The Institute for Water & Watersheds Annual Technical Report FY 2012

Introduction

Oregonians are witnessing the difficulties caused by water limitations. Water quantity and quality issues in the Willamette, Klamath, and Umatilla Basins are the Governor's top environmental and water allocation priorities. This situation is paralleled around the world, and points toward a strong emerging area for growth in research, education, and outreach. These challenges are particularly relevant given that Oregon just finished its first statewide Integrated Water Resources Strategy.
http://www.oregon.gov/OWRD/LAW/Integrated_Water_Supply_Strategy.shtml

Oregon State University is ideally positioned to assume a leadership role in addressing water problems, with about 125 faculty in six colleges who teach and conduct research in areas related to water and watersheds. OSU is renowned for its landscape-scale ecosystems research and continues to grow new graduate degree programs in Water Resources. These research and education efforts have all occurred without the benefit of programmatic coordination or strategic vision.

Oregon's Water Institute, called the **Institute for Water and Watersheds (IWW)**, coordinates transdisciplinary research, education, and technology transfer on issues related to water and environmental sustainability. The IWW assists faculty within the Oregon University System (OUS) to provide outreach and research related to water resources issues on an "as-requested" basis. Partners and constituents include educational institutions, state and local governments, watershed councils, and the general public. The new model for IWW is to support small grants to students, as well as outreach, as opposed to the historic approach of providing "mini-grant"s to faculty.

The IWW is involved in promoting the effective and sustainable use of water resources in the State of Oregon. IWW serves as a hub for water resources activities, for example:

- IWW is part of OSU's **Water Resources Graduate Program**.
- IWW is part of OSU's **Natural Resources Leadership Academy**.
- IWW staff serve as **expert "volunteers"** to state agency advisory committees, county water committees, and local watershed councils.
- IWW initiates and coordinates **transdisciplinary water resource research projects** through the USGS water institutes program by funding seed grants to graduate students on critical water issues for the state.
- IWW co-sponsors a regional water resources seminar each spring term on topics such as drinking water, stream restoration, water quality, and water conflict. Speakers from Oregon, the United States, and abroad participate in the program which has a different focus topic each year.
- Staff at IWW assist faculty at the state's institutions of higher education in research and outreach efforts related to its mission.

Staff resources have been reduced to part-time status with the continued downturn nation's economy. While the budget reductions have forced some re-defining of priorities within the IWW, it remains **committed to the NIWR mission** and providing research, education and outreach in water for the residents of Oregon. In many ways, these reductions have helped sharpen our knowledge of what is most critical in this regard and we are pursuing this with increased intensity with our world-class faculty in water within the Oregon higher educational system.

Research Program Introduction

At Oregon State University, over **125 faculty teach and conduct research** in areas related to fresh water supply and quality. These faculty members are spread among **six colleges** and represent many different academic disciplines – including engineering, ecology, geosciences, social sciences, economics and the arts. OSU also hosts a vibrant Water Resource Graduate Program where students can earn specialized degrees in water resources engineering, science, and policy and management. Students and professionals desiring advanced training in water conflict transformation and natural resources negotiations participate in the two-week intensive training during the summer months in the Natural Resources Leadership Academy, now in the second year of operation.

The IWW is the hub for this diverse water research community. It seeks to solve complex water issues by facilitating integrative water research. The IWW's functions are to:

- Assemble diverse research teams and lead interdisciplinary and transdisciplinary water research projects.
- Help policy makers and water managers collaborate with university faculty and students.
- Offer training and access to water quality and stable isotope analysis facilities through a shared laboratory called the IWW Collaboratory.
- Encourage community and collaboration among water faculty, students and water managers by sponsoring events and producing a weekly campus water newsletter **H2OSU News**.
- Assist water faculty with project development and management.

Why Focus on Water?

Oregon's economic vitality is directly tied to water. Water is "virtually" embedded in all Oregon products, from timber and salmon to solar panels and semiconductors. But water supply and demand in the state is changing. There is now less snowpack in mountain regions and the snow is melting earlier in the spring and summer. These changes have implications for irrigation, human consumption, hydropower generation and ecosystems. Shifting population, land use patterns and environmental policies will also influence the future supply and demand for abundant clean water. And the state of Oregon just finished developing an **Integrated Water Resources Strategy** to prepare for climate change and the wave of anticipated "climate change refugees" from drier and hotter regions of the United States.

In the academic community there is growing recognition that the solutions to future water challenges lie not within a single discipline or subject but through **transdisciplinarity** the connection of concepts between multiple academic fields and through successful collaboration between academics and water managers. For example, anticipating the effect of climate change on Oregon's water resources requires not just the input of climatologists and hydrologists but also the perspective of many others from biologists and sociologists to water managers and policy experts.

Through an integrative research approach, the IWW seeks answers to questions important for Oregon, the nation and the world, such as:

- Where are climate change and human activity most likely to create conditions of water scarcity?

- Where is water scarcity most likely to exert the greatest impact on ecosystems and communities?

- What strategies would allow communities to prevent, mitigate, or adapt to scarcity most successfully?

The campus also hosts strong graduate degree programs in Water Resources and is located near state-of-the-art experimental watersheds and a suite of federal environmental laboratories. Below are short descriptions of some of the university's strengths in the areas of:

- water science
- water engineering
- water policy and management
- water outreach and community education

Water Science

The OSU community has one of the largest gatherings of hydrologists and ecologists in the USA. They include not only campus faculty but also courtesy faculty from the suite of federal research laboratories located adjacent to campus. This combination makes for a world-class grouping of people, mapped against one of the strongest hydrological gradients (from the super-humid Oregon Coast to arid Eastern Oregon) in the world. The campus is known for its transdisciplinary collaborations -- for example faculty from the top-ranked forestry and conservation biology programs collaborating on salmon conservation studies. Many researchers take advantage of nearby field laboratories such as the NSF Long Term Ecological Research (LTER) facilities at the HJ Andrews Experimental Forest and industry timberland instrumented watersheds in the Oregon Coast range (Hinkle Creek, Alsea and Trask).

Faculty from Oregon State University, the University of Oregon and Portland State University completed the second year of work on a five-year project funded by the National Science Foundation titled **"Willamette Water 2100,"** a study that will use Oregon's Willamette River basin as a test case for managing regional water supply. This project is evaluating how climate change, population growth, and economic growth will alter the availability and the use of water in the Willamette River Basin on a decadal to centennial timescale.

Water Engineering

Unlike other land-grant institutions, OSU's engineering connection gives it strengths in treatment technologies for surface water, groundwater, wastewater systems, and humanitarian engineering. OSU Engineering now ranks in the top 50 programs in the US. Many OSU engineers specialize in biological treatment methods and emphasizes interdisciplinary research on soil and groundwater microbial ecology. Many engineering faculty are also connected to the Oregon Built Environment & Sustainable Technologies Center (Oregon BEST) that connects the state's businesses with its shared network of university labs to transform green building and renewable energy research. Partnering with the OSU College of Business places a “business face” on the sustainability of engineered solutions to water problems. Before graduating, many engineering students enroll in coursework leading to a business savvy Entrepreneurship Minor. A **Humanitarian Engineering** initiative is also under development for water, wastewater, and energy given the international focus of many faculty on campus.

Water Policy And Management

Addressing water resource challenges and reducing conflict in the US and abroad requires that water professionals and decision-makers receive specialized resources and skills that go beyond the traditional physical systems approach to water resources management. OSU offers a post-graduate certificate as part of their **Program in Water Conflict Management and Transformation**. The program leverages personnel from the top-10 nationally-ranked Geosciences Department, the top-five nationally ranked College of Forestry, as well as specialists in water policy, social science, communication, and anthropology. The "softer side" of OSU water has close links with UNESCO, the World Bank, the US Bureau of Reclamation and the US Army Corps of Engineers.

Information Transfer Program Introduction

OSU’s reputation for providing vital environmental information to students and the public is beyond reproach. A few of OSU's water-related outreach programs include:

- **The Master Watershed Steward Program** - An OSU Extension program offering educational sessions and materials to help watershed groups and individuals understand how their watersheds work and apply this knowledge to watershed stewardship on their own land or in their community.
- **The Oregon Well Water Program** – A joint IWW-Extension program designed to help Oregonians protect the groundwater that supplies their drinking water through education.
- **The Hydroville Curriculum Project** - A program proving water-themed educational materials and exercises to K-12 teachers. It is operated by OSU's Environmental Health Sciences Center.
- **The Oregon Explorer Progam** - An online digital library that provides natural resources information to decision makers through a growing series of Web portals.

Acknowledging that academics need to communicate research in different ways with policymakers, IWW has experimented with new ways to diversify our outputs. Gone are the days of simply sending academic journal articles to policy makers and staff. IWW now completes what is termed “just-in-time” white papers or short You-Tube videos on topics of interest. For example, white papers have been developed on the notion of water markets in Oregon, bottled water in Oregon, the importance of water to the multi-billion dollar per year Oregon wine industry, and climate change and Oregon water. Videos on water sustainability and greywater reuse in Oregon, biochar derived from forest products for treatment of Oregon stormwater, and community management of deep groundwater in northeastern Oregon are readily available for review. New projects will focus on arsenic in groundwater in eastern Oregon using funds bequeathed to the Institute for Water and Watersheds.

- **White Paper - Bottled Water in Oregon**
- **White Paper - Wine and Water in Oregon** (prepared in partnership with the Institute for Natural Resources)
- **White Paper - Water and Climate in the Pacific Northwest** (prepared in partnership with Oregon Climate Change Research Institute)
- **White Paper - Cyanobacterial Harmful Algae Blooms (CHABs) in Oregon** (prepared in partnership with Department of Fish and Wildlife)
- **Video on Water Sustainability and the Three Waters Program in Corvallis** http://www.youtube.com/watch?v=dMgCxrg8ado&feature=youtu.be
- **Video on Biochar Research at OSU** http://www.youtube.com/watch?v=Sd5cGox0D2Y
- **Voices of the Basin** a video summary on the 4th Annual Symposium on Columbia River Governance http://media.oregonstate.edu/media/Voices+of+the+Basin.m4v/1_odh0vk95

Other Collaborative Activities

- IWW assists in updating **AquaPedia**, the Water Diplomacy Case Study Database after IWW Interim Director Todd Jarvis participates in the Water Diplomacy Workshop at Tufts University http://aquapedia.waterdiplomacy.org/wiki/index.php?title=Main_Page

- IWW sponsors the student organization “Hydrophiles” Fall White Water Rafting Trip on the Deschutes River.

- IWW sponsors three graduate students and one undergraduate student to participate in the **4th Annual Symposium on Columbia River Governance** sponsored by Universities Consortium on Columbia River Governance held at the KwaTaqNuk Resort in Polson, Montana - http://www.columbiarivergovernance.org/4thAnnualSymposium.html

- IWW continues to be a co-sponsor of the Water Resources Graduate Program Spring Seminar series

- IWW sponsors the annual 2013 New Water Year Celebration with over 100 attendees.

- IWW sponsors an undergraduate student intern in the **Increasing Diversity in the Earth Sciences (IDES)** program to make a documentary video on water scarcity in Oregon

IWW and other Scholars who have shared information and datasets related to water resources research:

- IWW Interim Director Todd Jarvis serves as invited keynote speaker for the Spokane River Forum **Exploring the Interface Between Research, Management and Policy: Knowledge Entrepreneurialism to Knowledge Journalism**, Spokane, WA

- IWW Interim Director Todd Jarvis was an invited speaker at the UNESCO-FAO-GEF Regional Groundwater Governance Consultation **New Instruments and Niche-Diplomacy in Groundwater Governance**, The Hague, NL

- IWW Interim Director Todd Jarvis was an invited panelist at the Oregon Soil Science Society **She Flies With Her Own Wings: The Oregon Way Of Pursuing the Nation's Largest Critical Zone Observatory**, Troutdale, OR

- IWW Interim Director Todd Jarvis was an invited speaker for the UEA Water Security and ICID seminar What colour is your water? A critical review of blue, green and other 'waters' in London, England, where he presented **Social Media and the Colours of Water: The Rainbow Water Coalition** http://www.youtube.com/watch?v=xboMsjKlSro&feature=player_embedded

- IWW Interim Director Todd Jarvis was an invited panelist at the Olive Tree Initiative where he presented In Search of a New Identity? - **Good Water Neighbors, Deep Drilling Frontiers, and the Rehabilitation of the Lower Jordan** River for Groundwater and Climate Change in the Middle East: Next threat or opportunity for cooperation? University of California, Irvine, CA

- IWW Interim Director Todd Jarvis was an invited instructor for the annual PNWS-AWWA Water Works School **Finding Water the Ol' Timey Way: The Geography, History and Science of Water Witching**, Clackamas Community College, OR

- IWW Interim Director Todd Jarvis remains a regular guest lecturer for the Water Resources Graduate Program and Geography, Environmental Sciences, and Marine Resource Management Seminars - **Swimming the Hydro-Trifecta: Negotiations through the lens of Water Security, Water Conflict**

Transformation, and Water Diplomacy, Oregon State University

- IWW Interim Director Todd Jarvis presents on conflicts associated with well drilling in developing countries applications to **Engineers without Borders**, Oregon State University chapter.
- IWW Interim Director Todd Jarvis invited by UNESCO Amman to instruct a workshop on **Negotiations in Water Security and Water Diplomacy** for Jordanian, Iraqi, and Palestinian engineers at the Dead Sea, Jordan
- IWW Interim Director Todd Jarvis invited by UNESCO Africa to instruct a workshop on **Promoting Cooperation and Conflict Prevention in Transboundary Water Resources** for water ministers, engineers, hydrogeologists from the Southern Africa Development Community in Gaborone, Botswana

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2012OR125B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Oregon 5th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Management and Planning, Law, Institutions, and Policy, None
Descriptors:	
Principal Investigators:	Todd Jarvis, Todd Jarvis

Publications

1. **2013 Publications**

- Adame MF, Kauffman BJ, Medina I, Gamboa JN, Torres O, Caamal JP, Reza M, Herrera-Silveira JA. 2013. Carbon Stocks of Tropical Coastal Wetlands within the Karstic Landscape of the Mexican Caribbean. PLoS ONE. 8(2):e56569.
- Argerich A, Johnson SL, Sebestyen SD, Rhoades CC, Greathouse E, Knoepp JD, Adams MB, Likens GE, Campbell JL, McDowell WH et al.. 2013. Trends in stream nitrogen concentrations for forested reference catchments across the USA. Environmental Research Letters. 8(1):014039.
- Arismendi I, Johnson SL, Dunham JB, Haggerty R. 2013. Descriptors of natural thermal regimes in streams and their responsiveness to change in the Pacific Northwest of North America. Freshwater Biology. 58(5):880-894.
- Babbar-Sebens M, Barr RC, Tedesco LP, Anderson M. 2013. Spatial identification and optimization of upland wetlands in agricultural watersheds. Ecological Engineering. 52:130-142.
- Bogan MT, Boersma KS, Lytle DA. 2013. Flow intermittency alters longitudinal patterns of invertebrate diversity and assemblage composition in an arid-land stream network. Freshwater Biology. 58(5):1016-1028.
- Briggs MA, Lautz LK, Hare DK, González-Pinzón R. 2013. Relating hyporheic fluxes, residence times, and redox-sensitive biogeochemical processes upstream of beaver dams. Freshwater Science. 32(2):622-641.
- Campana ME, Vener BB, Lee BS. 2013. Hydrostrategy, Hydropolitics, and Security in the Kura-Araks Basin of the South Caucasus. Journal of Contemporary Water Research & Education. 149(1):22-32.
- Cobb BR, Sharp KV. 2013. Impulse (Turgo and Pelton) turbine performance characteristics and their impact on pico-hydro installations. Renewable Energy. 50:959-964.
- Curtis LR, Morgans DL, Thoms B, Villenueve D. 2013. Extreme precipitation appears a key driver of mercury transport from the watershed to Cottage Grove Reservoir, Oregon. Environmental Pollution. 176:178-184.
- Dickson JL, Head JW, Levy JS, Marchant DR. 2013. Don Juan Pond, Antarctica: Near-surface CaCl2-brine feeding Earth's most saline lake and implications for Mars. Scientific Reports. 3

- Evans W, Hales B, Strutton PG. 2013. pCO2 distributions and air–water CO2 fluxes in the Columbia River estuary.

  Estuarine, Coastal and Shelf Science. 117:260-272.
- Galipeau BA, Ingman M, Tilt B. 2013. Dam-Induced Displacement and Agricultural Livelihoods in China's Mekong Basin. Human Ecology.
- Gooseff MN, Barrett JE, Levy JS. 2013. Shallow groundwater systems in a polar desert, McMurdo Dry Valleys, Antarctica. Hydrogeology Journal. 21(1):171-183.
- Haggard KG, Geiger SN, Hayes PM, Milligan AJ. 2013. Suppression of cyanobacterial growth of Aphanizomenon flos-aquae by vascular plant decomposition products in Upper Klamath Lake, Oregon. Lake and Reservoir Management. 29(1):13-22.
- Hart SK, Hibbs DE, Perakis SS. 2013. Riparian litter inputs to streams in the central Oregon Coast Range. Freshwater Science. 32(1):343-358.
- Hughes J, Krebs EJ, Roundy D. 2013. A classical density-functional theory for describing water interfaces. The Journal of Chemical Physics. 138(2):024509.
- Johnson PTJ, Hoverman JT, McKenzie VJ, Blaustein AR, Richgels KLD. 2013. Urbanization and wetland communities: applying metacommunity theory to understand the local and landscape effects. Journal of Applied Ecology. 50(1):34-42.
- Leon AS, Gifford-Miears C, Choi Y. 2013. Well-Balanced Scheme for Modeling Open-Channel and Surcharged Flows in Steep-Slope Closed Conduit Systems. Journal of Hydraulic Engineering. 139(4):374-384.
- Leon AS, Kanashiro EA, González-Castro JA. 2013. Fast Approach for Unsteady Flow Routing in Complex River Networks Based on Performance Graphs. Journal of Hydraulic Engineering. 139(3):284-295.
- Ligeiro R, Hughes RM, Kaufmann PR, Macedo DR, Firmiano KR, Ferreira WR, Oliveira D, Melo AS, Callisto M. 2013. Defining quantitative stream disturbance gradients and the additive role of habitat variation to explain macroinvertebrate taxa richness. Ecological Indicators. 25:45-57.
- Marr SM, Olden JD, Leprieur F, Arismendi I, Ćaleta M, Morgan DL, Nocita A, ¦anda R, Serhan Tarkan A, García-Berthou E. 2013. A global assessment of freshwater fish introductions in mediterranean-climate regions. Hydrobiologia.
- Peszynska M, Trykozko A. 2013. Pore-to-core simulations of flow with large velocities using continuum models and imaging data. Computational Geosciences.
- Petersen-Perlman JD, Veilleux JC, Zentner M, Wolf AT. 2013. Case Studies on Water Security: Analysis of System Complexity and the Role of Institutions. Journal of Contemporary Water Research & Education. 149(1):4-12.
- Pisani O, Oros DR, Oyo-Ita OE, Ekpo BO, Jaffé R, Simoneit BRT. 2013. Biomarkers in surface sediments from the Cross River and estuary system, SE Nigeria: Assessment of organic matter sources of natural and anthropogenic origins. Applied Geochemistry. 31:239-250.
- Roselli L, Cañedo-Argüelles M, Costa Goela P, Cristina S, Rieradevall M, D'Adamo R, Newton A. 2013. Do physiography and hydrology determine the physico-chemical properties and trophic status of coastal lagoons? A comparative approach Estuarine, Coastal and Shelf Science. 117:29-36.
- Safeeq M. 2013. Coupling snowpack and groundwater dynamics to interpret historical streamflow trends in the western United States. Hydrological Processes. 27(5):655-668.
- Salzmann N, Huggel C, Rohrer M, Silverio W, Mark BG, Burns P, Portocarrero C. 2013. Glacier changes and climate trends derived from multiple sources in the data scarce Cordillera Vilcanota region, southern Peruvian Andes. The Cryosphere. 7(1):103-118.
- Surfleet CG, Tullos D. 2013. Variability in effect of climate change on rain-on-snow peak flow events in a temperate climate. Journal of Hydrology. 479:24-34.

- Vaz PG, Warren DR, Merten EC, Robinson CT, Pinto P, Rego FC. 2013. Effects of forest type and stream size on volume and distribution of stream wood: legacies of wildfire in a Euro-Mediterranean context. Freshwater Science. 32(1):126-141.

2. **2012 Publications**

- Akay AE, Wing MG, Sessions J. 2012. Estimating structural properties of riparian forests with airborne lidar data. International Journal of Remote Sensing. 33(22):7010-7023.
- Ali G, Tetzlaff D, Soulsby C, McDonnell JJ, Capell R. 2012. A comparison of similarity indices for catchment classification using a cross-regional dataset. Advances in Water Resources. 40:11-22.
- Ali G, Tetzlaff D, Soulsby C, McDonnell JJ. 2012. Topographic, pedologic and climatic interactions influencing streamflow generation at multiple catchment scales. Hydrological Processes. 26(25):3858-3874.
- Anthony SE, Prahl FG, Peterson TD. 2012. Methane dynamics in the Willamette River, Oregon. Limnology and Oceanography. 57(5):1517-1530.
- Arismendi I, Johnson SL, Dunham JB, Haggerty R, Hockman-Wert D. 2012. The paradox of cooling streams in a warming world: Regional climate trends do not parallel variable local trends in stream temperature in the Pacific continental United States. Geophysical Research Letters. 39(10)
- Arismendi I, Safeeq M, Johnson SL, Dunham JB, Haggerty R. 2012. Increasing synchrony of high temperature and low flow in western North American streams: double trouble for coldwater biota? Hydrobiologia.
- Armstrong RT, Porter ML, Wildenschild D. 2012. Linking pore-scale interfacial curvature to column-scale capillary pressure. Advances in Water Resources. 46:55-62.
- Armstrong, RT, Wildenschild D. 2012. Microbial Enhanced Oil Recovery in Fractional-Wet Systems: A Pore-Scale Investigation. Transport in Porous Media. 92(3):819-835.
- Beschta RL, Ripple WJ. 2012. The role of large predators in maintaining riparian plant communities and river morphology. Geomorphology. 157-158:88-98.
- Bogan MT, Boersma KS. 2012. Aerial dispersal of aquatic invertebrates along and away from arid-land streams. Freshwater Science. 31(4):1131-1144.
- Boston K. 2012. Impact of the Ninth Circuit Court Ruling (Northwest Environmental Defense Center v. Brown) Regarding Forest Roads and the Clean Water Act. Journal of Forestry. 110(6):344-346.
- Brewer AJ, Ort C, Banta-Green CJ, Berset J-D, Field JA. 2012. Normalized Diurnal and Between-Day Trends in Illicit and Legal Drug Loads that Account for Changes in Population. Environmental Science & Technology. 46(15):8305-8314.
- Brooks RJ, Wigington PJ, Phillips DL, Comeleo R, Coulombe R. 2012. Willamette River Basin surface water isoscape (18 O and 2 H): temporal changes of source water within the river. Ecosphere. 3(5):art39.
- Chen X-zhi, Chen S-sen, Zhong R-fei, Su Y-xian, Liao J-shan, Li D, Han L-sheng, Li Y, Li X. 2012. A semi-empirical inversion model for assessing surface soil moisture using AMSR-E brightness temperatures. Journal of Hydrology. 456-457:1-11.
- Christie MR, Marine ML, French RA, Blouin MS. 2012. Genetic adaptation to captivity can occur in a single generation. Proceedings of the National Academy of Sciences. 109(1):238-242.
- Christie MR, Marine ML, French RA, Waples RS, Blouin MS. 2012. Effective size of a wild salmonid population is greatly reduced by hatchery supplementation. Heredity. 109(4):254-260.
- Clark PU. 2012. Ice Sheets in Transition. Science. 337(6095):656-658.
- Connon RE, D’Abronzo LS, Hostetter NJ, Javidmehr A, Roby DD, Evans AF, Loge FJ, Werner I. 2012. Transcription Profiling in Environmental Diagnostics: Health Assessments in Columbia River Basin Steelhead (Oncorhynchus mykiss). Environmental Science &

Technology. :120522085146009.
- Crespo P, Bücker A, Feyen J, Vaché KB, Frede H-G, Breuer L. 2012. Preliminary evaluation of the runoff processes in a remote montane cloud forest basin using Mixing Model Analysis and Mean Transit Time. Hydrological Processes. 26(25):3896-3910.
- Czarnomski NM, Tullos DD, Thomas RE, Simon A. 2012. Effects of Vegetation Canopy Density and Bank Angle on Near-Bank Patterns of Turbulence and Reynolds Stresses. Journal of Hydraulic Engineering. 138(11):974-978.
- de Jonge LW, Moldrup P, Vendelboe AL, Tuller M, Wildenschild D. 2012. Soil Architecture and Physicochemical Functions: An Introduction. Vadose Zone Journal. 11(1)
- Evans AF, Hostetter NJ, Roby DD, Collis K, Lyons DE, Sandford BP, Ledgerwood RD, Sebring S. 2012. Systemwide Evaluation of Avian Predation on Juvenile Salmonids from the Columbia River Based on Recoveries of Passive Integrated Transponder Tags. Transactions of the American Fisheries Society. 141(4):975-989.
- Evans-Peters GR, Dugger BD, Petrie MJ. 2012. Plant Community Composition and Waterfowl Food Production on Wetland Reserve Program Easements Compared to Those on Managed Public Lands in Western Oregon and Washington. Wetlands. 32(2):391-399.
- Falke JA, Bailey LL, Fausch KD, Bestgen KR. 2012. Colonization and extinction in dynamic habitats: an occupancy approach for a Great Plains stream fish assemblage. Ecology. 93(4):858-867.
- Faulkner BR, Renée Brooks J, Forshay KJ, Cline SP. 2012. Hyporheic flow patterns in relation to large river floodplain attributes. Journal of Hydrology. 448-449:161-173.
- Flitcroft RL, Burnett KM, Reeves GH, Ganio LM. 2012. Do network relationships matter? Comparing network and instream habitat variables to explain densities of juvenile coho salmon (Oncorhynchus kisutch) in mid-coastal Oregon, USA Aquatic Conservation: Marine and Freshwater Ecosystems. 22(3):288-302.
- Gabrielli, C., J.J. McDonnell and Jarvis, WT. 2012. The role of bedrock groundwater in rainfall-runoff response at hillslope and catchment scales. Journal of Hydrology, volume 450–451, p. 117–133.
- Gallaway E, Trenhaile Alans, Cioppa MT, Hatfield RG. 2012. Magnetic mineral transport and sorting in the swash-zone: northern Lake Erie, Canada. Sedimentology. 59(6):1718-1734.
- Gao Y, Noakes DLG. 2012. Chemical signatures of otoliths and application in fisheries. Environmental Biology of Fishes. 95(4):415-418.
- González-Pinzón R, Haggerty R, Myrold DD. 2012. Measuring aerobic respiration in stream ecosystems using the resazurin-resorufin system. Journal of Geophysical Research. 117
- Green HC, Field KG. 2012. Sensitive detection of sample interference in environmental qPCR. Water Research. 46(10):3251-3260.
- Hacke UG, Jacobsen AL, Brandon Pratt R, Maurel C, Lachenbruch B, Zwiazek J. 2012. New research on plant-water relations examines the molecular, structural, and physiological mechanisms of plant responses to their environment. New Phytologist. 196(2):345-348.
- Hallett SL, Ray RA, Hurst CN, Holt RA, Buckles GR, Atkinson SD, Bartholomew JL. 2012. Density of the Waterborne Parasite Ceratomyxa shasta and Its Biological Effects on Salmon. Applied and Environmental Microbiology. 78(10):3724-3731.
- Hanshew Bretta, Garcia Tiffanys. 2012. Invasion of the shelter snatchers: behavioural plasticity in invasive red swamp crayfish, Procambarus clarkii. Freshwater Biology. 57(11):2285-2296.
- Held IM, Shell KM. 2012. Using Relative Humidity as a State Variable in Climate Feedback Analysis. Journal of Climate. 25(8):2578-2582.
- Hibbard M, Lurie S. 2012. Creating socio-economic measures for community-based natural resource management: a case from watershed stewardship organisations. Journal of Environmental Planning and Management. 55(4):525-544.

- Hoffman JS, Carlson AE, Winsor K, Klinkhammer GP, LeGrande AN, Andrews JT, Strasser JC. 2012. Linking the 8.2 ka event and its freshwater forcing in the Labrador Sea. Geophysical Research Letters. 39(18)
- Hughes RM, Herlihy AT, Gerth WJ, Pan Y. 2012. Estimating vertebrate, benthic macroinvertebrate, and diatom taxa richness in raftable Pacific Northwest rivers for bioassessment purposes. Environmental Monitoring and Assessment. 184(5):3185-3198.
- Hughes RM, Herlihy AT. 2012. Patterns in Catch Per Unit Effort of Native Prey Fish and Alien Piscivorous Fish in 7 Pacific Northwest USA Rivers. Fisheries. 37(5):201-211.
- Imbach P, Molina L, Locatelli B, Roupsard O, Mahé G, Neilson R, Corrales L, Scholze M, Ciais P. 2012. Modeling Potential Equilibrium States of Vegetation and Terrestrial Water Cycle of Mesoamerica under Climate Change Scenarios*. Journal of Hydrometeorology. 13(2):665-680.
- Izagirre O, Argerich A, Martí E, Elosegi A. 2012. Nutrient uptake in a stream affected by hydropower plants: comparison between stream channels and diversion canals. Hydrobiologia.
- Jackson TR, Haggerty R, Apte SV, Coleman A, Drost KJ. 2012. Defining and measuring the mean residence time of lateral surface transient storage zones in small streams. Water Resources Research. 48(10)
- Janisch JE, Wondzell SM, Ehinger WJ. 2012. Headwater stream temperature: Interpreting response after logging, with and without riparian buffers, Washington, USA. Forest Ecology and Management. 270:302-313.
- Jarvis WT. 2012. Book Review: Water Diplomacy: A Negotiated Approach to Managing Complex Water Networks. Ground Water. 50(6):825-825.
- Jarvis, WT and Stebbins, A. 2012. Examining Exempt Wells: Care for exempt wells provides opportunities for the water well industry, Water Well Journal, Sept. 2012, http://waterwelljournal.org/2012/09/examining-exempt-wells/
- Jones JA, Creed IF, Hatcher KL, Warren RJ, Adams MB, Benson MH, Boose E, Brown WA, Campbell JL, Covich A et al.. 2012. Ecosystem Processes and Human Influences Regulate Streamflow Response to Climate Change at Long-Term Ecological Research Sites. BioScience. 62(4):390-404.
- Kelsey EP, Wake CP, Yalcin K, Kreutz K. 2012. Eclipse Ice Core Accumulation and Stable Isotope Variability as an Indicator of North Pacific Climate. Journal of Climate. 25(18):6426-6440.
- Kizito F, Dragila MI, Senè M, Brooks JR, Meinzer FC, Diedhiou I, Diouf M, Lufafa A, Dick RP, Selker J et al.. 2012. Hydraulic redistribution by two semi-arid shrub species: Implications for Sahelian agro-ecosystems. Journal of Arid Environments. 83:69-77.
- Kratzer JF, Warren DR. 2012. How much temporal replication do we need to estimate salmonid abundance in streams? Fisheries Management and Ecology. 19(5):441-443.
- Kulkarni R, Tuller M, Fink W, Wildenschild D. 2012. Three-Dimensional Multiphase Segmentation of X-Ray CT Data of Porous Materials Using a Bayesian Markov Random Field Framework. Vadose Zone Journal. 11(1)
- Lancaster ST, Nolin AW, Copeland EA, Grant GE. 2012. Periglacial debris-flow initiation and susceptibility and glacier recession from imagery, airborne LiDAR, and ground-based mapping. Geosphere. 8(2):417-430.
- Langpap C, Kerkvliet J. 2012. Endangered species conservation on private land: Assessing the effectiveness of habitat conservation plans. Journal of Environmental Economics and Management. 64(1):1-15.
- Lanni C, McDonnell J, Hopp L, Rigon R. 2012. Simulated effect of soil depth and bedrock topography on near-surface hydrologic response and slope stability. Earth Surface Processes and Landforms. 38(2):146-159.

- Laudon H, Buttle J, Carey SK, McDonnell J, McGuire K, Seibert J, Shanley J, Soulsby C, Tetzlaff D. 2012. Cross-regional prediction of long-term trajectory of stream water DOC response to climate change. Geophysical Research Letters. 39(18)
- Leblanc CA, Noakes DL. 2012. Visible Implant Elastomer (VIE) Tags for Marking Small Rainbow Trout. North American Journal of Fisheries Management. 32(4):716-719.
- Levy J. 2012. Hydrological characteristics of recurrent slope lineae on Mars: Evidence for liquid flow through regolith and comparisons with Antarctic terrestrial analogs. Icarus. 219(1):1-4.
- Liu Z, Thorpe SA, Smyth WD. 2012. Instability and hydraulics of turbulent stratified shear flows. Journal of Fluid Mechanics. 695:235-256.
- Matzke MM, Allan SE, Anderson KA, Waters KM. 2012. An approach for calculating a confidence interval from a single aquatic sample for monitoring hydrophobic organic contaminants. Environmental Toxicology and Chemistry. 31(12):2888-2892.
- Maynard JJ, Dahlgren RA, O'Geen AT. 2012. Quantifying spatial variability and biogeochemical controls of ecosystem metabolism in a eutrophic flow-through wetland. Ecological Engineering. 47:221-236.
- McMullen LE, Lytle DA. 2012. Quantifying invertebrate resistance to floods: a global-scale meta-analysis. Ecological Applications. 22(8)
- Mueller-Warrant GW, Griffith SM, Whittaker GW, Banowetz GM, Pfender WF, Garcia TS, Giannico GR. 2012. Impact of land use patterns and agricultural practices on water quality in the Calapooia River Basin of western Oregon. Journal of Soil and Water Conservation. 67(3):183-201.
- Muñoz-Villers LE, Holwerda F, Gómez-Cárdenas M, Equihua M, Asbjornsen H, Bruijnzeel LA, Marín-Castro BE, Tobón C. 2012. Water balances of old-growth and regenerating montane cloud forests in central Veracruz, Mexico. Journal of Hydrology. 462-463:53-66.
- Muñoz-Villers LE, McDonnell JJ. 2012. Runoff generation in a steep, tropical montane cloud forest catchment on permeable volcanic substrate. Water Resources Research. 48(9)
- Nahlik AM, Kentula ME, Fennessy SM, Landers DH. 2012. Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice Ecological Economics. 77:27-35.
- Naiman RJ, Alldredge JR, Beauchamp DA, Bisson PA, Congleton J, Henny CJ, Huntly N, Lamberson R, Levings C, Merrill EN et al.. 2012. Developing a broader scientific foundation for river restoration: Columbia River food webs. Proceedings of the National Academy of Sciences. 109(52):21201-21207.
- Nason JA, Bloomquist DJ, Sprick MS. 2012. Factors Influencing Dissolved Copper Concentrations in Oregon Highway Storm Water Runoff. Journal of Environmental Engineering. 138(7):734-742.
- Nason JA, Sprick MS, Bloomquist DJ. 2012. Determination of copper speciation in highway stormwater runoff using competitive ligand exchange – Adsorptive cathodic stripping voltammetry. Water Research. 46(17):5788-5798.
- Oliver AA, Bogan MT, Herbst DB, Dahlgren RA. 2012. Short-term changes in-stream macroinvertebrate communities following a severe fire in the Lake Tahoe basin, California. Hydrobiologia. 694(1):117-130.
- Pan F, McKane RB, Stieglitz M. 2012. Identification of optimal soil hydraulic functions and parameters for predicting soil moisture. Hydrological Sciences Journal. 57(4):723-737.
- Payn RA, Gooseff MN, McGlynn BL, Bencala KE, Wondzell SM. 2012. Exploring changes in the spatial distribution of stream baseflow generation during a seasonal recession. Water Resources Research. 48(4)
- Polasky S, Johnson K, Keeler B, Kovacs K, Nelson E, Pennington D, Plantinga AJ, Withey J. 2012. Are investments to promote biodiversity conservation and ecosystem services aligned? Oxford Review of Economic Policy. 28(1):139-163.

- Rand PS, Berejikian BA, Pearsons TN, Noakes DLG. 2012. Ecological interactions between wild and hatchery salmonids: an introduction to the special issue. Environmental Biology of Fishes. 94(1):1-6.
- Ray RA, Holt RA, Bartholomew JL. 2012. Relationship Between Temperature and Ceratomyxa Shasta-Induced Mortality in Klamath River Salmonids. Journal of Parasitology. 98(3)
- Reddy KJ, Roth TR. 2012. Arsenic Removal from Natural Groundwater Using Cupric Oxide. Ground Water. 51(1):83-91.
- Redman AD, McGrath JA, Stubblefield WA, Maki AW, Di Toro DM. 2012. Quantifying the concentration of crude oil microdroplets in oil-water preparations. Environmental Toxicology and Chemistry. 31(8):1814-1822.
- Regoli L, Van Tilborg W, Heijerick D, Stubblefield W, Carey S. 2012. The bioconcentration and bioaccumulation factors for molybdenum in the aquatic environment from natural environmental concentrations up to the toxicity boundary. Science of The Total Environment. 435-436:96-106.
- Rupp D E, Wainwright T C, Lawson P W. 2012. Effect of forecast skill on management of the Oregon coast coho salmon (Oncorhynchus kisutch) fishery. Canadian Journal of Fisheries and Aquatic Sciences. 69(6):1016-1032.
- Safeeq M, Fares A. 2012. Interception losses in three non-native Hawaiian forest stands. Hydrological Processes.
- Saldías GS, Sobarzo M, Largier J, Moffat C, Letelier R. 2012. Seasonal variability of turbid river plumes off central Chile based on high-resolution MODIS imagery. Remote Sensing of Environment. 123:220-233.
- Sanders EC, Abou Najm MR, Mohtar RH, Kladivko E, Schulze D. 2012. Field method for separating the contribution of surface-connected preferential flow pathways from flow through the soil matrix. Water Resources Research. 48(4)
- Schwalm CR, Williams CA, Schaefer K, Baldocchi D, Black AT, Goldstein AH, Law BE, Oechel WC, Paw U KT, Scott RL. 2012. Reduction in carbon uptake during turn of the century drought in western North America. Nature Geoscience. 5(8):551-556.
- Scott J, Helmbrecht D, Thompson MP, Calkin DE, Marcille K. 2012. Probabilistic assessment of wildfire hazard and municipal watershed exposure. Natural Hazards. 64(1):707-728.
- Seow WJ, Pan W-C, Kile ML, Baccarelli AA, Quamruzzaman Q, Rahman M, Mahiuddin G, Mostofa G, Lin X, Christiani DC. 2012. Arsenic Reduction in Drinking Water and Improvement in Skin Lesions: A Follow-Up Study in Bangladesh. Environmental Health Perspectives.
- Shea CP, Peterson JT, Conroy MJ, Wisniewski JM. 2012. Evaluating the influence of land use, drought and reach isolation on the occurrence of freshwater mussel species in the lower Flint River Basin, Georgia (U.S.A.). Freshwater Biology. 58(2):382-395.
- Sobota DJ, Johnson SL, Gregory SV, Ashkenas LR. 2012. A Stable Isotope Tracer Study of the Influences of Adjacent Land Use and Riparian Condition on Fates of Nitrate in Streams. Ecosystems. 15(1):1-17.
- Stanaway D, Haggerty R, Benner S, Flores A, Feris K. 2012. Persistent Metal Contamination Limits Lotic Ecosystem Heterotrophic Metabolism after More Than 100 Years of Exposure: A Novel Application of the Resazurin Resorufin Smart Tracer. Environmental Science & Technology. :120905165830003.
- Stewart MK, Morgenstern U, McDonnell JJ, Pfister L. 2012. The ‘hidden streamflow’ challenge in catchment hydrology: a call to action for stream water transit time analysis. Hydrological Processes.
- Stewart RD, Hut R, Rupp DE, Gupta H, Selker JS. 2012. A resonating rainfall and evaporation recorder. Water Resources Research. 48(8)

- Stewart RD, Najm AMR, Rupp DE, Selker JS. 2012. An Image-Based Method for Determining the Soil Shrinkage Curve. Soil Science Society of America Journal. 76(4):1217-1221.
- Stewart RD, Najm AMR, Rupp DE, Selker JS. 2012. Measurement Tool for Dynamics of Soil Cracks. Vadose Zone Journal. 11(2)
- Surfleet CG, Tullos D, Chang H, Jung I-W. 2012. Selection of hydrologic modeling approaches for climate change assessment: A comparison of model scale and structures. Journal of Hydrology. 464-465:233-248.
- Surfleet CG, Tullos D. 2012. Uncertainty in hydrologic modelling for estimating hydrologic response due to climate change (Santiam River, Oregon). Hydrological Processes.
- Swanson RD, Singha K, Day-Lewis FD, Binley A, Keating K, Haggerty R. 2012. Direct geoelectrical evidence of mass transfer at the laboratory scale. Water Resources Research. 48(10)
- Thompson KA, Hill JE, Nico LG. 2012. Eastern mosquitofish resists invasion by nonindigenous poeciliids through agonistic behaviors. Biological Invasions.
- Vinett MA, Jarvis T. 2012. Conflicts Associated with Exempt Wells: A Spaghetti Western Water War. Journal of Contemporary Water Research and Education. (148):10-16.
- Wang T, Brender P, Ciais P, Piao S, Mahecha MD, Chevallier F, Reichstein M, Ottlé C, Maignan F, Arain A et al.. 2012. State-dependent errors in a land surface model across biomes inferred from eddy covariance observations on multiple timescales. Ecological Modelling. 246:11-25.
- Warren DR, McClure MM. 2012. Quantifying Salmon-Derived Nutrient Loads from the Mortality of Hatchery-Origin Juvenile Chinook Salmon in the Snake River Basin. Transactions of the American Fisheries Society. 141(5):1287-1294.
- Warrick JA, Hatten JA, Pasternack GB, Gray AB, Goni MA, Wheatcroft RA. 2012. The effects of wildfire on the sediment yield of a coastal California watershed. Geological Society of America Bulletin.
- Werner C, Schnyder H, Cuntz M, Keitel C, Zeeman MJ, Dawson TE, Badeck F-W, Brugnoli E, Ghashghaie J, Grams TEE et al.. 2012. Progress and challenges in using stable isotopes to trace plant carbon and water relations across scales. Biogeosciences. 9(8):3083-3111.
- White D, Rashleigh B. 2012. Effects of stream topology on ecological community results from neutral models. Ecological Modelling. 231:20-24.
- Wigington PJ, Leibowitz SG, Comeleo RL, Ebersole JL. 2012. Oregon Hydrologic Landscapes: A Classification Framework 1. JAWRA Journal of the American Water Resources Association. 49(1):163-182.
- Wilson G, Özkan-Haller TH. 2012. Ensemble-Based Data Assimilation for Estimation of River Depths. Journal of Atmospheric and Oceanic Technology. 29(10):1558-1568.
- Withey JC, Lawler JJ, Polasky S, Plantinga AJ, Nelson EJ, Kareiva P, Wilsey CB, Schloss CA, Nogeire TM, Ruesch A et al.. 2012. Maximising return on conservation investment in the conterminous USA. Ecology Letters. 15(11):1249-1256.
- Witter RC, Zhang Y, Wang K, Goldfinger C, Priest GR, Allan JC. 2012. Coseismic slip on the southern Cascadia megathrust implied by tsunami deposits in an Oregon lake and earthquake-triggered marine turbidites. Journal of Geophysical Research. 117(B10)
- Wohl E, Barros A, Brunsell N, Chappell NA, Coe M, Giambelluca T, Goldsmith S, Harmon R, Hendrickx JMH, Juvik J et al.. 2012. The hydrology of the humid tropics. Nature Climate Change.
- Zarnetske JP, Haggerty R, Wondzell SM, Bokil VA, González-Pinzón R. 2012. Coupled transport and reaction kinetics control the nitrate source-sink function of hyporheic zones. Water Resources Research. 48(11)

3. **Book Chapters**

- Jarvis, WT. 2012. Integrating Groundwater Boundary Matters into Catchment Management. Book Chapter in The Dilemma of Boundaries: Toward a New Concept of Catchment. (eds.) Taniguchi, M. and Shiraiwa, T. Global Environmental Studies, Springer. Tokyo.

BOTTLED WATER IN OREGON

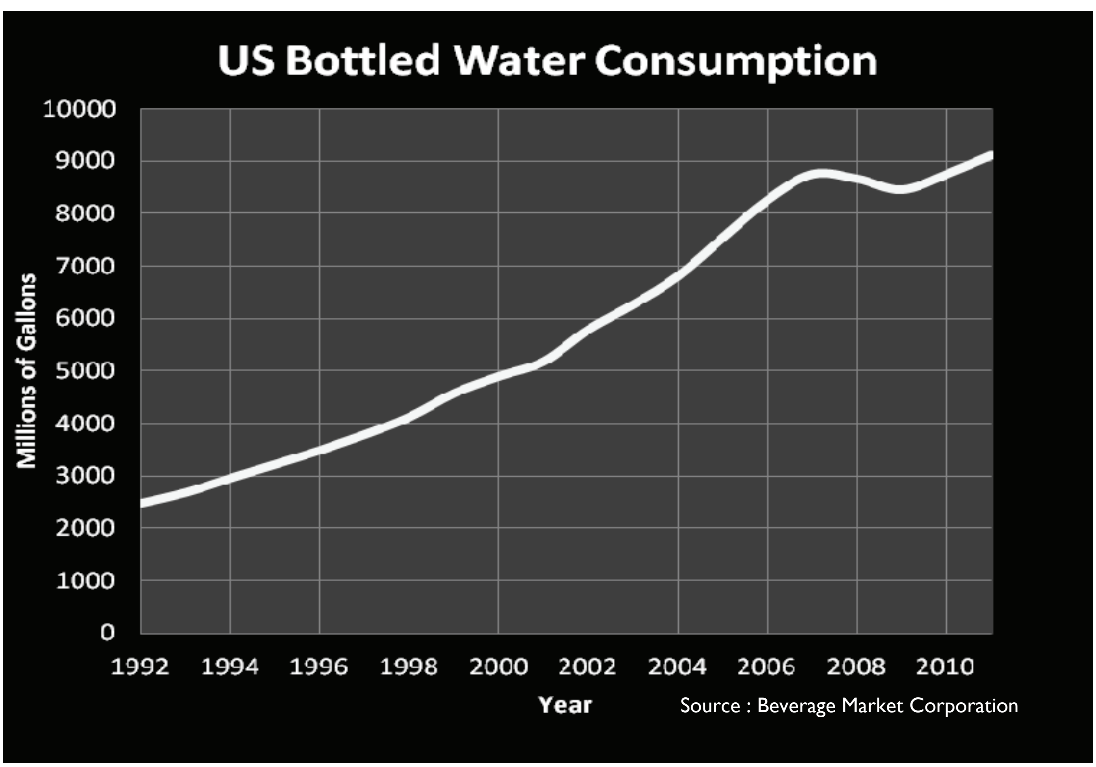
INSTITUTE FOR WATER AND WATERSHEDS —SEPTEMBER, 2012

Bottled water is a big and controversial business. Over the past two decades it has grown and become a powerful economic force. Bottlers say it is a healthy alternative to coffee, soft and energy drinks. Also they state that bottled water provides customers with clean and great tasting water. Opponents on the other hand say there is no significant difference between bottled and tap water. They note that almost half bottled water is in fact tap water. In addition, they note the immense amount of plastic in the bottles, and the environmental impact derived from fabrication to disposal.

Brief History of Bottled Water

Bottled water has been around for a long time, however over the past twenty years consumption has grown at a high rate. Water is essential for life, and humans have made use of ways to store and transport it throughout history. But the marketing of bottled water starts with "specialty" waters like Bath Spa in England and Vichy in France (early 1700s). These "spa waters" were believed to have medicinal qualities, and derived health benefits. In the 19th century bottled water from springs and retreat baths were marketed and consumed by the elite and were not accessible for the average person. In the middle of the 20th century bottled water became more available, but not common, and home delivery services and the "water cooler" were developed.
In 1976 the US had a per capita consumption of 1.6 gallons of bottled water.

Growth Spurt



Bottled water consumption has been on a steady increase for over 20 years.

Between 1992 and 2011 bottled water sales have increased by 266% in the United States.

After two years of negative growth associated with the recession (2008 and 2009), the bottled water industry has picked up where it left off. In general the liquid beverage industry had grown in 2011, but bottled water grew almost 5 times more.

Today

In 2011, the United States consumed 9,107 million gallons of bottled water and generated revenue in excess of 11 billion dollars. The average person in the US consumed 29.2 gallons of bottled water last year. Bottle water use in the state of Oregon is estimated to be between 120 and 182.14 million gallons.

The Water That Goes into the Bottle

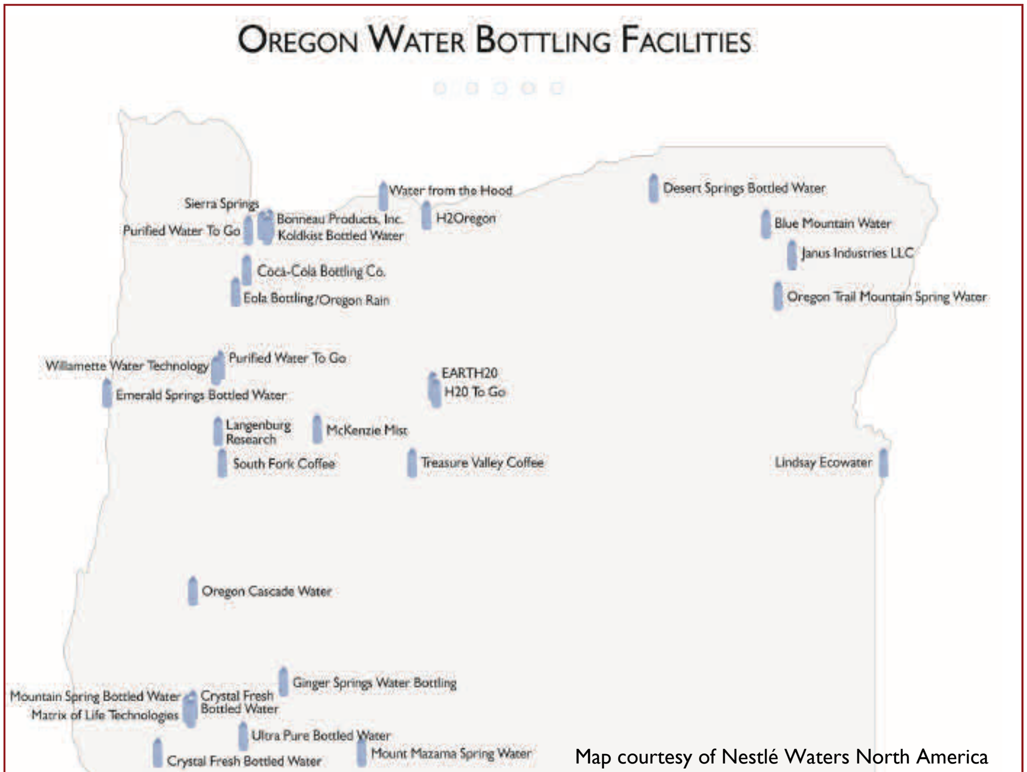
Water quality is regulated by two main federal agencies. The Food and Drug Administration (FDA) regulates bottled water, while the Environmental Protection Agency (EPA) is in charge of overseeing public water supply. Both agencies have their own standards for water, and while they are similar they are not equal. They also have distinct monitoring and enforcement practices.

What types of water are there, and where are the sources? Most of the companies that bottle water in Oregon use one or more purification methods. The most common processes are filtration, ultra violet, ozonification, and reverse osmosis. Many consumers believe that that bottled water is a "healthier option", but tests have shown that public water can have lower levels of restricted substances. In general, no guarantee can be made that bottled or tap water is "safer".

NAME	DEFINITION
Artesian Water or Artesian Well Water	Water from a well tapping a confined aquifer in which the water level stands at some height above the top of the aquifer.
Mineral Water	Water containing no less than 250 ppm total dissolved solids that originates from a geologically and physically protected underground water source. Mineral water is characterized by constant levels and relative proportions of minerals and trace elements. No minerals may be added to mineral water
Purified Water	Water that is produced by distillation, deionization, reverse osmosis or other suitable processes and that meets the definition of "purified water" in the U.S. Pharmacopeia, 23d Revision, Jan. 1, 1995. As appropriate, also may be called "demineralized water," "deionized water," "distilled water," and "reverse osmosis water
Sparkling Bottled Water	Water that, after treatment and possible replacement of carbon dioxide, contains the same amount of carbon dioxide that it had at emergence from the source
Spring Water	Water derived from an underground formation from which water flows naturally to the surface of the earth at an identified location. Spring water may be collected at the spring or through a bore hole tapping the underground formation feeding the spring, but there are additional requirements for use of a bore hole
Well Water	Water from a hole bored, drilled, or otherwise constructed which taps the water of an aquifer

Water Bottlers in Oregon

In Oregon there are almost 29 different companies that bottle water. Most of them are small companies that cater to the home and office delivery (HOD) markets. HOD comprises the 3, 4 and 5 gallon (mostly reusable) water jugs, whether they are delivered or bought at a grocery store. Many of the companies also have disposable bottled water for sale, but this is a minuscule part of the business. Nonetheless, HOD represents only 20% of the market for bottled water. The remaining 80% is covered by the retail portion of the industry. This includes disposable containers from 2.5 gallons or less. Retail bottled water does not only represent the largest sector of the business, but also the fastest growing one.



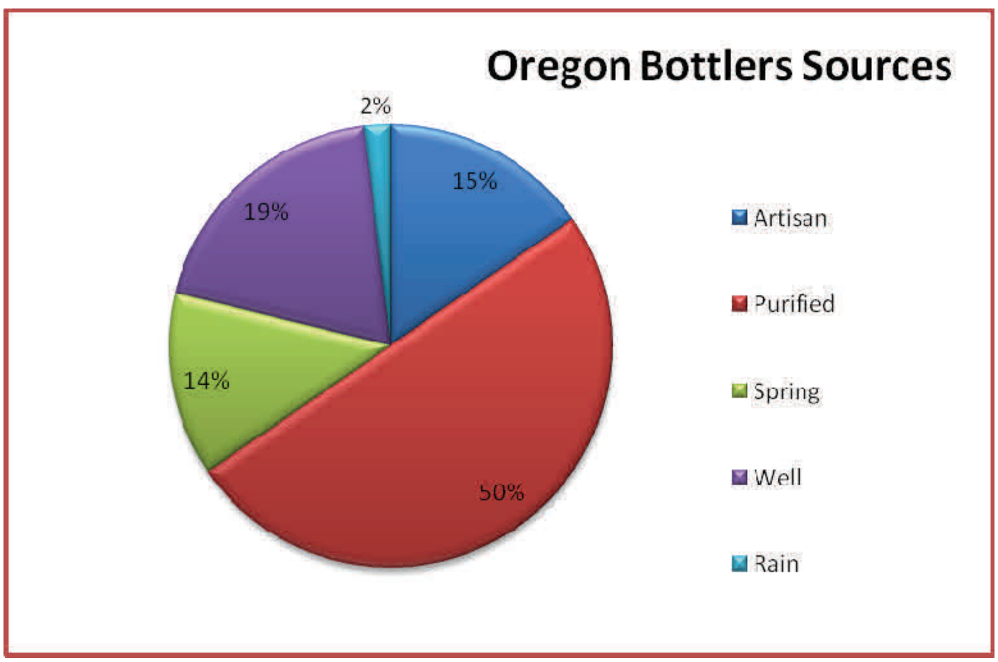
Map courtesy of Nestlé Waters North America

Five companies; Nestle, Pepsi, Coca-Cola, Crystal Geyser, and Dannon have a strong hold on the domestic market. Combined they hold 96% of the market. . The rest of the companies, both domestic and international share a mere 4%.

The sources of these companies are represented in the pie chart below. Purified water represents half of the bottling plants located in the state. Purified water often comes from municipal sources, comprising close to 50% of the United States market. In the state of Oregon 30% of the bottlers get their supply from a municipal source.

Financial Impact

The Oregon water bottle industry employs as many as 1,624 people, and generates an additional 3,970 jobs in ancillary and supplier industries. The International Bottled Water Association estimates the total impact of the bottled water industry in the state to be as much as $1.1 billion in 2011 (about 0.6 % of the gross state product). Nationally, the impact of the industry is larger with almost a 1% contribution to the GDP.



Water and Oil

Along with demand, questions about the environmental costs of bottled water have been raised. The resources needed to produce and transport bottled water, as well as the quantity of plastic waste that has to be recycled or ends up in landfills.

Last year about 18.7 million barrels of oil were used to produce water bottles for the US market. In the process of manufacturing those bottles 2.75 million tons of CO_2 were released into the atmosphere. When the energy requirements of bottling and transportation are included the total number is somewhere between 32 and 58 million barrels of oil, close to 1% of the total oil consumption in the country.

To supply Oregon consumers between 0.5 and 1.2 million barrels of oil were used. The Department of Environmental Quality recently conducted a life cycle assessment of drinking water systems. The analysis looked at tap, bottled and home and office delivery (HOD) services. All the scenarios represented in the study show a significant difference between public water and bottle waters. HOD services have the least impact, followed by in-state bottled water. Long hauled bottle water is by far the worst possible option.

Amongst all types of plastic bottles, water bottles are the most recycled. Nonetheless, only 23% of water bottles get recycled. The United States consumes 50 billion 16 oz. plastic bottles a year, that means 38.5 billion bottles annually are not recycled.

Many bottlers try to reduce the amount of plastic that goes into each bottle. In Oregon companies are looking for alternative solutions like using biodegradable plastics (Oregon Rain), biodegradable boxes (Ginger Springs Water), or maximizing the recycled plastic that goes into their bottles (EARTH2O).

The Fight Against Bottled Water

With the increased awareness of the environmental impacts associated with bottled water, national campaigns (like “Think outside the bottle” and “Take back the tap”) have been launched. The proponents of these campaigns want government to take charge by cutting water contracts, not buying bottled water, and enforcing stricter label disclosure requirements. In Oregon, Southern Oregon University, University of Portland and Pacific University have banned sales of bottled water on campuses. Other colleges and schools have campaigns that promote the use of reusable bottles and encourage drinking tap water, but have not restricted sales.

Consumers

Bottled water costs more than public water. Bring your own bottle stations charge 6 to 10 times more than municipal sources, but the difference against retail bottle water can be as high as 2000 the cost of tap water. Yet consumers keep buying, and every year they buy more. The perception of risk, flavor and the huge profits from bottled water are likely to continue the increase of the business. The quality of tap water in the United States, and the push against bottled water, can hope to slow the growth, but bottled water is here to stay.

Consumers have to blindly trust the quality of their bottled water because many bottlers do not include information on origin and purification processes on labels. Bottlers do not present information on the water quality tests that they conduct or their findings. Calls from consumer groups to make bottlers provide this information on bottled water labels has met with mixed success. A survey found almost 40% of bottlers provided more information in 2010 than in 2009, a similar fraction had no change, and more than 15% of the brands surveyed showed less information than the previous year.

Cascade Locks

Nestle Waters is evaluating a plan to build a bottling plant at Cascade Locks. The water from Oxbow Springs is currently used by the Oregon Department of Fish and Wildlife (ODFW) for its fish hatchery. The ODFW has applied to OWRD to transfer the water rights to the City of Cascade Locks. ODFW plans to use the water from a city well in its hatchery. In return, the city would get the rights to 0.5 cubic feet per second (more than 100 million gallons annually) of water from Oxbow Springs and they would sell it to Nestle at a price of 2 cents per 1000 gallons (the current commercial rate).

Photo courtesy of OSU Archives.

Build the Plant

Nestle is looking for a high quality spring water source to bottle. They believe that there is more than enough water to meet the community needs. The proposed plant would provide an economic boost to the City of Cascade Locks. The city is behind the plant as it would bring up to 50 well paying jobs, as well as indirect benefits, like doubling the property tax revenue. The bottling plant would require an investment of up to 50 million dollars, and would meet Leadership in Energy and Environmental Design (LEED) Standards. Nestle Waters conducted a long term study that shows the well water is suitable for raising fish.

Republican representative Mark Johnson supports the plant, he states that the opposition to the plant comes from urban legislators, and is an unfortunate example of the divide between rural and urban Oregon. Senator Mark Thompson is in favor as well. The proposed exchange of water rights received preliminary approval by Oregon's Water Resources Department.

Do not Allow the Transfer

The opposition against the Plant is lead by Food and Water Watch and the Sierra Club. They are joined by the Columbia River Keeper, American Federation of State, County and Municipal Employees (AFSCME), Oregon Physicians for Social Responsibility, Mount Hood forest group Bark, and Senator Jackie Dingfelder (D, Portland), among others. They seek to prevent a public resource from being used for the benefit of a multinational corporation. They believe the intended used of the water should be taken into account, and they say it is not in the public's best interest to allow Nestle to control the water supply. The proposal for the plant does not represent a win-win situation for the state, as the city will not give compensation for the transferred water. There are alternatives for economic development outlined in the City of Cascade Locks Comprehensive Plan (2009). Senator Dingfelder, and other democrats want the governor to prevent the transfer of rights. However, Governor John Kitzhaber stated he will not intervene in the decision.

"It is interesting that people spend a lot of time looking at organic food, organic vegetables, reading the labels of what they're going to eat. But when they choose to ingest a liquid beverage, whether it be bottled water or a carbonated soft drink or an energy drink they are not exploring the source. Yet that is the one thing that they are going to drink that is going to touch every single organ of their body."

Steve Emery, CEO of EARTH2O

More Information

If you want to learn more about bottled water, you can find in-depth information from the following sources:

EPA
http://water.epa.gov/drink/
FDA
http://www.fda.gov/food/foodsafety/product-specificinformation/bottledwatercarbonatedsoftdrinks/ucm077065.htm
Oregon Department of Environmental Quality, life cycle analysis
www.deq.state.or.us/lq/sw/wasteprevention/drinkingwater.htm
International Bottled Water Association
http://www.bottledwater.org/
Nestle Waters of North America
http://www.nestlewaterspnw.com/
Food and Water Watch
http://www.foodandwaterwatch.org/
The Story of Bottled Water
http://www.storyofstuff.org/movies-all/story-of-bottled-water/
Tapped, the movie
http://www.tappedthemovie.com/
The Sierra Club
http://www.sierraclub.org/watersentinels/

Bottled Water in Oregon. A report prepared for the Institute for Water and Watersheds, Oregon State University by Pablo Alvarez Tostado, a graduate student in the Environmental Science Graduate Program. Special thanks to Todd Jarvis the Director of IWW, Steve Emery of EartH2O, and Dave Palais of Nestle Waters North America Inc.

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Turning Water into Wine, Efficiently!

INSTITUTE FOR WATER AND WATERSHEDS • INSTITUTE FOR NATURAL RESOURCES • 10/2012

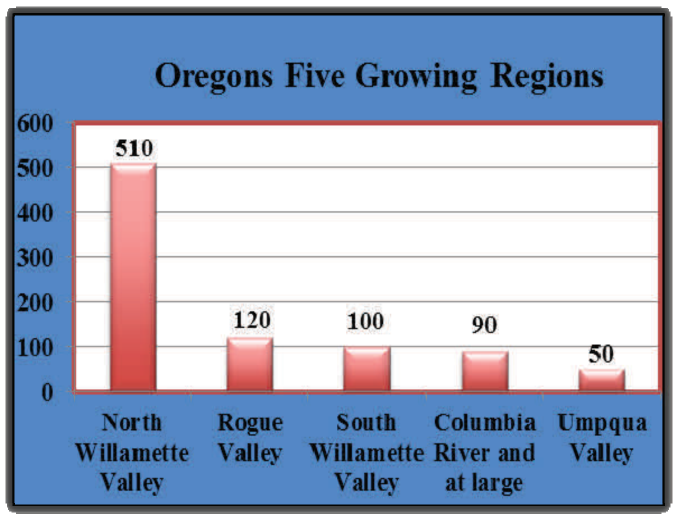
By Luca De Stefanis—Environmental Policy Research Assistant

Water is Oregon's most precious resource and the opportunity for vineyards to improve efficient irrigation beckons. The wine industry is answering that call through responsible stewardship of sustainable practices and great advancements in vineyard irrigation. The wine industry's attention to sustainable practices reaps many ecological benefits including improved water and soil quality. Although there are many ways to approach water conservation, a standardized certification of efficient irrigation practices has yet to be implemented. Each land steward determines its own watering practices and many are based on conventional wisdom rather than empirical evidence. It is time for the wine producing and wine consuming community to collaborate in addressing the most serious natural resource concern: Water Quantity Supply. It is imperative that all Oregon vineyards collaborate in practicing a standardized way of turning water into wine, efficiently!

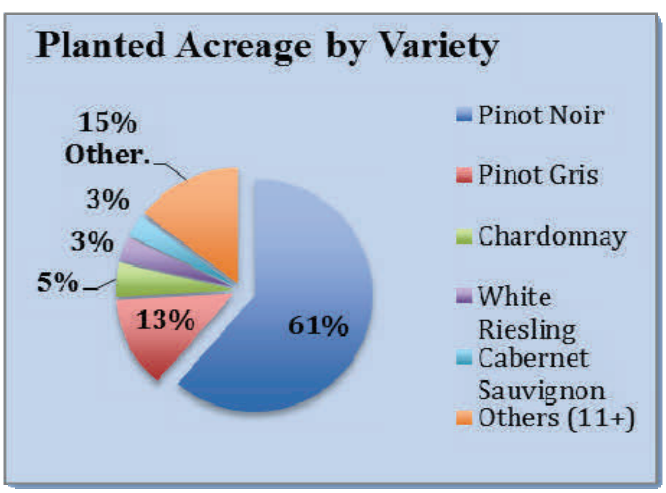
Oregon Wine: Past and Present

European and American settlers have been growing grapes in Oregon for winemaking since the mid-nineteenth century. Oregon's wine industry and culture had a resurgence in the 1960's but hit its stride in the 1980's with the international success of locally grown Pinot Noir varieties. By the 1990's Oregon received global recognition for its main cultivar Pinot Noir.

Oregon vineyards specialize in small acreage quality production. Oregon's 870 vineyards grow in five growing regions and produce 20,400 planted acres of grapes. Pinot Noir makes up more than half of all planted acreage. Yamhill County (located in the North Willamette Valley growing region) has the highest number of vineyards and planted acres in Oregon, nearly triple that of other counties in Oregon. Nationally, Oregon ranks third in the total number of wineries and fourth in wine production — following California, Washington, and New York. Oregon's wine industry's rapid growth, recession-proof trends, and role as a tourist attraction make it important to Oregon's economy.



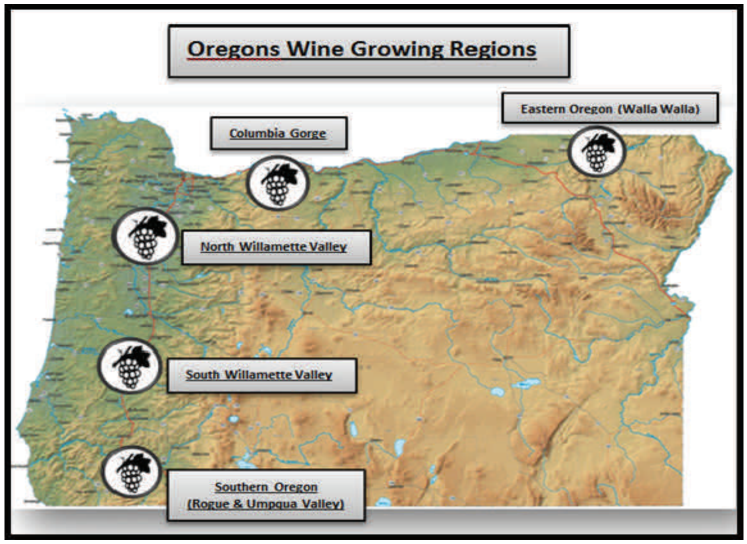
Data Source: National Agricultural Statistics Service (NASS)
Graphics by: Luca De Stefanis



Data Source: National Agricultural Statistics Service (NASS) Graphics by: Luca De Stefanis

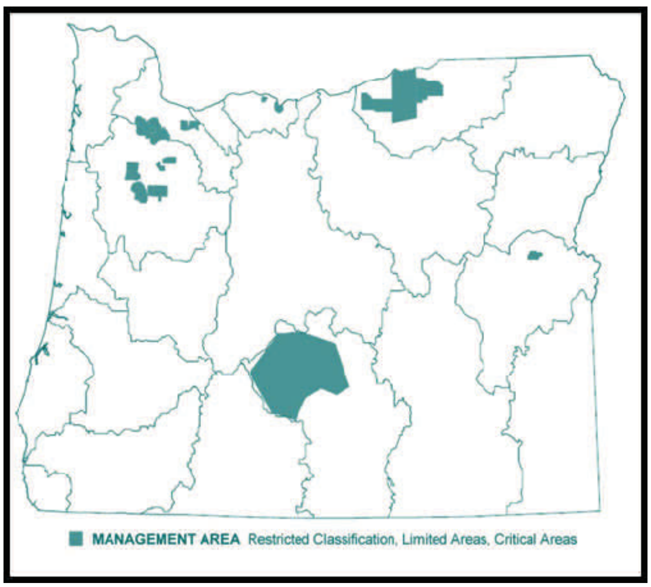
A 2011 Oregon Wine Board study shows that the economic impact of Oregon's wine industry nearly doubled to $2.7 billion from 2004-2010. And, the wine industry had a $1.56 billion net economic contribution (a measure of value added) to Oregon's economy which helped to create jobs rural communities. With more growth imminent this trend is likely to continue.

Oregon's wine industry nearly doubled to $2.7 billion from 2004-2010.



Graphics by: Luca De Stefanis

State of Oregon
Critical Groundwater Areas and Groundwater Limited Areas



Source: WATER RIGHTS IN OREGON - Oregon Water Resources , 2009

Oregon Water: Present and Future

According to the U.S. Census Bureau, Oregon's population has increased 12 percent since the year 2000. Total statewide water demand is currently estimated to increase 13 percent by the year 2050. Despite the high annual rainfall in Oregon, there are limits to Oregon's water resources and we as a community need to learn how to live within these limits. Oregon has established high-priority regions designated as Critical Groundwater Areas and Groundwater Limited Areas. There are seven critical groundwater areas in Oregon and The Dalles in Wasco County is one of them. This area represents a portion of the Columbia River Gorge wine growing region which is home to several vineyards. There are twelve Groundwater Limited Areas in Oregon with most located in the Northern Willamette Valley. Many are wine growing regions such as Chehalem Mountain, Eola Hills, South Salem Hills and Amity Hills.

Climate and Topography Determine a Vineyard's Water Use

Climate is the single most important factor in successful vineyard irrigation practices. Topography, soil structure, soil-depth and water availability are also significant factors in determining proper irrigation. Oregon has 16 distinct American Viticulture Areas (AVA's) that designate wine-growing regions based on geographic characteristics. Each AVA has its own microclimate. Microclimate variations are determined by temperature, humidity, rainfall, wind, or a combination of these. These factors may potentially lead to high demands on water. Drip irrigation is used more regularly in the more arid wine regions—Southern Oregon, Eastern Oregon and parts of the Columbia Gorge—when soil is shallow and rainfall is limited. In areas with higher rainfall, such as the Willamette Valley, vineyards need less water and might use *dryland farming*, which requires no irrigation. Once a crop is established, vineyards in areas with higher rainfall and deeper soils can often grow grapes without the use of irrigation.

Water efficiency in wine production

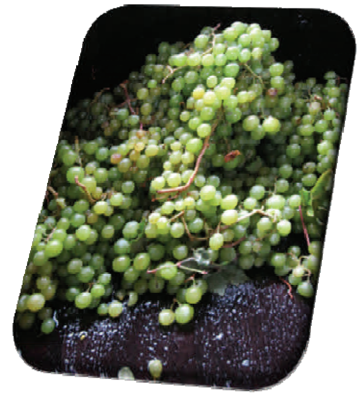


Photo by Ethan Prater, Flicker Community Commons 2012

Collaboratively taking on irrigation holds the greatest promise for the wine industry to reduce water demand and improve irrigation efficiency. Whether in Eastern Oregon, Southern Oregon, the Willamette Valley or the Columbia River Gorge region knowing how to operate electronic irrigation equipment to its full potential and proper management of micro- or subsurface drip irrigation system are key to the wine industry's contribution to conserve the most water. Establishing voluntary standardized practices that emphasize upgraded irrigation systems and hardware can serve as an industry-wide foundation to water conservation.

Water use inefficiencies often results from insufficient training, unclear guidance, and a do-it-yourself attitude that is not always the most effectual approach. Basing water needs on intuition or a common practice of observing a hot and sunny day and then irrigating can lead to unnecessary water use and excessive pumping of groundwater (personal communications with wine industry representatives, 2012).

Utilizing micro-irrigation and subsurface drip irrigation are the most basic steps forward in irrigation efficiency practices. Micro-irrigation uses the soil to move the water through the root mass. Knowing a vineyard's soil type (water holding capacity) and how much water to apply (application rate) is critical. Subsurface drip irrigation uses buried lines and emitters to apply slow, frequent applications of water to the soil surrounding plant roots. Water losses from surface evaporation and runoff are eliminated so higher irrigation efficiencies result. Conserving water has emerged as a conventional practice and free technical assistance is available to the public through Oregon State University Extension Services, and through the U.S. Department of Agriculture. The Farm Bill also has mechanisms to offset the costs of irrigation efficiency upgrades.

Photo by James Fischer, Flicker Community Commons 2012

Sustainability practices have consumer appeal

Consumer concerns over food safety, environmental and wildlife conservation, and climate change have caused substantial rethinking of growing and production practices by many producers. Sustainability Certifications display a vineyard's environmental responsibility. In 2007 the Oregon Wine Board showed that sustainability practices had substantial appeal to many consumers. The Oregon wine industry has been at the forefront of this movement and substantial acreage is now farmed using various forms of sustainable or organic methods and many wineries a have adopted carbon footprint reduction practices. Many organizations that offer certification for such methods are headquartered in Oregon.

Wine certification organizations have a done a brilliant job at addressing sustainability, environmental issues, organic production and social equity. Some of the leaders in this field are Low Input Viticulture & Enology (LIVE), VINEA –Winegrowers Sustainable Trust, Oregon Certified Sustainable Wines (OCSW), Salmon Safe, Oregon Tilth and the USDA National Organic Program. Most efforts to address water issues concentrate on water quality improvement rather than water quantity and irrigation efficiencies. The consumer demand for Oregon's wine has increased at the expense of water use. *How can Oregon vineyard certifying organizations, academic research institutes and the community improve strategies for conserving water on vineyards through efficient irrigation practices?*

Photo by James Fischer, Flicker Community Commons

Photo by Ethan Prater, Flicker Community Commons 2012)

Many Oregon vineyards are ripe for using water more efficiently. The success of Oregon wines will attract new vineyards and lead to greater expansions putting a significant stress on water supplies. Irrigation practices are good but they are not great. Water supplies are available but are finite. In order for the Oregon wine industry to live up to its glowing reputation for sustainability, improved standardized irrigation practices are required.

Photo by Robert Hamilton, Flicker Community Commons 2012

Photo by Robert Hamilton, Flicker Community Commons 2012

Turning Water into Wine Efficiently, is a report prepared for the Institute for Water and Watersheds and the Institute for Natural Resources.

Special thanks to all who participated in the development of this paper. Research and writing conducted by Luca De Stefanis, Environmental Policy Research Assistant, Institute for Natural Resources.

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References

Appellation America. (2012). Oregon Appellation Profile, http://wine.appellationamerica.com/wine-region/Oregon.html (2 August 2012).

Comas, L.H., Baurerle, T.L., Eissenstat, D.M. (2010). Biological and environmental factors controlling root dynamics. Australian Journal of Grape and Wine Research 16, 131–137.

Full Glass Research. (2011, May). The Economic Impact of the Wine and Wine Grape Industries on the Oregon Economy. Retrieved from http://industry.oregonwine.org/wp-content/uploads/2011/07/OR-EconReport-2010-Final-2.pdf.

Hall, Lisa Sharia. (2001). Wines of the Pacific Northwest. History of the Oregon Wine Industry. London: Mitchell Beazley Publishers Limited.

Keller, M. (2005). Deficit Irrigation and Vine Mineral Nutrition. American Journal Enology Viticulture. 56(3), 267-279.

Kriedemann, P.E. (2002). Regulated Deficit Irrigation and Partial Rootzone Drying: An information package on two new irrigation methods for high-input horticulture. Report number 4. Canberra, Australia. Land & Water Australia publishing. Retrieved September 18th, 2012: http://lwa.gov.au/files/products/national-program-sustainable-irrigation/pr020382/pr020382.pdf.

Low Input Viticulture and Enology, Inc. Irrigation Reporting Forms. (2012). Retrieved August 20, 2012 from http://liveinc.org/forms/12.

Low Input Viticulture and Enology, Inc. Salmon-Safe Winery Protocols Addendum. (2012). Retrieved August 15, 2012 from http://liveinc.org/forms/6276.

Low Input Viticulture and Enology, Inc. Salmon-Safe Conditions for Site Planning, Development, and Construction (2012). Retrieved August 15th,http://liveinc.org/forms/13017.

National Agricultural Statistics Service. (2010). 2011 Oregon Vineyard Report. Portland, OR: United States Department of Agriculture, National Agricultural Statistics Service, Oregon Field Office.

Nigro, D. (2010, May 31). Giving New Meaning to Green: Giving Credibility to Sustainability. Wine Spectator. Retrieved from http://www.winespectator.com/magazine/show/id/42498.

Oregon Agricultural Statistics Service. Office of USDA's NASS. Vineyard. Retrieved September 10, 2012 from http://www.nass.usda.gov/Statistics_by_State/Oregon/Publications/Vineyard_and_Winery/index.asp.

Oregon Water Resources Board (2009). An Introduction to Oregon's Water Laws: Water Rights in Oregon, Centennial Edition. Salem , OR: Government Printing Office.

Oregon Wine Board. (2012). Sustainability, http://www.oregonwine.org/Discover_Oregon_Wine/Sustainability (2 July 2012).

Oregon Wine Board (n.d.). Retrieved August 18th, 2012, from Oregon Wine Board, Oregon Wine Board -About OWB website http://industry.oregonwine.org/oregon-wine-board/about-owb/.

Oregon Wine Center. (2011, July 14). Impact of Oregon Wine on state's Economy Nearly Doubles since 2005. [Press Release] Retrieved from http://industry.oregonwine.org/wp-content/uploads/2011/07/EIS-press-release-2011-06-301.pdf.

Pacific Northwest Extension Publications. (2012). Considerations and Resources for Vineyard Establishment in the Inland Pacific Northwest. (PNW64). Prosser, WA; Washington State University: Pacific Northwest Extension Publications.

Paul, J. Cameroon Winery. Just Say No to Irrigation. Retrieved July 25th at http://cameronwines.com/who-we-are/just-say-no-to-irrigation/.

Salmon Safe. Vineyards – Download the Salmon Safe farm standards. Retrieved August 15, 2012 from http://salmonsafe.isitedesign.net/getcertified/farms.

Soar, C.J., Loveys, B.B. (2007). The effect of changing patterns in soil-moisture availability on grapevine root distribution, and viticulture implications for converting full-cover irrigation into a point-source irrigation system. Australian Journal of Grape and Wine Research 13, 1–13.

U.S. Census Bureau. (2012, September 18). State & County Quickfacts: State of Oregon, People Quickfacts. Retrieved October 1, 2012, http://quickfacts.census.gov/qfd/states/41000.html.

United States Department of Agriculture, Natural Resources Conservation Service. (2012). Subsurface Drip Irrigation: Conservation Today for Water Tomorrow. Lubbuck, TX: Author. Retrieved September10th 2012 from http://www.hpwd.com/Downloads/New%20SDI%20booklet%20from%20NRCS.pdf.

Water and Climate in the Pacific Northwest

INSTITUTE FOR WATER AND WATERSHEDS • OREGON CLIMATE CHANGE RESEARCH INSTITUTE • 8/2012

Water and climate in Oregon and Washington (hereby the Pacific Northwest, or PNW) are inextricably linked. Here, we explore how climate has changed and is projected to change during the 21st century, and the implications for water in the PNW and greater western United States.

How does climate vary over the Pacific Northwest landscape?

In the water cycle, surface water is both the accumulation from runoff from precipitation and groundwater. Precipitation can contribute to surface water immediately, either in the form of rain, or delayed, in the form of snowmelt-driven runoff. The seasonality of precipitation dictates the need for water storage in the form of snowpack in the PNW; most of the precipitation falls between October and March. Historically, mountain snowpack has served as natural storage for summertime water supply in much of the Pacific Northwest. In the future, as winter temperatures warm, mountain snowpacks will continue to diminish and summer water supply will likely decline.

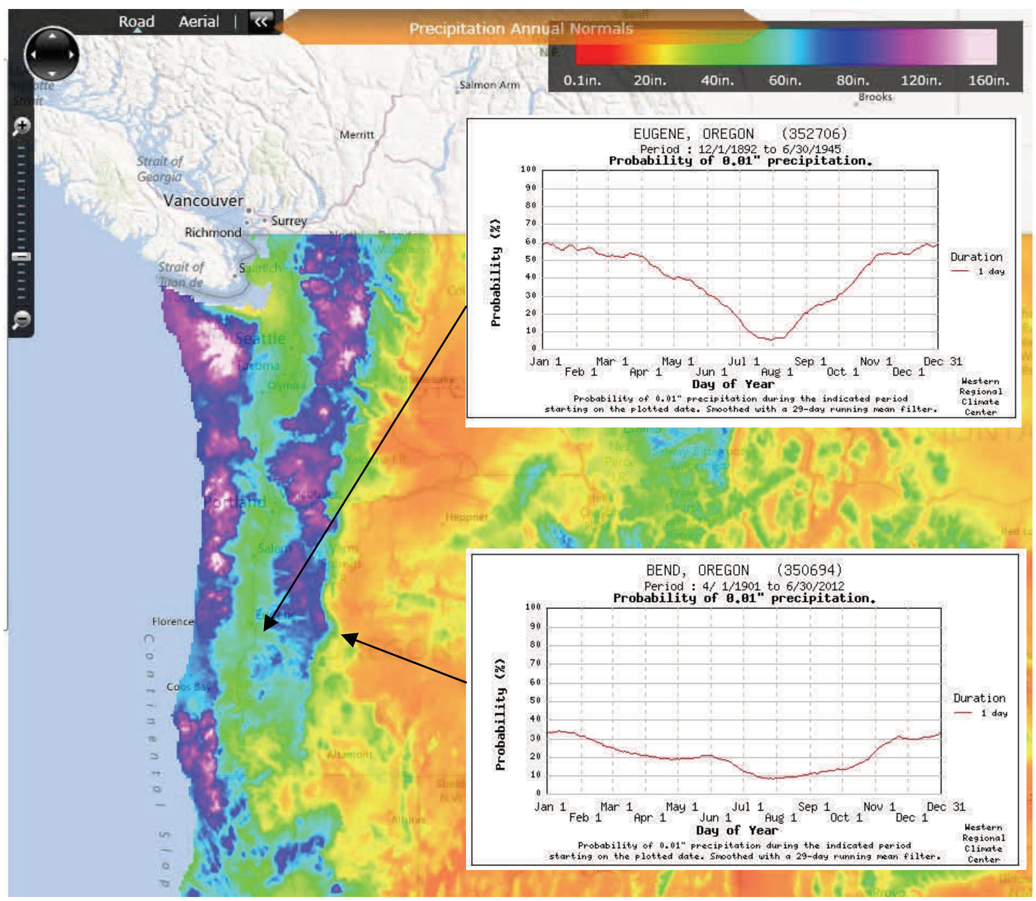


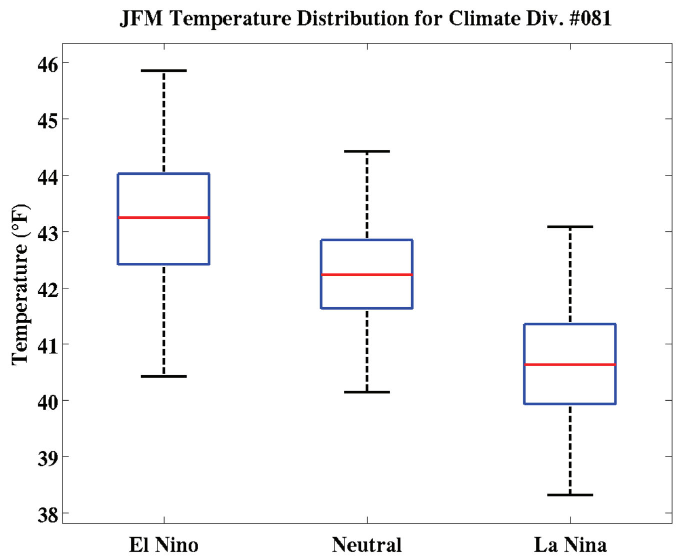
Figure 1. PRISM data mapped on 21st century climate services tool for Oregon and Washington. PRISM data (PRISM Climate Group, www.prism.oregonstate.edu, 21st Century Climate Services developed by Alex Wiggins of Oregon State University for OCS and funded by Microsoft Research, Bend and Eugene probability of at least 0.01" of precipitation in a 1-day period from Western Regional Climate Center).

Precipitation varies both spatially, or, across the landscape, and temporally (through time). Mountain ranges play an important role in where precipitation falls in the PNW. The highest annual precipitation amounts are found on the windward, or, upslope side of the ocean-adjacent mountain ranges. Parts of the Coast Range in Oregon and the Olympic Mountains in Washington can see around 200 inches per year of precipitation on average.

The Pacific Northwest is billed as an excessively rainy place, but in reality, it does not live up to its wet reputation in the regions two largest cities: Seattle, WA and Portland, OR. Both cities both receive less precipitation annually (on average less than 40" per year), than New York City or Miami. This reputation isn't rooted in the amount of precipitation, but the number of days with rain. This rainy moniker is unfairly assigned to the entire Pacific Northwest, when the inland areas east of the Cascades are actually quite arid. This is because the Cascade Mountains of Oregon and Washington also create a rain shadow effect, keeping the inland areas mostly dry year-round.

The Cascades rain shadow can be described as such: ocean-influenced moist air masses are forced to rise when they meet the tall mountains. The rising air cools, condenses, and the moisture falls as precipitation. On the leeward (dry) side of the mountain, the now dry air warms and sinks. This is why Eugene, OR is rainier than Bend, OR, which is located directly over the mountains to the east. The Oregon Coast Range and Olympic Mountains of Washington produces a smaller, and somewhat less significant rain shadow; part of the reason that Newport, OR is wetter than Corvallis, OR, directly to its east.

General atmospheric circulation tends to dictate the timing of precipitation. The Aleutian Low is a semi-permanent atmospheric feature found in the general vicinity of the Aleutian Islands during the winter. Cyclonic flow tends to bring the flow and direct the general stormtrack over the Pacific Northwest. In the summer, the low shifts north and an opposite, anticyclonic ridging pattern tends to set up over the Northwest, keeping summers dry and



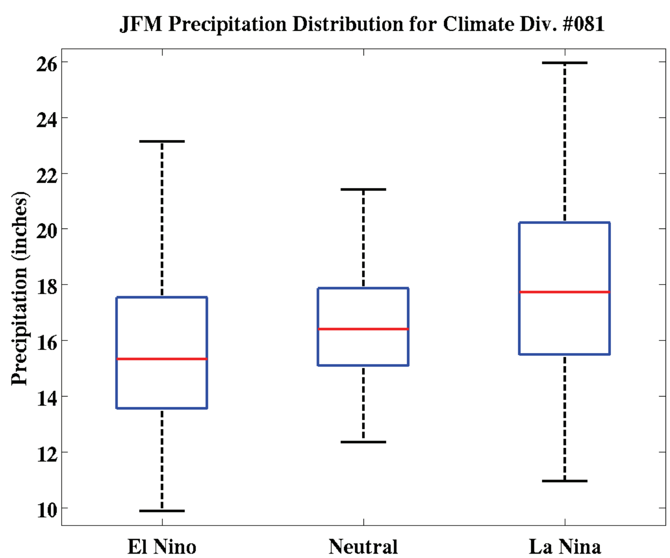


Figure 2. Shows temperature and precipitation distribution for interior Western Oregon for the months of January, February and March. The red line shows the mean, the blue box indicates the 33% and 66% values, and the end bars show the range from low to high for each mode of ENSO: El Niño, neutral (no signal detected in SST in ENSO area), and La Niña. In this part of Oregon, the temperature signal is a little more pronounced than the precipitation signal. The mid-range (33-66%) is different in temperature between El Niño and La Niña events, but there is overlap in the upper and lower ranges. In precipitation, the range from low to high precipitation in El Nino and La Niña events is greater than temperature, with overlap in the mid-range (33-66%) in warm, neutral, and cool phase conditions.

warm. Rain that does fall in the summer tends to be the result of small-scale convective events. Convective events usually bring short-lived bursts of heavy rainfall, and sometimes hail. These events are more typical east of the Cascades, where warm air required for ascent (a key element of thunderstorm development) is more free to mix with cold air aloft, triggering these events.

We've covered where and when precipitation tends to fall, and when, but temperature also plays a crucial role in water and climate in the Northwest. Proximity to the ocean also keeps temperatures mild in the winter; water doesn't cool as quickly as land. Winter, as we mentioned before, is the time of year when most of the precipitation falls in the Northwest. These mild temperatures are close enough to the freezing point (0˚C/32˚F), especially in the lower-mid elevations, that often a few degrees difference will spell the difference between rain and snow.

Modes of climate variability affect Pacific Northwest weather and climate on an interannual basis, namely the El Niño Southern Oscillation (ENSO), which is marked by an area in the equatorial Pacific Ocean. This area is where coupled sea surface temperature and atmospheric variations drive the overall global atmospheric circulation pattern. The warm phase of ENSO, is known as El Niño; the cool phase, La Niña. In the Pacific Northwest, especially the western portion of the region, the phase tends to affect seasonal temperature and precipitation. El Niño tends to split the jet stream, often bringing warmer air to Oregon and Washington and wetter weather to California. La Niña tends to position the northern storm track directly over the Pacific Northwest, bringing greater odds of cooler, wetter winters.

What are the overall trends in climate? How is human-caused climate change effecting the Pacific Northwest? What does climate change mean for water resources?

Human activity is primarily responsible for the observed 1.5 ˚F increase in 20th century annual averaged temperatures in the Pacific Northwest, though a formal detection and attribution study has not been performed for this region. Trends in annual averaged precipitation have been more ambiguous, with some USHCN stations showing a wetter trend and some a drier trend. Winter temperatures have warmed in the Pacific Northwest over the last 110 years. Figure 3shows United States Historical Climatology Network (USHCN sites over Washington, Oregon, Idaho. A red dot indicates a warming trend; a blue dot indicates cooling. The size on the dot is related to the magnitude of the trend per decade, a larger dot means a larger decadal trend.

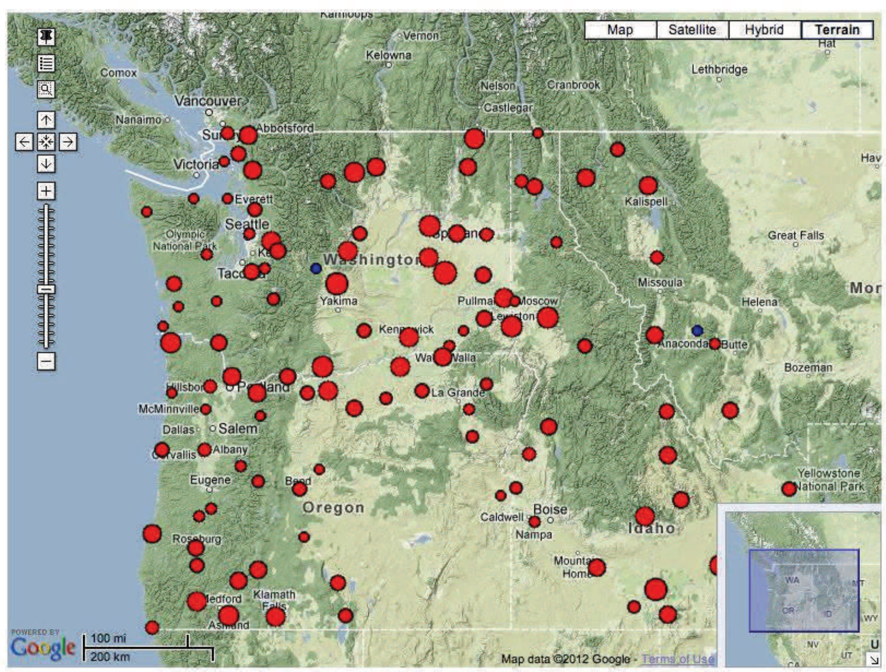


Figure 3. USHCN station trends in winter temperature for the Pacific Northwest. Office of the Washington State Climatologist, www.climate.washington.edu/trendanalysis

Historically, mountain snowpack has served as natural storage for summertime water supply in much of the Pacific Northwest. Increasing winter temperatures have left mountain snowpack, particularly lower-mid elevation snowpack vulnerable. In snowmelt-dominated basins in the Western U.S., there has been a shift in the timing of streamflow to earlier in spring, primarily driven by an increase in winter and spring temperatures. Formal detection and attribution studies show that human influence is responsible for 60% of the climate-related trends in historical streamflow and snowpack in the western U.S from 1950-1999. Nolin and Daly (2006) mapped at-risk snow in the PNW using a rain-snow classification of 0˚C (32˚F) Areas shaded in orange/red are considered to be warm snow and at high risk (figure 4). They found that the Cascade and Olympic Mountain snowpacks were considered to be at highest risk, covering an area of about 9200 km2, and could present adverse impacts not only for summer water supply, but to low elevation ski areas.

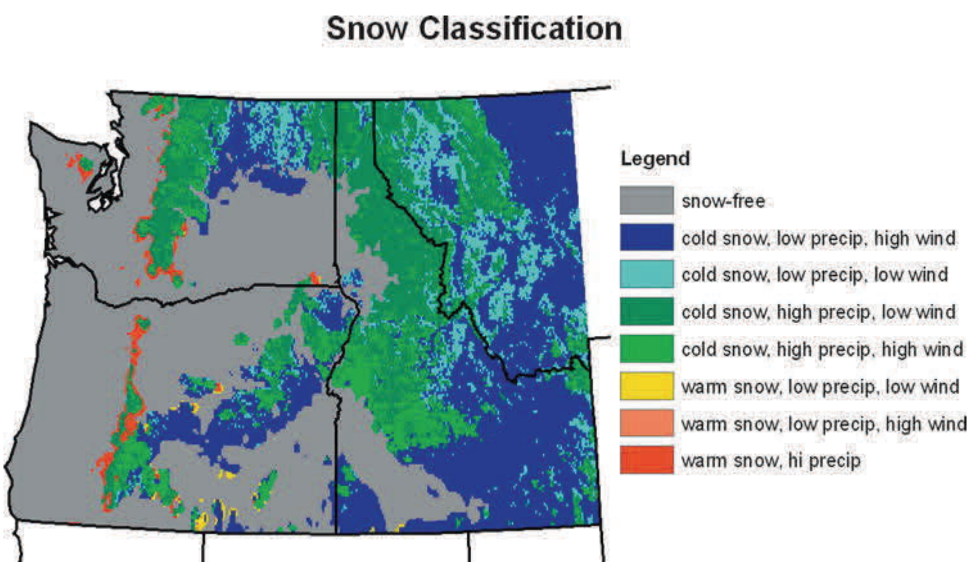


Figure 4. At-risk snow mapped across the Pacific Northwest (Figure from Nolin and Daly, 2006)

Earlier spring snowmelt will shift the timing of peak flows in streams; some streams will peak earlier in the year, as shown at the Willamette River at Newberg, OR in Figure 5. Global climate models also suggest that a decrease in summer precipitation is also likely in the future, which means the small amount of precipitation that the state receives in the summer will be even less in the future.

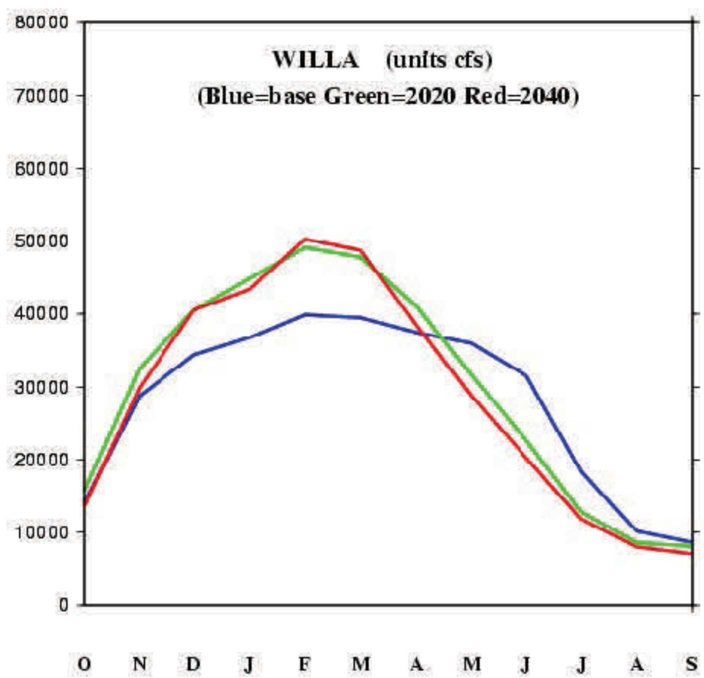


Figure 5. Infiltration Capacity (VIC) model as a part of University of Washington 2860 Project (Hamlet et al. 2010)

A viable water supply is needed for irrigation, residential and commercial water use, fish propagation and survival and overall ecosystem health. With a (1.8 ˚F) 1˚C rise in temperature, the amount and seasonality of water supply is projected to shift with seasonal changes in temperature and precipitation. It is important to note that not all past trends in streamflow can be attributed to global climate change; there is some interannual variability at play. Recent low flow years, particularly 2001 and 2005, stemmed from low winter precipitation. Snowmelt-related hydrologic variables already show a decline in basins with a snowmelt influence - earlier peak flow, lower summer flow, lower spring snowpack.

Cascade mountain snowpacks are projected to be less than half of what they are today by mid-century with lower elevation snowpacks being the most vulnerable. Through the end of the 21st century, April 1 snow water equivalent is projected to decrease in the Willamette River Basin in two emissions scenarios using an ensemble of GCMs from the Coupled Model Intercomparison Project 3 (CMIP3) experiment. There are two emissions scenarios: a1b (carbon intensive) or b1 (more renewables, less carbon intensive). Water demands are projected to increase throughout the 21st century, particularly in urban areas, adding an additional stress to water availability. Some climate change scenarios for the U.S. Pacific Northwest using global general circulation models (GCM) suggest a temperature-induced shift from snow to rain and earlier snowmelt5. Similarly, in the Colorado River Basin, future projections in changes in runoff using a more topographically-complex regional climate model (RCM) are dominated by a combination of winter snow cover change, increase in spring temperature and decrease in summer precipitation.

Other factors such as increased demand will pose an additional stressor to water availability. Water demands are projected to increase throughout the 21st century, particularly in urban areas. Part of the increased demand will likely be due to summer temperatures, and some of the demand can be attributed to overall population growth of the state. Data from Portland Water Bureau shows that there is a relationship between annual average water consumption and annual average temperature. While demand during winter months is expected to remain constant, research on urban water demand suggests that temperature is the most influential climate variable on water consumption, particularly among single family residential households. These impacts are also evident at multiple scales, including the household, neighborhood, and region.

Water quality is also likely to be impacted with rising air temperature and seasonal shifts in flow availability. Water temperatures are expected to rise as air temperature increases in the 21st century, particularly in urban streams where natural riparian vegetation is typically lacking. A decline in summer stream flow will exacerbate water temperature increases, because the low volume of water will absorb the sun's rays more than during times with larger instream flows. However, an increase in air temperature alone does not lead to major changes in stream temperature. Changes in riparian vegetation (either land use changes or climate -related) will influence streamflow and water temperature. Changes in water temperature can have significant implications for stream ecology and salmon habitat. Smaller streams in transient rain-snow basins and in eastern Oregon will be the most vulnerable to increasing summer air temperature and diminished low flows. There is little research on long term trends in water temperature in undisturbed watersheds; sites with long term data are rare. Sediment and phosphorus loads, which are a detriment to water quality, are expected to increase in winter as winter flow is projected to rise. It will be important for water resource managers statewide to include considerations for climate change in future planning.

Simulating future climate.

General circulation models/global climate models (GCMs) are numerical representations of the very complex climate system, including processes in the atmosphere, ocean, cryosphere and land surface. Many models are coupled with an ocean model to better understand the relationship between ocean and atmosphere. We use climate models to better understand how the climate may respond to increasing greenhouse gas emissions.

Climate modeling can be considered similar to a science experiment performed in a laboratory. GCMs are state-of-the-art powerful tools for recreating the earth in a laboratory, or more specifically, a supercomputer. GCMs are subject to rigorous testing, and are run for the 20th century with natural (chiefly volcanic and solar activity) and human forcings (anthropogenic greenhouse gases) and compared against observations to test how well the model can recreate past climate. GCMs are the most powerful tool available for simulating future climate, but the sheer size and computational power required for these to run means that they must do so at a coarse resolution, both horizontally (on the landscape) and vertically (in atmosphere). GCM outputs are used in the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (AR). IPCCA5 is due out in 2013; the last Assessment Report was released in 2007. GCM outputs are often used in seeing how future climate may impact other sectors such as water. Future climate is fed into hydrologic, social, or land-use models, among others.

The latest group of GCM experiments for AR5, the Coupled Model Intercomparison Project 5 (CMIP5): A freely available state-of-the-art multimodel dataset. An integrated set of experiments that offer a perspective on simulated climate change and variability. Hundreds of model simulations of the 21st century are available.

Resolution continues to get better with each set of GCM runs, but GCMs excel at understanding global and large-scale climate change as opposed to smaller-scale, regional change. GCMs can tell the location of the Pacific Northwest on the globe and that there is land bordering an ocean. The coarse resolution of GCMs are unable to capture PNW topography, which plays an important role in PNW climate. To make GCM outputs usable at regional scales, climate scientists use a technique called downscaling. Downscaling attempts to take the large GCM scale and bring them to resolution that is usable for decision-makers and resource managers, who are often operating on a watershed or state scale, and not a global scale. There are two methods of downscaling.

- Statistical downscaling: Uses empirical relationships between large scale global climate model output and local conditions to produce data at a local scale
- Dynamical downscaling: Uses mechanistic models run at high resolution to produce local data.

Greenhouse gas emissions scenarios, or simply emissions scenarios are used as inputs to climate models.The new Intergovernmental Panel on Climate Change (IPCC) AR5 scenarios are now emissions trajectories. These new trajectories, called Representative Concentration Pathway (RCP), are followed by a number indicating the radiative forcing (in watts per square meter) or how much heating they would produce. Higher radiative forcing = more warming.

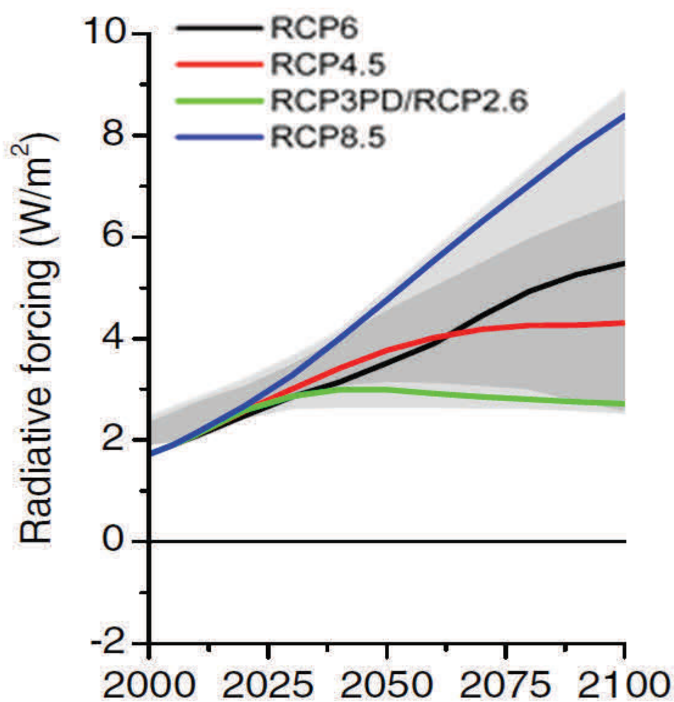


Figure 6. Representative Concentration Pathway total radiative forcing by year in watts/m^2, image from IPCC

RCPs replace the SRES (Special Report on Emissions Scenarios) used in CMIP3 (AR4). The new RCPs are based on consistent socioeconomic assumptions, unlike SRES. Scenarios are meant to be images of a possible future, and are not a forecast. (figure 6).

Four trajectories are used to eliminate the notion that the middle pathway is most likely.

- RCP 8.5: high emissions pathway
- RCP 6: stabilization scenario
- RCP 4.5: moderate reductions pathway
- RCP 2.6: greenhouse gas emissions zero by 2070, and then going negative (mitigation)

Regional climateprediction.net

Supercomputers that run GCMs are very expensive and take great amounts of time to run. Downscaling helps bring coarse GCM output to a more actionable regional level, but the process is still imperfect. Regional climate modeling experiments, either through regional climate modeling efforts such as NARCCAP (North American Climate Change Assessment Program) or innovative science experiments like climateprediction.net can produce simulations of future climate at a level that is useful for regional level planning.

Since 2000, this experiment at Oxford University, climateprediction.net, has made use of the personal computers of over 50,000 volunteers to perform global climate modeling that can answer fundamental questions about the response of global climate to rising greenhouse gases. For the first time, climateprediction.net will perform regional climate modeling for western North America that provides an unprecedented combination of a large ensemble of individual simulations, fine spatial detail, and many output variables relevant to society. Regional modeling provides better spatial detail, which is critically important in mountainous regions and much needed by decision makers. By producing thousands of simulated model futures, this regional experiment will provide detailed answers to key questions about those aspects of climate change that matter most to society: frost days, heat waves, consecutive dry days, extremely heavy rainfall, wind speed, extremely strong wind events, snowpack (figure 7), and coastal upwelling. These answers will be couched in terms of their probability. Changes in these quantities affect agriculture, energy demand, human health, coastal ecosystems, risk of floods, water supply, and many more economic and environmental values.

Regional climateprediction.net (regCPDN) for the western US is housed at Oregon State University, where researchers are receiving 1000s of simulations at a 25km resolution. The period of regCPDN spans 1960-2009 and 2029-2040, using RCP 4.5.

For more information, and to volunteer for the experiment:

http://climateprediction.net/weatherathome

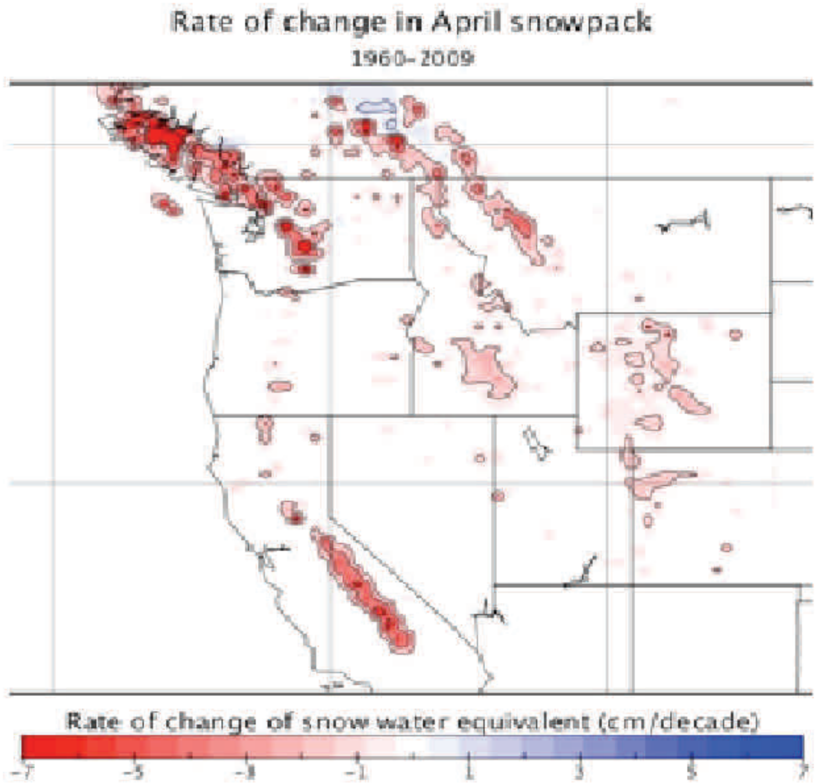


Figure 7. Rate of change in April snowpack, 1960-2009 from regCPDN. Red shows decline in April 1 snowpack from 1960-2009. Figure from David Rupp and Dean Vickers, OCCRI.

CIRC/OCCRI/OCS Water and Climate Projects

- **Willamette Water 2100**

Anticipating water scarcity and informing integrative water system response in the Pacific Northwest

This project is evaluating how climate change, population growth, and economic growth will alter the availability and the use of water in the Willamette River Basin on a decadal to centennial timescale. The project seeks to create a transferable method of predicting where climate change will create water scarcities and where those scarcities will exert the strongest impacts on human society. The five year project began in October 2010, and is a collaborative effort of faculty from Oregon State University, the University of Oregon and Portland State University. It is funded by the National Science Foundation.

http://water.oregonstate.edu/ww2100/

- **Water Utility Climate Alliance (WUCA): Piloting Utility Modeling Applications (PUMA)**

Urban water utilities have taken the lead in considering future climate in their planning activities. WUCA is a group of 10 major urban water utilities The Water Utility Climate Alliance is dedicated to collaborating on climate change issues affecting drinking water utilities. By enhancing climate change research and developing adaptation strategies, water utilities will be positioned to respond to climate change and protect our water supplies

Piloting Utility Modeling Applications (PUMA) is a collaborative venture bringing together Water Utility Climate Alliance (WUCA) members, Regional Integrated Sciences and Assessments (RISA) leaders, and selected representatives of the climate science and applications community. The PUMA project involves 5 major urban water utilities: Seattle Public Utilities, Portland Water Bureau, San Francisco Public Utilities Commission, Tampa Bay Water and New York City Department of Environmental Protection.

CIRC is the lead Regional Integrated Sciences Assessment (RISA) team, and working with Seattle Public Utilities and Portland Water Bureau on their PUMA assessments.

http://www.wucaonline.org/html/actions_puma.html

More on the Pacific Northwest's Climate Knowledge Network:

The Oregon Climate Change Research Institute is a network of over 100 researchers across the Oregon University System and affiliated state and federal labs. OCCRI is housed in the College of Oceanic and Atmospheric Science at Oregon State University.

http://www.occri.net

The Climate Impacts Research Consortium (CIRC) is the NOAA-funded Regional Sciences and Assessment (RISA) for the Pacific Northwest. The Climate Impacts Research Consortium (CIRC) provides information and tools for making decisions about landscape and watershed management in a changing climate.

http://www.pnwclimate.org

The Oregon Climate Service serves as the official state climate office for Oregon as recognized by the American Association of State Climatologists (AASC) OCS is the repository for weather and climate data and knowledge for the state of Oregon, focusing on research, outreach, and service.

www.ocs.oregonstate.edu

References

1. PRISM climate group, accessed at prism.oregonstate.edu
2. Average annual precipitation values from 1981-2010 NCDC 30-year normals
3. Mote P.W. et al., (2010). Overview of Global Climate Change. The Oregon Climate Assessment Report, K.D. Dello and P.W. Mote, eds. College of Oceanic and Atmospheric Sciences, Oregon State University
4. Trend analysis and figure from Office of the Washington State Climatologist, http://www.climate.washington.edu/trendanalysis/
5. Stewart, I. T., D. R. Cayan, and M. D. Dettinger (2005), Changes toward earlier streamflow timing across western North America, J. Clim., 18, 1136–1155, doi:10.1175/JCLI3321.1.
6. Barnett, T.P, D.W. Pierce, H.G. Hidalgo, C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nozawa, A.A. Mirin, D.R. Cayan, M.D. Dettinger (2008). Human-induced changes in the hydrology of the Western United States. Science 319, 1080(2000); doi: 10.1126/science.1152538
7. Nolin, Anne W., Christopher Daly, (2006): Mapping "At Risk" Snow in the Pacific Northwest. J. Hydrometeor, 7, 1164–1171.doi: http://dx.doi.org/10.1175/JHM543.1
8. "Hamlet, A.F., P. Carrasco, J. Deems, M.M. Elsner, T. Kamstra, C. Lee, S-Y Lee, G. Mauger, E. P. Salathe, I. Tohver, L. Whitely Binder, 2010, Final Project Report for the Columbia Basin Climate Change Scenarios Project, http://www.hydro.washington.edu/2860/report/".
9. Mote, P.W. and E.P. Salathé (2010) Future climate in the Pacific Northwest. Climatic Change 102(1-2_:29-50, doi:10.1007/s10584-010-9848-z.
10. Dello K.D and P.W. Mote, 2010. Legislative Summary, Oregon Climate Assessment Report, K.D. Dello and P.W. Mote, eds. College of Oceanic and Atmospheric Sciences, Corvallis, OR
11. Much of this section modified from Dello, K.D. and P.W. Mote, (2010.) Legislative and Executive Summaries, The Oregon Climate Assessment Report
12. Gao, Y. J.A. Vano, C. Zhu, D.P. Lettenmaier (2011). Evaluating climate change over the Colorado River Basin using regional climate models, Journal of Geophysical Research 116 D13104, doi:10.1029/2010JD015278
13. IPCC (2007) What is a GCM? http://www.ipcc-data.org/ddc_gcm_guide.html
14. Taylor, K.E., R.J. Stouffer and G.A. Meehl (2012), An overview of CMIP5 and the experiment of design. Bulletin of the American Meteorological Society, 93, 4
15. Scenarios process for AR5: http://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/RCPs.html
16. OCCRI (2012), About Regional climateprediction.net
17. "USDA ERS - Irrigation & Water Use." USDA ERS - Irrigation & Water Use. United States Department of Agriculture, 19 July 2012. Web. 01 July 2012. <http://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.aspx>.

photo: Columbia River Gorge, Dan Brown

Water and Climate in the Pacific Northwest. A report prepared for the Institute for Water and Watersheds, Oregon State University by Kathie Dello the Deputy Director of the Oregon Climate Service. Assistance from Cally Whitman, Water Research Graduate Assistant, Institute for Water and Watersheds.

Special thanks to the Oregon Climate Change Research Institute, PNW Climate Impacts Research Consortium, College of Earth, Ocean and Atmospheric Sciences, and Oregon State University.

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David Hulse, University of Oregon: Department of Landscape Architecture

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Chadi Sayde, Oregon State University: Biological & Ecological Engineering

Feb 20 *How a footnote in a book by a French Mathematician from the 1800's helped solve a salmon riddle in the Middle Fork of the John Day*
John Selker, Oregon State University: Biological & Ecological Engineering

Feb 27 *The Road to Brown v. the Board of Education...and Beyond: People, Education, and the Environment*
Lisa Gaines, Oregon State University: Institute for Natural Resources

Mar 6 *Novel approaches for examining the environmental fate and transport of engineered nanomaterials*
Jeffrey Nason, Oregon State University: School of Chemical, Biological & Environmental Engineering

Mar 13 *The Role of Wildfire in the Export of Particulate and Pyrogenic Organic Carbon from Small Mountainous Rivers Along the US West Coast*
Jeff Hatten, Oregon State University: Forest Engineering, Resources & Mgmt

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Seminar WRE 507 (CRN 36815)
Journal Club WRE 505 (CRN 34251)

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Water Resources Research at the Interface of Science and Policy

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Oct 3	**Salmon: A crucible for translational ecology in the Pacific Northwest** Denise Lach, OSU, School of Public Policy
Oct 10	**Beyond the Foundation: Achieving Robust Durability in Watershed Collaboratives** Ed Weber, OSU, School of Public Policy
Oct 17	**The Role of the Federal Government in Water Resource Law and Policy** Adell Amos, University of Oregon, School of Law
Oct 24	**Taking on Water: Challenging the Inner Hypocrite** Wendy Pabich, Water Futures Inc.
Oct 31	**Public Utilities and Corporations: the next love story?** Sally Duncan, OSU, School of Public Policy
Nov 7	**Water scarcity in hydro-economic models: Comparing Willamette Water 2100 and the Klamath** William Jaeger, OSU, Department of Agricultural & Resource Economics
Nov 14	**Rivers of Ideas: Keynes' dams, Hayek's meanders, and Aristotle's regimes** Martin Doyle, Duke University, Nicholas School of the Environment
Nov 28	**Social-Ecological Dynamics in Residential Landscapes: Water Conservation, Tradeoffs and Complexities** Kelli Larson, Arizona State University, Schools of Geographical Sciences and Urban Planning and Sustainability

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USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	2	1	0	0	3
Masters	5	0	0	0	5
Ph.D.	1	0	0	0	1
Post-Doc.	0	3	0	0	3
Total	8	4	0	0	12

Notable Awards and Achievements

IWW awarded funding for International Projects Leader Richard Meganck to continue work for the **International Center for Integrated Water Resources Management (ICIWaRM)**, a UNESCO Category 2 water center headquartered at the U.S. Army Engineer Institute for Water Resources (IWR). Dr. Meganck continues his work as a member of the U.S. National Commission to UNESCO by Secretary Clinton.

IWW Collaboratory demand holds steady from a sample count of 2,250 in 2008 to 10,325 in 2011, but drops to 7,070 in 2012. Number of users (departments, entities) remains at about 22 to 25 over same period.

IWW selected by OregonBEST for commercialization grant on Stormwater Treatment using UV-activated Nano-meshes manufactured by Oregon-based water treatment company Puralytics. Watch the television report here:
http://www.kgw.com/video/featured-videos/Solar-nano-lily-pads-may-help-solve-water-pollution--206363561.html

IWW interim Director Todd Jarvis and co-PI Aaron Wolf selected to offer Training Module on Transboundary Negotiation And Divergence Management Skills by the **Mekong River Commission Secretariat**.

IWW receives a **letter of intent for a joint initiative on water and peace** from UNESCO-IHE Institute for Water Education, Delft, The Netherlands.

Eastern Oregon rancher bequeaths $10,000 to IWW for research on water scarcity and water quality in eastern Oregon. Selected project is **arsenic in groundwater** to be co-investigated by the new OSU School of Public Health.

Theo Dreher of Oregon State University and Jennifer Graham, U.S. Geological Survey were awarded funding through the **NIWR/USGS National Competitive Grant (104(g)) Program** for their proposal "Biological Drivers of Freshwater Cyanobacterial Harmful Algal Bloom Extremes Assessed via Next-Generation DNA Sequencing Technology;"

Three Water Resource Graduate Program Students earn prestigious awards:

- Kim Ogren from the Geosciences Department received and Luke Pangle from the Forest Engineering Management and Resources Department received 2012-2013 AWRA Herbert Scholarships.
- Allison Danner won the top student poster award at the 3rd Annual NW Climate Science Conference for her poster about Cougar Dam work.

OSU's **Natural Resources Leadership Academy** won the Best Credit Program and the Best Overall Program awards at the Western Association of Summer Session Administrators Conference. The Water Resources Graduate Program participated in the Academy through WRP 521 - Water Conflict Transformation taught by Aaron Wolf and Todd Jarvis. The intent was to give professionals and graduate students a unique opportunity to enhance leadership skills, gain knowledge and connect with others in natural resources fields. The intensive two-week nature of the NRLA attracted dedicated graduate students and professionals from 10 states – including New York – and two countries, Jordan and South Korea.

Publications from Prior Years

1. 2009OR1178 ("A Local Assessment of Abandoned Wells in Linn and Benton Counties") - Articles in Refereed Scientific Journals - Jarvis, W.T. and A. Stebbins, 2012, Examining Exempt Wells: Care for exempt wells provides opportunities for the water well industry, Water Well Journal, Sept. 2012, http://waterwelljournal.org/2012/09/examining-exempt-wells/