NOOKSACK INDIAN TRIBE CLIMATE CHANGE PROJECT:
PROJECT PERFORMANCE REPORT

Name of project: NOOKSACK INDIAN TRIBE CLIMATE CHANGE PROJECT

Funding Source: NPLCC

Reporting period: January 1 - December 17, 2015

Description of project progress and accomplishments that occurred within this reporting period (including, if applicable, summary results to date and/or conclusions, with particular reference to the project objectives):

- **Conducted low-flow studies**
- **Conducted sediment and turbidity sampling**
- **Conducted glacier ablation studies**
- **Conducted stream gaging studies**
- **Contracted UW and WWU to model glacier ablation and Nooksack River basin hydrology with projected climate change**
- **Conducted oxygen isotope studies**
- **Collected meteorological data**
- **Prepared a Mass Wasting Inventory around Glaciers Located in the Nooksack Watershed on Mount Baker**
- **Collaborated with EPA-ORD to prepare a climate change vulnerability assessment and adaptation plan for salmon and salmon habitat – Primary activity under NPLCC grant; EPA document attached**
- **Collaborated with and provided workshops to the Lummi Nation, Stillaguamish Tribe, Sauk-Suiattle Tribe, Upper Skagit Tribe, and Swinomish Tribe on our climate change project**
- **Traveled to and presented at several conferences and workshops including the NWIFC Habitat Conference, National Adaptation Conference, NW Climate Science Conference**
- **Set up lapse rate study**
- **Prepared "2015 NOOKSACK RIVER WATERSHED**
- **GLACIER MONITORING SUMMARY REPORT**

Describe any significant challenges that hindered progress and/or the completion of established objectives:

- **No significant challenges that hindered progress; although, the climate change project is somewhat a discovery process requiring adaptive management for both technical work and budget management.**

Description of the progress/activities that will occur in the next reporting period, including any anticipated changes to the project:

- **Continue with:**
  - **low-flow studies**
  - **sediment and turbidity sampling**
  - **glacier ablation studies**
  - **stream gaging studies**
  - **oxygen isotope studies**
  - **meteorological data**
  - **SFNR watershed conservation plan**
  - **Model stream temperature and sediment dynamics in the Nooksack River watershed for projected climate change**
  - **Climate change vulnerability assessment and adaptation plan for the MFNR and NFNR**
  - **Develop and present webinars to inform other tribes on our climate change project**
  - **Continue with lapse rate study**

Describe any other pertinent information including, when appropriate, analysis and explanation of cost overruns or other factors, which may affect the attainment of project objectives:

- **We are progressing with the comprehensive work plan approved by the three grantors listed above**
- **We still need to execute contracts with UW and WWU to complete the balance of the modeling needed to project the impacts of climate change on stream temperature and sediment dynamics in the Nooksack River basin**
- **There have been no cost over runs, but are a little behind schedule on budget expenditures; however, we will have no problem expending the full budget with our continued work**
- **Budget status below**

	Expenditures through 12-17-15	**Total Funding**	**Balance**
Labor	**4074.74**		
Benefits	**1255.22**		
Indirect	**1603.94**		
TOTAL	**6933.9**	**15000**	**8066.1**

Draft-Final Qualitative Assessment - September 15, 2015: Evaluating the Impacts of Climate Change on Endangered Species Act Recovery Actions for the South Fork Nooksack River, WA.

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Citation: US-EPA (U.S. Environmental Protection Agency). 2015 In Review; Draft-Final Qualitative Assessment - September 15, 2015: Evaluating the Impacts of Climate Change on Endangered Species Act Recovery Actions for the South Fork Nooksack River, WA. In cooperation with EPA ORD (Office of Research and Development), EPA Region 10, Nooksack Indian Tribe, Washington Department of Ecology and NOAA Fisheries.

EPA Region 10 Climate Change and TMDL Pilot

Qualitative Assessment: Evaluating the Impacts of Climate Change on Endangered Species Act Recovery Actions for the South Fork Nooksack River, WA

Draft Final – September 15, 2015

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Executive Summary

The South Fork Nooksack River (South Fork) is located in northwest Washington State and is home to eight species of Pacific salmon, including Nooksack early Chinook (aka, spring Chinook salmon), an iconic species for the Nooksack Indian Tribe. Segments of the South Fork Nooksack River (South Fork) and some of its tributaries exceed temperature criteria established for the protection of cold-water salmonid populations, and were listed as Category 5 on Washington State's Clean Water Act (CWA) 2008 303(d) list of impaired waterbodies. Category 5 indicates that waters are impaired by a pollutant and in need of a Total Maximum Daily Load (TMDL) evaluation. High water temperatures in the South Fork are detrimental to fish and other native species that depend on cool, clean, well-oxygenated water. Populations of Nooksack salmon, especially Nooksack early Chinook, have dramatically declined from historic levels. Growing evidence shows that climate change will exacerbate legacy impacts to temperature, hydrologic, and sediment regimes of the South Fork.

The TMDL program, established by Section 303(d) of the CWA, is used to establish limits on loading of pollutants from point and nonpoint sources necessary to achieve water quality standards. One important use of the TMDL is to bring impaired waters back into compliance with water temperature criteria established for the protection of cold-water fisheries as a primary designated use of the South Fork. The U.S. Environmental Protection Agency (EPA) Region 10, EPA's Office of Research and Development (ORD) and Office of Water (OW), the Washington Department of Ecology (Ecology), and the Nooksack Indian Tribe have launched a Pilot Research Project to consider how projected climate change impacts can be incorporated into the South Fork TMDL program. The overarching goal of the project is to further EPA's understanding of how to incorporate projected climate change impacts into the TMDL regulatory mechanism, using the temperature TMDL developed for the South Fork as a pilot study. However, the collaborative framework and coordinated research components developed as part of the Pilot Research Project have provided the opportunity to focus more directly on the impact of climate change, primarily increased stream temperatures, on salmon that inhabit the river. Therefore, the pilot also provides the opportunity to move beyond the regulatory goal of the South Fork temperature TMDL and assess how climate change might influence salmon recovery plans including Endangered Species Act (ESA) recovery plans.

This qualitative assessment is a comprehensive analysis of climate change impacts on freshwater habitat and Pacific salmon in the South Fork. It also evaluates the effectiveness of restoration tools that address Pacific salmon recovery. The objective of the assessment is to identify and prioritize climate change adaptation strategies or recovery actions for the South Fork that explicitly include climate change as a risk. The recommendations in this report do not replace existing salmon recovery priorities, but could inform future updates to the *WRIA 1 Salmon Recovery Plan* and associated implementation and restoration strategy documents.

The qualitative assessment's findings will inform development of the South Fork temperature TMDL, including the TMDL Implementation Plan, updates to the Water Resource Inventory Area 1 (WRIA 1) Salmonid Recovery Plan, and other land-use and restoration planning efforts. A companion document, the quantitative assessment, compares projected increases in stream temperature with the thermal tolerances and requirements of various salmonids to inform the CWA TMDL numeric cold-water temperature water quality standard (Butcher et al. 2015).

This qualitative assessment utilized a stakeholder-centric involvement process that benefited from the involvement of knowledgeable scientists and informed lay-persons alike. The stakeholder process has included several stakeholder involvement events to date (i.e., 8 workshops, meetings, webinars) and will include additional opportunities for stakeholder engagement to refine this assessment and present key findings. It is hoped that the qualitative assessment will serve as a pilot project whereby the methods can

be applied to other drainages with similar species, limiting factors, and restoration planning, including the Middle Fork and North Fork Nooksack rivers.

The qualitative assessment methodology is based on *Restoring Salmon Habitat for a Changing Climate* (Beechie et al. 2012). The Beechie method is used to provide a systematic, stepwise approach to analyzing climate change impacts in the South Fork context, including evaluation per climate risk, per salmonid species, and per restoration action. To systematically consider the possible effects of climate change but also account for variability of impacts, the Beechie method is applied to five distinct segments, or reaches, each with relatively homogenous geographic characteristics, species distributions and habitats, legacy impacts, and restoration priorities. Subbasins that contribute to the reaches are also identified to further drive limiting factor analysis and restoration effectiveness planning.

The qualitative assessment evaluates historic conditions (or natural conditions in the South Fork temperature TMDL) and the changes, or legacy impacts, resulting from those conditions due to past land management. The cumulative effects of legacy impacts from timber harvest, flood control, transportation facilities, and conversion of forested land to agricultural uses in the South Fork have substantially altered the nature of the South Fork channel, floodplain, and watershed, and has resulted in degraded habitat conditions, including excessive stream temperatures and increased sediment loading, that threaten the survival of salmonids. Climate change has and will exacerbate those cumulative effects. Water temperature is highly correlated with air temperature. Recorded air temperature monitoring in the vicinity of the South Fork has suggested a 1.3 ºC increase from 1905 through 2010. This is consistent with other modeling and monitoring results for the Pacific Northwest. This could transform to a 0.9º C increase in stream temperatures over that historical period.

Modeling results presented in Section 5.1 (Evaluate Impacts by Climate Risk) show that climate change will have a significant effect on water temperature in the South Fork (projected to rise by 2.81 °C to 6.31 °C by the 2080s) and could substantially impact fish, and reduce the amount and quality of preferred salmon habitat. Other important climate change impacts will include altered hydrographs (including narrower base and higher peaks, higher peak flows, flood, and lower late-summer flows) and sediment dynamics (i.e., increased sedimentation). Climate change will increase the altitude of the lower limit of snow accumulation and reduce the area and depth of snow accumulation, which in turn will increase flows in the fall-winter-spring period, but reduce flows during the critical low-flow period in August and September. There will likely be an increase in the frequency and magnitude of mass earth failures during the high precipitation period (November through March) due to oversaturation of oversteepened glacially carved mountain slopes. More frequent landslides, both natural and human-induced (e.g., forest practices roads and clear cuts), could increase the sediment loading of the South Fork. All of these impacts will have adverse effects on Pacific salmon in the South Fork and must be taken into consideration when modifying, updating, and preparing restoration plans that are climate-ready for the future.

As part of this qualitative assessment, the potential magnitude of the impact that climate change could have on Pacific salmon species and life stages in the South Fork was evaluated (see Section 5.2 Evaluate Per Salmonid Species). The following salmon species were assessed: spring Chinook salmon (*Oncorhynchus tshawytscha)*, pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch)*, sockeye salmon (*O. nerka*), steelhead trout (*O. mykiss*), cutthroat trout (*O. clarkia*), and bull trout (*Salvelinus confluentus*). Three salmon species have been listed as threatened under the federal ESA and are of high priority in the South Fork—spring Chinook salmon, summer steelhead trout, and bull trout. For all species, the life stages with the greatest potential to be impacted by the changing climate were during spawning and intra-gravel development stages, with high potential also recorded for several species during upstream migration/holding and rearing.

Salmon recovery actions and the ability of each action to ameliorate climate change effects were then evaluated (see Section 5.3 Evaluate Per Salmon Recovery Actions). Restoration actions were prioritized

by reach and subbasins based on ability to ameliorate various climate change impacts and/or increase salmon resilience, and the potential effectiveness of each restoration action (see Table 5-6 and Table 5-7):

- Reach 1 (river mile [RM] 0–14, floodplain; impaired TMDL reach): This segment of the South Fork is the most impaired of the five segments due to cumulative legacy impacts resulting from agriculture, forest practices, flood control, bank protection, railroad embankments, and road embankments, which have continued to result in loss of riparian vegetation and loss of floodplain connection. Evaluation of the impact potential (e.g., potential effectiveness) of restoration actions in this reach identified the following priority rankings: floodplain reconnection (both lateral and vertical connectivity), restoring stream flow regimes and riparian functions, and instream rehabilitation ranked high; improving erosion and sediment delivery ranked low; and restoring longitudinal connectivity was identified as not applicable to this reach.
- Reach 2 (RM 14.3–18.5, canyon): This segment of the South Fork has a more confined morphology dictated by bedrock valley walls and erosion-resistant terraces. Evaluation of the impact potential (e.g., potential effectiveness) of restoration actions in this reach identified the following priority rankings: restoring riparian functions ranked high; restoring floodplain connection and stream flow regimes, addressing erosion and sediment delivery, and instream rehabilitation ranked low; and longitudinal connectivity was identified as not applicable to this reach.
- Reach 3 (RM 18.5–25.4, core Chinook spawning): The unconfined sections of the river in this segment represent the core spawning areas for South Fork spring Chinook and have been the focus of instream habitat restoration since the 1990s. Evaluation of the impact potential (e.g., potential effectiveness) of restoration actions in this reach identified the following priority rankings: instream rehabilitation ranked high; longitudinal connectivity, floodplain reconnection, erosion and sediment delivery, and riparian functions ranked moderate, and; stream flow regimes ranked low.
- Reach 4 (RM 25.4–31, confined areas): A partial passage barrier marks the break between this reach and the downstream core spawning area. The channel is sinuous and intermittently anastomosing in some reaches with occasional large gravel bars. Deep-seated landslides and abundant shallow-rapid landslides have occurred in this reach. Evaluation of the impact potential (e.g., potential effectiveness) of restoration actions in this reach identified the following priority rankings: erosion and sediment delivery, and riparian functions ranked moderate; longitudinal connectivity, floodplain reconnection, and stream flow regimes ranked low.
- Reach 5 (RM >31, lands administered by U.S. Department of Agriculture [USDA] and U.S. Forest Service [USFS]): This segment of the river lies above the anadromous barrier at RM 31. Much of the watershed above RM 31 lies within land administered by the USFS and is currently protected by the North West Forest Plan. Evaluation of the impact potential (e.g., potential effectiveness) of restoration actions in this reach identified the following priority rankings: riparian function ranked moderate; longitudinal connectivity, restoring floodplain connection and stream flow regimes, addressing erosion and sediment delivery, and instream rehabilitation ranked low.

From a watershed scale perspective, channel conditions and legacy impacts today are directly related to intensive and extensive land management. Forest practices dominate the watershed and are likely the largest contributor to the legacy impacts. The South Fork temperature TMDL project has indicated that restoring the riparian zone of the mainstem of the South Fork alone is not enough to ameliorate excessive temperatures in the river. This strongly suggests that additional focus needs to be given to watershed-scale actions that will address both legacy impacts and future continued climate change. The following is a list of possible actions that should be considered that address both legacy impacts and climate change:

Watershed-scale Actions:

- Better assessment of landslide/mass wasting-prone hill slopes so as to avoid such areas with clear cut harvest.
- More frequent monitoring of road competency should be implemented to identify problem areas before they fail.
- Continue to implement the orphan road abandonment/restoration program. Monitor the program for effectiveness and implement remedial action if found to be deficient.
- Work with and encourage forest landowners to voluntarily provide wider buffers on tributary streams.
- Initiate the planning and public involvement process required to initiate alterations of flood control levees and dikes as well as hard-armored shorelines. Allowing the river to access its floodplain is one of the most effective restoration measures in addressing the adverse impacts of climate change. This also includes sections of highways and railroad embankments that encroach on the channel environment.
- Provide for reconnection of floodplain wetlands to the river.
- Develop a South Fork watershed conservation plan that addresses numerous stakeholder objectives and is consistent with EPA's Healthy Watershed Initiative Program.

This section summarizes the restoration actions with the highest potential for addressing climate change and cumulative impacts with legacy impacts.

Longitudinal Connectivity:

- Assess factors influencing the recent lack of fish use in the watershed upstream of RM 25 and identify actions to address those factors. Assess current passage and feasibility of improving the passage at natural barriers to fish passage in the South Fork and tributaries, especially South Fork RM 25 and RM 31 but also Skookum Creek at RM 0.5 and RM 2.4 and Hutchinson Creek at RM 0.7. Feasibility assessment should evaluate possible negative impacts to viability and persistence of salmonid populations that use the upper watershed, which may require stream surveys to improve understanding of the distribution of various salmonid populations relative to natural barriers. For example, the RM 25 barrier on the South Fork effectively segregates winter-run and summer-run steelhead populations, and improving passage there may increase introgression between the two populations.
- Change current hatchery release strategy for Chinook smolts to restore use in the South Fork and tributaries upstream of RM 25 (Reach 4).
- In prioritizing fish-passage barrier replacement WRIA 1-wide, consider existing temperature regime and connectivity with the South Fork to elevate priority of addressing barriers to passage to cool-water tributaries to the South Fork that could function as coldwater refuge habitat. Seek funding to address such priority barriers.

Floodplain Reconnection:

- Continue to develop and implement restoration project designs that reconnect floodplains (setback/remove infrastructure, promote aggradation) to the extent feasible given landowner willingness.

- Increase the pace of floodplain reconnection by:
  - Increasing opportunity to restore floodplain connectivity for channel migration and flood routing and storage by acquiring conservation easements or fee simple title to property in the floodplain or otherwise working with existing landowners to increase stewardship (given considerable interest in maintaining the existing land base in agricultural production, exchanging river-adjacent land for property further from the river may prove the most feasible approach in the long term);
  - Integrate floodplain restoration with flood risk reduction via programs like Floodplains by Design and regulatory updates, such as the comprehensive flood hazard management plan;
  - Increase public support for floodplain reconnection; and
  - Procuring necessary funding to implement large floodplain reconnection projects where landowner willingness allows, such as through Floodplains by Design or Salmon Recovery Funding Board.
- Work with infrastructure owners to develop plans to set back infrastructure (railroads, roads, pipelines, bridges/bridge footings) in the floodplain to the extent possible, especially infrastructure that currently function as levees and/or requires bank hardening but also that which may be threatened under climate change scenarios. Realistically, such relocation will be implemented incrementally over the long-term, as structures are maintained and/or replaced.
- Incorporate climate change scenarios (i.e., expected increases in magnitude of 100-year flood), changing land use regulations and restoration plans into comprehensive flood hazard management planning, channel migration zone delineation, and shoreline management program and National Flood Insurance Program implementation. Given expected increases in sediment load, wood recruitment and peak flows, active channels and floodplains may widen.

Stream Flow Regimes:

- Adopt new instream flows for the South Fork and implement measures to meet those flows. Evaluate impacts of climate change on hydrology of the South Fork, including change in the frequencies of recommended instream flows.
- Enforce water rights and incentivize water conservation in the lower South Fork valley to the extent possible (e.g., water banking).
- Develop a groundwater-flow model coupled with a watershed model for the South Fork basin to evaluate future development/restoration scenarios to inform land use decisions and identify and prioritize floodplain wetland restoration projects.
- Work with floodplain land owners and managers to modify commercial forest harvest to reduce impacts on flow regimes.
- Implement floodplain wetlands restoration projects to improve stream temperature and support base flows in the South Fork; potential actions include: removing drainage tiles, filling drainage ditches, re-establishing direct connect of tributaries to the river, reforesting historically forested wetlands, revegetating scrub and herbaceous wetlands, and/or introducing beaver.
- Work with the U.S. Forest Service to assess, prioritize, and address forest road drainage deficiencies and improve road maintenance.
- Monitor effectiveness of Forest Practices rules (including Road Maintenance and Abandonment Plans) at reducing hydrologic impacts. Work within Forest and Fish Report (FFR) adaptive

management framework to incorporate findings into FFR rule updates and/or work with landowners to seek additional protections through alternate plans.

- Assess potential for orphaned roads to affect hydrologic regime and prioritize and implement orphaned road abandonment projects.

Erosion and Sediment Delivery:

- Develop a relative sediment budget to evaluate the magnitude of various sediment sources and their failure mechanisms and factor climate change impacts on the sediment budget
- When designing restoration in a project reach of the South Fork, continue to evaluate feasibility of reducing sediment inputs from any stream adjacent landslides in the reach.
- Continue to implement and monitor compliance with Forest Practice rules.
- Characterize and monitor sediment dynamics over the long term to document climate change impacts on sediment dynamics. As characterization of sediment dynamics is refined, update predicted impacts on fish habitat.
- Monitor the effectiveness of current Forest Practice rules at reducing sediment inputs to streams in the South Fork watershed. Work within FFR adaptive management framework to incorporate findings into FFR rule updates and/or work with landowners to seek additional protections through alternate plans.
- Work with USFS to evaluate, prioritize, and address road network deficiencies. USFS lacks funding to adequately maintain road network to FFR standards, so this may require grant funding to advance.
- Identify road segments that are chronic sources of sediment, and work with landowners on sediment reduction actions, road relocation and road abandonment.
- Assess potential for orphaned roads to deliver sediment and prioritize and implement orphaned road abandonment projects.

Riparian Functions:

- Continue to implement conservation reserve enhancement (CREP) program through the lower South Fork. Seek funding to extend 15-year lease terms and/or otherwise work to protect existing CREP buffers over the long-term.
- Continue to implement and monitor compliance of Forest Practice rules.
- Monitor the effectiveness of current Forest Practice rules at protecting riparian buffers and meeting water quality standards in the South Fork watershed. Work within FFR Adaptive Management framework to incorporate findings into FFR rule updates and/or work with landowners to seek additional protections through alternate plans.
- Increase opportunity and funding for riparian restoration along the lower South Fork through acquisition of conservation easements and/or fee simple title and/or working with landowners to foster stewardship. See above, under Floodplain Reconnection.
- Work with landowners and State Lands managers on alternative buffering strategies that provide greater protection for riparian forest and increase the amount of forest land cover in the South Fork watershed.

- Protect and restore riparian vegetation in tributary riparian areas, especially floodplain tributaries, but extending throughout the stream network, including through non-fish-bearing tributaries up to and including the upper extent of perennial flow. Recent monitoring of the effectiveness of various buffer treatments indicates that buffering the entire length of non-fish-bearing perennial streams results in lower water temperature increases than current forest practices rules buffers (CMER 2015).
- Control non-native invasive vegetation that outcompete native vegetation to accelerate trajectory to recovery in riparian areas along the South Fork and tributaries (especially Hutchinson Creek).
- Monitor the effectiveness of current Forest Practice rules at protecting riparian buffers and temperature meeting water quality standards reducing sediment inputs to streams in the South Fork watershed. Work within CMER Framework to the extent possible to incorporate findings into adaptive management.
- Work with forest landowners to voluntarily reduce rotation frequency and clearcut size to increase forest land cover in the South Fork watershed. Recent monitoring of the effectiveness of various buffer treatments indicates that even leaving vegetated buffers along the entire length of non-fish-bearing perennial streams leads to water temperature increases relative to the unharvested condition (CMER 2015).
- Increase lease term of CREP buffers to ensure that vegetation reaches a functional size.
- Develop a riparian restoration plan for the South Fork watershed that identifies and prioritizes appropriate treatments by location. Treatement options include: establishing a riparian buffer, controlling competition from non-native invasive plants, thinning, and interplanting conifers in hardwood dominated stands to speed stand succession and achievement of riparian function.
- Procure sufficient funding to restore riparian areas where opportunity exists.

Instream Rehabilitation:

- Continue to develop and implement reach-scale restoration designs throughout the South Fork that entail installation of engineered log jams to create temperature refuges, form deep pools with complex cover, encourage engagement of low-flow channel with forested riparian areas, and reconnect floodplain channels and other floodplain surfaces.
- Increase pace of instream restoration throughout the South Fork, developing log jam project designs that implement the following objectives:
    - Create cold-water refuges by placing log jams to form deep pools in areas of cool-water influence. Sources of cold water during summer include lateral and pool bottom seep inflow, cool tributaries, and hyporheic flow (Bilby 1984, cited in McCullough 1999).
    - Increase effective shade by narrowing active channel and/or encouraging the low-flow South Fork channel to engage with existing forested riparian areas. Promote the formation and maturation of forested islands and/or floodplain forest encroachment.
    - Increase channel roughness (i.e., through log jams) to promote bedform diversity and increase hyporheic exchange.
    - Reconnect floodplain channels (for flood refuge, overwinter rearing habitat) and other floodplain surfaces by promoting aggradation and/or locally increasing water surface elevations. See also Floodplain Reconnection.
    - Decrease velocities in the active channel to reduce potential for redd scour and flushing.

- Assess natural occurrence of temperature refuges and monitor effectiveness of log jam placement at creating new temperature refuges. Research mechanisms to maximize temperature refuge formation and maintenance (i.e. hyporheic, groundwater and surface flow dynamics that contribute cool water; pool morphology or structural elements like wood that prevent immediate mixing of cool and warm water). Incorporate findings into restoration project designs.
- Monitor the effectiveness of logjam placement at ameliorating temperature impacts on salmonids.
- Improve habitat quality in cool-water tributaries, especially floodplain tributaries that provide important flood refuge and overwinter rearing habitat, by placing logs and log jams.

Planning Actions:

- Continue to implement salmon recovery voluntary restoration priorities, but explicitly consider incorporating amelioration of climate change impacts and/or increasing salmon resilience into project designs.
- Identify the areas on the South Fork floodplain and tributaries that would have the largest influence on stream temperatures and sediment dynamics and identify measures to be implemented that would directly and indirectly affect stream temperature and sediment loading of tributaries and the South Fork.
- Design and implement a public outreach and scoping program to inform land owners, including commercial forestry operators, on measures that should be implemented watershed-wide to directly address temperature problems in the South Fork.
- Develop a watershed management/conservation plan in the context of EPA's Healthy Watersheds Initiative that comprehensively addresses the impacts of land management and climate change on the ecological health of the South Fork and rectification of direct, indirect, and cumulative impacts of land management. Identify land-owners and managers of land within the South Fork that have influence on stream temperatures and the results of the temperature TMDL. Work directly with land owners on voluntary measures that can affect cooler temperatures and reduced sediment loading in tributaries and the South Fork as an outcome of a watershed management/conservation plan.
- Seek funding that facilitates implementation of the recommendations made herein and of the temperature TMDL. Act on the results of the temperature TMDL and facilitate the implementation plan in the context of a watershed management/conservation plan.
- Work with regulatory agencies to develop measures beyond regulatory BMPs that would further rectify cumulative impacts and address future stream temperature and sediment impacts on tributaries and the South Fork.
- Incorporate results of research being conducted by Susan Dickerson-Lange (University of Washington) on the influence of landscape positioning and size of clear-cuts on the timing and duration of snowmelt and subsequent influences on the hydrograph of the South Fork into a watershed management/conservation plan for the South Fork watershed.
- Act on the results of the temperature TMDL and facilitate the implementation plan in the context of a watershed management/conservation plan.
- Better assessment of landslide/mass wasting-prone hill slopes so as to avoid such areas with clear cut harvest.

- More frequent monitoring of road competency should be implemented to identify problem areas before they fail.
- Continue to implement the orphan road abandonment/restoration program. Monitor the program for effectiveness and implement remedial action if found to be deficient.
- Work with and encourage forest landowners to voluntarily provide wider buffers on tributary streams.
- Initiate the planning and public involvement process required to initiate alterations of flood control levees and dikes as well as hard-armored shorelines. Allowing the river to access its floodplain is one of the most effective restoration measures in addressing the adverse impacts of climate change. This also includes sections of highways and railroad embankments that encroach on the channel environment.
- Provide for reconnection of floodplain wetlands to the river.
- Develop a South Fork watershed conservation plan that addresses numerous stakeholder objectives and is consistent with EPA's Healthy Watershed Initiative Program.

Monitoring, Research, and Adaptive Management:

Several monitoring, research, and adaptive management recommendations have been identified by action type earlier in this section. Additional recommendations include:

- Develop life cycle models for South Fork salmonid populations to identify limiting life stages to help inform climate change impacts on salmon recovery.
- Monitor distribution and periodicity and assess productivity by life stage of priority salmonid species. As resources allow, undertake studies of species/life-stage-specific survival in the South Fork.
- Incorporate refined climate change scenarios and model downscaling into adaptive management of South Fork restoration and protection actions.
- Work with salmon recovery partners to incorporate climate change, especially the findings and recommendations of this report, into WRIA 1 Salmonid Recovery Plan updates, salmon recovery voluntary restoration project prioritization and planning, and Salmon Recovery Monitoring and Adaptive Management Plan development.
- Incorporate new findings and work into adaptive management of South Fork temperature TMDL.
- As an extension of the work accomplished by Gendaszek (2014), a groundwater-flow model coupled with a watershed model for the South Fork basin should be developed to evaluate future development/restoration scenarios to inform land use decisions and identify and prioritize floodplain wetland restoration projects. Funding for this effort is currently not available and as an extension of the South Fork temperature TMDL Implementation, such funding should be secured for the model development and implementation.

Most of these recommendations will require substantial planning and feasibility assessment, agency consultation, landowner cooperation, stakeholder involvement, funding, and political fortitude if they are to be implemented in a manner that will effectively address the cumulative effects of legacy impacts and climate change on salmonids and ESA recovery. These parameters will require a substantial amount of time to work through and become effective. Thus, it is critical that the recommendations presented above are considered and implemented in a timely fashion to support a climate-resilient ecosystem and ESA recovery.