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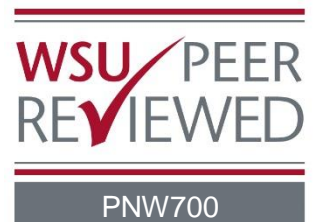
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A COMMUNITY-BASED RESPONSE TO FLOODING: JAY GORDON

FARMER-TO-FARMER CASE STUDY SERIES: INCREASING RESILIENCE AMONG
FARMERS IN THE PACIFIC NORTHWEST



A COMMUNITY-BASED RESPONSE TO FLOODING: JAY GORDON

By

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Abstract

Jay Gordon is a dairy farmer in Elma, WA, and the director of government relations and policy for the Washington State Dairy Federation. After recent frequent and severe flooding events, he has been working with others in his community to develop a strategy for lessening the impacts of future flooding in their watershed. The importance of active consensus-building, high-quality research partnerships, and having the capacity to support these efforts are key lessons he thinks can help other communities coping with climate change and water-related issues. See the [video](#) that introduces Gordon and describes his experience with flooding and helping to organize a response in the Chehalis Valley where he lives and farms.

This case study is part of the Farmer-to-Farmer Case Study project, which explores innovative approaches regional farmers are using that may increase their resilience in the face of a changing climate.

Case study information is based on growers' experiences and expertise, and should not be considered as university recommendations. Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement. Grower quotes have been edited slightly for clarity, without changing the meaning.

Readers interested in other case studies in this series can access them on the [REACCH website](#) as well as in the [WSU Extension Learning Library](#).

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A Community-Based Response to Flooding: Jay Gordon



Photo: Darrell Kilgore.

Location: Elma, WA

Annual Average Precipitation: 69 inches

Agricultural System: dairy and crops (both organic and conventional)

See the video that introduces Gordon and describes his experience with flooding and helping to organize a response [here](#).



Map: Kaelin Hamel-Rieken, Washington State University.

Introduction

Jay Gordon is a sixth-generation dairy farmer in Elma, WA, and the director of government relations and policy for the Washington State Dairy Federation, an organization he has helped lead since 2000. These two roles have given him a unique perspective on water-related issues, informed both by first-hand experience and a state-wide perspective.

Gordon generally milks between 100 and 140 cows on a dairy farm that he describes as similar to many other small dairies in southwest Washington (Figure 1). The dairy and associated cropland covers about 900 acres, both leased and owned. The farm grows a variety of organic and conventional crops, predominantly on Chehalis silt-loam clay soils (NRCS 2013). The region receives an average of 69 inches of precipitation annually, much of it from October to April. In addition, Gordon’s crops benefit from two reliable irrigation wells, essential water sources from roughly mid-May through the end of October, when there is little rain.



Figure 1. Dairies in southwest Washington have a strong history of pasturing animals, supported by seasonally-plentiful grass. Photo: Darrell Kilgore.

His dairy farm is located in the Chehalis River Valley, a watershed in western Washington State that drains 2,660 square miles. Along with about 30 other dairies, the Valley is also home to an increasing number of other farms, growing crops that include blueberries, raspberries, vegetables, corn, hay, and grain.

Historical Floods

Gordon’s ancestors first landed in the area by canoe in 1872, roughly a mile and a half from his current barn and house. They built two homestead cabins in the first year, right near the river. And as Gordon says, “the first winter they found out they didn’t quite build high enough... They relocated their homestead cabin very quickly to a little higher ground (Figure 2).”



Figure 2. After surviving flooding during their first year homesteading the land in 1872, Gordon’s ancestors built their house on higher ground, right near the barns in the background. Photo: Darrell Kilgore.

Gordon’s great-grandfather or grandfather planted a cherry tree that came to represent the historical flood mark (Figure 3). “The base of that cherry tree was the marker for where floods got to, going back to the early 1900s...and we built buildings and houses to that mark...above that, your buildings, capital investments, were going to be safe. And if you were building below those marks, you were an idiot.”



Figure 3. Gordon indicates the mark on the cherry tree that shows the highest level that water reached during historical floods. Photo: Darrell Kilgore.

A New Pattern to Floods

After fairly typical floods during the winters of 1990 and 1991, 1996 was different, as Gordon describes. “It was about a foot higher on our farm. It got up into places we’d never seen. And I think we all went, ‘Okay, there’s the big one.’ It was a classic snow with a melt and a Chinook and a rain that wouldn’t quit. And the area had a lot of logging at that time...so the local wisdom was, well, there weren’t a lot of trees left in the hills and that made the flooding worse than usual... Let the replant grow and we’ll be fine.”

However, flooding in 2007 surpassed the water volume in 1996 by a significant margin (Figure 4). “The ‘07 storm, they called it a horizontal hurricane. It came in, sat with a low pressure and it parked between here and the coast. 132-, 134-mile-an-hour winds I think were clocked out at the coast... That flood clearly was very different.”



Figure 4. The December 2007 flood in the Chehalis Valley caused widespread flooding throughout Gordon’s farm. In these fields, water reached approximately to the level of the hand railing. Photo: Darrell Kilgore.

Of the roughly 30 dairies that were in the Chehalis Valley at the time, 19 were flooded. Six of these dairies experienced severe flooding, losing barns, milking parlors, or equipment. Two farms lost all their cows when animals were trapped in barns that historically had been high enough to escape flooding.

Of the six farms that had the most severe flooding, two did not rebuild. And among the rest, “It was months to put those farms back together. The two that lost all their cows, it took the better part of a year, year and a half. We had donations of cows to repopulate the herds. They had to rebuild their barns.”

Meanwhile, the dairies were not the only farms that suffered impacts. Vegetable farmers in the upper Valley received “a foot, a foot and a half of silt on their farms, and the flood took all their greenhouses, their barns, their possessions, flooded their tractors (Figure 5).”



Figure 5. Irrigation equipment damaged during the flood. Photo: Conservation Commission, via Flickr (Creative Commons License).

Even among farmers who have rebuilt, or who escaped the worst of the flooding, Gordon says there continue to be impacts. “The longer-term effect of this you see in the eyes of those families in the upper Basin... Am I being smart to rebuild? Am I throwing good money after bad? We now don't know how high the floods actually get. It really was hubris to think that we did. And so now... most of them will tell you if it floods again like that they're done. It's too much work to rebuild a farm and drain water out of engines and pick up dead animals and bury them, rebuild a house... And so the effect really here is that people ask, ‘Is it safe to have a farm as an investment in this Valley now?’”

The historic 2007 flood was followed by another significant flood event in early 2009, similar in size to the 1996 flood.

More frequent, and particularly more severe floods, have caused area residents to take notice. Of the five largest floods historically, four have occurred since 1990 (see the *Flooding in the Chehalis Valley*

sidebar). “There’s only so much that an individual farmer can do to be prepared for the “next one.” Gordon explains, “We have enough information that, as prudent people, we need to start thinking about acting. Maybe we won't get another big one for 20 years. Maybe it'll be two years. But looking at the last five floods since '90, we really as a community up and down the Valley have said we got enough information that it's time to act.”

A Community Response for the Future

After some initial conversations with the Army Corps of Engineers, the focus of the long-term response has been at the local and state level. As Gordon puts it, “We, as a community, needed to do some arm wrestling and find a path, and so a lot of work was put into bringing groups together that had traditionally not worked together.”

Much of the local response activity has been organized through the Chehalis Basin Partnership (Partnership) and the Chehalis River Basin Flood Authority (Flood Authority). This partnership includes a wide range of county and municipal jurisdictions up and down the Chehalis Valley, along with the Chehalis Tribe, the Quinault Indian Nation, public utility districts, port districts, non-governmental interests (agriculture, fisheries, environmental, business), state agencies, and citizen representatives from each county. The Partnership has been working together since 1998 to assess, plan, and manage the Basin’s water to sustain viable and healthy communities and habitat conditions necessary for native fish.

The Flood Authority was created in 2008, in response to the 2007 flood's impacts. This entity convenes 13 local governments (cities and counties across the Chehalis Basin). Their focus is two-fold: improving the flood warning system across the Basin, and helping their member jurisdictions fund and implement local projects that improve flood preparedness.

Flooding in the Chehalis Valley

Sonia A. Hall, Center for Sustaining Agriculture and Natural Resources, Washington State University

Jay Gordon's account of floods in the Chehalis Basin suggests that flood dynamics may be changing. Relevant data has been collected by the U.S. Geological Survey (USGS) starting in 1940, and is freely available through their National Water Information System website (USGS 2016). These data include streamflow data for the Chehalis River near Doty. These data show that four of the largest five annual peak flows have occurred since 1990, and that the 2007 peak was more than twice that of the highest previously recorded peak flows (Figure 6).

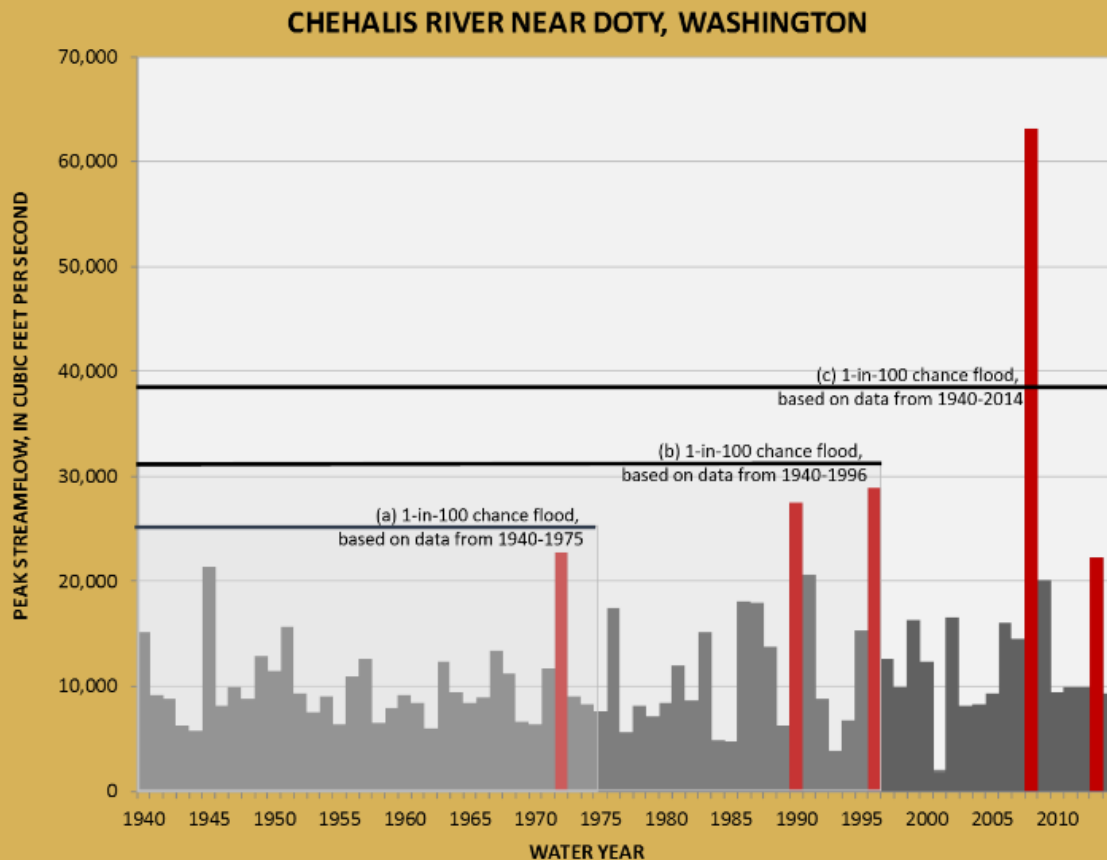


Figure 6. Peak annual streamflow data, from 1940 to 2014, collected by the U.S. Geological Survey at a stream gauge near Doty, Washington, on the Chehalis River. The three horizontal lines represent succeeding estimates of the 1-in-100 chance flood magnitude, based on the data from different time periods: (a) 1940-1975; (b) 1940-1996; and (c) 1940-2014. Red bars represent the top five recorded peak flows in the record. Graphic: Mark Mastin, Washington Water Science Center, U.S. Geological Survey.

However, it is difficult to determine with certainty whether flood frequency or magnitude are changing because floods are highly variable. To look at this question, the USGS's Washington Water Science Center evaluated trends in annual peak flows at many stream gauges across Washington (Mastin et al. 2016). They found that most gauges across Washington did not show a trend in annual peak flows. However, of the few gauges that did show trends, those with positive trends—that is, increasing peak flows over time—were concentrated in western Washington, including two in the Chehalis Basin (though the ones on the Chehalis River itself did not show a detectable trend; Mastin et al. 2016). Those with negative trends were mostly located east of the Cascade Crest. It is possible that, as additional data are collected, such increasing trends may align with the increasing flood risk projections from simulation and statistical models (see the *Projected Impacts of Climate Change on Flood Risk* sidebar).

The challenge of having long enough records to accurately capture flood dynamics is also visible in the USGS's efforts to quantify "100-year floods". These are large floods that cause substantial damage, and that are expected to occur relatively rarely. As Dinicola (1997) and others have worked hard to clarify, this does not mean that these floods occur once every 100 years, but that the chance that they will occur in any one year is 1 in 100; i.e., there is a 1% chance of a flood that size or larger occurring in any given year. Hydrologists' ability to accurately estimate how big that 1-in-100 chance flood has been in the past depends on the data they have to work with. And as the number of years of data increases, so does their ability to capture past flood dynamics in their estimate of the 1-in-100 chance flood.

The 1-in-100 chance flood for the Chehalis River, estimated using annual peak streamflow data from 1940 through 1975, was previously calculated to be around 23,000 cubic feet per second (cfs) (Dinicola 1997). When Dinicola used a more extensive set of annual peak flow data (through 1996), the estimate rose to around 31,000 cfs. In both time periods, these 1-in-100 chance flood magnitudes were slightly larger than the highest peak streamflow observed during that period (Figure 6).

The USGS has now used the same process to update the 1-in-100 chance flood estimate using data through 2014. Driven mainly by the unprecedented flood that Gordon described—which notched a 63,100 cfs peak streamflow at the gauge near Doty, Washington—the 1-in-100 chance flood based on 1940-2014 data is almost 60% greater than the 1975 estimate: 37,200 cfs (Figure 6).

There are additional challenges with this type of flood probability information. An important one is that these data predict the probability of a 1-in-100 chance flood based on an assumption called "stationarity"—that is, they assume that flood characteristics in the future will be the same as those of the past. Therefore, these values do not predict how climate change will affect the magnitude of 1-in-100 chance floods in the future (see the *Climate Projections for the Pacific Northwest* sidebar). Furthermore, these data do not take into account other changes in a watershed, such as land development, timber harvesting, water diversions, or wetlands removal, that can affect its hydrology. The characteristics of past floods are just one piece of information, however. Additional evidence, such as that arising from the use of global and regional climate models to make projections about flooding, can help decision-makers more comprehensively explore the flooding future of the Chehalis River.

In 2011 the Washington State Legislature commissioned a report on [potential flood damage reduction projects](#). After the report was finalized in November 2012, then-Governor Christine Gregoire asked a group of five diverse Chehalis Basin leaders, including Gordon, to develop recommendations to reduce future flood damage. The Work Group's Basin-wide focus would complement the Partnership and Flood Authority's local efforts. Other members of this initial Governor's Work Group (Work Group) included Dave Burnett, then chairman of the Chehalis Tribe (as of 2016 replaced by Don Secena); Karen Valenzuela, Thurston County Commissioner; Vickie Raines, who was at that time mayor of Cosmopolis; J. Vander Stoep, an attorney who represented the interests of Chehalis, Centralia and Pe Ell; and Governor Gregoire's Policy Advisor, Keith Phillips (as of 2016 replaced by Rob Duff).

Governor Gregoire provided the Work Group with a trained facilitator from the Ruckelshaus Center, a joint project of the University of Washington and Washington State University, and the prospect of significant state investment if the Work Group could agree on a set of shared recommendations. The Work Group also received access to agency and private hydrologists and other scientists who provided advice and guidance on the many technical questions that arose.

The Work Group’s long-term goal was to make the Chehalis Basin a safer place for families and communities impacted by flooding, and to improve and restore aquatic species habitat now and for future generations. They released joint recommendations in November 2014:

- to start the permitting process for a concrete flood retention structure on the upper Chehalis River, paired with levee improvements;
- to develop a Basin-wide effort to restore aquatic species and reverse the decline of Spring Chinook, including habitat restoration for Chinook and other aquatic species, repairing fish passage, and addressing bank erosion;
- to continue investment in flood-damage reduction projects, including raising homes, and flood-proofing businesses and public structures; and
- to protect remaining floodplain function through local government actions.

These recommendations stemmed from a shared understanding that flood damage mitigation and aquatic species habitat restoration across the entire basin are inextricably linked. As Gordon says, “that was a little surprising to all of us that the five of us actually agreed, because we did not walk in with the same vision in mind. But that team has worked very well together—and works well with the Chehalis Basin Partnership, the Flood Authority, and now with the state agencies.”

Progress

Gordon, who has been involved in both the Partnership and the Work Group, notes, “The Chehalis Basin Partnership and the Flood Authority have done some nice small projects. We’ve started on some fisheries work. We’ve done some obvious things like fixing some roads that were blocking and creating localized flooding. And those are great, but we are still working on the big challenge—getting rid of that extra 20,000 to 30,000 cubic feet of water per second, 60,000 to 65,000 acre-feet I think is what they figure we have.”

To tackle that bigger challenge, the Work Group recommended starting the permitting process for a

dam, exploring two initial options: one for a storage dam in the upper Chehalis, and the other for a run of the river dam that would store water only during floods. Informed by current predictions of future floods, both of these dams would aim to store enough excess water that flooding, and the associated damage, would be similar to what occurred during flood events from 1900 to 1990. “It would put the water level back to where the communities can say, ‘Okay, above here, you’re fine. Below here, you’re not.’” Meanwhile, a key question is whether an integrated strategy of flood damage reduction and aquatic species habitat restoration that includes a dam can benefit fish populations that are key to the economy and culture of the Chehalis Valley. As of 2017, these alternatives were compared in a State Environmental Policy Act (SEPA) Programmatic Environmental Impact Statement, and will be assessed further in project- and site-specific environmental reviews (for details and updates, see the *Additional Information* sidebar).

Additional Information on the Chehalis Basin Groups

The work of the Chehalis Basin Groups is continuing to evolve, and several other sources are likely to contain updates on these efforts:

- The [Chehalis Basin Partnership](#).
- The [Chehalis River Basin Flood Authority](#).
- The recommendations of the [Governor’s Work Group and the State Legislature’s response](#), and the [Office of the Chehalis Basin](#) within the Washington Department of Ecology, an office that formalizes the work group.
- The [environmental and public review](#) of potential actions in the Chehalis Basin Strategy.

What Is Making Consensus Possible?

Gordon suggests that it has been possible to achieve consensus on these difficult issues because participants are committed to the process, they have the patience to listen to each other and work through disagreements, and they have access to information that supports sound decision-making.

Commitment to the process has perhaps been the easiest piece. Both political realities and public budgets mean that there is little prospect of making headway without community consensus. And when the going has been difficult, commitment also comes from the fact that “There’s another flood coming. You can’t stand there and say no because doing nothing *is* an option—and we know what it’ll look like the next time it floods (Figure 7).”



Figure 7. The nearby Chehalis River serves as a reminder that flooding will return in the future, and the community hopes to be able to lessen its impacts. Photo: Mikey World, via Flickr (Creative Commons License).

Working through disagreements has sometimes been challenging, but the process has improved communications and helped build trust among the Work Group members. Gordon says, “This was a people problem here in the Valley. It was people not

talking to each other, people not listening to interests, people not getting interests on the table.” As one example, Gordon points to the leadership of the Chehalis Tribe. “The Chehalis Tribe was very blunt, and I really appreciate that. They were very clear in saying they were interested in more fish, not less. They are also interested in flood reduction, but it must be with more fish. And it’s not one or the other. It has to be both.”

The Work Group has also used scientific information to better understand likely future conditions and their impacts on their local watershed (see the sidebars on *Climate Projections for the Pacific Northwest*, *Projected Impacts of Climate Change on Snowpack*, and *Projected Impacts of Climate Change on Flood Risk*; also see *Regional Climate Research Resources* for links to providers of scientific information). Support has come through facilitation and project management provided by the Ruckelshaus Center, through connections with and work published by scientists at both University of Washington and Washington State University, and through the work of state agency scientists and private consultants targeting the Work Group’s specific information needs. As Gordon says, “Research is fundamental to getting good intelligent information from which to make a decision, and when you’re dealing with something so complex and so important as flooding and improving a fishery, we don’t want to have an ‘oops’ 20 years from now.”

Climate Projections for the Pacific Northwest

Lara Whitely Binder, Climate Impacts Group, University of Washington, and Sonia A. Hall, Center for Sustaining Agriculture and Natural Resources, Washington State University

Scientists have made significant advances over the last 30 years in understanding climate change and how it can affect global and regional climate. These advances have come through:

- Extensive analyses that relate observed weather patterns to climate impacts in the region, especially those related to water.
- The use of climate models and scenarios of future greenhouse gas emissions to project future global and regional climate.
- A concerted effort in the Pacific Northwest to integrate regional factors that affect climate—like mountain snowpack and ocean conditions—into future climate projections in ways that address the needs of decision-makers.

Climate models are mathematical representations of the physical, chemical, and biological factors that contribute to the climate we observe. Greenhouse gas scenarios, as inputs into climate models, represent different potential pathways for future global population growth, social and economic development, energy sources, and technological advances. Differences among greenhouse gas scenarios, combined with differences in how individual models represent the climate's response to higher concentrations of greenhouse gases, result in a range of possible futures, referred to as climate scenarios. These climate scenarios can be used to evaluate climate impacts at scales ranging from the entire globe to local watersheds.

A number of global and regional models have been used to make projections of different climatic variables and their impacts in the Pacific Northwest. Using multiple climate models to project changes in climate is a useful way to put some bounds on the uncertainty in climate change projections (Allen et al. 2015). Most climate change studies, therefore, use a suite of models to make projections into the future, and publish results that include some measure of the variability among the models in addition to mean values (see examples of this in Table 1 and Figure 8).

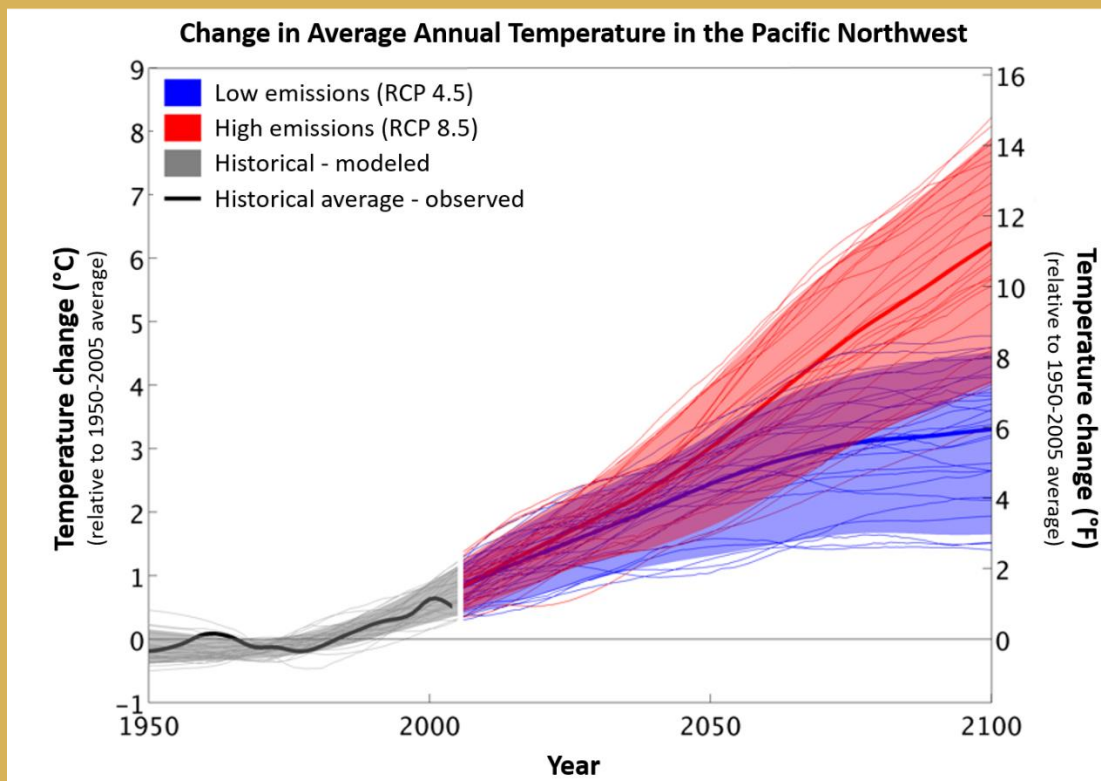


Figure 8. All scenarios project warming for the 21st century. The graph shows the expected change in average annual temperatures for the Pacific Northwest relative to the average for 1950-2005 (the “zero” line). The black line shows the observed average annual temperature, while the grey lines show individual simulation model results for the historical time period. Thin colored lines show individual model projections for two emissions scenarios: low emissions (a scenario called RCP 4.5, in blue), and high emissions (a scenario called RCP 8.5, in red). Thick colored lines show the average among model projections for each emissions scenario. *Figure source: Figure 2.5 in Mote et al., 2013. Reproduced, with slight modifications, with permission from the Oregon Climate Change Research Institute.*

All climate scenarios show increasing annual and seasonal temperatures for the Pacific Northwest (see, for example, the results of 76 scenarios that are summarized in Snover et al. 2013), with the amount of warming dependent on how quickly greenhouse gas emissions rise (Figure 8). Under a high greenhouse gas scenario (called Representative Concentration Pathway or RCP8.5 in the climate science literature), average annual temperatures in the Columbia River Basin are expected to increase 5.6°F, on average, by the 2050s (Table 1; Rupp et al. 2017). Note that “2050s” refers to the 30-year period spanning from 2040 to 2069, and increases are relative to the average for the period 1970–1999. Warming is even more pronounced by the 2080s, with average increases of 9.0°F (range: 5.2°F to 11.9°F) (Rupp et al. 2017). “2080s” refers to the 30-year period

spanning 2070–2099. While natural variability will remain an important feature of regional climate, by mid-century the Northwest is likely to regularly experience average annual temperatures that are well outside of the range observed during the 20th century.

Climate change will also affect annual and seasonal precipitation in the Pacific Northwest, although the projected changes are more varied between models. Most models project wetter fall, winter, and spring seasons (increases between 3% and 8%, on average for the 2050s) for a low (called RCP4.5) and high greenhouse gas scenario (Table 1; Rupp et al. 2017). In contrast, models consistently project drier summers (-5 to -7% on average for the 2050s, again for a low and a high greenhouse gas scenario, with some models showing as much as a -28% decrease in summer precipitation; Table 1). Overall, expected changes in average annual and seasonal precipitation are relatively small when compared to the region’s large natural year-to-year variability.

Table 1. Synthesis of expected climate change in the Pacific Northwest by the 2050s.

	Mean change	Variability 5 th to 95 th percentile	Source	Modeling details
Annual temperature	+5.6°F	3.2 to 7.9°F	Rupp et al. 2017	Multi-model ensemble of 35 GCMs ¹ RCP 8.5 (CMIP5 ¹) Columbia Basin above Bonneville Dam 2040-2069 vs 1970-1999
Annual precipitation	+4%	-3 to 13%	Rupp et al. 2017	
Winter precipitation	+8%	-3 to 21%	Rupp et al. 2017	
Spring precipitation	+7%	-1 to 21%	Rupp et al. 2017	
Summer precipitation	-7%	-28 to 11%	Rupp et al. 2017	
Fall precipitation	+3%	-9 to 17%	Rupp et al. 2017	
	Mean change	Variability Standard deviation	Source	Modeling Details
Freeze-free period	+35 days	6 days	Mote et al. 2013	Ensemble of 4 GCMs used to drive regional NARCCAP model SRES-A2 ¹ (CMIP3 ¹) Pacific Northwest 2041-2070 vs 1971-2000
No. days with precipitation > 25 mm	+13%	7%	Mote et al. 2013	
No. days with precipitation > 75 mm	+22%	22%	Mote et al. 2013	

¹ GCM: global climate model; CMIP3 and CMIP5: Coupled Model Intercomparison Projects No. 3 and No. 5. SRES-A2: moderately high emissions scenario.

Regional climate research has also investigated the impacts of climate change on extreme events. There is strong agreement among climate models that extreme heat events will become more frequent while extreme cold events become less frequent. The expected changes in variables that reflect the reduction in extreme cold events, in particular, are larger than their standard deviation (a measure of how variable they naturally are; Table 1; Mote et al. 2013). In addition, regional projections point to increasing number of extreme precipitation events, and these results are less ambiguous than those for total precipitation (Mote et al. 2013). Only the increase in frequency of moderate events (more than 1 inch [25 mm] of rainfall) is greater than its variability (measured as its standard deviation; Table 1; Mote et al. 2013). To provide some context, the City of Montesano, close to the mouth of the Chehalis River, had 10 such moderate events (days with more than 1 inch of rain) in 2009.

A wealth of information is available on increasing annual and seasonal temperatures, changes in the seasonality of precipitation, and the likelihood of extreme events in the Pacific Northwest. This information can help communities understand how climate change will affect their area and livelihoods, providing a foundation for local and regional efforts to reduce the risks associated with a changing climate.

Projected Impacts of Climate Change on Snowpack

Sonia A. Hall, Center for Sustaining Agriculture and Natural Resources, Washington State University, and Lara Whitely Binder, Climate Impacts Group, University of Washington

Declines in spring mountain snowpack over the past half century have been widely documented in the Pacific Northwest and across much of the western United States, in concert with long-term warming trends (Mote et al. 2005, Hamlet et al. 2005). However, shorter-term trends in snowpack associated with variability in temperature and precipitation may obscure the longer-term trend (Casola et al. 2009, Stoelinga et al. 2010). Snowpack losses, expected to continue into the future, can lead to important changes in hydrology, including:

- Greater runoff during winter and spring, when precipitation historically has been stored as snow; and
- Extreme low flows in summer, when flows have been supplemented historically by meltwater from seasonal snowpack.

These hydrological changes are of critical importance in many river basins, especially as snowpack stores more water than is held in the man-made reservoirs in the region (Mote et al. 2005).

In an effort to characterize the different contributions of rain and snow to streamflow, hydrologists have classified Pacific Northwest watersheds into three types: low-elevation watersheds where precipitation falls primarily as rain (“rain-dominant” watersheds), high-elevation watersheds where precipitation falls primarily as snow (“snow-dominant” watersheds), and mid-elevation watersheds that receive precipitation as a mix of rain and snow (“mixed rain-and-snow” watersheds; see, for example, Hamlet et al. 2013). Based on data from the last 30 years of the 20th century, the majority of the watersheds in the region are considered mixed rain-and-snow (Tohver et al. 2014). Snow-dominated watersheds are concentrated in the North Cascades and in the Rocky Mountains of Idaho and British Columbia. Meanwhile, rain-dominated watersheds occur mostly in coastal Washington and Oregon, west of the Cascade Range (Tohver et al. 2014). The Chehalis Basin is one of these rain-dominated watersheds.

Across much of the Pacific Northwest, snow accumulates in areas where winter temperatures are near or below freezing (Nolin and Daly 2006). It is therefore not surprising that many snow-dominated watersheds in the Pacific Northwest are expected to shift to a mixed rain-and-snow regime during this century, as temperatures increase (see the *Climate Projections for the Pacific Northwest* sidebar). In addition, the

majority of watersheds that are currently classified as mixed rain-and-snow are projected to shift to a rain-dominated regime (Figure 9; Tohver et al. 2014).

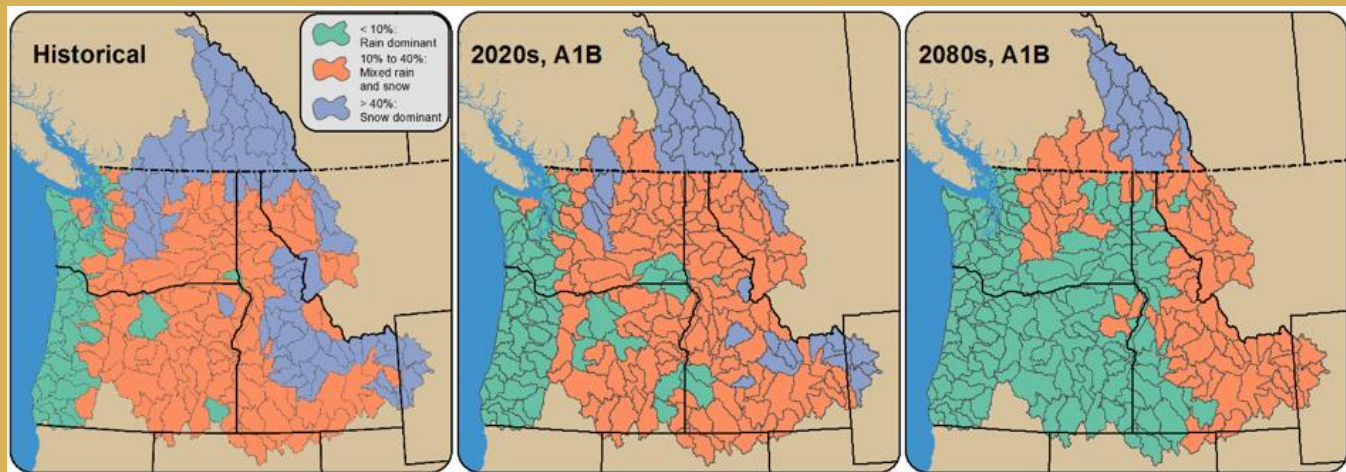


Figure 9. Distribution of snow-dominant (blue), mixed rain-and-snow (orange), and rain-dominant (green) watersheds in the Pacific Northwest, under historical climate (left panel), and under future climate (center and right panels). Classifications under future climates are provided for a moderately high greenhouse gas emissions scenario (A1B), and for two time periods in the future (2020s: 2010-2039; and 2080s: 2070-2099). Classification of the watersheds was based on the proportion of precipitation occurring when temperatures were low enough for it to fall as snow (see Tohver et al., 2014 for additional emissions scenarios and time periods). *Figure source: Modified from Figure 2 in Tohver et al., 2014. Reproduced with permission from the Climate Impacts Group.*

The combined effects of earlier spring snowmelt and precipitation increasingly falling as rain rather than snow will lead to increased risk of flooding in downstream communities and ecosystems. Rain-dominant basins such as the Chehalis Basin are not as sensitive to temperature increases because they are already too warm for substantial snow accumulation, but they *are* sensitive to extreme precipitation events, which are also expected to happen more frequently (for more on the impacts of these projections of extremes, see the *Projected Impacts of Climate Change on Flood Risk* sidebar).

Projected Impacts of Climate Change on Flood Risk

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How will the risk of floods in Pacific Northwest rivers change in the future? What are the implications of shifts in the dominant form of precipitation? Flooding events—where stream levels surpass established flood stages—can be caused by rapid snowmelt, as well as by extreme precipitation events, such as those caused by atmospheric rivers. Atmospheric rivers are long and narrow “conveyor belts” of moist air that can bring periods of heavy rain to the west coast of the United States (for more on atmospheric rivers, see: <http://www.esrl.noaa.gov/psd/atmrivers/>). These are the primary cause of flooding in low-elevation, rain-dominant watersheds along the coast, such as the Chehalis Basin. They can also contribute to flooding in snow-influenced watersheds, particularly when accompanied by warm temperatures (e.g., a “Pineapple Express” [Neiman et al. 2011]). The intensity of these big rain events is projected to increase (see the *Climate Projections for the Pacific Northwest* sidebar), and atmospheric rivers are expected to make landfall with even greater moisture content in the future (Warner et al. 2015). Consequently, flood risk—how likely it is that a flood will occur—is projected to increase throughout the region in both rain- and snow-influenced basins.

To generate future climate information at the scale of a watershed—necessary to understand impacts on hydrology—the output from global climate models (which do not capture much variation across the region) are “downscaled” to a more local scale. The downscaling can be accomplished by using statistical

relationships drawn from past observations of weather (statistical downscaling), or by using an additional set of regional-scale models that are often used in daily weather forecasts (dynamical downscaling). Hydrological models can then be run with the downscaled data to simulate snowmelt, runoff, and other hydrological processes.

To explore the potential for future flooding, Tohver et al. (2014) used statistically downscaled regional climate projections along with a hydrological model that estimated peak flows under future conditions. They found that, with the exception of a few snow-dominant watersheds, flood risk over the entire region is projected to increase. Mixed rain-and-snow watersheds are projected to experience the greatest increases in flood risk, resulting from an increase in winter streamflow as more precipitation falls as rain rather than snow. This conclusion is supported by other, earlier studies (e.g., Hamlet and Lettenmaier 2007; Mantua et al. 2010).

Safeeq et al. (2015) used a different method to explore this question. They also used statistically downscaled climate projections, but related the climate variables to peak flows through regression models rather than using a hydrological model. However, they also concluded that temperature-induced changes in snowpack dynamics would result in increases in flood magnitudes, with increases as large as 30–40% in some areas by the 2080s. Researchers using different approaches that reach the same conclusions increase the confidence placed in those results, particularly when making projections into the future (Allen et al. 2015).

Both the Tohver- and Safeeq-led studies highlight the importance of warming temperatures as a dominant driver of changes in flood risk in the future. However, projected increases in the intensity of precipitation on the windward slopes of the Cascades and Rockies could by themselves also lead to increased flooding (Salathé et al. 2010). Such changes in extreme precipitation events are not explicitly captured in Tohver's and Safeeq's analyses. Fortunately, additional research is tackling the issue. Salathé et al. (2014) used a finer-scale regional model in the Northwest that captures the interactions of the mountains with atmospheric rivers. They found that flood risk increased through mid- to late-21st century not only in mixed rain-and-snow basins, but also in warm, rain-dominated basins where peak flows occur in the late fall and winter, such as the Chehalis Basin. In these rain-dominated watersheds, the increased flood risk was substantially larger than Tohver et al.'s (2014) results suggested. Salathé et al. (2014) do caution, however, that more research is still needed, as their analysis only used projections from one global climate model. Efforts to expand the number of climate scenarios produced using the computationally-intensive type of dynamical downscaling that Salathé et al. (2014) used were underway in 2017.

Ultimately, managers need to know more than just how much more water will be coming down the river during future events. Information is also needed on what is likely to get flooded and at what depth. Recent studies have begun using hydrodynamic models to quantify the climate change impact on the depth and area of flooding. These studies have also incorporated a third factor affecting flood risk in low elevation areas: sea level rise. Higher sea level can increase the extent, depth, and duration of flooding by making it harder for flood waters in rivers and streams to drain to the ocean. Hamman et al. (2016) found that the area flooded in the Skagit River floodplain during a 100-year event is projected to increase by 74% on average by the 2080s, assuming a moderate greenhouse gas scenario. A similar study found that the 10-year event would flood 19% to 69% more area in the lower Snohomish River floodplain by the 2080s (Mauger and Lee 2014). These projections can help communities in those valleys make decisions about what actions to take, individually and collectively, to address these climate change impacts. And in watersheds where these detailed flooding projections are not available, decision-makers can still gain insights into what lies in their future from an understanding of expected changes in spring snowmelt, atmospheric rivers, and the resultant streamflows.

Gordon describes one small example of how additional scientific information has led to changes in their anticipated plan. “There's a road just below here we all thought was obviously a barrier.... When Larry Karpak, a private hydrologist that worked with the Work Group, got done with the hydrology, he said, ‘Well, if you took the road out, it might drop the water a mile up river by about a foot, and there are no houses up there. So, do you still want to spend a bunch of money to do that?’ And we said, ‘Go back and check your math.’ And he did. Came back and gave another meeting to a bunch of us, and we all went, ‘Nope. Don't need that.’”

Remaining Challenges

Remaining challenges include the technical challenge of figuring out whether either of the currently proposed dams or other large-scale flood damage reduction projects being analyzed can offer widespread community benefits related to salmon protection and flood mitigation. “We've done a lot of preliminary work, but the [permitting](#) is really the process that will tell us whether it's a good idea.” Gordon is committed to ensuring that if a dam is eventually permitted it benefits fish in addition to reducing flooding. “This is not going to be another Elwha dam. This has to be a dam that is there to augment flows in the summer, and if that'll help this fishery, especially the Spring Chinook, great. If not, then we've got to look at a different design.”

A permanent dam could augment low summer flows by allowing for water releases in years when the water is low, particularly in the late summer and early fall. Preliminary studies have suggested that this could benefit spring-run Chinook Salmon populations, but could reduce steelhead and Coho Salmon populations by flooding some of their spawning habitat. Future work will determine whether and how this impact could be mitigated.

While future research and technical work is one piece of the puzzle, continuing to build and maintain relationships is another key. Although they now have a history of some successful consensus and collaboration to build on, moving forward on the dam is still likely to be a challenge.

“Just saying the words ‘we're considering building a dam’...we don't do that in America. Tearing dams

Regional Climate Research Resources

Multiple universities and other research and extension institutions in the Pacific Northwest develop and share information on climate change, climate change impacts to agriculture, and adaptation and mitigation strategies. These include:

Climate change research and resources in the Northwest:

- The [Climate Impacts Group](#) at the University of Washington
- The [Oregon Climate Change Research Institute](#) at Oregon State University
- The [Climate Impacts Research Consortium](#) at Oregon State University
- The [Climatology Lab](#) at the University of Idaho

Climate change and agriculture research and resources in the Northwest:

- The [Center for Sustaining Agriculture and Natural Resources](#) at Washington State University
- [Northwest Climate Hub](#)

Examples of climate change and agriculture projects in the Northwest:

- [Regional Approaches to Climate Change—Pacific Northwest Agriculture](#)
- [Agriculture Climate Network](#)
- [The Northwest Climate Toolbox](#)
- [Integrated Scenarios of the Future Northwest Environment](#)

Examples of flood risk reduction efforts in the Northwest:

- [Chehalis Basin Strategy](#)
- [Floodplains by Design](#)
- [Willamette Partnership](#)

out is more standard. To have a group of folks considering building a dam intelligently and skeptically, to say can we do this, and do it in a smart

way, is not easy. We'll see if consensus will hold on that."

And yet Gordon also remains optimistic, though he knows it will take time. "The dairy farmers that I represent in the upper Valley say, 'what's taking so long?' Well, it's not easy, and there are a lot of people to talk to, and there's a lot of work to do. But there are also a lot of good people working on it, and we're making progress."

Looking Forward

While Gordon is dealing locally with the flooding in the Chehalis, he is also aware of water issues throughout the state through his work with the Washington State Dairy Federation. Because of accumulated evidence that the climate is changing and the long timeline required for many water-related projects, Gordon feels that action needs to begin as soon as possible. "Do we have enough information upon which to act, knowing that it's going to take twenty years or more to go through the permitting...to get those construction projects started, to make up for the loss of snowpack that's coming?" This includes actions to address the likely impacts of climate change, as less water is stored in snowpack during warmer winters and springs, and the expected increased frequency of big rainstorms from the Pacific.

There are also lessons that the Work Group has learned in the Chehalis Basin that Gordon thinks are transferrable to other communities coping with climate change and water-related issues. First, and maybe most importantly, is patient but active

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consensus-building, informed by high quality research partnerships. "Working out the issues that involve people and politics takes time and knowledge, and an ability to understand both science and people...this is the biggest challenge." Second, it is necessary to invest the time needed to achieve that understanding. From Gordon's perspective, such efforts will require community volunteers, but also trade organizations and others who can commit more time. "There aren't enough farmers that can volunteer the kind of time it takes to move these big projects." A third lesson is also related to capacity: the existing research on climate impacts, coupled with the resources and willing expertise in the region to address the information needs of this Work Group in this watershed, helped community members understand the implications of different decisions in a way that moved the process forward.

Climate change is impacting different regions and watersheds in various ways. It is not always easy to envision how individual agricultural producers can comprehensively address some of these broad-scale climate change impacts to their farms. Yet this experience in the Chehalis Basin is an example that highlights how community response—paired with commitment to shared solutions, relevant knowledge, and sufficient resources—can lead to increased resilience to a changing climate in the Pacific Northwest and beyond. Considering whether these enabling factors exist and are relevant to their situation can help other Pacific Northwest communities facing climate-related risks find a shared path forward.

References

- Allen, E., G. Yorgey, K. Rajagopalan, and C.E. Kruger. 2015. [Modeling Environmental Change: A Guide to Understanding Results from Models that Explore Impacts of Climate Change on Regional Environmental Systems](#). *Washington State University Extension Bulletin FS159E*.
- Casola, J.H., L. Cuo, B. Livneh, D.P. Lettenmaier, M.T. Stoelinga, P.W. Mote, and J.M. Wallace. 2009. [Assessing the Impacts of Global Warming on Snowpack in the Washington Cascades](#). *Journal of Climate* 22: 2758–2772.
- Dinicola, K. 1997. [The “100-Year Flood.”](#) U.S. Geological Survey Fact Sheet 229-96. Washington Water Science Center, U.S. Geological Survey. Tacoma, Washington. 2 pp.
- Hamlet, A.F., and D.P. Lettenmaier. 2007. [Effects of 20th Century Warming and Climate Variability on Flood Risk in the Western U.S.](#) *Water Resources Research* 43, W06427: 1-17.
- Hamlet, A.F., P.W. Mote, M.P. Clark, and D.P. Lettenmaier. 2005. [Effects of Temperature and Precipitation Variability on Snowpack Trends in the Western United States](#). *Journal of Climate* 18: 4545–4561.
- Hamlet, A.F., M.M. Elsner, G.S. Mauger, S.-Y. Lee, I. Tohver, and R.A. Norheim. 2013. [An Overview of the Columbia Basin Climate Change Scenarios Project: Approach, Methods, and Summary of Key Results](#). *Atmosphere-Ocean* 51(4): 392–415.
- Hamman, J.J., A.F. Hamlet, S.-Y. Lee, R. Fuller, and E.E. Grossman. 2016. Effects of Projected Twenty-First Century Sea Level Rise, Storm Surge, and River Flooding on Water Levels in the Skagit River Floodplain. *Northwest Science* 90: 57–78.
- Mantua, N., I. Tohver, and A. Hamlet. 2010. [Climate Change Impacts on Streamflow Extremes and Summertime Stream Temperature and Their Possible Consequences for Freshwater Salmon Habitat in Washington State](#). *Climatic Change* 102: 187–223.
- Mastin, M.C., C.P. Konrad, A.G. Veilleux, and A.E. Tecca. 2016. [Magnitude, Frequency, and Trends of Floods at Gaged and Ungaged Sites in Washington, Based on Data Through Water Year 2014](#). U.S. Geological Survey Scientific Investigations Report 2016–5118, 70 pp.
- Mauger, G.S., and S.-Y. Lee. 2014. Climate Change, Sea Level Rise, and Flooding in the Lower Snohomish River Basin. Report prepared for The Nature Conservancy. Climate Impacts Group, University of Washington, Seattle.
- Mote, P.W., J.T. Abatzoglou, and K.E. Kunkel. 2013. Climate: Variability and Change in the Past and the Future, in: Dalton, M.M., P.W. Mote, and A.K. Snover. eds. *Climate Change in the Northwest - Implications for Our Landscapes, Waters, and Communities*. Island Press.
- Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. [Declining Mountain Snowpack in Western North America](#). *Bulletin of American Meteorology Society* 86: 39–49.
- Neiman, P.J., L.J. Schick, F.M. Ralph, M. Hughes, and G.A. Wick. 2011. [Flooding in Western Washington: The Connection to Atmospheric Rivers](#). *Journal of Hydrometeorology* 12: 1337–1358.
- Nolin, A.W., and C. Daly. 2006. [Mapping “At Risk” Snow in the Pacific Northwest](#). *Journal of Hydrometeorology* 7: 1164–1171.
- NRCS (Natural Resources Conservation Service). 2013. [Web Soil Survey](#). Natural Resources Conservation Service, United States Department of Agriculture.
- Rupp, D.E., J.T. Abatzoglou, and P.W. Mote. 2017. Projections of 21st Century Climate of the Columbia River Basin. *Climate Dynamics* 49(5-6): 1783–1799.
- Safeeq, M., G.E. Grant, S.L. Lewis, and B. Staab. 2015. [Predicting Landscape Sensitivity to Present and Future Floods in the Pacific Northwest, USA](#). *Hydrological Processes* Wiley Online Library.

Salathé, E.P., A.F. Hamlet, C.F. Mass, S.-Y. Lee, M. Stumbaugh, and R. Steed. 2014. [Estimates of Twenty-First-Century Flood Risk in the Pacific Northwest Based on Regional Climate Model Simulations](#). *Journal of Hydrometeorology* 15: 1881–1899.

Salathé, E.P., L.R. Leung, Y. Qian, and Y. Zhang. 2010. [Regional Climate Model Projections for the State of Washington](#). *Climatic Change* 102: 51–75.

Snover, A.K., G.S. Mauger, L.C. Whitely Binder, M. Krosby, and I. Tohver. 2013. [Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers](#). State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle.

Stoelinga, M.T., M.D. Albright, and C.F. Mass. 2010. A New Look at Snowpack Trends in the Cascade Mountains. *Journal of Climate* 23.10: 2473–2491.

Tohver, I.M., A.F. Hamlet, and S.-Y. Lee. 2014. [Impacts of 21st-Century Climate Change on Hydrologic Extreme in the Pacific Northwest Region of North America](#). *Journal of the American Water Resource Foundation* 50(6): 1461–1476.

U.S. Geological Survey (USGS). 2016. [National Water Information System—Web Interface](#). Accessed March 1, 2016.

Warner, M.D., C.F. Mass, and E.P. Salathé Jr. 2015. Changes in Winter Atmospheric Rivers Along the North American West Coast in CMIP5 Climate Models. *Journal of Hydrometeorology* 16(1): 118–128.

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