SECTION 12

How Will Climate Change Affect the Built Environment?

Puget Sound's built environment – transportation, wastewater and water conveyance, urban centers, and energy systems – is projected to be affected by a continued rise in sea level, more intense heavy rains, more and hotter heat waves, and increased wildfire activity. These changes have significant implications for infrastructure, are likely to cause transportation closures, delays, or detours, and will be most pronounced for facilities and transportation lines located in or near coastal and low-lying areas. Some benefits may also be realized, including the potential for fewer snow-related road closures. Coastal infrastructure is likely to experience more problems with saltwater intrusion, corrosion, flooding, and inundation as a result of sea level rise. In addition, aviation, bus, and rail services located in or near current floodplains are likely to experience increases in the number of delays due to projected increases in heavy rainfall and river flooding. Many communities, agencies, and organizations are in the initial stages of assessing impacts and developing response plans; some are currently implementing adaptive responses.

Climate Drivers of Change

DRIVERS ***Most climate change effects are likely to increase the potential for damage to infrastructure and service disruptions (unplanned transportation closures, delays, or detours) in the Puget Sound region,[A] although some risks may decrease.*** Existing studies on infrastructure impacts in the Puget Sound region have primarily focused on transportation infrastructure and coastal infrastructure (particularly as it relates to sea level rise). In general:

- *Observations show a clear warming trend, and all scenarios project continued warming during this century*. Most scenarios project that this warming will be outside of the range of historical variations by mid-century (see Section 2).[1,2] Warmer conditions can lead to reduced snowpack, and more frequent and intense flood events (see Section 3), heat waves, mudslides, erosion (see Section 5), and wildfire.

- *Heavy rain events are projected to become more intense.* Current research is consistent in projecting an increase in the frequency and intensity of heavy rain

[A] Throughout this report, the term "Puget Sound" is used to describe the marine waters of Puget Sound and the Strait of Juan de Fuca, extending to its outlet near Neah Bay. The term "Puget Sound region" is used to describe the entire watershed, including all land areas that ultimately drain into the waters of Puget Sound (see "How to Read this Report").

events.[3] Changes in extreme events are more likely to damage infrastructure than changes in average conditions.[4,5,6,7]

- *Most models are consistent in projecting a substantial decline in summer precipitation.* Projected changes in other seasons and for annual precipitation are not consistent among models, and trends are generally much smaller than natural year-to-year variability.[2]

- *Nearly all scenarios project a rise in sea level.* Sea level rise is projected for all locations except Neah Bay, where a decline in sea level cannot be ruled out due to the rapid rates of uplift in that area.[8,9,10] Higher seas would result in greater risk of storm surge, saltwater intrusion, and permanent inundation of low-lying areas.

- *Some climate-related changes may lead to decreased risk or otherwise create benefits.* For example, increasing spring and fall air temperatures may extend the construction season, possibly improving cost efficiencies. Lower winter snowpack and increasing winter air temperatures will likely decrease the frequency of snow-related closures on mountain highways.[4,5,6] The benefits of reduced snow closures may be offset by an increase in landslides as a result of rain events on slopes not protected by snow, and because of an increase in the intensity of heavy precipitation events.[6]

- *Understanding the specific nature of climate-related changes on infrastructure often requires detailed, locally specific studies.* Similar types of infrastructure can have very different responses to climate change, depending on location, age, and specifics of design, maintenance, and operation.[4,6] For example, while a small amount (+3 inches) of sea level rise may have important effects on flooding and stormwater management in Olympia, sea level rise impacts on Washington State-owned coastal transportation infrastructure do not begin to emerge until much higher amounts (>+2 feet) of sea level rise occur.

- *New infrastructure and ongoing improvements to existing infrastructure generally increase resilience to climate impacts, although the resilience of individual pieces of infrastructure can be affected by vulnerabilities in other parts of the system.*[6,11] Infrastructure updates such as seismic retrofits, fish passage improvements, culvert replacement, and drilled shaft bridges generally make infrastructure more resilient to the effects of climate change.[6,11] Additionally, fish passage improvements and culvert replacement can improve salmon migration and increase habitat connectivity for wildlife. For example, large culverts with sufficient vertical clearance (> 8 feet) provide connectivity options for deer moving under roads.[12] While such updates can increase resilience to the effects of climate change, vulnerabilities in related parts of the system can affect that resilience. For example, while the majority of Washington State Department of Transportation's (WSDOT) newer bridges were found to be resistant to the effects of climate change, including up to +4 feet of sea level rise in some cases, use of those bridges may be affected by more frequent flooding or inundation of low-lying roads leading to bridges.[6]

Sea Level Rise

SEA LEVEL RISE ***Coastal wastewater and stormwater collection systems are likely to experience more problems with saltwater intrusion, corrosion, flooding, and inundation.***

- *Sea level rise is projected to temporarily or permanently inundate three or more King County Wastewater Treatment Division facilities as early as 2050,* depending on the combined effects of different sea level rise projections and the return frequency of specific storm sizes.[B,13] The County has also identified 20 facilities that are at risk of saltwater inflow into the conveyance system (pipes and pumps taking wastewater to and from the plant) by 2050, due to sea level rise, high tides, and storm surge.[14] This additional inflow can increase the volume of wastewater that has to be conveyed and treated, shortening equipment lifespan, and increasing treatment costs.[15] King County estimates the current cost of treating saltwater already entering the system[C] during high tides to be $0.5 to $1.0 million annually.[D]

- *City of Olympia.* Modest amounts of sea level rise (as little as +3 inches, below the low end of the range projected for 2050) increases the likelihood that saltwater will enter the city's combined sewer system and be conveyed to the Lacey, Olympia, Tumwater, and Thurston County (LOTT) wastewater plant for treatment, potentially increasing operating costs.[16]

SEA LEVEL RISE ***Port operations and infrastructure, including access to port facilities, are likely to be affected by sea level rise and increased coastal flooding.***[17,18] Climate-related effects in other parts of the world[E] may also affect Washington's marine trades, although little is known about the specific nature and potential size of those impacts on port business.[4,17]

- *Direct sea level rise impacts on Port of Seattle facilities.* Direct sea level rise impacts include increased storm surge damage to port facilities and more saltwater corrosion in docks and other infrastructure (e.g., piles, pile caps, and beams) exposed more frequently to saltwater as a result of higher tidal and storm surge

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B Periodic or permanent inundation of the Division's three lowest facilities occurs as early as 2050 with +1.8 feet (22 inches) of sea level rise and a +2.3 foot storm surge, currently considered a 50% chance (once every 2 years) storm surge event. As many as 14 facilities would be periodically or permanently inundated by 2100 with +4.17 feet of sea level rise (currently near the high-end of projections for Puget Sound) and a +3.2 foot storm surge (annual storm surge event with a 1% chance of occurring).

C Sources for saltwater intrusion are leaky gates, overflow weirs, groundwater infiltration, and local sewer connections. Intrusion already occurs during high tides in the industrial area along the Duwamish Waterway, the downtown Seattle waterfront, and the Salmon Bay area near the Ballard Locks.[15]

D This cost estimate is specifically for saltwater treatment at the West Point Treatment Plant and does not include the cost of repairing and replacing damaged equipment. King County estimates that 3 to 6 million gallons of salt water enters the system each day, totaling about 1 to 2 billion gallons each year.[15]

E Reduced sea ice in Alaska and the Arctic is likely to extend the shipping season and create new opportunities for shipping, although it is unknown at this time if, when, and how these changes could affect Washington's ports. Climate impacts on trading partners in Asia may also affect traffic in and out of Washington's shipping ports, although it is not known how traffic would be affected specifically.

reach. Sea level rise will also make it more difficult to drain stormwater from port facilities.[17] Projected increases in extreme precipitation (see Section 2) would exacerbate this problem.

- *Effect on low-lying areas serving Port of Seattle facilities.* Low-lying rail yards and roads serving the Port of Seattle are vulnerable to permanent inundation if sea level rise is +3 feet or greater. Lower amounts of sea level rise would likely result in more frequent temporary flooding of low-lying rail yards and roads. These impacts may affect the movement of goods in and out of port facilities regardless of how the Port of Seattle adapts its own infrastructure.[18]

SEA LEVEL RISE ***Sea level rise poses risks for transportation systems.***[6,19] In many cases, areas most likely to be affected by climate change are areas already experiencing problems or on "watch lists," such as bridges or roads that are being undercut by fast moving waters ("scour critical" transportation infrastructure) or chronic environmental deficiency sites.[F,6]

- *Sound Transit.* Sea level rise has the potential to affect Sound Transit's north Sounder rail alignment and the Edmonds and Mukilteo facilities. Sea level rise of +50 inches (currently near the high end of projections for 2100, see Section 4) or more could result in permanent inundation of rail track and facilities in Edmonds and Mukilteo. Sea level rise under +50 inches would not permanently inundate the track or facilities, but would expose more of the north Sounder rail alignment to higher high tides, temporary flooding, saltwater corrosion, and storm surge.[19]

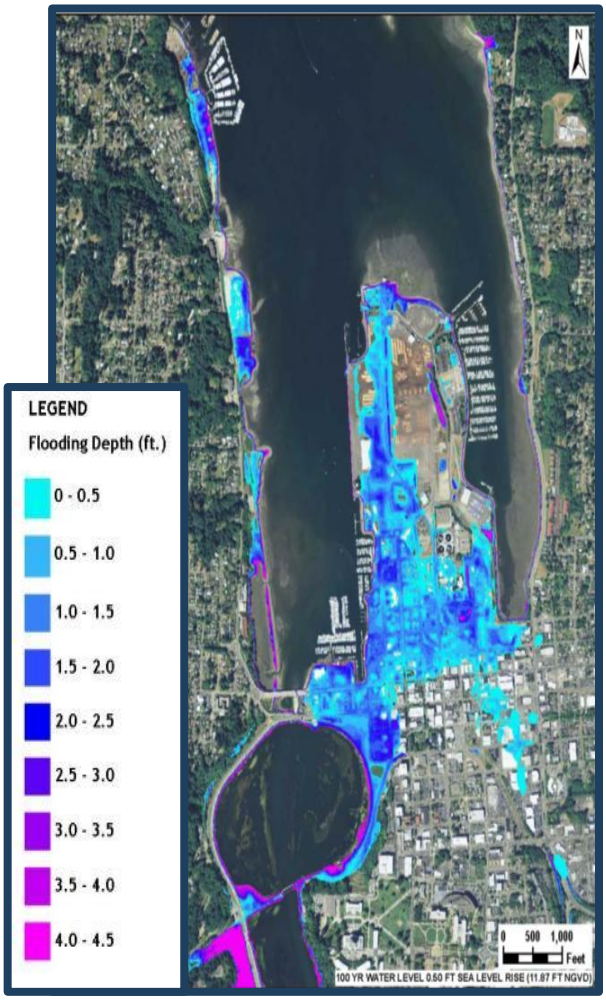

Figure 12-1. Increased flooding in Olympia. The map shows the projected area and depth of flooding in the City of Olympia during a 100-year flood event with +6 inches of sea level rise (near the low end of the range projected for 2050). The projected depth of flood waters ranges from less than 6 inches to 4.5 feet, as indicated by the map colors. *Figure source: Simpson 2012*[16]

[F] Chronic environmental deficiencies (CED) are locations along the state highway system where recent, frequent, and chronic maintenance repairs to the state transportation system are causing impacts on fish and fish habitat.

- *Washington State Department of Transportation*. Examples cited in WSDOT's assessment:[6] A +2 foot sea level rise could result in more logjams collecting on bridge piers of US 2 as they move down the Skykomish River, increasing the risk for damage to the bridge. Additionally, on and off-ramps in low-lying coastal areas are susceptible to flooding associated with sea level rise. For example, the flooding that occasionally occurs on the off and on-ramps of I-5 near McAllister Creek is likely to be made worse by sea level rise.[6]

- *City of Seattle.* Sea level rise may affect urban public transit routes and freight rail lines in some low-lying areas. An analysis evaluating sea level rise in the City of Seattle found that +2 feet of sea level rise would affect 8.2% of bus routes (0.04% of total lineal feet of bus routes) and 0.18% of freight rail throughout Seattle, while +5 feet of sea level rise would affect 20.5% (0.18% of total lineal feet of bus routes) of bus routes and 9.6% of freight rail lines.[G,20] Transit south of downtown in the Duwamish River basin is most vulnerable to the effects of sea level rise.[20]

- *Jamestown S'Klallam Tribe.* Moderate and high severity sea level rise scenarios project flooding on Highway 101 near Discovery Bay. While the near term potential for these floods is low, they could lead to the inability to access Highway 101 for 12-24 hours following extreme storms. The highway serves a critical function for the Tribe as it is the main access route for goods and services from the Tribe to other counties.[H]

SEA LEVEL RISE ***Low-lying urban and commercial infrastructure is likely to experience more frequent flooding or permanent inundation due to sea level rise.***

- *City of Olympia.* A small amount of sea level rise greatly increases the probability of flooding in downtown Olympia, potentially affecting public infrastructure, high-density development, and the City's historic district (Figure 12-1).[16,21] For example, a +3-inch rise in sea level makes it impractical to use common emergency response measures (sand bags and sealing catch basins) to control flooding associated with the 1-in-10 year (10% annual chance) flood event.[16] A +6-inch rise in sea level shifts the probability of occurrence for the 100-year flood event in Olympia from a 1% to a 5.5% annual chance event.[16]

G This assessment is based on 2014 data. Subsequent transit route changes may alter the conclusions of this report.

H Three representative scenarios were selected for mapping, a "Low Severity" scenario with a mean water level of +0.8 feet above the current sea level (projected to occur between 2025 and 2045), a "Moderate Severity" scenario with a mean water level of +2.0 feet above current sea level (projected to occur between 2055 and 2090), and a "High Severity" scenario with a mean water level of +5.1 feet above the current sea level, which may occur by the end of the century.

Floods and Extreme Precipitation

FLOODS ***Projected increases in extreme precipitation and river flooding increase the risk of aviation, bus, and rail service interruptions and damage to infrastructure located in or near current floodplains.*** In coastal drainages that flow to Puget Sound, sea level rise can exacerbate river flooding.[I] More extreme precipitation events can increase drainage problems and lead to more localized flooding.

- *The effect of floods and extreme precipitation events on highway, aviation, bus and rail operations could increase operation and maintenance costs, increase the potential for infrastructure damage, result in more frequent service delays, cancellations, and re-routes, and strand migrating salmon populations.*

    - *Sound Transit.* The Sounder, ST Express, Link, and Customer Facilities, specifically those located in Kent, Tukwila, and Sumner Stations are services that will potentially be affected by increasing risk of river floods. Areas with the greatest potential for flood impacts include: (1) the Link's crossing of the Duwamish River, and (2) Link's traction power substation at South 133rd Street and at 112th Street and East Marginal Way, which will potentially be affected by flooding in the Duwamish and Green rivers.[19]

    - *Washington State Department of Transportation.* Highways adjacent to rivers are expected to experience more frequent flooding due to more precipitation falling as rain, and are therefore likely to see an increase in temporary road closures.[6]

    - *The King County International Airport/Boeing Field*. Boeing Field is located in the Duwamish River floodplain near sea level, and is likely to be affected by more frequent and larger rain events, which could increase the number of standing water issues.[22]

    - *Seattle City Light*. The electric utility could experience delays in access and power restoration after storms because of heavy precipitation and standing water that reduces access to distribution infrastructure.

- *Larger flood events can reduce the effectiveness of existing levees and tide gates.* Flood flows in the Skagit basin are expected to more frequently exceed the design capacity of many of the basin's current dikes and levees, which are designed to the current 30-year return interval. Sea level rise is also expected to reduce the effectiveness of tide gates for draining low-lying cropland in the Skagit Valley.[23]

- *The ability of dams to mitigate increasing flood risk may be limited in some areas.* Initial research for the Skagit basin suggests that reducing community vulnerability to increasing flood risk will be more effective if those efforts focus primarily on

[I] Higher sea level can increase the extent and depth of flooding by making it harder for flood waters in rivers and streams to drain to the ocean or Puget Sound. Because of this, even modest river flooding could produce larger flood impacts in the lower portion of a river basin in the future relative to today's flood events.

improving management of the floodplain rather than on increasing flood storage in headwater dams (e.g., Ross Dam, Upper Baker Dam).[J,23] This is because most of the streamflows causing the increased flood risk originate *below* the headwater dams.

- *Climate change increases the risk of flooding in Green River communities.* By the 2080s, streamflow volume for the 100-year (1%) flood event in the Green River, as measured at Auburn, could increase by +15% to +76% relative to historical (1970-1999) climate for a moderate greenhouse gas scenario.[K,L,24] At the upper end of this range, the probability of today's 1-in-500 year (0.2% annual chance) flood event on the Green River increases to a 1-in-100 year (1% annual chance) flood event.[25] Recent research suggests that most of the projected increase in flood risk can be mitigated by flood control operations at Howard Hanson dam.[26] Inundation mapping of the current 500-year flood event by the U.S. Army Corps of Engineers estimates flood depths of 0-15 feet under different future scenarios following levee overtopping in the Kent-Auburn area.[M] Flooding in this area has widespread consequences; affecting residential and commercial properties, local roads, access to SR 167, and rail services in the area. Climate change is projected to increase the risk of these impacts.[25]

- *More sediment and flood debris in coastal rivers could adversely affect port and ferry facilities, as well as increasing flood risk in rivers.* Increased river flooding and reduced snow and ice cover in mountain watersheds are projected to increase the amount of sediment and flood debris carried by coastal rivers (see Section 5).[23] As a result, more frequent dredging near port facilities and ferry terminals in Puget Sound is likely to be needed.[17] Damage to port facilities and ferry terminals is also possible due to the potential for more flood debris.

- *Residential housing areas located in floodplains or adjacent to rivers are at risk from erosion and flooding.* For example, the Sauk-Suiattle Indian Reservation is situated in the channel migration zone of the Sauk River and could suffer significant infrastructure damage if higher flood flows cause the river to migrate into the inhabited areas of the reservation.[27]

- *Flooded roadways can affect salmon species in the Puget Sound region.* Floods enable

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J Results are based an integrated daily time step reservoir operations model built for the Skagit River Basin. The model simulated current operating policies for historical streamflow conditions and for projected flow for the 2040s and 2080s associated with five global climate model simulations, driven by the moderate A1B greenhouse gas scenario.

K Greenhouse gas scenarios were developed by climate modeling centers for use in modeling global and regional climate impacts. These are described in the text as follows: "very low" refers to the RCP 2.6 scenario; "low" refers to RCP 4.5 or SRES B1; "moderate" refers to RCP 6.0 or SRES A1B; and "high" refers to RCP 8.5, SRES A2, or SRES A1FI – descriptors are based on cumulative emissions by 2100 for each scenario. See Section 1 for details.

L This range was based on 20 global climate models and a moderate (A1B) greenhouse gas scenario. Data from the Pacific Northwest (PNW) Hydroclimate Scenarios Project website (http://warm.atmos.washington.edu/2860/).

M See "Potential Inundation, Shown as Simulated Water Depth, in Kent for a Peak Flow at Auburn Gage of 25,000 cubic feet Per Second" map produced by the U.S. Army Corps of Engineers to view the upper range of projected 500-year flood events. Map available at: http://www.nws.usace.army.mil/Missions/CivilWorks/LocksandDams/HowardHansonDam/GreenRiverFloodRiskMaps.aspx

salmon to exit stream channels and take more direct routes to reach natal spawning grounds. While flooded roadways may initially provide some salmon with a more direct path to spawning sites, receding floodwaters can strand and kill salmon before they are able to spawn.

- *Increases in extreme high precipitation and river flooding could expose aquatic organisms to chemical pollutants from increasing urban runoff.* Premature mortality of Coho salmon spawning in restored habitats in the Puget Sound region have been attributed to a phenomenon known to as Coho pre-spawn mortality (PSM).[28] PSM occurs when adult Coho salmon are exposed to chemical pollutants from urban runoff, and typically results in death within a few hours.[28,29] Egg retention[N] is frequently observed in females that died of PSM.[28] Projected increases in extreme high precipitation could result in increased runoff,[30] and exposure to chemical pollutants from urban runoff.

Wildfire

WILDFIRE ***Increased wildfire risk west of the Cascades may affect energy transmission within the Puget Sound region.*** Projected increases in area burned by wildfire (see Section 9) could cause damage and interruption of power generation facilities and transmission and distribution infrastructure. Even when wildfires do not directly threaten infrastructure, generation and transmission can be interrupted if transmission lines are de-energized because of smoke or safety concerns. [31]

Climate Risk Reduction Efforts

CLIMATE RISK REDUCTION ***Many Washington communities, government agencies, and organizations are preparing for the effects of climate change on infrastructure.*** Most are in the initial stages of assessing impacts and developing response plans; some are implementing adaptive responses. For example:

- *State, county, and local agencies are taking steps to increase the resilience of publically-owned transportation infrastructure and services.*

  <u>*WSDOT*</u>

  - *Considering climate change and weather events in project-level environmental review.* WSDOT is integrating the results of its statewide vulnerability assessment[6] into the environmental review of proposed projects. WSDOT has published specific guidance on how to consider climate in project-level

[N] Female Coho salmon that did not spawn (deposit eggs) prior to death from PSM.

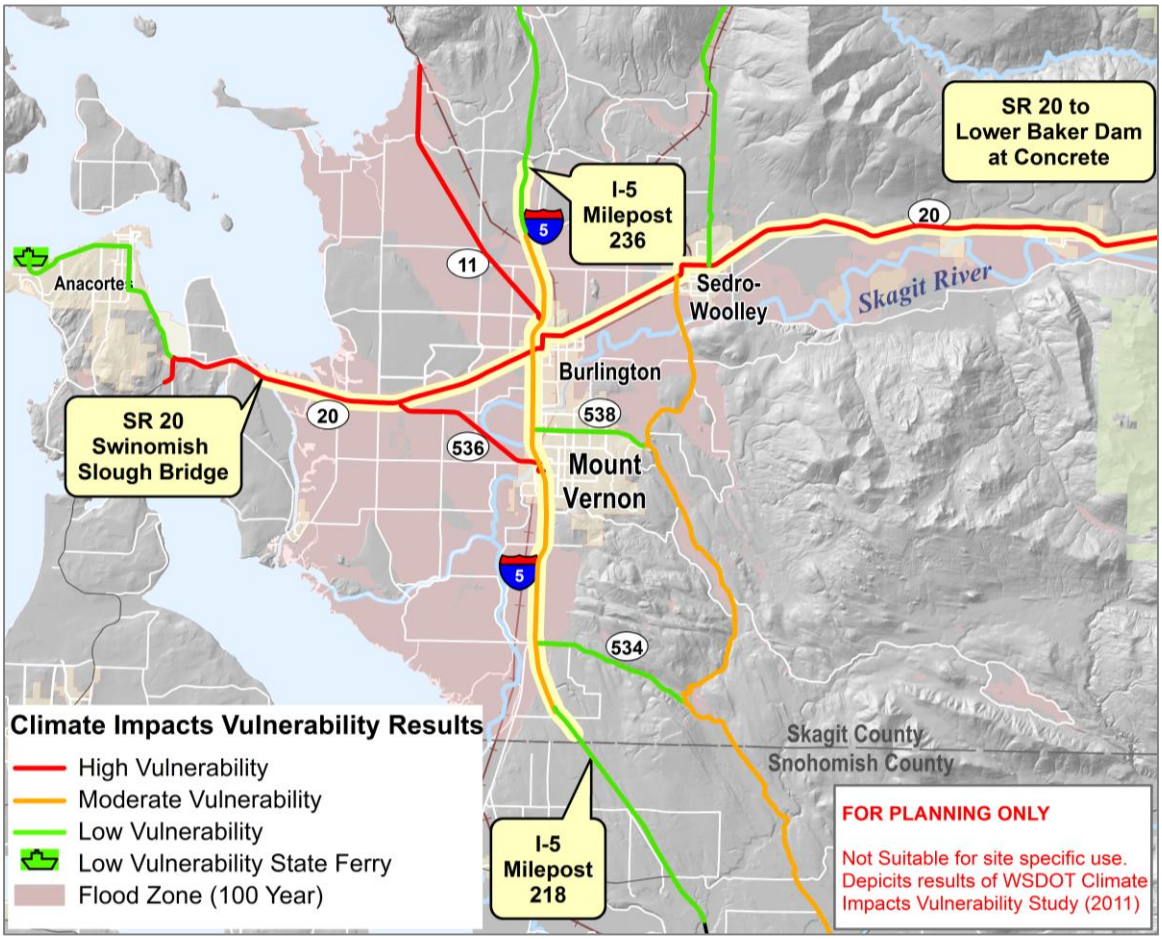

Figure 12-2. Evaluating the vulnerability of Washington State's transportation infrastructure to extreme flooding. Study area for WSDOT's Preparing Interstate and State Routes in the Skagit River Basin pilot project, funded by the Federal Highway Administration. Red lines highlight routes that are highly vulnerable to the impacts of climate change, while orange and green lines highlight routes of successively lower vulnerability. Low vulnerability classifies roads that will remain open, but may result in reduced capacity, or no impact. Moderate vulnerability classifies roads that will experience temporary closures (no more than 60 days). High vulnerability classifies roads that experience closures for more than 60 days for any one event. *Figure source: WSDOT.*[33]

environmental review under NEPA and SEPA.[0] As a result, more than a dozen project documents contain information about the relationship of the proposed project to a changing climate. For example, the Mukilteo Multimodal Ferry Terminal (MMFT) environmental impact statement evaluated impacts of sea level rise and increased storm intensity. With assistance from the Puget Sound Regional Council, WSDOT developed maps showing a 2- and 4-foot sea level rise in the Mukilteo project area. WSDOT then evaluated the potential for project design measures to withstand the projected sea level rise and increased storm intensity.[32]

[0] The National Environmental Policy Act (NEPA) and State Environmental Policy Act (SEPA) were both written to promote the enhancement of valuable environmental resources. Both require environmental impacts assessments to better document and understand the impacts of proposed projects.

- *Long-term planning for corridor improvements.* WSDOT's strategic plan requires all plans to document how climate change and extreme weather vulnerability are considered. Recent studies for US 2, SR 516, and SR 520 discuss the level of climate risk, emergency response and hazard reduction strategies, and options for increasing resilience.

- *Preparing interstate and state routes in the Skagit River basin for climate change.* WSDOT recently completed a project which developed site-specific adaptation options to improve the resilience of Interstate 5 and state routes in the Skagit basin (Figure 12-2). For example, in response to Skagit River flooding on North SR 9 WSDOT highlighted two options that will reduce flood concerns for this route and will improve transportation infrastructure resilience to future flood events: (1) develop a new road alignment out of the floodway, and (2) raise the road in existing alignment.[33] This work complements flood hazard reduction strategies proposed by the U.S. Army Corps and Skagit County.

- *Partnering with others to share tools and results.* WSDOT is working with local governments and state agencies to share information on how to complete a qualitative assessment of transportation infrastructure vulnerability to climate change. Specifically, WSDOT is working with the Department of Commerce to share data and develop tools for local governments to better integrate transportation planning into comprehensive city and county plan updates.[34]

King County

- *Building floating docks and gangways that are able to accommodate several feet of sea level rise.* In 2010, King County Marine Division replaced the existing dock and gangway in West Seattle used by the Water Taxi (owned and operated by WSDOT) with a new floating dock and gangway, which is able to handle rising sea levels.[22]

- *Levee improvements and flood-risk reduction activities.* King County formed a new Flood Control District in 2007 to increase county capacity for addressing regional flood risks due to a variety of factors, one of which was climate change. The creation of the new District resulted in a ten-fold increase in local funding[P] for flood risk reduction efforts. Accomplishments in 2014 include mapping of channel migration hazards along the Cedar River, completing a critical levee extension project, implementing five projects that raised structures in flood zones, and purchasing forty-two acres of floodplain on the Tolt, Snoqualmie, Cedar, and White rivers (including 20 acres in Pierce County). Public ownership of this land and removal of structures will reduce

[P] Funding for the Flood Control District comes from a county-wide property levy of 10 cents per $1,000 assessed value. This amounts to $40 per year on a $400,000 home. The levy raises roughly $36 million a year. http://www.kingcountyfloodcontrol.org/

flood risks and preclude development in these flood prone areas.[11]

- *Widening bridge spans and increasing the resilience of roads.* As of 2012, King County had replaced 15 short span bridges with wider span structures and 42 small culverts with large box culverts. These changes will increase resilience of bridges and roads to major flooding. In many cases these wider structures also allow for the movement of a variety of wildlife along the river's edge during normal flows and elevated flood events thereby protecting wildlife connectivity between critical habitats.[11] King County's Road Services Division[Q] will incorporate information about changes in future flooding, storm size and frequency, and landslide risk projections into roads maintenance and preservation programs and projects.[22]

Sound Transit

- *Assessing the vulnerability of the Sound Transit system to the effects of climate change.* The Sound Transit Climate Risk Reduction Project assessed the vulnerability of Sound Transit assets and services to climate change while creating a process and a model for transit agencies across the United States. The analysis found that while climate change exacerbates many existing issues such as sea level rise, extreme precipitation events, heat stress, mudslides, and river flooding, Sound Transit already possesses some degree of climate resilience and capacity to address climate impacts, both of which will be further enhanced by integrating climate considerations into decision making.[19]

National Parks and Forests

- *The National Parks Service and Forest Service are incorporating climate change into transportation plans and infrastructure maintenance and development activities.* The National Parks Service 20-year National Long-Range Transportation Plan incorporates the effects of climate change in the transportation planning process, and will be updated at least every 5 years.[35,36] Mount Baker-Snoqualmie National Forest (MBSNF) engineers are replacing failing bridges and culverts, and disconnecting roads from waterways to mitigate impacts on aquatic ecosystems. However, limited funding and staff impede current efforts to upgrade infrastructure to current standards, and therefore future costs for upgrades to accommodate projected hydrological shifts (see Section 3) poses a barrier to adaptation.[36] Additionally, MBSNF engineers are adapting road management to the effects of climate change by reducing the size of the road system in the national forest; this includes closing, decommissioning, or converting roads to non-vehicular modes of transportation.[36] Road decommissioning is an expensive process. To date, MBSNF has decommissioned more than 130 miles of roads

[Q] King County's Road Services Division maintains roads, bridges, culverts, and other related infrastructure in unincorporated King County.[22]

(~5% of the total road miles within MBSNF), with each decommissioned mile costing between $40,000-$100,000.[37]

- *Local public utilities are working to incorporate the effects of climate change into siting and design procedures, and to protect facilities from current flood risks.*

    - *Incorporating sea level rise into the Wastewater Treatment Division facility siting and design procedure.* A 2008 study evaluating the effects of sea level rise on King County's Wastewater Treatment Division facilities recommended that sea level rise should be incorporated in planning for major asset rehabilitation or conveyance planning that involves the facilities included in the analysis.[13] Since the release of the report King County has modified the conveyance system and outfalls of the Wastewater Treatment Division facilities to reduce or eliminate seawater intrusions, even during high tide. [15,22] Additional preparations for limiting saltwater intrusion include installing flap gates, raising weirs, and other similar controls.[22]

    - *Protecting Water Treatment Division facilities in floodplains from flood risk.* The King County Wastewater Treatment Division has reviewed all of its facilities within the Federal Emergency Management Agency's (FEMA) 100-year floodplains and is identifying steps to ensure all facilities are protected from current flood risks.[22]

    - *The redesigned Anacortes Water Treatment Plant reduces the potential for flooding.* Projections for increased flooding and sediment loading in the Skagit River led to design changes for the City of Anacortes' new $65 million water treatment plant (completed in 2013). The new plant includes elevated structures, water-tight construction with minimal structural penetrations, no electrical control equipment below the (current) 100-year flood elevation, and more effective sediment removal processes.[21]

    - *Increasing capacity to manage extreme high precipitation events in Seattle.* Seattle Public Utilities' RainWatch system[R] provides operators and decision-makers with 1-hour precipitation forecasts and 1- to 48-hour rain accumulation totals that can be used to manage extreme high precipitation risks at the neighborhood- or basin-scale in real-time.

    - *Increasing capacity to manage storm-related power outages.* Seattle City Light's WindWatch tool provides operators with real time wind speed forecasts and alerts up to three days in advance of major storms. This can be used to better prepare crews and equipment for power restoration work following storms.

    - *Considering sea level rise in facilities master planning.* Seattle City Light is reviewing a facility in the Duwamish River basin for potential flooding

[R] See http://www.atmos.washington.edu/SPU/

impacts associated with sea level rise and storm surge.

- *Urban centers are planning for sea level rise.*
    - *Planning for sea level rise in the City of Olympia.* In an effort to reduce flood risk in association with sea level rise, the City of Olympia conducted GIS mapping of projected inundation zones, incorporated sea level rise considerations into the City's Comprehensive Plan and Shoreline Management Plan, and develops annual work plans to address adopted goals and priorities, key information needs, improve emergency response protocols, and survey and identify shorelines, structure elevations, and sewer basins that are vulnerable to flooding.[38]
    - *Planning for sea level rise at the Port of Bellingham.* Plans by the Port of Bellingham to redevelop the 228 acre Georgia Pacific site near downtown Bellingham include raising site grades approximately +3 to +6 feet in areas with high value infrastructure as a buffer against sea level rise.[39]
    - *Evaluating the robustness of the Seattle sea wall design to sea level rise.* An evaluation of sea level rise impacts on design considerations for the new Seattle sea wall found that the current sea wall height would be able to accommodate +50 inches of sea level rise and a +3 foot storm surge (a 100-year event surge).[S] As a result, the City determined that it was not necessary to build a higher structure to accommodate sea level rise over the next 100 years.[T]
- *Tribes are working to identify climate hazards affecting their communities and infrastructure.*
    - *Adaptation planning for multiple climate-related hazards: the Swinomish Indian Tribal Community.* The Swinomish Indian Tribal Community is implementing adaptation recommendations developed in 2010. This includes revisions to shoreline codes, development of a detailed coastal protection plan for the most vulnerable 1,100 low-lying acres on the north end of the Reservation, development of a Reservation-wide wildfire risk reduction program, and development of a system of community health indicators to measure knowledge of and impacts of climate change within the Tribal community.[40]
    - *Vulnerability assessment and adaptation plan: Jamestown S'Klallam Tribe*. The climate vulnerability assessment and adaptation plan identified key tribal resources, the expected impacts from climate change, and created adaptation strategies for each resource. Moderate and high severity sea level rise scenarios project potential flooding on Highway 101 near Discovery Bay,

[S] The Mean Higher High Water, which is the average of the highest daily tide at a place over a 19-year period.

[T] See http://sdotblog.seattle.gov/2013/01/23/sea-level-and-the-seawall/ for more details.

preventing the Tribe's access to the highway for 12-24 hours. The adaptation plan recommends that the Tribe work with Washington Department of Transportation to discuss raising the vulnerable infrastructure, especially in conjunction with future repairs.[41]

- *In addition to previous examples, there are a number of efforts that are currently underway that will help increase regional resilience to climate change.* Final results of these efforts will be included in updated editions of this report.
    - *Efforts to increase climate resilience for infrastructure in the Puget Sound region are underway:* in the City of Tacoma (climate change vulnerability assessment), City of Seattle (adaptation plan), Seattle City Light (vulnerability assessment and adaptation plan), King County Wastewater Treatment Division (impact assessment), WSDOT (landslide mitigation), Hood Canal Coordinating Council (adaptation plan), North Olympic Peninsula Resource Conservation and Development Organization (risk assessment and adaptation plan), and the Puyallup Tribe (vulnerability assessment and adaptation plan). Additionally, climate resilience benefits are expected from programs that incorporate climate-related changes in risk – as well as current risks – in the prioritization and design of project implementation. For example, programs like Floodplains by Design, which was created to promote the reduction of flood risks and floodplain ecosystem recovery while maintaining or improving agricultural production, water quality, and open space.

Additional resources for evaluating and addressing the effects of climate change on agriculture in Puget Sound.

The following tools and resources are suggested in addition to the reports and papers cited in this document.

- **National Climate Assessment | Infrastructure:** The National Climate Assessment summarizes the impacts of climate change on the United States (addressing national and regional issues) now and in the future. The infrastructure section addresses sea level rise, extreme precipitation events, and extreme heat: http://nca2014.globalchange.gov/highlights/report-findings/infrastructure

- **Federal Highway Administration (FHWA) | Climate Change:** FHWA is partnering with both state and local transportation agencies to increase the resilience of the transportation system to the impacts of climate change. Resources discussing how the FHWA is increasing resilience of federal transportation systems is available on the following FHWA website:
  http://www.fhwa.dot.gov/environment/climate_change/

- **U.S. Department of Energy | Infrastructure:** The Partnership for Energy Sector Climate Resilience is an initiative to enhance U.S. energy security by improving the resilience of energy infrastructure to extreme weather and climate-related changes:
  http://energy.gov/epsa/partnership-energy-sector-climate-resilience

- **EPA | Infrastructure:** The Environmental Protection Agency (EPA) is working with partners to provide the knowledge and tools to ensure that investments made in water infrastructure are moving towards a sustainable future:
  http://water.epa.gov/infrastructure/
  EPA's Climate Ready Water Utilities (CRWU) resources provides water utility managers with tools, training, and technical assistance needed to adapt to climate change:
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