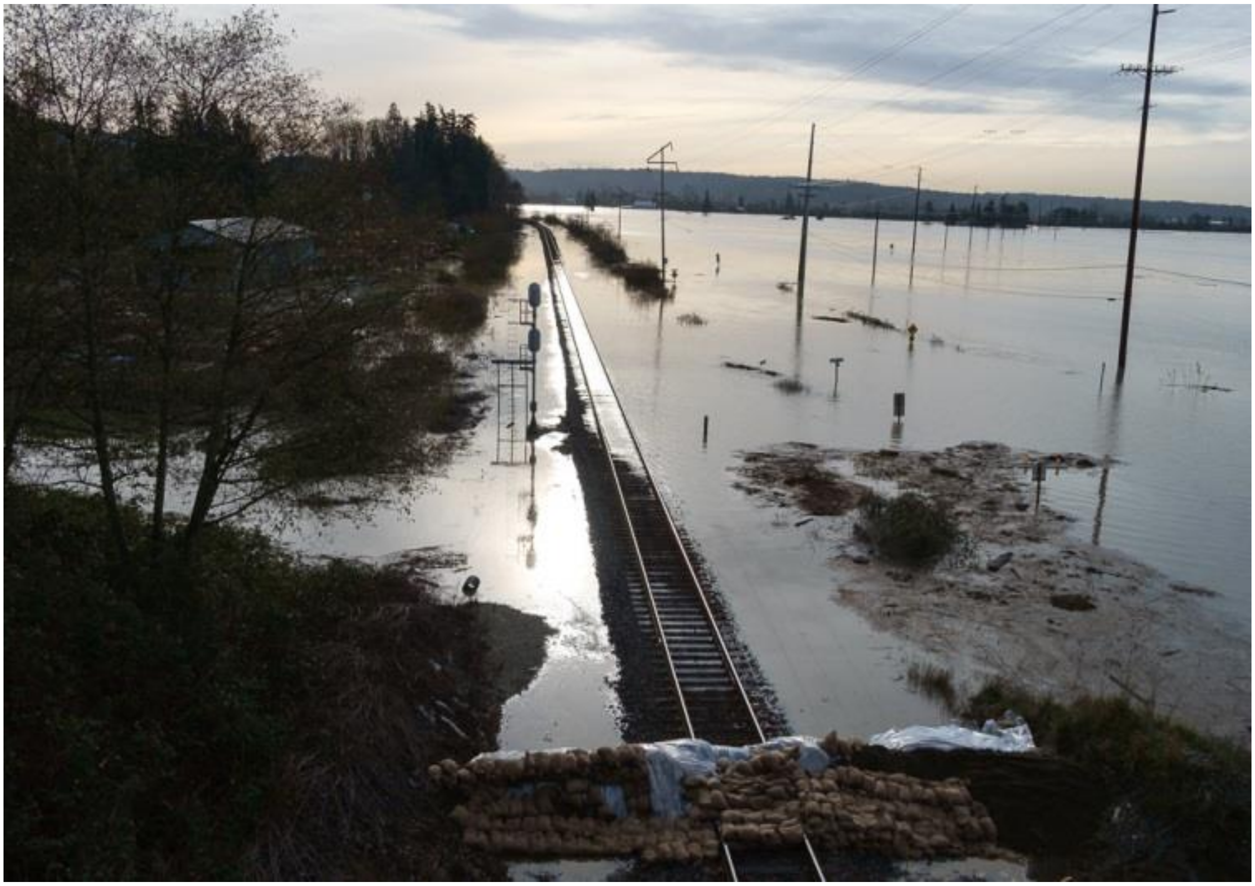

Climate Resilient Floodplains:

Local Perspectives on Integrating Climate Resilience into Floodplain Management and Planning in the Stillaguamish and Puyallup River Watersheds

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"The regional consequences of climate change will be strongly shaped by past choices – of what to build where, what to grow where – and by the laws, institutions, and procedures that shape how natural resources are managed and allocated, risks from natural hazards are identified, and trade-offs among conflicting objectives resolved."

Snover, A.K., Mauger, G.S., Whitely Binder, L.C., Krosby, M., Tohver, I. 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.

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Cover photo: Flooding in the Stillaguamish watershed, November 18, 2015. *Julie Morse, The Nature Conservancy.*

Contents

1 Introduction

The low elevation coastal floodplains of Puget Sound are among the region's most valuable natural assets. These lowland river valleys contain rich farmland, host the Sound's signature salmon runs, and support wetlands and forests that filter pollutants and recharge aquifers. They also contain commercial, residential, and industrial development worth over $18 billion and provide recreational opportunities for the 4 million people living in the Puget Sound region. Finally, the Puget Sound lowlands are the ancestral homelands and cultural center for Puget Sound tribes.

Puget Sound lowlands are facing numerous pressures. Rapid development continues to change the landscape, affecting habitat, river function, and water quality. In some cases, development patterns are bringing more people and infrastructure into areas historically affected by floods and other hazards. The agricultural industry is trying to maintain its viability in the face of increasing development, habitat restoration needs, and regulatory pressure. Meanwhile, salmon runs continue to decline. Growing recognition that the protection and restoration of floodplain ecosystems is critical to salmon recovery is creating additional opportunities and demands on Puget Sound floodplains.

Climate change is another pressure that will exacerbate many of the issues already affecting Puget Sound watersheds. The region is already experiencing long-term warming, decreases in glacier area, and declining spring snowpack; many rivers are exhibiting earlier peak streamflows and lower summer streamflows as a result of long-term declines in snowpack and earlier spring snowmelt. Absent a significant reduction in greenhouse gas emissions, the region can expect an acceleration of these and other changes affecting the region's water resources. These hydrologic changes will have consequences on the economic, cultural, and natural resources supported by floodplains.

Floodplain managers and stakeholders are increasingly gravitating toward an integrated approach to floodplain management as a means for addressing challenges related to development, flood risk management, and salmon recovery. Several programs have been initiated to help identify management solutions that satisfy the multiple objectives of diverse floodplain interests in Puget Sound watersheds. These programs include the Floodplains by Design program, the Puget Sound Natural Resource Alliance, and the Alliance for Puget Sound Shorelines. Each seeks to create new solutions to conservation via collaboration among local stakeholders, rather than a prescriptive, single outcome approach that may lack support from the community.

The long term success of these efforts will be shaped in part by climate change and the ability to integrate climate change impacts into decisions affecting Puget Sound floodplains. Recognizing this, The Nature Conservancy and the University of Washington Climate Impacts Group partnered to conduct

Box 1. Goals of the Climate Impacts Interviews

1. Share the latest information regarding climate change impacts on floodplains with interview participants.
2. Identify how climate change could affect local floodplain management priorities and activities.
3. Identify additional actions or information needs that could help participants address climate change impacts discussed in the interviews.
4. Explore broader views on what a more climate resilient watershed would look like.

interviews with local stakeholders in two Puget Sound watersheds to better understand how climate change could affect current floodplain management planning priorities and activities. The interviews also sought to identify additional actions or information needs that could help participants address climate change impacts through their ongoing efforts. Finally, the interviews explored broader views on what a more climate resilient watershed would look like (Box 1).

This report summarizes what was learned in the course of those interviews. The report begins with an overview of the watersheds selected for the project and the interview process (Sections 2 and 3). Interview results for each watershed are presented in Sections 4 and 5. Closing thoughts, including ways in which the interviews revealed similarities between the two watersheds, are summarized in Section 6.

2 Watershed Selection

Two watersheds were selected for the project interviews: the Stillaguamish River and the Puyallup River watersheds. These watersheds were selected based on criteria and a guiding framework developed by the project team to evaluate candidate watersheds. The criteria used by the team reflected the team's desire to view the interviews as a first step in a longer-term engagement with the selected watersheds. For that reason, the criteria not only considered the current status and tenor of floodplain planning efforts in a watershed but also the potential for continued engagement and future implementation of on-the-ground climate adaptation projects. Evaluation criteria included:

- *Opportunity* - Does the watershed have high potential for measurable progress in planning over next year, and project implementation over the next five years?
- *Momentum* – Is the watershed already making progress on integrated planning and not stuck in intractable political situation?
- *Generalizability* – Will solutions to climate issues likely be relevant to other geographies?
- *Value Added* – Can the project team provide expertise/resources that the watershed partners don't already have?

The project team also solicited input from partners working in the candidate watersheds through informal discussions. More information on each watershed is provided in the following sections.

2.1 The Stillaguamish Watershed

The Stillaguamish Watershed is a relatively low elevation basin draining from the Central Cascade foothills into Puget Sound at Port Susan Bay (Figure 1). The watershed covers more than 700 square miles and includes about 3,100 miles in stream length, making it the fifth largest tributary draining into Puget Sound.[1]

The Stillaguamish River floodplain is relatively large compared to the size of the river – an important feature resulting from the historical eruption of Glacier Peak, which cut off the Sauk River and redirected

[1] Source: The Puget Sound Partnership, http://www.psp.wa.gov/downloads/2014_action_agenda/LIO_Profiles/SnoStilly_Profile_20140408.pdf

Figure 1. Mouth of the Stillaguamish River in Port Susan Bay (above). Location of the Stillaguamish watershed in the Puget Sound region (left). Photo credit: Marlin Greene, One Earth Images. Map credit: USGS.

it north to drain into the Skagit River. The glacially deposited loose sandy soil makes this watershed prone to erosion and landslides. Snohomish County has had 25 Presidential Disaster declarations in the last 50 years, most involving flooding and/or landslides (Snohomish County Hazard Mitigation Plan, September 2015). Municipalities in the Stillaguamish watershed include the cities of Arlington (2010 population: 17,926) and Stanwood (2010 population: 6,231).

The majority of the Stillaguamish floodplain is prime agricultural lands and rural residential areas. Sixty percent of the upper watershed is forested, and primarily managed by the Washington State Department of Natural Resources. Integrated watershed planning efforts are underway in the Stillaguamish under Snohomish County's Sustainable Land Strategy. The Stillaguamish Tribe, the Stillaguamish Flood Control District, and Snohomish County are leaders in this effort, which is attempting to balance flood, fish recovery and agricultural interests. Eight salmonid species use the watershed for spawning and rearing, including two runs listed as threatened under the Endangered Species Act (Chinook salmon and bull trout).

2.2 The Puyallup Watershed

The Puyallup watershed is a high elevation watershed covering 1,053 square miles in south Puget Sound (Figure 2).[2] The watershed originates at over 14,000 feet from the glaciers on Mount Rainier, dropping steeply to the mouth of the Puyallup River and Puget Sound at the City of Tacoma. The major rivers in the watershed are the Carbon, White and Puyallup Rivers; combined, these rivers drain approximately 60% of Mount Rainier. The watershed includes 17 incorporated areas in Pierce and King County. The majority of the floodplain is medium to high development, with intense development (the Port of Tacoma) at the mouth of the river. The Muckelshoot Indian Tribe and the Puyallup Tribe of Indians have been the traditional stewards and inhabitants of the Puyallup Watershed.

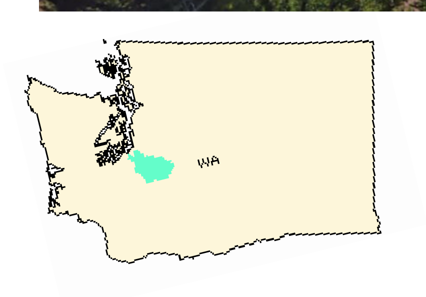

Figure 2. Headwaters of the Puyallup River (above). Location of the Stillaguamish watershed in the Puget Sound region (left). Photo: Chris Margill, USGS. Map: US EPA.

[2] Puyallup Watershed statistics from *Puyallup River Watershed Council 2013 Annual Report*, available at: www.piercecountywa.org/ArchiveCenter/ViewFile/Item/2458

Over 400,000 people live in the Puyallup watershed, and the floodplain contains an estimated $2.7 billion in assessed value. Some of the smaller cities, like Orting, are chronically at high risk of flooding. Numerous integrated watershed planning efforts are underway through Pierce County, the Puyallup River Watershed Council, and the Puyallup Watershed Initiative. The Pierce County Rivers Flood Hazard Management Plan, adopted in 2012, indicated a significant shift from seeking to provide 100-year protections everywhere to providing differing levels of flood protection across the floodplain.

3 Interview Process and Questions

Interview participants were selected based on project team knowledge of the organizations and individuals involved in floodplain planning in the Stillaguamish and Puyallup watersheds, as well as through referrals from partners working at the watershed scale in the Puget Sound region. A key objective in selecting participants was getting a range of perspectives. This required soliciting participation from federal, state, and local governments; tribal governments; the private sector; and the non-profit sector.

A total of 32 people were interviewed in 12 separate interviews conducted between June and October 2015. Most interviews were conducted in person with groups ranging from one to 10 people; three interviews were conducted over the phone to accommodate scheduling needs. Prior to the interviews, participants received a brief summary of projected climate change impacts for their watershed (see Appendix 1). The summary was developed by the Climate Impacts Group to spur conversation during the interviews and to provide a framework for discussing different categories of potential impacts.

The interview questions consisted of seven open-ended questions exploring:

- Current watershed issues, concerns driving near-term and long-term planning in the watershed,
- How today's weather and climate extremes affect what the interviewee does,
- How projected changes in climate ("tomorrow's weather") may affect what the interviewee does, and
- Broader views on what a more climate resilient watershed would look like.

Other topics discussed in the interviews included suggestions for additional actions or projects that would help address climate change impacts, and additional information or technical services needed to support those actions. The interview questions are provided in Appendix A.

Interviews took 60 to 90 minutes depending on the number of people being interviewed and schedule availability. In some cases, the number of people being interviewed, the nature of their organization, or schedule limitations required minor adjustments to the number of questions were asked. All responses were considered anonymous.

4 Interview Results: Stillaguamish Watershed

Thirteen interviews with staff or residents working in state, tribal, county, and local governments; a local watershed council; and farming were conducted for the Stillaguamish watershed (Box 2).

Box 2. Participating Groups: Stillaguamish Watershed

- City of Arlington
- City of Stanwood
- Private sector (farming)
- Snohomish County
- Stillaguamish Tribe
- Stillaguamish Watershed Council
- Washington Department of Natural Resources

4.1 Current Planning Priorities and Climate Impacts

Current planning priorities identified by interview participants varied but generally fell within the context of economic growth/stability and salmon restoration. Related actions included economic development, supporting agricultural production in the lower watershed, replacing culverts, increasing floodplain connectivity, riparian planting, estuary restoration, increased stream temperature monitoring, placement of large woody debris in streams, and managing forests to meet sustainable timber harvest levels.

Climate change was widely recognized as an issue that will affect floodplain management and planning activities in the Stillaguamish. In most cases, climate change was expected to exacerbate existing challenges associated with today's extreme events (Table 1). For example, warmer summer temperatures, more extreme heat events, and lower summer streamflows will create additional stress for salmon and may reduce the efficacy of some salmon restoration projects (e.g., if dewatered). Warmer and drier summers also increase the risk of forest fires, which to date has not been a major concern in the Puget Sound region. Any increase in forest insects or disease would contribute to a higher fire risk.

In the lower watershed, climate change could put a squeeze on agricultural production if August temperatures are too warm for the crops typically grown in the Stillaguamish and wetter spring conditions make it more difficult to plant earlier to avoid the warmer August temperatures. This squeeze, it was noted, may occur even as climate change-induced drought in California creates higher demand for products grown in the Stillaguamish. This could lead to more intensive farming in the lower watershed and increase the need for on-farm water storage for irrigation.

When asked about more extreme precipitation and flooding, participants noted that a bigger concern would be if heavy rain events stick around longer. The Stillaguamish basin has a history of "flashiness" (i.e., quickly rising and falling flood flows). More prolonged rain events and larger floods could have more damaging effects in the basin, including increased scouring of salmon redds and increased sediment loading in rivers and streams. Larger floods could also lead to more frequent or longer closures of State Route 530 and damage to transportation infrastructure.

Sea level rise is another aspect of climate change that interview participants recognized as affecting their work or priorities. Sea level rise will accelerate marsh habitat loss and could cause the smoltification zone to shift higher in the watershed. Sea level rise also may exacerbate existing drainage problems in agricultural fields by making it harder to effectively use and maintain drainage ditches.

Table 1. Observed impacts of today's extreme events in the Stillaguamish Watershed

Today's extreme events	*Observed impacts*
Lower summer streamflows	Dewatering of salmon restoration projects Reduced efficacy of smolt traps Increased salmon poaching (lower flows increase stream access for people)
Summer heat events	Reduced opportunity for seining juvenile salmon due to temperature-related mortality Delayed migration and higher pre-spawning mortality (compounded by lower summer streamflows) Increased heat stress on young plants, affecting overall growth and requiring more irrigation Reduced crop quality (e.g., lettuce gets bitter) More agricultural pests (e.g., aphids) Accelerated ripening of crops, which has led to labor shortages (laborers still picking other crops) and difficulties getting crops to market (e.g., because berries from California are still in season) Increased wildfire risk and reduced fire response capacity as big fires in eastern Washington stretched resources Wastewater treatment plant discharges have been close to temperature limits on a few occasions
Flooding	Reduced incubation success, with multi-year impacts (e.g., big peak flow events during the 2012 incubation period led to low returns 3-4 years later) Increased siltation, particularly in the old channel for the Stillaguamish Closure of State Route 530 during larger events (2006, 2010, 2015[3]) Increased scour of salmon redds More incising on smaller channels in the watershed Risk of water quality problems for municipal water supplies (e.g., bigger flood events have "gotten close" to increasing turbidity in the groundwater wells used by the City of Arlington)
Extreme precipitation	Increased stormwater flooding in areas with poor drainage and/or undersized culverts (e.g., flooding of a business park in Arlington that supplies $500,000 per day of real-time manufacturing to Boeing) More runoff from hillside developments onto agricultural lands Restrictions on timber harvest activities under heavy rain conditions if there is potential for sediment going into streams. Increased forest roads inspections Increased likelihood for landslides and culvert damage
King Tides/High tides	Difficulty draining stormwater and drainage ditches during high tides

[3] SR 530 east of Arlington was closed on November 17, 2015 due to floodwaters from the South Fork of the Stillaguamish River. This flooding occurred after the interviews were conducted.

Efforts to explicitly address climate impacts in the Stillaguamish are in the early stages, where occurring. The City of Arlington added brief information on climate change in the natural resources section of their Comprehensive Plan. The inclusion is considered more of a place holder for future work on adaptation. The city is also considering planting more trees around town to mitigate heat impacts. The Stillaguamish Tribe has included climate change in their evaluation of what properties would benefit from restoration and is currently working on a natural resources climate change adaptation plan. At the state level, the Washington Department of Natural Resources (DNR) is completing a series of internal workshops in various programs on how climate change is likely to impact DNR programs. The agency is also working on a risk assessment for west side forests.

In some cases, climate change is creating new opportunities. For example, the Tulalip, Stillaguamish, and Sauk-Suiattle Tribes are partnering on a mountain goat (*Oreamnos americanus)* study designed to help the tribes develop a better understanding of the factors that could affect the species' population growth now and in a changing climate.[4] The Stillaguamish have also formed a partnership with the USGS for stream temperature monitoring. These types of partnerships and new program opportunities are increasing as more grant applications start asking applicants to consider climate change in their work.

4.2 Suggested Actions for Addressing Climate Change Impacts in the Stillaguamish Watershed

After discussing how climate change could affect the Stillaguamish watershed and floodplain management and planning activities, participants were asked to identify specific actions that could help address the impacts and concerns discussed during the interview.

Thirty-nine specific actions, needs, or suggestions were noted during the interviews (Table 2). Responses ranged from technical data requests to general thoughts about what's needed to more broadly increase resilience in the watershed (e.g., trust-building steps). A general interest expressed in nearly all of the Stillaguamish interviews was the idea of looking at management of the upper watershed for ways to buffer the higher flood flows and lower summer streamflows expected with climate change. This could be done, for example, by managing the upper watershed to retain as much snowfall as possible and maximizing groundwater recharge.

> *"We have to find ways to retain groundwater. What good are engineered log jams if we don't have any water?"*
>
> *- Stillaguamish watershed interview participant*

[4] Mountain Goat Status in the North Cascades: Population Dynamics, Habitat Selection and Seasonal Movement Patterns in a Changing Climate, US Fish and Wildlife Service Tribal Wildlife Grant (2015-2016)

Table 2. Suggested actions and information needs for addressing climate change impacts in the Stillaguamish Watershed

Related to…	***Suggested Actions and Needs: Stillaguamish Watershed***
Upper Watershed Management	Better forestry practices
	Increase forest monitoring so DNR and others can build an understanding over time of how climate will affect vegetation
	Restore forest land (where needed) and keep existing forest land in forest cover to help reduce peak flows
	Manage forests to maximize snow cover
	Stop building in north County; need to save the trees to hold that water
	Need higher standards to capture runoff in upland developments
	Focus restoration on upper watershed, not just emergent marsh
Floodplain Management	Restore floodplains to allow the river to move more rather than incising
	Remove dikes, bank armoring in the estuary and river to help slow the river
	Look at opportunities to set back dikes
	Skim off the peak flows – bifurcate the river, create side channels, etc. Summer low flows could be helped if you can capture 20% of that high flow and meter it back into the system in the low flow season.
	Need to learn to live with flooding and its benefits (it's helpful with the soils)
Land Use Planning/Other Policy Measures	End the use of exempt wells
	Possibly create a trust program for trading water rights
	Pursue land acquisition (needs additional funding)
	Link salmon recovery with Growth Management Act, comprehensive planning
	Reduce development in the floodplain (specifically at-risk areas)
	Allow expansion of the Urban Growth Area outside the floodplain
	Need a strong and multi-jurisdictional Growth Management Act to allow for resource sharing
	Technical assistance, e.g., grants to look at climate change and Growth Management Act analysis
	Maintain connected farmland in the fertile bottomlands
	Incentivize good behavior; provide *dis*incentives to rebuilding in the floodplain
Data/Information Needs	Climate data and information needs to be tailored and translated for a wide range of audiences. Key is how the problem is presented. For example, how climate change affects the pocket books (via dike maintenance and design, pumping costs) will work for diking districts.
	Need to know how to best achieve greater forest cover – incentivizes? Regulation?
	Need better understanding of the genetics of local adaptation. After disturbance (natural or because of harvest), what trees, what species, what mixes should be planted given climate change?
	Can we better predict weather patterns better?
	Potential impacts on water supply
	More information on/visualization of what impacts on the Stillaguamish look like. For example, we've seen inundation models but people are not

	understanding what that actually means because we haven't given people the numbers (quantification of impacts needed). Data about levees height on both sides of the delta More specific Skagit/Port Susan Bay sea level rise data More information on the impact of low summer flows. How do you measure pre-spawning stress? Better general data about the watersheds ("we are flying blind in a lot of watersheds; don't know a lot about them). Need a good store of knowledge so people can start making decisions rapidly. Need to look at how they are managing salmon in drier places. Updated FEMA flood maps
Other	Need to change the focus from salmon recovery to riverine function Strong leadership – it takes a strong leader to plan 40-50 years out. Need a champion in the urban planning and resource management community who can "carry water and get buy-in from a community that is living paycheck to paycheck" Focus on partnerships can be slow but beneficial. More networking would be good so they can learn about opportunities to share. Need to engage in lots of trust building. It will take 1-to-1 conversations and other actions to build trust. Need to take a more holistic, watershed perspective. Have to provide a solution and hope (and a couple of big floods to get the conversation going)

4.3 Views on What a Climate Resilient Stillaguamish Watershed Looks Like

Interviews closed with discussion on what a climate resilient Stillaguamish watershed looks like. For this question, interview participants were asked what they would look for as signs of a more resilient watershed if they were transported to the watershed in the 2050s.

Participants described resilience in both ecological and socioeconomic terms. Ecologically, the watershed would have greater biodiversity and increased habitat connectivity in floodplains and the nearshore environment. One participant described the idea of a one mile wide riparian corridor with no houses or dikes; this corridor would allow for large channel migration zones and let the river "move the way it needs to."

In the upper watershed, a resilient watershed would include a good mixture of forest structures with older and more complex stands around water resources such as rivers and wetlands. Tree cover would be restored wherever possible to increase habitat and provide more buffering for floods. Sustainable forest practices in the upper watershed would still play a role in supporting a rural economy.

The continued viability of farming was also considered an important indicator of resilience. In addition to supporting the rural economy, local food production would reduce reliance on food produced from other regions. The continuation of farming in the lower watershed would also preserve the flood risk reduction benefits provided by farmland to developed areas.

Other signs of a resilient watershed include the availability of incentives to property owners to keep private property forested, no further development in high risk areas, continued emphasis on conservation, and awareness of climate change and what's needed "to be better stewards."

4.4 Other Issues That Can Affect Resilience Efforts in the Stillaguamish Watershed

Throughout the interviews, participants often commented on challenges and other issues that could directly or indirectly affect resilience planning or the outcomes of those efforts. For the Stillaguamish watershed, these issues included the following:

- *There is a desire for more economic development, but that development also creates challenges for addressing climate risks.* Some interview participants expressed the need for more economic development, including commercial and industrial development, to increase retail sales tax revenue, keep property taxes low, and to support public safety and other services. There is concern that discussions about climate risks could lead to reduction in value or lead to disinvestment in parts of the watershed. Additionally, some potential adaptation options, such as developing outside the floodplain to help reduce flood risk, may bump into Growth Management Act (GMA) restrictions. The GMA would have to change to allow for expansion of Urban Growth Areas outside of the current limits (currently required to build out all buildable areas within the GMA zone before changing the GMA zone).

- *Change takes time, particularly extreme change.* Major changes, including retreat from sea level rise or moving out of the floodplain, will have to be done via a gradual process. As noted by one participant, "it took 100 years to develop downtown Stanwood; it will take another 100 years to move out" (if that is what the community decided to do at some point in the future).

- *A lot of trust building is still needed within the Stillaguamish watershed.* Engagement around climate adaptation and resilience planning needs to occur through small steps (at least initially) to build trust between participants. As one participant noted, "the watershed is not ready for a big radical shift in thinking yet." You need to start with smaller efforts to build trust and then expand the conversation. The South Slough Project was mentioned as an example of a multiple benefit project that is (so far) working to build trust in the process and in different outcomes.

- *There are difficult tradeoffs in converting farmland (via levee removal) to estuarine habitat that are not fully resolved.* Farmland conversion is creating some concern that it will bring marine water (and with that, storm surge) closer to the City of Stanwood. These conversions have also raised concerns about the ability to drain storm water, an increased risk of coastal flooding, and losing productive farmland. It was noted, however, that some of the lands been converted are getting more difficult farm because of drainage problems and difficulties maintaining levees and drainage ditches.

- *Communities can be penalized for doing well at risk reduction.* The better communities get at addressing repetitive flood losses, the less funding communities receive to address the potential for repetitive flood loss. This, in effect, creates a financial penalty for doing a good job that makes it harder to continue flood mitigation efforts.

- *It is difficult to take a systems perspective*. Salmon recovery planning stresses on-the-ground salmon recovery projects, making it difficult to take a system-wide perspective for considering risks and opportunities across the watershed and across programs that heavily influence the watershed, including the Growth Management Act and comprehensive plans.

- *Changes in management of upland state forests (suggested as an opportunity in interviews) would need to navigate the balance that WA DNR has to strike between meeting conservation objectives and the agency's trust/fiduciary responsibility.* WA DNR currently manages 3 million acres in Washington as public trust lands; 17% of the Stillaguamish watershed (around 8,000 acres, 7,600 acres of which is forested) is DNR public trust lands. State trust lands have been managed since 1889 as an ongoing source of financial support for public K-12 schools, state universities, and other public facilities.[5] They are also managed for habitat and recreation. Changes in upland forest management to maximize retention of flood waters, for example, could come into conflict with DNR's trust responsibilities for those lands.

5 Interview Results: Puyallup Watershed

Nineteen people were interviewed for the Puyallup River watershed, including staff from two tribes, local and federal government staff, and members of the Puyallup River Watershed Council (Box 3).

5.1 Current Planning Priorities and Climate Impacts

Interview participants identified salmon recovery (particularly Chinook and steelhead), flood risk reduction, stormwater management, water quality improvements, and continued viability of agriculture as the priorities guiding their floodplain management and planning activities.

Salmon recovery activities are focused on rebuilding salmon runs and habitat improvements. Efforts include riparian improvements, replacing large woody debris, addressing migration barriers (e.g., culverts), and finding partners for decommissioning old forest service roads in upper watershed.

Flood risk reduction efforts are a major focus due in part to large flood events in 1996, 2006, and 2009. Mud Mountain Dam (a federal flood control dam on the White River) is an important component of managing downstream flood risk, however the dam only regulates flood flows from 400 square miles of a 1,000 square mile drainage area. In a big flood event, there is still a lot of unregulated flow that can cause flooding. Buying out land,

Box 3. Participating Groups: Puyallup Watershed

Muckleshoot Tribe

Pierce County Public Works

Pierce County Conservation District

Puyallup River Watershed Council *(including: Citizens for a Healthy Bay, City of Puyallup, City of Tacoma, King Co. River and Floodplain Management, Pierce Co. Conservation District, Pierce Co. Surface Water Management, Port of Tacoma, private sector consultant, Puyallup Tribe)*

The Puyallup Tribe

U.S. Army Corps of Engineers

[5] For more on Washington's Public Trust Lands, see http://www.dnr.wa.gov/managed-lands/forest-and-trust-lands

setting back levees, and other efforts to “give the river more room” are being pursued in the Puyallup watershed to help mitigate flood risk.

Stormwater management is a priority due to the need to reduce flooding in urban areas and, increasingly, the need to reduce associated water quality impacts. Efforts are focused on ensuring effective stormwater treatment going forward but urban areas are also dealing with older infrastructure with no treatment or outdated treatment. Funding for stormwater management projects has been a continual challenge. A related priority is getting streams removed from the Total Maximum Daily Load list, with the goal of making every stream, lake, and beach swimmable and shellfish harvestable. Other noted priorities include public education and partnership building around the issues of clean water and clean air for fish, wildlife, and people, and ensuring that the watershed has a sustainable agricultural economy and local food access.

Interview participants identified several ways in which today’s extreme events have affected the watershed (Table 3). Responses were weighted towards impacts associated with summer heat events and low streamflow due presumably to the timing of most of the interviews (July 2015[6]).

Several participants noted that the summer drought and extreme low streamflows were prompting new conversations around traditional and non-traditional solutions. This has included questions about using Mud Mountain Dam to augment summer streamflows, the feasibility of shading ponds or chilling hatchery water, and the potential for transporting stranded fish in unregulated streams. At the other end of hydrologic spectrum, recent flood events have reinvigorated debate around dredging, which was halted in 1990s due to impacts on salmon habitat.

As in the Stillaguamish watershed, Puyallup watershed interviewees saw climate change as exacerbating the impacts associated with today’s extreme events. For example, lower and warmer streamflows would increase the prevalence of fish pathogens and reduce maintstem spawning habitat. Warmer streamflows could also lead to more temperature violations and ultimately the establishment of more Total Maximum Daily Load limits, which have expensive legal obligations for local governments.

With regards to flood risk and more extreme precipitation, participants noted that more intense atmospheric river events will increase winter flood risk in the Puyallup watershed. Mitigating the additional flood risk via Mud Mountain Dam could be challenging, however. The dam’s use in winter is already being maximized and structural changes (i.e., making the dam higher) would be difficult. Operational changes at Mud Mountain Dam to address projected summer low flow problems could be equally difficult. Because the dam is federal, operational changes require an act of Congress. Operational changes are not unprecedented (e.g., Howard Hanson Dam on the Green River) but it can take a decade or more before changes are implemented.

Another concern expressed was the potential that more extreme precipitation could reduce the effectiveness of infiltration and low impact development (LID) projects. This could make it more difficult to sustain support for installation of LID projects. Finally, it was noted that sea level rise could affect Port of Tacoma operations and the movement of cargo via roads and rail.

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[6] January-August 2015 was the warmest January-August period on record and the 9th driest for Washington State. June-August was also the warmest on record for the Puget Sound region (source: Office of the Washington State Climatologist)

Table 3. Observed impacts of today's extreme events in the Puyallup Watershed

Today's extreme events	Observed impacts
Summer low flows	Low dissolved oxygen in the river (exacerbated by warm water temperatures) Below normal fish catches Reduced water quality near wastewater treatment facilities (lower flows concentrate permitted effluent)
Summer heat events	Higher pre-spawning mortality due to higher prevalence of bacterial diseases (e.g., furunculosis) High summer water temperatures (exacerbated by low summer streamflows) Difficulty managing water temperatures in salmon hatcheries that rely on surface water (can lead to higher mortality of hatchery stock) More agricultural pests Earlier and more irrigation for agriculture in the watershed Growing concern about summer water availability for agriculture, including groundwater levels Wells going dry or getting really low
Flooding	Increased salmon egg scour mortality Increased awareness of flood risk from people who thought they were immune to floods Reinvigorated debate around dredging
Extreme precipitation	Increased river and urban flooding Increased difficulty with conversations around green infrastructure (perception that the green infrastructure will fail)
King Tides/High tides	Significant problems with bulkheads and overwater structures

5.2 Suggested Actions for Addressing Climate Change Impacts in the Puyallup Watershed

Interview participants identified 28 actions, needs, or suggestions for addressing climate change impacts in the Puyallup watershed (Table 4). This included actions related to forest management in the upper watershed, floodplains, habitat restoration, infrastructure, and land use planning. Numerous data and information needs were also identified.

> *"Salmon are very plastic and can adapt to a range of conditions. What's different now is the rate of that change."*
>
> *- Puyallup watershed interview participant*

Table 4. Suggested actions and information needs for addressing climate change impacts in the Puyallup Watershed

Related to…	***Suggested Actions and Needs: Puyallup Watershed***
Upper Watershed Management	Increase work with small forest land owners (small land owners can have a big impact on little systems) Consider offering Conservation District services (i.e., technical assistance) related to forest management Increase canopy cover over streams
Floodplain Management/ Riparian Habitat Restoration	Increase channel maintenance, including selective dredging Reduce sediment loads wherever possible Increase levee setbacks (to give fish a chance to avoid high flows and to provide more room for sediment deposits) Ramp up riparian enhancement work Revegetate the lower watershed Restore riparian habitat with more native cover Account for lower flows in habitat projects
Infrastructure	Engineering changes could be made to hatchery, but they can be expensive Explore potential for chilling surface water coming into hatcheries Consider going to tertiary treatment for wastewater flows Provide more technical support related to irrigation efficiencies for farmers
Land Use Planning/Policy	Move people out of harm's way Need to find ways to demand and expect a multi-benefit result when it comes to land use planning and related decisions, e.g, are levee improvements to protect farmland or to stimulate suburban development? (projects argue they are multi-benefit when they really aren't)
Data/Info Needs	Guidance on how to integrated climate change impacts into levees design and construction Delineation of channel migration zones to accommodate lateral erosion. Accounting for lateral erosion is typically poor and need will become greater with climate change. Information on how Atmospheric River-driven flooding may change. Will the frequency get worse? Will the intensity get worse? Will the seasonality shift/get bigger? Would be good to know how the current 1-in-50 year flood event changes (changes in frequency, volume of flows). How will peak flows change? (what are the numbers?) How long does the flood risk get reduced by setting back a levee, removing gravel, or building higher? Pretty clear that the amount of sediment coming from Mt Rainier in the next 40 years is large. Need to update Pierce County's continuous record of rainfall for projects to include the last 15 years and then project out. Will use instantly on sizing facilities (integrate into models) How is flooding duration affected? Would use that information in set-back design What water is important to who and when?

	Need for agreement on the methodology that should be used for assessing the impact of changes in forested areas in the lower watershed; not sure there is a good forest assessment tool (but there are a variety of standards of how you might evaluate it)
	Need messaging about cumulative impacts
	More research on changes in Growing Degree Days specific to Pierce County
	1) What level of protection to be designing to? 2) what are the freeboard/safety factors, and 3) what do the potential flows mean for raising levels in the future….for a while it's been hard to get good information related to peak flows.

5.3 Views on What a Climate Resilient Puyallup Watershed Looks Like

Puyallup interviewees were asked to describe what a more climate resilient Puyallup watershed would look like if given the chance to visit the watershed in the 2050s. The responses were diverse, a finding that reflects the diversity of the watershed itself (from forested to urban) as well as the planning activities within the watershed. Responses are summarized below by major themes.

- *Resilient uplands.* In the upper watershed, the risk of large forest fires is eliminated because people will have planned for increasing fire risk and have managed the forests to improve forest health. Additionally, there will be more water retention in the upper watershed (possibly via more beaver dams) that has been designed to emulate glacier retention and release of water.

- *Resilient riparian and shoreline habitat.* Wider levee setbacks, wider floodplains, and more off-channel habitat are being used to improve habitat in the Puyallup watershed. Groundwater restoration is being used to maintain streamflows, particularly in smaller streams. More native vegetation has been planted along the streams to help with water temperatures and to create habitat. Coming into urban basins, innovative solutions are being used to address water temperature impacts. Shoreline habitat has improved despite increased storm surge reach because residents are seeing the value of green infrastructure for shoreline protection. Finally, the public supports habitat maintenance in the same way they are willing to support levee maintenance.

- *Salmon recovery and cultural connection*. Gains in salmon recovery continue to be made. A sustainable salmon fishery exits for tribal fishermen. More kids would be interacting on a regular basis with salmon and the resources required to sustain salmon (e.g., riparian habitat).

- *Flood resilience.* Communities have given a lot more latitude to the river. As noted by one interviewee, you can't keep putting "five gallons of water into a one gallon container." Channel capacity has been restored, and sediment is being safely removed from the river by shelving rather than dredging, for example. Through these and other activities, resilience to flooding has been increased throughout the whole watershed to the point that the flood warning threshold has been raised for all areas. Today, for example, the upper Puyallup River (upstream of the Carbon River) can now have twice the flood flow that used to trigger flood warnings; this higher threshold would apply everywhere in the watershed in the future.

- *Stormwater/infrastructure improvements.* Stormwater improvements are seen through improved conditions downstream of tributaries. Past practices that emphasized getting water off your property have been replaced with practices that promote more onsite retention and treatment. The condition of private culverts is improving via better enforcement of rules. More people in the urban/suburban areas see green projects as the preferred solution to stormwater issues, leading to more public demand for those approaches.

- *Water supply/Streamflows*. The watershed would not have flow issues; the watershed will have figured out how to have water for various competing interests. Culturally, people change habitats in ways that reduce water use.

5.4 Other Issues That Can Affect Resilience Efforts in the Puyallup River Watershed

Throughout the interviews, participants often commented on challenges and other issues that could directly or indirectly affect the ability to engage in resilience planning and/or affect the outcomes of those efforts. For the Puyallup watershed, these included the following points.

- *Participants are feeling process fatigue.* The number of ongoing planning efforts related to flooding, salmon recovery, and stormwater is considerable. These efforts often draw on many of the same individuals. This has led to planning process fatigue and the feeling of being "over-processed."

- *Participants have to see the value in working on climate change at a watershed scale.* A recent effort to launch a watershed-scale climate change adaptation planning project for the Puyallup failed due, in part, to uncertainty about the usefulness of the effort. According to one participant, "people had a hard time wrapping their heard around expectations, deliverables, and outcomes." Process fatigue and unfamiliarity with the group trying to organize the planning effort also affected the outcome.

- *There are difficult tradeoffs and conflicting priorities with levee setbacks*. While levee setbacks are often pursued to create habitat and increase flood resilience, conflicting project priorities (sometimes mandated by funding sources) can lead to compromises that reduce flood control and habitat benefits. For example, setback allotments for planting riparian habitat may be restricted to accommodate parks, trails, infrastructure, and views. In some cases, funding for those trails may be tied to recreation funding from the State. The additional restrictions that come with these multiple uses can limit the location, number, and types of trees that get planted, potentially reducing the shade, habitat, and flood buffering benefits provided by levee setbacks. Several interview participants also noted that the levee setbacks result in more development behind the levees, ultimately increasing what's at risk if levees are overtopped.

- *Climate change would require larger levees, compounding issues with adequate planting space.* Adding to the existing challenge of preserving adequate planting space is the fact that projected changes in streamflow volume for the 100-year flood would require higher levees, resulting in a bigger structural footprint. Levee slopes can't be more than 3:1 to support big trees. However, it will be difficult politically and economically to design bigger levees that preserve the 3:1 slope.

- *Sediment loading is a growing problem (again), creating pressure to dredge (again).* The Puyallup River is a dynamic system with large amounts of sediment coming off Mt. Rainier. The lower river channel is naturally filling itself in as a result, increasing flood risk and affecting habitat quality. Climate change and development will exacerbate this problem. There is social and political pressure to resume dredging, which was stopped more than a decade ago because of habitat concerns.

- *For some, it is difficult to accept the Puyallup as a dynamic system.* For some people, it was noted, "a river that moves is a poorly managed river." This sentiment can create public and political pressure to constrain the river in defined channels.

- *Rapid development in the Puyallup Basin and increasing operating costs make it more challenging to implement some actions*. The last two decades have seen significant development in the lower Puyallup watershed. Areas that were primarily agricultural lands in the early 1990s have been converted into industrial, commercial, and residential land uses. The rapid development increases the cost of land acquisition for habitat restoration and flood reduction efforts, potentially limiting the pace and scale of implementation. Additionally, every time a piece of property is acquired, that acquisition adds to operating costs. The higher operating costs ultimately reduces the amount of funding available for future capital projects.

- *Big flood events get the attention – and the opportunities – while other problems don't.* Big flood events are big news items with lots of compelling visual images. This creates political and public support for flood mitigation efforts, especially as the area gets more developed. Big flood events can also create funding opportunities that may not have been available otherwise. Other extreme events may not get the same level of attention, however. For example, more frequent heavy rain events are not seen as having a big impact even though stormwater runoff is known to be a major problem in Puget Sound waterways. Lower summer streamflows are also not getting much attention even though the impact on salmon can be widespread. As noted in the interviews, severe low flows tend to affect the whole basin while flood severity tends to vary by sub-basin. Additionally, low flows tend to last longer while flood flows move through the watershed quickly.

- *Coastal flooding is harder to get traction on*. Efforts to address coastal flooding tend to get less public support due to fewer examples of what coastal flooding looks like and public perception that when something happens along the coast, it is considered a private property issue.

- *Climate change impacts may make it harder to implement green infrastructure projects.* More extreme precipitation events and increasing storm surge are making it more difficult to convince private landowners to build green infrastructure. In coastal areas, people are expressing concern that non-traditional ways won't protect their property against bigger storm surge. For stormwater runoff, there is a perception that the green infrastructure will fail under more extreme precipitation events.

- *More protective risk reduction measures are hard to keep in practice.* Even when communities adopt more aggressive risk reduction measures, it can be hard to implement those measures. For example, the threat of lahar flows from Mount Rainier has allowed for more conservative planning requirements (e.g., requirements for two feet of freeboard on the levees). However, the people who permit buildings are in a different department. Those folks are rewarded for ease of permitting, which can create incentive to reduce any requirements that make it harder to develop.

- *Resilience efforts focusing on the upper watershed will have to deal with a diversity of uplands ownership.* There is a fair amount of land cover in small and larger corporate/family forests. This can make it more challenging to proactively manage forest lands for resilience (e.g., to increase water retention).

6 Conclusions

The Stillaguamish and Puyallup watershed interviews provided an opportunity to share information about climate change impacts with a diversity of stakeholders engaged in floodplain management, and to learn how those impacts could affect floodplain management and planning priorities and activities. The interviews also identified additional actions or information needs that could help participants address climate change impacts through their ongoing efforts. Finally, the interviews explored participant views on what a more climate resilient watershed would look like.

While the two watersheds are different in a number of ways (e.g., size, degree of urbanization), several common issues related to climate change, floodplain management, and floodplain planning emerged from the discussions. First, and most significantly, all interview participants felt that climate change would exacerbate the challenges they are working to address through floodplain management and planning (salmon recovery, flood mitigation, habitat restoration, water quality improvements, stormwater management, viability of farming, etc.).

A second issue that came up frequently in both watersheds was interest in focusing more on the upper watershed as a tool for addressing increasing flood risk *and* lower summer streamflows. This could include optimizing forest management practices and land cover to retain as much snowfall as possible, reduce peak flows, and recharge groundwater. Diverse land ownership and the historical obligations of state trust lands could be factors in implementing actions in the upper watersheds, however.

Another view expressed in both watersheds (although not universally expressed) was the opinion that more extreme summer low flows could present bigger challenges in the future than increased flooding, particularly for salmon. The reasons related to differences in the geographic extent, duration, and familiarity of the two extremes. First, flood severity tends to vary within sub-basins while extreme low flow conditions are more likely to affect an entire watershed. Second, flood events move through a watershed fairly quickly while extreme low flow events tend to occur over a prolonged period of time (i.e., several weeks or longer). Third, flooding is not necessarily a new event ("we are flooding the same areas more frequently") while the conditions experience in summer 2015 were considered unprecedented in many ways (a fact that may have biased the perspective reported here).

Interviews in both watersheds touched on the difficulty of balancing the tradeoffs that come with levee changes. In the case of the Stillaguamish, removing levees in the lower floodplain has created more habitat but may also increase the risk of coastal flooding and storm surge to nearby infrastructure, particularly with sea level rise. In the Puyallup, levee setbacks are allowing for riparian habitat improvements and flood risk reduction but they are also resulting in more intense development behind the levees, ultimately increasing what's at risk if levees are overtopped. The need to design for multiple-use levees (e.g., to include space for recreation) also creates difficult tradeoffs with the location, number, and types of trees that can be planted for habitat restoration.

Finally, the importance of relationships, trust, and the ability to see value in and ways of working at a watershed scale were raised in both watersheds.

Understanding each watershed's context and how that context can shape preparing for climate change at the watershed scale is an important first step in developing climate resilience at the watershed scale. While the views expressed during the interviews are only a small sample of the potential views on climate change and watershed planning within each watershed, the interviews underscored the fact that responding to climate change will not be a "one-size-fits-all" approach. Climate impacts and responses will vary by location and over time. In addition, floodplains and the effectiveness of floodplain management and planning activities in addressing climate change impacts will be affected by a number of issues that go beyond changes in climate. Many of these—including development, institutional barriers, and limits on funding—were discussed by interview participants in the course of responding to specific interview questions.

Appendix A: Supporting Materials for the Interviews

How Will Climate Change Affect the Stillaguamish Watershed?
Prepared by the University of Washington Climate Impacts Group, June 2015

How Will Climate Change Affect the Puyallup Watershed?
Prepared by the University of Washington Climate Impacts Group, July 2015

Interview Questions

How Will Climate Change Affect the Stillaguamish Watershed?

Prepared by the University of Washington Climate Impacts Group, June 2015

Climate

Rapid warming is expected this century and the heaviest rain events are projected to become more intense. All scenarios project warming for the Stillaguamish Watershed as a result of rising greenhouse gas emissions. Although annual precipitation is not expected to change significantly, heavy rainfall events are expected to intensify and summers are expected to be drier.

Coasts

Sea level rise and ocean acidification will continue to affect the Stillaguamish delta. Both are projected to rise substantially under all greenhouse gas scenarios. Sea level rise in the Puget Sound region reflects the combined effects of a rising global sea level and subsidence of land surfaces due to plate tectonics, among other factors.

Water

The Stillaguamish watershed is projected to experience decreasing snowpack and widespread changes in streamflow timing, flooding, and summer minimum flows but little change in average annual streamflow volume. Warmer winter temperatures will reduce snowpack volume in the Stillaguamish watershed and shift the timing of snowmelt earlier (Figure 1). Lower snowpack in the upper watershed will also contribute to lower streamflow volume during the summer months. Flood risk increases in the fall/winter months due to expected increases in extreme precipitation and shifts in seasonal precipitation from snow to rain over larger portions of the watershed. While these seasonal changes are large, annual streamflow volumes are not projected to change substantially.

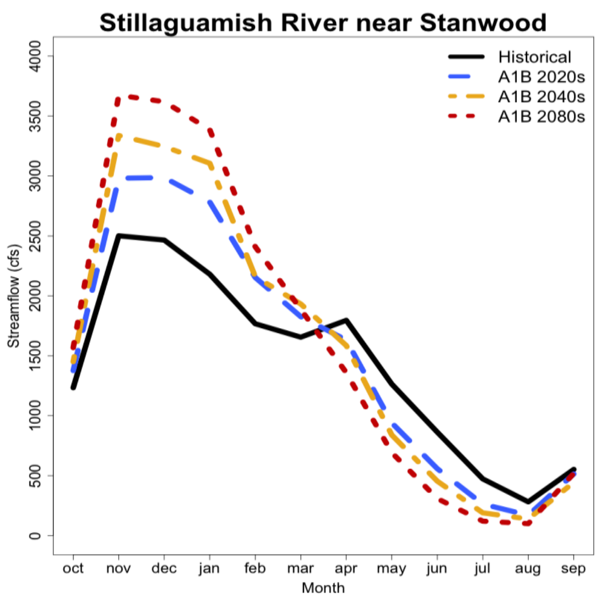

Figure 1. Change in the seasonality of streamflow, showing monthly average runoff for the water-year (Oct-Sep), for the 20th century (1916-2006; black line), the 2020s (2010-2039; blue line), the 2040s (2030-2059; gold line), and the 2080s (2070-2099; red line), all based on a medium (A1B[1]) greenhouse gas scenario. *Source: http://warm.atmos.washington.edu/2860*.[2]

Water Quality

Stream temperatures in the Stillaguamish are projected to increase, along with sediment loading and possibly landslides. Warming air temperatures and declining snowpack result in warmer stream temperatures, while a receding snowline and increasing winter rain will cause greater erosion, increasing the sediment supply to rivers. Although future landslides are difficult to predict, several studies indicate that future conditions will favor an increase in landslide risk for the Stillaguamish.

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[1] To make projections, climate scientists use greenhouse gas scenarios – "what if" scenarios of plausible future emissions – to drive global climate model simulations of the earth's climate. Wherever possible, scenarios used in this document include both a low and a high emissions scenario of 21st century greenhouse gas emissions.

[2] 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, doi: 10.1080/07055900.2013.819555: http://warm.atmos.washington.edu/2860/

Observed and Projected[1] Changes

Temperature	
Annual Temp - Observed[3]	Increase in average historical temperature (1895-2014) for nearby stations Everett: +0.71 ± 1.05°F Sedro Woolley: +1.19 ± 1.11°F
Annual Temp – Projected[4]	Projected increase in average annual temperature for the 2050s (2040-2069), relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): +4.4°F (range: +3.0 to +5.6°F) High emissions (RCP 8.5): +5.7°F (range: +4.5 to +7.3°F)
Frost-free season[4]	Longer freeze-free period expected (average for the Stillaguamish watershed). Low emissions (RCP 4.5): +16 days (range: +12 to +22 days) High emissions (RCP 8.5): +22 days (range: +16 to +28 days)

Precipitation	
Seasonal Precipitation - Observed[3]	No historical trend in seasonal precipitation; large variations from year-to-year.
Seasonal Precipitation – Projected[4]	Increased winter precipitation and decreased precipitation in summer (2050s relative to 1970-1999), for the Stillaguamish watershed: *Winter (Oct-Mar)* Low emissions (RCP 4.5): +8% (range: +2 to +18%) High emissions (RCP 8.5): +9% (range: +4 to +19%) *Summer (Apr-Sep)* Low emissions (RCP 4.5): −8% (range: −19 to 0%) High emissions (RCP 8.5): −8% (range: −21 to +1%)
Heavy Precipitation - Projected[4]	Increased maximum daily precipitation totals in Stillaguamish watershed (2050s relative to 1970-1999): Low emissions (RCP 4.5): +13% (range: +7 to +25%) High emissions (RCP 8.5): +16% (range: +3 to +29%) Recent research indicates that heavy precipitation events may be larger than what is projected in the above models.[5]

[3] Menne, M. J., Williams Jr, C. N., & Vose, R. S. (2009). *The US Historical Climatology Network monthly temperature data, version 2*. Bulletin of the American Meteorological Society, 90(7), 993-1007.
[4] Integrated Scenarios of the Future Northwest Environment: https://www.nwclimatescience.org/node/231
[5] Salathé, EP, AF Hamlet, CF Mass M Stumbaugh, S-Y Lee, R Steed (2014) Estimates of 21st Century Flood Risk in the Pacific Northwest Based on Regional Scale Climate Model Simulations. *J. Hydrometeorology*

Water Supply	
Snow	
Spring Snowpack – Projected[4]	Substantial declines in April 1st snowpack, 2050s relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): −66% (range: −75 to −54%) High emissions (RCP 8.5): −73% (range: −88 to −55%)
Streamflow	
Winter – Projected[4]	Increases in winter (October−March), 2050s relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): +28% (range: +20 to +44%) High emissions (RCP 8.5): +32% (range: +19 to +52%)
Summer – Projected[4]	Decreases in summer (April−September), 2050s relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): −24% (range: −29 to −16%) High emissions (RCP 8.5): −27% (range: −34 to −18%)
Flooding – Projected[2]	Most models indicate increases in volume associated with the 100-year (1% annual probability) flood event, 2040s (2030-2059), relative to 1970-1999, for the North Fork Stillaguamish: Low emissions (B1): +12% (range: −15 to +38%) Moderate emissions (A1b): +20% (range: +5 to +57%)
Low flows – Projected[2]	Most models indicate decreased volumes associated with the 7-day lowest flow in 10 years, 2040s (2030-2059), relative to 1970-1999, for the North Fork Stillaguamish: Low emissions (B1): −16% (range: −30 to +1%) Moderate emissions (A1b): -22% (range: −31 to −7%)

Water Quality	
Stream temperatures – Projected	*Char*[6]*:* Decline in number of river miles within thermal thresholds for char spawning/rearing (mean August stream Temp. <54°F[7]): Historical (1993 – 2011): 205 miles 2040s, Moderate emissions (A1b): 78 miles (−62% loss) 2080s, Moderate emissions (A1b): 27 miles (−87% loss) *Salmonids*[6]*:* Decline in number of river miles within thermal thresholds for core summer salmonid habitat (mean August stream Temp. <60°F): Historical (1993 – 2011): 650 miles 2040s, Moderate emissions (A1b): 580 miles (−10% loss) 2080s, Moderate emissions (A1b): 410 miles (−36% loss)

[6] NorWest Regional Database and Modeled Stream Temperatures: http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html

[7] Note that these thresholds are actually intended for 7-day average stream temperatures, not monthly averages. This means that the projections shown here are optimistic – an overestimate of suitable habitat.

Sediment & Landslides	Loss of snowpack and glaciers due to warmer temperatures contributes to the exposure of highly mobile sediment sources and increases in flood flows, which triggers faster sediment movement. Geomorphic hazards, like debris flows and landslides, could also increase in response to decreasing snowpack and glaciers.[8],[9] Increasing heavy precipitation may increase erosion rates and also threaten slope stability.

Oceans	
Sea Level – Observed[10]	Historical rise in sea level (Seattle is the closest long-term gauge) Seattle, WA: +0.8 in./decade (1900-2008)
Sea Level – Projected[11]	Rising for all scenarios Seattle, WA: +4 to +56 inches (2100, relative to 2000)
Ocean Acidification – Observed[12]	Global increase in ocean acidity since 1750 +26% *(decrease in pH: −0.1)*
Ocean Acidification – Projected[12]	Global Increase by 2100 for all scenarios (relative to 1986-2005). Low emissions (RCP 4.5): +38 to +41% High emissions (RCP 8.5): +100 to +109%

This document was prepared by the Climate Impacts Group to support interviews planned as part of the ***Integrating Climate Resilience in Puget Sound Floodplain and Working Lands Programs*** project.

For more information on climate change impacts in Washington, see *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers* (2013), available at http://cses.washington.edu/cig/reports.shtml, or contact the Climate Impacts Group (cig@uw.edu, 206-616-5350).

[8] Miller, D.J. (2004) Landslide Hazards in the Stillaguamish basin: A New Set of GIS Tools. A report prepared for the Stillaguamish Tribe of Indians, Natural Resource Department

[9] Lee, S-Y., and A.F. Hamlet. 2011. Skagit River Basin Climate Science Report. A summary report prepared for Skagit County and the Envision Skagit Project by the Department of Civil and Environmental Engineering and the Climate Impacts Group, University of Washington, Seattle. September, 2011.

[10] NOAA Sea Level Trends: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

[11] (NRC) National Research Council 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.* Washington, DC: The National Academies Press

[12] (IPCC) Intergovernmental Panel on Climate Change. 2013. *Working Group 1, Summary for Policymakers.* Available at: http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf

How Will Climate Change Affect the Puyallup Watershed?

Prepared by the University of Washington Climate Impacts Group, July 2015

Climate

Increasing greenhouse gases will lead to warmer temperatures throughout this century for the Pacific Northwest region. Climate modeling studies indicate that the Puyallup watershed will become warmer under all future scenarios, and will also undergo more intense rainfall events under most future scenarios. Although average annual precipitation is not expected to change significantly, summer months are projected to be drier than they were historically.

Water

The Puyallup watershed will undergo shifts in streamflow timing, increased winter flooding, and lower summer streamflows as a result of warmer temperatures and lower snowpack projected for the region (Figure 1)***.*** The overall amount of annual streamflow is not projected to change, however. Flood risk is projected to increase during the fall and winter seasons as warmer temperatures cause more precipitation to fall as rain over a larger portion of the basin area and as more intense extreme rainfall events contribute to higher flows. Likewise, less snowmelt will cause the lowest flows to become lower in the summer months.

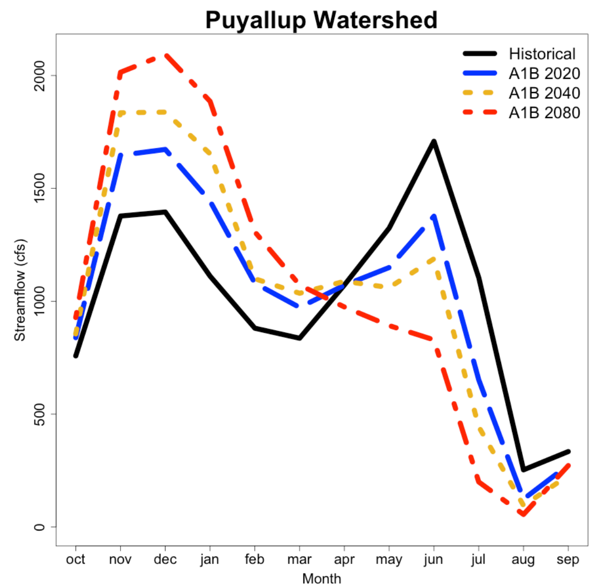

Figure 1. Change in the seasonality of streamflow, showing monthly average runoff for the water-year (Oct-Sep), for the 20th century (1916-2006; black line), the 2020s (2010-2039; blue line), the 2040s (2030-2059; gold line), and the 2080s (2070-2099; red line), all based on a medium (A1B[1]) greenhouse gas scenario. *Source: http://warm.atmos.washington.edu/2860.*[2]

Water Quality and Sediment

The Puyallup watershed is projected to undergo higher water temperatures, increased sediment loading and possibly more frequent landslides. Warmer air temperatures and lower summer streamflow will increase water temperature, while receding snowlines and more winter rainfall enhance erosion, increasing sediment supply in the watershed. Predicting landslide risk is complicated, however projections of higher rainfall, increased soil saturation, and steep slopes in the Puyallup watershed provide the conditions that favor more landslide activity.

Coasts

Commencement Bay will experience sea level rise and increasing ocean acidification. Increased greenhouse gas emissions will exacerbate both of these marine conditions. Local characteristics of the Puget Sound region will influence the extent of sea level rise and ocean acidification in the region. Sea level rise could be amplified by land subsidence occurring as a result of plate tectonics. Ocean acidification could be locally magnified by nutrient rich runoff from the urban and agricultural areas surrounding the Puyallup delta.

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[1] To make projections, climate scientists use greenhouse gas scenarios – "what if" scenarios of plausible future emissions – to drive global climate model simulations of the earth's climate. Wherever possible, scenarios used in this document include both a low and a high emissions scenario of 21st century greenhouse gas emissions.

[2] 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, doi: 10.1080/07055900.2013.819555: http://warm.atmos.washington.edu/2860/

Observed and Projected[1] Changes

Temperature	
Annual Temp - Observed[3]	Increase in average historical temperature (1895-2014) for nearby stations Buckley 1NE: +1.1°F ± 1.11°F McMillin RSVR: +0.6°F ± 0.98°F
Annual Temp – Projected[4]	Projected increase in average annual temperature (2050s, relative to 1980s): Low emissions (RCP 4.5): +4.2°F (range: 2.8 to 5.7°F) High emissions (RCP 8.5): +5.5°F (range 4.3 to 7.3°F)
Growing Season and Growing Degree Days - Projected [4]	Longer freeze-free period expected. Low emissions (RCP 4.5): +19 days (range: +14 to +23 days) High emissions (RCP 8.5): +25 days (range: +19 to +30 days) Increase in growing degree days (GDD) projected (base 50°F)[5]: Low emissions (RCP 4.5): +863 GDDs (range: +595 to +1140 GDDs) High emissions (RCP 8.5): +1119 GDDs (range: +800 to +1534 GDDs)

Precipitation	
Seasonal Precipitation - Observed[3]	No historical trend in seasonal precipitation; large variations from year-to-year.
Seasonal Precipitation – Projected[4]	Increased wet season precipitation and decreased dry season precipitation (2050s relative to 1980s): *Wet season (Oct – Mar)* Low emissions (RCP 4.5): +8% (range: −3 to +16%) High emissions (RCP 8.5): +9% (range: +2 to +17%) *Dry season (Apr – Sep)* Low emissions (RCP 4.5): -10% (range: −3 to -24%) High emissions (RCP 8.5): -9% (range: +1 to -21%)
Heavy Precipitation - Projected[4]	Increased maximum daily precipitation totals in Puyallup watershed (2050s relative to 1970-1999): Low emissions (RCP 4.5): +16% (range: +4 to +30%) High emissions (RCP 8.5): +20% (range: +1 to +39%) Recent research indicates that heavy precipitation events may be larger than what is projected in the above models.[6]

[3] Menne, M. J., Williams Jr, C. N., & Vose, R. S. (2009). *The US Historical Climatology Network monthly temperature data, version 2*. Bulletin of the American Meteorological Society, 90(7), 993-1007.
[4] Integrated Scenarios of the Future Northwest Environment: https://www.nwclimatescience.org/node/231
[5] Growing degree days are measurements used in agriculture to estimate growing season potential. For the current calculation, a growing degree day is counted for each degree the average temperature for a day moves above 50°F. For example, if the average temperature for the day was 55°F, that would count as 5 growing degree days.
[6] Salathé, EP, AF Hamlet, CF Mass M Stumbaugh, S-Y Lee, R Steed (2014) Estimates of 21st Century Flood Risk in the Pacific Northwest Based on Regional Scale Climate Model Simulations. *J. Hydrometeorology*

Water	
Snow	
Spring Snowpack – Projected[4]	Substantial declines in April 1st snowpack, 2050s relative to 1970-1999, for the Puyallup watershed: Low emissions (RCP 4.5): −52% (range: −59 to −36%) High emissions (RCP 8.5): −58% (range: −76 to −39%)
Streamflow	
Winter – Projected[4]	Increases in winter (October–March), 2050s relative to 1980s: Low emissions (RCP 4.5): +27% (range: +21 to +37%) High emissions (RCP 8.5): +34% (range: +19 to +62%)
Summer – Projected[4	Decreases in summer (April–September), 2050s relative to 1980s: Low emissions (RCP 4.5): −18% (range: −25 to −10%) High emissions (RCP 8.5): −20% (range: −31 to −9%)
Flooding – Projected[2]	Most models indicate increases in volume associated with the 100-year (1% annual probability) flood event, 2040s (2030 – 2059) relative to 1980s for the White River at Buckley[7]: Low emissions (B1): +39% (range: −14 to +85%) Moderate emissions (A1b): +56% (range: +22 to +115%)
Low flows – Projected[2]	Most models indicate decreased volumes associated with the 7Q10 (or 7-day lowest flow in 10 years) low flow event, 2040s (2030 – 2059) relative to 1980s for the White River at Buckley[7]: Low emissions (B1): −13% (range: −26 to +2%) Moderate emissions (A1b): −16% (range: −30 to −2%)

Water Quality and Sediment	
Stream temperatures – Projected	*Char*[8]*:* Decline in number of river miles within thermal thresholds for char spawning/rearing (mean August stream Temp. <54°F[9]): Historical (1993 – 2011): 726 miles 2040s, Moderate emissions (A1b): 531 miles (−26% loss) 2080s, Moderate emissions (A1b): 412 miles (−43% loss)) *Salmonids*[8]*:* Decline in number of river miles within thermal thresholds for core summer salmonid habitat (mean August stream Temp. <60°F): Historical (1993 – 2011): 988 miles 2040s, Moderate emissions (A1b): 934 miles (−5% loss) 2080s, Moderate emissions (A1b): 868 miles (−12% loss)

[7] Projected extreme statistics are reported here for the White River as a proxy for the Puyallup watershed since it is a major tributary and extreme flow data for the Puyallup is not available.

[8] NorWest Regional Database and Modeled Stream Temperatures: http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html

[9] Note that these thresholds are actually intended for 7-day average stream temperatures, not monthly averages. This means that the projections shown here are optimistic – an overestimate of suitable habitat.

Water Quality and Sediment	
Sediment & Landslides	Since the practice of dredging was halted in the mid-1990s for water quality improvement, the Puyallup watershed has aggraded, raising the channel elevations of the Puyallup, White and Carbon Rivers by 7.5', 6.5' and 2', respectively.[10] Loss of snowpack and glaciers due to warmer temperatures contributes to the exposure of highly mobile sediment sources and increases in flood flows, which triggers faster sediment movement. Geomorphic hazards, like debris flows and landslides, could also increase in response to decreasing snowpack and glaciers.[11] Increasing heavy precipitation may increase erosion rates and also threaten slope stability.

Coasts	
Sea Level – Observed[12]	Historical rise in sea level (Seattle is the closest long-term gauge) Seattle, WA: +9 inches (1899-2014)
Sea Level – Projected[13]	Rising for all scenarios Seattle, WA: +4 to +56 inches (2100, relative to 2000)
Ocean Acidification – Observed[14]	Global increase in ocean acidity since 1750 +26% *(decrease in pH: −0.1)*
Ocean Acidification – Projected[14]	Global increase by 2100 for all scenarios (relative to 1986-2005). There are no projections for ocean acidification specific to Washington State. Low emissions (RCP 4.5): +38 to +41% High emissions (RCP 8.5): +100 to +109%

This document was prepared by the Climate Impacts Group to support interviews planned as part of the ***Integrating Climate Resilience in Puget Sound Floodplain and Working Lands Programs*** project.

For more information on climate change impacts in Washington, see *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers* (2013), available at http://cses.washington.edu/cig/reports.shtml, or contact the Climate Impacts Group (cig@uw.edu, 206-616-5350).

[10] Czuba, J.A., Czuba, C.R., Magirl, C.S., Voss, F. 2010. Channel-Conveyance Capacity, Channel Change, and Sediment Transport in the Lower Puyallup, White, and Carbon Rivers, Western Washington: US Geological Survey Scientific Investigations Report 2010-5240, 104p.

[11] Lee, S-Y., and A.F. Hamlet. 2011. Skagit River Basin Climate Science Report. A summary report prepared for Skagit County and the Envision Skagit Project by the Department of Civil and Environmental Engineering and the Climate Impacts Group, University of Washington, Seattle. September, 2011.

[12] NOAA Sea Level Trends: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

[13] (NRC) National Research Council 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.* Washington, DC: The National Academies Press

[14] (IPCC) Intergovernmental Panel on Climate Change. 2013. *Working Group 1, Summary for Policymakers.* Available at: http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf

Interview Questions – Final

Subject to modification as needed for individual interviews.

Part 1. Introductions and Brief Review

- Introductions
- Review purpose and what the questions will cover.
- Brief summary of how climate change is expected to affect the watershed (referring to summary sheet)
- Review any handouts that may be useful to the interviewee

Part 2. Watershed Issues

2.1 What are the major issues, concerns, or priorities driving your near and long term planning (or interests) in the watershed?

Part 3. How does today's weather affect what you do?

3.1 Based on your experience, how has [fill in the blank] affected what you do?
[note: due to the conversational nature of the interviews, participant responses tended bounce between these different issues, as relevant]

- Prolonged summer heat or extreme heat events
- Cold air outbreaks, snow and ice events
- Flooding (river or stream/creek, localized flooding)
- Prolonged periods of above normal precipitation or extreme precipitation events
- Prolonged periods of below normal precipitation or drought
- Storm surge or unusually high tides

Related issues (if relevant):

- drainage,
- sediment loading,
- salt water exposure
- water supply

Part 4. How will tomorrow's weather affect what you do?

Related supporting materials:	• Impacts summary • Watershed map

After a general review the projected changes in climate…

4.1 In your opinion, how much does climate change affect the issues, concerns, or priorities you noted at the start of the interview?

4.2 More specifically, how do you expect [fill in the blank] will affect what you do?
[note: due to the conversational nature of the interviews, participant responses tended bounce between these different issues, as relevant]

- Increased temperatures and more extreme heat events
- Fewer cold air outbreaks, snow and ice events
- Increased precipitation and more extreme precipitation events

- Increased flooding (river or stream/creek, localized flooding)
- Prolonged periods of below normal precipitation or drought
- Sea level rise, higher storm surge, and/or higher high tides

Related issues (if relevant):

- drainage,
- sediment loading,
- salt water exposure
- water supply

4.3 In your opinion, what additional actions or projects are needed to better manage the impacts of today's weather extremes and projected climate change impacts?

4.4 What additional information or technical services are needed to support the actions discussed today?

Part 5. Stepping Back: Broader Views on Resilience

5.1 In your opinion, what does a more climate resilient watershed look like in the context of what you do and care about? In other words, what would you see as evidence of success in terms of adapting to the impacts of climate change?