Washington State Climate Change Response Strategy

Interim Recommendations of the Built Environment:
Infrastructure & Communities Topic Advisory Group (TAG)

January 26, 2011

Built Environment: Infrastructure and Communities Topic Advisory Groups Members

Co-Chairs:

- Stephen Bernath, Dept. of Ecology
- Nancy Boyd, Dept. of Transportation

Staff:

- Joanna Ekrem, Dept. of Ecology
- Sandy Salisbury, Dept. of Transportation

Members (See Appendix D for all participants and reviewers):

- Kristin Bettridge and Ginny Stern, Dept. of Health
- Lloyd Brewer, City of Spokane
- Mike Canavan, Federal Highway Administration
- Tom Clingman, Dept. of Ecology
- Paul Fleming, Seattle Public Utilities
- Sandy Mackie, Perkins Coie LLP, Association of Washington Businesses
- Keith Maw, American Planning Association/Washington
- Joanne McCaughan and Tim Nogler, State Building Code Council
- Mary McCumber, Futurewise
- John Miller, Clallam County
- Ahmer Nizam, Dept. of Transportation
- Darcy Nonemacher and Michael Garrity, American Rivers
- Joyce Phillips, Dept. of Commerce
- Carol Lee Roalkvam, Dept. of Transportation
- Hal Schlomann, Washington Assoc. of Sewer and Water Districts
- Mike Schoonover, Washington Association of Realtors
- John Ufford, Military Dept. Emergency Management Division
- Kurt Unger, Dept. of Ecology
- Rick Walk, City of Lacey
- Laura Wharton, King County

Table of Contents

1. Introduction

Climate change has significant implications for the built environment, infrastructure, and communities in Washington State. Impacts and the ability to adapt will vary across the state and within the individual communities.

- Flooding and inundation of coastal and near-shore infrastructure are expected to increase in frequency and severity due to changes in flood dynamics and rising sea levels. This will likely put critical elements of our transportation infrastructure, ports, businesses and homes, water treatment facilities, stormwater infrastructure, and drinking water supplies at risk.
- Changes in precipitation amounts and patterns are expected to increase existing challenges in supplying adequate water for Washington's communities, agriculture and forestry resources, and ecosystems. Declines in summer streamflow and higher surface temperatures are expected to exacerbate current problems with water quality in the state.
- Increases in average temperature and frequency of extreme heat events are expected to result in increasing energy use in the summer at a time when declines in snowpack are anticipated to result in reduced hydropower resources.

These examples underscore the importance of proactive planning to prepare for and adapt to the impacts of climate change.

The Built Environment: Infrastructure and Communities Topic Advisory Group (TAG)

The mission of the Built Environment: Infrastructure and Communities TAG is to collect and communicate information and to develop recommendations used by the Steering Committee to inform the development of an integrated climate change response strategy for the state. The response strategy will focus on strategies and actions for state government to better enable state, local, and tribal governments; public and private businesses; nongovernmental organizations; and individuals to prepare for and adapt to the impacts of climate change.

The co-chairs and staff recruited members for the group who had a broad representation of interests in the state's infrastructure and who acknowledged the importance of developing a statewide plan for adaptation to climate change for the state's infrastructure.

The TAG's mission is primarily to focus attention on the strategies most relevant and vital to our state's communities and the services provided to those communities by transportation, energy, water, waste, and information infrastructure.

The objectives of the TAG are to:

- Select priority issues to address during the course of the TAG work.
- Summarize, for each selected priority issue, what is known about both the currently observed and projected impacts of climate change and associated adaptive strategies.
- Summarize known key vulnerabilities and risks related to each TAG priority issue.

- Assess the capacity of governments to undertake actions and the barriers to action (administrative, regulatory, and financial) related to each TAG priority issue.
- Identify near- and long-term strategies and actions to implement those strategies.
- Support suggested strategies and identify technical resources and opportunities for partnerships between state, local, and tribal governments; private businesses; NGOs; and federal agencies.
- Review funding mechanisms used in other jurisdictions and recommend funding strategies for Washington that support suggested strategies.
- Develop priority recommendations for monitoring efforts and ongoing research needs.
- Draft a report outlining TAG 1 recommendations.
- Participate in a cross-TAG dialog to identify additional broad and cross-cutting strategies.

Approach for Developing Recommendations

Early in the process, the TAG was polled to determine which infrastructures were most vulnerable to climate change. Seawalls, dikes, and floodgates rated as the most vulnerable, followed by municipal water supplies, and dams. Over time, the following areas emerged in group discussions as either vulnerable to the stressors of climate change or, in the case of sea level rise, that had impacts that affected all types of infrastructure along the coastline:

- Water supply
- Water quality
- Floodplain management
- Energy
- Transportation
- Commerce and ports
- Land use
- Sea level rise

The TAG divided into two subgroups to address issues:

- 1A focused on commerce, transportation, housing, and energy (CTHE).
- 1B focused on water (floodplain, sea level rise, water resources, and water quality).

After working separately, the members combined into the full TAG and worked together to refine goals, objectives, and recommendations.

The TAG met ten times between March 2010 and January 2011. In addition, many TAG members met separately as subgroups to tackle the TAG issues, and some were assigned homework to assist with producing draft products. To a large degree, the willingness of TAG members to commit time outside of the main meetings is the reason the TAG was able to successfully move toward developing a first cut at strategies for adapting the state's infrastructure to climate change.

2. Overview of the Impacts of Climate Change

In 2009 the Climate Impacts Group (CIG) at the University of Washington completed a comprehensive assessment of the impacts of climate change on Washington State, as mandated by the 2007 Washington State Legislature. Using global climate models scaled to the Pacific Northwest, CIG projects that Washington is likely to see:

- **Higher temperatures** – Increases in average annual temperature of 2.0°F by the 2020s, 3.2°F by the 2040s, and 5.3°F by the 2080s (compared to 1970–1999) are projected. Increasing likelihood of extreme heat events (heat waves) that will stress energy and water infrastructure.
- **Enhanced seasonal precipitation patterns** – Wetter autumns and winters, drier summers, and small overall increases in annual precipitation in Washington (+1 to +2 %) are projected. Increases in extreme high precipitation in western Washington are also possible.
- **Declining snowpack** – Spring snowpack is projected to decline, on average, by approximately 28% by the 2020s, 40% by the 2040s, and 59% by the 2080s (relative to 1916–2006).
- **Seasonal changes in streamflow** – Increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow-dominant and rain/snow mix basins, and decreases in summer streamflow are expected. Also, the risk of extreme high and low flows is expected to increase.
- **Sea level rise –** Medium projections of sea level rise for 2100s are 2 to 13 inches (depending on location) in Washington State. (see Appendix A).
- **Increase in wave heights –** An increase in significant wave height of 2.8 inches per year is expected through the 2020s
- **Warmer sea surface temperature** – Sea surface temperature is projected to increase 2.2°F for the 2040s for coastal ocean between 46°N and 49°N, relative to the 1970–1999 average.
- **Ocean acidification** – Continuing acidification is expected in coastal Washington and Puget Sound waters

More information on these impacts, including all related publication references, is found in the summary table prepared by the CIG in Appendix A. The TAG used this information as the basis for developing recommendations.

Our understanding of these climate impacts continues to evolve as models are further downscaled to the regional level and take into account "slow" feedback mechanisms, such as reduced sea ice and permafrost thaw. The choice of any future date for changes to occur is simply a best estimate of future conditions, and does not imply a new end state or slowing of the underlying change dynamic. Even at current levels of atmospheric greenhouse gases, we are locked into a pattern of long-term change that will play out over centuries.

3. Key Vulnerabilities and Risks

Using the information on the impacts of climate change provided by CIG and other reliable sources, the TAG identified the following key elements of our infrastructure and communities that are vulnerable to and at risk from the impacts of climate change:

Key Vulnerabilities

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007). Another way to say this is that vulnerability is a function of impacts and the ability to adapt. The TAG defined "infrastructure" as all public and private facilities necessary for the functioning of the economy and the people who live in Washington. In that context, the group looked qualitatively at which infrastructures are vulnerable to which climate change impacts. In most cases, our infrastructure is, or will be, subject to more than one stressor at a time. For example, a road in the Puget Sound lowlands crossing a floodplain will likely be subject to sea level rise, flooding, overwhelmed culverts, and bed aggradation due to glaciers melting. Each stressor will build upon others.

Sea Level Rise and Coastal Issues

Sea level rise, increases in extreme weather events, flooding, and increases in wave heights are all expected to result in inundation (flooding) of coastal areas, increased erosion of unstable bluffs, a shift of coastal beaches inland, deposition, and intrusion of salt water into freshwater aquifers.

A rising sea level can inundate the transportation infrastructure; ports and their associated facilities; drinking water, waste water, and stormwater facilities; housing; and businesses. Inundation from rising sea levels and heavy surface flow from storms will challenge the capacity of storm drains, natural conveyances (creeks and rivers), and wastewater treatment facilities. In addition, rising seas can inundate freshwater habitats, including wetland mitigation sites tied to infrastructure projects.

Sea level rise may change the nature of coastal community access and local populations and economies. Communities with single road access could be periodically and eventually totally cut off as seas rise without adaptation measures.

Severe storm impacts can include erosion and flooding; failure of urban and suburban services; disrupted transportation, energy, and information lines; and evacuations. Higher sea levels and higher storm surge will steadily increase these impacts. As bluffs are undercut and landslides occur, or as river channels migrate, transportation may be slowed or stopped, port facilities may be jeopardized, and homes may be lost along the coastline.

Heat and Temperature Changes

Average temperatures are anticipated to rise, and seasonal temperature trends may change. Minimum and maximum temperatures are predicted to rise, and the gap between daily highs and lows should decrease in winter and increase in summer. Temperature changes will influence snowpack, stream flow, soil moisture availability, wildfires, air quality, water quality and temperature, and the urban heat island effect. Cities will warm proportionally more than natural areas. Extreme heat events will become more likely, increasing stress on water and energy resources, often at times when those resources are already under stress. Increasing summer temperatures will lead to increased use of air conditioning in existing structures; once this capacity is in place, base loads as well as peak loads will increase.

The glaciers in Washington are receding, leaving bare ground where once there was snow. This results in a larger watershed contributing to flooding and movement of exposed sediment down river channels.

Many water supply systems will not meet the demand for communities, agriculture, and natural resources as they are allocated now. Warmer temperatures and population growth are projected to increase energy demand substantially in the summer, by 165–200% by the 2020s. Energy demand in the winter is projected to increase more modestly, by 22% by the 2020s, primarily due to population growth. Competition will increase between the need for energy and the need for water in streams.

Precipitation, Snowpack, and Streamflow Changes

Across Washington State, we experience annual and seasonal variability in spring snowpack, precipitation, and stream flow. Climate change is expected to result in:

- Decline in snowpack.
- Increase in winter precipitation and decrease in summer precipitation, with lower low flows in summer and higher flood risks in winter for snow-dominant and mixed rain/snow basins.
- More precipitation falling as rain instead of snow, due to warmer temps.
- Snow-dominant basins shift to mixed snow/rain basins, mixed snow/rain basins shift to rain-dominant basins.
- Earlier peak streamflow in spring.

The difference in rainfall and snowfall will vary by location, and impacts will be basin-dependent. Some watersheds will remain rainfall dominant and vary little, while others will shift from snow dominant to rain dominant. This change will affect the timing of water moving through river systems. The snowpack acts as a water reservoir. This water will be less available in the future, which will require adjustment in how water is used for housing, industry, and farming in those basins. This change in the timing of river flows will require more efficient use of municipal, industrial, and agricultural water, and may require other ways to store water for use in summer.

Earlier snowmelt and earlier peak river flows are projected to affect water supplies. By the 2020s, summer production of hydropower is projected to decrease 9–11% and winter production is projected to increase by 0.5–4%. The effect is compounded by population growth and increased summer temperatures, which create high demand during low supply.

Key Risks

In general, there are three risk types for infrastructure: reduced capacity, temporary operational failure, and complete and catastrophic failure. The type of failure will affect how and when society responds.

"Risk" is the evaluation of the likelihood and the consequence of an impact. TAG 1 did not quantitatively address the level of risk for each climate impact. Effects will be location-dependent.

Evaluating the likelihood and magnitude of an impact against the consequences of failure allows for planning in the face on uncertainty. Scenario planning can be used to evaluate risk and indicate the need and timing for action.

A qualitative risk matrix can look something like the following table:

Likelihood	**Consequence**			
	Complete and catastrophic failure	Temporary operational failure	Reduced capacity	Insignificant
High				
Medium				
Low				

Impacts with a high likelihood of occurrence within a short timeline, and which result in complete and catastrophic failure (red), can be addressed through strategies with a shorter timeline, while impacts with a low likelihood of occurrence and an impact of reduced consequence (blue) can be watched and reevaluated at a later date.

Risk can be evaluated using an asset management approach that is location-specific for the anticipated impacts at that location. Scenario planning can be used in the face of uncertainty to chart a course of action to address risk while further research and monitoring is being done.

4. Unifying Themes and Overarching Strategies to Prepare for and Adapt to Climate Change

Key Principles that Informed the Development of Strategies

The TAG agreed to several principles that guided the approach for developing recommendations and strategies:

- Use the best-available science on the impacts of climate change, and rely on the information developed by UW CIG and other peer-reviewed sources.
- Build from existing knowledge and research on adaptation, including the work of the Preparation and Adaptation Work Group recommendations developed in 2007–2008.
- Identify opportunities to integrate climate science and projected impacts into current planning, decision making, and funding.
- Consider key vulnerabilities and risks to plan for as a result of climate change.
- Reduce the vulnerability and increase the resilience of infrastructure and communities to climate change. Protect vulnerable human populations and ecosystems.
- Develop an integrated approach that considers implications for multiple interrelated components (such as human systems, natural systems, and the economy).
- Include adaptive management approaches that account for changes in science and information over time.
- Identify "no regrets" strategies and strategies with co-benefits. Seek to avoid unintended consequences.
- Apply risk management principles, and seek to recommend actions that are prudent and responsible for public agencies.

Key Overarching Strategies and Unifying Themes

Key overarching strategies and themes identified include:

- A forum is needed for state, regional, and local development of a framework to make decisions on when or whether to defend, adapt, or retreat. The typical life of infrastructure is decades or centuries. In what situation(s) is it acceptable to defend, adapt, or retreat due to climate change impacts?
- Adaptation actions should not increase greenhouse gases (GHGs) or jeopardize mitigation options. Counties and cities should consider the impacts of their mitigation measures. Care should be taken that mitigation does not negatively impact adaptation needs; for example, high-density development in climate risk areas.
- Sustainability Framework**:** Our preferred approach is to evaluate strategies in the context of a sustainability framework. Sustainability can be simply defined, paraphrasing the Brundtland Report, as practices that meet the needs of the present without compromising the ability of future generations to meet their own needs.

- Localized resiliency on the level of individual sites. Innovation and ability to adapt.
- Bolster risk management planning and response capacity, including emergency response systems to include actuarial costs for insurance.
- Land use planning is needed (examine jurisdictional barriers, conflicts, and regional cooperation).
- Communicating with the public and building public literacy, defining and defending leadership; capacity building, and education.
- Research, monitoring, and adaptive management.
- Governance is a cross-TAG issue that must be faced in the integrated strategy. Who decides, how, what is a balance of needs/costs, how to address competing interests among and between neighboring jurisdictions? Partnerships are critical between federal, state, local, tribal, NGO, and private sector entities.
- Integrated decision making, unified approach, bold and compassionate action is needed.
- Need interim strategy to define success – even if it is early. "Action in the face of uncertainty is unavoidable, as is elimination of all potential risk." Adaptive management is critically important to success (NAS Figure 3.3).
- Equity: Climate change impacts will fall unevenly on regions, firms, and populations. Appropriate consideration must be given to sharing the costs of adaptation responses and investments across the entire economy.
- Economics: We can't ignore the marketplace. What are the unintended consequences of recommendations? What are the near- and long-term economic consequences of taking no action to prepare for and adapt to climate change impacts?
- Interim tools and actions are needed that take into consideration future climate scenarios and ranges of uncertainty regarding local and regional impacts.

Key Unresolved Issues to Address / Divergent Viewpoints

SEPA:
The TAG discussed the State Environmental Policy Act in several contexts in regard to the development of TAG recommendations. There was agreement among the TAG that SEPA is one of the tools for considering the impacts of climate change at the planning level (sometimes referred to as the "nonproject level"). TAG members did not reach consensus on whether SEPA is an appropriate tool to use to consider the impacts of climate change at the project level.

Ecology is currently working to address issues regarding how to incorporate climate change into a SEPA analysis. It has developed a draft "working paper" to assist agencies and project proponents in performing an analysis of GHGs and their impacts on the environment as a result of climate change. (See the working paper at: http://www.ecy.wa.gov/climatechange/sepa.htm.)

Members of the group agreed to continue to work with Ecology in its efforts to clarify the role of SEPA and how to use SEPA to evaluate GHG emissions and vulnerability to climate change at the planning and project levels.

The group recognized the difference in the capacity to consider climate change at the project level between state agencies serving as SEPA lead agency and local agencies serving as lead in reviewing private proposals. For example, WSDOT is including available climate projections during the analysis of environmental effects on large transportation projects.

Key Barriers

The TAG identified key barriers to planning for and adapting to climate change impacts. The group considered these barriers and options for addressing barriers as recommendations were developed. Barriers include:

Resources needed

- Funding and capacity is lacking
- Available funding is often in response to emergencies rather than proactive planning and investment

Information needed

- Risk mapping at an appropriate level of detail
- Enhanced monitoring networks to develop better estimates of ecosystem function and support better forecasts of future changes due to climate impacts
- Tools and guidance for communities to self-identify risks and vulnerability
- Clearinghouse of information on adaptive strategies
- Clear articulation of the uncertainties embedded in the tools used to make climate projections.

Legal/regulatory barriers

- Water rights, especially in the context of long-term predictions about increasing demand and decreasing supply
- Stormwater, reclaimed water, and grey water management and reuse
- Land use: property rights, local control fragments response to large issue
- Lack of statewide planning direction on climate adaptation issues and land use planning
- Mechanism to deal fairly with at risk properties and infrastructure
- Cumulative effects
- Lack of mechanisms to address unsustainable trends
- Lack of alignment of state agency missions

Cultural barriers

- Education is needed on future impacts of climate change
- Historic settlement patterns and legal, cultural, economic patterns and the difficulty of implementing change
- Changes to communities and community structure
- Bailouts for property owners who build in threatened areas – insurance issues
- Absence of support structure to encourage abandonment

Economic Issues

- Climate impacts are risks to investment—how to adapt, minimize risks to investment in the short and long term, and not jeopardize economy
- Need to make decisions based on impacts to economic system, infrastructure, communities, and environment

Opportunities for Taking Action

- Federal action on climate impacts and adaptation.
- State, local, and tribal governments increasingly developing adaptation plans, tools, and resources.
    - In the course of the TAG's work, the group examined existing federal, state, local, and sector-specific adaptation plans, as well as tools and additional resources on adapting to climate change. Several new adaptation plans and resources were completed over the course of the group's work, such as the National Academy of Sciences report, "Adapting to the Impacts of Climate Change,"[1] the recently released Swinomish Climate Change Action Plan, and the EPA Climate Ready Utilities toolbox and Climate Ready Water Utilities Working Group report. Where possible, the TAG's recommendations were developed in consideration of these existing resources.
- Many of the TAG recommendations are "no regrets" and address existing challenges.
- New partnerships and resources, such as LCCs, RISA at OSU, new DOI Climate Science Center partnership between CIG, U of Idaho, and U of Oregon.
- Opportunity to develop better tools for evaluating sustainability. As each strategy evolves into specific actions to adapt to climate change, the actions and alternatives can be evaluated against the Sustainability Principles to better understand long-term impacts.
- Align state agency mission statements.
- Minimize near- and long-term economic risks of not taking any action to prepare for and adapt proactively to climate change.

[1] See the report at: http://americasclimatechoices.org/

5. Recommended Adaptation Strategies and Resilience Actions

The TAG developed strategies and actions for each of the eight priority planning areas:

- Water supply
- Water quality
- Floodplain management
- Sea Level Rise
- Energy
- Commerce and Ports
- Transportation
- Land Use

These recommendations are outlined in Table 1. Actions that have been identified may require partnerships at different government levels.

Table 1: Built Environment, Infrastructure, and Communities TAG – Recommended Strategies and Actions

Strategies		Recommended Actions
WATER SUPPLY (see Appendix B for more detail)		
1	Determine water availability and demand in high-priority basins.	a. Improve statewide water availability and supply and demand forecasting. *(high priority)* b. Develop water budgets in basins that will be impacted by climate change. *(high priority)* c. Clarify water rights and claims through streamlined judicial processes or non-judicial settlement agreements to enable more accurate supply and demand forecasting. (*high priority*)
2	Develop and implement water strategies to manage supply and demand in a climate-changed future.	a. Transition from watershed planning to implementation in high-priority climate change-affected basins: evaluate options to manage supply and demand, exploring a full range of options, including an increased use of water masters (high priority) b. Prioritize low-cost, no regrets options such as conservation, efficiency (i.e., demand management), and expanded use of non-potable water (high-priority strategy, suite of options available). c. Evaluate options such as new supply, timing, and transfers (high-priority strategy, suite of options available). Emphasize water supply options that provide in-stream and out of stream benefits. d. Improve legal and fiscal framework for water banking. e. Improve supply for streamflow mitigation and use through aquifer storage and recovery (ASR) program. f. Obtain water savings through green building legislation, building code updates, and tax holidays.

Strategies		Recommended Actions
		g. Discourage use of turf grass and other high-water-demand landscaping. h. Develop industrial and agricultural conservation and efficiency standards and continue to improve municipal conservation and efficiency.
3	Integrate climate change into policy and planning efforts.	a. Integrate water supply considerations into land use planning in high-priority basins. *(high priority)* b. Map critical source water and groundwater infiltration areas in order to identify and protect them (for example, through requiring their protection in comprehensive plans). c. Update the definition of "drought" and remove barriers to drought relief to better reflect climate change.
4	Increase monitoring and mapping to better understand the effects of climate change.	a. Increase water use monitoring. *(high priority)* b. Increase water rights mapping. *(high priority)* c. Increase surface and groundwater monitoring. *(high priority)* d. Create and utilize data integration tools. Ensure all data is available in accessible digital formats (GIS).
5	Increase resilience through building and site design.	a. Encourage local storage of rainwater as a component of building design.
WATER QUALITY		
6	Identify areas of potential impacts to water quality.	a. Work with the UW Climate Impacts Group and other experts to determine the priority areas where climate change has a high likelihood of affecting ground and surface water quality using appropriate scenarios. NOTE: There is a need to discern when historical paradigm is not best the indication for the future; for example, when determining 7Q10 low flows or applying temperature water quality standards. b. Update the hydrologic models used in stormwater systems and site design in priority areas.
7	Enhance and expand water quality monitoring strategies. Evaluate changes in priority areas identified in 6a, as funding allows.	a. Develop an integrated groundwater monitoring network to monitor trends and changes in water quality over time in priority areas. b. Monitor water quality in coastal areas at risk for saltwater intrusion and inundation (see Sea Level Rise). c. Integrate climate change assessment needs into Ecology's surface water flow and water quality monitoring network. d. Identify and fund monitoring, modeling, and research needs to evaluate emerging and cumulative impacts of climate change.
8	Create climate-ready utilities.	a. Review the report of EPA's Climate Ready Water Utilities Working Group to determine what recommendations the state may want to adopt. b. Provide water utilities and local governments the resources, tools, and guidance to evaluate risk and vulnerability for water and wastewater systems c. Consider age of facilities and length of useful life. d. Provide utilities the tools needed to increase use and reuse of

Strategies		Recommended Actions
		non-potable water supplies.
9	Require consideration of the impacts of climate change in the planning and design of water and wastewater infrastructure facilities that are funded by the state, including stormwater facilities	a. When giving state money for water or wastewater projects, ensure climate impacts are considered in planning and design. b. Provide guidance on how to consider climate change impacts in the planning and design of water and wastewater projects. c. Develop guidance on evaluating risk and vulnerability to climate change impacts. d. Leverage federal and other funding options for upgrading emergency sources of supply. e. Include in local risk analyses an assessment of stormwater system capacity to identify priorities for system retrofits in priority areas/basins (6a above).
10	Continue to promote low-impact development (LID) and best management practices (BMPs) for stormwater	a. Continue to incorporate LID practices into stormwater permitting and strengthen stormwater control requirements and incentives for maximizing groundwater infiltration (see Maryland's stormwater law). b. Retain native vegetation on a landscape scale rather than on individual sites. Retain or increase canopy cover of urban and community forests. c. Encourage biofiltration, green roofs, porous pavement, vegetated roofs, and water harvesting. d. Consider retrofitting existing structures to incorporate LID practices. e. Provide information and examples of LID BMPs and link with existing initiatives (e.g., Bullitt Foundation million gallon cistern, Gates Foundation green roof, BMPs). f. Encourage and support use of nonmotorized transportation and alternatives to single-occupancy vehicle transportation. g. Green infrastructure: restoring in a sensible way the predevelopment conditions. Develop ways to retrofit into existing community.
11	Continue to promote use of reclaimed water.	a. Create incentives for use of reclaimed water where appropriate. b. Consider potential issues and concerns with water rights, in-stream flow, and water quality. c. Consider the energy/water nexus (energy requirements) when evaluating reclaimed water projects.
12	Encourage use of grey water (DOH).	a. Develop a clearinghouse to provide information and resources to local governments, developers, and others on safely and effectively using grey water. Include good examples of effective grey water projects.
13	Use the existing triennial process and permitting cycles to adapt water quality standards and permits to climate change over time.	a. Prioritize areas (6a above) where standards may need to be reviewed to reflect the changing climate. As climate change occurs, if the capacity of the environment is no longer able to meet current standards as a result of warming trends, water quality standards may need to be addressed. NOTE: One of the challenges is discerning the effects of climate change given the

Strategies		Recommended Actions
		influences of human water management decisions (e.g., climate change should not be used as an excuse to downgrade water quality requirements). b. Consider likely climate scenarios (6a above) in reviewing standards. c. As standards are adjusted over time in response to climate change, adjust permits accordingly. d. Assess the stormwater regulatory framework (e.g., NPDES permits) in priority areas (6a above) for modification as hydrologic conditions change.
FLOODPLAIN MANAGEMENT		
14	Identify changes in future flood risk due to climate change by basin.	a. Work with the Climate Impacts Group, hydrologists, and other experts to identify where climate change will likely result in greater flood risks from changes in hydrology and more pronounced channel migration.
15	Develop tools to evaluate risk and vulnerability.	a. Work with FEMA on revising the data used to map flood hazard areas to incorporate anticipated future flood risk due to climate change. b. Provide interim tools/guidelines for local governments to consider future flood risk due to climate change until better mapping and information is developed.
16	Require consideration of changing flood risk in management of state and local government infrastructure.	a. Consider changes in future flood risk when planning, siting, and designing public infrastructure, including water supply, stormwater, wastewater, and roads.
17	Provide communities the tools to minimize future risks of flooding due to climate change impacts.	a. Where changes to flood elevation and channel migration are anticipated, work with local communities to minimize risk and accommodate natural processes through floodplain management (e.g., protecting and restoring floodplains, setting back levees, and protecting and restoring wetlands) and shoreline regulation. b. Incorporate changes in flood risk into policies and planning efforts, such as Flood Hazard Management Plans, Critical Areas Ordinances, and Shoreline Master Plans. c. Ecology will work with stakeholders to identify a dedicated fund source for FCAAP, so that grants for planning and implementation can be available to small communities with increased flood risk due to climate change. d. In certain highly developed areas, have regional dialog to consider environmental trade-off for areas we need to defend rather than developing natural areas; conduct a risk assessment.
SEA LEVEL RISE		
18	Develop and share information resources on sea level rise.	a. Characterize and map sea level rise vulnerability for all marine shorelines, including outer coast. b. Identify and assess what has been done, to provide examples

Strategies		Recommended Actions
		and the starting point for further work. Obtain LIDAR mapping of all coastal areas. c. Obtain high-accuracy elevation benchmarks to support sea level monitoring. d. Identify scope, responsibilities, and timeframe to get this accomplished and share statewide.
19	Address sea level rise in land use and infrastructure planning and permitting.	a. Develop a single state location for climate change information to encourage optimal use in local planning updates: well-maintained, comprehensive, user-friendly website. b. Require that sea level rise and other climate change impacts be considered in future Comp Plan updates. This would include Capital Facilities Planning (updated annually). c. Require sea level rise be considered in Shoreline Master Plan updates and incorporated as data become available Promote "Green shoreline" stabilization alternatives to bulkheads. Armoring can directly impede adaptation, by starving the beach of new material. Property owner concerns about shoreline stability will likely increase. **Green shorelines** use vegetation and natural materials to reduce negative impacts on coasts and near shore habitats while protecting property. d. Identify feasible approaches to avoid or minimize hardening, especially on Puget Sound (localized sources of beach material). e. Streamline permitting for "green" projects. Tendency is to streamline permitting for known projects and "replacement in kind." Greater hurdles are common for innovative approaches such as replacement of bulkhead with "green" stabilization. Actions may include changing statutes (parallel with existing streamside fish habitat project streamlining), providing design manual, and/or coordinated interagency permitting.
20	Address sea level rise in coastal facility planning and design.	a. Provide information, tools, and guidance on how to address the issue of considering sea level rise in planning and design of public infrastructure. b. Avoid mandates like a set sea level elevation for facility planning, due to significant uncertainty in science and wide variation of settings and management approaches. c. Develop a central clearinghouse to share information. d. Require sea level rise and climate change consideration in design of state-funded facilities: i. Add to statute or agency requirements for Centennial and other ECY funds, PWTF, etc. ii. Good guidance will be vital (perhaps same guidance as in strategy #1). iii. Allow creative approaches, such as demonstration projects, that do not set precedent for future decisions. e. Develop guidance on incorporating consideration of sea level rise and climate change in facility design: highlight key

Strategies		Recommended Actions
		considerations of facility life, criticality, and vulnerability based on available science. Provide links to good examples and models (especially for smaller jurisdictions).
21	Increase monitoring and mapping to better understand the rate of sea level rise.	a. Monitor saltwater intrusion and inundation of freshwater areas. b. Expand monitoring and mapping of sea level rise and evaluate the impacts to the shoreline, such as changes in erosion and unstable bluffs.
ENERGY		
22	Identify vulnerabilities.	a. Identify vulnerabilities of power transmission due to extreme heat and other changes. b. Analyze vulnerabilities of power facilities, specifically for hydro and wind. c. Research and project future wind patterns for facility siting. d. Analyze potential effects of reduced electricity reliability during winter. e. Assess environmental impacts from climate change in siting and relicensing of new and existing energy facilities. f. Identify how state renewable energy goals could be impacted from future climate impacts.
23	Diversify energy resources.	a. Prioritize and promote conservation and efficiency as the least costly, most immediately available alternative to minimize the need for maintaining existing polluting energy sources. b. Construct more diverse, renewable generation facilities. c. Review standards from I-937 going forward fifty years. d. Construct more generation, prioritizing and incentivizing well-sited renewables such as wind and solar. e. Create additional transmission capacity. f. Encourage the development of distributed generation near and within load centers, to increase reliability by having redundant systems and to reduce risks associated with the long-distance transmission of energy. g. Develop a detailed climate vulnerability assessment and adaptation plan for Washington's transmission infrastructure.
24	Increase resilience to extreme weather events and demands from population increases (includes power and information systems).	a. Construct stronger, more resilient transmission and distribution systems, through undergrounding, redundancy, stronger poles/equipment, etc., to protect equipment from key weather affects. [Utility and WUTC action required] b. Protect infrastructure from flood impacts. Consider relocation to less vulnerable locations in longer term. c. Strengthen response and recovery capabilities [EMD and state agencies could expand resource capabilities to aid utilities, conduct exercises to validate capabilities.] d. Expand redundancy in transmission and storage. e. Incentivize backup systems for schools, clinics, and emergency shelters. Prepare for supply interruptions. f. Encourage the development of distributed generation near and

Strategies		Recommended Actions
		within load centers; to increase reliability by having redundant systems, and to reduce risks associated with the long distance transmission of energy g. Encourage building practices (including materials selection, orientation, vegetation type/and placement, use of natural lighting, etc.) that will reduce energy demand from new construction and in retrofitted buildings. h. Reduce impacts associated with urban heat island effect (urban forestry programs, open space areas, etc.) in urban areas. i. Plan for reduced electricity reliability, especially in winter. j. Encourage water-efficient cooling systems at existing power plants that need them.
25	Increase resilience to climate changes in housing and site design.	a. Increase end-use efficiency in residential and commercial buildings b. Encourage local storage of rainwater as a component of building design. c. Discourage use of turf grass and other high-water-demand landscaping. Encourage low water use landscapes that allow water to infiltrate. d. Increase energy efficiency in buildings. Design and retrofit buildings to use less energy: weatherize, better insulation, passive solar, natural lighting, ventilation, etc. e. Identify and encourage the use of building materials that reduce reflectivity and therefore energy demand for heating and cooling. f. Identify and encourage the use of building practices that reduce contribution to the urban heat island effect in both new construction and retrofit of existing buildings. g. Increase energy use efficiency. Use energy efficient appliances (Energy Star), lighting, etc. h. Modify regulatory codes to address urban heat island effect and stormwater management based on climate issues and population densities. i. Encourage “smart” buildings and appliances that can reduce power consumption during high demand periods. j. Ensure that future updates of the State Energy Code are reflective of future conservation needs; adopt codes accordingly
26	Address energy storage/ capacity and timing.	a. Assess vulnerability to heat waves in generation, transmission, and delivery systems. b. Reduce electrical demand at time periods when hydropower generation capacity is reduced. c. Construct more generation (renewable—less water dependent, dispersed renewable generation) [Utility/Industry actions required, WUTC may have some influence] d. Assess whether decentralized power generation reduces risk. e. Construct more transmission and a smarter transmission grid

Strategies		Recommended Actions
		[Utility/Industry actions required, WUTC may have some influence, Governor's office may have some federal influence] f. Ensure future updates of the State Energy Code are reflective of future conservation needs; adopt codes accordingly.
TRANSPORTATION		
27	Identify risks and vulnerabilities to all transportation modes.	a. WSDOT/FHWA is in the process of conducting a vulnerability assessment that includes WSDOT-owned facilities and modes; includes ferries, state-owned rail and airports. b. Conduct risk assessment for rail, Sound transit, BNSF, and others. There are multiple owners for these without a single point of contact. c. Air. d. Barge. e. Pipelines. f. Recommend UTC and USDOT conduct risk assessment for regulated utilities (rail and pipelines). a. Risk of rail to heat effects b. Rail lines in vulnerable areas along shoreline g. Provide information to state and local governments on risk assessment.
28	Increase transportation system redundancy to improve resiliency.	a. Coordinate and integrate emergency evacuation procedures between adjacent cities and between adjacent counties. b. Multiple mode redundancy. c. Decrease reliance on GHG producing modes and technologies. d. Increase mass transit, especially electrified. e. Protect critical evacuation routes or create alternate paths that avoid the impact of hazards. f. Raise and/or reinforce harbor infrastructure. g. Protect bridge piers and abutments. h. Increase culvert capacity in a manner that is compatible with maintaining or expanding effective fish passages. i. Upgrade drainage systems.
29	Improve information.	a. Expand systems for monitoring scour of bridge piers and abutments. b. Increase monitoring of land slopes, stormwater runoff, and drainage systems. c. Consider the changing storm patterns to make sure facilities are adequate to handle runoff. See Floodplain section d. Increase monitoring of real-time flood levels and storm surge and provide messaging to public.
30	Create statewide policy to guide private and local actions.	a. Return some coastal and floodplain areas to nature. b. Restrict development in floodplains and vulnerable coastal areas. c. Determine threshold for when state will not invest in at-risk locations; tie to project life.
31	Other	a. Develop modular traffic and signing features for easier

Strategies		Recommended Actions
		replacement/repair.
COMMERCE AND PORTS		
32	Increase resilience to changes in sea level rise, precipitation changes, increased temperatures, glacial melting, and decreased summer river flows.	a. Determine critical shipping channels and their vulnerability to riverbed aggradation. b. Identify options to respond to changed conditions. c. Evaluate need for restrictions on shipping due to channel depths, impacted inland waterways. and rivers. d. Evaluate impacts of increased dredging on critical shipping channels.
33	Increase resilience to sea level rise and higher river flows in winter due to potential flooding.	a. Determine vulnerability to flooding/inundation at port facilities. b. Evaluate need to increase protection of ports and associated infrastructure such as docks, roadbeds, and bridge abutments near ports and marinas. c. Consider strengthening existing dike and levee systems and restoring natural floodplains to mitigate flow changes. d. Improve early warning systems and weather forecasts to allow on-site protections to be engaged in advance of emergency. e. Coordinate to streamline GMA, Shoreline, and Critical Area regulations to address existing facilities and their associated infrastructure as essential public facilities. f. Consider relocation where channel migration occurs and/or where existing river channels can no longer be reasonably defended. g. If relocation is chosen, determine where or whether relocation is feasible within the existing community. h. Develop balance within regulations between marine trade and industry areas with natural areas and their buffers. i. In considering port facilities, recognize the links of their support facilities, such as rail, warehouses, commerce, and roads. j. Integrate port plans with local planning and require consideration of sea level rise. Consistency with adjacent local jurisdictions is necessary.
34	Increase resilience to sea level rise in coastal facility planning, siting, and design.	a. Examine all modal options to move goods to determine if climate change impacts will affect mode choice, for example rail vs. barge. b. Develop guidance on including sea level rise and climate changes in facility design: highlight key considerations of facility life, criticality, and vulnerability based on available science. c. Develop guidelines on selected relocation of facilities to avoid impacts: strategic disinvestment. d. Develop decision processes to determine facility location and how/where we invest state funds.
LAND USE		
35	Leverage existing regulatory processes to adapt to climate change.	a. Provide climate change impact assessments and maps across the state on a basin-by-basin basis, using consistent data from CIG (e.g., CIG scenarios).

Strategies		Recommended Actions
		b. Require local governments to update countywide and multicounty planning policies (under the GMA) to include climate change adaptation issues. c. Amend GMA and SMA to require climate change adaptation planning using impact assessment information (state provides regional framework and basic information, local governments consider and make decisions). d. Amend GMA to require designation of "climate change risk areas." e. Require that urban growth area expansions must consider all climate change impacts, including likely future migration of floodplains. f. Consider a time horizon longer than the 20-years currently typical under the GMA when considering urban growth area boundary expansions or long-term infrastructure investment decisions, incorporating anticipated climate change impacts (e.g., sea level rise considerations). g. Encourage counties with commercial-scale wind and solar energy potential to develop permitting processes to streamline their deployment while still providing adequate environmental and land use protections. h. Encourage counties and cities to plan for a wide variety of energy facilities, with an emphasis on well-sited renewable energy sources. i. Provide timely updates of the state building codes to facilitate greater adaptation and mitigation measures in the building sector; utilize technical advisory groups to address green building standards as related to land use. j. Establish benchmarks local governments can use to determine what levels of development are acceptable in climate change risk areas until anticipated impacts occur. k. Provide a consensus planning forecast of the changing environmental conditions that include projected impacts (e.g., precipitation changes). l. Encourage "Complete Streets," with a full range of motorized and nonmotorized options. **Complete Streets are streets for everyone**. They are designed and operated to enable safe access for all users. Pedestrians, bicyclists, motorists, and transit riders of all ages and abilities must be able to safely move along and across a complete street. m. Urban forestry: increase tree cover, use for shading, etc., in balance with solar access. Restore funding for the Evergreen Communities Act to develop best practices and model regulations and community forestry management plans.
36	Address climate change impacts in local land use	a. Info access: the state should provide a single location for climate change information to encourage optimal use in local planning

Strategies		Recommended Actions
	planning.	updates (well-maintained, comprehensive, user-friendly website). b. Prioritize "green shoreline" stabilization alternatives over bulkheads. (Armoring can directly impede adaptation by starving the beach of new material. Property owner concerns about shoreline stability will likely increase.)
37	Increase carbon storage (carbon sequestration)	a. Encourage and facilitate efforts to maintain or increase carbon sequestering land uses; for example, preservation of forest or agricultural land uses. b. Enhance Green Infrastructure to provide environmental and social services. **Green infrastructure** encompasses the preservation and restoration of natural landscape features – forests, wetlands, floodplains, natural drainage features. At the site scale, it involves low-impact development (LID) and sustainable building features such as rain gardens, green roofs, permeable pavement, rainwater harvesting, etc. c. Develop methods to retrofit into existing community. d. Preserve resource lands (agricultural and forestry resource lands of long-term commercial significance. e. Enhance urban and community forestry to address temperature issues, air quality, etc.
38	Address increased fire potential.	a. When considering potential impacts on wildland/urban interface areas caused by extreme temperature changes/increases, local jurisdictions should give consideration to adoption of the Wildland/Urban Interface Code (WUI Code). This is currently in WAC as Appendix K of the 2009 Washington State Fire Code. WAC 51-54-4800 is available for voluntary adoption by local jurisdictions and has currently been adopted by two counties: Kittitas and Yakima. This voluntary code section mandates specific regulation regarding vegetation management plans, fire danger rating systems, and water supplies for development, among other approaches. b. Local fire services may be unable to respond to increasing wildland/urban interface zone fires, likely to be exacerbated as a result of higher temperatures as projected over the next 40 to 80 years. This will be due to lack of water and other resources to fight wild fires, as well as dramatic and unsustainable cost increases that will drain public financial resources.
39	Provide state predictability.	a. Identify state funding priorities and limits, but not control local responses. (At what point will the state end funding in certain locations due to the risks associated with climate change? How will this affect local governments?)

Strategies		Recommended Actions
40	State Environmental Policy Act (SEPA)	a. Use SEPA during non-project review of comprehensive plans and development regulations to evaluate climate change impacts. b. During project review, consider climate change impacts when appropriate (potential impacts from the project that may exacerbate climate change impacts; potential climate change impacts that may affect the project). c. Amend SEPA or WAC to specifically identify climate change-related issues to be considered via SEPA, including SLR for coastal projects/plans. d. Nexus and proportionality must be considered when applying mitigation standards to projects
41	Other	a. Increase flood insurance rates to reflect actuarial costs. b. Shift greater share of insurance risk to customers; create pricing incentives to reduce exposure to risks. c. Identify social equity issues and how to best address them (e.g., a disproportionately high number of low-income people may be affected by increasing flood risks, and they may have fewer opportunities to relocate out of existing or enlarged floodplains). d. Determine role of regional organizations.

Discussion on Implementation

The state agency plan will need to work on several areas, including integration of recommendations, clear delineation of roles and responsibilities across state agencies and vertically through different levels of government, identification of funding mechanisms, and legal and regulatory changes. This work will be challenging and will require candid, plain language that exposes policy and programs that conflict.

Unclear or conflicting mandates on state agencies may undermine our ability to clearly outline an integrated approach. For example, TAG 1 members discussed shoreline armoring. We talked about places where it may make sense to limit or prohibit armoring, and places the state may want to promote armoring to save infrastructure. To assist in resolving this conundrum, it may be important to develop criteria—such as habitat value and population density—derived from a sustainable vision of economic/social/environmental priorities. Private property ownership, local land use authority, and state authority are immediately drawn into the discussion, along with the jurisdictional variations (one town may allow bulkheads and the next town may ban them). Incentives and regulatory controls are two of the primary tools. However, the challenge is in reaching a coordinated approach that all levels of government and society can support or adhere to. Other jurisdictions may provide an example of how to address these issues. For example, the Swinomish Action Plan has an extensive discussion on this issue.

Several key elements of the state strategy are in place today! TAG 1 members strongly endorse the concept that we must leverage what we currently have in place. We don't want to undermine

essential programs—we want to see where they may need to be enhanced or where coordination is needed to improve their ability to respond to climate changes.

The state's integrated approach will be used to develop more effective and efficient:

- Infrastructure investment decisions.
- Regional transportation services and response coordination.
- Water and waste water management.
- Diking programs and flood protection programs.
- Habitat preservation, research, and mitigation coordination.
- Local and regional utilities coordination.
- Emergency planning and response.

Opportunities to leverage existing programs—maximizing the state's current response mechanisms:

- Risk management and coordinated response strategies for seismic, tsunami, wildfire, flood, and severe storm impacts fit naturally with climate change preparation planning.
- Communication and public education programs at all levels that build public knowledge, readiness, and willingness to prepare.
- Research.
- Federal leadership, British Columbia, regional research and programs.
- Tribal partners.

6. Concluding Remarks and Next Steps

The scope of TAG 1's efforts—communities, infrastructure, and the built environment — encompassed a diverse array of interests and disciplines. The team was inspired and compelled by the recognition that while individual interests acting alone may find it difficult to achieve meaningful, sustainable results, the coordinated adaptation strategies of many are necessary to produce meaningful results.

The state should ensure the provision of baseline information—presented in a clear, concise, and easy to understand manner that is scientifically derived or based on science supported by Washington State—to assist citizens, businesses, and local governments in making informed decisions regarding adaptation to climate change. Information should be shared to assist entities that need more focused analyses and assessments. Such information should be provided at a scale that is useful and meaningful for both planning and investment purposes.

Important next steps to implementing any of TAG 1's recommendations include the development of communication and education materials so the public and decision makers can be well informed to make climate-ready decisions. It is also important to identify and leverage existing tools and resources, such as the EPA Climate Ready Water Utilities Toolbox and Climate Ready Water Utilities Working Group report and the Swinomish Climate Change Initiative: Climate Adaptation Action Plan.

Guidance for Integration

- Consider economic impacts; state, regional, and local embedded cultural values when choosing strategies and the impact of those strategies to existing and long-term ability to respond to change.
- Begin with interim tools and local information.
- Caution—avoid negative unintended consequences. Think through how recommendations can be misused.

7. References

Impacts of Climate Change:

- The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. 2009. Climate Impacts Group, University of Washington, Seattle, Washington. http://cses.washington.edu/cig/res/ia/waccia.shtml#report

Adaptation and Preparation Planning Resources

- EPA, State and Local Climate and Energy Program, Impacts and Adaptation, http://www.epa.gov/statelocalclimate/local/topics/impacts-adaptation.html
- ICLEI Climate Resilient Communities Program http://www.icleiusa.org/adaptation/
- King County/ICLEI/CIG Guidebook, September 2007 http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf
- Pew, Adaptation Planning – What U.S. States and Localities are Doing, http://www.pewclimate.org/docUploads/state-adapation-planning-august-2009.pdf
- United States National Academy of Sciences. 2010. Adapting to the Impacts of Climate Change. Part of America's Climate Choices Study. http://americasclimatechoices.org/paneladaptation.shtml
- Washington Climate Change Impacts Assessment, Climate Impacts Group (CIG) http://cses.washington.edu/db/pdf/wacciach11adapt654.pdf

State, Local, and Tribal Adaptation Plans:

- California Adaptation Strategy, Dec. 2009, http://www.climatechange.ca.gov/adaptation/
- City of Olympia, http://www.ci.olympia.wa.us/community/sustainability/climate-change.aspx
- City of Seattle, Climate Action Plan, http://www.seattle.gov/archive/climate/
- King County, http://www.kingcounty.gov/environment/climate.aspx
- Swinomish Indian Tribal Community, Office of Planning and Community Development. 2010. Swinomish Climate Change Initiative: Climate Adaptation Action Plan. http://www.swinomish-nsn.gov/climate_change/project/reports.html
- Washington Climate Change Challenge. 2008. Leading the Way: Preparing for the Impacts of Climate Change in Washington. Recommendations of the Preparation and Adaptation Working Groups, http://www.ecy.wa.gov/pubs/0801008c.pdf

Economics

- Impacts of Climate Change on Washington's Economy, http://www.ecy.wa.gov/climatechange/economic_impacts.htm

Energy

- Northwest Power and Planning Conservation Council. 2010. Sixth Northwest Conservation and Electric Power Plan. http://www.nwcouncil.org/energy/powerplan/6/default.htm

Flooding

- National Association of State Floodplain Managers, Strategic plan 2007-2012. http://www.floods.org/PDF/ASFPM_Strategic_Plan_2007-2012.pdf
- California Dept. of Water Resources, Oct. 2008. Managing an Uncertain Future. Climate Change Adaptation Strategies for California's Water. http://www.floodplain.org/cmsAdmin/uploads/DWR_ClimateChangeWhitePaper_Oct08.pdf
- California Water Plan Update 2009. http://www.waterplan.water.ca.gov/cwpu2009/index.cfm

  http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v2c28_floodriskmgmt_cwp2009.pdf
- Toronto and Region Conservation Authority for the Region of Peel. February 2009. Preparing for the Impacts of Climate Change on Stormwater and Floodplain Management: A Review of Adaptation Plans and Practices http://sustainabletechnologies.ca/Portals/_Rainbow/Documents/95903b5b-93a9-4cc0-8a13-7580fdd2b7c8.pdf
- Floodplain Management in NSW – Adapting for Sea Level Rise. http://www.ipwea.org.au/Content/NavigationMenu/SIGS/ClimateChange/RespondingToSeaLevelChange/DewarMcLuckie_FloodplainManagement.pdf.

Shorelands/Oceans

- US EPA memo: Integrated Reporting and Listing Decisions Related to Ocean Acidification – Memo from EPA to US States to assist States in preparing and reviewing integrated reports related to ocean acidification impacts under Sections 303(d), 305(b), and 314 of the Clean Water Act (CWA). November 2010.
- Addressing Sea Level Rise in Shoreline Master Programs
- Sea Level Rise in the Coastal Waters of Washington – State Joint Ecology/UW CIG Report
- West Coast Governor's Agreement on Ocean Health
- Planning for Climate Change – Ecology's Coastal Training Program
- Mitigating Shoreline Erosion along Sheltered Coasts – Report Summary, National Academy of Sciences (2006)
- Impacts of Climate Change on the Coasts of the Washington – Washington Climate Change Impacts Assessment, Climate Impacts Group (CIG)

Land Use and SEPA

- APA, Climate and Energy Resources, http://www.planning.org/research/energy/resources.htm
- CAKE, http://www.cakex.org/category/sector-addressed/land-use-planning
- Environmental Health Perspectives, Urban Heat, http://ehp03.niehs.nih.gov/article/info%3Adoi%2F10.1289%2Fehp.0901879
- EPA, State and Local Climate and Energy Program, Land Use Planning, http://www.epa.gov/statelocalclimate/local/topics/land.html
- Dept. of Ecology. Greenhouse Gas Emissions and SEPA. http://www.ecy.wa.gov/climatechange/sepa.htm
- ICLEI, STAR Sustainability Goals and Guiding Principles, http://www.icleiusa.org/programs/sustainability/star-community-index/star-goals-and-guiding-principles
- JAPA, Adaptation to Climate Change, http://dx.doi.org/10.1080/01944363.2010.502047

Sustainability

- http://www.greeninfrastructure.net/content/definition-green-infrastructure
- http://cfpub.epa.gov/npdes/home.cfm?program_id=298
- http://greenvalues.cnt.org/green-infrastructure
- http://www.asla.org/ContentDetail.aspx?id=24076
- http://www.americanforests.org/resources/urbanforests/greeninf.php
- http://www.landpolicy.msu.edu/modules.php?name=News&op=viewlive&sp_id=88
- http://www.sustainablesites.org/

Transportation

- AASHTO Transportation and Climate Change Resource Center. http://climatechange.transportation.org/
- US DOT. Transportation and Climate Change Clearinghouse. http://climate.dot.gov/

Water

- City of Olympia. Sea Level Rise Response. PowerPoint presentation. http://olympiawa.gov/en/community/sustainability/climate-change.aspx
- Ecology's Office of the Columbia River, Anticipating Impacts in the Columbia River Basin http://www.ecy.wa.gov/programs/wr/cwp/cr_climate.html

- Ecology, Developing Low Impact Development (LID) Standards Advisory Committee, http://www.ecy.wa.gov/programs/wq/stormwater/municipal/LIDstandards.html.
- Ecology Reclaimed Water Rule Adoption, http://www.ecy.wa.gov/programs/wq/reclaim/index.html
- EPA, Climate Ready Water Utilities, http://water.epa.gov/infrastructure/watersecurity/climate/index.cfm
- EPA Office of Water, Climate Change and Water, http://water.epa.gov/scitech/climatechange/index.cfm
- EPA. 2010. Climate Change Vulnerability Assessments: Four Case Studies of Water Utility Practices. http://water.epa.gov/scitech/climatechange/implementation.cfm#CP_JUMP_489011
- King County, July 2008. Vulnerability of Major Wastewater Facilities to Flooding from Sea-Level Rise. http://your.kingcounty.gov/dnrp/library/archive-documents/wtd/csi/csi-docs/0807_SLR_VF_TM.pdf
- NRDC. "A Clear Blue Future: How Greening California Cities Can Address Water Resources and Climate Challenges in the 21st Century." http://www.nrdc.org/water/lid/
- Washington Climate Change Impacts Assessment, Climate Impacts Group (CIG), Implications for Hydrology http://cses.washington.edu/db/pdf/wacciach3hydrology644.pdf
- Washington Climate Change Impacts Assessment, Climate Impacts Group (CIG), Puget Sound water supply http://cses.washington.edu/db/pdf/wacciach3pswater645.pdf
- Washington Climate Change Impacts Assessment, Climate Impacts Group (CIG), Yakima Basin water supply http://cses.washington.edu/db/pdf/wacciach3yakima646.pdf
- Climate Impacts Group, WA Climate Impacts Assessment, Chapter 9 - Precipitation Extremes and the Impacts of Climate Change on Stormwater Infrastructure in Washington State , http://cses.washington.edu/db/pdf/wacciach9storminfra652.pdf

Appendix A: Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts

Prepared by the University of Washington Climate Impacts Group

December 16, 2010

The information provided below is largely assembled from work completed for the 2009 Washington Climate Change Impacts Assessment. Other sources have been used where relevant, but this summary should not be viewed as a comprehensive literature review of Pacific Northwest (PNW) climate change impacts. Confidence statements are strictly qualitative with the exception of IPCC text regarding rates of 20th Century global sea level rise. Note that periods of months are abbreviated by each month's first letter, e.g., DJF = Dec, Jan, Feb.

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Temperature	Increasing temperatures expected through 21st century	Projected multi-model change in average annual temperature (with range) for specific benchmark periods: • 2020s: +2°F (1.1 to 3.4°F)** • 2040s: +3.2°F (1.6 to 5.2°F) • 2080s: +5.3°F (2.8 to 9.7°F) These changes are relative to the average annual temperature for 1970-1999. The projected *rate* of warming is an average of 0.5°F per decade (range: 0.2-1.0°F). ---------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected warming by the end of this century is much larger than the regional warming observed during the 20th century (+1.5°F), even for the lowest scenarios.	Warming expected across all seasons with the largest warming in the summer months (JJA) Mean change (with range) in winter (DJF) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.1°F (0.7 to 3.6°F)** • 2040s: +3.2°F (1.0 to 5.1°F) • 2080s: +5.4°F (1.3 to 9.1°F) Mean change (with range) in summer (JJA) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.7°F (1.0 to 5.3°F)** • 2040s: +4.1°F (1.5 to 7.9°F) • 2080s: +6.8°F (2.6 to 12.5°F)	High confidence that the PNW will warm as a result of increasing greenhouse gas emissions. All models project warming in all scenarios (39 scenarios total) and the projected change in temperature is statistically significant.	Mote and Salathé 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Precipitation *(extreme precipitation addressed in separate field)*	A small increase in average annual precipitation is projected (based on the multimodel average, Mote and Salathé 2010), although model-to-model differences in projected precipitation are large (see "Confidence"). Potentially large seasonal changes are expected.	Projected change in average annual precipitation (with range) for specific benchmark periods: • 2020s: +1% (-9 to 12%)** • 2040s: +2% (-11 to +12%) • 2080s: +4% (-10 to +20%) These changes are relative to the average annual temperature for 1970-1999. ---------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected increase in average annual precipitation is small relative to the range of natural variability observed during the 20th century and the model-to-model differences in projected changes for the 21st century	*Summer:* Majority of global climate models (68-90% depending on the decade and emissions scenario) project decreases in summer (JJA) precipitation. Mean change (with range) in JJA precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: -6% (-30% to +12%) ** • 2040s: -8% (-30% to +17%) • 2080s: -13% (-38% to +14%) *Winter:* Majority of global climate models (50-80% depending on the decade and emissions scenario) increases in winter (DJF) precipitation. Mean change (with range) in DJF precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: +2% (-14% to	Low confidence. The uncertainty in future precipitation changes is large given the wide range of natural variability in the PNW and uncertainties regarding if and how dominant modes of natural variability may be affected by climate change. Additional uncertainties are derived from the challenges of modeling precipitation globally. Model to model differences are quite large, with some models projecting decreases in winter and annual total precipitation and others producing large increases. Expect that the region will continue to see years that are wetter than average and drier than average even as that average changes over the long term.	Mote and Salathé 2010; Salathé et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
				+23%)** • 2040s: +3% (-13% to +27%) • 2080s: +8% (-11% to +42%)		

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Extreme precipitation	Precipitation intensity may increase but the spatial pattern of this change and changes in intensity is highly variable across the state.	State-wide *(Salathé et al. 2010)*: More intense precipitation projected by two regional climate model simulations but the distribution is highly variable; substantial changes (increases of 5-10% in precipitation intensity) are simulated over the North Cascades and northeastern Washington. Across most of the state, increases are not significant. For sub-regions *(Rosenberg et al. 2010)*: Projected increases in the magnitude (i.e., the amount of precipitation) of 24-hour storm events in the Seattle-Tacoma area over the next 50 years are 14.1%-28.7%, depending upon the data employed. Increases for Vancouver and Spokane are not statistically significant and therefore cannot be distinguished from natural variability.	Projected increases in the magnitude of 24-hour storm events for the period 2020-2050 for the Seattle-Tacoma area (14.1 to 28.7%) is comparable to the observed increases for 24-hour storms over the past 50 years (24.7%) *(Rosenberg et al. 2009).*	The ECHAM5 simulation produces significant increases in precipitation intensity during winter months (Dec-Feb), although with some spatial variability. The CCSM3 simulation also produces more intense precipitation during winter months despite reductions in total winter and spring precipitation *(Salathé et al. 2010)*	Low confidence. Anthropogenic changes in extreme precipitation difficult to detect given wide range of natural precip variability in the PNW. Computational requirements limit the analysis of sub-regional impacts within WA to two scenarios, reducing the robustness of possible results. Simulated changes are statistically significant only over northern Washington.	Salathé et al. 2010 Rosenberg et al. 2009 Rosenberg et al. 2010
Extreme heat	More extreme heat events expected	Generally projecting increases in extreme heat events for the 2040s, particularly in south central WA and the western WA lowlands *(Salathé et al. 2010).*** Changes in specific regions vary with time period (2025, 2045, and 2085), scenario (low, moderate, high), and region (Seattle, Spokane, Tri-Cities, Yakima) but all four regions and all scenarios show increases in the mean annual number of heat events, mean event duration, and maximum event duration *(Jackson et al. 2010, Table 4).*	Projected increases in number and duration of events is significantly larger than the number and duration of events between 1980-2006 (specific values vary with location, warming scenario, and time period). In western Washington, the frequency of exceeding the 90th percentile daytime	n/a (relevant to summer only)	Medium confidence. There is less confidence in sub-regional changes in extreme heat events due to the limited number of scenarios used to evaluate changes in extreme heat events in Jackson et al. 2010 (9 scenarios) and Salathé et al. 2010 (2 scenarios), although confidence in warmer summer temperatures overall is high (see previous entry for temperature).	Salathé et al. 2010 Jackson et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		---------- ** *Definitions of extreme heat varied between the two studies cited here. Salathé et al. 2010 defined a heat wave as an episode of three or more days where the daily heat index (humidex) value exceeds 90°F. Jackson et al. 2010 defined heat events as one or more consecutive days where the humidex was above the 99th percentile.*	temperature (Tmax) increases from 30 days per year in the current climate (1970-1999) to 50 days per year in the 2040s (2030-2059).			
Snowpack (SWE)	Decline in spring (April 1) snowpack expected	The multi-model means for projected changes in mean April 1 SWE for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: -27% (B1), -29% (A1B) • 2040s: -37% (B1), -44% (A1B) • 2080s: -53% (B1), -65% (A1B) All changes are relative to 1916-2006. Individual model results will vary from the multi-model average.	Projected declines for the 2040s and 2080s are greater than the snowpack decline observed in the 20th century (based on a linear trend from 1916-2006).	n/a (relevant to cool season [Oct-Mar] only)	High confidence that snowpack will decline even though specific projections will change over time. Projected changes in temperature, for which there is high confidence, have the most significant influence on SWE (relative to precipitation).	Elsner et al. 2010
Streamflow	Expected seasonal changes include increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow dominant and rain/snow mix (transient) basins, and decreases in summer streamflow.	The multi-model averages for projected changes in mean annual runoff for Washington state for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: +2% (B1), 0% (A1B) • 2040s: +2% (B1), +3% (A1B) • 2080s: +4% (B1), +6% (A1B)	During the period from 1947-2003 runoff occurred earlier in spring throughout snowmelt influenced watersheds in the western U.S. *(Hamlet et al. 2007)*.	Projected changes in mean cool season (Oct-Mar) runoff for WA state: • 2020s: +13% (B1), +11% (A1B) • 2040s: +16% (B1), +21% (A1B) • 2080s: +26%(B1), +35%	*Regarding changes in total annual runoff:* There is high confidence in the direction of projected change in total annual runoff but low confidence in the specific amount of projected change due to the large uncertainties that exist for changes in winter (Oct-Mar) precipitation. The large	Elsner et al. 2010 Hamlet et al. 2007 Mantua et al. 2010 Tohver and Hamlet 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
	Increasing risk of extreme high and low flows also expected. In all cases, results will vary by location and basin type.	All changes relative to 1916-2006; numbers rounded to nearest whole value *(Elsner et al. 2010)* The risk of lower low flows (e.g., lower 7Q10** flows) increases in all basin types to varying degrees. The decrease in 7Q10 flows is greater in rain dominant and transient basins relative to snow-dominant basins, which generally see less snowpack decline and (as a result) less of a decline in summer streamflow than transient basins. *(Mantua et al. 2010; Tohver and Hamlet 2010)* Changes in flood risk vary by basin type. Spatial patterns for the 20-year and 100-year flood ratio (future/historical) indicate slight or no increases in flood risk for snowmelt dominant basins due to declining spring snowpack. There is a progressively higher flood risk through the 21st century for transient basins, although changes in risk in individual transient basins will vary. Projections of flood risk for rain dominant basins do not indicate any significant change under future conditions, although increases in winter precipitation in some scenarios nominally increase the risk of flooding in winter. *(Tohver and Hamlet 2010, in draft)*		(A1B) Projected changes in mean warm season (Apr-Sept) runoff for WA state: • 2020s: -16% (B1), -19% (A1B) • 2040s: -22% (B1), -29% (A1B) • 2080s: -33%(B1), -43% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value. *(Elsner et al. 2010)*	uncertainties in winter precipitation are due primarily to uncertainty about the timing of, and any changes in, dominant models of natural decadal variability that influence precipitation patterns in the PNW (e.g. the Pacific Decadal Oscillation) as well as changes in precipitation caused by climate change. *Regarding streamflow timing shifts:* There is high confidence that peak streamflow will shift earlier in the season in transient and snow-dominant systems due to projected warming and loss of April 1 SWE. There is less confidence in the specific size of the shift in any specific basin given uncertainties about changes winter precipitation *(see previous comment)*. *Regarding summer streamflows:* Overall, there is high confidence that summer streamflow will decline due to projected decreases in	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		---------- *** 7Q10 flows are the lowest stream flow for seven consecutive days that would be expected to occur once in ten years.*			snowpack (relevant to snow dominant and transient basins) and increasing summer temperatures (relevant to all basin types). There is medium confidence that late summer streamflow will decline given 1) the sensitivity of late summer streamflow to uncertain precipitation changes, and 2) uncertainties about if and how groundwater contributions in any given basin may affect late summer flows. For all changes in streamflow, confidence in *specific* projected values is low due to high uncertainty about changes in precipitation and decadal variability.	
Sea level	Varying amounts of sea level rise (or decline) projected in Washington due to regional variations in land movement and coastal winds.	Projected global change (2090-2099) according to the IPCC: 7-23", relative to 1980-99 average *(Solomon et al. 2007)*** 2050: Projected medium change in Washington sea level (with range) *(Mote et al. 2008)*: • NW Olympic Pen: 0" (-5-14")	Relative change in Washington varies by location. Globally, the average rate of sea level rise during the 21st century very likely‡ (>90%) exceeds the 1961-2003 average rate (0.07 ± 0.02 in/year) *(Solomon et al. 2007)*	Wind-driven enhancement of PNW sea level is common during winter months (even more so during El Niño events). On the whole, analysis of more than 30 scenarios found minimal changes in average wintertime northward winds in the PNW. However, several models produced strong increases. These potential increases contribute to the upper estimates for WA sea level	High confidence that sea level will rise globally. Confidence in the amount of change at any specific location in Washington varies depending on the amount of uncertainty associated with the global and local/regional factors affecting rates of	Mote et al. 2008 Solomon et al. 2007

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		• Central & So. Coast: 5" (1-18") • Puget Sound: 6" (3-22") 2100: Projected medium change in WA sea level (with range) *(Mote et al. 2008)*: • NW Olympic Peninsula: 2" (-9-35") • Central & So. Coast: 11" (2-43") • Puget Sound: 13" (6-50") ---------- ** *Since 2008, numerous peer-reviewed studies have offered alternate estimates of global sea level rise. The basis for these updates are known deficiencies in the IPCC's 2007 approach to calculating of global sea level rise, including assumptions of a near-zero net contribution from the Greenland and Antarctic ice sheets to 21st century sea level rise. A comparison of several studies in Rahmstorf 2010 (Figure 1) shows projections in the range of 1.5ft to over 6ft. Overall, recent studies appear to be converging on projected increases in the range of 2-4ft (e.g., Vermeer and Rahmstorf (2009), Pfeffer et al. 2008, Grinsted et al. 2009, Jevrejeva et al. 2010).*	---------- ‡ *= as defined by the IPCC's treatment of uncertainties (Solomon et al. 2007, Box TS1)*	rise. *(Mote et al. 2008)*	sea level rise. Regionally, there is high confidence that the NW Olympic Peninsula is experiencing uplift at >2 mm/yr. There is less confidence about rates of uplift along the central and southern WA coast due to sparse data, but available data generally indicate uplift in range of 0-2mm/yr. There is high uncertainty about subsidence, and rates of subsidence where it exists, in the Puget Sound region. Although annual rates of current and future uplift and subsidence (a.k.a. "VLM") are well-established at large geographic scales, determining rates at specific locations requires additional analysis and/or monitoring. Uncertainties around future rates are unknown and would be affected by the occurrence of a subduction zone earthquake.	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Wave Heights	Increase in "significant wave height" ** expected in the near term (through 2020s) based on research showing that a future warmer climate may contain fewer overall extra-tropical cyclones but an increased frequency of very intense extra-tropical cyclones (which may affect the extreme wave climate). ---------- *** "Significant wave height" is defined as the average of the highest 1/3 of the measured wave heights within a (typically) 20 minute period*	Based on extrapolation of historical data‡ and assumptions that the historical trends continue into the future, the 25, 50, and 100 year significant wave height events are projected to increase approximately 0.07m/yr (2.8 in/yr) through 2020s. ---------- *‡ the five highest significant wave heights measured at Washington NDBC Buoy #46005 (at the WA/OR border)*	Projected changes through 2020 are comparable to the observed increase in the average of the five highest significant wave heights for the mid 1970s-2007 (0.07m/yr, or 2.6 in/yr). *More on past changes:* Over the last 30 years, the rate of increase for more extreme wave heights has been greater than the rate of increase in average winter wave height. For the WA/OR outer coast (mid 1970s-2007): • The average of all winter significant wave heights increased at a rate of 0.023m/yr (0.9 in/yr) • Annual maximum significant wave height increased 0.095m/yr (3.7 in/yr).	These findings relate to the winter season (Oct-March), which is the dominant season of strong storms	*Regarding general trend:* There is low confidence that significant wave height will increase given the dependence of this increase on a limited number of studies showing potential increases in the intensity of the extra-tropical cyclones that can affect the extreme wave climate. *Regarding specific projected increases in wave height:* There is low confidence in the calculated trend for 25, 50, and 100 year significant wave height events given that this calculation is based on extrapolation of historic data and assumptions of continued historical trends rather than physical modeling.	Ruggiero et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Sea surface temperature (SST)	Warmer SST expected	Increase of +2.2°F projected for the 2040s (2030-59) for coastal ocean between 46°N and 49°N. Changes are relative to 1970-99 average.	Projected change is substantially outside the range of 20th century variability.	*No information currently available*	Medium to low confidence in the degree of warming expected for the summertime upwelling season. Global climate models do not resolve the coastal zone and coastal upwelling process very well, and uncertainty associated with summertime upwelling winds also brings uncertainty to coastal SSTs in summer.	Mote and Salathé 2010
Coastal upwelling	Little change in coastal upwelling expected	The multimodel average mean change in winds that drive coastal upwelling is minimal	Comparable to what has been observed in the 20th century	Little change in seasonal patterns.	Low confidence given the fact that this hasn't been evaluated with dynamical downscaling of many climate model scenarios at this point.	Mote and Salathé 2010
Ocean acidification	Continuing acidification expected in coastal Washington and Puget Sound waters	The global surface ocean is projected to see a 0.2 - 0.3 drop in pH by the end of the 21st century (in addition to observed decline of 0.1 units since 1750) (Feely et al. 2010). pH in the North Pacific, which includes the coastal waters of Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO2 to 560 and 840 ppm, respectively (Feely et al. 2009). pH in Puget Sound is projected to decrease, with ocean acidification	Projected global changes are larger than the decrease of 0.1 units since 1750, and greater than the trend in last 20 years (0.02 units/decade). The observed decrease of 0.1 units since 1750 is equivalent to an overall increase in the hydrogen ion concentration or "acidity" of about 26%.	The contribution of ocean acidification to Dissolved Inorganic Carbon (DIC) concentrations within the Puget Sound basin can vary seasonally. Ocean acidification has a smaller contribution to the subsurface increase in DIC concentrations in the summer (e.g., 24%) compared to winter (e.g., 49%) relative to other processes (Feely et al. 2010).	For global changes, confidence that oceans will become more acidic is high. Results from large-scale ocean CO_2 surveys and time-series studies over the past two decades show that ocean acidification is a predictable consequence of rising atmospheric CO_2 that is independent of the uncertainties and outcomes of climate change (Feely et al.	Feely et al. 2009 Feely et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		accounting for an increasingly large part of that decline. Feely et al. 2010 estimated that ocean acidification accounts for 24-49% of the pH decrease in the deep waters of the Hood Canal sub-basin of Puget Sound relative to estimated pre-industrial values. Over time, ocean acidification from a doubling of atmospheric CO2 could account for 49-82% of the pH decrease in Puget Sound subsurface waters.			2009). For Puget Sound, estimates of the contribution of ocean acidification to future pH decreases in Puget Sound have very high uncertainty since other changes that may occur over the intervening time were not taken into account when calculating that estimate (a percentage) (Feely et al. 2010).	

Sources

Elsner, M.M., L. Cuo, N. Voisin, J. Deems, A.F. Hamlet, J.A. Vano, K.E.B. Mickelson, S.Y. Lee, and D.P. Lettenmaier. 2010. Implications of 21st century climate change for the hydrology of Washington State. *Climatic Change* 102(1-2): 225-260, doi: 10.1007/s10584-010-9855-0.

Feely, R.A., S.C. Doney, and S.R. Cooley. 2009. Ocean acidification: Present conditions and future changes in a high-CO_2 world. *Oceanography* 22(4):36–47.

Feely, R.A., S.R. Alin, J. Newton, C.L. Sabine, M. Warner, A. Devol, C. Krembs, and C. Maloy. 2010. The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. *Estuarine, Coastal and Shelf Science* 88(4): 442-449, doi:10.1016/j.ecss.2010.05.004.

Grinsted, A. J.C. Moore, and S. Jevrejeva. 2009. Reconstructing sea level from paleo and projected temperatures 200 to 2100 AD. *Climate Dynamics* 34:461–472, doi: 10.1007/s00382-008-0507-2.

Hamlet, A.F., P.W. Mote, M.P. Clark, and D.P. Lettenmaier. 2007. 20th century trends in runoff, evapotranspiration, and soil moisture in the Western U.S. *Journal of Climate* 20(8): 1468-1486. DOI: 10.1175/JCLI4051.1

Jackson, J.E., M.G. Yost, C. Karr, C. Fitzpatrick, B. Lamb, S.H. Chung, J. Chen, J. Avise, R.A. Rosenblatt, and R.A. Fenske. 2010. Public health impacts of climate change in Washington State: projected mortality risks due to heat events and air pollution. *Climatic Change* 102(1-2): 159-186, doi: 10.1007/s10584-010-9852-3.

Jevrejeva, S., J. C. Moore, and A. Grinsted. 2010. How will sea level respond to changes in natural and anthropogenic forcings by 2100? *Geophys. Res. Lett.*, 37, L07703, doi:10.1029/2010GL042947.

Mantua, N.J., I. Tohver, and A.F. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change* 102(1-2): 187-223, doi: 10.1007/s10584-010-9845-2.

Mote, P.W., and E.P. Salathé. 2010. Future climate in the Pacific Northwest. *Climatic Change* 102(1-2): 29-50, doi: 10.1007/s10584-010-9848-z.

Mote, P.W., A. Petersen, S. Reeder, H. Shipman, and L.C. Whitely Binder. 2008. *Sea Level Rise in the Coastal Waters of Washington State*. Report prepared by the Climate Impacts Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington and the Washington Department of Ecology, Lacey, Washington.

Pfeffer, W.T., J. T. Harper, and S. O'Neel. 2008. Kinematic constraints on glacier contributions to 21st-century sea-level rise. *Science* 321: 1340, doi: 10.1126/science.1159099.

Rahmstorf, S. 2010. A new view on sea level rise. *Nature Reports Climate Change* Vol. 4: 44-45, doi:10.1038/climate.2010.29

Rosenberg, E.A., P.W. Keys, D.B. Booth, D. Hartley, J. Burkey, A.C. Steinemann, and D.P. Lettenmaier. 2009. Precipitation extremes and the impacts of climate change on stormwater infrastructure in Washington State. Chapter 9 in *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate*, Climate Impacts Group, University of Washington, Seattle, Washington.

Rosenberg, E.A., P.W. Keys, D.B. Booth, D. Hartley, J. Burkey, A.C. Steinemann, and D.P. Lettenmaier. 2010. Precipitation extremes and the impacts of climate change on stormwater infrastructure in Washington State. *Climatic Change* 102(1-2): 319-349, doi: 10.1007/s10584-010-9847-0.

Ruggiero, P., P.D. Komar, and J.C. Allan. 2010. Increasing wave heights and extreme-value projections: the wave climate of the U.S. Pacific Northwest, *Coastal Engineering* 57: 539-552, doi:10.1016/j.coastaleng.2009.12.005.

Salathé, E.P., L.R. Leung, Y. Qian, and Y. Zhang. 2010. Regional climate model projections for the State of Washington. *Climatic Change* 102(1-2): 51-75, doi: 10.1007/s10584-010-9849-y.

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and D. Wratt. 2007. *Technical Summary*. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Tohver, I. and A.F. Hamlet. 2010. Impacts of 21st century climate change on hydrologic extremes in the Pacific Northwest region of North America. Chapter 7 in Final Report for the Columbia Basin Climate Change Scenarios Project, Climate Impacts Group, University of Washington, Seattle, Washington.

Vermeer, M. and S. Rahmstorf. 2009. Global sea level linked to global temperature. *Proceedings of the National Academy of Sciences* 106(51): 21527-21532, doi: 10.1073/pnas.0907765106

Appendix B: Detailed Water Supply Strategies and Actions

Principles for Prioritizing Water Supply Strategies

1. An accurate assessment of current and future water supply and water demand should inform all water management decisions.
2. The full range of alternatives available for meeting the demonstrated water supply shortfall must be evaluated.
3. Water supply and demand should be managed and addressed using the most cost-effective tools that benefit communities, the environment, promote economic vitality, and that can be readily adapted to meet changing circumstances.
4. Beneficiaries of water management services and supply projects should pay for an equitable share of the costs.
5. Public involvement should be a priority during each stage of the evaluation of a new water supply project.
6. Prioritize strategies that help the state meet legal/regulatory obligations including recovery of ESA listed species, water quality standards, etc.
7. Prioritize strategies that utilize green infrastructure and efficiency measures as a core component to water quality and management.

Recommended Strategies and Actions

1. Determine water availability and demand in high priority basins

a) Improve statewide water availability and supply and demand forecasting *(high priority)*

Ecology is preparing a description of surface water and where feasible, groundwater, availability throughout Washington. The document will describe where and when water is available, the multiple factors that affect availability, and potential options for obtaining future water rights. Ecology is currently conducting a detailed assessment of water supply and demand forecasting in the Columbia basin. This work could be expanded to cover all areas of the state. There are many existing studies and plans to draw from on the west side of the state. Rather than recreate the wheel, Ecology would maximize the use of existing resources and information. Discussion will also involve GHG implications of energy intensive plans to bring water to basins where there is currently not enough water available to meet forecasted demand.

b) Develop water budgets in basins that will be impacted by climate change *(high priority)*

Obtain basin water budget information needed to understand hydrologic systems in areas where information is lacking. This information could be used to identify future supply problems, support mitigation plans and reclaimed water projects, assist water banking and stormwater management, and identify areas where further water development (aquifer storage and recovery, off channel storage) would be acceptable. As an additional resource, some watershed plans adopted under Chap 90.82 RCW may also have relevant information and studies assessing water availability where such information was

previously lacking. This approach differs from 1.1.1 in that it is more local: a WRIA by WRIA approach will be taken where feasible given aquifer connectivity. Barriers and resiliency will also be part of the discussion.

c) **Clarify water rights and claims through streamlined judicial processes or non-judicial settlement agreements to enable more accurate supply and demand forecasting (*high priority*)**
Increase adjudication of water rights and claims to determine legally allocated water in select basins via performing more adjudications, streamlining the adjudication process, and/or creating water courts. Desired end result could also be achieved by entering into more non judicial settlement agreements. Pursue the quantification of federal reserve rights where feasible.

2. Develop and implement water strategies to manage supply and demand in a climate changed future

a) **Transition from watershed planning to implementation in high priority climate change affected basins - evaluate options to manage supply and demand exploring a full range of options including an increased use of water masters (*high priority*)**
Compile and integrate data of existing water use (both instream and out of stream), current ground and surface water supplies, information in locally adopted watershed plans, and anticipated future demands based on climate change and other factors (e.g. full inchoate water rights build out in incorporated areas). Incorporate data from OCR's 2011 Supply and Demand Forecast and information from Chap. 90.82 RCW watershed plan development activities. Identify gaps.

Increase the amount of water masters. The Water Resources Program does not have enough water masters to effectively deal with statewide water use compliance and enforcement needs.

b) **Prioritize low-cost, no regrets options such as conservation, efficiency (demand management) and expanded use of non-potable water (high priority strategy, suite of options available)**

i. **Expand the use of non-potable water supplies**
Implement strategies to conserve, be more efficient and expand use of reclaimed water and non-potable water supplies for non-potable uses. These strategies can be an essential component of meeting water demand in a climate changed future.

Propose legislation or develop an Ecology issued Interpretive Statement to allow the beneficial use of unpermitted stormwater as part of a stormwater management project (stormwater management often involves beneficial use so the two are not mutually exclusive) provided the use of stormwater in the stormwater management plan meets certain conditions (essentially serves to mimic the natural hydrograph).

ii. **Decrease demand through demand side efficiency and demand management**
Implement a new rebate or grant program to help pay for WaterSense certified water efficiency plumbing fixture replacement and for landscape conversion to low water use types. Ask other organizations (i.e. Partnership Water Conservation) to administer program.

Establish grant/loan program for privately-owned water systems to install source/service meters. As a condition of loan/grant, require that they demonstrate financial capacity/viability.

c) **Evaluate options such as new supply, timing and transfers (high priority strategy, suite of options available)**

i. **Emphasize water supply options that provide instream and out of stream benefits**
Address statewide water supply and demand issues that complement the work the Office of the Columbia River is doing on the eastside of the State.

Propose a budget add for a desalination study for water-scarce coastal area(s) where new water from a desalination project would replace diversion of water from an over appropriated source to benefit ESA listed fish species.

d) **Improve legal and fiscal frameworks for water banking**
Propose legislation and pursue rulemaking to seed funds for regional water banks, provide guidance for creation of banks for statewide consistency and mitigation, charge cost recovery fees for transaction costs, create revolving accounts for funds to purchase water and receive funds for mitigation payments.

e) **Improve supply for streamflow mitigation and use through aquifer storage and recovery (ASR) program**
Supplement the state water plan and water supply action items with a deliberate effort to identify and evaluate the feasibility of ASR opportunities throughout the state. This action entails conducting a statewide assessment to identify viable aquifer recharge and recovery projects that provide the greatest benefit. Opportunities to integrate stormwater management and wetland restoration practices into aquifer recharge and baseflow augmentation efforts would also be considered where appropriate.

f) **Obtain water savings through green building legislation, building code updates and tax holidays**
Propose legislation to authorize Ecology and General Administration to work together to develop rules that would require public buildings to integrate water saving strategies in addition to their existing requirement to comply with green building standards. This effort could be broadened to address sustainable sites and heating, cooling and energy water related issues.

Amend RCW 36.70A to encourage local governments to adopt ordinances that require low water use developments. Encourage local governments to offer incentives to these types of developments. Use WaterSense certified single-family housing concept.

Option A: Amend/update RCW 19.27.170 to mandate water efficiency standards. Develop legislation that would allow a 2-year pilot program under this code with public buildings. The pilot phase will allow for evaluation of feasibility and identify issues that could be modified in official code change. Option B: Amend code or update RCW 19.27.170 (water conservation performance standards, state building code) to mandate/phase in WaterSense and other water efficiency standards. Could start with new state funded building only and phase in other new construction.

Support efforts to mandate rainwater harvesting in urban areas with supply and/or stormwater management issues via locally administered building, health or other relevant ordinance or code amendments.

Under Washington law, purchases of personal property are subject to sales taxes. Implement a sales tax holiday (a temporary period such as one week for example) during which purchases of certain items are exempt from the sales taxes.

g) Develop industrial and agricultural conservation and efficiency standards and continue to improve municipal conservation and efficiency
There are currently municipal conservation standards but no similar standards for the industrial and agricultural sector.

3. Integrate climate change into policy and planning efforts

a) Integrate water supply considerations into land use planning in high priority basins *(high priority)*
Develop recommendations for research, legislation, and, if needed, regulations that address changes in hydrology at the subbasin scale. Consider integrating water resource management tools, stormwater management and land use.

b) Map critical source water and groundwater infiltration areas in order to identify and protect them (e.g. through requiring their protection in comprehensive plans)

c) Update the definition of drought and remove barriers to drought relief to better reflect climate change
Remove the 10 percent cap for non-agriculture uses for emergency drought relief.

Clarify and explain to stakeholders that the definition of “normal” in the context of drought conditions would be better based on a 30-year running mean, instead of the mean of the entire historic record.

4. Increase monitoring and mapping to better understand the effects of climate change

a) Increase water use monitoring *(high priority)*
Enhance and improve water use monitoring throughout the state. Monitor and quantify new water uses including water rights permitting actions and permit-exempt uses (new and existing where appropriate using building permits or other appropriate data). Compare water use to water rights. Increase compliance and enforcement.

b) Increase water rights mapping *(high priority)*
Digitize all water rights and claims records in the state. Each record (points of diversion or withdrawal and place of use) will be mapped using GIS software. The records will be mapped as recorded on the water right documents (as opposed to field verification). Ecology currently has approximately 35% of the water rights records mapped and this action item will continue this effort. Other items could also be mapped (such as instream flow indicators) to make this more comprehensive. See also PAWG 1.1 and 1.3 (water supply availability and supply and demand forecasting).

c) Increase surface and groundwater monitoring *(high priority)*
Setting instream flows, salmon restoration activities, and other water management strategies demand an effective gaging network. Stream gaging is in high demand across the state but there are insufficient resources to meet needs. Climate change will exacerbate the need for an effective gaging network. Ecology's Watershed Advancement Group (WAG) sanctioned the development of a Statewide Stream Gaging Strategy in late 2007. The outcomes of or recommendations from this strategy should guide this action.

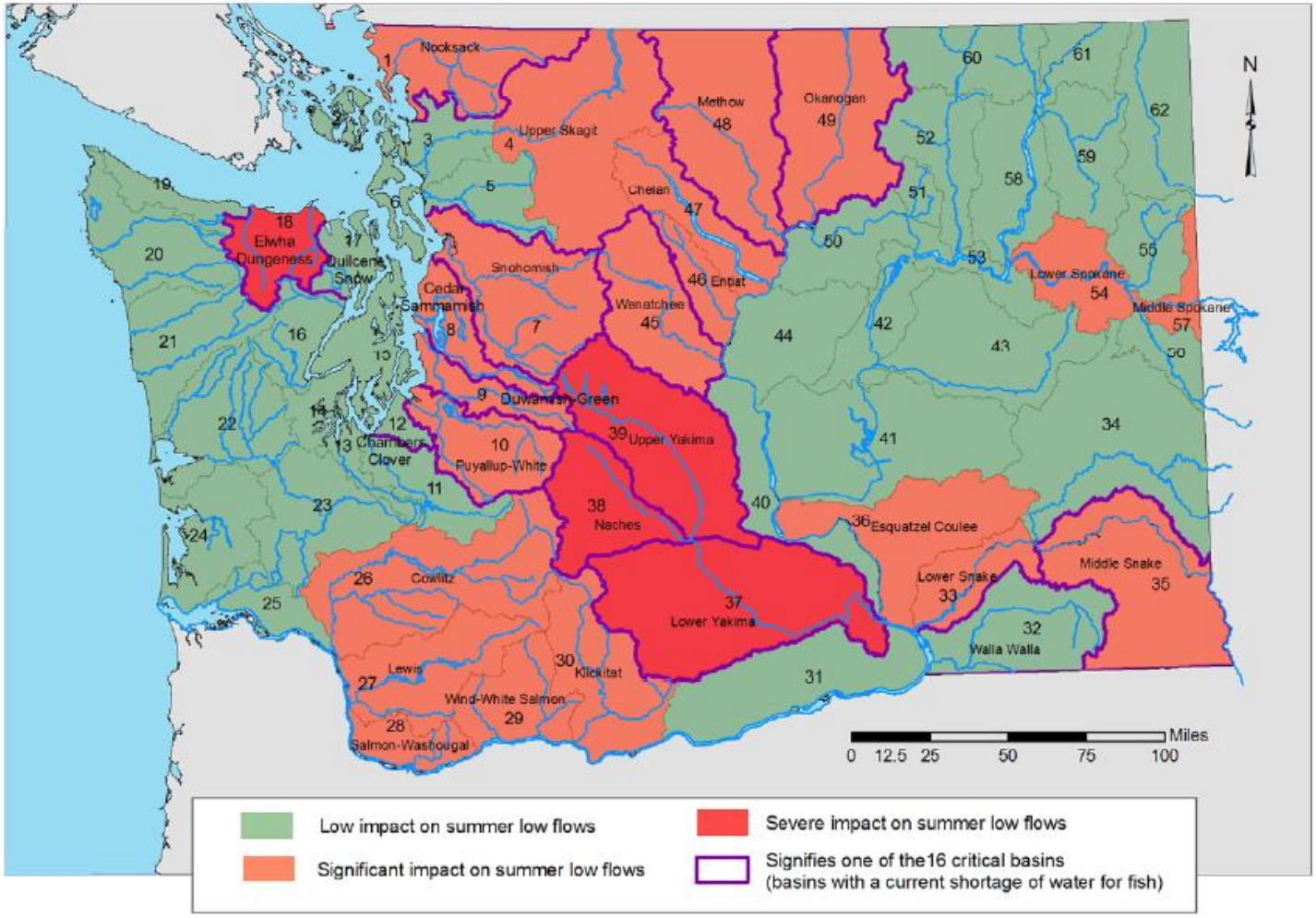
In 2008 Ecology drafted recommendations for a basin-specific ambient groundwater monitoring program that covers all areas of the state. Recommendations included assessment of current monitoring efforts, capture of available and useful data into Ecology's environmental database, improving database usability, establishment of additional monitoring locations, and ongoing assessment of monitoring results. Monitoring efforts could utilize data loggers for continuous water level measurements.

A combination of temporary and full-time staff could collect static water levels (SWLs) of wells for one week prior to irrigation season and one week after across the state. Other time would be spent obtaining access to monitoring locations, coordination with local other agencies collecting data, training, mapping out routes and then entering and evaluating data. One FTE at each region could be in charge of regional water level monitoring program.

d) Create and utilize data integration tools. Assure that all data is available in accessible digital formats (GIS)
Build information management tools to integrate water resources data and information.

Appendix C: Impacts to summer flows by Water Resource Inventory Areas (WRIA)

2040 Projected Climate Change Impact on Summer Flows by WRIA



Appendix D: Invited participants and reviewers

Built Environment, Infrastructure and Communities

Topic Advisory Groups Members

Co-Chairs:

Stephen Bernath	Dept. of Ecology
Nancy Boyd	Dept. of Transportation

Participants and Reviewers:

Hedia Adelsman	Dept. of Ecology
Mark Augustyniewicz	Boeing
Geri Beardsley	Washington State Transit Association
Kristin Bettridge	Dept. of Health
Robert Bippert	Dept. of General Administration
Lloyd Brewer	City of Spokane
Mike Canavan	Federal Highway Administration
Chris Carlson	Office of the Insurance Commissioner
Tom Clingman	Dept. of Ecology
Mike Doherty	Clallam County (alternate)
Milt Doumit	Verizon
Paul Fleming	City of Seattle
Michael Garrity	American Rivers
Glen Gaz	Burlington Northern Santa Fe Railway
David Geroux	Dept. of Ecology
Patricia Jatczak	Office of Superintendent of Public Instruction

Eric Johnson	Washington Public Ports Association
Eric Lohnes	Building Industry Assoc. of Washington
Sandy Mackie	Association of Washington Businesses
Keith Maw	American Planning Association/Washington
Chris McCabe	Association of Washington Businesses
Joanne McCaughan	State Building Code Council
Mary McCumber	Futurewise
Jeanette McKague	Washington Association of Realtors (alternate)
Greg Miller	Washington State Patrol
John Miller	Clallam County
Sheila Miller	Clallam County
Ahmer Nizam	Dept. of Transportation
Tim Nogler	State Building Code Council
Darcy Nonemacher	American Rivers
Thomas O'Keefe	American Whitewater
Joyce Phillips	Dept. of Commerce
Larry Pursley	Washington Trucking Associations
Carol Lee Roalkvam	Dept. of Transportation
Claire Schary	EPA Region 10
Hal Schlomann	Washington Assoc. of Sewer and Water Districts
Mike Schoonover	Washington Association of Realtors
Cal Shirley	Puget Sound Energy
Ginny Stern	Dept. of Health
Chris Townsend	Puget Sound Partnership
John Ufford	Military Dept. Emergency Management Division

Kurt Unger	Dept. of Ecology
Alison Van Gorp	Cascade Land Conservancy
Rick Wagner	Burlington Northern Santa Fe Railway
Rick Walk	City of Lacey
William Weinman	Utilities and Transportation Commission
Josh Weiss	Washington State Association of Counties
Laura Wharton	King County
Dave White	King County (alternate)
Terry Wright	Northwest Indian Fisheries Commission
Lon Wyrick	Thurston Regional Planning Council

Staff:

Joanna Ekrem	Dept. of Ecology
Sandy Salisbury	Dept. of Transportation
Lara Whitely-Binder	University of Washington, Climate Impacts Group

Appendix E: Excerpt from *Decision Frameworks For Effective Responses To Climate Change*

Reprint with permission

Climate change is often characterized as a complex problem because it lacks both a definitive assessment and a clear point at which the problem is solved (Rittel and Webber, 1973; Dietz and Stern, 1998). Complex problems involve intense conflicts over definitions of the problem, objectives, and even what issues and topics are relevant to the decision. They also confront significant uncertainty, so that parties involved in problem solving must rely on highly imperfect, often conflicting information about what is known and not known. Even more difficult, values are intertwined with assessments of fact. Complex problems are commonly thought of as unique; although some aspects of the problem may have been seen before, each complex problem involves a distinctive constellation of constituent problems, meaning that prior experience with other problems may offer little guidance. An iterative risk management framework with a heavy emphasis on learning and embedded in a distributed institutional capacity to make sensible reforms can help address such complex problems (NRC, 2009a).

DECISION FRAMEWORKS FOR EFFECTIVE RESPONSES TO CLIMATE CHANGE page 81 PREPUBLICATION COPY

FIGURE 3.3 An iterative risk management and adaptive governance approach for climate change at multiple levels of government, public and private sectors in which risks and benefits are identified and assessed, responses implemented, evaluated, and revisited in sustained efforts to develop more effective policies or to respond to emerging problems and opportunities.

This iterative risk management has several advantages for climate-related decisions. The approach emphasizes that:

- Action in the face of uncertainty is unavoidable. All assessment and management efforts involve uncertainty, and while it is important to assess and reduce uncertainties where possible, significant uncertainty can rarely be eliminated.
- Eliminating all potential risks is impossible. Even the best possible decision will entail some residual risk.
- Determining which risks are acceptable (and unacceptable) represents an integral part of the process of risk management. Different stakeholders will inevitably hold different views.
- Risk management actions can achieve an appropriate balance among the potential cost and benefits from the broadest range of potential outcomes, taking full consideration of available information on the likelihood of occurrence. These actions can be reassessed and rebalanced in an on-going process over time.