Groundwater Session
Marshall W. Gannett, Chair
Tuesday, May 24
9:30 AM – 5 PM

How Much Groundwater does a Wetland Need? Setting Ecological Water Requirements for Groundwater-Dependent Ecosystems

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ABSTRACT

Many freshwater ecosystems are sustained by a continuous supply of clean groundwater. For example, groundwater may provide late season baseflow to rivers or a sustained high water table in wetlands. These ecosystems, termed GDEs, often are affected by management activities that reduce, interrupt, or contaminate their groundwater supply, including groundwater pumping and waste disposal. Despite these issues, no methods exist to set limits to groundwater extraction or contamination to protect these ecosystems. To address this need, The Nature Conservancy and USDA Forest Service are developing methods for setting thresholds to groundwater change, termed Ecological Water Requirements. Here we discuss this method applied to three wetlands from which water is extracted to water livestock in the Fremont and Winema National Forests.

We evaluated the Ecological Water Requirements for GDEs in two steps. First, we developed empirical relationships between the groundwater-driven hydroperiod, and two key ecological parameters: indicator plant distributions and peat accretion. We did this by collecting data on hydroperiod fluctuations, species distributions, and peat depths. We then used these quantitative relationships to determine water table thresholds beyond which these ecological parameters could be impaired. Second, we used MODFLOW to evaluate the potential dewatering effects of pumping on these wetlands. A 4-layer model was constructed (peat, muck, pumice, bedrock). The muck is simulated as a thin, leaky confining layer between the peat and pumice. Pumping was simulated in the pumice layer to evaluate effects to water table depth in the peat. This was compared to the threshold data obtained in the first step.

We identified 14 indicator species and peat accretion rates which only occur where the depth to water table was less than 15cm, thus we established this as our threshold for the model. Hydraulic parameters were varied, but for each scenario, pumping at predicted rates of 0.009 L/sec for 75 days produced a maximum drawdown in the peat that did not exceed the 15cm drawdown threshold. These data are being used to inform grazing management on this national forest. We plan to refine these methods to help evaluate ecological water requirements more broadly in a variety of settings.

Keywords: Groundwater; GDE; Ecological water requirements; Wetland; Peatland

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OR Chapter, American Water Resources Association and OR Section, American Institute of Hydrology

Managing Ecological Water Requirements for Groundwater-dependent Wetlands on National Forests: A View from the Bottom Up and the Top Down

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ABSTRACT

The USDA Forest Service and The Nature Conservancy are collaborating on developing a method for setting Ecological Water Requirements (EWRs) for groundwater-dependent wetlands on National Forests and Grasslands to inform groundwater management from the site to the national scale. This method is one piece in a growing Forest Service groundwater resource management program across the United States. The Forest Service has responsibility for management of more than 190 million acres of National Forests and Grasslands located in 42 states and Puerto Rico. In Oregon, approximately 25 percent of the land is managed by the Forest Service. Water from National Forests and Grasslands provides irreplaceable high quality habitat for aquatic, riparian, and terrestrial species, and a sustainable supply of water for humans. In the Western United States, over 65 percent of the water supply for domestic, agricultural, and industrial uses comes from National Forests. The need for a more comprehensive view of water resources is now critical. Until recently, the focus of Forest Service water management has been above ground, but attention has turned to including subsurface flows and groundwater resources. The Forest Service groundwater resource program is organized around management of groundwater-dependent ecosystems (GDEs). Considering the water needs of these GDEs is important to protect and sustain these ecosystems. Methods for determining EWRs for GDEs, is one piece of the inventory and monitoring component of the groundwater program. National protocols for two levels of inventory, broad level characterization and project level support, are completed. Field tests at five pilot sites across the country were completed in 2010. Level 3 Inventory and Monitoring and EWR protocols are under development. The methods for determining EWRs are being developed and tested as part of a grazing management plan revision on the Fremont-Winema National Forests. The concepts and lessons learned will be tested in other settings and refinement of the approach will translate into the National EWR protocol.

Keywords: Groundwater dependent ecosystems; Ecological water requirements, Forest Service; The Nature Conservancy; Management

A Collaborative Effort to Evaluate Water Resources in the Lower Siuslaw Watershed

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ABSTRACT

The City of Florence, local stakeholders, and partner agencies recently formed the Siuslaw Estuary Partnership (SEP) to address threats to drinking water quality and fish and wildlife habitat in the lower Siuslaw watershed. The Sole Source Dunal Aquifer within the lower Siuslaw watershed, which supplies the City 's drinking water, is characterized by rapid infiltration, a shallow water table, and hydrologic connection with area streams, wetlands, and the estuary. These characteristics make the watershed highly susceptible to contamination from surface activity in Florence, the only major urban center in the watershed, and to climate change. Possible sources of aquifer contamination include fuel storage tanks, septic tanks, stormwater runoff, pesticides, and fertilizers. Potential effects from climate change include altered precipitation patterns that increase winter flooding and decrease summer stream flows, increased air and surface water temperatures, and rising sea levels.

The SEP is funded by a 3-year US EPA grant and its objectives are: to collaborate, to conduct scientific investigations, to foster public education and stewardship, to protect water quality and quantity, to plan for ecological growth, and to protect wetlands, riparian areas, and key estuary wetlands. Many of these objectives led to a groundwater and surface water monitoring program to collect baseline data on water quality and quantity. A groundwater flow model was developed to provide hydrogeologic constraints. Sampling of 10 groundwater wells, located to reflect differing land uses and position along groundwater flow paths, and 2 streams began in October 2010 and will continue through November 2012. Parameters sampled regularly in one or both of the water types include: water temperature, conductivity, dissolved oxygen, pH, ORP, turbidity, *E.coli*, groundwater level, and stream flow. Periodically sampled parameters include nitrate, phosphates, volatile organic chemicals, inorganic chemicals, glyphosate,2,4-D, and caffeine. The SEP plans to use the data collected to respond to any contamination discovered, to monitor water quality and quantity over time, to develop sustainable water management practices, and to plan for potential future impacts of climate change. This initiative provides a model for addressing threats to water quality and fish and wildlife habitat using collaboration and scientific investigation.

Keywords: Groundwater; Surface water; Monitoring; Collaboration

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Hydrologic Monitoring and Trends in the Upper Klamath Basin over the Last Decade

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ABSTRACT

Over the last decade hydrologic monitoring efforts in the Upper Klamath Basin (UKB) of Oregon have increased in response to the continued strain on surface water and groundwater to meet competing biological and agricultural demands. The Oregon Water Resources Department (OWRD) increased its stream gaging network from three to ten gages, and approximately 80 long–term sites were added to the OWRD and US Geological Survey (USGS) well monitoring network to track both anthropogenic and climate related stresses to the hydrologic system. The expanded monitoring effort accompanied several hydrologic studies to better understand the basin hydrology. A major result of the hydrologic investigations was to quantify groundwater/surface water interactions in the UKB (e.g., Gannett, et. al. 2007). For example, the estimated gross groundwater discharge in UKB is roughly 2600 cubic feet per second (cfs), of which 1800 cfs occurs into or above Upper Klamath Lake—approximately 70 percent of the lakes' gross annual inflow.

Data collected over the last 10 years demonstrate that dry climate conditions persist in the UKB. Recorded precipitation at Crater Lake reveals below normal precipitation in seven of the last ten years. Although near normal precipitation has occurred in the last few years, this trend has only halted not reversed the decadal decline in summer baseflows and groundwater levels at most monitoring locations above Upper Klamath Lake (UKL). The trends in stream baseflows generally follow groundwater levels observed in nearby wells. Most monitoring locations reflect hydrologic lows similar to or slightly above the droughts of 1992 and 1994. USGS stream gages operated on the lower Sprague and Williamson Rivers reflect baseflows similar to those encountered during the drought of the late 1930s and early 1940s.

Below UKL, anthropogenic stresses are more prominent than climate influences on streamflow and groundwater. Streamflow below Link River Dam is entirely regulated. Groundwater monitoring shows the added pumping stresses from expanded use since 2001 have locally produced 15 to 20 feet of decline in the Klamath Valley and Tule Lake sub basin. The increased groundwater pumping has also resulted in a greater amount of seasonal fluctuation.

Keywords: Upper Klamath Basin; Hydrologic monitoring; Hydrologic trends; Anthropogenic stress

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Assessing Streamflow Response to Climate Change: Why Geology Matters

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ABSTRACT

Climate change will continue to profoundly affect water supply and aquatic ecosystems in the Pacific Northwest. Changes such as warmer air temperatures, increases in the proportion of winter rain versus snow, reduced spring snowpack, and earlier snowmelt all affect streamflow. The response to these climate impacts includes earlier runoff peaks, decreased baseflows, increased summer water temperatures, and increased winter flooding from rain on snow events. Developing effective adaptation strategies to address these impacts requires knowledge on the climate vulnerability of stream ecosystems.

Not all streams in the region respond similarly to the same climate signal. Two important landscape factors influencing the streamflow response to climate are elevation and geology. Elevation and its effects on air temperature and the form of winter precipitation are widely recognized. It is generally thought that basins at intermediate elevations on the cusp of rain-snow transitions will be most susceptible to warmer winter temperatures and reduced snowpack. Less attention has been given to geology and the partitioning of hydrologic flowpaths between surface and sub-surface flow. This partitioning affects summer/fall baseflow volumes, the timing and attenuation of the snowmelt peak, water temperatures, flooding and geomorphic characteristics, and ultimately, the streamflow response to climate.

This study explores some of the streamflow characteristics and responses of groundwater-dominated versus surface-dominated streams to climate and climate change. Baseflows are much greater in groundwater streams and are seasonally very important for sustaining downstream mainstem flows during summer. But these same flows may also be more susceptible to reduced snowpack and earlier snowmelt. Summer water temperatures in groundwater streams are generally cooler and may be less sensitive to warming air temperatures. Flooding risks from rain-on-snow events may be lower as well, since streamflows in these systems are generally more stable and less flashy than in surface-dominated streams. The unique characteristics and responses of groundwater streams demonstrate the importance of considering geology as well as elevation when evaluating streamflow response to climate change, both past and future.

Keywords: Climate change/variability; Rivers/streams; Klamath Basin; Groundwater hydrology; Surface water/Groundwater interactions; Base flow reductions; Upper Klamath Lake

What Will Oregon's Future Streamflow Regimes Look Like? Integrating Snowpack and Groundwater Dynamics.

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ABSTRACT

Spatial patterns of summer streamflow in the Cascade Mountains of Oregon vary dramatically between the geologically distinct High and Western Cascade regions. A key control is the partitioning of water input between a fast-draining shallow subsurface flow network (Western Cascades) versus a slow-draining deeper groundwater system (High Cascades). These differences result from large contrasts in rock permeability, porosity, and drainage density between landscapes dominated by the older Western Cascade versus younger High Cascade volcanic rocks.

How do these geologically-based differences in groundwater storage capacity affect streamflow response to projected climatic warming? We initially expected that for the High Cascades of Oregon and Northern California, large groundwater storage will lead to groundwater recharge independent of precipitation type (rain or snow), thereby buffering low flows against potential changes in snowpack volume due to warming climate. We also expected that low groundwater storage in the older volcanic and granitic landscapes of Oregon and California will result in greater sensitivity to diminished snowpacks and summer streamflow changes.

By coupling simple theory with hydrologic modeling, we found that interpreting low flow response to warming involves a convolution of both the snowpack and groundwater dynamics. Using this approach, the High Cascades displays much greater low flow sensitivity to climate change than the Western Cascades. Because the High Cascades discharge groundwater throughout the summer season, both timing of recession and annual fluctuations in total precipitation are reflected in changes in late summer streamflow. The Western Cascades in contrast, displays much less late season sensitivity to changing climate; streamflow is always very low in late summer regardless of winter recharge. We extend these results across the entire western Cordillera and consider implications for water supply in the future. These results imply that current models linking climate and streamflow changes need to account for differences in groundwater storage as a first-order control.

Keywords: Streamflow; Oregon; Climate Warming; Snowpack; Dynamics; Groundwater

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Sensitivity of Oregon Watersheds to Streamflow Changes Due to Climate Warming: A Geohydrological Approach

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ABSTRACT

A key challenge for resource and landscape managers is to predict the consequences of climate warming on streamflows and water resources. Different approaches are being developed to forecast the direction, magnitude, and timing of future streamflow changes in specific landscapes. One approach that is being utilized in the Pacific Northwest involves coupling downscaled climate predictions to macroscale hydrologic models, such as the Variable Infiltration Capacity (VIC) model. VIC is typically parameterized and calibrated in selected watersheds, and then applied to a regional scale that includes larger population of uncalibrated watersheds.

Summer streamflows are sensitive to both changes in the timing of snowpack accumulation and melt, and intrinsic, geologically-mediated differences in the efficiency of landscapes in transforming recharge (either as rain or snow) into discharge. Here we explore the importance of this effect by using geologically focused "bottom-up" approach to empirically characterize the sensitivity of late-summer streamflows to climate warming for a range of basins across Oregon. We define sensitivity as the slope of the relation between annual precipitation and summer streamflow, characterized as 7-day low flow and total summer flow. Drainage efficiency was defined in terms of the: 1) rate of recession (K) of the streamflow hydrograph; and 2) ratio of base flow to total flow (Base Flow Index or BFI). We compare our sensitivity results with those derived from VIC simulated streamflow.

Using the bottom-up approach, we found that the both K and BFI are good predictors for streamflow sensitivity to climate change. Fast-draining basins (high K / low BFI) are much less sensitive to changes in annual precipitation, whereas slow-draining basins (low K / high BFI) are much more sensitive. For basins where VIC was calibrated, downscaled VIC simulations are similar to empirical data. Uncalibrated basins, however, do not show a clear relationship with drainage efficiency, meaning that VIC may under predict sensitivity of summer stramflows to climate change in uncalibrated groundwater-dominated watersheds. This implies that spatial heterogeneity in aquifer properties must be explicitly incorporated into parameterization and calibration schemes if the full range of hydrologic response to warming is to be captured across the landscape.

Keywords: Climate change: Geologic framework, Streamflow

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GIS and Wells: An Examination of Groundwater in Benton County by Georeferencing Well Logs

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ABSTRACT

A major challenge in understanding groundwater use, including exempt well use of groundwater, is the spatially disconnected nature of most groundwater studies. While individual consultants or contractors may be able to determine large amounts of information about the local subsurface at their work sites, little work has been performed to connect their local knowledge to an understanding of entire formations. Remarkable efforts put forth in the past decade by the USGS and OWRD have provided this type of understanding for the major formations in the Willamette Valley, but little has been done since the 1970's USGS Professional Papers to aggregate regional groundwater knowledge for the majority of relevant hydrogeologic units across the state.

However, the rapid advances in GIS and digital imagery over the past decade allow new opportunities to investigate hydrogeology at the aquifer scale. First, the Oregon Water Resources Department has painstakingly digitized well log information across the state, making these data available for investigation (including scanned copies of the original logs) based on spatial queries. Second, documentation to georeference domiciles has continued to improve, including historical addresses. Third, digitized geologic maps allow geographic subsetting of the well dataset into hydrogeologically-relevant categories. These converging advances allow for statistical analysis of the geographic variability across and within water-bearing formations.

Well data for Benton County have been georeferenced using an aliquot grid and identified address. These data have been spatially investigated using GIS to understand variability of initial depth to water, post static water level, specific yield, and specific capacity. While the resulting coverages need to be considered in conjunction with site-specific consultant reports, output maps are relevant to drillers and planners for the purposes of zoning and development. In particular, spatial analyses of this type are useful for examining hydrogeologic differences between adjacent formations.

Keywords: Groundwater; Hydrogeology; GIS, Well logs; Siletz River volcanics

Groundwater Storage and Flow in an Unconfined Pumice Aquifer, Antelope Unit, Chemult Ranger District, Winema-Fremont National Forest, Oregon

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ABSTRACT

The study area lies north-northeast of Crater Lake National Park and is covered by 2 to 3 m of pumice deposited during the climactic eruption of Mount Mazama approximately 7700 years before present. The pumice deposit hosts unconfined, seasonally connected, perched aquifers that support groundwater dependent ecosystems at points of discharge in the 80 km^2 study area. Sparse bedrock outcrops are dominated by basalt lava flows, but cores from groundwater monitoring wells at four sites contain abundant moderately to weakly indurated, interlayered basalt hydroclastic- and pyroclastic-flow deposits, and matrix-rich tuff breccia. Although some water may enter the unconfined pumice aquifer from flow paths within bedrock units, the lithologies encountered in wells and little to no water in piezometers screened in bedrock suggest little contribution to the unconfined aquifer from bedrock-hosted flow paths.

Pre-Mazama surficial deposits are the local base or may locally augment storage in the unconfined aquifer. The distribution of these deposits is strongly influenced by the pre-eruption topography with poorly to moderately well sorted silt- and clay-rich sedimentary deposits common in pre-eruption valleys and shallow, bed-rock controlled depressions. Post-eruption landscape response included erosion of pumice with valley bottoms cut into pumice, pre-eruption surficial deposits, or bedrock. Where pumice is preserved, the coarser-grained upper pumice unit (moderately to poorly sorted coarse lapilli to blocks) has been removed and the erosion surface is cut into the finer-grained lower pumice unit (well-sorted, fine to coarse lapilli). This early-formed erosion surface is commonly buried by alluvium consisting of crystal-rich sand near the lower contact grading upward to rounded pumice-bearing glassy silt, silty sand, and pumice gravel. The contacts between the alluvium and valley walls cut into pumice deposits are commonly iron stained and locally intensely cemented by iron oxide. In some pre-eruption valley configurations, alluvial fans composed of glassy-silt, crystals, and rounded pumice extend across the valley bottom and overlie the complete pumice section. These deposits are 1.0 to 1.5 m thick in some fans.

Recharge of the unconfined pumice aquifer occurs during spring snow melt from direct contribution by snow melting on valley floors and upland depressions, runoff from partially frozen ground, and shallow flow paths in the pumice blanket. Once in the unconfined pumice aquifer groundwater may infiltrate to deeper levels, be consumed by evapotranspiration, migrate through the aquifer along seasonally connected flow pathways, or return to the surface at fens and springs. Where the water table within the pumice is within approximately 1 m of the surface during the dry season, grasses and sedges are common in well-vegetated meadows. Where year-round discharge takes place, fens characterized by high biodiversity and peat deposits are present. The location of these discharge sites appears to reflect ongoing response of the landscape to the eruption of Mount Mazama. At the discharge points, water is consumed by evapotranspiration through lush and diverse vegetation communities, evaporates, or infiltrates back into the unconfined aquifer down valley.

Groundwater temperature may provide an inexpensive way to define flow pathways in the unconfined pumice aquifer and to detect contribution of ground water contributed from deeper seated flow pathways in bedrock. Two monitoring sites, one at the Wilshire fen and the other at the Johnson Meadow fen, suggest cooler water entering the unconfined pumice aquifer in late summer.

Keywords: Groundwater; Pumice; Unconfined aquifer

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Surface Water Interaction with "Confined" Columbia River Basalt Aquifers – Impacts to Streams from Declining Groundwater Levels near Mosier, Oregon

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ABSTRACT

Columbia River Basalt Group (CRBG) aquifers are commonly thought to be relatively flat lying, laterally extensive, and mostly confined, and therefore not likely to be directly connected to surface water. However, many of the CRBG units in south-central Washington and north-central Oregon were deposited within evolving synclinal structures of the Yakima Fold Belt. The synclines hosted drainage systems that interacted with the encroaching lava flows, resulting in enhanced porosity and permeability where the flows encountered water or wet sediment. The geometry of the synclines also constrained the lateral extents of the lava flows.

Modern streams within the synclines have exposed some of the permeable flow contacts and locally allowed connectivity between the streams and aquifers. Where the elevation of the hydraulic head in the aquifer is above the elevation of the exposed contact, the aquifer typically discharges to the stream. Historically, this was the case in Mosier Creek.

In confined ($S= 10^{-4} – 10^{-5}$) and syncline-controlled ground-water flow systems like that near Mosier, seasonal and long-term changes in hydraulic head in aquifers can propagate rapidly to stream/aquifer boundaries. For example, as hydraulic head in the Mosier groundwater flow system declined over 150 feet in the last 4 decades, Mosier Creek has gone from a gaining stream to a losing stream in the vicinity of the exposed contacts. The exposed contacts in Mosier Creek represent head-dependent boundaries to the Mosier groundwater flow system.

Hydraulic head decline in the Mosier area is due to depressurization of aquifers by interaquifer flow through uncased sections of wells, and overdraft conditions in one of the aquifers. But regardless of the decline mechanism, any head decline in a CRBG aquifer connected to a gaining stream will result in diminished streamflow.

Keywords: Groundwater; Columbia River Basalt; Groundwater/surface water interaction

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Coupled Simulation and Optimization Models for Managing Groundwater in the Upper Klamath Basin, Oregon and California

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ABSTRACT

Managing limited surface water in the Klamath Basin of Oregon and California to satisfy needs of both agriculture and aquatic wildlife has been a challenge for resource managers in recent years, as well as a source of considerable contention. In the past decade, groundwater has been used (heavily at times) to supplement overtaxed surface water supplies, and groundwater use is being considered as part of a long-term water management strategy. Supplemental groundwater pumping, however, has the potential to diminish already stressed surface water supplies and to result in seasonal and long-term groundwater level declines.

Developing a groundwater management strategy, therefore, requires the ability to predict the temporal and spatial distribution of pumping-related drawdown and impacts to hydrologic boundaries such as streams, springs, lakes, wetlands, and agricultural drains. Also required is a method for efficiently determining the optimal groundwater pumping strategy with which to meet resource management objectives without causing impacts that are unacceptable to the community or in violation of water law.

To meet this need, the U.S. Geological Survey and the Oregon Water Resources Department have collaboratively developed a regional groundwater flow model of the 8,000 square mile upper Klamath Basin and a coupled groundwater management model that employs methods of constrained optimization. Initial work has provided information on the tradeoffs between pumping volumes, seasonal and long-term drawdown, and impacts to surface water, and suggests that useful volumes of groundwater can probably be pumped with minimal interference with existing uses. Initial work has also quantified impacts to agricultural drains (which are water sources for some irrigators and wildlife refuges) that may represent an unanticipated, and not fully understood, constraint on groundwater pumping.

Keywords: Groundwater modeling; Groundwater management, Optimization, Klamath Basin