

Integrating Climate Resilience in Flood Risk Management: A Work Plan for the Washington Silver Jackets Team



Snoqualmie River Valley, Dec. 2010

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1. Executive Summary

Climate Change and Flood Risk Management in Washington

- Climate change is projected to exacerbate existing challenges associated with flooding and further stress complex flood management institutions and processes.
- Communities and agencies need to account for the impacts of climate change to ensure that public resources are used effectively and that local communities are prepared to deal with future changes in flood risk.
- Planning alone is not sufficient in this multi-stakeholder environment. Effective floodplain management also requires coordination across different groups and interests.

The Washington Silver Jackets

- The Washington State Silver Jackets (WA SJ) is an inter-agency group aimed at coordinating among flood risk management agencies.
- WA SJ agency roles and expertise range from technical to engagement to policy aspects of flood risk management.
- Both the expertise of the WA SJ group and the explicit emphasis on coordination mean that it is uniquely positioned to provide insight into agency priorities, practices, and challenges associated with incorporating climate change in flood risk management.

Objective of this Research

- This study explored ways to better integrate climate change information into flood risk management, with the goal of documenting current practices and identifying opportunities to further integrate climate change into this work.
- The study team also evaluated barriers to the use and integration of climate change information in flood risk management: technical and research gaps as well as institutional, political, and social barriers.

WA SJ Work Plan: Integrating Climate Resilience in Flood Risk Management

Interviews with the WA SJ team informed a work plan, which was refined and agreed upon at a workshop in June 2017. It has the following goals:

1. The public understands and appreciates flood risk

“If people don’t believe it then people don’t take action on it” (FEMA 2017)

2. Local planners have the resources to incorporate climate change considerations into FRM

“There’s definitely ... a sense that we haven’t been providing the tools to communities that they need to make these decisions” (ECY 2017)

3. Agencies consistently use climate information in risk management, planning, and project design

“If it’s not in our planning process, it’s not going to get used” (USACE 2017)

4. Agency roles are clear and do not conflict; agencies coordinate and leverage resources and expertise accordingly

“If there was more consensus across agencies that would help [...] If there are things that we really do know then getting everybody on the same page.” (FEMA 2017).

5. FRM increases floodplain resilience over time

“If we are constructing those without recognition of climate science we’re going to be in a circular pattern of repair or reconstruction” (USACE 2017)

Work Plan Themes

In partnership with the WA SJ, based on interviews and discussions, the study team created a work plan focused on the following five broad recommendations. Each action area also has a number of sub-actions discussed in greater detail in the report:

A. Develop improved estimates of future flood impacts

Estimating future flood impacts will allow agencies and communities to better understand, plan for, and manage their risk. Current information does not adequately portray risk.

B. Develop resources for local planners

Local planners lack the tools and guidance needed to both communicate risk and plan effectively within the floodplain.

C. Build capacity and coordination on resilient floodplain management

Improve coordination among the WA SJ Team, scientists, and local floodplain leaders,

with the ultimate aim of cultivating a network for shared learning and information exchange.

D. Improve public engagement

A public that is informed and cares about their flood risk will communicate that to local planners and elected officials. Specifically, these actions focus on outreach to city/county councils and homeowners/landowners/residents in flood-prone areas.

E. Coordinate floodplain management goals and planning

Clearly articulated agency goals and better alignment among planning processes would free up capacity for local managers while also ensuring that floodplain management is applied consistently across programs.

Priorities for Near-Term Action for the WA SJ Team

WA SJ members evaluated the recommended actions based on their feasibility, impact on existing agency-defined flood risk management priorities, and impact on achieving climate resilient flood risk management. The following near-term priorities were identified:

- Improving estimates of precipitation extremes
- Development of coordinated outreach materials
- Creation of a planning checklist

Two other actions emerged as priorities: improved future flood maps and the cultivation of a learning network among flood risk agencies, local managers, and scientists. However, these were not discussed in detail at the workshop.

The WA SJ team is already taking action to fund and begin work on these priorities. The work plan is intended to serve as a framework for prioritizing ongoing collaboration on climate-resilient flood risk management.

2. Purpose of this Report

Climate change is projected to exacerbate existing challenges associated with flooding. Flood management decisions that are made today will have implications for flood risk extending well into the 21st century, if not beyond. This means that communities and agencies need to plan for the impacts of climate change in order to ensure that public resources are used effectively.

The implications of climate change affect a wide range of institutions, decision-makers, and stakeholders. This report is specifically focused on the Washington State Silver Jackets team ([WA SJ](#)), an inter-agency group that is intended to facilitate collaboration on Washington state flood risk priorities. The study has three goals:

1. Document how and to what degree climate change science resources are being used today by WA SJ agencies,
2. Identify existing barriers to the integration of climate science in flood risk management, and
3. Create a work plan for the WA SJ team to further incorporate climate change in flood risk management within the State of Washington.

Results are based on a series of interviews and discussions aimed at identifying opportunities for integrating climate change among WA SJ agencies. The research assessed both science and non-science factors that could affect the integration of climate change considerations in flood risk management. The intent is that this work plan can serve as an initial roadmap for the WA SJ team, for use in identifying priorities for ongoing collaboration on climate-resilient flood risk management.

3. Background

3.1 The Washington State Silver Jackets (WA SJ)

WA SJ is an inter-agency group convened by the U.S. Army Corps of Engineers (USACE) to facilitate collaboration on state flood risk priorities. Formed in 2010, the following agencies are currently involved in the WA SJ group: USACE, Federal Emergency Management Agency (FEMA), the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS), the U.S. Geological Survey (USGS), the Washington State Emergency Management Division (EMD), the Washington State Department of Ecology (ECY), and the Washington State Department of Transportation (a roster is included in the appendix). Collectively, this group possesses multi-disciplinary expertise on flood risk management, and plays an important role – both individually and as an inter-agency team – in flood risk management in Washington State.

This report focuses on the Washington State Silver Jackets team as its members are uniquely positioned to provide insight into agency priorities, practices, and challenges associated with incorporating climate change in flood risk management. Collectively, the group has expertise ranging from technical to engagement to policy aspects of flood risk management, and plays an important role – both individually and as an inter-agency team – in managing flood risk within Washington State (see Table 1 for more information).

Table 1: Summary of agency flood risk planning and management activities

<i>Agency</i>	<i>Primary Flood Risk Planning and Management Activities</i>
USACE	• Convenes Silver Jackets Teams • Construction of flood control structures (e.g., levees, dams, floodwalls) • Ongoing maintenance of flood control structures • Occasional non-structural flood risk management (e.g., buyouts) • Provision of technical assistance to cities, counties, communities • Immediate disaster response • Conducts flood risk planning (General Investigations, System Wide Improvement Framework) • Provides funds for local flood protection projects
FEMA	• Manages the National Flood Insurance Program (NFIP) • Generates “Flood Risk Products” including maps, reports, databases to inform local flood risk planning and management • Engages in flood risk outreach with local communities • Immediate disaster response and rebuilding efforts • Funds rebuilding and flood mitigation efforts (structural and non-structural)
USGS	• Observational data collection (e.g., river gauges, sediment monitoring) • Research on flood risk

NWS	• Weather and Flood forecasts • Communication of immediate/short-term flood risk through weather predictions and flood warnings • Monitors rivers and rainfall to support flood warnings
ECY	• State coordinating agency for FEMA's NFIP • Engages with local decision-makers and trains floodplain managers • Reviews local floodplain ordinances required by NFIP • Balances flood risk management with agency mission of environmental protection. • Provides grants to local communities for projects that integrate flood risk management with other benefits, including environmental protection.
NRCS	• Provides technical and financial assistance to individual landowners (primarily to farmers, ranchers) for flood prevention and management • Disaster response through Emergency Watershed Protection program
EMD	• Administers FEMA's Hazard Mitigation Grant Program (HMGP) • Administers Pre-disaster planning through Pre-Disaster Mitigation Grant program (PDM) • Immediate disaster response and rebuilding efforts • Funds disaster-preparedness, response, and long-term recovery
WSDOT	• Manages transportation infrastructure for the state including roads that are affected by flooding or may affect flood risk

3.2 Causes of Flooding in Washington

Flooding in Washington is caused by a number of different phenomena, with important differences between the Western and Eastern parts of the state. Atmospheric Rivers (ARs) are a common cause of flooding across the state, and are the primary cause of flooding in western Washington. The distribution of rainfall during AR events is often relatively localized, so that one watershed may experience flooding while others do not. Whereas western Washington tends to receive most of the precipitation during AR events, these events can also cause flooding in eastern Washington, particularly when an AR approaches the region from a more southerly direction. Although AR events tend to bring warmer temperatures and rain on snow events are often cited as a major cause of flooding, snowmelt rarely contributes more than 10% of runoff during these events (Brent Bower, personal communication). In eastern Washington, thunderstorms can also result in flooding, although these events tend to only affect very localized areas.

The spring “freshet” – the increase in spring streamflows due to snowmelt – can result in flooding, particularly in cold watersheds where a substantial fraction of winter precipitation is captured as snow. Flooding due to snowmelt tends to persist for much longer than flooding during rain events, rising and falling over many days as opposed to several hours as during a rain event. Flooding associated with snowmelt is more important for rivers in eastern Washington. In western Washington, river flows resulting from snowmelt rarely exceed flows resulting from

Atmospheric River events.

Fires and other changes in forest cover can affect flood risk by decreasing the amount of water that is retained and increasing sediment and debris transported during storm events. Although such changes would have important implications anywhere in the region, it is a much more common problem for eastern Washington.

Flooding can also occur due to changes in the position and shape of the river channel. In the geologically-active Pacific Northwest, river channels can migrate, change course, or even create entirely new channels (avulsions) in some locations, drastically altering flood risk as a result. In addition, rivers in the region tend to carry high amounts of sediment. Where this sediment is deposited the capacity of the river channel to accommodate floods is decreased, which causes flooding to occur at lower flow rates.

Finally, coastal areas can also experience flooding due to some combination of high tides, storm surge, and waves. These events tend not to co-occur with river flooding, and so can be considered independent of the flooding that results from high river flows. High intensity precipitation events, in contrast, may sometimes co-occur with storm surge.

3.3 The Challenge: Balancing Protection with Risk Reduction

In Washington State, damages due to flooding are more costly than any other natural hazard (Ecology 2017). Management of flood risk is challenging due to the fact that people and businesses have historically settled in floodplains due to the flat land, higher quality soils, and proximity to water. Although engineered flood protections (e.g.: levees, flood walls) have greatly reduced flood risk in many instances, these protections also often result in greater exposure to risk. For example, by protecting certain flood-prone areas levees incentivize development in the parts of the floodplain that they protect, thereby resulting in greater damages when levees fail or are overtopped. Similarly, flood insurance can encourage development in the floodplain by distributing the burden of damages among all policy-holders and the nation's taxpayers. This is further complicated by the high value of floodplain areas for multiple sectors and interests -- agriculture, habitat, recreation, development -- and the strong personal ties that many landholders have to their properties. As a result, many regions experience a vicious cycle of increased protections followed by increased development, which in turn drives increased protections, and so on. This has long been recognized as a central challenge in flood risk management (e.g., Galloway 1994), and is an ongoing challenge both in the State of Washington and beyond.

3.4 Climate Change Impacts on Flooding

Climate change is expected to exacerbate existing flood challenges due to increasing temperatures, decreasing snowpack, higher intensity rain events, and sea level rise (Snover et al. 2013). In western Washington, the combination of heavier rain events and a higher snowline will result in higher flows during rain events. Coastal floodplains are expected to see the greatest

increases in flood risk due to the combined influences of sea level rise, heavy rains, and peak river flows. In eastern Washington, decreased snowpack could reduce spring flooding due to snowmelt, but could also contribute to higher peak river flows in winter and increased wildfire risk in summer, both of which could result in increased flood risk. Very little research has been done to quantify changes in sediment accumulation in rivers, or to evaluate changes in high intensity rain events in eastern Washington.

The following two sections summarize the observed and projected changes in sea level, climate, and hydrology, obtained from a variety of different studies and approaches. These results are discussed in greater detail by Snover et al. (2013) and Mauger et al. (2015).

3.4.1 Observed Trends

An important note about interpretation of these trends: Trends are affected by a variety of factors that are unrelated to climate change, including land use change, long-term climate variability, measurement biases, and a variety of other factors. The trends reported here are simply the observed trends, and are not separated into the proportion that can be attributed to climate change vs. other factors.

- *Sea level is rising at most locations in or near Puget Sound.* At the Seattle tide gauge, one of the longest-running gauges in Puget Sound, sea level rose by +8.6 inches from 1900 to 2008 (+0.8 in./decade, NRC 2012). Although sea level is rising at most locations, records show a decline in sea level for the northwest Olympic peninsula, a region experiencing uplift. At the Neah Bay tide gauge, for example, relative sea level dropped by -5.2 inches from 1934 to 2008 (-0.7 in./decade, NRC 2012).
- *Air temperatures are rising.* The Pacific Northwest warmed about +1.3°F between 1895 and 2011, with statistically-significant (95% confidence) warming occurring in all seasons except for spring (Kunkel et al. 2013). This trend is robust: similar 20th century trends are obtained using different analytical approaches (Mote 2003). All but five of the years from 1980 to 2011 were warmer than the 1901-1960 average (Mote et al. 2013).
- *No clear trend in heavy rainfall.* Trends in heavy precipitation events are ambiguous for the Pacific Northwest. Most studies find modest increasing trends, but only a few are statistically-significant and results depend on the dates and methods of the analysis (Kunkel et al. 2012, Madsen and Figdor 2007, Mass et al. 2011, Rosenberg et al. 2010).
- *Spring snowpack is declining.* Spring snowpack fluctuates substantially from year-to-year, but declined overall in the Washington Cascades from the mid-20th century to 2006 (Mote et al. 2008, Stoelinga et al. 2009). This trend is due primarily to increasing regional temperature and reflects the influence of both climate variability and climate change (Hamlet et al. 2005, Pierce et al. 2008). Natural variability can dominate over shorter time scales, resulting (for example) in an increase in spring snow accumulation in recent decades (Stoelinga et al. 2009).

- *Earlier peak in streamflow.* The spring peak in streamflow is occurring earlier in the year for many snowmelt-influenced rivers in the Pacific Northwest (observed over the period 1948-2002) as a result of decreased snow accumulation and earlier spring melt (Stewart et al. 2005).
- *No clear trends in peak streamflow.* Only a small fraction of ungauged streamflow sites in Washington State have a statistically significant (95% confidence or greater) long term trend in peak flows. Similarly, there is no statistically significant change in the frequency of peak flow events occurring across Washington State (Mastin et al. 2016).

3.4.2 Projected Changes

Local and regional-scale projections of changing flood risk include estimated increases in precipitation intensity, rising seas, changes in hydrology, as well as studies evaluating the specific implications for management.

- *Coastal areas in Washington will experience sea level rise, although some areas may continue to experience decreases due to trends in vertical land movement.* According to a recent report by the National Research Council, sea level is projected to rise an additional +24 in. (range: +4 to +56 inches) in Washington by 2100 (relative to 2000, NRC 2012). Locally, however, sea level will increase by different amounts in different places. Although most global projections would result in sea level rise for the northwest Olympic Peninsula, it is not yet possible to conclusively rule out a continued decline in sea level for that region.
- *Continued rise in annual average temperature.* Warming is projected to continue throughout the 21st century (Figure 5-1). For the 2050s (2041-2070) relative to 1950-1999, temperature is projected to rise +5.8°F (range: +3.1 to +8.5°F, Mote et al. 2013) for a high greenhouse gas scenario (RCP 8.5, Van Vuuren et al. 2011). Much higher warming is possible after mid-century. Lower emissions of greenhouse gases will result in less warming. The projected changes are large compared to variability: By mid-century, the Pacific Northwest is likely to regularly experience average annual temperatures that exceed what was observed in the 20th century
- *Winter precipitation extremes are projected to increase.* Heavy rainfall events – so-called “Atmospheric River” events – are expected to become more severe. Global models project that days with the top 1% (99th percentile) in daily water vapor transport, the principal driver of heavy rain events in the Pacific Northwest, will intensify by +22% (range: +5 to +34%), on average, by the 2080s (2070-2099, relative to 1970-1999, for a high greenhouse gas scenario: RCP 8.5, Warner et al. 2015). These high intensity events are also projected to occur more frequently: occurring about seven days per year (range: four to nine days per year) by the 2080s in comparison to two days per year historically. Another study evaluating extreme rainfall projections for the Sea-Tac weather station reported similar results (Rosenberg et al. 2010).

- *Substantial declines in snowpack.* Average spring snowpack (April 1st Snow Water Equivalent, or SWE) in Washington is projected to decline by –56 to –70% by the 2080s (2070-2099, relative to 1970-1999; based on an average of 10 global model projections for a low (B1) to a medium (A1B) greenhouse gas scenario, respectively; Elsner et al. 2010, Nakicenovic et al. 2000).
- *Annual area burned is projected to increase.* Compared to the median annual area burned in the Northwest during 1916-2006 (0.5 million acres), one set of fire models projects an increase to 0.8 million acres in the 2020s, 1.1 million acres in the 2040s, and 2 million acres in the 2080s (relative to 1970-1999, based on two global climate models and a medium (A1B) greenhouse gas scenario, Littell et al. 2010, Nakicenovic et al. 2000). Another set of models projects +76% to +310% increases in annual area burned for the Northwest from 1971-2000 to 2070-2099 under a high (A2) greenhouse gas scenario (Rogers et al. 2011, Nakicenovic et al. 2000).
- *Earlier peak in streamflow.* The spring peak in streamflow is projected to occur earlier in snow-influenced watersheds. For instance, peak streamflow is projected to occur 4 to 9 weeks earlier by the 2080s (2070-2099, relative to 1917-2006) in four Puget Sound watersheds (Sultan, Cedar, Green, Tolt) and the Yakima basin (based on an average of 10 global model projections for a low (B1) to a medium (A1B) greenhouse gas scenario, respectively; Elsner et al. 2010, Nakicenovic et al. 2000).
- *Projected changes range from modest decreases to large increases in extreme river flows depending on location and watershed type.* The highest river flows are generally expected to increase in rain-dominant and in mixed rain and snow watersheds. Some snow dominant watersheds will see flood increases, while others experience decreases. Projections for specific Washington locations can be found here: <http://warm.atmos.washington.edu/2860/products/sites/>.
- *Changes in flow regulation may not always be sufficient to mitigate increases in flood risk.* In the Skagit River, for instance, with current flood management practices, the magnitude of the 100-year peak streamflow event is projected to increase by +49% on average by the 2080s (2070-2099, relative to 1970-1999). Simulations indicate that even with changes in water management designed to decrease peak flows, the 100-year flood flow will still increase by +42% (only 7% less than with current practices). The risk of flooding remains high because the dams on the Skagit only affect a portion of the watershed – other major uncontrolled tributaries contribute substantially to downstream flooding (based on an average of five global climate models and a moderate (A1B) greenhouse gas scenario; Lee et al. 2016).
- *The extent, depth, and duration of flooding are expected to increase.* In the Skagit River floodplain, the area flooded during a 100-year event is projected to increase by +74% on average by the 2080s (2070-2099, relative to 1970-1999, assuming all levees remain intact), when accounting for the combined effects of sea level rise and higher peak flows

(Hamman et al. 2016). 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 (2070-2099, relative to 1970-1999; based on the average of 10 global climate model simulations and a moderate (A1B) greenhouse gas scenario; Mauger et al. 2014).

4. Methods

Data for this research was collected through a series of semi-structured key informant interviews (Edwards and Holland 2013) of Washington State Silver Jackets team members. Interviews lasted between one and three hours, with the majority lasting between 90-120 minutes. The research team utilized an interview guide in all of these interviews (Appendix B), but allowed key informants to guide responses and additional lines of discussion based on the recognition that interviewees possess deep contextual knowledge on the subject of flood risk management (Edwards and Holland 2013, Tuler et al. 2002).

Interviewees were selected to roughly reflect the composition of the Silver Jackets group in terms of agency representation and geographic focus (Table 2). Interviewees were selected in consultation with WA SJ members, with preference given to those who are most engaged in Silver Jackets activities. Several interviewees were also selected from beyond the WA SJ team, in order to ensure that different perspectives from within key agencies were adequately represented. In total, thirteen interviews were conducted by the two-person research team. Nine were conducted in person, two via video-conference, and two over the phone due to the fact that some interviewees were too far away to justify the travel expenses.

Table 2. Number of interviews conducted for each participating Silver Jackets agency. At the time of the project, WSDOT did not have any staff participating in the WA SJ team.

<i>Agency</i>	<i>Number of Interviews</i>
US Army Corps of Engineers (USACE)	3
Federal Emergency Management Agency (FEMA)	2
National Weather Service (NWS)	2
US Geological Survey (USGS)	1
WA Emergency Management Division (EMD)	2
WA Department of Ecology (ECY)	2
Natural Resource Conservation Service (NRCS)	1
WA Department of Transportation (WSDOT)	0

Interviews were recorded, transcribed, then coded in their entirety using [Atlas.ti software](#). Atlas.ti is a social science analysis program which allows the researcher to systematically organize and categorize large amounts of qualitative data using “codes” (Miles et al. 2014, Saldaña 2015). Codes are simple categories or labels for organizing the statements made by interviewees (Miles et al. 2014). The coding approach used can be described as “topic coding” (Saldaña 2015), which focuses on identifying and categorizing the content of the qualitative data. In this project we used 17 distinct codes (see Appendix for full list of codes) some of which were

pre-identified to correspond with research questions while others emerged through the initial analysis. The interviews were then further analyzed through “theoretical memoing”. This process allows the researcher to reflect and develop their conceptual ideas about the data (Miles et al. 2014), while providing additional credibility and traceability by creating a record of the researcher’s analytical process (Groenewald 2014).

In parallel with the interviews, the research team continued to engage with the WA SJ team in order to facilitate continued information exchange. The Washington Silver Jackets currently has an annual meeting in December as well as monthly calls. The research team participated in these meetings and calls, presenting on existing climate change science and resources while also learning about agency concerns, issues, and interests.

Finally, researchers hosted the WA SJ group for a final project workshop. At the workshop, researchers presented a draft work plan, based on the barriers, needs, and priorities identified in the interviews and other discussions with the WA SJ team. The workshop was designed to provide participants with a chance to provide feedback on these initial conclusions, while also engaging the group in a prioritization exercise to identify specific focus areas for near-term work. The workshop also included time for participants to begin scoping specific tasks for the three focus areas that ranked highest: clarifying goals, assigning a project lead, identifying funding opportunities.

5. Flood Risk Management Priorities

The interviews included an exploration of current priorities for flood risk management. Understanding how participants view their priorities and define their own success helped the research team ensure that the work plan was designed to address agency needs. Although individual agencies have their own specific priorities, there were three general themes that were common to many of the responses.

Protection of life and property:

Interviewees identified the protection of the lives and property of Washington residents as a top priority in their flood risk management activities: *“Our number one paramount goal in flood risk management [...] is the protection of life and property. Life being paramount for sure but property [also].”* (USACE 2017). A key aspect of this priority is the communication and minimization of risk. Many agencies are directly involved with the communities and local city or county government. They view informing the public about their risk and appropriate actions to minimize it as an important piece of protecting life and property: *“ultimately what we’re trying to do is we’re trying to help the communities understand their risk and take action on the risk to minimize their exposure”* (FEMA 2017).

Environmental considerations:

Second, many interviewees pointed to environmental concerns as a priority for managing flood risk in Washington State. Some of these concerns were related to salmon and salmon habitat, partly a result of the 2013 Biological Opinion (BiOp) requiring floodplain development to account for salmon recovery. One interviewee commented: *“It’s recognized that fisheries habitat restoration has to be part of the package along with flood safety”* (ECY 2017). However, some interviewees addressed the issue of environmental concerns more broadly, referring to the restoration of natural processes as a flood risk priority: *“We’re trying to move as much as we can towards a sustainability for the natural processes, consistency of the natural process approach so we’re not putting things in the landscape that are clearly not designed to be there.”* (USACE 2017). The recognition that other (environmental) priorities must be accounted for in flood risk management in the region shapes the way interviewees frame their own priorities.

Land use planning to reduce exposure and risk:

Careful planning and management of current and potential future uses of the floodplain was identified as an additional priority. This priority is in many ways a combination of the first two in that it addresses the need for comprehensive and multi-faceted floodplain planning as a way of managing flood risk. Interviewees recognize that fundamentally, development in the floodplain will flood and therefore existing and future structures should be carefully considered: *“we’re also looking at more preventative measures, elevating houses that have been built on the floodplain, looking at what development should go where in the floodplain.”* (ECY 2017). Removing existing infrastructure from the floodplain or preventing future development is a challenging and highly political issue, one that agencies recognize as important but are currently grappling with how to effectively realize. One interviewee commented: *“I would still say 99*

percent or 95 percent of our money is still just putting things back exactly the way they were. They may get some elevation, but they're not really getting out of the footprint of the floodplain and they're not thinking about the bigger picture of things: should the critical structure even be put back in that floodplain.” (FEMA 2017).

These three overarching priorities guided the creation of the work plan and informed the framing climate resilient flood risk management goals and recommendations of the proposed action items. While achieving these priorities would be challenging under any circumstances, interviewees noted that climate change adds an additional layer of complexity to their work. Incorporating preparations for uncertain future conditions (both in terms of climate change and land-use changes) into these guiding priorities is an ongoing and increasingly pressing need.

6. Benefits and Opportunities

While there are many challenges to incorporating climate change considerations into flood risk management, interviewees also identified a number of important benefits to increasing the resilience of FRM to a changing climate. Many of these benefits relate directly to the priorities for flood risk management cited in the previous section. A primary benefit identified was reducing the long-term economic costs of flood risk management, particularly around flood infrastructure (i.e. levees). These structural flood risk management elements are expensive to plan and build, but they can also be expensive to maintain, especially if they are not built with climate change in mind. One interviewee noted that *“structures are going to be under-designed and money is going to be overspent without an eye for climate change”* (USACE 2017), which another interviewee characterized as *“a waste of public dollars”* (NWS 2017). Interviewees emphasized the importance of incorporating climate change in order to reduce the long-term costs of significant projects. This benefit is seen as particularly important because local communities, as project sponsors, are often responsible for long-term maintenance costs: *“to the extent we can make these things resilient to climate change, right, the less burden we’re putting on [the local sponsor] in the future. [...] We strive to build things that are least burdensome from an O&M [Operations & Maintenance] perspective as we can.”* (USACE 2017).

Interviewees also discussed climate resilience in terms of its potential to inform land-use planning. Climate-resilient FRM is seen as essential to well-planned development, successful agriculture, and the location of critical infrastructure. Understanding how and where flood risk is likely to change is important for local planners: *“Think about the local officials and their flood zoning ordinances. If you know that this area is going to be flooding more frequently, it’s probably not a place they want to put a lot more houses or subdivisions. Knowing that, I think, is critical for local planning”* (NWS 2017). FRM is connected to a variety of planning processes and touches a wide variety of sectors, offices, and agencies across multiple scales. Increasing the resilience of FRM to a changing climate will positively affect the resilience of these various planning processes, helping ensure the safety of local communities and improving their ability to respond to a changing climate and changing flood risk.

Related to this, interviewees highlighted that incorporating climate change into their FRM work would improve the accuracy of their maps, models, predictions, and recommendations. More accurate models and better information on future conditions would lead to better understanding of – and ability to manage for – flood risk. Because these models, maps, and recommendations drive FRM action at multiple scales, their accuracy (or lack thereof) has significant consequences. One interviewee commented that *“the advantage [of increased climate resilience] would be that it would be more accurate. If something is changing from what we have been expecting or used to expect, in order to get that right, our information is going to have to take that into account [...] keeping our science up with changes.”* (NWS 2017).

As discussed in the FRM priorities section, WA SJ agencies prioritize reductions in risk communities and the environment. Improving the way they incorporate climate into their work

improves their ability to accurately predict and manage risk. One interviewee commented “*I focus on human vulnerability and I think that [we need] to plan for the kinds of damages we’re going to see in the future rather than from the kinds of damage we’ve seen in the past*” (EMD 2017). A clear benefit of incorporating climate change into FRM is that it improves the accuracy of risk management, which has direct and significant impacts on human safety.

7. Existing Resources

7.1 Policy and Guidance

7.1.1 Policy

Both federal and agency guidance are clear about the inclusion of climate change in flood risk management. Executive Order 13690, the Federal Flood Risk Management Standard (FFRMS) specifically requires agencies to consider climate change impacts on flood risk when federal tax dollars are used in the floodplain. Under the order, agencies are given three options:

1. Use the best available science,
2. Add 3 feet of freeboard for critical infrastructure and 2 feet for everything else.
3. Design to the 500-year (0.2% annual chance) floodplain

Similarly, the U.S. Army Corps has developed a climate change adaptation plan which states that *“It is the policy of USACE to integrate climate change adaptation planning and actions into our Agency’s missions, operations, programs, and projects”* (USACE 2015). In 2012, FEMA issued a policy statement that emphasizes the importance of incorporating climate change into their programs and operations, and lists seven actions that the agency would take to plan for climate change (FEMA 2012).

The courts have recently ruled that climate change must be incorporated in Endangered Species Act (ESA) decisions. A Biological Opinion (BiOp) has been issued for Puget Sound, based on the conclusion that FEMA’s National Flood Insurance Program (NFIP), as implemented, was at odds with salmon recovery (NWF v. FEMA 2004). Although the BiOp does not currently concern climate change, given the large impact of climate change on flood risk and the ESA mandate to use the “best available science”, it is possible that this could be a required consideration in the future.

7.1.2 Guidance

It can be difficult for even a well-acquainted user to know how to interpret climate change projections, select appropriate scenarios, and evaluate different approaches to assessing impacts. Numerous resources exist to support impacts assessment and adaptation efforts.

The Climate Resilience Toolkit (<https://toolkit.climate.gov/>) brings together tools, data, guidance, and a library of case studies, all compiled into one location to make it easier to use these resources. Another recent publication, Snover et al. (2013), decomposes the decision-making process into phases that require climate information and expertise, and other phases that rely on local knowledge and context-specific information about the timeline and acceptable level of risk. Although the paper is focused on assessing climate change impacts on biological systems, the ideas apply more generally to any effort to use climate projections in decision-

making. For example, Table 3 below (Table 3 in Snover et al. 2013) lists common misconceptions about climate change projections, along with the reality associated with each.

Several agencies have also developed guidance. USACE has issued several guidance documents, including a series on incorporating sea level rise in planning and another on inland hydrology. The sea level rise guidance includes quantitative sea level projections that are to be used in planning, and an online tool that allows users to extract projections for their site of interest (Engineering Regulation, ER #1100-2-8162). Sea level rise is now a required element of USACE planning and design studies. Inland hydrology is not currently required and does not include specific projections, as is the case for sea level rise. However, it does provide guidance on conducting a qualitative assessment of climate change impacts (Engineering Construction Bulletin, ECB 2016-25). Both the inland and sea level rise guidance include step-by-step instructions and case studies that describe how to incorporate climate change in design and planning.

Although FEMA does not currently incorporate future flood risks in its regulatory standards, it has initiated the Risk Mapping Assessment and Planning (RiskMAP) program, in which non-regulatory information on future flood risk is provided to interested communities. FEMA's Technical Mapping Advisory Council (TMAC) has also issued a set of specific recommendations for incorporating climate change in the NFIP (TMAC 2015). In addition, several independent organizations have begun developing guidance that may support the integration of climate change in FEMA programs: (1) the Community Rating System (CRS) "Green Guide", developed by the Association of State Floodplain Managers (ASFPM, ASFPM 2017), and (2) the Nature Conservancy's (TNC) "Naturally Resilient Communities" website (TNC 2017). Although neither website is specifically focused on climate change, both include guidance and recommendations that are relevant to addressing climate change impacts on flooding.

Table 3 (following page). Common misconceptions about the utility of climate scenarios. Copied, with permission, from Table 3 in Snover et al. 2013

Table 3. Common misconceptions about the utility of climate scenarios for ecological-impact assessments and decision making, implications for scenario selection and use, and links to guidelines for scenario selection.

<i>Misconception</i>	<i>Reality*</i>
Pessimism about climate-change scenarios Climate models (CMs) do not produce output variables relevant for determining ecological responses. Because CMs are accurate only at continental spatial scales, CM output is unsuitable for projecting regional or local changes and effects. A single CM simulates all variables equally well or poorly for all locations and time steps. Because the projected direction of change in important variables is not the same among CMs, CM output cannot usefully inform decision making. The cascade of uncertainty, caused by linking multiple models, combined with the typically large range in climate-change projections means that projected biological effects are too uncertain to be useful. Every time a new set of climate-change scenarios is released (e.g., by the Intergovernmental Panel on Climate Change (IPCC)), impact assessments must be completely redone.	CMs simulate a large variety of variables, including many appropriate for direct use in ecological impact assessment (step 2a). There are a variety of ways in which the robust output of CMs can be used to drive local biological assessments, depending on the spatial scale of controlling processes (step 2 and Fig. 2). Accuracy of CM simulations differs significantly by variable, temporal and spatial scale, and geographic region. This diversity must be considered when evaluating CM output for use in local impact assessment (step 2). Despite directional uncertainty in CM projections of some variables, robust scenarios of future conditions can be developed when biological effects are dominated by changes in other better-understood variables. In the western United States, for example, spring snowpack important for wolverine reproductive success is projected to decrease in all future scenarios as a result of projected warming, despite significant uncertainty in future precipitation (McKelvey et al. 2010) (step 1). Evaluations of the ability of joint climatic-biological response modeling to replicate observed conditions can be used to evaluate the degree to which small errors in initial climate conditions lead to larger errors in projections of biological response (Littell et al. 2011). If the assumed linkages among changes in global climate, local climate drivers, and biological effects are clearly articulated, and the ranges of changes projected for local climate drivers identified for the current scenario set, new global climate scenarios can be evaluated for the degree to which they would alter that range and therefore for the necessity of updating decisions associated with projected biological effects of climate change.
Optimism about climate-change scenarios Climate-change scenarios are climate predictions. Climate scientists can identify which scenarios are best or most likely. Climate-change scenarios define the range of plausible foreseeable outcomes. Climate-change scenarios with higher resolution are necessary, possible, and will improve ability to project biological effects. Uncertainties associated with climate-change scenarios will decrease in the near term, making them more useful for biological assessments.	Climate scientists carefully distinguish between climate projections, which are based on scenarios of future changes in climate forcings, and predictions (or forecasts), which attempt to simulate the actual climate state forward in time. Although the IPCC's 5th assessment report (AR5) will include results of climate-prediction experiments, the expected divergence of these decadal climate forecasts suggests the continued importance of evaluating a range of possible futures. Irreducible uncertainty about future greenhouse gas emissions, the fact that there is no single most reliable CM, and the confounding effect of natural variability mean it is impossible to determine the best, or most likely, climate-change scenario. The choice of the "best" scenario depends on the characteristics of the biological system of interest and the associated decision context (Table 1). Although scenarios indicating the least change seem well founded, the largest change scenario in CM archives does not necessarily represent the largest plausible future change. Managing for the worst case as identified by currently available scenarios may not be sufficient to guarantee resilience, and this should be clearly communicated to decision makers (step 3c). Not all aspects of the climate are simulated more accurately with higher resolution (e.g., Stock et al. 2010; Delworth et al. 2012). Development of higher resolution scenarios is limited by fine-scale data for validation of downscaled scenarios (Lundquist & Cayan 2007), especially in oceanic, aquatic, and mountainous environments, where much resource management is focused. Uncertainty regarding future climate changes is often not the primary factor limiting projections of future biological change (step 1). The IPCC AR5 is expected to increase uncertainty in estimates of climate change due to the increased complexity of current CMs (Knutti & Sedláček 2013). This suggests the need to identify climate-change scenarios that appropriately represent the range of projected outcomes (step 3) and improve understanding of biological linkages to climate so that ecological impact assessments can appropriately use the information provided by CMs (step 1).

* Indicated steps refer to those in the guide for choosing and using scenarios, above.

7.2 Science Resources

7.2.1 *Synthesis Reports*

International, national, and regional reports summarize the current state of climate science and impacts (Table 4). For example, the Intergovernmental Panel on Climate Change report (IPCC 2013) includes the well-known climate science synthesis as well as an entire separate report on climate change impacts and adaptation. The National Climate Assessment provides a similar high-level overview of climate science and impacts that is focused on the U.S. (Mellilo et al. 2014). It includes a chapter summarizing the implications for the Pacific Northwest. Finally, there are an increasing number of reports that address the science and impacts at a more local level. The two most recent of these focus on Washington State (Snover et al. 2014) and Puget Sound (Mauger et al. 2015). These reports all include high-level overview statements as well as detailed discussions of the research and links to the key studies in the primary literature.

Table 4. Synthesis reports. These span from global to local scales, and provide both synthesis projections and a review of key studies in the primary literature.

<i>Report</i>	<i>Domain</i>	<i>Citations</i>	<i>Next Update</i>
Intergovernmental Panel on Climate Change (IPCC)	Global	IPCC 2013, IPCC 2014a, IPCC 2014b	2021
National Climate Assessment	National	Mellilo et al. 2014, Mote et al. 2014	2018
Global and Regional Sea Level Rise Scenarios for the United States	National	Sweet et al. 2017	Unknown
CIG State of Knowledge Reports	WA State, Puget Sound	Snover et al. 2014, Mauger et al. 2015	Unknown

7.2.2 *Future Sea Level, Climate, and Streamflow Datasets*

In the Pacific Northwest, climate change is expected to impact flooding via changes in sea level, extreme precipitation, peak river flows, and sediment deposition. Mauger et al. (2015) synthesized the state of the science on these topics as of 2015.

Numerous climate change datasets exist that can be used to quantify changes in flood risk. All projections stem from greenhouse gas scenarios and global climate model (GCM) projections used in recent IPCC reports. Downscaling methods are often categorized as either “statistical” (meaning that it is based on empirical relationships obtained from observations) or “dynamical” (meaning that the downscaling is performed using a physically-based climate model). These are produced using coarse-scale GCM projections obtained from one of the Coupled Model

Intercomparison Projects (CMIP), either the previous CMIP3 (Meehl et al. 2007) or the more recent CMIP5 archive (Taylor et al. 2012; see Mauger et al. 2015 for additional details). Most climate datasets include an “ensemble” of multiple climate model projections, in order to provide an estimate of the uncertainty in projections.

A selection of currently-available sea level rise, downscaled climate, and hydrologic projections are listed in Tables 5-7. Each table also lists ongoing projects that will update the science on each topic. There are three principal challenges to using these projections:

1. Most climate change datasets require some degree of additional post-processing to use.
2. Projections differ among datasets, and the best approach may not be the same for each application.
3. The science and projections are continually evolving, meaning that the best available dataset today will eventually be superseded by newer projections.

In other words, the challenge with climate change projections is not so much the availability of data, but the use and interpretation of what already exists. Guidance documents, such as those outlined above, provide helpful criteria for selecting and applying climate change projections. Additional work is needed to minimize the additional effort needed to use these projections and provide better information on the relative merits and pitfalls of various approaches. These are addressed in the work plan items below.

Finally, these datasets are exclusively concerned with the drivers of flood risk. Very few studies have taken the additional step of quantifying the implications for the depth and area of inundation as a result of climate change. Examples that do exist cover very specific river reaches within Washington State (Hamman et al. 2016, Mauger et al. 2014), and differences in methodologies do not allow for apples-to-apples comparisons of risk. This gap is also addressed in the work plan.

Table 5. A selection of sea level rise projections.

<i>Title</i>	<i>Citation</i>
Sea-Level Rise for the Coasts of California, Oregon, and Washington	NRC 2012
Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites	Kopp et al. 2014
Global and Regional Sea Level Rise scenarios for the United States	Sweet et al. 2017
<i>Ongoing:</i> WA Coastal Resilience Project (WCRP)	Lead Author: Ian Miller, WA Sea Grant

Table 6. A selection of downscaled climate projections

	Greenhouse Gas Scenario			Climate Models		Down-scaling		Resolution	Citation
	Low	Moderate	High	New (CMIP5)	Old (CMIP3)	Statistical	Dynamical		
Pacific Northwest Hydroclimate Scenarios Project	✓	✓			10	✓		6 km	Hamlet et al. 2013
NASA-NEX Downscaled Climate Projections	✓	✓	✓	33		✓		800 m	Thrasher et al. 2012, 2013
Bias Corrected and Spatially Downscaled CMIP5 (BCSD5)	✓		✓	39		✓		6 km	Reclamation 2014
Multivariate Adaptive Constructed Analogs (MACA)	✓		✓	10		✓		4km	Abatzoglou and Brown 2012
Localized Constructed Analogs (LOCA)	✓		✓	32		✓		6 km	Pierce et al. 2015
North American Regional Climate Change Assessment Program (NARCCAP)			✓		4		✓	50 km	Mearns et al. 2017
North American Coordinated Regional Downscaling Experiment (NA-CORDEX)	✓		✓	7			✓	25-50 km	Bukovsky et al. 2017
<i>Ongoing:</i> UW Weather Research and Forecast Model Projections (UW WRF)	✓	✓	✓	2	2		✓	12 km	Salathé et al. 2010, Lead Investigators: Guillaume Mauger, Eric Salathé (UW)
<i>Ongoing:</i> Regional Climate Prediction dot Net (RegCPDN)	✓		✓	1			✓	25 km	Mote et al. 2016. Lead Investigators: David Rupp, Phil Mote (OSU)

Table 7. A selection of hydrologic change projections. Hydrologic models used in these projections are the Variable Infiltration Capacity (VIC, Liang et al. 1994) and the Precipitation Runoff Modeling System (PRMS, Markstrom et al. 2015).

<i>Name</i>	<i>Downscaling</i>	<i>Hydrologic Model</i>	<i>Citation</i>
Pacific Northwest Hydroclimate Scenarios Project	Statistical	VIC	Hamlet et al. 2013
Western U.S. Hydroclimate Scenarios Project	Statistical	VIC	Salathé et al. 2013
Integrated Scenarios of the Future Northwest Environment	Statistical	VIC	Mote et al. 2014
<i>Ongoing:</i> River Management Joint Operating Committee Projections, Part 2 (RMJOC-II)	Statistical, Dynamical	VIC, PRMS	Lead investigator: Bart Nijssen, UW
<i>Ongoing:</i> Structure for Unifying Multiple Modeling Approaches (SUMMA)	Statistical, Dynamical	SUMMA	Clark et al. 2015a, 2015b

8. Climate Resilient Flood Risk Management: Challenges

A number of challenges were identified by interviewees. They fall into five broad categories, each of which is discussed briefly in below along with relevant quotes from the interviews are included.

8.1 Uncertainty in existing climate change projections and agency lack of knowledge on how to use them:

Interviewees expressed that uncertainty in climate science data is an ongoing barrier to the integration of climate science into flood risk management. There are two main aspects to this challenge. The first is that climate predictions inherently contain a degree of uncertainty, presenting ranges rather a single definitive number. Particularly for precipitation and inland and riverine flood predictions, interviewees feel that these ranges are broad enough to seriously complicate flood risk planning: *“The temperature we have high confidence in, but precipitation, which is important for rainfall-runoff models is kind of all over the place, different models of different results.”* (USGS 2017). Another commented: *“I guess the difficulty there is taking the science which right now [has] a fairly large range of probabilities and converting that to a range where people feel comfortable [...] having modeling where we can at least get some kind of confidence level and say here’s the range we can work with [...] to be able to say] you will most likely see increased floods of this level.”* (ECY 2017).

The second challenge associated with uncertainty is that agencies don’t know how to use or don’t feel comfortable using data with such ranges of uncertainty. Uncertainty makes agency planning difficult and complicates communication to local planners and communities: *“The other real difficulty here is uncertainty. We I think society are largely past the question about whether climate change exists or not but what the effects are still we’re really working to figure out. So that uncertainty is all too often easy for people to turn this off when they see okay we don’t know what the risk really is to tune it out. They’ll say well I’ll deal with that when I have better information* (ECY 2017). Although there will always be a range among projections, resources exist to assist in decision-making with uncertainty. There is a need to build agency capacity to deal with and understand how to use information with a high degree of uncertainty.

8.2 Gaps in existing science and data resources

Interviewees identified a number of broad science and data deficiencies which they felt posed a challenge to successful integration of climate science in flood risk management. Gaps included flood modeling that does not adequately account for a changing climate, a lack of local-scale climate and flood risk information, and limited information on the specific mechanisms driving flood risk in different locations.

Another challenge was the use of historical information on flood risk as opposed to projected

future changes. Interviewees noted that this is particularly problematic when particular datasets that lack future changes are mandated by agencies, essentially reinforcing the omission. *“It’s kind of hard when climate change is not going to be static and so in fifty years it’s going to be different than it is today. [...] The federal government in general and FEMA specifically is not a fast adapting agency. So generally we are ten to fifteen years behind the big changes that happen [...] and if it takes us ten to fifteen years to get it implemented into our studies and our analysis that’s kind of too late.”* (FEMA 2017). Another interviewee commented: *“I think the big question that you’ll probably get to at some point is stationarity and all the flood statistics are based on this concept of stationarity. We know that’s not exactly true”* (USGS 2017).

In addition to maps and resources that don’t account for a changing climate, agencies are often attempting to support local planning with maps that aren’t scaled to the local level. One interviewee stated the need for *“clear tools for planning level folks to go in and go okay in this location in this site what are? How are my conditions likely going to change over my planning horizon?”* (USACE 2017). Others pointed to county or watershed level climate change and flood risk modelling in order to support local planning processes.

8.3 Limits to local capacity

In addition to agency capacity, interviewees expressed the need to build local capacity on climate change and flood risk management. This local capacity can be thought of in three general stages:

1. local managers are aware of risk,
2. local managers are aware of response options and resources to address risk, and
3. local managers have the motivation, knowledge, and resources to act to reduce risk.

The first, an awareness of the risks associated with climate change-related flooding, is at least partly achieved via effective agency communication of the risk. One interviewee stated: *“It would really be nice if the public was more informed [...] They have this misconception that well they’ve never had water in this area before and maybe they’ve lived there for 20 [...] So they have this misconception that we’re not telling them the truth, that there’s not really any risk to them”* (NRCS 2017). Interviewees expressed that accurately and clearly communicating risks associated with climate change can be challenging both because the information is complex and because of other factors, including politics.

Public awareness of options for mitigating flood risk is an additional challenge. Current resources include funding opportunities from various agencies, assistance and training in flood risk management, and guidance on coordinating with agencies on flood risk management projects. For example, at the Corps *“There are parts [of a project] in there where the locals can come to us and go we’d really like to know how this sea wall might be affected by climate change in the next 50 years. Can you study that for us? We’d be like yeah. Sure we can do that. But we’d be handling it on some other authority, not call it climate change studies”* (USACE 2017). In spite of their potential, interviewees noted that local planners and flood risk managers are generally unaware of these opportunities.

The third piece of building local capacity is that local planners and communities are motivated to take action to address their flood risk. Again, this is partially related to support and communication from agencies but also related to a belief in and political inclination to deal with climate change (a more challenging aspect for the WA SJ to address). The idea that agencies can provide resources, outreach, and communication in a way that motivates local communities to action was commonly expressed: *“We need to do things in such ways as people know how to take action, what action to take and will take action.”* (NWS 2017). Although limited local capacity is an ongoing challenge in flood risk management, the WA SJ is well-positioned to augment this capacity through communication and engagement activities.

8.4 Actions and guidance sometimes contradict goals

Interviewees noted that common approaches taken within each agency could sometimes be in conflict with their stated goals of protecting life, property, and the environment. Some felt that their actions did not comprehensively or effectively address flood risk or contribute to a climate-resilient floodplain management and could, in fact, be exacerbating existing and future flood risk. FEMA, for example, often rebuilds houses in the same locations where they were damaged by floods in the absence of an existing plan at the community level: *“I would still say 99 percent or 95 percent of our money is still just putting things back exactly the way they were. They may get some elevation, but they’re not really getting out of the footprint of the floodplain”* (FEMA 2017). This rebuilding does little for the overall resilience and safety of the floodplain. Similarly, because of the Army Corps’ benefit cost calculation, they generally fund structural approaches to flood risk management (e.g., levees), even where non-structural approach (e.g., buyouts) might be the more flood and climate-resilient option: *“It’s not that we couldn’t but the effort and cost involved with getting the real estate, purchasing them, the requirements at the time for placing their house somewhere else and it was just very cumbersome”* (USACE 2017). In general, cultural and institutional issues within each agency can sometimes lead to actions that are not optimally effective at reducing flood risk.

An additional challenge is that guidance and data used by agencies are routinely outdated and do not account for climate change or increases in development over time, both of which can increase flood risk. One interviewee noted: *“Our curves, our guidance, our historical operations do not apply to the White River right now and haven’t for a couple years. Not only has the channel changed, the geometry has changed so there’s not the capacity downstream but also the landscape, the economic landscape has changed in the valley as well. So what may have been nuisance flooding in 1995 or whatever now you know is a foot of water in 50 industrial buildings.”* (USACE 2017). Where guidance does exist, Silver Jackets members are sometimes unaware of it or do not use it regularly in their work. Numerous interviewees throughout the Silver Jackets Team discussed that the use of outdated floodplain maps and modelling based on historical data are not providing accurate information – therefore undermining stated agency priorities.

8.5 Coordination:

While the Silver Jackets is seen as an important nexus for information sharing and collaboration, interviewees identified a lack of coordination among agencies as a challenge to comprehensively incorporating climate considerations into flood risk management. In the interviews, the Washington SJ Team was widely seen as having the potential to do more with more communication and better coordination. One interviewee commented that *“we were trying to still figure out what the [Silver Jackets] program was and how it could best be utilized [...] but we weren’t doing the coordination very well. So it was almost we were doing it within a bubble, which is not ideal for the silver jackets.”* (USACE 2017). In addition to coordination internally among the SJ Team, interviewees suggested that this challenge extends to coordinating processes and communication with the public: *“if there was more consensus across agencies that it would help [...] they [the public] ask a few different people and if they get two to three different answers suddenly they kind of shut down. They figure well this is just complicated and we don’t know yet. If there are things that we really do know then getting everybody on the same page”* (FEMA 2017). A lack of coordination and alignment, particularly regarding engagement efforts, leads to confusion and mixed messages, and is a hindrance to climate-resilient planning and management.

9. Climate Resilient Flood Risk Management Goals: Framing the Work plan:

Through analysis of the interviews, the research team identified five overarching goals which the work plan action items address. These goals align with existing flood risk management priorities, address the challenges identified by the interviewees, and were purposefully framed to be conducive to feasible action by the WA SJ Team. The goals are as follows:

1. The public understands and appreciates flood risk
2. Local planners have the resources to incorporate climate change considerations into flood risk planning.
3. Agencies consistently use climate information in risk management, planning, and project design.
4. Agency roles are clear and do not conflict; agencies coordinate and leverage resources accordingly.
5. Flood risk management increases floodplain resilience over time

Goals are discussed individually in more detail below:

9.1 Goal 1: The public understands and appreciates flood risk

Existing Problem: The public as a whole does not understand and/or appreciate the flooding associated risks from climate change for two primary reasons:

- *Politicization of climate change:* portions of the public do not accept climate change science as real and some federal agencies have been told not to address it/use the term
- *Lack of appropriate resources and tools for communities:* existing climate change and flood risk information is not written for a public audience and is not at a scale relevant to the community-level, where much agency outreach occurs.

Description: The interviewees highlighted that a lack of public awareness/understanding/belief in/appreciation of the increased flood risk associated with climate change is a challenge they face in better addressing climate change in flood risk management. Interviewees identified two distinct, if interrelated components of this issue which should inform the approach in addressing it. The first, is more a socio-political problem; that people don't believe in climate change and are therefore unmotivated to address climate associated flood risk: *"If people don't believe it then people don't take action on it [...] It's the community; it's the individual land owner. [...] There is a certain element of shutting down."* (FEMA 2017). The lack of belief in climate change on an individual/community level is a reflection of the greater politicization of climate change. Many interviewees, particularly those that work primarily in Eastern Washington highlighted the political challenge of even communicating about climate change: *"In fact we were recently told that we're not to use the term climate change anymore. We're supposed to be using climate resilience"* (NRCS 2017). While this is a more challenging problem to address, it's worth noting the obstacle of preparing communities to take action for something they don't believe in using

politicized terminology is something that many Silver Jackets members face.

The second aspect of this challenge that interviewees noted was a failure on their part to provide the appropriate tools and resources to individual landowners and communities about the increasing flood risk they likely face. A general sentiment was that the existing resources about climate change and flood risk are a) not written for a general/layman audience, and b) not at an appropriate scale to be seen as applicable on the community level. Interviewees involved in direct outreach and communication at the community level also stressed the need to expand and improve their activities and resources for this work, which is often resource-constrained: *“if I had the resources even now I would want to make it a point to get out to every community [...] and at least meet with their staff, offer to attend a city council meeting and talk to the city council and say here is your risk and here are some possible remedies; we recommend you incorporate the following things. I’d like to do that now. Don’t have the information, don’t have the resources.”* (ECY 2017). There is also an element of thinking about the framing and messaging of this information. For example, the NWS has conducted social science research to help them think about how they might better communicate risk information so that communities take action, and a number of interviewees highlighted the need for climate change information to be communicated via a source that the community trusts. Of course, the two components of this issue are interrelated. One can imagine that providing better information about climate change flood risks would help convince people that it is in fact real.

9.2 Goal 2: Local planners have the resources to incorporate climate change considerations into flood risk planning

Existing Problem: Local planners lack the information and agency support to incorporate climate change into flood risk planning and management on the local level. Because of this, local-level flood risk planning is not comprehensive or preemptive and does not account for long-term costs and impacts.

Description: Interviewees expressed that local planners are often central in addressing and planning for flood risk on the local level. In many cases however, local planners do not have adequate and accessible information, agency support, or local community interest in incorporating climate change considerations into their flood risk planning efforts. One interviewee said *“Community planners are doing so much. I’m just in awe of all the things they do. They can only do so much at one time. They can’t start making up their own programs.”* (ECY 2017). While this problem is exacerbated by a general lack of resources for planning in small communities, in many cases it is also related to a lack of straightforward and accessible information and agency support to effectively utilize that information. One interviewee stated: *“there’s definitely ... a sense that we haven’t been providing the tools to communities that they need to make these decisions”* (ECY 2017). Our interviewees agreed that climate change effects on flood risk are complicated; to model, to understand, and to use effectively, particularly for a local planner with no background in hydrology or climate science.

While some of this challenge can be addressed at the level of the planners, interviewees identified a number of mechanisms by which their own agencies may fail to support the use of climate change science in local flood risk management (beyond a simple lack of resources). USACE, for example, limits comprehensive planning and management of flood risk through its cost-benefit analysis procedures which routinely prioritize structural (levees, dams, etc.) over non-structural approaches (e.g., acquisitions) to reducing flood risk. In some instances, structural options could actually result in longer-term maintenance costs and greater risk to life and property in the long term. *“At one point unless things have changed we were expected for flood risk reduction to look at a structural alternative and look at a non-structural alternative and compare them. Generally speaking, the structural alternative is typically cheaper [...] So you know but if your system is set up where it just turns out that you’re set up to more often go to a structural response than a non-structural response and you get really good at enacting structural responses”* (USACE 2017). Re-evaluating this work – either the benefit-cost analysis, or the design and approval process, might alter the balance between structural and non-structural approaches within USACE.

Similarly, FEMA interviewees highlighted the role their maps play in constraining comprehensive and long-term flood risk planning in that the binary inside-outside the floodplain approach and associated insurance structure means that only those communities/individuals within the FEMA-defined floodplain engage in planning activities. *“right now we do a one percent chance flood and we create the map based off of that; that’s what you have to build to; that’s what their insurance is based on and I think it would be better to have a kind of a graduated risk in the understanding of the full range of frequencies and so the policies will be reflective of [that]”* (FEMA 2017).

Interviewees also highlighted that much of the current flood risk planning occurs at the (limited) project scale and that a watershed or reach-scale perspective is often needed. One main area where a more holistic perspective could help is in development in the floodplain. There is wide agreement that both present and future floodplain development should be evaluated closely. *“Really looking at communities and looking at the larger flood risk and looking ahead of it, not just looking at the development permit in some of them right now, but asking where should development go related to the floodplain? What sort of floodplain [...] approaches are needed? [...] We would very much like to reinvigorate the floodplain planning program on the planning side and get resources out to counties particularly to do floodplain planning”* (ECY 2017). The lack of this kind of planning not only puts people and property at risk, but it is also costly and frustrating to federal agencies involved in disaster relief and rebuilding activities. FEMA and EMD interviewees referred specifically to the need for pre-existing and comprehensive flood response plans.

9.3 Goal 3: Agencies consistently use climate information in risk management, planning, and project design

Existing Problem: The lack of clear guidance to agencies on how to incorporate climate change considerations into their work leads to piecemeal incorporation or, more commonly, no incorporation at all. The identified problem is twofold in nature:

- *Lack of knowledge of and confidence* in existing climate resources that might be used
- *Lack of clear institutional process* to facilitate incorporation of climate change science into flood risk planning, management, and project design

Description: Interviewees expressed that they both do not know how to use existing climate resources in their work and/or that there is no formal agency process/guidance which allows them to use climate change resources in their work. The lack of knowledge of and confidence in existing climate change science was discussed in a number of ways, but most suggested the need for capacity building and possibly some additional research. For some, the issue is around better understanding the methods and models used to formulate climate projections: *“I want to engage with those people that are developing that [climate & flood risk projections] and talk through it so that I really understand it and I’m not just communicating some bullet point that I read.”* (NWS 2017). For others, the barrier to using climate information is the large ranges of impacts that the models predict: *“having modeling where we can at least get some kind of confidence level and say here’s the range we can work with within a certain confidence level and being able to present that”* (ECY 2017). Other interviewees feel that they don’t know how to “ask the right questions” and navigating the existing resources to be “too mysterious.”

On the other hand, even when practitioners would like to incorporate climate considerations into their work and have identified useful resources, they are often not permitted to incorporate it into planning/design/management work because there is no existing institutional framework or process for using that information. This is a widespread challenge that many interviewees identified:

- *“currently right now, none of our agency policies require that we account for climate change in the design of certain flood control structures”* (NRCS 2017)
- *“[the framework] hasn’t been interpreted to make addressing climate change something that has to be done, a mandatory element like a minimum floodplain standard. [...] There is no equivalent for climate change”* (ECY 2017)
- *“some sort of fairly prescriptive guidance that made it easy for us to implement climate science into our planning process. If it’s not in our planning process, it’s not going to get used”* (USACE 2017)

In the absence of a policy, a push to incorporate climate considerations must come from a local sponsor or partner, or agency staff who is likely to be told that the project budget will not cover the additional cost: *“I think that’s really the crux of it [...] what I’m seeing now with our efforts to try and account for climate change in our designs and planning is to the extent that costs more to do now to save us some problems down the road, I’m seeing a reluctance from the funding folks to allow for that to happen.”* (USACE 2017).

9.4 Goal 4: Agency roles are clear and do not conflict; agencies coordinate and leverage resources accordingly

Existing Problem: There is a lack of coordination between agencies and the Silver Jackets have not yet realized their potential as a nexus of coordinated action. There is an increasing need to coordinate and for agencies to examine their own mandates and actions to ensure that they are not counterproductive to long-term coordinated flood risk goals.

Description: A few interviewees expressed that there is a lack of coordination between agencies and that Silver Jackets has not yet realized its potential as a coordinating and active body. One interviewee commented that a lack of agency consensus can complicate communication with the public *“if there was more consensus across agencies that would help [...] they [the public] ask a few different people and if they get two to three different answers so they kind of shut down. They figure well this is just complicated and we don’t know yet. If there’s things that we really do know then getting everybody on the same page.”* (FEMA 2017). Interviewees identified the Silver Jackets as a potential nexus of communication and coordination, as well as a natural avenue for partnerships. While interviewees were overwhelmingly positive about the Silver Jackets program, it is mainly seen as a resource for information exchange and sharing project updates. The Washington Silver Jackets team is relatively new and still exploring how it might be most effective *“I think we were trying to still figure out what the program was and how it could best be utilized and we weren’t doing a very good job. We were actually funded for some of these interagency projects where they gave us a pot of money to do a study with the Silver Jackets. But [...] we weren’t doing the coordination very well. It was almost like we were doing it within a bubble within the Corps, which is not ideal for the Silver Jackets”* (USACE 2017). Those involved in Silver Jackets are highly positive about it as an education and information sharing resource, particularly around climate change issues, and feel that it could be doing more *“For me being you know being a planner, a regulatory person, the technical perspective [of Silver Jackets] because there are a number of climatologists that attend the meetings. That’s been an education for me. [...] In the future I think they could be a big help is [...to] help us to move towards a common vision of how to approach these problems. That might be helpful.”* (ECY 2017).

Interviewees expressed some concern that coordination can be challenging at times because agency mandates and processes may actually undermine the long-term flood risk management goals. For example, interviewees from the Corps noted that ultimately continuing to build levees may not be the best long-term solution to managing risk in the floodplain. However, due to existing processes and the constraints of the existing cost-benefit analyses, large structural projects are the most common approach to flood risk management. *“As always is the case you’ve got this conflict or tension between trying to give the river space to breathe, you know and folks that want to maximize use of the land whether its farming or development”* (USACE 2017). An NRCS interviewee also expressed that some of their activities in the floodplain may be contrary to long-term goals, particularly around climate-associated changes in flood risk.

Ensuring that flood risk management actions do not conflict with overarching priorities (of protection of life and property and the environment) or with the actions of other agencies, particularly when facing a changing climate, is an important component of climate resilient flood risk management.

9.5 Goal 5: Flood risk management increases floodplain resilience over time

Existing Problem: Current practices in flood risk management do not include consideration of climate change. Furthermore, existing practices do not always reduce current and future risk, and may at times be counter-productive. Ultimately, climate-resilient flood risk management should result in less work for practitioners.

Description: Flood risk management currently operates largely on a case-by-case basis: it is reactive to disasters and usually proactive in only the most extreme/high risk situations. An interviewee commented on the current approach: “we are working kind of in this circular pattern of constructing flood control structures [...] If we are constructing those without recognition of climate science we’re going to be in a circular pattern of repair or reconstruction” (USACE 2017). This pattern of repair and reconstruction indicates a lack of long-term vision or resilience for the region: “We’ll help pay for the protection of [infrastructure from flood]. And then you [...] set up a situation where now it’s incentivizing [development]. You’ve now set up a situation where things can then be changed on a landscape and make it even more imperative that things don’t get wet.” (USACE 2017). Allowing continued development in the floodplain without a coordinated long-term vision incentivizes the construction of infrastructure in flood-prone areas. Incorporating a few extra feet of freeboard or building higher levees does not necessarily increase resilience. This challenge is exacerbated by the fact that “resilience” of floodplains is not an agreed upon goal or even term: “How do you actually define resilience in that sense? [...] It could be that at some point we decide there’s a possible population of what’s going to happen with climate change. Do we design so that if the worst thing occurs we’re still at a minimum for life safety or for damage, casualties or something [else]? Anything that’s less than that we should do better on.” (USACE 2017).

This goal requires looking beyond the processes to the desired outcome: Specifying what it means for a floodplain to be resilient. Existing flood risk management systems in Washington State are complicated and multi-layered. As with any complex system, there is the risk that capacity devoted to process may limit the capacity available to achieve desired outcomes. The purpose of this goal is to ensure that success is measured in terms of outcomes as well as process: “I think it’d be very difficult to react or proactively make adjustments or influence people’s desires based on something that may happen 40 years from now. I think that’s really the crux of it in terms of what I’m seeing now with our efforts to try and account for climate change in our designs and planning: the extent that while it costs more to do now [it will] save us some problems down the road” (USACE 2017).

10. Solutions: Washington Silver Jackets Work plan

The following recommended actions are based on the goals and challenges discussed above, as well as the knowledge of the research team and their estimates as to feasibility. The research team has attempted to provide concrete, descriptive, and actionable work plan items that are grounded in the needs and priorities discussed in the interviews. The actions presented below are to be reviewed and prioritized by the Silver Jackets team members at the Workshop on June 1. They are in no particular order now and will be re-ordered, updated, and added to after the Workshop to reflect the priorities identified at that event. Broadly, the work plan recommendations are as follows:

- a. Develop improved estimates of future flood impacts
- b. Develop resources for local planners
- c. Build capacity and coordination on resilient floodplain management
- d. Improve public engagement
- e. Coordinate floodplain management goals and planning

10.1 Work plan Item A: Develop improved estimates of future flood impacts

- **Goals Addressed:** (1) Public understanding, (2) Local planning, (3) Agency practices
- **Rationale:** Estimating future flood impacts will allow agencies and communities to better understand, plan for, and manage their risk. Current information does not adequately portray risk
- **Interviewee perspectives:**
 - *“So here are the areas at risk and being able to lay it out for communities saying here’s the risk, here’s the dollar amount you’re talking about, here’s the public infrastructure, the city’s infrastructure at risk; here’s your risk. So to reduce that here’s some things we suggest and then we move into that.” (ECY 2017)*
 - *“If something is changing from what we have been expecting or used to expect in order to get that right our information is going to have to take that into account and portray that as well” (NWS 2017)*

10.1.1 A.1. Precipitation Extremes

Heavy precipitation events are a key driver of flood risk across Washington State. Although much is known about the key drivers of precipitation extremes, additional work is needed to (1) better characterize current extreme statistics and their spatial distribution, and (2) improve estimates of future precipitation extremes and their impacts across the state. Specific tasks range from updating the NOAA Atlas to optimizing regional climate model simulations of future precipitation events.

Examples:

- **Updating the NOAA Atlas.** The NOAA Atlas 14 “Precipitation-Frequency Atlas of the United States” serves as the standard for engineering design and planning for precipitation extremes. The current analysis is both out of date and premised on the assumption that the statistics of precipitation are stationary. This task could include preliminary work intended to either complement and/or motivate future updates to the Atlas, or could involve coordinating states among the NW region to provide funding for NOAA’s update of the atlas.
- **Do PMF estimates change with climate?** Resample the historical record to estimate probable maximum flood (PMF), or other design storms, and evaluate how these change as a function of temperature and precipitation. Use the sensitivities to estimate possible future changes. Are historical design storms sufficiently conservative? This could be coupled with an analysis of regional climate model projections to evaluate the potential for changes in the future.
- **What are the large-scale drivers of Atmospheric River (AR) events?** The general conditions that determine AR events are known: these require high vapor convergence driven by a large southerly swing of the jet stream. In contrast, the specific conditions that affect the spatial distribution precipitation within the region are not well known. This work would seek to identify large-scale conditions that are linked with high-intensity precipitation in specific parts of the state (e.g., Eastern Cascades, Puget Sound lowlands, Palouse Hills). This work would leverage existing work by the Climate Impacts Group to identify diagnostics that can be developed from global model projections and used to estimate changes in precipitation on sub-regional scales.
- **Validation and intercomparison of existing climate change datasets.** Numerous downscaled climate projection datasets are now available, but very little information exists about the relative merits of each. For example, most existing projections are derived from statistical downscaling, yet several recent studies have shown that a physically-based approach – dynamical downscaling – is needed to capture the effects of climate change on extreme precipitation (e.g., Salathé et al. 2014). This project would compare a selection of existing datasets to observations for a selection of flood-relevant metrics. This would provide information on the performance of each approach as a function of metric and location.
- **Updated historical simulations of precipitation.** Observationally-based historical datasets are used to drive hydrologic models in order to reproduce past flood events. Current datasets are limited in their characterization of historical weather events: results are limited to a 6-hourly or daily time resolution; existing records end in 2010 or 2013; and many exhibit areas where observations are lacking, particularly in high elevation areas where snow accumulation is important. New historical simulations, using a regional climate model, could be developed in order to provide a better baseline for estimating historical flood risks. In addition to simulations of the recent past (1950-2017, 1979-2017), long-term control simulations could be used to better characterize very rare extremes (e.g., the 500-year event).

- **More future precipitation simulations.** Future precipitation is best assessed using regional climate model simulations (Salathé et al. 2014). Existing simulations are limited in number, making it difficult to assess uncertainty in the projections and arrive at robust estimates of future conditions. This work would augment the existing projections with new regional climate model simulations along with the post-processing needed to develop datasets that can easily be incorporated into flood studies.
- **Optimization of precipitation simulations.** Existing work by the UW Regional Modeling Consortium, under the direction of Cliff Mass, has already optimized the 12-km implementation of WRF for weather forecasting. However, some processes that are important for flood risk (e.g., thunderstorms) may not be adequately represented in the current model configuration. In addition, the current model is optimized for weather forecasting, and may not be adequately optimized for climate simulations. This research would test different model configurations, evaluating the sensitivity to model resolution, parameterizations, and updates to newer versions of the model. Existing performance evaluations of the forecasting system would be leveraged by focusing only on metrics for which statistics do not already exist.

10.1.2 A.2: Streamflow Extremes

The primary climate drivers of peak streamflow events are the intensification of rain events and the reduction in snowpack at higher elevations. These changes are confounded by changes in land cover and land use that are not related to climate -- such as logging or development. Past and ongoing work has quantified climate change impacts on peak flow events. Additional work is needed to both assess the implications of existing projections and improve on those datasets. Specifically, existing work has primarily been applied at relatively coarse spatial scales (5x7 km grid cells), and relatively little work has been done to account for the combined influences of climate change, land use, and reservoir management. In addition, model evaluation metrics have generally emphasized the historical averages in streamflow as opposed to the sensitivity of streamflow to warming. This task should include any project -- modeling or empirical -- that improves the characterization of future changes in peak streamflow.

- **Influence of land use and land cover change on streamflow and stream temperature.** Link observed changes in both streamflow and stream temperature to changes in land use over time, across a range of watersheds and conditions. The assessment would include both flood risk and salmon-relevant metrics (low flows, stream temperature) in order to highlight the interplay between impacts on flood risk and salmon recovery. Identify areas where improved land cover or soils information is needed. If desired, this could be combined with a modeling assessment of future flood risk that incorporates projected changes in land use under various policy or development scenarios. Although analyses like these have been performed for some communities and watersheds, a major advantage of this analysis would be a standardized assessment for all of Washington State.

- **What is the maximum runoff ratio?** Relate precipitation and peak flow measurements to identify an upper limit to the peak flows expected for a given precipitation total. Use this as a constraint on hydrologic model projections by comparing what would be obtained from precipitation changes alone. Similar work is in progress at USGS by Chris Konrad and Mike Dettinger. This project would expand on their work.
- **Better calibration metrics for hydrologic modeling.** Hydrologic model calibration typically emphasizes static measures of streamflow such as the long-term average monthly and annual flows. In a non-stationary climate, this does not guarantee that simulations will behave accurately in future simulations. This task would identify and test new metrics that aim to ensure that the *sensitivity* of hydrologic model simulations is well calibrated.
- **Small-stream monitoring.** Flood risk assessments, along with major flood protections, are often limited to larger mainstem sites. Yet floods remain an issue on many smaller tributaries. A lack of measurements can often hinder flood risk assessments and infrastructure design decisions. This effort would identify a subset of small streams for monitoring, selected based on exposure to flooding and to cover a range of conditions.
- **Historical and Paleo hydrology: Better characterization of past flood risk.** Recent and paleo evidence of past flood extents can drastically alter estimates of peak flood events. This task would compile existing information from both historical accounts and geologic evidence, highlighting areas where these records lead to a different estimate of flow extremes than would be derived from gage observations alone. If feasible, additional work could be done to search historical records or evaluate the geologic evidence of large floods. In addition to the central estimates for specific exceedance values, special attention would be given to quantifying the uncertainty in these estimates.
- **Which trends are significant?** Mark Mastin's recent report ([Mastin et al. 2017](#)) provides an assessment of trends in peak flows in Washington State. This work could be expanded to include other metrics related to flood risk (e.g., precipitation extremes, storm surge, wind intensity, and snowpack). These could be integrated into an online tool that users can use to browse trends in the region (e.g., the Climate Impacts Group recently produced a [similar tool](#) for Seattle City Light).
- **Validation and intercomparisons of existing hydrologic change datasets.** In the past decade, many datasets have become available that quantify future changes in streamflow. The ongoing Structure for Modeling Multiple Alternatives project ([SUMMA](#)) is aimed at more accurately quantifying the uncertainty in future climate change projections. This work would complement the SUMMA work by evaluating existing hydrologic projections, in comparison with observations, for a suite of locations and peak flow metrics. This would shed light on the relative merits of each approach, and how the performance differs as a function of metric and location.
- **Can existing reservoirs mitigate changing flood risk?** Existing projections of changing streamflow, with the exception of one study on the Skagit River (Lee et al.

2016), do not account for the effects of reservoir operations. In watersheds with major reservoirs, this could mean that existing projections overestimate the change in flood risk. This task would provide survey-level information on existing dams and the potential for mitigating future flood risk in Washington State. This would include both an inventory of dams and a set of summary products that illustrate the potential for flow modification at each location (e.g., maps showing the percent of the upstream catchment that is captured by reservoirs and the capacity of each dam relative to anticipated peak flow volumes). If feasible, this could be augmented by using existing streamflow projections and reservoir models to estimate future changes in regulated flows.

10.1.3 A.3. Coastal Flood Risk

Substantial work has already been done to develop sea level rise projections and guidance that clarifies how this information can be used in planning and design (e.g., NRC 2012, USACE Engineering Regulation: ER #1100-2-8162). Ongoing work is already funded and underway to update sea level rise projections using a probabilistic framework and develop new community-scale estimates of vertical land motion. However, current projects are limited in their assessment of both current and future risks due to storm surge and waves.

- **CoSMoS (Coastal Storm Monitoring System).** USGS is currently initiating an effort to develop an integrated model that is capable of capturing interactions among sea level change, tides, storm surge, and waves with river flow, as well as the associated implications for coastal flood risk. This follows other [CoSMoS](#) efforts that have been completed in other parts of the country. Initial development of the model and supporting datasets is already underway, including preliminary wave forecasts and an evaluation of existing wind products. Ultimately, the model will couple forecasting capabilities with long-term climate simulations. In addition to providing direct estimates of coastal flood risk, the model can provide information on the potential for shoreline change due to wave energy dissipation and other processes.
- **Observed winds analysis: trends and extremes.** This task would undertake a systematic assessment of observed wind extremes, quantifying differences among extreme quantiles, wind directions, and seasonality. These would be evaluated to quantify current conditions as well as the significance and direction of trends. Previous efforts have quantified historical extreme statistics; the proposed analysis would expand on previous efforts by assessing the presence or absence of trends.
- **What are the large-scale drivers of wind storms?** The conditions that drive high wind events are generally well known. However, the specifics of how these are linked to high-intensity winds in specific parts of the state are not well defined (e.g., outer coast, Eastern Cascades, Puget Sound lowlands). This project would identify links between large-scale conditions and wind events and use these to evaluate the potential for changes in wind intensity in the future.
- **Validation and intercomparison of existing high-resolution wind datasets.**

Although several high-resolution wind datasets are available for use in surge and wave modeling, little is known about how these perform relative to observations, in particular for the purpose of surge and wave modeling in Washington State. This effort would build on current efforts by USGS to evaluate existing wind forecasts by expanding their validation efforts and evaluating regional model simulations of historical winds (their analysis is currently focused on forecast products). This would provide information on the performance of various wind datasets as a function of metric and location.

- **Updated historical simulations of winds.** Observationally-based historical datasets are used to drive surge and wave models to estimate coastal flood risk. Current datasets are limited in their characterization of historical weather events: results are limited to a 6-hourly or daily time resolution; existing records end in 2010 or 2013; and many exhibit areas where observations are lacking, particularly along the coasts where winds can change dramatically from one location to the next. New historical simulations, using a regional climate model, could be developed in order to provide a better baseline for estimating peak wind events. In addition to simulations of the recent past (1950-2017, 1979-2017), long-term control simulations could be used to better characterize very rare extremes (e.g., the 500-year event).
- **More future wind simulations.** Global models are too coarse to estimate future winds, and no current approach allows for statistical downscaling of winds. Existing simulations are limited in number, making it difficult to assess uncertainty in the projections and arrive at robust estimates of future conditions. This work would augment the existing projections with new regional climate model simulations, along with the post-processing needed to develop datasets that can easily be incorporated into surge and wave modeling.
- **Optimization of wind simulations.** Existing work by the UW Regional Modeling Consortium, under the direction of Cliff Mass, has already optimized the 12-km implementation of WRF for weather forecasting. However, wind extremes may not be adequately represented given the complex coastline of Washington State. In addition, the current model is optimized for weather forecasting, and may not be adequately optimized for climate simulations. This research would test different model configurations, evaluating the sensitivity to model resolution, parameterizations, and updates to newer versions of the model. Existing performance evaluations of the forecasting system would be leveraged by focusing only on metrics for which statistics do not already exist.

10.1.4 A.4: Future Flood Maps

To date, most studies have evaluated future flood risk in terms of changes in peak flows in rivers, or the extent of sea level rise expected in the future. Yet flood risk management is typically premised on an understanding of the combined influence of peak flows and sea level on the depth and extent of flooding. Many floodplains have been mapped for flood insurance, but these studies have emphasized the 100-year flood and few studies have evaluated the effects of climate

change. In addition, few studies exist for smaller tributaries, especially in areas with relatively little development. The purpose of this task is to assess future changes in the depth and extent of flooding across Washington State. These could be applied directly to planning or additional economic modeling could be conducted to estimate the cost of future flooding.

- **Refined topographic floodplain analysis.** This work would refine and improve up on the topographically-based estimates of floodplain extent developed by Konrad (2014). These have great potential for use in resilient floodplain management since they illustrate the geomorphic floodplain as opposed to the regulatory floodplain, which may be restricted by human modifications to the landscape. However, the current dataset requires additional refinement to correct for inaccuracies and identify a robust best-estimate of floodplain extent. In addition, the dataset could be augmented to include smaller tributaries, coastal floodplains, and areas at risk of coastal erosion and channel migration.
- **Pilot studies leveraging existing efforts.** This task would pilot the integration of climate and hydrologic projections in hydrodynamic modeling studies. Leveraging existing flood studies (e.g., RiskMAP, USACE, etc.), researchers would tailor existing projections for use as inputs to the hydrodynamic modeling with the goal of obtaining maps of future flood risk while creating little to no additional work for the hydrodynamic study leads. Results of these efforts would be compiled into a set of case studies detailing lessons learned and the potential for expansion to facilitate incorporation of climate change in future studies.
- **Statewide hydrodynamic modeling.** Recent advances in computing power and modeling approaches have made it possible to run hydrodynamic simulations over large areas at once (e.g., Sampson et al. 2015). Ongoing work aimed at quantifying climate change impacts on streamflow, precipitation extremes, and sea level rise can be used as input to flood models, resulting in regional maps of changing flood risk. Given the scope of the current model, any domain up to and including the coterminous U.S. is possible. Smaller scales may allow for better hydrologic projections and a more complete census of levees and other flow restrictions. Results would serve two primary purposes: (1) awareness raising about the severity of future flood risks, and (2) as a basis for regional planning and prioritization.
- **Economic impacts of flooding.** Use hydrodynamic modeling results to estimate the future costs of flooding. This could be accomplished using FEMA's statewide HAZUS model, or using local implementations of HAZUS or HEC-FDA. The economic modeling could be further expanded to capture the ripple effects that extend beyond the direct damage to infrastructure (e.g., lost productivity, transportation delays) using a computable general equilibrium (CGE) model.

10.2 Work plan Item B: Develop resources for local planners

- **Goals Addressed:** (2) Local planning, (4) Public engagement
- **Rationale:** Developing useful and appropriate resources for local planners will help ensure that they have the tools they need to both understand and communicate risk to their communities, but also effectively plan within the floodplain
- **Interviewee perspectives:**
 - *“Community planners are doing so much. I’m just in awe of all the things they do. They can only do so much at one time. They can’t start making up their own programs. They really need guidance and someone with the informed opinion and a monetary reason why they should be doing these things” (ECY 2017)*
 - *“We need to do things in such ways as people know how to take action, what action to take and will take action.” (NWS 2017)*

10.2.1 B.1: Flood Risk “Bible”

Individual Silver Jackets agencies already have some guidance on integrating climate change in flood risk management. This project would develop guidance that would enable consistent application among locals and across agencies. Designed to function similarly to the [fish passage “bible”](#) developed by WDFW (Barnard et al. 2013), this guidance would be intended to support incorporation of climate change information in project design and implementation (planning guidance is described under work plan item E.2). Although the guidance document would not have the same authority as WDFW holds with fish passage, it would include information on assessing the sensitivity to climate change, use and interpretation of climate change projections, and approaches to mitigating future risks. The document will be designed to be consistent with existing agency guidance, noting areas where the requirements differ among agencies.

10.2.2 B.2: Centralized Resources

Numerous resources exist -- ranging from datasets to guidance to funding opportunities -- for use in preparing for the effects of climate change. Yet interviewees indicated that agency staff and local managers are frequently unaware of existing data, guidance, and opportunities for resilient floodplain management (e.g., existing hydrologic projections, USACE guidance on inland hydrology, EMD funding for HMP development, etc.), nor do they always know how best to make use of what is available. This project would create a centralized resource, or set of resources, for existing data, guidance, and funding resources. This could be a website, a set of fact sheets or infographics, or both. The new resource would be designed to be a “one-stop” destination for existing resources, combined with guidance to help users navigate the options and select the information that best applies to their particular needs.

Climate change datasets on sea level rise, streamflow, and precipitation would be compiled along with information about how to use the data, how it compares to other data resources, and what methods were used to create it. Ideally, this resource would be searchable by location, project type, etc. Rather than duplicating existing archives, the site would direct users to existing

repositories containing original source data. When additional post-processing is necessary, products could be created to minimize the additional work for users. Finally, since the science and projections are continually changing, the site would be designed to be scalable so that new projections can easily be incorporated.

Similarly, the site would catalog existing planning processes and funding resources that are relevant to floodplain management. As above, the emphasis would be on existing materials and resources, but the site would include information to help users identify the guidance and resources that best apply to their situation. If the case studies project in B2 is pursued, these could be added to the site.

This project could be designed to be relatively simple (e.g., augmenting the Salish Sea Wiki) or more complex (e.g., searchable database, user tools, etc.). The scope of work should include a plan for updating the resource as necessary.

10.2.3 B.3: Case Studies

The purpose of this work is to highlight real-world examples of resilient flood risk management with the goal of illustrating ways in which similar successes could be achieved elsewhere. Case studies focused on successful flood risk management provide a practical complement to better information resources. An example is the [CRS Green Guide](#), which includes success stories from communities that have implemented the CRS program. As a complement to the Green Guide, which provides a very high-level overview, this task would be designed to identify specific actions and approaches that facilitate resilient flood risk management in each example. Examples could range from single projects (e.g., the Mt. Vernon flood wall) to watershed planning efforts (e.g., the flood elements of the Yakima Integrated Water Plan). Examples need not be uniquely focused on successes, nor would they need to have incorporated climate change. Instead, case studies would be picked to illustrate elements that lead to greater resilience overall and highlight the pros and cons of various decisions. Summaries would include information on the context (social, political, institutional, etc.) within which the process occurred, data on the flood risks faced, the planning process, obstacles encountered and overcome, funding sources, the outcomes and approaches considered, and the role of different agencies in contributing to the process. Lessons drawn from the case studies would highlight actions that could be taken at the local as well as the agency level. Materials could be designed to be modular and include both high-level and detailed information, allowing for a variety of audiences. These could also be incorporated in both internal and external training efforts.

10.3 Work plan Item C: Build capacity and coordination on resilient floodplain management

- **Goals Addressed:** (2) Local planning, (3) Agency practices, (4) Public engagement
- **Rationale:** All of the efforts below involve convening professionals interested in resilient floodplain management (the SJ Team, scientists, and local floodplain leaders, etc.), with the ultimate aim of cultivating a network for shared learning and information exchange. Learning networks have been shown to increase capacity through information sharing and relationship building. They have been shown to increase capacity of all involved through leadership creation, information sharing, and innovation (Christie et al. 2016).
- **Interviewee Perspectives:**
 - *“I want to engage with those people that are developing that [climate models] and talk through it so that I really understand it and I’m not just communicating some bullet point that I read. That at this point is a barrier.” (NWS 2017)*
 - *“I think you wouldn’t want to limit [education resources] to a specific group. I think that you would want to try to get the information out to as many people as possible.” (NRCS 2017)*

10.3.1 C.1: Seminar series

Interviewees noted a lack of capacity for dealing with climate change in floodplain management. The research team is currently presenting briefly at each monthly Silver Jackets call to build capacity and awareness on existing resources. This project would continue and expand on those presentations as a mechanism for sharing information internally and hearing from other specialists outside of the group (e.g., Jeff Arnold from USACE headquarters, Ann Bostrom from the UW Communications department, Paula Harris from Whatcom County). While one objective of this effort would be to provide information and an opportunity to answer specific questions, it is also focused on relationship building. The networking aspect could be enhanced by convening an in-person speaker series, as opposed to webinars, along with time for networking before or after each talk. Or, occasional talks could be coupled with existing meetings convened by WA SJ, Floodplains by Design, NORFMA, etc. Regardless of format, attendees could be invited from beyond WA SJ to include other agencies and locals who may benefit from the exchange.

10.3.2 C.2: Local Interviews

The current project involves interviewing WA SJ agencies about the needs, challenges, and opportunities associated with climate resilient floodplain management. Many interviewee comments concerned the needs of locals. An important complement to the current interviews would be to repeat the same discussions with local floodplain managers. This would both serve as a way to “ground truth” the findings of the current project while also highlighting gaps in the current work plan.

In addition to an updated and more comprehensive work plan, results could highlight opportunities for altering agency policies and practices to better support resilient floodplain

management. Shared recommendations, coming from floodplain managers across the state, would lend more strength and impact than if they were made individually. This feedback could be synthesized in the form of letters to specific agencies, presentations on suggested changes, or the creation of specific training modules for agency staff. In general, a synthesis of the needs of both the WA SJ agencies and local managers would help clarify which barriers and opportunities should be the focus of continued efforts to increase the resilience of Washington's floodplains.

Substantial efforts have already been undertaken by WA SJ and others to engage with local floodplain managers. This project would begin by gathering information about those efforts and identifying ways to build on previous findings without burdening locals with duplicative processes.

10.3.3 C.3: Learning Network

The Silver Jackets teams involve coordination among state and federal agencies concerned with flood risk management. This does not include local floodplain managers and does not include other agencies whose policies and practices affect floodplain management (and, by extension, flood risk management). In particular, given the scope of the issues implicated in accounting for climate change impacts, it would be helpful to increase coordination and information among a network of agency and local staff involved in resilient floodplain management. This purpose of this effort would be to convene a network among interested floodplain professionals and create opportunities for shared learning and relationship building. Rather than creating an entirely new network, this effort would leverage existing groups, such as:

- o WA SJ. The Silver Jackets team could be expanded to include non-agency floodplain leaders.
- o "Floodplain Leaders" group, convened by The Nature Conservancy (TNC) under the Floodplains by Design program.
- o The Coastal Hazards Resilience Network (CHRN), convened by the Washington department of Ecology and Sea Grant.
- o Northwest Regional Floodplain Management Association (NORFMA): Regional network of floodplain managers.
- o Floodplains Implementation Strategy team, convened by the Puget Sound Partnership (PSP).

Activities could include networking sessions, field visits, short courses, webinars, or simply a quarterly conference call. In person activities could leverage existing meetings and events: the WA SJ annual meeting, semi-annual Floodplains by Design meetings, NORFMA, etc.

10.4 Work plan Item D: Improve public engagement

- **Goals Addressed:** (1) Public understanding, (2) Local planning, (3) Agency practices
- **Rationale:** A public that is informed and cares about their flood risk will communicate

that to local planners and elected officials. These actions focus on outreach to two specific groups with whom various Silver Jackets agencies already interact in some capacity: city and county councils, and homeowners/landowners/residents in flood-prone areas.

- City and County councils were identified as key to the decision-making process due to their role in setting local budgets and priorities. Turnover is also among this group, meaning that regular engagement is necessary to maintain institutional knowledge.
- The general public ultimately inform the actions of local government. They are also the most personally affected by a lack of climate-resilient flood risk management in that they suffer directly from flood damages to their homes and communities. Making this group aware of both the risks and opportunities to mitigate future flood risks will motivate and empower them to address their flood risk on an individual and community level.
- **Interviewee Perspectives:**
 - *“get some public information out there because there needs to be the public support instead of just rampant public opposition. Let’s say some public support. The city councils need to have some feeling that they’re not going to really just get lost when they start adopting higher regulatory standards.”* (ECY 2017).
 - *We really are focusing on expanding our outreach efforts. Since they are statewide, I don’t have the luxury of just going to Seattle suburbs and talking to folks who already know half of it. I have to have material that can speak to them but can also be transferrable with maybe another presentation to the town of Whitesburg or a really small community that’s just at the very early stages of even understanding what the issue is. The range, I think, is the challenge.* (EMD 2017)

10.4.1 D.1: Outreach Materials

Drawing on existing science resources, create maps and figures that illustrate flood risks and costs for use in engaging the public and decision makers. Similar resources already exist; these documents would be reviewed to ensure that they are accurate and up-to-date, contain guidance on climate change where relevant, are easily available both online and in physical outreach and training materials, and written in clear and accessible language. In addition, this task would identify opportunities to augment existing resources (e.g., if there are gaps in the information provided) and consolidate them into one set of materials. Interviewees indicated that communicating the costs of future flood risk will likely have a strong impact on public understanding and engagement with flood risk; a priority in this work will be to synthesize and interpret existing information on the economic consequences of flooding. Conversations with local floodplain leaders could provide additional perspectives on needs and approaches that are likely to be effective.

10.4.2 D.2: Coordinated Engagement

The Idaho Silver Jackets Team, considered by many interviewees to be a good model for successful utilization of the Silver Jackets program, has organized a number of activities around National Flood Safety Awareness Week (see [National Flood Safety Awareness Week Activities](#) of Idaho SJ Team). This comprehensive awareness and engagement campaign targets a different key group each year. Activities include agency booths at the state capital to answer questions, public service announcements via social and traditional media, the creation of the Idaho Floods! guidebook to raise flood awareness, and workshops with community groups. This work would begin by gathering lessons learned from the Idaho SJ Team. However, Idaho's flood context is distinct from Washington's in that flooding in Eastern and Western Washington takes place at different times of the year and is linked to distinct drivers. Additional work could identify ways to address this issue and effectively engage both geographic audiences. WA SJ interviewees identified city councils as an important audience, both due to their ability to advance flood risk management goals and the high turnover inherent in these positions. We recommend that outreach be targeted at local councils. Suggested activities might include:

- Identify specific city councils for focused engagement, rotating each year.
- SJ presentations on flood risk management and climate change at city council meetings across the state
- Regional meetings for city council members and agency staff to discuss climate-resilient flood risk management, answer questions, and better understand needs.
- Targeted emails with information resources and opportunities for immediate action, identified based on existing contacts and relationships
- Media posts (social and traditional) highlighting and celebrating good flood risk management actions in local communities
- Select a target action that city council members could take (e.g., updates to a specific portion of an existing plan, adopting a new flood management ordinance) and encourage all city councils statewide to take action on it during the Flood Safety Awareness Week activities

10.5 Work plan Item E: Coordinate floodplain management goals and planning

- **Goals Addressed:** (2) Local planning, (3) Agency practices, (4) Public engagement
 - **Rationale:** Local managers have limited capacity to address flood risk issues while also complying with an array of planning processes that are required by state and federal agencies (hazard mitigation plans, comprehensive plans, shoreline master plans, salmon recovery plans, etc.). This is complicated by the fact that planning efforts are not always centralized within a single city or county department. Duplication and incompatibility among various planning efforts may result in ineffective floodplain management and may also limit the capacity for locals to address other considerations, including climate change. This could be alleviated by developing collectively-defined goals for the Silver Jackets agencies, by working to align the flood risk elements of various planning
-

processes, and by providing guidance to communities for improved coordination and consistency among floodplain management plans and activities.

- **Interviewee Perspectives:**

- *“Strengthening partnerships and relationships with agencies that are on the cutting edge. We should be on the cutting edge. [...] We might have a piece of the puzzle, but no single agency is going to own the whole puzzle.” (EMD 2017)*
- *“But if you try to combine [FRM] across the entire watershed you might actually get better accounting of who is actually responsible for specific risk. [...] The easiest is mitigation planners working with community development planners and identifying projects and preventing development of flood plain” (EMD 2017)*

10.5.1 E.1: Goals Statement

Silver Jackets teams are intended to *“facilitate collaborative solutions to state flood risk priorities”* (<https://silverjackets.nfrmp.us/>, accessed May 20, 2017). The purpose of this task is to develop a concise definition of the WA SJ team’s goals for floodplain management, which can be used to prioritize future efforts by the group. Given differences among agency roles and the potential for climate change to drive changes in best practices, a well-defined goals statement would serve to clarify the group’s aspirations and systematize decisions about future work. This definition should be referred back to and used as a criterion for determining what actions and projects the WA SJ team selects to work on.

10.5.2 E.2: Planning Checklist

Floodplain management is implicated in a wide range of planning processes within Washington State: Comprehensive plans, Shoreline Management plans, Hazard Mitigation Plans, Salmon Recovery Plans, Watershed Plans, etc. Although these plans include common elements, it is rare that they are created consistently or even coordinated among the same local staff or departments. Internal consistency and improved coordination among planning processes could reduce the staff time required for these processes while also ensuring that floodplains are managed using a consistent set of goals and strategies.

The purpose of this project would be to ensure that climate-related planning requirements are consistent across agency programs and provide support for local planners to address climate change. Initial work could develop a consolidated list of planning information that could then be replicated, as applicable, across a wide variety of local plans. Initial work would identify plans that relate to floodplain management and determine how exactly climate and flood risk fit into each process. This information would be consolidated into a set of unique planning elements. These would be synthesized in a checklist covering all required planning elements related to floodplain management, along with guidance on incorporating the relevant elements into various

plans, ways to leverage agency-specific expertise, and opportunities for integrating climate change considerations. Additional guidance would identify where to extract floodplain relevant elements from one plan for use in another (e.g., from a salmon plan to a comprehensive plan). This analysis would also highlight ways that current agency planning requirements could be improved. For example, agencies could include consistency with existing plans as part of their evaluation criteria when reviewing new plans.

Table 8 (next page) summarizes the work plan action items and their correspondence with climate resilient flood risk management goals from section 9.

Table 8: Summary of work plan action items and their alignment with the climate resilient flood risk management goals:

		<i>Work plan Goals</i>				
		1. Public Understanding	2. Local Planning	3. Agency Practices	4. Agency Coordination	5. Resilient Floodplains
<i>Work plan Action Items</i>	A1. Precipitation Extremes		✓	✓		
	A2. Streamflow Extremes		✓	✓		
	A3. Coastal Flood Risk		✓	✓		
	A4. Future Flood Maps	✓	✓	✓		
	B1. Flood Risk “Bible”		✓	✓		
	B2. Case Studies	✓	✓	✓	✓	
	B3. Centralized Resource	✓	✓	✓		
	C1. Seminar Series		✓		✓	
	C2. Local Interviews		✓	✓	✓	
	C3. Learning Network		✓	✓	✓	
	D1. Outreach Materials	✓	✓		✓	
	D2. Coordinated Engagement	✓	✓		✓	
	E1. Goals Statement	✓		✓	✓	
	E2. Planning Checklist		✓	✓	✓	

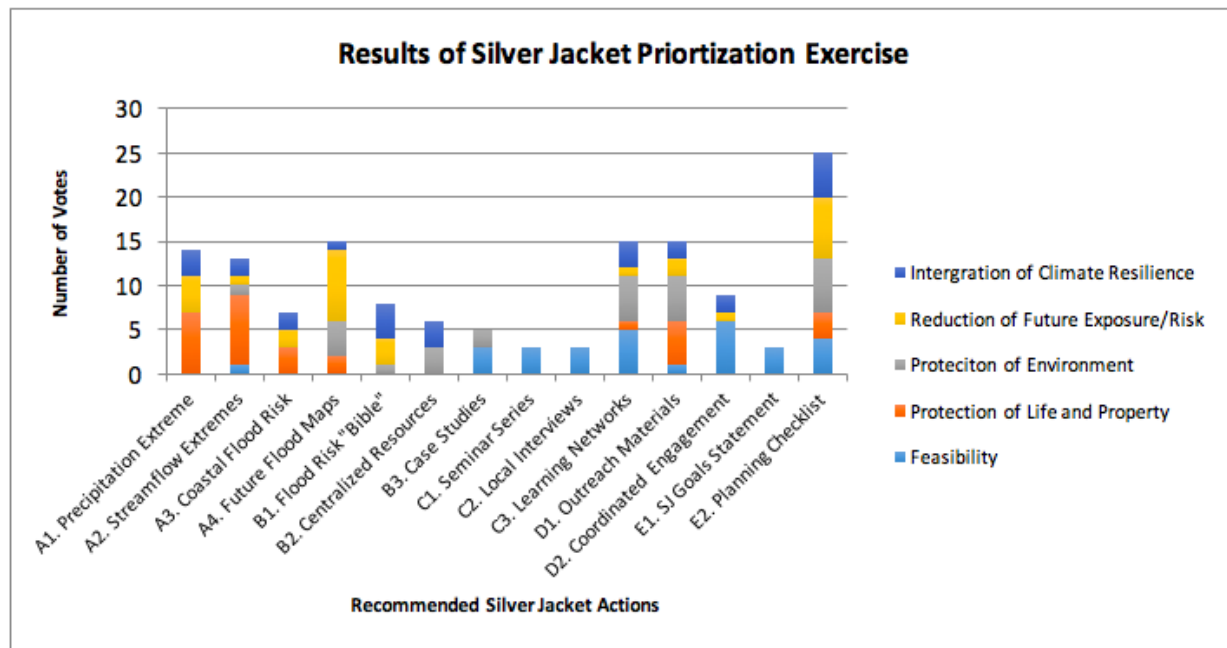
11. Priorities for Near-term Action

The Silver Jackets Workshop, held on June 1 2017, served as a validation exercise for the draft recommendations, which were developed out of the interviews. Following a 90-minute small group review of the supporting actions, Silver Jacket members worked to prioritize the specific actions to inform their work plan over the next two years. The actions were assessed by 9 Silver Jacket members using the following criteria:

1. **Feasibility:** Is the action technically and financially feasible for Silver Jacket members to lead and/or implement?
2. **Impact on flood risk management:**
 - a. protection of life and property
 - b. environmental considerations
 - c. reduction of future exposure/risk:
3. **Impact on Climate Resiliency Integration Goals:** Will the action help achieve the goals of integrating climate resilience into flood risk management?

All fourteen draft work plan actions were displayed in the front of the room. Silver Jacket members were given three votes for each of the five criterion listed above. Members were asked to for the actions that best met the criteria. They were free to apply all votes to a single action or distribute them across multiple actions. Since the purpose of the workshop was to prioritize work for the Silver Jackets team, workshop participants from outside the Silver Jackets group were not given the opportunity to vote. The results are shown in Figure 1.

Figure 1: (next page) WA SJ prioritization of action items based on feasibility, impact on flood risk management goals (protection of life and property, environmental considerations, and reduction of future exposure/risk)



Following the prioritization exercise, all workshop participants discussed the results and reached consensus on supporting the following actions as near-term priorities:

- **A1:** *Precipitation Extremes*
- **D1:** *Develop Outreach Materials*
- **E2:** *Create a planning checklist*
- **A4:** *Future Flood Maps* [Not discussed in detail at the workshop]
- **C3:** *Create Learning Networks* [Not discussed in detail at the workshop]

Participants then broke out into small group discussions to identify leads for the first three priorities and delegate tasks for each team. Following are brief descriptions of each group's conclusions.

11.1 Near Term Priority A1: Precipitation Extremes

Washington Silver Jackets Lead: Brent Bower, National Weather Service

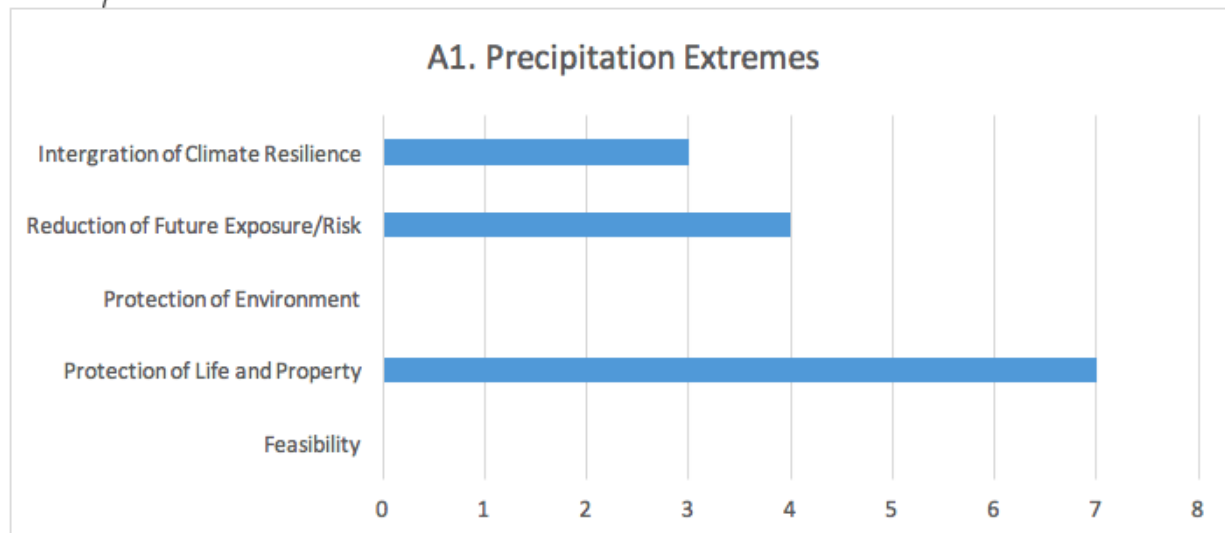
Goal of the Work: Improve estimates of future flood extremes and their impacts including their spatial distribution

Climate Resilient FRM Goals Addressed:

- 2 – Local Planning
- 3 – Agency Practices

Prioritization Scores:

Figure 2: WA SJ prioritization scores breakdown for action A1: Precipitation Extremes



Description of Initial Actions:

The Silver Jackets agreed that for Washington State as a whole, the most effective way to address the need to better characterize, understand, and improve estimates of future extreme precipitation events is through supporting the regional update to NOAA Atlas 14. NOAA has prepared a proposed scope and budget both for an update to the Atlas, as well as an optional separate scope to assess non-stationarity in precipitation.

The NOAA budget for the Atlas 14 update would cost Washington State \$400-600K. Efforts by the WA SJ team will focus on coordination with other groups that may benefit from the NOAA Atlas update, writing and soliciting letters of support, performing example calculations, and otherwise identifying tasks and approaches that may increase the chance of funding.

The WA SJ Team plans reach out to other agencies and regional coordination groups since these groups may have already looked into options for funding the NOAA effort, and the cost is lower if the states of Washington, Oregon, Idaho, and Montana can coordinate. The team currently plans to consult with the Oregon and Idaho Silver Jackets teams, the Northwest Region Floodplain Management Association (NORFMA), and the Washington State departments of Transportation (WSDOT) to assess current efforts to obtain this funding.

Preliminary Actions Identified in the Workshop:

- Brent Bower (NWS) to communicate with NOAA Headquarters and act as liaison between WA SJ Team and NOAA on this work
- Ted Perkins (FEMA) to communicate with the Oregon SJ Team
- Katherine Rowden (NWS) to communicate with the Idaho SJ Team

- Hans Hunger (NORFMA) to gauge NORFMA support for NOAA Atlas update

Potential Funding Sources: The Washington Silver Jackets team will support this effort through in-kind contributions of time and resources.

Unassigned Tasks:

- SJ volunteer to contact WSDOT regarding acting as another potential lead
- SJ volunteer needed to perform example analyses showing differences in precipitation statistics when observations after 1970 are included

11.2 Near Term Priority D1: Outreach Materials

Washington Silver Jackets Lead: Travis Ball, Army Corps of Engineers

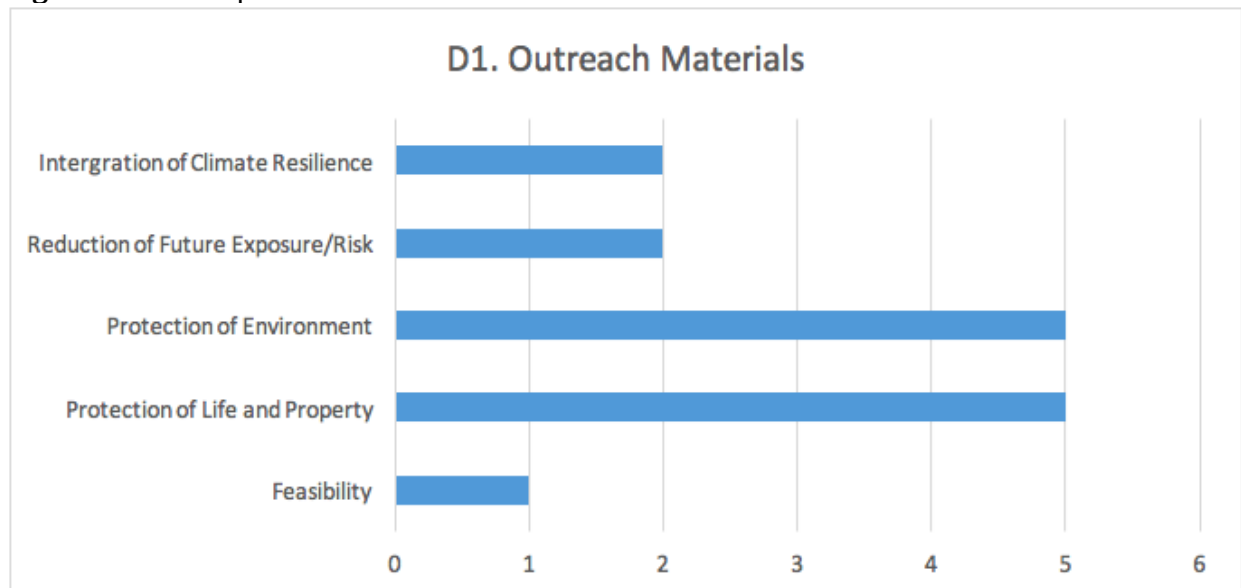
Goal of the Work: Develop interagency outreach materials on climate change and flood risk management, tailored with locally-relevant information for individual jurisdictions (PowerPoints, website, brochures, videos)

Climate Resilient FRM Goals Addressed:

- 1 – Public Understanding
- 2 – Local Planning
- 4 – Agency Coordination

Prioritization Scores:

Figure 3: WA SJ prioritization scores breakdown for action D1: Outreach Materials



Description of Initial Actions:

The SJ group agreed that targeting local elected officials should be the priority of outreach, with a secondary goal of strategic outreach to the general public on reducing flood risk and building climate resilience. The small group emphasized that different strategies and materials may be needed for each group and location, and noted the importance of communicating via a trusted messenger. They also felt it was important that the Silver Jackets name and brand was included on outreach materials in order to present a unified, consistent, and trustworthy message.

Preliminary Actions Identified in the Workshop:

- Review NWS social science and FEMA outreach contractor research on communicating flood risk in a manner that leads to risk-reducing actions. If needed, engage a consultant or someone in the academic community on messaging around climate change and flood risk to ensure that existing materials are appropriate and new materials are effective
- Review existing outreach materials across agencies
- Ensure that relevant sources of climate information are included and explained

Potential Funding Sources: The research team helped draft a Floodplain Management Services (FPMS) grant application, a program of the USACE. The WA SJ has successfully received this grant in previous years for their post-fire flooding communication grants, and USACE staff familiar with the program believe it is a good fit.

Unassigned Tasks:

- Submission of FPMS funding opportunity
- Contacting NWS, FEMA, and/or academic partner regarding communication

11.3 Near Term Priority E2: Create a Planning Checklist

Washington Silver Jackets Lead(s): Derrick Hiebert, Emergency Management Division and Dave Radabaugh, WA State Department of Ecology

Goal of this work: Ensure that climate-related planning requirements are consistent across agency programs and provide support for local planners to address climate change through creation of a planning checklist

Climate Resilient FRM Goals Addressed:

- 2 – Local Planning
- 3 – Agency Practices
- 4 – Agency Coordination

Prioritization Scores:

Figure 4: WA SJ prioritization scores breakdown for action E2: Planning Checklist



Description of Initial Actions:

The WA SJ Team determined that the creation of a planning checklist would be an effective method to align what “climate integration” means as a requirement and to ensure consistency across planning processes. The checklist will support local governments in identifying what plans require climate information and developing a consistent set of information that can be used for multiple planning processes and requirements across departments. This work will require a thorough review of existing guidance information and the incorporation of local perspectives.

Preliminary Actions Identified at the Workshop:

- Gather existing guidance information from agencies that currently incorporate climate considerations in future flood predictions in their planning processes including:
 - Department of Commerce: comprehensive plans and CAOs
 - Department of Ecology: floodplain management and NFIP, SMPs
 - Department of Natural Resources & Fish and Wildlife: mitigation programs
 - NOAA: salmon recovery plans and ESA considerations
 - EMD: HMPs
- Compare existing guidance and make recommendations for consistency
- Hold a workshop for agencies to review recommendations
- Pilot the guidance on a select few jurisdictions (large and small, east and west side)
- Review feedback from pilot jurisdictions and adjust checklist resource accordingly

Potential Funding Sources: Dave Radabaugh and Derrick Hiebert are both funded for their participation in the WA SJ. Additional funding is being discussed via WA SJ discretionary funds.

Unassigned Tasks:

- Application for additional funding if deemed necessary

12. Conclusions

As climate change continues to affect flood risk in Washington State, coordination and communication, both among agencies and between agencies and local communities, will become increasingly important. Climate change challenges existing flood management approaches and highlights important data gaps. It also stresses existing management systems and increases the need for improved institutional processes and outreach efforts. Given their technical and management expertise and the impact of their combined actions as an inter-agency team, the Washington Silver Jackets group is uniquely positioned to act as a resource and a leader in increasing the climate resilience of Washington's flood risk management system. The WA SJ team is new relative to teams in other states, but members are engaged and enthusiastic about addressing this challenge. They are already taking action to fund and begin work on the near-term priorities they identified. We hope that this project has helped catalyze their collective energy and resources around this topic and that the work plan continues to serve as a roadmap for ongoing collaboration on climate-resilient flood risk management.

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Appendices

I. Washington Silver Jackets Roster

Agency	Last Name	First Name	Position
FEMA	Perkins	Dwight (Ted)	Regional Engineer
FEMA	Riedy	Michael	Voluntary Agency Liaison
FEMA	Stone	Kelly	Risk Analyst
NOAA	Bower	Brent	Service Hydrologist
NOAA	Bryant	Andy	Service Hydrologist
NOAA	Intermill	Joe	Hydrologist-In-Charge
NOAA	Lohmann	Marilyn	Service Hydrologist
NOAA	Rowden	Katherine	Service Hydrologist
NOAA Federal	King	Stephen	Service Coordination Hydrologist
NORFMA	Hunger	Hans	Capital Improvement Program Manager
NRCS	Johnson	Larry	Conservation Engineer
NRCS	Lange	Joe	Design Engineer
OWSC	Bumbaco	Karin	Assistant State Climatologist
USACE	Ball	Travis	Hydraulic Engineer
USACE	Bessey	G.H.	Levee Safety Program Manager
USACE	Boen	Cindy	Project Manager
USACE	Downing	Daryl	Project Manager
USACE	Hobbs	Brandon W.	District Outreach Coordinator
USACE	Ifft	Charles H.	Levee Safety Program Manager
USACE	Katz	Daniel M.	Hydraulic Engineer
USACE	Schwarz	Tracy	Walla Walla District Hydraulic Engineer
USACE	Sclafani	Paul	Hydraulic Engineer
USACE	Stidham	Jeffery L.	Disaster Response Manager
USACE	Weber	Douglas T.	Emergency Management Chief
USGS	Mastin	Mark	Surface Water Specialist
WA ECY	Franklin	Jerry	Risk Analyst
WA ECY	McKinney	Scott	Floodplain Management: State Coordinator
WA ECY	Radabaugh	David	NFIP State Coordinator
WA ECY	Schmidt	Lynn	Floodplain Management: Eastern Washington
WA ECY	Talebi	Bobbak	Coastal Program Planner

WA ECY	Walther	Martin	Hydrologic Engineer
WA EMD	Hiebert	Derrick	Hazard Mitigation Strategist
WA EMD	Spicer	David N.	Hazard Mitigation Grant Coordinator
WA EMD	Tomt	Sarah	Tsunami Program Coordinator
WA EMD	Walker	Brynne	Tsunami Program Coordinator
WSDOT	Himmel	John	WSDOT Emergency and Security Manager

II. Workshop Attendee List

<i>Agency/ Organization</i>	<i>Last Name</i>	<i>First Name</i>	<i>Title</i>
CIG	Morgan	Harriet	Research Consultant
ESA Consulting	Easton	Spencer	Project Manager
FEMA	Perkins	Dwight (Ted)	Regional Engineer
King County	Comanor	Kyle	Senior Engineer
King County	Murray	Brian	Policy and Program Supervisor: River and Floodplain Management
NOAA	Bower	Brent	Service Hydrologist
NOAA	Rowden	Katherine	Service Hydrologist
NORFMA	Hunger	Hans	Capital Improvement Program Manager
Pierce County	Walker	Brynne	Tsunami Program Coordinator
USACE	Brettman	Kenneth	Senior Water Manager: Western Washington
USACE	Dillon	Jeff	Civil Works Project Management Chief
USGS	Labiosa	Bill	Regional Science Coordinator
USGS	Matsin	Mark	Surface Water Specialist
WA ECY	Radabaugh	David	NFIP State Coordinator
WA ECY	Schmidt	Lynn	Floodplain Management: Eastern Washington
WA ECY	Walther	Martin	Hydrologic Engineer
WA EMD	Hiebert	Derrick	Hazard Mitigation Strategist
Organizer: UW SMEA	Kennard	Haley	Graduate Student Research Assistant
Organizer: CIG	Mauger	Guillaume	Research Scientist
Organizer: Hook Environmental	Hook	Abby	Facilitator

III. Interview Guide

1. Introductory Questions:

- a. For the recording, could you tell us your name, your job title, and a bit about your current role?
- b. How long have you been working as a flood risk manager?
- c. How long have you been involved with WA Silver Jackets and what is the role of your organization within Silver Jackets?
- d. How would you rate your familiarity with climate change impacts in Washington State and current climate science resources?

2. Description of problem and current state of integration, and use of resources:

- a. What are the primary causes of flooding in your region? What events typically lead to extreme flood events?
- b. Broadly speaking, what are some elements of successful flood risk management??
- c. In your work, what are the current priorities for managing flood risk?
- d. What, if any, are the benefits to making flood risk management more resilient to climate change?
- e. Are you currently using climate change information in your work?
 - If NOT USING CC info: Why not? Do you have a use for climate change projections? What barriers exist to you using this information?
 - If USING CC info: If so, how? What resources do you use? What sources do you turn to for this information? Are those resources effective?

3. Challenges and Opportunities:

- a. What are the opportunities for making flood risk management more resilient to climate change in the near term (< 5yrs)? In the longer term (> 5yrs)?
- b. What are the primary institutional/organizational/political/legal/technological barriers facing the integration of climate change science into flood risk planning and management in your work?
- c. What is needed for your agency to better integrate climate science into flood risk planning?
- d. In an ideal world, what one factor or barrier would you change so that your institution might better address climate change and flood risk management?
- e. If you had to find a way to make flood risk management more resilient to climate change within your agency's current authorities and programs, how would you go about it?
- f. How does your agency's participation in Silver Jackets or other collaborations improve your ability to address these challenges?

4. Solutions and Information Needs:

- a. What additional science/data/modeling resources would make integration of climate information easier/better?

- b. What would you do with that information? How would you use it to improve management?
- c. What else is needed in order to better integrate climate change science into flood risk planning and management, outside of science needs?

IV. Analytical Codes List

- Benefits to improving CC-resilience of FRM
- Challenge/barrier: Other
- Challenge/barrier: Science
- Decision-making and agency
- Effects of CC on FRM
- Existing management
- FRM: actions
- FRM: impacts & causes
- FRM: priorities
- Future management
- Opportunities & successes
- Risk & uncertainty
- Solutions/needs: Other
- Solutions/needs: science & data
- Successful FRM
- Use of existing CC resources
- Value of Silver Jackets