities are often concerned about impacts of development on nearby surface water and groundwater. These impacts can vary significantly depending on surface conditions, hydrogeology, and stormwater management post-development. This case study demonstrates how the hydrologic impacts of a 330-lot subdivision were evaluated using a combination of field observations and hydrologic modeling. The conceptual model of the site included a perched lake and stream, a groundwater flow basin that differed from the topographic flow basin, groundwater pumping to maintain the lake level during summer months, mapped streams that were not apparent in the field, and unmapped drainage courses that were discovered during field visits. This assessment demonstrates the importance of careful field observations, including subsurface explorations, and the dangers of depending entirely on maps. After developing a conceptual model that matched observed hydrologic and hydrogeologic conditions, hydrologic modeling demonstrated that site development, using the proposed stormwater management system, would increase baseflow to the stream, thus improving fish habitat, and may improve baseflow to the lake. These improvements would be balanced by a small decrease in groundwater recharge. Slight modifications of the stormwater management system could be implemented to eliminate the decrease in groundwater recharge.

Field Methodology for Monitoring Surface Water and Groundwater Interactions in Agricultural Settings

Presenting: Sarah Faubion, GIT, *Associated Earth Sciences, Inc.*

Authors: Sarah Faubion, GIT, Anton Ypma, L.G., L.Hg., Jessica Peila, GIT, Isaac Apaez-Gutierrez, GIT, *Associated Earth Sciences, Inc.*

Streamflows in the Nooksack River and its tributaries are necessary to sustain critical habitat for salmonid and other threatened aquatic species. Over the last several decades, increased population growth in Whatcom County (County) has led to an increase in the demand for surface and groundwater resources to meet the growing domestic, industrial, commercial, and agricultural needs of the County. This increase in demand for water use, along with other social/political changes, has led to a heightened level of concern regarding surface/groundwater interactions and the resulting effect on streamflows. The Water Resource Inventory Area 1 (WRIA 1) Watershed Management Plan was developed to address concerns regarding surface/groundwater interaction and the resulting streamflow effects. The Whatcom Groundwater Model (WGM) was developed as a result of the efforts by the Joint Board (Whatcom County, Public Utility District No. 1 of Whatcom County, City of Bellingham, Lummi Nation, and the Nooksack Indian Tribe, now a part of the WRIA 1 Watershed Management Board) in cooperation with the Bertrand Watershed Improvement District (Bertrand WID) and the Washington State Department of Ecology to characterize the Lower Nooksack groundwater flow system.

This presentation encompasses the field methodology for two studies supporting the future WGM refinements. The goal of the Quantification of Timing and Magnitude of Groundwater (Pumping) on Streamflow Depletion project is to conduct hydrogeologic investigations quantifying groundwater pumping impacts on streamflows in the Bertrand Creek, Fourmile Creek, and Johnson Creek watersheds within WRIA 1. The goal of the Investigation into the Impacts of Agricultural Tile Drains on Stream Flows project is to collect shallow groundwater elevation data and streamflow from tile drained areas and quantify the impacts of agricultural tile drains on stream flows in the Fishtrap Creek, Pangborn Creek, and Fourmile Creek watersheds within WRIA 1.

This presentation discusses groundwater and surface water monitoring field methods in agricultural settings, including novel refinements to address site conditions. Discussion includes monitoring point location selection, installation of groundwater monitoring wells and surface water staff gauges, field data collection, and addressing challenges associated with streamflow monitoring in channels with soft sediment substrates. The discussion contributes to development of refined field data collection strategies and improves the quality of data provided to refine the WGM.

Evaluating the accuracy of base-flow estimation techniques in catchments across Oregon and Washington

Presenting: Ana-Turi Maher, *USGS*

Authors: Ana-Turi Maher, Stephen Gingerich, Amanda Garcia, *USGS*

Base-flow (groundwater input to streams) estimation techniques such as graphical hydrograph separation (GHS) and median low-flow (LF) are widely used because they require only streamflow data, but their accuracy across the varying Pacific Northwest landscape is uncertain. Chemical hydrograph separation (CHS) techniques that use binary mixing models have been shown to provide the most accurate base-flow estimates across a range of environments, but require both streamflow and chemical data, which can be a limitation for many studies. As part of ongoing studies by the U.S. Geological Survey, in cooperation with Oregon Water Resources Department and Washington State Department of Ecology, base flow is being estimated at more than 200 streamgages across Oregon and SE Washington using GHS, LF, and CHS techniques. Preliminary comparisons between CHS, GHS, and LF estimates, and the mean of GHS and LF estimates at 21 sites indicate that GHS estimates are generally similar to CHS estimates in the North Coast and rain-dominated catchments in the Willamette River Basin whereas the mean of GHS and LF estimates is generally representative of CHS estimates in snow-dominated catchments in the Willamette, Sandy, and Walla Walla River Basins and Harney Basin. Despite the general similarities among techniques, many catchment base-flow estimates were inconsistent depending on the technique used. Ongoing analyses at more than 200 streamgages with varying landscape characteristics will ultimately allow for statewide comparisons among techniques that can be used to refine base-flow estimates at streamgages where CHS data are not available.

Design Considerations and Implementation Techniques for In Situ Applications of Modified Clay for PFAS Sequestration

Presenting/Author: Mike Mazzaresse, *AST Environmental, Inc.*

Use of common adsorbents for the remediation of per- and polyfluorinated substances (PFAS) in situ has generally been limited to colloidal activated carbon (CAC) or conventional pump and treat systems. Most of these low-energy CAC applications are not adequate to capture the total PFAS contaminant mass present due to limits in total effective sorption capacity and mobility of the product in the subsurface pore space. Further, conventional emplacement techniques of CAC can be ineffective for optimal distribution within certain overburden and regolith mediums and, due to this mobility, are less ideal for permeable reactive barrier (PRB) design and deployment. Overburden injection of a modified clay (MC) has been demonstrated on several pilot programs using direct push technology (DPT) and high-solids slurry batching and injection equipment to be effective in the sequestration of PFAS compounds.

The MC used in these field demonstrations for remediation of PFAS was FluoroSorb[®], which is manufactured by applying an organic chemical modifier to bentonite clay. The resultant product has high sorption kinetics, significant sorption capacity, is effective across a wide range of PFAS concentrations, and, if necessary, is compatible for co-mixing with many other common site remediation reactants. This has been verified by independent university laboratory testing where the MC was comparatively assessed with ion exchange resin (IX), GAC, and biochar. Additionally, competitive adsorption was tested with co-contaminants such as chlorinated volatile organic compounds (CVOCs) and petroleum hydrocarbons (PHCs). Relevant sorption and kinetics data will be discussed.

Field deployments of MC were conducted in demonstration projects in the United States and Canada to prove the injectability and performance of the technology in source (grid) and plume bisection (PRB) deployments. These demonstrations verified the injectability and distribution of the MC as effective in numerous geologies and site implementations.

Various MC slurry densities have been tested, examining increasingly dense and higher solids mixes to mimic site situations where significant product mass would be matched to significant PFAS mass. The slurry designs and specifications will be discussed from bench scale evaluation to field deployment, and the lessons learned from varying the ratios of product and carrier fluid (water). For one site, the MC was co-injected with calcium polysulfide (CaSx) for treatment of both PFAS and hexavalent chromium, proving slurry design flexibility and compatibility. In Canada, the MC was installed as a PRB and then monitored for over a year with a continued PFAS source upgradient. The performance and longevity of this installation will be discussed, along with groundwater monitoring data and post-injection soil core evaluation of product distribution in situ using a newly developed MC dye test.

Colloidal Silica Gels for Blocking Vertical Flow in Long-Screened Wells

Presenting: Katherine Muller, *Pacific Northwest National Laboratory*

Authors: Katherine Muller, Lirong Zhong, Jonah Bartrand, Rob Mackley, Jonathan Thomle, Zoe Vincent, Frederick Day-Lewis, *Pacific Northwest National Laboratory*

Long-screened wells, such as those used at the US Department of Energy Hanford site, can experience significant vertical flow within the well annulus during groundwater sampling, leading to biased contaminant concentration measurements. Effective methods are needed to block vertical flow in the well annulus to seal off a target interval within the aquifer to obtain more representative groundwater samples. Colloidal silica (CS) suspensions show promise for this application due to their controllable gelation behavior, tunable viscosity, and environmentally benign nature.

The performance and long-term stability of CS gels for blocking vertical water flow in the annuli of long-screened wells was assessed through rheological characterization, laboratory experiments, and numerical simulation. During gelation, the nanosized silica suspension transitioned from Newtonian to shear thinning, while viscosity increased. CS gelation in sand columns completely blocked water flow and sustained injection pressure up to 50 psig. The permeability of an emplaced CS gel was estimated experimentally to be on the order of 10^{-17}m^2 , and sandbox experiments demonstrated successful reduction of hydraulic conductivity in the well annulus following CS gel injection. Numerical simulations performed in PFLOTRAN corroborated experimental observations and were able to provide an estimate of the minimum CS gel permeability to be $< 10^{-12} \text{m}^2$. The silica gel formed in the annulus also effectively blocked chemical transport through the gelled zone.

Wood Waste-Related Contamination at VCP Sites in Western Washington

Presenting/Author: Frank Winslow, *WA State Department of Ecology*

The abundance of wood waste in Western Washington reflects the region's rich history with the lumber industry. Fill materials containing wood waste are commonly found at many sites. In recent years, the environmental consequences of buried wood waste have become more apparent. These consequences include:

- Mobilization of arsenic in groundwater due to reducing conditions caused by buried wood waste.
- Generation of methane by buried wood waste.

Several cleanup sites within the Expedited VCP process that have worked through these concerns will be discussed. Specifically, elements to be discussed include:

- Distinguishing between natural and anthropogenic causes of arsenic mobilization.
- Approaches for addressing arsenic mobilization in groundwater.
- Regulatory framework for methane at VCP sites and addressing it as an (Appropriate and Relevant or Appropriate Requirement (ARAR) under the Model Toxics Control Act.

When 2D Is Not Enough: Three-Dimensional and Boundary-Condition Controls on Groundwater Flooding and Salinity in Diked Coastal Lowlands

Presenting: Xuehang Song, *Pacific Northwest National Laboratory*

Authors: Xuehang Song, Steven Yabusaki, Scott Waichler, Peter Regier, *Pacific Northwest National Laboratory*; Devin Smith, Greg Hood, *Skagit River System Cooperative*; Nicholas Ward, *University of Washington*

Groundwater flooding and salinity intrusion in coastal lowlands are commonly evaluated using two-dimensional (2D) transect models with simplified representations of tidal forcing and sea-level rise. These approaches are computationally efficient and widely used, but they can bias predictions in low-gradient, tide-gated systems where subtle topography, surface–subsurface connectivity, and time-varying boundary conditions strongly influence groundwater behavior. In such settings, small changes in boundary forcing or water levels can produce disproportionate subsurface responses that are difficult to capture with simplified model formulations. This study examines how model dimensionality and boundary-condition representation shape simulated groundwater flooding and salinity patterns in diked coastal lowlands.

Results from a coastal groundwater modeling study indicate that 2D transect models can reproduce large-scale, boundary-parallel salinity intrusion driven by coastal hydraulic gradients, but they tend to underrepresent interior salinity accumulation and shallow groundwater flooding observed away from tidal boundaries. In contrast, three-dimensional (3D) simulations capture a broader range of subsurface responses, including the development of persistent salinity and elevated water tables in interior portions of the landscape. These differences reflect the influence of multidirectional flow pathways and spatially variable surface–subsurface exchange that are not resolved in 2D representations. The results further show that boundary-condition realism—particularly how tidal forcing and tide-gate behavior are represented—can substantially influence predicted groundwater levels and salinity distributions, in some cases producing effects comparable to changes in mean sea level itself.

Guided by these insights, the same modeling framework is being applied at another diked lowland site to explore the generality of these responses under different boundary and landscape configurations. Preliminary three-dimensional simulations exhibit similar sensitivity to model dimensionality and boundary-condition representation, suggesting that the limitations of simplified 2D approaches extend beyond a single location. Together, these findings highlight that realistic boundary forcing and three-dimensional representation are often necessary to assess early groundwater flooding and salinity risks in diked coastal lowlands—risks that may be overlooked when relying solely on simplified two-dimensional models.

Transitional Zone Monitoring Approaches at Marine and Riverfront Cleanup Sites in the Pacific Northwest

Presenting/Author: Brett Beaulieu, *Floyd | Snider*

Monitoring of transitional zone water (TZW) where groundwater and surface water mix before discharging is a useful cleanup strategy element at a range of waterfront sites. Compared to monitoring wells, TZW monitoring can measure groundwater contaminant concentrations closer to where they often matter most at waterfront sites, the point of discharge to surface water. This provides an opportunity to maximize the benefits of a waterfront conditional point of compliance (CPOC) under the Washington Model Toxics Control Act (MTCA). Applications at distinct waterfront environments with varied contaminants offer insights into TZW monitoring program design, data collection method selection, water quality evaluation, and attenuation considerations. Field methods include a direct-push porewater sampler with integrated sensors, a dialysis passive porewater sampler, and direct-push stainless piezometers. TZW monitoring environments include an industrial marine waterfront, tidally-influenced rivers, and a mountain stream.

From Conflict to Collaboration: Safeguarding Redmond's Urban Aquifer

Presenting: Amanda Balzer, *Redmond Public Works*

Authors: Amanda Balzer, *Jessica Atlakson, Redmond Public Works; John Porcello, GSI Water Solutions, Inc.*

The City of Redmond's five water supply wells, screened in a shallow unconfined alluvial aquifer beneath downtown, provide approximately 40% of the city's drinking water. As urban densification began to quickly accelerate in the downtown core, the conflict between development pressures and aquifer protection reached a critical threshold. This presentation chronicles a comprehensive investigation over the past 15 years that integrated groundwater modeling, stakeholder collaboration, and land-use planning to safeguard this essential resource. Advanced modeling analyses revealed the cumulative impacts of construction dewatering on groundwater levels, well sustainability, and capture zone integrity. By forging partnerships between water utility management, comprehensive planning, and the community, Redmond developed an innovative framework that aligns 2050 growth targets with aquifer protection, ultimately eliminating the most significant threat to the city's drinking water supply while enabling continued urban development.

Supporting Agricultural Producers in Groundwater Protection: A Suite of Nutrient Management Tools

Presenting: Adam Peterson, *Washington State Department of Agriculture*

Authors: Adam Peterson, Jadey Ryan, Dani Gelardi, *Washington State Department of Agriculture*

Managing nitrogen within a crop's root zone offers one of the greatest opportunities to maximize nitrogen uptake and limit movement below the root zone. For effective management, agricultural producers need accessible and actionable information that is tailored to their specific crops, growing conditions, and yield goals. This presentation introduces a suite of web-based tools developed by Washington State Department of Agriculture to meet these needs. Built largely in R Shiny, these tools target distinct aspects of nutrient management while sharing a common design philosophy: reduce complexity and increase accessibility without sacrificing technical rigor.

The **Deep Soil Sampling Visualization Tool** helps producers interpret results from incremental soil samples extending several feet below the soil surface. This tool visualizes vertical nitrate movement dynamics and the potential for carryover nitrogen to offset fertilizer requirements. Users enter their soil sample data and receive crop-specific interpretation, data visualizations, economic estimates, and links to relevant resources. The tool can also generate reports for both online and offline use.

The **Manure Plant Available Nitrogen (PAN) Calculator** addresses the complexity of organic nitrogen sources. Nitrogen mineralization from manure occurs over time and varies with application methods, soil conditions, and manure characteristics, leading many producers to rely on rough estimates. This tool calculates nitrogen availability across current and future years while incorporating practical considerations like equipment capacity and spreading schedules. Compared to current resources for these calculations that often involve intensive spreadsheets, this tool offers a simplified and more accessible workflow.

Supporting these tools is a **curated Zotero library** containing over 300 extension publications relevant to nutrient management for crops grown in Washington state. The library allows producers and advisors to browse up-to-date and context-specific nutrient management guidance.

No single tool provides a complete solution to agricultural nitrate loading. However, targeted interventions in each aspect of nutrient management can help producers optimize both yield and environmental outcomes.

Integrated Hydrogeologic Investigations, Groundwater Modeling and Decision Support Tool Development in the Livermore Valley Basin

Presenting: Aaron Lewis, PE, PG, *EKI Environment & Water, Inc.*

Authors: Aaron Lewis, PE, PG, Nathan Cutlerm GIT, *EKI Environment & Water, Inc.*

The Zone 7 Water Agency serves drinking water to over 270,000 residents within the Livermore Valley Basin of the California Bay Area and is responsible for managing Basin-wide groundwater and interconnected surface water resources to quantitative thresholds imposed by the California Sustainable Groundwater Management Act (SGMA). With its extensive surface water import, groundwater recharge, production, treatment and conveyance operations, Zone 7 has long proven itself as a leader in designing and implementing effective conjunctive use and adaptive management frameworks to ensure continued regional drinking water supply reliability under future hydrologic uncertainties.

Zone 7 and its engineering consultant EKI Environment & Water, Inc. recently completed an ambitious project designed to address several existing data gaps, improve the conceptual understanding of Basin hydrogeology, and develop a suite of innovative tools that will collectively enhance the Agency's abilities to manage regional surface and groundwater resources to SGMA compliance. The project consisted of five phases involving a series of: (1) field investigations; (2) hydrogeologic conceptual model refinements; (3) historical groundwater model development and calibration; (4) predictive groundwater flow and chemical transport modeling evaluations; and (5) integrated Decision Support Tool (DST) development.

Under Phase 1, the Zone 7 team performed a series of multi-aquifer pumping tests from its municipal supply well network along with several ground-based geophysical investigations of presumed hydraulic flow barriers and interconnected stream reaches that were previously identified in the Basin. These data were subsequently incorporated into a 3D Leapfrog geologic digital model and used to refine the conceptual understanding and geometric representation of Basin stratigraphy under Phase 2. The geologic model was applied to define layering and aquifer properties within Zone 7's groundwater flow and transport model under Phase 3, which was rebuilt in MODFLOW-6 and recalibrated using over two decades of historical water level, streamflow, and groundwater quality data. A fully-coupled 'child model' with a localized grid refinement was developed and applied to conduct a series of short-term predictive groundwater flow and per- and polyfluoroalkyl substances (PFAS) transport simulations under Phase 4 in support of an ongoing municipal well-siting feasibility study. Finally, a custom-built DST was developed under Phase 5 that enables Zone 7 staff to directly run and compare predictive MODFLOW scenarios under a range of hydrologic, water supply availability, and operational assumptions, and automatically visualize key model outputs such as groundwater elevation maps and hydrographs using an intuitive R-Shiny interface.

This presentation will provide an overview and touch on lessons learned in implementing Zone 7's integrated hydrogeologic investigations, modeling, and planning project under the SGMA regulatory regime. Project designs, methods, and results will be discussed in the context of achieving short- and long-term sustainability

objectives and will draw parallels to similar efforts being undertaken by water agencies, tribes, and municipalities across the PNW and greater Western US where mounting water supply challenges (e.g., Washington's historic 2025 drought and floods) and evolving regulations (e.g., Oregon's updated groundwater allocation rules [ORS 537.621]) require increasingly sophisticated, innovative approaches to integrated water resources planning and adaptive management frameworks.

Aquifer Storage and Recovery in Washington State – Is It Working?

Presenting/Author: Ben Lee, *Landau Associates, Inc.*

Aquifer Storage and Recovery (ASR) is a valuable water supply management tool for municipalities and other water users. It involves injecting treated water into an aquifer during times of availability (e.g., winter wet season) and extracting it back out during times of high demand (e.g., dry summer season), using the aquifer as a natural storage reservoir. ASR has numerous environmental benefits, as it avoids the need for a surface level reservoir/dam and it recharges the aquifer. ASR is a proven technology used throughout the United States but is underutilized in Washington State, despite the physical suitability of our aquifer systems, especially the basalt aquifers of eastern Washington. The primary impediment to more ASR projects in Washington is a complex and difficult regulatory framework, intended to be protective of human and environmental health. This presentation will provide context for the state's current ASR regulatory framework, describe the challenges in permitting ASR projects from a municipality's perspective, and introduce efforts being led by the Columbia Basin Sustainable Water Coalition to improve that regulatory framework to make ASR more feasible to implement.

Geochemical Controls on Arsenic Attenuation in a Tidal Estuary: Insights from Field Data and Reactive Transport Modeling

Presenting: Brad Bessinger, *GSI Water Solutions*

Authors: Brad Bessinger, *GSI Water Solutions*; Lynn Grochala, Brett Beaulieu, Nathan Schachtman, *Floyd Snider*

Understanding how redox-sensitive contaminants behave in tidally influenced aquifers is critical for evaluating exposure pathways in coastal systems, where groundwater–surface-water exchange governs ecological risk. This study evaluated arsenic fate and transport in a tidal estuary downgradient of a former industrial facility in Washington State, integrating field data with a site-specific reactive transport model (RTM).

Field investigations followed EPA guidance for monitored natural attenuation and included groundwater sampling, soil mineralogy, redox characterization, sequential extraction, batch adsorption tests, and passive porewater samplers deployed through the sediment column. Groundwater showed reducing conditions with elevated ferrous iron, depleted nitrate, and the predominance of As(III) over As(V). Although sequential extraction and batch adsorption tests identified adsorption to iron oxyhydroxides as the primary attenuation mechanism in the aquifer, the effectiveness of this attenuation mechanism is being constrained by a significant fraction of arsenic occurring as As(III), which adsorbs less strongly than As(V). Despite this constraint, porewater sampling using passive samplers showed steep vertical concentration gradients and minimal arsenic transfer during groundwater discharge, with arsenic concentrations remaining low in the biologically active zone (BAZ).

A 1-D RTM was developed to evaluate the processes that explain these gradients and to understand long-term behavior under persistent upgradient loading. Model inputs included measured arsenic speciation, calibrated adsorption parameters, and iron phase stability. The model predicted that tidal dilution is the primary control on arsenic attenuation, as twice-daily oscillations exchange porewater with lower-arsenic estuarine water and maintain depressed porewater concentrations. Oxidation of As(III) to As(V) during tidal intrusion provides secondary attenuation by shifting arsenic to a more strongly adsorbing form. Because the calibrated model predicts that steady-state conditions were reached decades ago—with dissolved arsenic decreasing sharply from upgradient sources and stabilizing at low concentrations where groundwater discharges to the estuary—no future risk to ecological receptors is forecast to occur.

In summary, study findings demonstrate that attenuation via tidal exchange, oxidation, and adsorption limits arsenic concentrations from increasing significantly above background conditions in porewater.

Groundwater chemistry in the Columbia River Basalt Group aquifer

Presenting: Lee Florea, *Washington Geological Survey*

Authors: Lee Florea, *Washington Geological Survey*; Ellen Svadlenak, *Summit Water Resources*

The Columbia River Basalt Group (CRBG) aquifer is an important source of potable and irrigation water in the Columbia basin of central and eastern Washington. The thickness and basaltic composition of the CRBG are of growing interest for geologic carbon sequestration, geothermal resources, thermal energy storage, and hydrogen storage. In this study are analyses from 1,537 groundwater samples from the CRBG that distinguish deeper CRBG groundwaters from those at shallower depths. A report of investigations and companion dataset were published by the Washington Geological Survey in 2025. A geospatial layer of all data is available on the Washington Geology Portal.

Chemical summary diagrams, bivariate regressions, modeled mineral solubility, principal component analyses, and a hierarchical cluster analysis support observations noted by prior work and provide additional insight into water-rock reactions in the CRBG aquifer. There are distinct variations with depth in dissolved ions, stable isotopes, and radiometric carbon. We also identified patterns between analytes and geologic setting. The CRBG aquifer can be subdivided into an upper aquifer with active groundwater circulation in the Holocene and characterized by Ca-Mg-HCO₃-type groundwater, and a lower aquifer that is modestly thermal, relatively stagnant, and comprised of Na-Cl-type groundwaters of Pleistocene age and older. The depth of the boundary between the upper and lower aquifers is 650 to 750 m in this dataset.

Perhaps the most telling result of this investigation is that only three of the samples in the dataset are saline (TDS >10,000 mg/L) and are associated with oil and gas wells that fully penetrate the CRBG. All other samples have TDS < 1,700 mg/L, even at depths > 1,300 m. The freshwater nature of most CRBG groundwater is notable and speaks to the non-marine origins of the connate water in the Columbia basin and the slow pace of water-rock interactions in these deep settings.

Late Pleistocene high-volume, regional recharge to the Columbia River Basalt groundwater system of eastern Oregon and Washington

Presenting/Author: Hank Johnson, *US Geological Survey*

The evolutionary theory of “punctuated equilibrium” may provide a useful analogue for recharge to the Columbia River Basalt Group (CRBG) groundwater system of eastern Oregon (OR) and Washington (WA). Introduced in 1972 by Niles Eldredge and Stephen Jay Gould, “punctuated equilibrium” described the speciation process as a geologically rapid event, which punctuates much longer periods of evolutionary stasis. Recent studies in the Umatilla and Walla Walla River basins have determined that precipitation recharge to CRBG groundwater systems in eastern OR and WA generally is 3 mm/yr or less (the “stasis” recharge condition of the system). Both studies found that groundwater recharged during the late Pleistocene was common, and that some of these late Pleistocene groundwater samples had water stable isotope (WSI) values inconsistent with local precipitation recharge. A new compilation and synthesis of more than 50 years of age-tracer and WSI data from 171 wells completed in CRBG units throughout eastern OR and WA has extended these observations. In this expanded dataset, samples of late Pleistocene groundwater having WSI values inconsistent with local precipitation recharge were ubiquitous. The WSI values were uniformly consistent with a source of recharge that fell as precipitation considerably east of Pullman, WA. The distribution of these samples aligns with the mapped path and extent of outburst megafloods that repeatedly inundated eastern OR and WA to depths of up to about 275 m during the terminal Pleistocene. It is likely that rapid, voluminous, and regional recharge during these megaflood events “punctuated” the typical low-volume “stasis” recharge derived from precipitation infiltration. Megaflood inundation would have resulted in immense downward head gradients lasting days to weeks in areas that received little precipitation and were rarely (if ever) subject to local seasonal flooding. The widespread occurrence of late Pleistocene groundwater in the CRBG across eastern OR and WA indicates minimal displacement of this “punctuated” pulse of floodwater recharge by the ensuing 12,000 years of precipitation recharge. The management implications for late Pleistocene recharge by megaflood inundation are substantial and numerous.

Integrating Site-Specific Geochemistry and Reactive Transport Modeling to Support Post-closure Care Decisions at a Municipal Landfill

Presenting: Grace Weatherford, *Anchor QEA*

Authors: Grace Weatherford, Minna Carey, Masa Kanematsu, Dimitri Vlassopoulos, *Anchor QEA*

A reactive transport model was developed for a closed landfill to simulate changes in groundwater flow and the fate and transport of metals (i.e., arsenic, iron, and manganese) and chlorinated ethenes (CE's), and to predict future downgradient groundwater quality conditions following a proposed breach of an existing barrier (slurry) wall.

Site-specific data were obtained by analyzing samples of aquifer soils collected at locations downgradient and outside the slurry wall to develop representative aquifer parameter values for transport (e.g., porosity and soil organic carbon [SOC] content) and geochemical properties (e.g., mineralogy, cation exchange capacity, and iron oxide sorption capacity) for use in the reactive transport model.

Key biogeochemical processes that influence groundwater chemistry and contaminant transport included adsorption, redox reactions, and mineral dissolution-precipitation for inorganic constituents of concern (COCs; arsenic, iron, and manganese) and sorption and biodegradation for CE's. These processes formed the basis of a biogeochemical reaction network that was formulated as kinetic and equilibrium reactions using the geochemical modeling software PHREEQC. First-order biodegradation rate parameters for CE's were estimated by calibration to a groundwater chemistry dataset spanning approximately 30 years of groundwater monitoring.

The reaction network was tested in a 1D reactive transport simulation to evaluate and confirm the sequence and extent of biogeochemical reactions and transformations of COCs. Reactive transport of COCs along groundwater flow paths was simulated by PHT3D. A calibrated regional transient flow model developed in MODFLOW-NWT formed the basis of the PHT3D model, including model domain and discretization, boundary conditions, and hydraulic parameters. The PHT3D model incorporated the geochemical reaction network developed for inorganic and organic COCs, as well as representative parameter values determined from the geochemical characterization and groundwater monitoring data.

COC fate and transport was simulated for various alternative barrier wall breach scenarios for a period of 20 years post-breach. Sensitivity analyses for select model parameters were also performed to assess predictive uncertainty. The results of each breach scenario simulation were evaluated and compared to determine changes in groundwater flow patterns and COC concentrations downgradient of the landfill and inform the alternatives analysis. This work demonstrates a successful approach for integrating geochemical characterization with an existing groundwater flow model to build a reactive transport model for organic and inorganic COCs in support of remedial decision-making.

Cosmogenic Isotopes of Halogens in the Cascades of Washington

Presenting/Author: Lee Florea, *Washington Geological Survey*

Thermal and mineral springs in Washington have a wide geochemical variation that reflects the source of heat and the origin of the mineralized fluids. Many in Washington are associated with the Cascade Volcanic Arc; however, some exist in the accretionary prism (Olympic Mountains), the forearc basin (Puget Lowlands), and the backarc basin (Columbia Basin). Even among the sites along the Cascade Crest, the chemical composition of thermal waters has notable differences. Some sites are enriched in alkali metals (e.g., Na), affiliated halogens (e.g., Cl), and sulfur species (e.g., H₂S and SO₄), and other sites are enriched in alkaline-earth metals (Ca and Mg) and dissolved carbonate (CO₂ and HCO₃).

The Washington Geological Survey is engaged in studies of springs in Washington to better understand potential geothermal resources. This builds upon earlier studies that were part of geothermal play fairway analyses of focus areas identified at Mount Baker, Mount Saint Helens, and the Wind River Valley. The present study repeats critical sampling and adds novel parameters to the list of analytes. In this presentation, we will consider the composition of radioactive isotopes of halogens (³⁶Cl and ¹²⁹I) produced naturally in the upper atmosphere by interactions with cosmic rays. These cosmogenic isotopes are one method to assess the mixing between modern meteoric waters circulating in groundwater and interacting with a shallow heat source, and ancient ocean water that was conveyed along the subducted Juan de Fuca plate and conveyed toward the surface through permeability pathways associated with volcanism and tectonic activity.

This “first look” in an ongoing study illustrates key differences between hot springs in the Wind River Valley, the breach of Mt. Saint Helens, surrounding Mt. Rainier, and at Mt. Baker. Mt. Saint Helens stands out as a notable example of intense meteoric recharge “scrubbing” heat and gas from the recent lava domes. In contrast, geothermal waters in the Wind River Valley and at Baker Hot Springs tap into deep thermal fluids rising along faults and mixing with shallower groundwater along the flow path.

Inferring spatial and temporal qualities of groundwater recharge sources using water stable isotopes in the Klamath River Basin, Oregon

Presenting: Alysa M. Yoder, U.S. Geological Survey, Oregon Water Science Center

Authors: Alysa M. Yoder, Henry M. Johnson, U.S. Geological Survey, Oregon Water Science Center

Drought and groundwater pumping have caused groundwater levels to decline in many areas of the Klamath River Basin, straining ecological, economic, and agricultural systems. The highlands of the northern portion of the Klamath River Basin are the main water source to Upper Klamath Lake which supplies the Klamath Irrigation Project and serves as habitat for two endangered fish species, the shortnose sucker (*Chasmistes brevirostris*) and the Lost River sucker (*Deltistes luxatus*), but the reliability and sensitivity to changes in the hydrologic system of this critical water source are inadequately understood. To help inform management of water scarcity problems, spatial variations in water stable isotopes (specifically, deuterium) in the shallow groundwater system are being used to characterize groundwater recharge sources and flow paths in the northern portion of the Klamath River Basin. A map of the spatial variation of deuterium in shallow groundwater (an isoscape) was created by spatially applying a linear model that related the deuterium values of stream base flow collected from 19 mountain catchments to the geographic characteristics of the sampled catchments. Comparisons of the isoscape with deuterium samples collected from springs and wells constrained potential recharge area and flow direction for some sites. However, deuterium values from most springs and wells were outside the range of values measured in the calibration sites and predicted by the isoscape, which indicated the probable influence of paleoclimatic recharge across most of the study area. The isoscape provides a framework to constrain potential recharge sources using water stable isotope samples and provides novel insight to help resolve unanswered questions about the groundwater system dynamics.

Identifying Anthropogenic Contributions to Saline Groundwater Using Sulfate CSIA and Geochemical Inverse Modeling

Presenting: Brad Bessinger, *GSI Water Solutions*

Authors: Brad Bessinger, *GSI Water Solutions*; Mary Dolhancey, Julie Oriano, Todd Knause, *Stanley Consultants*

Sulfate compound-specific isotope analysis (CSIA), when integrated with geochemical inverse modeling, provides a robust framework for resolving groundwater salinity sources in systems where multiple natural and anthropogenic processes produce overlapping chemical signatures. By coupling sulfate isotope systematics with mass-balance constraints on major-ion chemistry, this approach allows anthropogenic contributions to be evaluated quantitatively while explicitly accounting for mineral reactions that confound simpler mixing models.

This framework was applied at a former coal-fired power plant in the southwestern United States, where groundwater salinity reflects evaporite dissolution, irrigation-related recharge, regional groundwater flow, and historical operation of saline process water ponds. Groundwater was sampled across multiple hydrostratigraphic zones and analyzed for major ions, stable isotopes of water ($\delta^{18}\text{O}$ and δD), and compound-specific isotopes of oxygen and sulfur in sulfate ($\delta^{18}\text{O}\text{-SO}_4$ and $\delta^{34}\text{S}\text{-SO}_4$). Sulfate isotope compositions of native groundwater and evaporite minerals were also characterized to constrain natural sources of groundwater salinity.

Water isotopes provided a strong process-water signature in source waters and proximal groundwater but were less sensitive to low-percentage contributions in downgradient groundwater, where a threshold fraction is required for reliable detection. In contrast, sulfate CSIA provided enhanced discrimination because small process-water fractions were found to measurably shift sulfate isotope ratios. Geochemical inverse modeling was employed to simultaneously account for sulfate isotope ratios, major-ion chemistry, and mineral interactions (evaporite dissolution, precipitation, and ion exchange). The model predicted that many high-TDS groundwater samples could be explained by natural sources alone, whereas others required small but measurable process-water contributions. Results were used to define the nature and extent of the anthropogenic process-water plume using EVS.

Overall, the results illustrate how sulfate CSIA, combined with inverse modeling, improves confidence in source attribution in saline groundwater systems where conventional indicators are ambiguous.

Stable Isotopes as a Tool for Deciphering Hydrogeologic Relationships in the Yakima River Basin

Presenting/Author: Carey Gazis, *Central Washington University*

There is a need for science-based groundwater management in the Yakima River basin and other arid watersheds in the west. This management should restore water to depleted aquifers and strategically store water in aquifers to safeguard supplies during droughts. For managed aquifer recharge, it is essential to have a solid understanding of hydrogeologic relationships in the region. This includes a knowledge of which aquifers are influenced by surface waters, where there are barriers to flow and the timescales of recharge and discharge.

Stable isotopes are a useful tool for tracing surface water/groundwater interactions and other hydrogeologic relationships. They are particularly useful in settings, where surface water and resident groundwater are distinctly different isotopically. This is the case in the Yakima River basin where Yakima River water and much of the irrigation water are derived from precipitation at the crest of the Cascade Mountains while resident groundwater is derived from a different source, either from local precipitation/meltwater or an ancient surface water source or a combination of the two. When surface water and resident groundwater are isotopically distinct, isotopic compositions can be used to trace surface water infiltration and to calculate percentages of mixtures of surface water and resident groundwater. Isotopes can also be used to identify barriers to flow. If water samples from two nearby wells have distinctly different isotopic signatures, this indicates that there is no mixing between the aquifers that they access and there must be some barrier to flow between the aquifers.

This presentation will give examples from across the Yakima River basin in which stable isotope geochemistry reveals information and details about hydrogeologic interactions. Much of the data was collected over the past 25 years by Central Washington University graduate students. In these examples, stable isotopes are used for:

- Tracing water movement through the soil and quantifying evaporative loss of soil moisture.
- Learning details of seasonal recharge of groundwater near streams.
- Tracking the movement of artificially recharged waters.
- Analyzing exchange between streams and hyporheic zone.
- Characterizing groundwater in the sedimentary basin aquifers and the extent of surface water influence within these aquifers.
- Differentiating between different groundwaters in basalts, including ancient groundwater and groundwater that has significant input of modern agricultural water.
- Determining the influence of seasonal pumpage on aquifer storage and exchange.

Climate Model Effects on Stormwater Facility Size Within WWHM

Presenting/Authors: Jade Cooley, *Thurston County*; Joseph Brascher, *Clear Creek Solutions*

In 2024, Thurston County tasked Clear Creek Solutions with updating the Western Washington Hydrology Model (WWHM) to create a tool that could account for projected climate impacts to engineered stormwater designs in Thurston County. The WWHM model update is based on inclusion of modeled future weather from ongoing research by the University of Washington's Climate Impacts Group (CIG). WWHM currently utilizes the 25- year, 24-hour event to size stormwater facilities at project locations. WWHM's new feature scales this 25- year 24-hour event according to 12 climate projection models, corresponding to the grids in the UW CIG Extreme Precipitation Tool. This allows project designers to test their designs in response to modeled future climate change. Thurston County staff evaluated sensitivity to climate models for various scenarios, and found that on average, facilities grow slight faster than precipitation, with detention ponds showing a stronger response than infiltration ponds (based on 0 infiltration for type C soils and 3 in/hr infiltration for A/B soils). This presentation walks through the methodology used to reach these conclusions and outlines possible additional updates to WWHM.

Which Climate Model Should You Choose? A Brief Guide to Why “It Depends”

Presenting/Author: Jade Cooley, *Thurston County*

Have you ever found yourself trying to choose a climate model for predicting future rain patterns, but not knowing where to start? While long-term averages and bounds on “bestcase” or “worst-case” scenarios are often recommended, some applications require selecting a single time series from a single model. To address this challenge, a Thurston County analyst compared observed station measurements to results from climate models downscaled by the University of Washington's Climate Impacts Group, developing a framework for evaluating the strengths and weaknesses of different climate models. This framework compares 4 parameters: amount of rainfall, timing of rainfall, intensity of storms, and frequency of storms. Results indicate the answer is expectedly complex. This presentation details ongoing work aimed at bringing greater clarity to model selection and invites discussion on a deceptively simple question: Which downscaled climate model is the best choice for your project?

Open-Loop Ground Source Heat Pumps – Hydrogeology and Modeling

Presenting: Sarah Weeks, *Landau Associates, Inc.*

Author: Sarah Weeks, Eric Weber, *Landau Associates, Inc.*

An open-loop ground source heat pump (GSHP) system involves pumping groundwater from an aquifer through a heat exchanger and injecting the water back into the same aquifer. Pumping is done through an extraction well, and injection is done through a separate return well. The heat exchanger can either extract heat from the groundwater in the winter, or transfer heat to the groundwater in the summer. GSHP systems can be designed to operate at a campus or business park scale and provide an energy efficient heating and cooling option. In Washington State, GSHP systems have benefited from passage of the Climate Commitment Act targeting a 95% reduction in greenhouse gas emissions by 2050 with a focus on large emitting sources and industries. Grant funding has been available to assist with program implementation. Within this legislative backdrop, multiple university campuses have started the process of reducing greenhouse gas emissions through implementation of campus-wide GSHP systems. Completing the projects requires a multidisciplinary team of mechanical, electrical, water resource, planning, and administrative professionals. Permitting and design of the wellfield system is a critical component of a GSHP system. These groundwater-related technical aspects are addressed through the requirements of a non-consumptive water right permit issued by the Department of Ecology. The permit requires a demonstration of water availability and non-impairment. Water availability is demonstrated through aquifer characterization. Non-impairment is typically demonstrated through groundwater flow and heat transport modeling that predicts temperature impacts associated with long-term operation of the GSHP system. Modeling can be accomplished using the numerical groundwater flow modeling program MODFLOW to model hydraulic impacts and the contaminant transport model MT3DMS to model temperature impacts. We will demonstrate the permitting and technical requirements of implementing a GSHP system on a campus-wide scale through case studies of recent projects in alluvial and basalt aquifer systems.

Assessing and Modeling PFASs Leaching to Groundwater Pathway

Presenting: John Stults, *CDM Smith*

Author: John Stults, Charles Schaefer, Jeffery McDonough, *CDM Smith*

Per- and Polyfluorinated Alkyl Substances (PFASs) are anthropogenic contaminants of concern in the environment. Because PFAS are frequently released through surface spills, accidental releases, and atmospheric deposition, they must migrate through the vadose zone prior to impacting the underlying aquifer. The last decade of research into PFASs has shown that many PFASs of regulatory concern are strongly retained within the vadose zone of source areas. Conducting appropriate site assessments to understand the nature and extent of release is critical to modeling the long-term risk posed by PFASs to the underlying aquifer. This talk discusses elements of PFASs sampling and site investigation methodologies, laboratory tests for assessment of leaching, and available model options for simulating PFAS transport in the vadose zone.

The nature of the PFAS release is a key determinant of the degree of transport through the vadose zone. Specifically, PFAS are a broad class of chemicals with distinct transport characteristics. Targeted analysis of PFAS via EPA Method 1633A quantify PFAS that typically account for only a fraction of the total PFAS mass. Attempting to close the fluorine mass balance requires additional information from advanced analytical methods, such as the Total Oxidizable Precursor (TOP) assay and Total Organic Fluorine (TOF). By completing the fluorine mass balance, practitioners can gain a better understanding of the leaching risk posed by the PFAS plume and the potential future risk posed by PFAS precursor transformation.

To understand PFAS migration in the unsaturated zone, information about PFAS associated with soils and their desorption into and mobility in porewater is important. This requires an understanding of the partitioning processes of the PFAS (solid phase, air-water interfacial, and in some cases volatilization) that can be determined experimentally, empirically, or through correlations developed from literature data. Experimental determinations of PFAS leaching require laboratory analysis of leachability from soils using the SPLP, LEAF, or alternative laboratory methods to determine a solid coefficient (K_d). These can be coupled with empirical estimates of air-water interfacial partitioning and mass balance calculations to determine porewater concentrations. Alternatively, empirical measurements of porewater concentrations using lysimeters, both at the bench and field scale, can be used.

Once sufficient site data have been collected, modelling assessments of leaching can be conducted. Model tiers for PFAS are conducted ranging from Empirical (Tier 4) and Screening (Tier 3) to 1-D Numerical (Tier 2) and 2-D/3-D Numerical (Tier 1) models. The most simplistic model typically used to develop site-specific Soil Screening Levels (SSLs) is the EPA-DAF model. The EPA-DAF model has recently been adapted for PFAS and can be used with empirical porewater measurements or leaching data from SPLP and LEAF. This presentation will specifically review Tier 3 screening models (PFAS-LEACH-Analytical,

SESOIL/AT123D,) and full scale numerical modelling options (HYDRUS, PFAS-LEACH-COMP, MODFLOW-PFAS) with respect to their strengths and weaknesses.

The overall goal of this presentation is to present a soup-to-nuts crash course on methods/tools for assessing the leaching to groundwater risk posed by PFAS. Pro/cons of different methods/tools will be reviewed, along with their fundamental basis.

Integrated Geophysical Characterization of PFAS Transport Pathways in the Columbia River Basalt Group

Presenting: Greg Byer, Arcadis, Army

Author: Greg Byer, Michael Brown, Arcadis, Army

Groundwater flow and contaminant transport in basalt aquifer systems are strongly controlled by volcanic flow architecture, fracture networks, and structural deformation. This study presents an integrated hydrogeologic and geophysical investigation conducted near the boundary of a site in south central Washington State, where per and polyfluoroalkyl substances (PFAS) occur within the Columbia River Basalt Group (CRBG). Previous investigations indicated that PFAS distributions are highly heterogeneous and span multiple aquifer types, including permeable interflow zones within basalt flows and sedimentary interbeds.

In the CRBG, hydraulic conductivity varies by several orders of magnitude within individual flows, with laterally extensive flow tops and flow bottoms forming preferential groundwater pathways, while massive basalt interiors typically exhibit low permeability. Groundwater flow is further influenced by folding and faulting, which can either enhance permeability through fracture development or impede flow depending on fault characteristics. These features are often steep, discontinuous, and concealed by soil and sediment cover, limiting the effectiveness of drilling only site characterization approaches.

To improve delineation of hydrostratigraphic units and preferential flow paths, surface and borehole geophysical methods were integrated with targeted drilling. Objectives included differentiating basalt from sedimentary units, identifying hydraulically conductive zones within basalt flows, delineating folds and fault zones, and mapping large scale sedimentary features to depths of approximately 200–300 ft. Methods included electrical resistivity tomography (ERT), multichannel analysis of surface waves (MASW), refraction microtremor (ReMi), frequency domain electromagnetics (FDEM), downhole seismic logging, and borehole geophysics.

Geophysical datasets were processed and interpreted in cross section, enabling identification of basalt flow boundaries, structural features, and zones of enhanced permeability. Electrical resistivity contrasts proved effective for distinguishing basalt and sedimentary units, while seismic velocity variations were useful for inferring relative permeability within basalt flows. Strong correlation between geophysical interpretations, core descriptions, and borehole logs supported the development of a robust conceptual site model. The results demonstrate the value of integrated geophysics for resolving groundwater flow pathways and contaminant transport in layered and structurally complex basalt aquifer systems.

Yakima Training Center Per- and Polyfluoroalkyl Substances (PFAS) Remedial Investigation Time Critical Removal Actions - Installation of Residential Whole-Home Point-of-Entry-Treatment (POET Systems, Yakima, WA

Presenting: Audra Balson, PG, ECC

Author: Audra Balson, PG, ECC; Michael Brown, USAEC

Background/Objectives

The United States Army Environmental Command's (USAEC) per- and polyfluoroalkyl substances (PFAS) remedial investigation and private water supply treatment initiative at the Yakima Training Center in East Selah, Washington, has entered its fourth year. Since the fall of 2022, the investigation has progressed in accordance with the United States Environmental Protection Agency's (USEPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) framework. Investigation activities are expected to continue for several more years in order to thoroughly assess PFAS impacts both on the installation and in the surrounding areas.

This ongoing effort is a collaborative endeavor involving multiple federal and state stakeholders, as well as Army contractors. The initiative employs a data-driven approach, incorporating extensive hydrogeologic and subsurface geophysical surveys to optimize drilling locations. These surveys aim to identify the primary groundwater and contaminant migration pathways that originate from the Training Center.

Treatment of Private Water Supplies

As part of the Time-Critical Removal Actions (TCRAs), the Army and its contractors are installing residential, whole-house point-of-entry-treatment (POET) systems in affected homes as an interim remedial measure. Since August 2023, 69 residential POETs have been installed in the East Selah community and dozens more are planned. POET systems are routinely monitored and maintained in accordance with USAEC's Granular Activated Carbon (GAC) Vessel Management and Sampling Policy, which is conservatively modified from USEPA's Final PFAS National Primary Drinking Water Regulation (May 2025). The Army and its stakeholders are working to develop long-term drinking water solutions for the impacted community.

PFAS in the Greater Lake Washington Watershed: Assessment of the Groundwater Pathway

Presenting: Diane Escobedo, *Washington State Department of Ecology*

Author: Diane Escobedo, Siana Wong, *Washington State Department of Ecology*

Per- and polyfluoroalkyl substances (PFAS) are a pervasive contaminant, particularly in dense urban areas. The Washington State Department of Ecology conducted a field study from 2020-2023 in the Greater Lake Washington area, a large, primarily urban watershed, to better understand sources and pathways of PFAS entering the lake and its tributaries. This study included over 500 environmental samples including groundwater, surface water, sediment, road dust, biofilm, stormwater, bulk atmospheric deposition, and aquatic macroinvertebrates.

This presentation focuses on the groundwater pathway, highlighting results from three subbasins within the watershed. Groundwater samples were primarily collected at the groundwater-surface water interface and co-located with surface water sample locations. PFAS were detected in all but one groundwater sample, with higher PFAS concentrations found in areas of industrial land use.

How urban stormwater systems shape streamflow and water quality in streams in King County, Washington

Presenting: Kristina Hopkins, U.S. Geological Survey, Washington Water Science Center

Author: Kristina Hopkins, Malia Scott, U.S. Geological Survey, Washington Water Science Center

Urban development alters hydrology and degrades water quality, with these impacts being pronounced in areas with a high density of impervious surfaces. It is not just the amount of impervious surfaces that matters to stream health, but also the connectivity of impervious surfaces to streams. When considering connectivity, urban stormwater systems can be a key driver shaping streamflow and water quality patterns in streams. To address this connectivity, we used geospatial data on stormwater systems and high-resolution elevation and land cover data to delineate 1) topo-watersheds, which are watersheds based predominantly on topography, and 2) storm-watersheds, which are watersheds that were hydro-enforced to route flow to stormwater pipes. We plan to calculate and compare common metrics of urbanization using the boundary from the topo-watershed and stormwatershed. Urban metrics will include percentage of impervious surfaces at high resolution (1-meter), percentage of impervious surfaces at low resolution (30-meter), road density, population density, and housing density. We will then test the ability of metrics based on topo- and storm-watershed boundaries to predict common water quality and streamflow metrics in small watersheds (<75 square kilometers) located in the Puget Sound Lowlands within King County, Washington. Water quality metrics were calculated at 25 sites based on King County monthly grab samples from water years 2019 through 2024 for constituents of nitrogen and phosphorus, specific conductance, E. coli, and fecal coliform. Streamflow metrics were calculated at 12 sites based on King County daily mean streamflow for water years 2021 through 2024. Streamflow metrics included the fraction of the time flow is greater than the mean annual flow (TQmean), the count of flow reversals, Richard-Baker flashiness index, high flow pulse count, and high flow pulse duration. Initial results for correlations between topo-watersheds urban metrics and water quality metrics indicated the strongest significant ($p < 0.05$) Spearman rank correlations between road density and median specific conductance, low-resolution impervious cover and median ammonia concentration, high-resolution impervious and median orthophosphate concentration and median total phosphorus, and housing density and median E. coli and fecal coliform counts. There were no significant ($p < 0.05$) positive correlations between urban metrics and median nitrate-nitrite concentration or median total nitrogen concentration. Initial results for topo-watersheds urban metrics indicated population and housing density had the strongest Pearson correlations ($r = 0.70 - 0.83$, $p < 0.05$) with all streamflow metrics, except high flow pulse duration which had the strongest correlation with road density ($r = -0.65$, $p < 0.05$). Future work will summarize urban metrics based on topo-watersheds and storm-watersheds and evaluate correlations between urban metrics, water quality metrics, and streamflow metrics based on storm-watershed boundaries.

Chasing the Yakima Basin’s “Sixth Reservoir” with Groundwater Storage

Presenting/Author: Jeff Dermond, *Office of Columbia River, Washington State Department of Ecology*

Located in arid eastern Washington, the Yakima River Basin covers over 6,000 square miles. Time-immemorial treaty rights, instream flow needs for fish, a \$4.5 billion agricultural industry, dozens of municipalities, and nearly 400,000 residents all rely not only on the natural flow of rivers and streams in the basin, but also on the careful management of five surface reservoirs with a combined capacity of just over 1 million acre-feet. Often referred to as the “sixth reservoir,” snowpack plays a key role in filling these reservoirs. Climate change threatens this essential water resource in the form of reduced snowpack and increased rain, along with earlier, flashier melting events. The Yakima Basin Integrated Plan (YBIP), an innovative comprehensive watershed management collaboration, recognizes groundwater storage as an essential tool to combat early runoff. YBIP is developing multiple Aquifer Storage and Recovery (ASR) and Shallow Aquifer Recharge (SAR) operations throughout the basin to capture and retime excess winter and spring flows. In addition to bolstering total water supply available, ASR projects offer a chance to halt or reverse declining aquifers and can even be used to generate green energy during the injection phase. During hot summer months, both ASR and SAR operations could be leveraged to reduce surface water temperatures for the benefit of salmonid species. As the frequency of drought years increases, municipal, industrial and agricultural water users need new tools for opportunistic water storage. As a suite of cost-effective and geographically diverse options, groundwater storage is emerging as an increasingly essential watershed management tool.

Nisqually Watershed Planning using Large-Scale Surface and Groundwater Modeling

Presenting: Kevin Hansen, *Thurston County*

Authors: Kevin Hansen, Derek Day, Amelia Schwartz, *Thurston County*

Thurston County, the Nisqually River Council and potentially other counties and cities are developing a watershed plan for the entire Nisqually River watershed (WRIA11) using large-scale surface water and vegetation modeling (VELMA) and groundwater modeling (MODFLOW-6/NWT) as primary guidance tools. These models, combined with estimates of population growth, and build-out projections, will be used to test the effects on water of future land use scenarios. Because of the large modeling scale, upper-basin practices like alternative forest harvest methods or agricultural techniques, for example, can be directly compared with lower-basin land development practices for effects on fish populations, streamflow, TMDLs, development density, forestry and agriculture, summer low flows and some information about winter floodwaters. A design charrette of multiple watershed stakeholders will transparently develop scenarios for testing against baseline conditions. We also intend to test using modeling a range of alternatives of interest to individual stakeholders - from easily achievable objectives to those outside the range of typical planning. The project leverages prior development of a large-scale VELMA simulation over the Nisqually Watershed, and MODFLOW-6/NWT simulations of Thurston County and Pierce County. Current results for the project will be presented.

Participatory Modeling of Reductions in Pumping to Stabilize Declining Groundwater Levels in the Harney Basin, Oregon

Presenting: Ben Scandella, *Oregon Water Resource Department*

Authors: Ben Scandella, Darrick Boschmann, *Oregon Water Resource Department*

Groundwater pumping supports large-scale irrigation in the Harney Basin of southeast Oregon, but groundwater level declines in parts of the basin have become excessive. To address this problem, the Oregon Water Resources Department developed new rules for the Harney Basin to reduce the annual amount of groundwater that can be pumped under water rights. This rule modification was developed in consultation with an advisory committee comprised of a range of interested parties, including irrigators who will have their rights curtailed. It was also aided by the publication of a numerical model of the basin's groundwater flow system by the U.S Geological Survey in 2024.

This presentation describes how the Harney numerical groundwater model was used to inform the planned reductions in authorized groundwater pumping. Initial pumping scenarios that were developed by the advisory committee were simulated to estimate the range of future groundwater level declines in various subareas of the basin. Alternate scenarios were derived to minimize the reductions in pumping while stabilizing groundwater level declines. Finally, the model results informed the creation of an adaptive management framework to adjust the pumping reductions in response to future changes in measured water levels. These innovations elevated the discussions with the advisory committee from how to achieve a particular goal to what the appropriate goal should be. At the same time, opinions varied among advisory committee members about how well this participatory modeling process supported their engagement.

The proposed Harney Basin rules were adopted by the Oregon Water Resources Commission in December 2025. The Commission's unanimous vote reflected the rigor of a decade of science and rulemaking process that included this collaborative modeling effort. This experience highlights both opportunities and challenges of using advanced technical tools to support planning for water resources management.

Water use data and science in the USGS: from national-scale modeling to regional Puget Sound water use estimates

Presenting: Malia Scott, U.S. Geological Survey

Authors: Malia Scott, Cheryl Dieter, U.S. Geological Survey

A thorough assessment of the nation's water use is critical to understanding the balance between water supply and demand, now and in the future. Historically, the U.S. Geological Survey (USGS) has collaborated with local and state agencies to compile and publish water use data by county and category of use at 5-year intervals. To improve the spatial and temporal resolution of publicly available water use data for the country, the USGS is now working to integrate reported water use data with a modeling framework to produce monthly and annual water use estimates for the largest categories of use by 12-digit Hydrologic Unit Code watershed boundaries and by groundwater and surface-water sources. Within the past few years, estimates for public supply, irrigation, and thermoelectric water use have been published, which comprise the three largest categories of use nationally. Estimates of five additional categories including mining, aquaculture, livestock, industrial, and domestic water use, are currently underway. In addition to national-scale efforts, there have also been local studies aimed at improving our understanding of water use in the Puget Sound region. Monthly estimates of water use for 2017 were published for public supply, domestic self-supply, agriculture, and aquaculture categories at 250-meter resolution. These water use estimates, from national to regional, not only help to provide a more thorough depiction of water usage across the country, but are also a critical component to understanding water availability. This presentation will provide an overview of the USGS water use datasets available nationwide and within the Puget Sound region.

Understanding the Possible Causes of Many Dry Wells Recently Reported Near Lake St. Clair

Presenting/Author: Kevin Hansen, *Thurston County*

Starting in July 2025, numerous homeowners reported dry domestic water supply wells in the vicinity of Lake St. Clair, in eastern Thurston County. In total, twelve wells and thirteen properties eventually reported no water availability during some parts of the period between July and December of 2025. A significant drought including this area was declared in WRIA11 during the spring, intensifying during the summer of 2025. Simultaneously, the surface water level of Lake St. Clair dropped to near-record lows. There is a large body of information available to investigate the causes for these dry wells. Multiple monitoring points surround Lake St. Clair, installed by the City of Olympia as part of hydrogeologic investigations in the 1990s to 2010s. These wells preceded development of the large McAllister wellfield from high-capacity pumping wells near the lake. These large production wells supply roughly 70% of the potable water for the City of Olympia and some surrounding communities. County stream gaging on Eaton Creek monitors stream inflows, while the County monitors lake levels and a weather station is nearby. Lake levels and monitoring wells both show strong seasonal periodicity – and probable long-term water level declines. Finally, a MODFLOW 6 model of Thurston County including the Lake St. Clair area is maintained to evaluate questions such as this. Unusually, the aquifer encountered by most of the dry wells is highly productive: sand, gravel and cobbles are common. Aquifer testing and modeling suggest hydraulic conductivities can range from 1000 ft/day to 6,000 ft/day. Investigations into the causes for these dry wells were guided by the requirements of the Washington State Supreme Court’s 2016 Hirst decision. Hirst required Growth Management Act (GMA) entities such as Thurston County to independently determine if water is available for development that relies on permit-exempt water wells. We will report on the current findings of this ongoing investigation.

Evaluating and Updating Groundwater-Recharge Estimates for Oregon Basins

Presenting: Stephen Gingerich, *USGS Oregon Water Science Center*

Authors: Stephen Gingerich, *USGS Oregon Water Science Center*; Matthew Barker, Adel Haj, *USGS Washington Water Science Center*

Groundwater recharge from precipitation is typically estimated using models of watersheds or soil water or, lacking models, computed from groundwater discharge estimates of a particular basin. The first statewide estimates of recharge across Oregon were mainly based on low-flow streamflow measurements prior to 1968 (Robison, 1968). More recently, recharge across Oregon was estimated by several national scale studies including 1) a water-budget analysis during 2000–13 based on empirically derived regression equations (Reitz and others, 2017), 2) WLDAS, a physically based land-surface model of the shallow subsurface covering 1979–present (Erlingis and others, 2021; Erlingis and others, 2024), and 3) NHM 1.1, a physically based surface watershed model covering 1980–2016 (Hay, 2019; Markstrom and others, 2024). Recharge estimates from these four methods are compared with recharge estimates from more-detailed local studies of several Oregon basins. In most cases, the detailed studies estimated more recharge than the national studies. Currently, the USGS and the Oregon Water Resources Department are constructing a detailed watershed model (Oregon Hydrologic Model; OHM) that is being calibrated to more than 200 new estimates of base flow across a broad geographic area, among other hydrologic data, to further refine basin recharge estimates statewide.

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Post-wildfire impacts to water supply in Washington state

Presenting: Nicholas Sutfin, *USGS Washington Water Science Center*

Authors: Nicholas Sutfin, Julia David, James Foreman, Andrew Spanjer, Sarah Dunn, Steven Pestana, *USGS Washington Water Science Center*; Renee Takesue, *USGS Pacific Coastal & Marine Science Center*

Increased sedimentation and associated contaminants following wildfire can impact aquatic habitat, reservoir storage capacity, and water quality. These impacts can threaten public water supplies and pose risks to communities that rely on wildfire-affected watersheds for irrigation, drinking water, and fisheries. We synthesize findings from two studies that examine the impact of wildfire on water quality and sedimentation. Following the 2021 Muckamuck Fire in Okanogan County, Washington (WA), we examined: (1) metals and organics in burned watershed soils, (2) metals concentrations of burned-area runoff in North Fork Salmon Creek and an unnamed tributary using the Diffusive Gradients in Thin Films (DGT) technique, (3) background sedimentation rates using repeat bathymetry and sediment cores we extracted from Conconully Reservoir, (4) and post-wildfire debris flow sediment input using repeat bathymetry, lidar, and structure-from-motion derived from uncrewed aerial systems. In response to the 2022 Bolt Creek wildfire in King County, WA, we measured stage, discharge, and turbidity on Bolt Creek and the South Fork Skykomish River. Periodic depth-integrated water samples of storm event runoff were also collected at Bolt Creek and the South Fork Skykomish River to measure suspended sediment concentrations, organics, major ions, and metals. Our results suggest that basin size and location within the context of the surrounding landscape and larger drainage network likely play a major role in the post-wildfire impact on water quality and the downstream extent of river and reservoir sedimentation. Runoff from both burned watersheds contained elevated concentrations of fine sediment and metals. Elevated concentrations of metals and sediment in Bolt Creek runoff were diluted less than a mile downstream from the Bolt Creek site after confluences with the Beckler River and South Fork Skykomish River. Metal concentrations in Conconully Reservoir sediments were not elevated, likely because of substantial inputs of deep-seated geologic material deposited after post-fire mass wasting events, such as the observed 2022 debris flow and the historically documented 1894 event that buried the Town of Conconully. While the long-term sedimentation rate at the depocenter of Conconully Reservoir underlain by pre-dam riparian wetland appears relatively slow, differencing of pre- and post-debris flow topobathymetric surfaces suggests debris flows could be a major source of sediment deposition at the two inlets of the reservoir. Results indicate that further research is needed to compare water quality of runoff in burned and unburned basins of various sizes and sedimentation rates of reservoir and lake inlets. Such comparisons are essential to better understand how wildfires in Washington influence sedimentation, potential contamination, and implications for water supply and reservoir management.

Hydrogeologic framework and groundwater chemistry near the Yakima Training Center, Washington

Presenting: Jackson Mitchell, *U.S. Geological Survey*

Authors: Jackson Mitchell, Stephen Breen, Mackenzie Mills, Jennifer McLean, Stephen Cox, *U.S. Geological Survey*

The U.S. Geological Survey, in cooperation with the U.S. Army Environmental Command, conducted a study to refine the hydrogeologic framework of the groundwater system near the Yakima Training Center (YTC) in south-central Washington to support remedial investigations of per- and polyfluoroalkyl substances (PFAS) contamination. The investigation integrated groundwater-level measurements from 113 wells, geochemical data from 95 wells and 5 surface-water sites, discharge measurements from irrigation canals, and the construction of a 3D hydrogeologic-framework model. The 3D model defines five hydrogeologic units in the study area: the Wanapum Basalt, Selah interbed, the Pomona Member of the Saddle Mountains Basalt, upper Ellensburg Formation, and unconsolidated deposits. A prominent north-south trending structural feature in the center of the study area, interpreted as a potential fault or dike, was identified via aeromagnetic anomalies and may influence local groundwater flow. Groundwater flow is predominantly westward toward the Yakima River. The study determined that leakage from unlined irrigation canals acts as a primary source of recharge for the shallow aquifer. Discharge measurements in the two irrigation canals that cross YTC within the study area suggest that the canals leak an estimated 1.8 million gallons per day of recharge during the irrigation season. Continuous monitoring revealed rapid hydraulic connectivity between the surface and the shallow aquifer, with water levels in some wells responding within 2 to 3 days of canal operation. Geochemical and age-dating analyses indicate considerable heterogeneity and mixing within the system. Stable-isotope data show that shallow groundwater is enriched by surface water derived from the Yakima River. Age dating utilizing sulfur hexafluoride and radiocarbon revealed that shallow groundwater in the Pomona basalt is mostly modern, with typical ages of 10–30 years. In contrast, a lone radiocarbon sample from the deep Wanapum Basalt contains paleogroundwater with an uncorrected radiocarbon age of 17,700 years, suggesting this resource is not recharged on human timescales. These findings are critical for understanding contaminant transport near YTC and assessing the impact of future irrigation infrastructure changes.

A Hydrogeologic Model of the Duwamish River Valley utilizing Leapfrog Works

Presenting: Mackenzie Mills, *Washington Water Science Center, United States Geological Survey*

Authors: Mackenzie Mills, Jackson Mitchell, *Washington Water Science Center, United States Geological Survey*

We present a preliminary hydrogeologic framework for the Duwamish River valley, south of Seattle, WA. We also present a novel approach to modeling subsurface hydrogeologic units (HGU) in the Leapfrog Works software

(LW) by Seequent. Our study area has two distinct subareas: the “valley”—the highly industrialized, flat-lying area bordering the river—and the “uplands”—consisting of surrounding glacial sequences and bedrock. The “uplands” area has well-documented stratigraphy of Vashon-era glacial sequence units, which can be distinguished with high confidence; however, units below the Vashon deposits are less constrained. In contrast, the “valley” area has been heavily infilled and modified by human activities. Fill thicknesses (frequently tens of feet or more) and compositions fluctuate depending on location. This presents challenges in assigning geologic units in sequence. The “valley” subarea is enclosed by the “uplands” to the east and west.

We use borehole lithology and surface geology to identify and assign HGU for each of the subareas. We then model the subsurface using the hydrogeologic stratigraphy for each subarea, which were then merged into a single integrated model. Our results include a hydrogeologic framework that can be used to understand subsurface geology and its effect on local groundwater flow. It models the spatial extent and 3D geometry of each HGU. The model has implications for the hydrology of the Duwamish River valley, which impacts industrial, public, and residential infrastructure

The workflow we produce in LW addresses the challenge of combining two lithologically distinct hydrogeologic models. In our study area, the “uplands” on either side of the “valley” have identical HGU, while the “valley” is an entirely distinct set. Because the two HGU families are classified independently, we cannot utilize the “combined geological model” default approach in LW. That approach requires matching lithologies between the models to enable merging, or for all layers of one model to correspond to a single layer in the other. This new workflow allows for merging without interference between HGU families during the merge. It is highly useful in cases where a secondary geological model cannot be directly related to spatial layers within a different, enclosing geological model.

New Hydrostratigraphic Interpretations of a Portion of the Black Diamond Quadrangle

Presenting: Gustaf Carlson, *Associated Earth Sciences, Inc.*

Authors: Gustaf Carlson, Curtis Koger, Jenny Saltonstall, Carrie Mozingo, James Johnson, Luke Mioduszewski, Stanley Thompson, Joshua Greer, *Associated Earth Sciences, Inc.*

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The Ten Trails Master Planned Development (Ten Trails) is located on a plateau approximately 400 feet above the Green River in Black Diamond, Washington. Ten Trails will incorporate multiple distributed and regional stormwater infiltration facilities to maintain treated stormwater recharge to the underlying aquifer system. Multi-year subsurface exploration, geologic reconnaissance and mapping, water level monitoring, and water quality sampling allow for an updated characterization of Pleistocene glacial and nonglacial stratigraphy beneath the upland. The revised stratigraphic characterization supports development of a conceptual hydrogeologic model of the subsurface and quantitative groundwater flow modeling at regional and facility specific scales.

The plateau is mantled by Vashon-age deposits, primarily recessional outwash (Qvr), icecontact kame terrace deposits (Qvic), and lodgement till (Qvt). Beneath the Vashon sequence are glacial and nonglacial deposits previously mapped as undifferentiated drift (Qg) and Orting Drift (Qor) by D.R. Mullineaux in 1965. Extensive subsurface exploration drilling, supplemented by radiocarbon age-dating and petrographic analysis, demonstrate these units are Olympia Formation to pre-Olympia in age. The units previously mapped as Qg and Qor were subdivided based on their glacial or nonglacial origin, grain size, and relative age. The units include 1) Pre-Olympia glacial coarse-grained (Qpog1c), 2) Pre-Olympia nonglacial coarse-grained (Qpon1c, Qpon2c), 3) Pre-Olympia nonglacial finegrained (Qpon1f), and 4) Pre-Olympia undifferentiated fine-grained (Qpo2f). Geologic reconnaissance and mapping along steep slopes south of the Ten Trails site identified geologic units interpreted as correlative with the subsurface deposits observed in deep borings.

The Pre-Olympia deposits directly overlie Tertiary bedrock mapped as Hammer Bluff Formation and Puget Group, both of which are exposed along the valley walls of the Green River. The Hammer Bluff Formation is made up of the upper and lower members, consisting of fluvial and lacustrine deposits, respectively. The Puget Group was encountered during drilling and consists of fine to medium-grained sandstone with common siltstone, claystone, and coal.

Treated stormwater is primarily infiltrated into surficial Vashon recessional outwash and deeper Pre Olympia glacial deposits. Regional infiltration facilities are evaluated using MODFLOW to simulate mound heights beneath specific facilities to demonstrate compliance with Ecology stormwater standards. Cumulative effects of

stormwater infiltration are superimposed on the regional groundwater flow system to simulate travel time and demonstrate mound dissipation as groundwater flows to spring systems at downgradient discharge locations.

Leverage data assimilation and machine learning to improve the forecast of reservoir water temperature and thermal release

Presenting: Zeli Tan, *Pacific Northwest National Laboratory*

Authors: Zeli Tan, Hoang Tran, Tian Zhou, *Pacific Northwest National Laboratory*

Many power plants and data centers rely on river water for cooling, for which deviations of intake water temperature as little as 1–2°C can lead to reduced cooling efficiency or forced shutdowns. However, river temperature perturbations exceeding 5°C by the operation of reservoirs can persist for tens to hundreds of kilometers downstream of large dams, which is still poorly represented in hydrological models. To overcome the limitations, we are developing a modeling framework using the emerging techniques of data assimilation (DA) and machine learning (ML) and leveraging widely accessible satellite observations. Specifically, we assimilated satellite data of surface water temperature and Secchi depth to a 1-D process-based lake model to improve the simulation of vertical water temperature profiles within a reservoir. Also, we combined simulate water temperature and satellite data of water storage, inflow, and outflow to build machine learning models for reservoir heat release. Using the Grand Coulee Reservoir in the Columbia River Basin as a test case, we would demonstrate the effectiveness of the model framework in improving the forecast of reservoir water temperature and thermal release, particularly during heatwaves.

AI-Enabled Decision Support for Groundwater–Surface Water Systems to Protect Drinking Water and Reduce Public Health Risk in the Pacific Northwest

Presenting/Author: **Ishita Srivastava, University of California, Berkeley**

Groundwater–surface water systems are a critical foundation of drinking water supply in the Pacific Northwest and directly influence public health through water availability, water quality, and exposure risk. In Washington State, many communities rely on groundwater sources that are increasingly vulnerable to climate-driven changes in recharge, intensified groundwater withdrawals, and declining stream baseflow. These hydrogeologic stressors can concentrate contaminants, elevate water temperatures, and reduce source reliability, increasing health risks for populations served by small public water systems and private wells.

This project proposes the development of an AI-enabled decision support framework that explicitly integrates hydrogeologic processes with public health-relevant indicators to identify and mitigate drinking water risk in coupled groundwater–surface water systems. The framework will integrate continuous groundwater level data, streamflow and baseflow metrics, precipitation and recharge estimates, land-use and well density information, and routinely monitored drinking water parameters such as nitrate, temperature, and salinity proxies using publicly available datasets across Washington State. Time-series machine learning methods, including regression-based forecasting and unsupervised classification, will be applied to identify early warning signals of declining source reliability, increased contaminant vulnerability during low-flow conditions, and aquifer–stream systems associated with elevated public health risk.

To ensure interpretability and regulatory relevance, data-driven analyses will be constrained by conceptual hydrogeologic models informed by aquifer stratigraphy, well logs, and hydraulic properties. Scenario-based analyses will evaluate management strategies such as managed aquifer recharge, seasonal pumping adjustments, and streamflow protection under projected climate and demand conditions, with direct implications for drinking water safety and exposure risk reduction.

A central goal of this work is translating hydrogeologic complexity into actionable public health insights. Decision support outputs will include spatial vulnerability maps linking hydrogeologic stress to drinking water dependence, probabilistic metrics of source reliability, and threshold-based indicators designed to support coordination among water managers, public health agencies, and policymakers. Equity-informed metrics, including reliance on small systems, proximity of disadvantaged communities, and cumulative environmental stressors, will be incorporated to prioritize interventions where health risks are greatest.

By expanding public access to hydrogeologic and drinking water risk information, this framework aims to improve transparency and empower communities to engage in water resource decision-making. The approach is designed to reduce disparities in monitoring capacity and technical expertise by providing accessible, interpretable tools that support smaller utilities and underserved populations. Ultimately, this work demonstrates how AI-enhanced hydrogeology can advance equitable drinking water protection, reduce

preventable public health burdens, and strengthen resilience across both ecosystems and communities in the Pacific Northwest.

Groundwater-Level Mapping and Monitoring Network Evaluation Using Diffusion Models

Presenting: Xuehang Song, *Pacific Northwest National Laboratory*

Authors: Xuehang Song, Tse-Chun Chen, Grigoriy Kondyukov, Zhangshuan Hou, Inci Demirkanli, Rob Mackley, *Pacific Northwest National Laboratory*

Reliable groundwater-level (GWL) maps are essential for understanding flow directions, evaluating remediation performance, and supporting long-term groundwater management. At complex sites with large and evolving monitoring networks, however, GWL measurements are often inconsistent in space and time, making it difficult to generate temporally consistent maps and to assess the information value of individual wells. Traditional geostatistical interpolation and steady-state groundwater models can produce physically reasonable maps, but they typically require substantial manual effort to construct and calibrate and do not directly quantify how monitoring network changes affect map uncertainty.

We present a data-driven framework that combines generative diffusion models with score-based data assimilation (SDA) to produce observation-conditioned GWL maps and to evaluate groundwater monitoring networks. The diffusion model is trained on outputs from a calibrated physics-based groundwater flow model and learns the spatial and temporal structure of groundwater levels across the domain. During inference, SDA enables the model to assimilate sparse and irregular well observations without retraining, producing groundwater-level fields that remain consistent with available measurements while preserving physically plausible spatial patterns.

Applied to a long-term groundwater monitoring dataset from the Hanford Site in Washington State, the framework demonstrates strong performance in reconstructing historical groundwater-level fields and quantifying uncertainty. Ensemble predictions are generated naturally through the stochastic diffusion process, allowing spatial maps of prediction uncertainty to be derived alongside the mean groundwater-level estimate. Areas with dense monitoring show low uncertainty and small reconstruction error, while sparsely monitored regions exhibit higher uncertainty, providing an intuitive and quantitative measure of map confidence.

Beyond mapping, the framework supports monitoring network evaluation through systematic add- and drop-well experiments. By selectively withholding individual wells or groups of wells during assimilation, we quantify the resulting increase in mapping error and uncertainty, providing a direct measure of each well's marginal information value. Conversely, synthetic observations can be introduced at candidate locations to assess where new wells would most effectively reduce uncertainty. Results show that the impacts of removing or adding wells are spatially localized, highlighting under-monitored areas and distinguishing high-value wells from redundant ones.

This approach offers a flexible alternative to traditional groundwater mapping workflows by integrating physics-based knowledge, observational data, and uncertainty quantification within a single framework. The method supports adaptive monitoring strategies by linking monitoring density and placement directly to mapping accuracy, with potential applications to long-term groundwater management, remediation monitoring, and network optimization across a wide range of hydrogeologic settings.

Large Language Model (LLM)-Assisted Access to Subsurface and Contamination Information

Presenting: Rebecka Iveson, *Pacific Northwest National Laboratory*

Authors: Rebecka Iveson, Xuehang Song, Chao Zeng, Patrick Royer, Christian Johnson, Anurag Acharya, Amzi Jeffs, Rob Mackley, Inci Demirkanli, *Pacific Northwest National Laboratory*

Effective groundwater remediation at complex sites requires the integration of geologic characterization data, contaminant monitoring information, and historical site knowledge. Environmental remediation programs at the Department of Energy (DOE) and other federal facilities manage extensive repositories of geologic reports, monitoring data, and interpretive frameworks that contain valuable insights for remedy optimization and decision-making. However, accessing and synthesizing this distributed information is often time-consuming and labor-intensive, requiring technical experts to manually crossreference multiple documents, databases, and spatial datasets. This fragmented process may delay remediation decisions, produce suboptimal site outcomes, and limit engagement with non-technical stakeholders who would benefit from clear, accessible summaries of site conditions and trends.

To address these challenges, this study is developing an artificial intelligence (AI) agent driven by large language models (LLMs) that serves as an intuitive interface for subsurface characterization and contamination data. Using the Hanford Site in southeastern Washington State as a demonstration case, the prototype chatbot will allow users to query geology, hydrostratigraphy, groundwater monitoring results, and contaminant behavior through natural language interactions. The system will utilize retrieval-augmented generation (RAG) to draw upon authoritative geologic and monitoring reports and databases such as the Hanford Environmental Information System (HEIS) and the Hanford Geologic Framework (HGF). This ensures responses are grounded in qualified, peerreviewed sources. All responses are traceable to underlying documents and databases, supporting transparency and regulatory confidence.

The prototype will support two core capabilities: (1) report-driven question answering, which retrieves and synthesizes information from historical geologic interpretations, annual monitoring reports, and technical summaries with explicit citations; and (2) framework-driven question answering, which leverages spatial databases and stratigraphic relationships to answer queries about geologic setting, unit extents, well characteristics, and their implications for contaminant migration and remediation design. The system will output concise summaries, basic visualizations, and citations to underlying data sources. Responses can be tailored to the user's technical expertise, from site managers seeking high-level summaries of contaminant trends to data scientists requiring detailed quantitative analyses. This initial demonstration establishes an AI-enabled interface layer between subsurface data repositories and end users, to augment, not replace, expert interpretation.

This approach is particularly valuable at sites with complex geology, extensive historical datasets, and diverse stakeholder groups. By automating information retrieval and synthesis from validated sources, the AI agent

accelerates decision-making, improves data accessibility, and supports more inclusive stakeholder engagement. Moreover, this initial demonstration will be foundational for future, planned expansions towards semi-automated reporting. Ultimately, the replicable architecture demonstrated at Hanford will provide a scalable model for improving remediation performance at other DOE sites and commercial environmental remediation programs facing similar data integration challenges.

Analysis of the Pilot Infiltration Test Method and Correlation between the Vertical Saturated Hydraulic Conductivity and Grain-Size Distribution of Normally and Glacially Consolidated Sediments in Western Washington

Lam Nguyen, Jennifer Saltonstall, Curtis Koger, Luke Mioduszewski, *Associated Earth Sciences, Inc.*

The Pilot Infiltration Test (PIT) is a widely used field method for measuring the infiltration rate of native soils in the design of stormwater infiltration facilities as documented in the Washington State Department of Ecology (WADOE) and King County stormwater management manuals. The PIT method is governed by the Green–Ampt principle of vertical infiltration and is performed under constant low head and constant flow, with a minimum inflow period of 6 to 7 hours to approximate a saturated steady-state condition. In this state, horizontal flow and capillary effects are reduced, and the calculated infiltration rate becomes a reasonable approximation of the saturated hydraulic conductivity (K_{sat}) with appropriate correction factors. The method combines straight-forward flow and water head measurements during testing with the advantage of direct visual observation of the PIT sidewalls prior to and during post test dig-out of the subgrade.

Correlative equations have been developed over many decades to estimate K_{sat} using grain-size parameters but most rely on limited field data along with laboratory tests and computer simulations to estimate K_{sat} . Current approaches that calibrate equations using laboratory data or numerical models typically assume homogeneous and isotropic conditions. As a result, they often perform poorly when applied to real-world sites where sediments are frequently layered and can display substantial lateral and vertical variability over short distances.

Associated Earth Sciences, Inc. (AESI) has conducted over 600 pairs of PITs and sieve analyses across western Washington, primarily in the Puget Lowland. AESI modified a widely used grain-size equation using a subset of AESI's PIT and sieve data, to estimate K_{sat} for normally and glacially consolidated sediments. AESI's revised grain-size method improves the estimation of K_{sat} by several factors compared to the existing approach in the 2024 WADOE stormwater manuals. To avoid calibration bias, AESI independently verified the performance of the modified method against the existing approach using PIT and sieve data not involved in the development of the revised equation.

The findings highlight the importance of distinguishing normally consolidated sediments from those that have been glacially consolidated. Glacial compaction can reduce K_{sat} by two to three orders of magnitude. Despite its improvements, the grain-size equations developed in this study are not intended to replace the established field-based PIT, as grain-size equations cannot fully account for site variability. In contrast, the PIT method accounts for site variability through (1) visual confirmation of subsurface variability during the dig-out process, (2) a cross-check between the constant-head and falling-head rates, and (3) guidance for remediation when layering or adverse conditions are encountered, including construction of highly permeable pit drains below the infiltration facility to increase the effective infiltration rate and overall facility performance.

Characterizing Bedrock Topography Using Electrical Resistivity Tomography to Constrain Aquifer Geometry for Groundwater Modeling in a Glaciated Puget Lowland Setting

Collin Marshall, Ellis Kotchka, *Associated Earth Sciences, Inc.*; Curtis Koger, *Central Washington University*

The Orting Plateau is situated in the Southeastern portion of the Puget Lowland, an elongated, north-south topographic depression situated between the Olympic Mountains and the Cascade Range.

Pleistocene glacial and non-glacial deposits in the Puget Lowlands provide a record of bedrock provenance originating from multiple drainages formed in the Cascade Range. These sediment sequences were repeatedly eroded and redeposited by multiple southward advances of the Puget Lobe of the Cordilleran ice sheet, alpine glaciation sourced within the Cascade Range, and interglacial drainage networks. The complex interplay between competing depositional and erosional processes results in a wide range of provenance signatures.

The current understanding of Pleistocene stratigraphy in the Puget Lowland is dominated by detailed studies of Vashon-Stade deposits. Much of the pre-Vashon stratigraphic framework is inherited from mid-20th-century studies that emphasized unit identification and outcrop-based correlation, often without the benefit of modern geochemical or provenance tools. This study characterizes provenance signatures within Puget Lowland deposits to improve subsurface to outcrop correlations.

Petrographic, geochemical, and radiocarbon analyses allow for detailed evaluation of sediment sources within glacial and non-glacial deposits. Conventional petrographic analyses (monocrystalline to polycrystalline quartz (Qm:Qp) ratios, lithic and mineral identification) of epoxy sand-mount thin sections from AESI's internal sample inventory, combined with select outcrop exposures provide a framework for identifying provenance signatures. These signatures coupled with radiocarbon age dates allow for interpolation of sediments with known ages.

Point-counting of Vashon-age glacial sediments typically yields low Qm:Qp ratios, low volcanic lithic proportions, low heavy mineral content (pyroxene, hornblende), and a higher proportion of metasedimentary and metamorphic lithics. Conversely, point-counting of pre-Vashon-age nonglacial sediments (Olympia, Puyallup, and Alderton Formations) typically yields high Qm:Qp ratios, higher volcanic lithic and heavy mineral proportions (pyroxene, hornblende, opaques), and a lower proportion of metamorphic lithics.

Resulting ternary diagrams of point count data and bulk sediment geochemistry support existing interpretations that glacial sediments represent a distinct assemblage of cordilleran ice-sourced lithic types, and that nonglacial sediments generally contain a high proportion of local bedrock types dependent on source-area lithologies. Although distinct end-member petrographic signatures are discernable for both glacial and nonglacial sediment packages, point-count data also indicates that samples often represent some degree of mixing or reworking between provenance types, resulting in a wide variety of signatures.

Washington State's Geothermal Energy Collaborative Process

Alexandra Shin, Diane Butorac, Amelia Fujikawa, *WA Dept of Ecology*; Jessica Czajkowski, *WA Dept of Natural Resources*

To support Washington state's transition to clean energy, the Legislature recognized geothermal energy as a potential resource and directed the Washington State Department of Ecology to bring people together to talk about its associated opportunities and risks.

The geothermal energy collaborative process is an early look at issues because there is interest in developing the state's geothermal resources. We are engaging with communities, Tribes, industry, utilities, and local and state agencies to learn about the state's geothermal resources and new technologies and to provide opportunities for feedback on concerns and impacts. The process has statewide considerations, but it is focused on the three geothermal resource areas identified by the Washington State Department of Natural Resources: Mount Baker, Mount St. Helens, and the Wind River valley. The Department of Natural Resources developed an interactive Geothermal Experience website with information about geothermal energy, technology types, and the three resource areas.

There is a high level of interest in the collaborative process and how it will inform communities and Tribes about geothermal development. Topics include emerging geothermal technologies, state regulatory framework, cultural and Tribal resource impacts, injection fluids and water quality impacts, induced seismicity, and strategies to manage risk. We are working closely with experts from the state departments of Archaeology and Historic Preservation, Commerce, Fish and Wildlife and Natural Resources and engaging outside technical experts.

We are looking at conventional geothermal and the emerging technologies of enhanced geothermal systems and advanced geothermal systems. These technologies have different applications and use cases, potential impacts, and siting and development factors. Our collaborative process will explore these and offer recommendations for future projects to consider.

Findings and recommendations from the collaborative process will be provided to the governor and Legislature in an interim report due June 30, 2026, with a final report due June 30, 2027.

Water Temperature Dynamics in the Quillayute River Basin, Washington, 2021 – 2023**Chad Opatz, *USGS Washington Water Science Center***

By Daniel E. Restivo, Chad C. Opatz, Rich W. Sheibley, Anya C. Leach, Mousa Diabat, Chris Miwa, and Leland T. Fuhrig

Late-summer water temperature dynamics in the Quillayute River Basin in northwestern Washington were evaluated from 2021–2023 to support restoration of cold-water habitat for salmonids. Using multi-depth continuous temperature monitoring, airborne thermal infrared imaging, longitudinal float surveys, vertical stream-bed sediment temperature profiling, and paired air–stream temperature analyses, the study characterized thermal heterogeneity and groundwater–surface water exchange across major basin rivers and small-order streams.

Spatial variation in the warming rates of major basin rivers was primarily governed by solar radiation exposure modulated by riparian and topographic shading and cool water inflows. Warmer conditions occurred where channels widened, riparian cover decreased, or valley geometry reduced topographic shade. River cooling was driven by diffuse and lateral groundwater inflows, tributaries, and tidal mixing in lower river reaches.

Surface geology was identified as a likely determinant of river morphology and the incidence and cooling efficacy of groundwater contributions, thereby partially governing thermal heterogeneity. Fine-grained alpine glacial deposits corresponded with wider, more radiatively exposed channels, while coarse, permeable continental glacial deposits supported stronger groundwater upwelling and localized thermal refugia.

Groundwater specific discharge rates in the Quillayute River were highly variable, showing both upwelling and downwelling at each site, but with downwelling more common in tidally influenced areas and upwelling more common in upstream areas.

Shallow groundwater influence was identified at all small-order stream sites, indicating moderate susceptibility of these streams to warming as a result of atmospheric or land-use changes. All continuous monitoring sites in the Quillayute River exceeded the 16 °C criterion for core summer salmon habitat between 24% and 87% of summer days, while thermal imagery revealed critically high-water temperatures between 20.0 °C to 23.5 °C for 24 river miles of the Bogachiel River, underscoring the risk of high-water temperatures to salmonids in the Quillayute River Basin.

Using complimentary surficial geophysical techniques to assess the effectiveness of channel spanning engineered log jams to increase floodplain connectivity and groundwater storage on the South Fork Nooksack River, Northwest WA

Jake Peckenpaugh, Bernard Housen, *Western Washington University*; Sydney Jantsch, *Lummi Nation Natural Resource Department*

Climate change is reducing snowpack and summer streamflow in Northwest Washington, increasing water temperatures threatening Pacific salmon populations. Channel spanning engineered log jams have emerged as a new restoration strategy to improve groundwater storage and create cold water refugia, but their effectiveness remains poorly understood in natural settings. This study used ground penetrating radar and electrical resistivity tomography to measure seasonal changes in groundwater levels and soil moisture at four sites along the South Fork Nooksack River from 2024 to 2025. Two sites contained channel spanning engineered log jams (Larsons and Lower Fobes), while two sites served as controls (Upper Fobes and Cavanaugh). Results showed that sites with channel spanning engineered log jams had groundwater tables within 0.1-0.3 meters of river elevation year round, while Upper Fobes remained 1-2 meters below the river surface across all seasons. Electrical resistivity measurements showed Upper Fobes experienced seasonal changes of above 400 Ω *m, while Lower Fobes only changed by 35 Ω *m. A two way ANOVA confirmed significant differences between sites and seasons, with channel spanning engineered log jam sites showing less seasonal variability in groundwater depth. These findings suggest channel spanning engineered log jams effectively increase floodplain groundwater storage and connectivity to the river, supporting salmon habitat restoration goals. This work shows how noninvasive geophysical methods give consistent, reliable measurements that help show how well restoration is working, and they can guide future habitat improvements.

The Geomorphology and Hydrology of Pre-Restoration West Fork Teanaway River, Kittitas County, WA**Maggie Egan, Lisa Ely, Carey Gazis, *Central Washington University***

The West Fork Teanaway (WFT) River, Kittitas County, WA is a bedrock river channel with shallow stream depth, low alluvium sediment, and high stream temperatures that are inhospitable for spawning and rearing of native anadromous fish. Stream restoration of the WFT with the intent to halt bedrock incision, retain channel sediment, raise river water depth, and raise floodplain groundwater levels will begin in 2026 by the Washington State Department of Fish & Wildlife and the nonprofit organization Mid-Columbia Fisheries Enhancement Group. This research characterized the pre-restoration hydrogeology and geomorphology of the WFT to quantify changes in these factors after restoration completion. Stable isotope geochemistry ($\delta^2\text{Hydrogen}$ and $\delta^{18}\text{Oxygen}$) of surface water and groundwater from shallow piezometers was used to characterize surface water/groundwater interactions in the WFT floodplain over the 2025 water-year. WFT floodplain stratigraphy and floodplain groundwater levels were compared with those of the North Fork and mainstem Teanaway River to determine differences in shallow floodplain aquifer characteristics across the Teanaway River Basin during the 2025 water-year. The results will provide a baseline to assess the efficacy of river restoration methods with achieving their design objectives at the WFT and quantify the effects of two different stream restoration techniques on a shallow floodplain aquifer in a mountainous headwater system.

Spring Revival: Quantifying Managed Aquifer Recharge on the Toppenish Alluvial Fan Using Stratigraphy and Hydrochemistry

Sam Dossa, Carey Gazis, Lisa Ely, *Central Washington University*

The Toppenish Fan Shallow Aquifer Recharge Project (TFSAR) is a managed aquifer recharge (MAR) project conducted by the Yakama Nation. The project diverts flow from Toppenish Creek into existing unlined irrigation canals during winter and early spring. Water is used to recharge the alluvial fan aquifer before the start of the irrigation season. The TFSAR has shown success in raising local groundwater levels and supporting spring-fed streams that are important to riparian habitat and cultural values of the Yakama Nation. The goal of this project is to quantify the hydrochemistry, stratigraphy, and hydrogeology of the Toppenish alluvial fan to assess the extent, location, and seasonality of recharge; mixing of surface water with groundwater; groundwater travel times and flow directions; and physical characteristics of the Toppenish Fan aquifers. The hydrochemistry and stratigraphy will be used to assess the sources of water that contribute to groundwater wells and springs on the Toppenish Fan and what proportion of that water is from the existing Toppenish Fan Shallow Aquifer Recharge Project. Specifically, this project will examine existing well logs, water-level readings, pH, conductivity, temperature, dissolved oxygen, alkalinity, major ion analysis, and repeated oxygen and hydrogen stable isotopes samples before, during, and after the recharge season. Water samples collected from surface streams, recharge canals, and groundwater wells will be collected within and adjacent to the TFSAR Project. This research can help inform the use of MAR during the non-irrigation months on other parts of the Toppenish Basin or other alluvial fans in the Yakima Basin. The project is being conducted in collaboration with the Yakama Nation.

Experiments on the Use of H₂O₂ to Control DBPs in Aquifer Recharge Water**Julian Howe, Carey Gazis, *Central Washington University***

Warmer winters in the Pacific Northwest means less snowpack that can slowly melt through spring and into summer to help meet water demands. One solution to this problem is pumping surface water into depleted aquifers, and pumping it back out of the ground when it is needed, particularly in the summer. This management practice, referred to as Aquifer Storage and Recovery (ASR), is being pursued by a number of municipalities throughout Washington state. Water quality criteria in Washington State require disinfection of recharge water, which can result in the formation of disinfection byproducts (DBPs), some of which can be toxic and carcinogenic. One group of DBPs of concern are Trihalomethanes (THMs) which form when organic matter interacts with the hypochlorite ion (the active disinfectant in chlorinated water). It has been proposed that treating the recharge water with hydrogen peroxide before the chlorination step can reduce the formation of THMs. Due to the complexity of water treatment processes, it is necessary to perform benchtop laboratory experiments to determine the efficacy of this proposed treatment as well as the optimal timing and dosage of hydrogen peroxide before in situ pilot studies are conducted. This presentation will describe experiments that will be performed at Central Washington University in the summer of 2026. These experiments will test treatment methods in starting waters with a range of total organic carbon (TOC) and determine reaction rates for pertinent reactions. The results will inform treatment recommendations, including optimal chlorine dose, optimal hydrogen peroxide dose, and retention times following treatments.

Storm drain StreamStats: Integrating stormwater infrastructure into web-based watershed delineation tool

Sarah Dunn, Kristina Hopkins, U.S. Geological Survey, Washington Water Science Center; Pete Steeves, U.S. Geological Survey, New England Water Science Center

For over two decades, the U.S. Geological Survey's (USGS) StreamStats web application (<https://streamstats.usgs.gov/>) has enabled users to delineate drainage areas, calculate basin characteristics, and generate estimates of streamflow statistics in Washington. While StreamStats remains a leading tool for assessing ungaged locations, it is built upon a digital elevation model and hydrographic network that may not fully capture the nuances present in suburban and urban landscapes. To provide a more realistic representation of stream and storm drain connectivity, the USGS has added functionality to StreamStats in select areas (St. Louis, Missouri; the Mystic River basin in Boston, Massachusetts; and Washington, District of Columbia) to incorporate storm drains and culverts and enforce flow directions and "sinks" in the digital elevation model. The USGS is working to expand this new storm drain functionality in StreamStats within the Lower Green-Duwamish River watershed located in King County, Washington. The goal of this new functionality is to serve as a tool for stormwater management to help local water resource managers address water quantity and quality concerns. The project will compile high-resolution elevation data and existing municipal data on stormwater infrastructure systems and integrate these datasets into a new tool within StreamStats. The StreamStats base hydrography will be updated from a layer based on 30-meter resolution elevation data to 1-meter resolution elevation data, allowing for more precise delineation of stormwater drainage areas. The tool will also provide additional basin characteristics to StreamStats that represent highresolution impervious cover, tree cover, traffic counts, population density, precipitation, and slope. The information provided by the tool will support assessments of water quality and quantity, and inform local decision-making, water resource planning, and engineering design. This poster will introduce the new Lower Green-Duwamish Storm Drain StreamStats application and invite feedback on key basin characteristics and potential use cases for StreamStats that will support water resource management and planning.

PFAS Monitoring in East Selah, Spokane, and the West Plains

Jacob Carnes, *Washington State Dept. of Ecology*

Groundwater in the East Selah area north of Yakima and the West Plains area outside of Spokane is contaminated with per- and polyfluoroalkyl substances (PFAS). In both areas, the contamination is, at least in part, the result of historical use of aqueous film-forming foam in firefighting training activities. In the East Selah area, the contamination originates from the Yakima Training Center (YTC), a sub-installation of Joint Base Lewis-McChord. In the West Plains, known PFAS sources include Fairchild Air Force Base and Spokane International Airport.

Extensive sampling of drinking water wells has confirmed the presence of PFAS contamination in groundwater at concentrations well above state and federal limits. However, surface water sampling near the affected areas has been sparse. In 2024 and 2025, the Washington State Department of Ecology (Ecology) conducted studies to determine whether PFAS-contaminated groundwater is discharging into nearby surface water.

In the East Selah area, Ecology sampled surface water in the Yakima River, two ponds, a wetland, and two irrigation canals. Groundwater discharging into the Yakima River was also sampled using a PushPoint sampler. Additionally, effluent from the YTC wastewater treatment plant was sampled where it discharges into the Yakima River. PFAS were detected in all PushPoint samples collected along the banks of the Yakima River. PFAS were also detected in co-located surface water samples. Field measurements taken prior to sampling indicated that groundwater was discharging to the river at each PushPoint sample location. The two ponds sampled have no surface water inputs and are presumed to be groundwater-fed. PFAS were detected in all pond surface water samples.

Near the West Plains and Spokane, Ecology collected surface water and PushPoint samples from the Spokane River and several of its tributaries. PushPoint samples and field measurements indicate that PFAS-contaminated groundwater is discharging to the Spokane River on the left bank across from Plese Flats. Surface water and PushPoint samples from tributaries to the Spokane River, including Garden Springs Creek, Indian Canyon Creek, and Deep Creek, had elevated PFAS concentrations. Field measurements on these tributaries indicate that some sample locations had gaining conditions, while others had losing conditions.

Yakima Training Center Per- and Polyfluoroalkyl Substances (PFAS) Remedial Investigation Time Critical Removal Actions - Installation of Residential Whole-Home Point-of-Entry-Treatment (POET Systems, Yakima, WA

Audra Balson, PG, ECC; Michael Brown, USAEC

Background/Objectives

The United States Army Environmental Command's (USAEC) per- and polyfluoroalkyl substances (PFAS) remedial investigation and private water supply treatment initiative at the Yakima Training Center in East Selah, Washington, has entered its fourth year. Since the fall of 2022, the investigation has progressed in accordance with the United States Environmental Protection Agency's (USEPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) framework. Investigation activities are expected to continue for several more years in order to thoroughly assess PFAS impacts both on the installation and in the surrounding areas.

This ongoing effort is a collaborative endeavor involving multiple federal and state stakeholders, as well as Army contractors. The initiative employs a data-driven approach, incorporating extensive hydrogeologic and subsurface geophysical surveys to optimize drilling locations. These surveys aim to identify the primary groundwater and contaminant migration pathways that originate from the Training Center.

Treatment of Private Water Supplies

As part of the Time-Critical Removal Actions (TCRAs), the Army and its contractors are installing residential, whole-house point-of-entry-treatment (POET) systems in affected homes as an interim remedial measure. Since August 2023, 69 residential POETs have been installed in the East Selah community and dozens more are planned. POET systems are routinely monitored and maintained in accordance with USAEC's Granular Activated Carbon (GAC) Vessel Management and Sampling Policy, which is conservatively modified from USEPA's Final PFAS National Primary Drinking Water Regulation (May 2025). The Army and its stakeholders are working to develop long-term drinking water solutions for the impacted community.

Microplastics (MP) in Drinking Water Linked with Colorectal Cancer Across Urban-Rural Counties of Maryland**Millen Singh, *Landon School***

Microplastics, defined as plastic particles less than 5 mm in diameter, are evident in the environment and a growing public health concern because they are found in drinking water systems. Here, we investigate the correlation between microplastic levels in drinking water and colorectal cancer rates in Maryland. Drinking water samples were collected and analyzed. Statistical analyses were conducted to test the relationship between microplastic concentration in drinking water and colorectal cancer incidence. Some rural Maryland counties tended to show significantly higher microplastic concentrations in the drinking water than their urbanized counterparts. Even though one would expect urbanized areas with higher population density and plastic waste generation to show higher microplastic concentrations in their drinking water. Adding to this unexpected pattern, the same rural counties (Allegany, Caroline, and Dorchester) that had the highest microplastic contamination in their drinking water were also noted to have the highest incidence of colorectal cancer rates in the state of Maryland. This research highlights the importance of addressing microplastic contamination in drinking water, the pathways through which it enters public systems, and its broader implications for public health policies and practices. By identifying potential risks, this study contributes to a growing body of knowledge on environmental toxins and their impact on human health, and to our knowledge, it is the first study that shows a correlation between microplastic-contaminated drinking water in rural counties of Maryland and increased colorectal cancer rates.

Tracing Groundwater Movements and Mixing with Stable Isotopes at the Taneum Managed Aquifer Recharge Site

Adriana Pacheco García, *Central Washington University*

Managed aquifer recharge (MAR) is increasingly viewed as a critical tool for improving groundwater storage and enhancing instream flows in the Yakima Basin, yet significant uncertainty remains regarding the fate, transport pathways, and timing of recharged water once it enters alluvial aquifer systems. This research focuses on the Taneum Creek MAR site, a high-priority recharge location identified by the Kittitas Reclamation District (KRD) near the confluence of Taneum Creek and the Yakima River. Previous hydraulic monitoring and a pilot recharge test conducted in 2023 demonstrated rapid groundwater mounding and delayed discharge toward the Yakima River, suggesting meaningful potential for streamflow augmentation. However, key questions persist regarding the fate of recharged water, including travel times, mixing with ambient groundwater, preferential flow paths, and the partitioning of recharged water between Taneum Creek and the Yakima River.

This study uses stable isotopes of oxygen and hydrogen as conservative tracers to directly track the movement and mixing of recharged water in the aquifer. The isotopic approach builds on prior regional studies that show a clear isotopic distinction between Yakima River water, which is typically isotopically heavier due to its westerly source regions and evaporation during storage, and locally derived groundwater and Taneum Creek, which reflect more easterly precipitation and snowmelt inputs. When Yakima River water is applied during MAR events, its unique isotopic signature serves as a natural tracer that can be tracked through space and time in the subsurface.

In this research, groundwater samples will be collected from existing monitoring wells before, during, and after both natural recharge events (snowmelt and precipitation) and an artificial recharge event conducted using KRD infrastructure. Complementary sampling of Taneum Creek, the Yakima River, and on-site precipitation will constrain isotopic end members and seasonal variability. Two-end-member mixing models will be used to quantify the fraction of recharged water present in each well over time. These data will be integrated with continuous groundwater-level records to compare the movement of water molecules with the propagation of the recharge-induced pressure pulse. Finally, a simplified numerical groundwater flow model will be compared to these results to better understand flow paths and timing.

By combining isotopic evidence with hydraulic observations and groundwater flow modelling, this project aims to estimate recharge travel times, identify dominant flow paths, and evaluate the timing and magnitude of recharge contributions to surface waters. The results will refine the conceptual hydrogeologic model of the Taneum floodplain aquifer and improve estimates of MAR-derived streamflow benefits. More broadly, this thesis serves as a proof of concept for applying stable isotope tracers to MAR assessment in Washington State,

providing a transferable framework for evaluating recharge efficiency and groundwater-surface water connectivity at other candidate MAR sites across the Yakima Basin.

An Evaluation and Update of Guemes Island Groundwater Conditions

Leland Fuhrig, Elise Wright, *USGS*

Guemes Island is a small island in northern Puget Sound, Washington, that relies solely on groundwater for its freshwater supply. Increasing population, nearshore development, and associated well failures from seawater intrusion have heightened concern about the long-term sustainability of this resource. To address these concerns, current island-wide groundwater conditions were evaluated, including aquifer recharge, groundwater use, and groundwater levels. Island-wide recharge was estimated using the U.S. Geological Survey Soil-Water Balance (SWB) model, and groundwater withdrawals were estimated by water use category to construct a preliminary water budget. Water-level and water-quality data collected in 2022 were used to characterize groundwater flow directions, gradients, and present-day water-quality conditions across the island. These results provide an updated assessment of groundwater conditions relative to a previous U.S. Geological Survey study completed in 1995 and are intended to support informed, sustainable groundwater management on Guemes Island.

Field Trips

pages 93-94

Workshops

pages 95-96

FT 1: Reclaimed Water for Groundwater Recharge: Woodland Creek & Hawks Prairie

Monday, May 11, 2026, 8:00 AM – 5:00 PM

Leaders: Erik Iverson (City of Lacey); Wendy Steffensen & Matt Valenta (LOTT Clean Water Alliance)

WAHGS Contact: Stephen Breen | 650-303-6183 | sbreen@usgs.gov

This two-part field trip explores innovative reclaimed-water infiltration systems that play a crucial role in groundwater recharge and watershed resilience in Lacey, Washington. The morning visit to the Woodland Creek Groundwater Recharge Facility highlights how 4.7 miles of underground infiltration chambers replenish groundwater and streamflow using reclaimed water from the Martin Way Plant. Participants will learn about key system components, including the chlorine analyzer, SCADA monitoring system, and the infiltration gallery design, as well as see a demonstration of a stream-depth measurement.

In the afternoon, the group continues to the Hawks Prairie Ponds and Recharge Facility, a 40-acre site consisting of multiple ponds and recharge basins that infiltrate Class A reclaimed water. The tour focuses on the fate and transport of residual contaminants of emerging concern (CECs), large-scale water-quality management, and long-term aquifer recharge strategies.

What's Included: Guided tours of both facilities; box lunch at Woodland Creek Community Park; transportation between sites

What to Bring: Weather-appropriate layers, boots suitable for muddy areas, and an optional reusable water bottle or binoculars.

Where to Go:

- Meet at front desk of Hotel Murano at 7:45 A.M. to board the bus/van
- Depart at 8:00 A.M.

FT 2: Geology Cruise: Commencement Bay & Tacoma Narrows

Monday, May 11, 2026, 2:30 PM – 6:00 PM

Leader: Dr. Kathy Goetz Troost (UW Department of Earth & Space Science)

WAHGS Contact: Chris Martin | 425-577-3854 | cmar461@ecy.wa.gov

Join us for an afternoon geology cruise through Commencement Bay and the Tacoma Narrows, offering a unique opportunity to study Puget Sound coastal geology directly from the water. Dr. Kathy Goetz Troost will guide participants along the bluffs of Point Defiance and through the Tacoma Narrows, highlighting the Tacoma Fault Zone, shoreline processes, landslides, port development, and the evolution of the Puyallup River delta. The cruise provides exceptional views of well-dated Quaternary sediment exposures, including Olympia, Whidbey, Possession, and Double Bluff–aged deposits. Participants will gain insight into vertical and lateral heterogeneity common in Puget Sound deposits, along with cultural and environmental context of the region. There will be a total of 21 stops aboard the M/V Doolin Rodgers.

What's Included: 2.5-hour scenic, geology-focused cruise; light snacks provided on board

What to Bring: Weather-appropriate layers, closed-toed shoes, sun protection, optional binoculars, and any non-alcoholic beverages or snacks.

Where to Go:

- Boarding Location: Foss Waterway Seaport (705 Dock Street, Tacoma, WA 98402); boarding at 2:30, departure at 3:00 sharp
- Dock Access: Use the white gangway from the parking lot. Staff will assist.
- Paid Parking: Foss Waterway Seaport Lot (535 Dock Street) – \$2 per 2 hours (pay by phone)

WS 1: Water Rights, Ecology, and Best Practices – A Day of Hands-On Water Right Analysis with an Ecology Water Master

Thursday, May 14, 2026 | 8:00 AM – 4:00 PM

Has Ecology sent a report back to you completely marked up with unexpected feedback? Did it lead to project delays and changes to the budget?

Spend a day with Kellie Gillingham, one of Ecology's Water Masters, working through multiple exercises to better understand how Ecology staff use their own databases and other public data when permitting decisions. We'll re-familiarize ourselves with Ecology's Water Right and Well Log Datasets, GIS, reading legal descriptions, accessing historic land records, and Ecology's policies and procedures.

Bring your laptop and power supply, this is going to be an interactive day! This also counts as 8 hours of Continuing Education Credits for Certified Water Right Examiners (CWREs).

Instructor:

- Kellie Gillingham, *Department of Ecology*

Cost: \$200

Light breakfast and refreshment breaks provided.

WS 2: Python Applications in Hydrogeology

Thursday, May 14, 2026 | 8:00 AM – 5:00 PM

MODFLOW is a free, open-source, and widely used groundwater modeling program relied upon by government scientists, academic researchers, and private consultants to address complex groundwater flow and transport problems.

The purpose of this workshop is to provide an overview of the latest version of the U.S. Geological Survey MODFLOW program (MODFLOW 6) and demonstrate how models are developed using the Python-based FloPy package. The workshop will combine short lectures of underlying concepts with practical, hands-on exercises to demonstrate modern workflows for constructing, running, and post-processing groundwater models.

Instructor:

- Chris Langevin, Principal Hydrogeologist, *USGS*

Cost: \$200

Light breakfast and refreshment breaks provided.

WS 3: AI Applications with Environmental Data

Thursday, May 14, 2026 | 8:00 AM – 5:00 PM

Artificial Intelligence (AI) and related machine learning (ML) approaches are all the rage these days, with AI tools popping up in everyday life in facets such as web searching, meeting summaries, writing/grammar suggestions, and code development. Environmental work is an evolving area for AI, with significant potential. Given the decades of information from research and application in the environmental science domain, there is a lot of information to draw as a basis for AI tools. This training workshop with PNNL staff will introduce participants to AI/ML concepts and approaches. After an overview, we will look at the span of methods/algorithms, talk about data, get into what prompt engineering is about, and discuss cautions and best practices. Instructors will go through a suite of example applications to illustrate how AI/ML can be used for environmental science. Then participants will have an opportunity to do hands-on investigations of AI tools and approaches (bring your own laptop).

Instructors:

- Anurag Acharya, Research Scientist, *PNNL*
- Xuehang Song, Earth Scientist, *PNNL*
- Anastasia Bernat, Data Scientist, *PNNL*
- Hongfei Hou, Software Engineer, *PNNL*
- Theresa Pham, Data Scientist, *PNNL*
- Jason Hou, Chief Data Scientist, *PNNL*
- Maruti Mudunuru, Earth Scientist, *PNNL*

Cost: \$200

Light breakfast and refreshment breaks provided.

Presenter Index

pages 98-103

PRESENTER INDEX

Name	Email	Title	Session	Page
Aaron Lewis, PE, PG	alewis@ekiconsult.com	Integrated Hydrogeologic Investigations, Groundwater Modeling and Decision Support Tool Development in the Livermore Valley Basin	3B	38-39
Adam Peterson	adam.peterson@agr.wa.gov	Supporting Agricultural Producers in Groundwater Protection: A Suite of Nutrient Management Tools	3B	37
Adel Haj	ahaj@usgs.gov	Methods for modifying the USGS Geospatial Fabric for a regional recharge modeling application, Oregon, USA	4A	26
Adriana Pacheco García	adriana.pachecogarcia@cwu.edu	Tracing Groundwater Movements and Mixing with Stable Isotopes at the Taneum Managed Aquifer Recharge Site	Poster	89-90
Alex Simpson	asimps10@uoregon.edu	Hydrologic State Shifts Across the Volcanic Cascade Range	1A	14
Alexandra Shin	ashi461@ecy.wa.gov	Washington State's Geothermal Energy Collaborative Process	Poster	79
Alysa M. Yoder	ayoder@usgs.gov	Inferring spatial and temporal qualities of groundwater recharge sources using water stable isotopes in the Klamath River Basin, Oregon	6A	46
Amanda Balzer	abalzer@redmond.gov	From Conflict to Collaboration: Safeguarding Redmond's Urban Aquifer	3B	36
Andrew Long	ajlong@usgs.gov	Ensemble methods for parameter estimation and uncertainty quantification for a watershed model	5A	27
Ana-Turi Maher	annamaher@usgs.gov	Evaluating the accuracy of base-flow estimation techniques in catchments across Oregon and Washington	1B	30
Audra Balson, PG	abalson@ecc.net	Yakima Training Center Per- and Polyfluoroalkyl Substances (PFAS) Remedial Investigation Time Critical Removal Actions - Installation of Residential Whole-Home Point-of-Entry-Treatment (POET) Systems, Yakima, WA	8A, Poster	55,87
Ben Lee	blee@landauinc.com	Aquifer Storage and Recovery in Washington State – Is It Working?	3B	40
Ben Scandella	benjamin.p.scandella@water.oregon.gov	Participatory Modeling of Reductions in Pumping to Stabilize Declining Groundwater Levels in the Harney Basin, Oregon	5B	60

PRESENTER INDEX

Blake Lytle-Goldstein	blytlegoldstein@haleyaldrich.com	A New Approach to Deep-Well Infiltration Testing and Design: Case Study in Seattle, WA	1A	13
Brad Bessinger	bbessinger@gsiws.com	Geochemical Controls on Arsenic Attenuation in a Tidal Estuary: Insights from Field Data and Reactive Transport Modeling	5A	41
Brad Bessinger	bbessinger@gsiws.com	Identifying Anthropogenic Contributions to Saline Groundwater Using Sulfate CSIA and Geochemical Inverse Modeling	6A	47
Brett Beaulieu	brett.beaulieu@floydsnider.com	Transitional Zone Monitoring Approaches at Marine and Riverfront Cleanup Sites in the Pacific Northwest	2B	35
Carey Gazis	carey.gazis@cwu.edu	Stable Isotopes as a Tool for Deciphering Hydrogeologic Relationships in the Yakima River Basin	6A	48
Chad Opatz	copatz@usgs.gov	Water Temperature Dynamics in the Quillayute River Basin, Washington, 2021 – 2023	Poster	80
Christian Johnson	cd.johnson@pnnl.gov	Statistical Characterization of Groundwater Composition	2A	19
Christian Johnson	cd.johnson@pnnl.gov	Colloidal Silica Gels for Blocking Vertical Flow in Long-Screened Wells	4B	42
Christopher Konrad	cpkonrad@waterinform.org	Recent Developments in Streamflow Forecasting with the Baseflow Separation Model	3A	24
Collin Marshall	cmarshall@aesgeo.com	Characterizing Subsurface Stratigraphy through Petrographic Analysis, Radiocarbon Dating, and Geochemical Methods, Orting Plateau, East Pierce County, Washington.	Poster	78
Deviyani Gurung	dgurung@anchorqea.com	ARTi3D: A New Software Package for Reactive Transport Modeling	3A	21
Diane Escobedo	diane.escobedo@ecy.wa.gov	PFAS in the Greater Lake Washington Watershed: Assessment of the Groundwater Pathway	8A	56
Elise Wright	eewright@usgs.gov	Groundwater Recharge and Water Budget Assessment for San Juan County, Washington	1A	15
Emily Oberhoffer	eoberhoffer@agr.wa.gov	Sampling results for WSDA's Regional Groundwater Quality Monitoring Program	2A	16
Eugene Freeman	eugene.freeman@ecy.wa.gov	Groundwater, Surface Water, and Precipitation at the Olympic Peninsula	2A	20

PRESENTER INDEX

Frank Winslow	fwin461@ecy.wa.gov	Wood Waste-Related Contamination at VCP Sites in Western Washington	2B	33
Gilbert Barth	gbarth@sspa.com	The Whatcom Groundwater Model: Status and Planned Refinements of the Groundwater/Stream-Depletion Management Tool	3A	23
Grace Weatherford	gweatherford@anchorqea.com	Integrating Site-Specific Geochemistry and Reactive Transport Modeling to Support Post-closure Care Decisions at a Municipal Landfill	5A	44
Greg Byer	gregory.byer@arcadis.com	Integrated Geophysical Characterization of PFAS Transport Pathways in the Columbia River Basalt Group	8A	54
Gustaf Carlson	gcarlson@aesgeo.com	New Hydrostratigraphic Interpretations of a Portion of the Black Diamond Quadrangle	7B	68-69
Hank Johnson	hjohnson@usgs.gov	Late Pleistocene high-volume, regional recharge to the Columbia River Basalt groundwater system of eastern Oregon and Washington	5A	43
Ishita Srivastava	ishita.srivastava@berkeley.edu	AI-Enabled Decision Support for Groundwater–Surface Water Systems to Protect Drinking Water and Reduce Public Health Risk in the Pacific Northwest	8B	71-72
Jackson Mitchell	jnmitchell@usgs.gov	Hydrogeologic framework and groundwater chemistry near the Yakima Training Center, Washington	7B	66
Jacob Carnes	carj461@ecy.wa.gov	PFAS Monitoring in East Selah, Spokane, and the West Plains	Poster	86
Jade Cooley	jade.cooley@co.thurston.wa.us	Climate Model Effects on Stormwater Facility Size Within WWHM	7A	49
Jade Cooley	jade.cooley@co.thurston.wa.us	Which Climate Model Should You Choose? A Brief Guide to Why “It Depends”	7A	50
Jake Peckenpaugh	jakepeckenpaugh@outlook.com	Using complimentary surficial geophysical techniques to assess the effectiveness of channel spanning engineered log jams to increase floodplain connectivity and groundwater storage on the South Fork Nooksack River, Northwest WA	Poster	81
Jeff Dermond	jeff.dermond@ecy.wa.gov	Chasing the Yakima Basin’s “Sixth Reservoir” with Groundwater Storage	5B	58

PRESENTER INDEX

Jessica Rogers	jrogers@sspa.com	The Distributed Drawdown Function: An Analytical Tool for Estimating Effects of Pumping Adjacent to Complex Stream Networks	3A	22
Joe Brascher	brascher@clearcreeksolutions.com	Climate Model Effects on Stormwater Facility Size Within WWHM	7A	53
John Stults	stultsjf@cdmsmith.com	Assessing and Modeling PFASs Leaching to Groundwater Pathway	8A	52-53
Joseph Natale	jnatale@aesgeo.com	Characterizing Bedrock Topography Using Electrical Resistivity Tomography to Constrain Aquifer Geometry for Groundwater Modeling in a Glaciated Puget Lowland Setting	Poster	
Julian Howe	howejuli@cwu.edu	Experiments on the Use of H ₂ O ₂ to Control DBPs in Aquifer Recharge Water	Poster	84
Katherine Muller	katherine.muller@pnnl.gov	Colloidal Silica Gels for Blocking Vertical Flow in Long-Screened Wells	2B	32
Kevin Hansen	kevin.hansen@co.thurston.wa.us	Nisqually Watershed Planning using Large-Scale Surface and Groundwater Modeling	5B	59
Kevin Hansen	kevin.hansen@co.thurston.wa.us	Understanding the Possible Causes of Many Dry Wells Recently Reported Near Lake St. Clair	6B	62
Kristina Hopkins	khopkins@usgs.gov	How urban stormwater systems shape streamflow and water quality in streams in King County, Washington	5B	57
Lam Nguyen	languyen@aesgeo.com	Analysis of the Pilot Infiltration Test Method and Correlation between the Saturated Hydraulic Conductivity and Grain-Size Distribution of Normally and Glacially Consolidated Sediments in Western Washington	Poster	77
Lee Florea	lee.florea@dnr.wa.gov	Cosmogenic Isotopes of Halogens in the Cascades of Washington	6A	45
Lee Florea	lee.florea@dnr.wa.gov	Groundwater chemistry in the Columbia River Basalt Group aquifer	5A	42
Leland Fuhrig	lfuhrig@usgs.gov	An Evaluation and Update of Guemes Island Groundwater Conditions	Poster	91
Luke Mioduszewski	lukem@aesgeo.com	Integrating Field Testing, Groundwater Flow Modeling, and Nitrate Tracer Evidence to Inform Indirect Groundwater Recharge Design	2A	17-18
Mackenzie Mills	mmills@usgs.gov	A Hydrogeologic Model of the Duwamish River Valley utilizing Leapfrog Works	7B	67

PRESENTER INDEX

Maggie Egan	maggie.egan@cwu.edu	The Geomorphology and Hydrology of Pre-Restoration West Fork Teanaway River, Kittitas County, WA	Poster	82
Malia Scott	mhscott@usgs.gov	Water use data and science in the USGS: from national-scale modeling to regional Puget Sound water use estimates	6B	61
Matthew Barker	mbarker@usgs.gov	An introduction to NHM-Assist: A tool for visualizing and evaluating the USGS National Hydrologic Model	4A	25
Mike Mazzaresse	mmazzaresse@astenv.com	Design Considerations and Implementation Techniques for In Situ Applications of Modified Clay for PFAS Sequestration	1B	31
Millen Singh	millensingh529@gmail.com	Microplastics (MP) in Drinking Water Linked with Colorectal Cancer Across Urban-Rural Counties of Maryland	Poster	88
Nicholas Sutfin	nsutfin@usgs.gov	Post-wildfire impacts to water supply in Washington state	6B	65
Rebecka Iveson	rebecka.iveson@pnnl.gov	Large Language Model (LLM)-Assisted Access to Subsurface and Contamination Information	8B	75-76
Sam Dossa	sam.dossa@cwu.edu	Spring Revival: Quantifying Managed Aquifer Recharge on the Toppenish Alluvial Fan Using Stratigraphy and Hydrochemistry	Poster	83
Sarah Dunn	sdunn@usgs.gov	Storm drain StreamStats: Integrating stormwater infrastructure into web-based watershed delineation tool	5A	85
Sarah Faubion, GIT	sfaubion@aesgeo.com	Field Methodology for Monitoring Surface Water and Groundwater Interactions in Agricultural Settings	1B	29
Sarah Weeks	sweeks@landauinc.com	Open-Loop Ground Source Heat Pumps – Hydrogeology and Modeling	7A	51
Scott Kindred	scottk@kindredhydro.com	Evaluating the hydrologic impacts of site development requires an accurate understanding of both surface and subsurface conditions	1B	28
Stephen Gingerich	sbginger@usgs.gov	Evaluating and Updating Groundwater-Recharge Estimates for Oregon Basins	6B	63-64
Steve Graham	stevegraham@dccnet.com	Groundwater-Induced Slope Instability on the Tsawwassen Peninsula	1A	12
Xuehang Song	xuehang.song@pnnl.gov	Groundwater-Level Mapping and Monitoring Network Evaluation Using Diffusion Models	8B	73-74

PRESENTER INDEX

Xuehang Song	xuehang.song@pnnl.gov	When 2D Is Not Enough: Three-Dimensional and Boundary-Condition Controls on Groundwater Flooding and Salinity in Diked Coastal Lowlands	2B	34
Zeli Tan	zeli.tan@pnnl.gov	Leverage data assimilation and machine learning to improve the forecast of reservoir water temperature and thermal release	8B	70

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