Preparing for the Impacts of Climate Change in Washington:

Draft Recommendations of the Preparation and Adaptation Working Groups

PRELIMINARY DRAFT FOR PUBLIC REVIEW

December 21, 2007

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Executive Summary

To be developed (following public comment)

I. Preparation and Adaptation Needed Now

From ocean beaches to snow-capped mountains, Washington's diverse landscapes are under threat. Worldwide, and here at home, the climate is changing – warming of the climate system is unequivocal. There is widespread international agreement and evidence that climate change impacts are underway; and it is more than 90 percent likely that the accelerated warming of the past 50 to 60 years is due to human contributions.

According to the Climate Impacts Group (CIG) at the University of Washington, a warming of 1° F per decade for the next 50 years is projected for the state of Washington. Climate change is already disrupting Washington's natural environment, economy and communities. We must stop the growth of and eventually reverse greenhouse gas emissions and begin to effectively prepare and adapt to the climate changes.

Preparation and adaptation actions are particularly important given the mounting evidence that some degree of climate change is inevitable and will affect many of the essential resources and services we depend on. Also, impacts and costs of inaction could potentially be very significant and devastating. Recognizing a role for preparation and adaptation does not, however, diminish or detract from the importance of working to reduce greenhouse gases and avoid even worse future impacts.

Washington's Preparation and Adaptation Working Groups

Governor Christine Gregoire, in her commitment to prepare the state for the impacts of climate change (Executive Order 07-02, section C), directed the Directors of the Washington Departments of Ecology and Community, Trade and Economic Development (CTED) to:

- Determine specific steps the state of Washington should take to prepare for the impacts of global warming, including impacts to public health, agriculture, the coastline, forestry and infrastructure.
- Assess what further steps the state of Washington should take to be prepared for the impact of global warming to water supply and management.

To assist with this charge, five Preparation and Adaptation Working Groups (PAWGs) were formed with representatives from state and local governments, tribal, business, academic, and various public and private organizations. The working groups include: Agriculture, Human Health, Coastal and Infrastructure, Forestry, and Water Resources and Quality (Freshwater).

The Climate Impacts Group (CIG), associated with the University of Washington, provided the PAWGs scientific expertise regarding the likely impacts of climate change over the next 50 years on each of the sectors and implications for adaptation.

This document includes reports from the individual PAWGs, as well as supplemental recommendations from the Washington State Department of Fish and Wildlife.

Unifying Themes

In formulating preparation and adaptation strategies and recommendations, the PAWGs identified several recurring and unifying themes:

Early actions are needed while we improve scientific knowledge. In the various sectors, there is enough current scientific information and understanding to support specific recommended actions now while simultaneously gaining understanding and capacity to respond more completely over time. A critical need is the dissemination of current scientific information to decision makers, resource managers, stakeholders, and the public in order to gain support for action.

Impact of climate change on water resources has broad economic, biological and social implications across all sectors. Significant changes in temperature, precipitation and related variables (e.g., stream flow) across the state will cause water availability to decline and will likely increase the frequency of droughts. A reliable supply of water is crucial for communities, businesses, industries, public health, ecosystems, and quality of life in Washington state. Water availability problems will increase conflict over water use and will create conditions that are detrimental to fish and wildlife, water quality and overall health of our watersheds.

Restore and maintain ecosystems. Climate change is likely to make its most dramatic initial impact on fish and wildlife, pushing some species closer to extinction. Climate change can reduce the resiliency of species and ecosystems, which will in turn result in loss of critical ecological services, such as carbon sequestration. Therefore, restoring and maintaining healthy ecosystems is imperative to reducing emissions and adapting to climate impacts.

Preparation and adaptation needs to recognize the variability of potential impacts of climate change on sectors and geographic areas within the state. Unlike mitigation efforts that work somewhat universally, preparation and adaptation is very specific to geographic areas and activities. For example, projected changes in temperature and precipitation will affect forests differently, depending on their elevation and geographic location. Projected increases in summer temperature and impacts on water availability will affect crop yields differently. Warming could adversely affect wine grape growers in parts of Eastern Washington while increasing the potential for growing new crops in the Puget Sound region.

Some populations are affected disproportionately. Climate change has disproportional impacts on the poor and disenfranchised. Increasing temperatures will result in degraded air quality, heat-related illnesses, increases in pests and diseases, and extreme weather events such as floods and landslides. The poor and the isolated often have difficulty gaining access to medical services and amenities that could help them cope with increased temperatures. In addition, they often live in areas that are most susceptible to poor air quality or flooding.

Preparation and adaptation is costly. Adaptation is not likely to be a smooth process or free of costs. While many of the recommendations identified by the PAWGs rely on long-term strategies, such as planning and monitoring, there is universal agreement that action needs to be taken now. These actions, such as strategies for storing water or dealing with increasing weather-related emergencies, require cross-jurisdictional cooperation and adequate funding.

II. Overview of Climate Change Impacts for Washington

The impacts of climate change on Washington (and the Pacific Northwest) will be profound. This document summarizes the trends in observed regional climate during the 20th century, the likely changes in regional climate during the 21st century, and the recent key findings from the interim report of the Climate Impacts Group (CIG) House Bill 1303 (HB1303) Statewide Climate Impacts Assessment (CIG 2007). The statewide assessment project consists of eight sector groups (Hydrology, Agriculture, Salmon, Forests, Coasts, Infrastructure, Energy, and Human Health), in addition to a Climate Scenarios Working Group that serves all other sectors by providing projections of future regional climate downscaled to the state of Washington, and an Adaptation Group that will begin looking at issues in 2008 related to preparing for climate change. Several members of the sectors have also been involved with PAWG recommendations.

CLIMATE CHANGE OF THE 20TH CENTURY

Pacific Northwest climate has experienced substantial change over the 20th Century. Average annual temperature increased 0.7 – 0.9°C (1.5°F) in the Pacific Northwest (or PNW, defined as WA, OR, ID, and western MT) between 1920 and 2000. Temperature trends from 1916-2003 are largest in winter (January-March). Annual precipitation fluctuates on a range of timescales with no clear influence from rising greenhouse gases. Though the average annual precipitation over the last 10 years has been roughly the highest of any 10-year period, it included some exceptionally dry years.

April 1 snow water equivalent (SWE) declined at nearly all sites in the PNW during the past 35-70 years. The declines are strongest at low and middle altitudes, and can be explained by observed increases in temperature and declines in precipitation over the same period of record. Low elevation declines in the Cascades are frequently 40% or more (average across all elevations ~ 29%). Peak streamflow in snowmelt-dominated river basins shifted 0-20 days earlier in much of the PNW between 1948 and 2002. These findings are corroborated by modeling studies that show similar changes in runoff timing.

PROJECTED 21ST CENTURY CLIMATE CHANGE

Projections of 21st Century climate are based on simulations by multiple Global Climate Models (GCMs) with various scenarios of future greenhouse gas emissions. The CIG at the University of Washington utilized GCM results from the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) to make projections of future climate as part of the HB1303 climate impacts assessment. Among the IPCC global emissions scenarios for the next century, CIG selected scenarios referred to as B1 and A1B. B1 represents a slower increase in greenhouse gas emissions with stabilization of CO2 concentrations by 2100. A1B has higher emissions but is not the highest of IPCC scenarios; most modeling groups ran only A1B, A2, and B1.

Based on results from a number of Global Climate Models (GCMs), we can expect annual temperature to increase approximately 0.5°C, or roughly 1.0°F, per decade over the next 50 years (Table 1).

Table 1. Mean and range of future annual and seasonal temperature changes (in °C and °F) for the 2020s and 2040s, relative to 1970-1999. Projections are based on 20 GCMs running B1 and 19 running A1B. Two IPCC emissions scenarios (B1 and A1B) were chosen to bracket the likely range of greenhouse gases.

	2020s: Temperature in °C (°F)			**2040s: Temperature in °C (°F)**		
Season	**B1**	**A1B**	**Range**	**B1**	**A1B**	**Range**
Annual	**+1.2** (2.1)	**+1.3** (2.3)	**+0.6 to +1.9** (1.1 to 3.4)	**+1.7** (3.1)	**+2.3** (4.1)	**+0.9 to +2.9** (1.6 to 5.2)
Winter Dec - Feb	**+1.0** (1.8)	**+1.0** (1.8)	**+0.4 to +2.0** (0.7 to 3.6)	**+1.4** (2.5)	**+1.8** (3.3)	**+0.6 to +2.8** (1.0 to 5.1)
Spring Mar - May	**+1.1** (2.1)	**+1.1** (1.9)	**+0.2 to +2.0** (0.4 to 3.6)	**+1.5** (2.7)	**+1.8** (3.3)	**+0.6 to +3.0** (1.0 to 5.4)
Summer Jun - Aug	**+1.4** (2.5)	**+1.8** (3.2)	**+0.5 to +2.9** (1.0 to 5.2)	**+2.1** (3.7)	**+2.8** (5.0)	**+0.9 to +4.4** (1.5 to 7.9)
Autumn Sep - Nov	**+1.0** (1.8)	**+1.0** (1.8)	**+0.1 to +1.8** (0.1 to 3.2)	**+1.4** (2.6)	**+1.9** (3.5)	**+0.8 to +2.9** (1.4 to 5.2)

The best estimate of annual precipitation, on the other hand, is that it is likely to remain roughly the same as in the 20th Century (Table 2). Some models indicate large increases in winter precipitation and some also indicate large decreases in summer precipitation.

Table 2. Mean and range of future annual and seasonal precipitation changes (in %) for the 2020s and 2040s, relative to 1970-1999. Projections are based on 20 GCMs running B1 and 19 running A1B. Two IPCC emissions scenarios (B1 and A1B) were chosen to bracket the likely range of greenhouse gases.

	2020s: Precipitation change, %			**2040s: Precipitation change, %**		
Season	**B1**	**A1B**	**Range**	**B1**	**A1B**	**Range**
Annual	**+1.8**	**+0.1**	**-9 to +10**	**+2.1**	**+2.0**	**-10 to +11**
Winter Dec - Feb	**+2.0**	**+2.1**	**-14 to +23**	**+2.6**	**+5.1**	**-13 to +27**
Spring Mar - May	**+1.3**	**-0.3**	**-11 to +9**	**+3.3**	**+3.9**	**-11 to +16**
Summer Jun - Aug	**-3.0**	**-7.9**	**-30 to +13**	**-4.6**	**-12.0**	**-30 to +17**
Autumn Sep - Nov	**+5.9**	**+2.8**	**-11 to +20**	**+5.1**	**+4.7**	**-10 to +21**

For marine ecosystems and other aspects of coastal issues, sea surface temperature (SST) is an important quantity. Mean SST from the 20-model GCM average for the late 20th Century will increase only approximately 1.5°C (2.7°F), less than over land, but this is substantially larger than the natural variability, and this will pose challenges to marine ecosystems. The best estimate of sea level rise for

most coastal waters of Washington is 15cm (6 inches) by 2050 and 35cm (14 inches) by 2100, though we cannot rule out much higher rates of sea level rise, say 1.2m (4 feet) by 2100.

PNW REGIONAL IMPACTS OF 21ST CENTURY CLIMATE CHANGE

Key findings based on the CIG interim report (2007) include but are not limited to the summary below. The preliminary key findings are predominantly based on implementation of a delta method approach, in which historical temperature and precipitation inputs are scaled up or down based on the monthly or seasonal (depending on the sector) composite changes predicted by the suite of GCMs.

Water Resources. Climate change has and will continue to impact water resources of the Pacific Northwest with implications for the timing and quantity of snow accumulation, soil moisture, and streamflow. Changes in water availability in turn will impact all resources that rely on surface water. In general, higher temperatures will likely cause an increasing portion of precipitation to fall as rain rather than snow, resulting in continued decreases in spring snowpack and earlier snowmelt, especially at lower elevations. Key findings in the HB1303 interim report on projected changes in regional hydrology are summarized below.

a) The state's snowpack will, on average, be reduced through the next century, with mean changes associated with the average of the AR4 scenarios ranging from 28 to 41% for the 2020s to 2040s for A1B emissions, and 26 to 35% for B1.
b) Changes in summer soil moisture will be associated both with changes in temperature, leading to increased evaporative demand, and reduced summer precipitation, the result of which will be overall decreased soil moisture in both mountainous and arid regions, with some increases at highest elevations.
c) In rain/snow mixed watersheds, projected changes in climate for the 2020s under the A1B scenario show streamflows are slightly higher in autumn, winter and early spring, and lower in late spring and summer, compared to historic conditions (1970-1999 and these changes persist through the century, until by the 2080s the winter rainfall-related peak dominates the seasonal cycle, and much of the spring peak is gone.

Salmon. The impacts of climate change on freshwater salmon habitat follow two primary pathways. The first is direct climatic influence on hydrologic processes that influence the volume and timing of stream flow and stream temperature. The second is via the indirect climatic influences on the human use of water resources that in turn impact the same hydrologic parameters influencing stream flow and temperature. Key findings in the HB1303 interim report on impacts of climate change on salmon populations are summarized below.

a) In the 2001-2006 period, 15% of the stations included in the preliminary analysis had an observed maximum weekly average water temperature greater than the 21ºC (70°F) water quality criteria, and all of those stations are located in the interior Columbia Basin.
b) Under a delta method analysis of the A1B emissions scenario, 49% of these stations are projected to exceed the 21ºC (70°F) criteria by the 2040s, including

many recording stations in southwest Washington and the Puget Sound Lowlands and all the stations in the Columbia Basin. This preliminary projection highlights increased stress on salmon populations that use these watersheds in the warmest summer months.

c) Regional warming will result in reduced springtime snowmelt flooding in snowmelt dominant (mostly eastside) watersheds, and increased fall and winter flooding (including rain on snow events) for warmer (mostly westside) watersheds. The latter will likely reduce egg-to-fry and overwinter survival rates for some fall spawning salmon populations. In contrast, warmer stream temperatures and reduced late-summer-to-early-fall flows are projected for watersheds statewide, and this combination will likely stress salmon populations that utilize freshwater habitat in the warm summer months (adults on their spawning migrations and rearing juveniles).

Infrastructure. Infrastructure systems are among the most critical in modern societies, particularly for urban areas, and so even modest disruptions to them have significant impacts on daily life. Based on our initial studies of potential disruptions resulting from future climate change, critical impacts in the state of Washington will likely involve alterations to the hydrologic regime and their consequences for urban stormwater. Key findings in the HB1303 interim report on impacts of climate change on urban stormwater systems are summarized below.

a) Global climate models predict that precipitation intensity will most likely increase in the Northwestern US over the next 50 years.
b) Municipal water utilities have generally not integrated climate change impacts into stormwater planning and drainage infrastructure.
c) Stormwater impacts and stormwater management already carry significant economic costs for municipalities throughout western Washington, as well as across the rest of the state.

Energy. Climate has a number of direct and indirect effects on energy supply and demand in the Pacific Northwest that are of importance to Washington State. Direct effects include changes in energy demand associated with temperature and changes in the seasonality and annual amount of hydropower related to changes in streamflow timing or annual volume. Some potential indirect effects include changes in hydropower production related to climate change adaptation for other water management objectives. Key findings based on the preliminary estimates of mean annual heating degree days, are summarize by the following:

a) Heating degree days will continue to be the dominant energy-related factor into the 2020s and 2040s based on the A1B emissions scenario, but cooling degree days become a much more important factor in eastern WA as the region warms.
b) In the Spokane metro area, heating degree days will decline by about 15% in the 2040s compared to the historic condition, but cooling degree days will increase by 88%.

Forests. The affects of climate change on forest ecosystems are both direct and indirect. Projected 21st century changes in temperature and precipitation will affect forests differently depending on elevation and proximity to the coast.. Key findings based on the CIG interim report, are summarize by the following:

a) Wildfires are strongly associated with climate, especially in eastside forests. This relationship is expected to continue, particularly the influence of summer drought (low precipitation and warmer temperatures between May and September).
b) Although other insect populations may increase with warmer temperatures, the mountain pine beetle poses the greatest threat of damage to Washington forests over the next several decades because it responds directly to warmer temperatures.
c) Tree species composition will change as species respond uniquely to a changing climate. Washington state forests most likely to experience major changes in composition in a changing climate will be those near the lower treeline on the east side (ponderosa pine and Douglas-fir) and at the upper treeline on both sides of the Cascade Crest
d) Productivity of Douglas-fir forests is likely to decrease statewide. The most vulnerable part of the state will initially be montane Douglas-fir stands on the east side, but eventually the more productive commercial forests of the west side.

Agriculture. The potential impacts of climate change on the state's agriculture will vary across crop types, and dry land and irrigated agriculture in ways that are not yet well known. Key findings of the impacts of climate change on dryland and irrigated agriculture are summarize by the following:

a) The average total water supply available to irrigated agriculture in some eastern Washington irrigated areas (such as the Yakima basin) is likely to decline significantly under climate change, resulting in more frequent and more stringent prorationing of water to holders of junior water rights, and resulting decreases in crop production.
b) For dryland agriculture, climate change will force agricultural practices to adapt to longer growing seasons, reduced summer precipitation, and increasingly competitive weeds.
c) Diseases will generally become more problematic over the next century, especially as a result of warmer temperatures.

Human Health. Rising global temperatures threaten the health and well-being of the entire human population. Five mechanisms through which climate change is likely to affect health have been identified:

- thermal stress/heat waves
- degradation of air quality
- infectious diseases, especially vector-borne and zoonotic diseases (VBZ)
- extreme weather events affecting public safety
- psychological stress, social disruption and economic disparities

The following summarizes the impacts of climate change on these aspects of human health:

a) Short, intense heat waves have been responsible for hundreds of deaths in the United States and thousands in Europe in recent years. As heat waves become more frequent, more intense and longer lasting, the greatest impacts will be felt in cities with milder summers, less air conditioning and higher population densities, which describes the major cities of Washington State.
b) The effects of climate change on air quality known to affect human health are increases in ambient concentrations of ozone and fine particulate matter, and a longer pollen season with increased allergenicity of some aeroallergens. Potential health effects are serious and include asthma, lung cancer, cardiovascular disease, and low birth weight or prematurity in newborns.
c) Increased temperatures and flooding may contribute to communicable disease by influencing the habitat and range of disease reservoirs and vectors, by shaping human behaviors that might lead to increased exposure to a disease or vector, and through effects on the characteristics of the disease pathogen, or on the immune response of the host. Important VBZ in Washington include Hantavirus pulmonary syndrome (spread by rodents), Vibriosis (raw shellfish), and mosquito-borne diseases such as malaria and West Nile virus.

Coasts. The manifestation of climate change on Washington State's coastal sector will be through direct and indirect effects of sea level rise. Changes in atmospheric circulation patterns and coastal vertical land movements will affect the amount of sea level rise we will experience locally. The follow is a summary of project impacts of climate change to coastal areas:

a) GIS based mapping of inundation and flood events shows that episodic flooding will likely pose greater risks than inundation caused by sea level rise. Beach erosion and bluff landslides are also projected to increase.
b) Ecosystems are projected to experience significant changes, most importantly the loss of near-shore marine organisms and coastal habitats as these areas are squeezed between rising water levels and upland barriers. Increases in water temperature may facilitate expansion of disease and increase the range of invasive species. Pocket estuaries, spits, and nearshore habitats with heavily armored shorelines are likely to be the most susceptible.
c) Foresight and planning by public and private property owners, along with shoreline management policies that encourage adaptation, will determine the magnitude of economic impact to high value coastal property, public coastal infrastructure, and shellfish harvests.
d) Social vulnerability varies throughout the coastal zone and dependents on demographic factors such as: age, income, ethnicity, access to resources, and education. These factors influence a community's ability to adapt and coastal tribes, with their cultural connections to the landscape and place based treaty rights, face unique adaptation challenges.

III. Preparation and Adaptation Issues and Recommendations

Human Health
Agriculture
Coastal and Infrastructure
Forestry
Water Resources and Quality
Supplemental Recommendations from Washington Department of Fish & Wildlife

HUMAN HEALTH

Climate change is one of the major public health challenges of the 21st century. Rising global temperatures threaten the health and well-being of the entire human population. Much of the progress we have made in understanding, preventing, and treating human disease could be jeopardized by changes in the earth's climate and ecosystem, both by harming vulnerable patient groups and disrupting the social and health care institutions upon which we depend.

The major impact on the climate in Washington state is captured in the regional climate scenarios developed by the Climate Impacts Group (CIG) at the University of Washington. From the standpoint of human health, the major driving force will be rising temperatures caused by climate change. CIG estimates that by the 2040's, Pacific Northwest mean annual temperature will rise roughly 3-4°F compared with the average for 1970-1999. This increase will occur even if we are successful in stabilizing or reducing the production of greenhouse gases locally and world-wide.

Summer temperatures are expected to rise even more than the annual mean, by as much as 8 °F in the most extreme scenario, increasing the potential for more frequent and/or severe heat waves and reduced air quality, both of which affect human health. Winter temperature increases, though not as severe, will by themselves increase flood risk even if increases in winter precipitation are modest. Rising global temperatures will also lead to significant sea level rise which, if combined with more severe weather events, poses a threat to human populations through coastal erosion, landslides, flooding, inundation, and contamination of coastal aquifers.

The premise of the Governor's Climate Challenge is that the concerted actions of educated citizens and their governments can lessen global climate change, and thus mitigate the deleterious impact on humans. The medical and public health communities have a special responsibility to identify the threats to human health from climate change, and to set in motion collective steps that will help us to prepare for and adapt to those threats. This report is the initial response of the Human Health Preparation and Adaptation Work Group to that challenge.

Key Human Health Impacts and Issues for Washington State

The following is a summary of the most likely serious impacts to human health caused by climate change (see Appendix B for more detailed information on each of these human health areas of concerns).

Thermal Stress

Humans are susceptible to high temperatures, and heat waves are a major public health threat. Elderly and very young populations, pregnant women, and the chronically ill are particularly vulnerable. The frequency and duration of heat waves and thermal stress is expected to increase; temperatures in some Washington towns have already reached 118 °F, and will almost certainly exceed 120 °F in the coming decades. The spectrum of human effects of thermal stress includes heat cramps, brief loss of consciousness, heat exhaustion and heatstroke. Thousands of people have died in the United States from hyperthermia in the last decade alone, and this will continue to grow as a public health problem in Washington state as we experience the negative effects of climate change.

Degradation of Air Quality

Air quality is adversely affected by higher temperatures, causing increases in both ozone levels and particulates. Poor air quality has direct impacts on both respiratory and cardiac function; both acute and chronic pulmonary and cardiovascular disease is exquisitely sensitive to air quality. Large wildfires (greater than 200 acres) - which have become more frequent in the late 20th century with a warming climate - contribute to air pollution, particularly in rural Washington. An enormous amount of effort has been spent in the health sector to try to reduce the harm done by asthma and heart disease as a result of poor air quality. The impacts of climate change must be addressed if progress is going to be made in combating air pollution-related health issues.

Increase in Vector-Borne and Other Infectious Diseases

One of the first impacts of rising temperatures is an expansion of the range of important insect and animal vectors and the diseases they transmit. More than 30 infectious diseases may be affected by climate change, and the whole spectrum of vector-borne and zoonotic disease (animal disease, such as rabies, that can be transmitted to humans) could change as temperatures rise. Many of these conditions – such as West Nile Virus and hantavirus – are already targets of public health monitoring and surveillance, and we need to understand the role that climate change is likely to play as a causal agent in the spread of these diseases. Other diseases such as malaria, dengue fever, and certain vector-borne encephalitides could also become a health problem as temperatures rise.

Impact of Extreme Weather Events

Many climate models suggest an intensification of storms that reach the Pacific Northwest coast. Coupled with rising sea levels from thermal expansion of the oceans and melting of land-based ice sheets world-wide, coastal erosion is expected to become severe. Various factors increase the likelihood of destructive river flooding. Coastal inundation, flooding, and landslides, create direct hazards to humans who are living or traveling in harm's way. In addition, flooding can spread toxins and negatively impact water sources, local septic systems, and combined sewer outflows, each of which can threaten human health in the short and long term.

Social and Psychological Impacts

Socially and economically vulnerable groups will be most affected by climate change, albeit all segments of society are at risk. The poor and the isolated often have difficulty gaining access to medical services, and also live in areas that are most susceptible to poor air quality and some kinds of flooding. Climate change also has the potential to undermine the social institutions that allow us to prepare for, adapt and respond to public health threats. The possibility of uncontrolled migration of climate refugees from even more heavily impacted parts of the world may further strain the public's capacity to respond.

Human Health Preparation and Adaptation Work Group Recommendations

The following preparation and adaptation priority strategies are recommended as initial steps for Washington state to take in our efforts to minimize the potential human health impacts associated with climate change. The Human Health PAWG offers the following high priority, short-term recommendations, described in greater detail below:

1. **Public health surveillance enhancement strategy**
   - 1.1. The departments of Health and Agriculture should collaborate on zoonotic disease surveillance improvements.
   - 1.2. The departments of Health and Ecology should collaborate on air quality surveillance and outreach improvements.
   - 1.3. The Department of Health should increase the overall efficiency and sensitivity of the current surveillance systems to monitor and respond to disease events.
2. **Emergency preparedness and response efforts enhancement strategy**
   - 2.1. A Heat Emergency Task Force should be convened to review emergency management planning requirements and guidelines for heat emergencies and emergency preparedness exercises.
   - 2.2. The Emergency Management Division should coordinate improvements to the state's ability to respond to heat wave emergencies.
3. **Built environment policies enhancement strategy**
   - 3.1. Adapt the built environment to make communities more walkable and pedestrian friendly, and ensure consideration of climate change in planning.
   - 3.2. Adapt the built environment to mitigate the impacts of climate change on human health.

1. Public Health Surveillance Enhancement Strategy

Climate change is anticipated to have impacts on the health of our communities in terms of increased communicable and vector borne diseases, degraded air quality, and extreme weather events. Contributing to the magnitude of these changes is the possible immigration of "climate

refugees" to Washington state (e.g., those individuals fleeing or forced from their community, state or country due to severe climate change impacts), and possible internal displacement of Washington state citizens.

To prepare and adapt to the anticipated, as well as unanticipated, effects of climate change upon the citizens of Washington state, critical public health surveillance systems will need to be enhanced. Public health surveillance is defined by the Centers for Disease Control and Prevention as "the ongoing, systematic collection, analysis, interpretation, and dissemination of data about a health-related event for use in public health action to reduce morbidity and mortality and to improve health." The ongoing and systematic collection of data is critical for monitoring changes in the magnitude of current public health threats and the early detection of new or emerging threats. Public health surveillance will also aid the development and monitoring of strategies to mitigate the impacts of these threats, including those related to climate change.

To prepare for the projected public health impacts of climate change, enhancements to the following existing surveillance systems are recommended: zoonotic diseases; air quality; and notifiable disease conditions.

Recommendation 1.1: The departments of Health and Agriculture should collaborate on zoonotic disease surveillance improvements.

Zoonotic diseases are diseases caused by infectious agents that can be transmitted from animals, directly or via a vector, to humans. Zoonotic disease spread is highly sensitive to climate change due to resulting ecological changes, or changes in human settlement. Surveillance for zoonotic diseases that may affect humans requires the ongoing collection, identification, testing, and reporting of disease among known vectors or animal hosts. The Department of Health and Department of Agriculture should collaborate on zoonotic disease surveillance improvements that include the following:

- Enhance surveillance of vector mosquitoes and mosquito-borne diseases, including such diseases in animals;
- Establish ongoing surveillance of vector ticks and tick-borne diseases;
- Increase monitoring of vector fleas and plague in fleas and animals;
- Establish long-term laboratory capacity and funding for identification and testing of potential arthropod disease vectors and zoonotic disease reservoirs;
- Establish web-based notifiable conditions reporting for veterinarians;
- Increase training of veterinarians on zoonotic diseases and disease reporting; and
- Explore the potential benefits of, and needed authorities for, establishment of Vector Control Districts in Washington State.

Recommendation 1.2: The Department of Health and Department of Ecology should collaborate on air quality surveillance and outreach improvements.

Exposure to air pollutants including ground-level ozone, particulate matter, and allergens – all of which are likely to increase as a result of climate change – poses significant public health risks. Local climate warming is predicted to have a direct impact on air pollution levels due to increase air stagnation events and increased pollution from wildfires, as well as an indirect impact from mitigation activities such as the increased demand for electricity needed for cooling. Currently, the Washington state Department of Ecology is participating in the development of the Northwest Air Data Exchange Network (NWADEN), an electronic network to collect, store, and make available air quality monitoring data. The departments of Ecology and Health should collaborate on air quality surveillance and outreach improvements which include the following:

- Improve coordination and communication between regional air pollution control authorities, non-governmental health organizations, Department of Ecology, Department of Health, and local health jurisdictions;
- Adopt standardized air health-risk communication strategies;
- Improve health information dissemination strategies; and
- Increase health care provider outreach and education on air quality information sources and health implications.

Recommendation 1.3: The Department of Health should increase the overall efficiency and sensitivity of the current surveillance systems to monitor and respond to disease events.
By law, hospitals, health care providers, laboratories, local health jurisdictions and veterinarians, are required to report various disease conditions to the Department of Health within a defined period of time. The list of conditions includes: communicable and infectious diseases, environmental exposure-related diseases and conditions such as childhood lead poisoning, and water-borne and zoonotic diseases. The Department of Health should pursue the following recommendations for increasing the overall efficiency and sensitivity of the current surveillance systems to monitor for and respond to disease events:

- To enhance public health investigation and follow-up on emerging disease trends, revise Washington Administrative Code (WAC) 246-101 to mandate laboratory reporting of patient identification, age, sex, and contact information (home address and phone number) to Department of Health consistent with health care provider and health care facility reporting;
- Require electronic reporting to Department of Health of all notifiable conditions; and
- Develop web-based training modules on notifiable conditions and reporting for health care providers, laboratories, veterinarians, and local health jurisdictions.

To prepare for and adapt to the public health impacts of climate change, it will be important to ensure that surveillance systems include a focus on sensitive populations (i.e. individuals and communities of low socio-economic status, the elderly, and children). Such a focus not only includes data collection, but must also include methods of disseminating essential information to these populations in an appropriate and timely manner.

2. Emergency Preparedness and Response Efforts Enhancement Strategy

As previously described, climate change is predicted to contribute to severe weather events that may have dangerous and deleterious effects on the health of the citizens of Washington state. Washington state should undertake concrete steps to mitigate and prepare for such events, including the following initial recommendations for enhancing emergency preparedness and response efforts.

Recommendation 2.1: A Heat Emergency Task Force should be convened to review emergency management planning requirements and guidelines for heat emergencies and emergency preparedness exercises.

The Emergency Management Division, in collaboration with the Department of Health, should convene a Heat Emergency Response Task F to review the emergency management planning requirements and guidelines for heat emergencies and emergency preparedness exercises. The Heat Emergency Response Task Force membership should strive to improve cooperation across sectors and between agencies, and should include broad representation of state and local health, emergency response, and community agencies and associations.

Recommendation 2.2: The Emergency Management Division should coordinate improvements to the state's ability to respond to heat wave emergencies.

In conjunction with the efforts noted above, the Emergency Management Division should coordinate improvements to the state's ability to respond to heat wave emergencies. Considerations for system improvements should include the following:

- Enhancement of statewide public awareness of the dangers of excessive heat and ways that individuals and the public can prevent health-related problems;
- In close coordination with the National Weather Service, development of an effective statewide early warning system for heat wave emergencies;
- Enhancement of public health infrastructure at the local level that will enable public health organizations to assume the role of Incident Command during heat wave events and to assure effective coordination with state and federal resources (if needed) under National Incident Management System (NIMS) guidelines;
- Improved collaboration among municipal agencies, hospitals, public safety, emergency medical services, industry and businesses, non-governmental organizations, and others;
- Establishment of standards for public cooling centers for those without access to air conditioning;
- Planning for response to extreme heat events accompanied by blackouts or power shortages;
- Plans for providing transportation to at-risk persons to cooling centers or to triage and/or health care facilities; and

- A comprehensive system of training and exercises that enhances interagency coordination, that finds areas for plan improvement, and that revises the plan accordingly.

3. Built Environment Policies Enhancement Strategy

As discussed throughout this report, changes in Washington's climate have the potential to affect the health of our residents in many ways. From more severe flooding events in the winter to increased ground level ozone concentrations in the summer, climate changes will negatively impact public health unless we individually and collectively take action to prepare and adapt to these predicted changes. The ways in which our communities are built and organized will have a significant influence on how severely the health of our communities is impacted by climate change.

At the state level there are two primary vehicles for regulating our built environment. The Growth Management Act (GMA) considers land use planning, and the State Environmental Policy Act (SEPA) focuses on the environmental impacts of specific proposals. The Department of Community, Trade and Economic Development (CTED) leads the implementation of GMA, and the Department of Ecology is the lead for SEPA. GMA and SEPA can be used to consider how our built environment can be adapted to reduce green house gas emissions and reduce the health impacts resulting from further and more severe climate change. The planning and project tools in GMA and SEPA can also be used to ensure decision makers consider and mitigate impacts likely to result from climate changes, before new development occurs. Initial recommendations for enhancing policies targeted towards our built environment include the following:

Recommendation 3.1: Adapt the built environment to make communities more walkable and pedestrian friendly, and ensure consideration of climate change in planning.
CTED should evaluate Growth Management Act requirements and advance policy recommendations to the Legislature that are targeted towards reducing urban sprawl, making communities more walkable and pedestrian friendly and promoting more efficient modes of transportation. ESSB 5186, passed in 2005, encourages alternative transportation by requiring inclusion of bicycle and pedestrian elements in local comprehensive plans. CTED and other state agencies should evaluate the effectiveness of this statute and look for ways to further reduce urban sprawl, making communities more walkable and pedestrian friendly, and promote more efficient modes of transportation. Specifically, as CTED revises and updates the GMA procedural criteria rules, the connection to ESSB 5186 should be strengthened.

The Department of Ecology should pursue revisions to the State Environmental Policy Act (SEPA) rule to ensure climate change considerations are taken into account for non-project proposals (comprehensive plans, ordinances, rules, regulations) and for project proposals (new development). Specific actions could include:

- Improving SEPA guidance and training to government agencies, applicants and the public.
- Amending the SEPA rules to add questions to the environmental checklist specifically addressing climate change.

Appropriate state, regional, and local agencies should work together to modify zoning and development regulations to make it easier, safer, and more efficient for people to drive less. Less combustion of fossil fuels will directly improve air quality, help to reduce the heat-island impacts in cities, and reduce our vulnerability to interruptions of critical energy supplies. Recommendations for local government actions include:

- Provide incentives for compact development and mixed land uses.
- Modify housing policies to promote mixed-income housing development in closer proximity to jobs.
- Design new street networks and retrofitting old street networks to achieve higher connectivity.
- Adopt "Complete Streets" policies so that infrastructure for pedestrians, bicycles, cars, and transit are included in new street construction and in major maintenance activities of existing streets.
- Developing standards for pedestrian environments focused on aesthetics, comfort, safety, and maintenance.
- Prioritize commercial economic development activities that draw and accommodate non-motorized transportation and transit users.

Recommendation 3.2: Adapt the built environment to mitigate the impacts of climate change on human health.

CTED should update requirements for local critical area ordinances so that efforts to develop such ordinances further define and set policy recommendations for appropriate land use activities on or near unstable slopes and flood plains. These updates should:

- Ensure adequate drinking water resources and fire protection are addressed in areas likely to be affected by drought.
- Discourage building in areas identified at a risk from sea-level rise, including the failure of bluffs that may be undermined by sea-level rise, storm surges, or flooding.
- Provide guidance to planners and reviewing agencies on how to analyze and when to mitigate for impacts.

The departments of Health, CTED and Ecology should collaborate to enhance the needed resources and capacity for providing input on land use planning and project review documents, in order to ensure health mitigation measures are considered at both the planning and project stages.

Priority Recommendations for Ongoing Research

Continued study and evaluation of climate change impacts on human health is needed to better prepare Washington communities to meet the climate change challenges in the years ahead. With our rich interdisciplinary resources located at the University of Washington, Washington State University, and with agency scientists (departments of Ecology and Health, U.S. Forest Service, etc.), more refined, precise and quantitative local assessments are possible to better address the public health issues associated with climate change. Specific recommendations for further work have been categorized below into the following areas: better understanding the risks, more clearly identifying the areas and populations at greatest risk, and exploring new methods to address the identified risks.

Better Understanding the Risks

We can better understand and prepare for the risks associated with thermal stress by conducting retrospective epidemiological analysis of the human health consequences of heat waves in Washington state. In addition, examining the capacity of weather prediction agencies to accurately forecast heat events with potential human consequences will better position the state to prepare and adapt to heat wave events.

Integrated air quality modeling under differing climate change scenarios and using local meteorology and emissions patterns should be performed. The resultant predictions would be useful for subsequent application using health risk models and advancing our understanding of the health risks involved. By using demographic predictions for the state's regions in the next century and applying both national and regional dose-response data, a characterization of the burden of premature cardiopulmonary death, asthma, low birth weight, and premature birth in these case examples for the state would provide a quantitative tool for public health planning in Washington.

We can better understand the potential impacts of climate change on infectious disease transmission by conducting new laboratory and animal model research into the impact of temperature and humidity on pathogenesis of disease. In addition, work should be done to incorporate climate parameters into standard Susceptible, Exposed, Infectious or Recovered (SEIR) modeling efforts on infectious disease; the SEIR model predicts the rate of transmission of disease agents as a function of the proportion of population members who are Susceptible, Exposed, Infectious or Recovered.

Better understanding of the health impacts associated with extreme weather events could be advance by further refinement of the University of Washington's Climate Impacts Group's estimates of sea-level rise for the coasts and estuaries of Washington state, broken into short, medium, and long-term time frames. The same types of refinements are needed for the likely impact of climate change on riverine flooding over the same time frames.

Studies of energy capacity within the state overlaid with population projections to determine future needs and potential shortfalls will also assist in evaluating potential human health risks, with particular focus on the resilience of the electrical grid and the consequences of grid failure.

Furthermore, better understanding is needed on the projected increase in the cost of living associated with climate change, especially in areas involving water, food, housing, and energy. This information will assist in better estimating the potential impacts of climate change on the public health and health care systems.

More Clearly Identifying the Areas and Populations at Greatest Risk

We can better prepare local communities for heat wave emergencies by developing population predictions over the next century for Washington state with specific attention to the number of vulnerable groups living in areas subject to extreme heat events. The development of GIS capability to map the dwelling locations of vulnerable populations and the use of labor and employment statistics to identify the location of groups who indulge in heavy outside labor during times of heat emergencies will also provide valuable tools in our preparation and adaptation efforts. For all areas of our public health work, reliable population projections that also include estimates of age distribution, ethnicity, and poverty status, and that account for anticipated immigration, will assist in addressing the needs of our most vulnerable populations

Improvements in our demographic tracking programs to map major population immigrations and associated disease risks at their source countries would provide valuable information to the public health system and the ability to address new and emerging infectious diseases. In addition, tracking the flow of "high-risk" imports into the state, e.g., poultry and other animals and animal feed, will assist in identify areas of potential risk.

Wildfires affect air quality, particularly in communities downwind from forests that are susceptible to catastrophic forest fires. Retrospective epidemiological analysis – and more accurate predictions of the frequency, intensity and location of future wildfire events – would allow us to determine the human health consequences of past wildfires, and to develop plans to respond to future events.

Population predictions over the next century for Washington state, with specific attention to the number of people who will be living within the areas potentially affected by coastal inundation and riverine flooding, will provide important information for the development of public heath preparedness and response strategies. Similarly, collection of engineering and epidemiology data on water supply and sewage disposal system disruption and malfunction, and a prediction of the extent of such disruption over the next century will also be important information to develop.

Exploring New Methods to Address Identified Risks

The state should explore and experiment with various means of reducing body temperature during times of heat wave emergencies, including innovative techniques that do not rely on intact electrical grids.

Worsening air quality will also increase related health problems in Washington state. The state should continue to explore methods and programs designed to alleviate air quality problems (e.g., reduction in fossil fuel burning). Actions that result in the improvement of air quality will have a direct impact on improving public health.

In addition, exploring the use of remote sensing and use of vegetation change to direct vector-borne disease investigation and control efforts could potentially result in new tools to effectively and efficiently respond to emerging disease threats.

Additional Considerations

The key overarching consideration the Human Health PAWG wishes to highlight in this report is the recognition that the health impacts of climate change will fall disproportionately on those in lower socio-economic brackets. People who stand lower in society's hierarchy undergo more chronic stress and have worse health outcomes no matter what the stressor. They also typically experience poorer existing health conditions, more barriers to health care, unstable employment, and lower quality housing. In addition, the poor face more barriers to accessing healthy food, have more limited transportation options, and live in neighborhoods with lower social and financial capital, high crime rates, and unsafe built environments. There is also a greater likelihood that climate change effects will exacerbate one or more of the above factors, or will create synergies between factors that may further reduce the ability and adaptive capacity of individuals and communities to cope with climate change effects, or will do both.

In light of the above, the Health PAWG recommends that in any and all follow-up action addressing the impacts of climate change, special consideration be given to the poor and disenfranchised members in our communities.

AGRICULTURE

Climate change will impact many aspects of Washington's current social and economic landscape. There are distinct signs that many of the predicted changes are beginning to occur and their effects are now being felt across many sectors. Among those sectors currently experiencing the effects of climate change is the state's agricultural industry.

Agriculture, by its very nature, is an adaptive industry that exists at the whim of nature and human ability to address the short- and long-term changes that may occur. The predictions of climate scientists indicate that within the next century temperature, precipitation patterns, and carbon dioxide levels will change at a rate that may tax the ability of agriculture to adapt.

Washington's agriculture industry is important to the nation and the world. Washington is the ninth largest producer of crops in the U.S. and one of the top producers of many crops, ranging from apples to wheat. Further, Washington is the nation's third largest exporter of food and agricultural products.[1]

Washington is unique as a producer of food and agricultural products. The combination of climate, soils and typography creates opportunities for growing a wide variety of crops (more than 300). Growing these crops supports a large food processing and distribution industry. Together, the industry contributes about $34 billion to the state economy annually, about 13 percent of the gross state product.

Agriculture itself is a $6.72 billion business in Washington state. It is practiced in almost every region of the state, under a wide variety of climate and resource conditions, and it is also the key economic driver and employer in most counties in Washington. In 2002, the five top counties in agricultural sales were Grant, Yakima, Benton, Franklin, and Walla Walla, accounting for 52.8 percent of state total receipts. The top five commodities by value in 2006 were apples ($1.4 billion), milk ($686 million), livestock ($649 million), wheat ($520 million), and potatoes ($497 million). Other important commodities include cherries ($273 million), hay ($268 million), pears ($150 million), grapes ($144 million), and onions ($128 million). Field crops, livestock, and fruits and nuts accounted for most of the state's farm production value. In several cases, production sets off a chain of economic activities that dwarf the original on farm production value.

Climate change will affect agriculture in a number of ways, some positive (e.g., longer growing seasons), some negative (e.g., reduced water supplies, increased water demand), and some with

[1] www.worldtradestatistics.com

unknown impact (e.g., changed behavior of weeds, pests, and crop diseases). The main climate change drivers in the region can be generalized as follows, with some modifications expected as more information becomes available. Average annual temperatures are projected to increase roughly 2ºF by the 2020s and roughly 3-ºF by the 2040s, compared with averages for 1970-1999. Higher temperatures will directly affect plant growth, water availability, weeds, pests, and diseases. Impacts related to changes in water availability are likely to be of particular significance. Average annual precipitation is not currently projected to change significantly, but more winter precipitation will fall as rain. Snow pack is expected to melt earlier in the spring, depressing summer stream flows. This is likely to reduce water availability for irrigated agriculture. Atmospheric carbon dioxide concentrations are expected to increase, a change that may promote crop growth, but may also favor weeds.

Examples of climate change impacts on agricultural production include the following:

- Agricultural output in the Yakima Basin and other irrigated areas dependent on water from low-elevation transient snowmelt basins are highly sensitive to water availability, and to climate change impacts that increase the probability of water shortages. In the Yakima Valley, expected annual crop losses with water shortage could rise from an historic average of $13 million to $79 million by mid-century, or from 1.4 percent to 8.8 percent of the $901 million agricultural output during good years.
- Dairy production is sensitive to temperature changes, but Washington's average temperatures are likely to remain in a range in which direct impacts on milk output are small. Washington's two most productive counties would likely experience production declines no larger than 3-6 percent by the end of the century due to temperature effects alone.
- Effects of climate change on the wine grape industry are likely to be mixed. Warming could push some growing areas in Eastern Washington toward the upper limits of temperature tolerance ranges for some important wine grape varieties within the next half-century, while increasing the attractiveness of cooler areas such as the Puget Sound.

Impacts to agriculture will vary across Washington state. Different agronomic zones (see Table 1) across Washington support different commodities and agricultural practices, and are likely to have different responses to climate change. Agricultural areas in Western Washington are in the low end of growing degree days and have much greater precipitation compared to areas in the eastern part of the state. The agricultural areas in Eastern Washington can be classified in six agronomic zones according to the length of the growing season (cumulative thermal time base 0^{o}C from January 1 to May 31), annual precipitation, and soil depth (an indicator of soil water storage): [2]

[2] Agronomic Zones for the Dryland Pacific Northwest, PNW 354, Sept. 1990

Table 1. Agronomic Zones

Zone	Degree Days[3] (^oC)	Soil Depth (cm)	Annual Precipitation (mm)
1	<700	All	>400
2	700-1000	All	>400
3	700-1000	>90	350-400
4	<1000	<90	250-400
5	<1000	>90	250-350
6	>1000	All	<250

Key Agriculture Impacts and Issues for Washington State

Climate change has many important implications for agricultural production and crop viability. The Agriculture PAWG identified two key impacts from climate change that will affect agricultural practices in Washington, and developed specific recommendations for these key impact areas:

- Impacts to water availability, and
- Impacts to pest and vector population.

In addition, the Group found it necessary to consider the wider climate change impacts to economics as it pertains to Washington agriculture and the changes likely to arise from regional and global conditions.

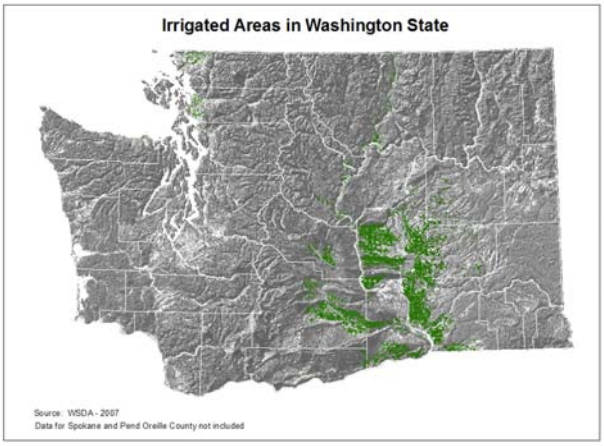
Key Impacts and Issues Related to Agriculture from Reduced Water Supply[4]

Climate change predictions for Washington state in the next century indicate that there will be a reduction in current snow pack within the central to northern Cascade Mountain Range. This snow pack has historically contributed significantly to the early spring to late summer water needs for agriculture. Additionally, changes in precipitation patterns resulting in less snowfall and increased rainfall in late fall and winter will pose significant challenges to areas reliant on direct stream withdrawals and/or groundwater for irrigation water during the peak growing season.

[3] Degree days is the number of degrees that the average temperature is above a baseline value. Every degree that the average temperature is above a baseline value becomes a growing degree day. Used by horticulturists and growers to predict the date that a crop will reach maturity. (Source:www.usask.ca/agriculture/plantsci/vegetable/definition.htm)

[4] This section focuses on agricultural sector. See the Chapter V – Water Resources and Quality for more description of the impacts and issues for water resources.

As of 2003 more than 1.8 million acres of farm land were under irrigation in Washington state, accounting for approximately 37 percent of all land under cultivation. Approximately 3.9 million acre-feet of water was applied to the irrigated acreage accounting for an average application of 2.2 feet per acre. Seventy-eight (78) percent of this water was supplied from off-farm or "other" sources (irrigation districts, direct pumping from surface water bodies) the remainder was obtained from groundwater sources. Irrigated acreage generally is dedicated to raising high value crops such as apples, cherries, potatoes, and various vegetables. The 2005 estimated farm gate value of irrigated crops in Washington state was $2.5 billion.[5] The table below lists the 12 top counties in terms of irrigated acreage and 2005 farm gate value[6].



Some geographic shifts in irrigated agriculture have occurred in the last decade as fallow land came under cultivation due to increase demand for high-value Washington agricultural products and land use shifts from agriculture to residential uses. A comparison of data collected in 2002 by the USDA with that collected by the Washington State Department of Agriculture in 2006, indicates that there has been a loss of irrigated acreage of approximately 4 percent statewide. However this has been accompanied by increases in value of most irrigated crops across the state.

Table 2: Crop Value and Irrigated Acreage

County	Irrigated Acreage	Irrigated Crop Value (Millions of Dollars)
Grant	446,183	514
Yakima	277,589	657
Franklin	221,145	280
Benton	153,254	285
Adams	148,018	142
Walla Walla	97,136	94
Kittitas	75,859	32

[5] WSDA estimates for 2005 drought analysis

[6] Irrigated acreage calculated based on 2006 WSDA-NRAS field mapping data. Note: Adams County is included as the number five county for irrigated crop value, Walla Walla County is specified as number five in overall agricultural sales (see *Overview of Climate Impacts for Washington Agriculture* section of this report)

Lincoln	47,984	12
Okanogan	47,679	145
Chelan	30,562	146
Whatcom	25,792	31
Douglas	21,199	88

While irrigated crops provide a substantial portion of the value of the state's agricultural economy, dry land crops also provide a sizable contribution. These crops, such as wheat, dry peas and beans, and lentils, are grown in areas that rely solely on precipitation, mostly in Eastern Washington. Predicted shifts in precipitation patterns may prove beneficial to this sector of the industry. However, events such as increased incidences of drought periods and increased temperatures resulting in reduction of overall annual soil moisture would counteract any positive effects of long-term shifts in precipitation.

Western Washington agricultural areas utilize both ground and surface waters. These water supplies are also used by municipalities and rural residents. It is expected that there will be continued increased competition for water supplies in these areas for both urban and rural growth. As Eastern Washington continues to urbanize, competition for water among users in that part of the state is also expected to increase.

Impacts on Agriculture from Reduced Snowpack

Irrigation water supply

The predicted reduction of snow pack will reduce available water for irrigation, resulting in crop losses. Issues surrounding this impact are:

- Need for new and improved water storage (surface water, aquifer recharge)
- Implementation of water conservation technologies
- Changes to water right regulatory system to allow irrigation of more acreage under same water right, or "water spreading"

Increased water use competition

As water availability decreases, competition for water will increase between agriculture, industry, and domestic/municipal interests. This will require the development of regulatory mechanisms to allow exchange of water use, and to protect irrigated agriculture.

Increased utilization of groundwater resources

Reduction in available surface water is likely to increase the use of groundwater resource. This will more likely result in:

- Intense pressure on regulatory agencies to allow "emergency wells" to preserve established crops.
- Water levels in wells dropping below sustainable yield and potentially creating areas of groundwater "mining".

Crop loss

Lack of availability and rising cost of water delivery system and techniques may result in the potential loss of low value crops. Issues related to this include research needs for high-value replacement crops that require less supplemental irrigation (drought-resistant crops).

Impacts on Agriculture from Shifting Precipitation Patterns

Changes in soil conditions

Shifts in precipitation patterns will result in more fall and winter precipitation and less spring and summer precipitation. The increase in fall and winter rainfall will increase soil moisture, which could have the following implications:

- Potentially positive impacts for dry land crops.
- Inability to harvest or plant due to excessive soil moisture.
- Increased use of fungicides and herbicides due to improved conditions for fungus and pest plants resulting from wetter conditions.

Key Impacts and Issues Related to Agricultural Practices from Pests and Vector Populations

With higher temperatures and changing precipitation patterns, Washington will likely become increasingly hospitable to invasion by new agriculture pests and vectors of human and livestock diseases. Higher average winter temperatures will allow new pest species to survive the winter, while longer summers will allow these pests to complete their life cycles. Additionally, the expansion of global demand for agricultural products has opened new pathways for invasive species as well as for plant and animal pathogens that are potentially damaging to Washington agriculture.

For example, in the last few years the potato tuber moth has become a major pest of potatoes in eastern Washington, an invasion believed to be due to warmer winter temperatures that foster over-wintering. Additional examples of potential invasive exotic species include fire ants, Africanized honeybees, Mediterranean fruit fly, and Sudden Oak Death. Other pests [7] are arriving through international ports and on foreign goods, with Washington's heavy involvement in international trade as a major receiving port heightening this state's exposure to invasion from overseas.

Since 1992 a total of 34 species of exotic insect pests have been discovered in the state (see Appendix C). While all but one are now considered to be established as permanent residents, most have not resulted in an economic impact to the state. Federal agricultural agency responses to the discovery of these exotic pests here (most of which are, in fact, new to the United States as well as Washington state) have recommended that the majority of these immigrant pests be assessed for impacts here and monitored for spread.

[7] Written communication, Mary Toohey-Asst. Director WSDA,. 12/05/07

Impacts on Agriculture from Pests and Diseases

Increased losses from weeds, insects, and diseases

Increased temperatures and changes in precipitations patterns will result in an expansion of areas where pest are found, longer pest life cycles, and increased losses from weeds, insects and diseases. Issues for agriculture from these impacts include:

- Increased cost of production from increased pest inputs.
- Decreased yields and crop quality.
- Increased root-rot in perennial crops, due to increased soil temperatures, resulting in the need to develop new "rot-resistant" varieties, or to modify current practices.
- Expansion of insect pests into areas and crops in Washington not previously seen, resulting in:
    - Current statewide insect monitoring program being insufficient to provide "early warning" of major pest movement
    - Current integrated pest management measures potentially being insufficient for predicted expansion of new pests, and
    - Increased use of pesticides to control insects and weeds

Key Impacts and Issues Related to Agricultural Economics

In assessing the impacts of climate change on Washington's agriculture industry, it is essential that this assessment be done in context of the trade and economic environment that will exist concurrent with these changes. Some of these may have more impact on Washington agriculture than climate change, at least looking forward twenty years. Few studies of climate change impacts on agriculture consider market trends. This discussion does not attempt to predict the market conditions as they may be affected by global warming, but only to identify some of the main trends that might increase or mitigate some of these effects and that may create challenges or opportunities for Washington agricultural producers.

Below is a short description of the major global trends that are likely to affect the demand for and value of Washington's agricultural products looking to 2025-2030. The major factors include:

- Changes in supply and demand, resulting from
    - Increasing world population
    - Increasing economic power and demand from developing countries, especially China and India
    - Changes in food production due to climate change, especially to major customers and competitors
- Production and distribution changes, resulting from
    - Reduced availability and increased costs of fuel for transportation and energy
    - Biofuel production

Economic Impacts on WA Agriculture from Changes in Food Supply and Demand

Increasing demand from developing countries

Although the rate of population growth in the world has been declining since 1980, growth still continues at about 1.3-1.5 percent per year[8]. For the past couple of decades, there has been increasing economic growth in less developed countries. The most significant of these are China and India which will comprise 36 percent of the world population in 2030 where per capita purchasing power is rising rapidly.[9] This wealth is currently concentrated into a significant, but relatively small portion of the population, but the effects are spreading through the societies.

The significance to Washington agriculture is that as per capita income increases, food purchases shift from subsistence foods to higher value products, such as those grown in Washington. China's food demand could increase 55 percent due to diet changes alone, exclusive of population growth.[10] Some of the food demands will be satisfied by China's own production, and the rest, which could be significant, will be imported from various regions, including the Pacific Northwest.

Economic Impacts on Agriculture from Food Production and Distribution

Reduced availability and increased costs of petroleum based energy

Concurrent with the above trends will be the continuing decline of cheap oil. Total energy demand varies by crop, but farms – especially wheat producers – depend on fuel to power equipment and on petroleum-based synthetic fertilizers and chemicals. In 2005, the price for a gallon of diesel exceeded the price of a bushel of wheat, and together with high fertilizer costs, created extreme hardship throughout the industry. Continued high costs for petroleum will strain the industry unless they are offset by high agricultural prices.

The freezing of fruits and vegetables is Washington's primary food processing industry. This industry is energy intensive and has depended on the relatively low-cost hydropower in the region. As electrical generation from fossil fuels becomes more expensive, costs for all electricity, including hydropower, are likely to increase, increasing processing costs.

Finally, Washington ships about 70 percent of its harvest out of the state, with the nearest major markets over 1,000 miles away. The current global distribution of goods depends on cheap, fast transportation. Transportation costs restrict our access to many markets and hamper our competitiveness. Higher fuel costs drive up the cost of trucking. Transportation by rail, which is more fuel efficient and cost effective, is limited. Fortunately, Washington has well-developed ports and can export its products at lower ocean freight rates.

Biofuels Production

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[8] US Census Bureau

[9] Ibid

[10] Heilig, G.K., 1999. Can China Feed Itself? A System for Evaluation of Policy Options. www.iiasa.ac.at/Research/LUC/ChinaFood

Biofuels such as ethanol and biodiesel are increasingly being produced as alternative liquid fuels to replace petroleum-based gasoline and diesel. Large areas of farmland have been switched to cultivating corn for ethanol, and to a much smaller degree, canola, soy and other oil crops for biodiesel. In 2006, 2.2 billion bushels of corn were used for ethanol – 21 percent of the 10.5 million-bushel U.S. corn harvest, driving the price of corn from $2.18/bushel prior to 2006, to $3.56 bushel in May 2007.[11] This has lead to increased costs and feed shortages for cattle, hog and other livestock industries, reducing profitability and increasing consumer prices. Indirectly it has raised wheat and other grain prices, benefiting those farmers

Agricultural Adaptation and Preparation Work Group Recommendations

The Agriculture PAWG offers the following strategies and associated recommendations to begin to address the impacts of climate change on Washington's agriculture production and viability:

1. **Agricultural water availability strategy**
   - 1.1. The state should continue to investigate and invest in the development of large scale and small scale water storage.
   - 1.2. Increase funding to expand current programs focusing on improved conservation and efficiency techniques and capital investment for all water use sectors.
   - 1.3. Provide incentives and programs to facilitate the rapid transfer of new knowledge and technologies to assist farmers in adapting to climate.
2. **Monitoring and controlling pest and vector populations strategy**
   - 2.1. The efforts of the Invasive Species Council to establish a statewide strategic plan and invasive species baseline should be supported and used as a foundation for future efforts to monitor and control pests detrimental to public health, the environment, and the agricultural sector of the state.
   - 2.2. Continue operational and financial support of efforts by Washington state and the federal government to improve the tracking and monitoring movement of plant and animal pathogens.

1. Agricultural Water Availability Strategy[12]

[11] National Corn Growers Association, www.ncga.com

[12] This strategy focuses on the need to ensure adequate water supply for the agricultural sector. Elements of these recommendations also appear in Chapter V –Water Resources and Quality developed by the Water PAWG for more detailed recommendations on water resources. We have not, at this time, reconciled the recommendations of the two working groups.

Strategies related to water availability for agricultural needs focus on three recommendations, which must be considered together in order to achieve the goal of ensuring adequate water to support Washington agriculture given the predicted impacts from climate change. Success will depend on how well these strategies are integrated and implemented in order to achieve the goal of maintaining adequate water supplies necessary to continue to provide for a healthy agricultural industry in Washington.

- **Water Storage** Proceed with the evaluation and development of new or improved water storage and distribution systems that focus on both large scale and small regional or on farm facilities;
- **Conservation** Preserve existing water supplies for irrigation at current levels (minimize reduction in current water availability for irrigation) by expanding water conservation efforts to the agriculture sector and the other sectors; and
- **Crop Management Techniques** Research the merits of transitioning to methods and techniques (where appropriate) that reduce on-farm water use and crop irrigation requirements (i.e., develop drought tolerant species, increase soil moisture holding capacity, employ no-till farming techniques, etc.).

Additionally, the Agriculture PAWG would like to encourage that work continue on addressing the impacts of new and existing exempt wells to ensure that existing surface water and groundwater withdrawals remain adequate to support agricultural needs.

Recommendation 1.1: The state should continue to investigate and invest in the development of large scale and small scale water storage options.

In order to address future needs for water from all sectors, storage must be a crucial element in any strategy related to agriculture and climate change. Improvements in the state's storage capacity (large and smaller scale projects) are necessary to compensate for predicted losses in snow pack that conservation and/or advanced farming techniques will be unable to provide. Given the predictions for both water availability and projected water needs, there exists a real potential for competition between sectors for this valuable and scarce resource.

Current storage capacity for irrigation needs is highly dependent on utilization of snow pack in the Washington Cascades, which supplies up to two-thirds of the state's stored water. This snow pack is predicted to decline over the next fifty years due to warming temperatures while overall precipitation is expected to change little. As a result, water that would have been held in snow pack for release during peak growing periods will fall earlier in the year as rainfall. Currently, the capacity necessary to capture precipitation that enters the watershed as surface water rather than as snow pack is inadequate to meet needs. Therefore, it will be necessary to develop storage mechanisms to hold sufficient water for use by agriculture during the growing season. This may include a variety of mechanisms from large or small scale reservoir construction to aquifer storage and recovery systems.

The Washington State Department of Ecology, the Federal Bureau of Reclamation and the Army Corps of Engineers are currently engaged in the evaluation of storage options related to the Columbia Basin Initiative: the Columbia Mainstem Option, Yakima Basin Water Storage, Walla Walla pump exchange, and Aquifer and Small Storage options. These feasibility studies should be completed and an option (s) should be selected that will allow for water storage equivalent to up to one-half of the potential loss due to snow pack reductions predicted for the next fifty years. While this number may seem high, it considers increased competition for water from competing interests outside of agriculture, including instream flow needs, and considers irrigation efficiencies that may be obtained through new technologies or wider use of currently effective technologies.

The state should continue to investigate and invest in the development of large-scale storage options, but should also focus on the development of smaller scale cooperative storage projects. These types of projects may offer significant alternatives for the small-to-medium-sized farms that lie outside of large scale irrigation projects or who may have junior water rights. Further investigation of smaller scale water storage projects should be considered from both a water supply and financial feasibility standpoint.

The development of additional storage is estimated to run in the billions of dollars. Development costs such as these will likely require a partnership between the state, the federal government, agricultural entities, municipal governments and private parties. Expenditures of this magnitude will require legislative approval from both the state and federal governments, if the federal government participates financially in development of storage projects..

Recommendation 1.2: Increase funding to expand current programs focusing on improved conservation and efficiency techniques and capital investment for all water use sectors.

Increased storage capacity in and of itself will likely not be sufficient to address all water use needs (agriculture, industry, municipal, instream uses, and others). Therefore, conservation and efficiency must play a foundational role in the overall water management strategy in the state. It will be necessary to continue the progress currently demonstrated through the use of new irrigation technologies, upgrades of water distribution systems, and progressive crop management activities, such as using the Ag Weather Net to provide site-and-time-specific decision-making information to irrigators. Conservation and efficiency efforts must include all water use sectors including municipal and industrial users. Agriculture in and of itself cannot be relied upon to contribute disproportionately, and still meet the goal of ensuring adequate water supplies for irrigated agriculture.

Water availability and use for agriculture is interconnected with demands by other users and for instream flow needs. To ensure water supplies for agriculture are not disproportionately reduced, new programs are needed to increase the efficiency of water use by municipalities experiencing population growth. Urban users and other residential, commercial and industrial users need to

reduce water use and reuse water wherever possible – for example, practicing low-water-use gardening, recycling industrial and commercial water (car washes, etc.), and utilizing storm water runoff for irrigation.

Related to agriculture conservation and efficiency, several successful programs have resulted in improves conveyance system efficiency and on-farm delivery systems. These include cost-share programs implemented through the Columbia Basin, federal Farm Bill Programs such as the Environmental Quality Incentives Program (EQIP), and Washington's Irrigation Efficiency and Conveyance Improvement Programs.

Increased funding is needed through grants and/or loans to expand current programs. Doubling the funding of current conservation and efficiency programs will likely result in significant savings of water from agriculture. It is vital that water saved through these programs provides some assurance that current levels of agriculture can be maintained.

Additionally, improvements in weather and climate prediction techniques and networks are needed to allow for maximum effectiveness of conservation and efficiency improvements. Education is needed to promote and demonstrate the value of improved conservation techniques. However, conservation efforts must be considered in tandem with current water law, which is an obstacle to conservation efforts.

Recommendation 1.3: Provide incentives and programs to facilitate the rapid transfer of new knowledge and technologies to assist farmers in adapting to climate change.

Improving soil organic carbon (SOC) levels through a variety of management practices has been shown to increase soil moisture, improve water use efficiencies, and therefore reduce irrigation needs – by up to 10 percent. Increasing SOC levels can be accomplished through a number of strategies and practices, including direct-seeding / high-residue farming systems, use of biological / organic soil amendments such as manure and compost, improved crop residue management, and the use of cover-crops and fall-planted crops that can better utilize winter precipitation. Many of these practices and strategies also contribute to greenhouse gas mitigation goals by improving soil carbon storage and reducing the use of synthetically manufactured nitrogen.

For instance, no-till (direct-seeding / high-residue farming systems) agriculture practices improves the moisture-holding capacity of the soil and increases water infiltration by increasing soil organic carbon. Moisture from snowmelt and heavy rainfall events is more likely to infiltrate into the soil and recharge aquifers instead of running off as surface drainage.

New programs are needed that work with producers and industry leaders to create networks within the industry to transfer production methods that use less water without reducing yields. Incentives and programs should be created to facilitate the rapid transfer of new knowledge and

technologies to assist farmers in adapting to climate change with new production methods, drought tolerant species, etc.

Additional Comments

There are recommendations within the Water Resources and Quality PAWG report that will significantly benefit agriculture. They include the following:

- Evaluate Options to meet water demand (considering potential climate change effects).
- Fund the drought preparedness and emergency water supply projects accounts and modify the utilization requirements therein.
- Create appropriate statewide drought management strategies that account for evolving drought risks in a warmer climate.

2. Monitoring and Controlling Pest and Vector Populations Strategy

Coordinated efforts are in place between the federal and state governments to detect and respond to animal pathogens that pose a threat to both agricultural economy and public health. Efforts, within the Washington State Department of Agriculture to build upon its programs for animal tracking and pathogen detection are ongoing. These efforts are complemented by Washington's research universities, which conduct research in the development of new and more effective means for detecting and responding to animal (livestock) pathogens.

Mechanisms and mandates currently exist within state, federal, and local agencies to detect, assess, and manage introduced pests and plant and animal pathogens. However, these efforts can be improved. Washington state (through the Invasive Species Council) is currently developing a strategic approach to prevent and control invasive species – non-native organisms that threaten Washington's environment and economy. This plan is due to the Legislature in March 2008. Information on invasive species is lacking in completeness and accessibility. This lack of information limits the Council's ability to fulfill its charge to coordinate a strategic statewide response to this threat. The Council has asked the Legislature for funds to conduct an assessment of baseline conditions that will provide valuable information necessary to address questions about the extent of infestations and how they can best be managed from a statewide perspective. The assessment will bring all the information together in one place, allowing for improved decision making by many federal, state, and local agencies. The Council will use the information to develop and implement its strategic plan, and to provide policy level planning and coordination as part of its charge to coordinate on invasive species issues with agencies such as departments of Agriculture, Ecology and Natural Resources, Weed Boards; EPA; USDA; county governments; and Washington tribes.

The assessment, enhanced Web capacity, and technical support would:

- Provide analysis of the worst invasive species in the state, the locations of the areas most affected, pathways, and resources most at risk;

- Identify public and private efforts to prevent, control, or eradicate invasive species;
- Bring together in one place, for the first time, the multitude of invasive species data compiled by county, state, federal, tribal, and non-governmental organizations, including GIS data created by local Weed Control Board;
- identify gaps and duplication of efforts;
- Provide critical information for the development of risk-assessment standards that will be used for meaningful priorities for preventing, controlling, and eradicating invasive species; and
- Inform public and private entities and increase their ability to coordinate efforts and resources.

The work of the Invasive Species Council will likely establish a solid baseline on which to build the tracking of invasive species and agricultural pests. However, agricultural pests are not the sole focus of this effort. Therefore, it is reasonable to consider a complementary effort focused on research and enhancement of predictive tools to enhance future planning efforts related to invasive pests and plant and animal pathogen occurrence with the potential to impact agriculture.

Recommendation 2.1: The efforts of the Invasive Species Council to establish a statewide strategic plan and invasive species baseline should be supported and used as a foundation for future efforts to monitor and control pests detrimental to public health, the environment, and the agricultural sector of the state.

The efforts of the Invasive Species Council to establish a statewide strategic plan and invasive species baseline should be supported. The Agriculture PAWG recommends that, as part of the Council's activities, consideration be given to establishing activities that will assist in predicting invasive species' movements and their impacts in the short and long term. These activities should be factored into the invasive species strategic plan.

Recommendation 2.2: Continue operational and financial support of efforts by Washington state and the federal government to improve the tracking and monitoring of the movement of plant and animal pathogens.

Current efforts by Washington state and the federal government to track and monitor the movement of plant and animal pathogens appear to be successful within limitations of available funding for the existing system. Climate change factors may make conditions more favorable to expansion or movement of these pathogens. The Agriculture PAWG encourages continued efforts by the state Department of Agriculture and USDA to coordinate animal/plant tracking and monitoring activities in order to address any current or future occurrences of plant/animal disease outbreaks.

Priority Recommendations for Ongoing Research

The Agriculture PAWG identified the following key additional research needs:

- Compile information on invasive species of economic importance in Oregon, California, other states to the south, and other regions of the world
- Improve invasive species identification and monitoring networks
- Further develop outreach capacity for education and technology transfer to mitigate new pest impacts
- Develop additional or improve current control and eradication techniques for invasive species and plant and animal pathogens.

Additional Considerations

The Agriculture PAWG recognizes the need to continue identifying impacts not only to agriculture but to all aspects of Washington's social, environmental and economic landscape. Therefore, it appears necessary that consideration be given to establishing a long-term state sponsored entity to continue the work of the Agriculture Preparation and Adaptation Working Group as well as the work of the other working groups. The success of any subsequent effort can be improved through focused outreach to the agricultural community, and the establishment of forums on this issue to facilitate an expanded discussion on the impacts of climate change to agriculture.

COASTAL AND INFRASTRUCTURE

Local rates of sea level rise depend on both global and local factors. The expected range of global sea level rise by 2100, published by the Intergovernmental Panel on Climate Change (2007), is 7-23 inches; although higher levels are possible as noted below. Locally, changes in atmospheric circulation patterns and vertical land movements will affect the amount of sea level rise at any given location (known as "relative sea level rise"). Based on our understanding of these factors to date, sea level rise in the Puget Sound region is expected to closely match the changes in global sea level. Very little relative sea level rise is expected in the northwest Olympic Peninsula due to rates of tectonic uplift that exceed projected rates of sea level rise. On the central and southern Washington coast, the number of continuous monitoring sites with sufficiently long data records is small, adding to the uncertainty of sea level rise estimates for this region. Available data points suggest, however, that uplift is occurring in this region, but at rates lower than that observed on the northwest Olympic Peninsula.

Uncertainties in both the climate system and in human response to climate change will make exact predictions difficult. Future climate will depend upon the future rate of greenhouse gas emissions, which is subject to policy initiatives and economic incentives. Future sea level rise also depends on uncertainties in climate-carbon cycle feedbacks (e.g., how increased forest fire frequency contributes to more carbon emissions) and rates of ice sheet melting in Greenland and Antarctica. Recently observed higher rates of ice sheet melting makes 50 inches of sea level rise by 2100 within the range of possibility. The application of any specific sea level rise estimate in decision making will depend on the specific location of interest, the time horizon of the decision (including the overall "footprint" of the decision over time, not just the lifespan of a specific structure), and risk tolerance for the range of sea level rise estimates.

It is well established that physical impacts of climate change and sea level rise will manifest themselves in a variety of ways, which are discussed below. The specifics of all these impacts are driven by sea level rise scenarios, forecasts of increased storm activity, and the dynamics of coastal erosion caused by sea level rise and storms.

Inundation
As sea levels rise, the lowest lying areas will be inundated and regularly flooded during the daily tide cycle. Specifically, low-lying river deltas, port areas, and ocean beach communities on the Long Beach peninsula of Willapa Bay and the Ocean Shores community near Grays Harbor are known to be at risk.

Episodic Flooding
Coastal impacts of sea level rise will not be limited to simple property inundation as sea levels increase. Changes in sea level will predominately be experienced through increased episodic flooding as what are now considered extreme events become both less extreme relative to new

sea levels and more frequent. During major storm events, sea level rise will compound the impacts associated with storm surge and could contribute to more extensive coastal flooding. Changes in the seasonal pattern of rainfall could also lead to more frequent and serious flood events during the cool (October-March) season.

Saltwater Intrusion
As the sea level rises, freshwater aquifers and wetlands will be subject to increased intrusion by salt water. Intrusion could threaten drinking water sources, affect local drainage, and impact coastal estuaries. Increased groundwater pumping in coastal areas and climate change-related changes in the timing and volume of freshwater runoff contributing to recharge of coastal aquifers may also contribute to saltwater intrusion in some coastal aquifers.

Erosion
Erosion, and the sediment transport and deposition that occur as a result, is a natural and ongoing coastal process that plays a key role in shaping coastlines and nearshore habitat. Major episodes of erosion often occur during storm events, particularly when storms coincide with high tide. Increased erosion can have both positive and negative impacts depending on location. For example, while increased erosion removes sediment from nearshore environments, nearby deposition of the eroded sediment may help offset the losses otherwise expected from sea level rise by enlarging some beaches, spits, and nearshore habitat. In other areas, however, increased erosion can increase the costs of protecting infrastructure. Erosion will likely increase due to sea level rise, although predicting exact local effects is difficult at this time.

Nearshore Habitat

In some regions, nearshore habitat will be squeezed between rising water levels and armored beaches. This could reduce the coastal and intertidal habitat available to migrating shorebirds, forage fish, shellfish, juvenile salmon, and other species. Nearshore habitat – and use of this habitat – may also be affected by changes in estuarine and marine water quality, including changes in water temperature, salinity, density, stratification, dissolved oxygen, and nutrient content. Specific changes will vary by parameter, location, and season. Increasing ocean temperatures may also affect species survival rates and the vitality of invasive species (e.g., spartina in Willapa Bay), though it is difficult to make exact predictions of complex ecological changes at this time.

The vulnerability of coastal areas to increasing sea levels, storms, and other climate change stressors will depend not only on the physical stressors to the environment, but also on the ability of those areas to adapt to those changes. The long-term nature of the sea level rise issue affords response opportunities not necessarily available in other areas of impact from climate change. Pro-active policy choices have the potential to decrease the economic costs of responding to sea level rise and limiting future impacts.

Key Coastal and Infrastructure Impacts and Issues for Washington State

The Coastal PAWG identified key implications for Washington's natural environment and built environment from climate change. Coastal environments include river deltas, bluffs, beaches, spits, estuaries and lagoons. Impacts to these areas will affect both natural and developed areas. Many coastal bluffs on Puget Sound have been developed into residential uses, where erosion events are anticipated to increase. Agriculture is a dominant land use in most of our delta areas, where increased flooding and soil saturation is anticipated. Sea level rise will threaten dikes and drainage will become more difficult. In some areas, cultural resources may be threatened.

Key Issues Affecting Natural Environments

River Deltas

Low-lying river deltas are subject to extensive inundation. The extent of intrusion will depend on the degree of diking and commitment to maintaining protection as costs escalate. Most deltas are dominantly agricultural; a few are urban and industrial. Key impacts and issues for river deltas include:

- Increased costs of repairing and maintaining dikes and levees.
- Loss of nearshore habitats seaward of dikes.
- Increased flooding, soil saturation, and drainage problems.
- Significant influence on long term decisions regarding agricultural use or ecological restoration.
- Increased intrusion of saltwater into estuary.

Coastal bluffs

Coastal bluffs are a widespread landform on Puget Sound, and primarily have residential development. These sites are often hazardous due to erosion and landslides. Extensive armoring has occurred; existing concerns about long-term ecological impacts of armoring are heightened when considering beach resilience to sea level rise. Key impacts and issues for coastal bluffs include:

- Loss of beach habitats where they are squeezed between shoreline armoring and rising sea levels.
- Shifts from forested bluffs to unstable bare slopes.
- Changes in bluff erosion may impact beaches elsewhere along shoreline.

Spits and Barrier Beaches

Spits and barriers are common on Puget Sound. Many protect valuable salt marshes and estuaries. Residential development of spits and barrier beaches is common, although many remain relatively undeveloped as parks and reserves. Key impacts and issues for spits and barrier beaches include:

- Increased frequency and severity of flooding and storm damage.
- Rapid erosion and potential for breaching.
- Failure of septic systems, which will threaten water supplies and utilities.

- Loss of beaches where shorelines are armored.
- Loss of associated wetland and estuarine habitats.

Nearshore Habitats

Nearshore habitats include beaches, salt marshes, tide flats, stream mouth estuaries, and lagoons, which increasingly are targets of restoration actions. The sea level rise vulnerabilities of these sensitive areas need to be considered in our efforts to protect nearshore habitat. Key issues affecting the resilience of nearshore habitat include the rate of sea level rise, the ability of habitats to migrate, and the availability of sediment. Key impacts and issues from climate change for nearshore habitat include:

- **Elimination of habitats.** Habitats will be eliminated if they cannot migrate landward. Where habitat still exists in front of diked areas, the adaptability of nearshore habitat should be considered along with the cost of dike maintenance in deciding future maintenance or expansion of rural area dikes. This should especially be considered where the protected areas are marginally productive or relatively small.
- **Changes in tidal dynamics and sedimentation.** Tidal dynamics and sedimentation are likely to change, which will change the type and condition of nearshore habitat (for good or bad, depending on the needs of particular species)
- **Viability of restoration actions.** Viability of restoration actions will change or become less certain with impacts from climate change. Where property is intended for long-term protection, long-term sea level rise should be considered in restoration and/or acquisition planning.

Key Issues Affecting Our Built Environments

Urban Waterfronts

Of special concern for sea level rise are our highly developed urban waterfronts. Here, major infrastructure is threatened by sea level rise. Shorelines of our urban areas have been largely modified by landfill and seawalls, and extensive overwater development and marine facilities have been constructed. These areas have major investments in public and private infrastructure. In some areas – such as our most active ports – redevelopment and upgrade is an ongoing process. We need to consider how we invest in maintenance and upgrade to maximize adaptation and resilience related to sea level rise. Key impacts and issues for our urban waterfronts include:

- Increased risks to infrastructure such as treatment plants, transportation corridors, commercial and industrial waterfronts, and parks.
- Requirements for expensive repairs to storm drainage systems.
- Increasingly steep public costs to maintain, protect, and repair public facilities and property.
- Redevelopment opportunities.

Ports

Ports usually have heavily engineered shorelines. Freight handling requires extensive rail yards near water level. Associated industrial areas may contain currently or historically contaminated sites, creating risk of increased water pollution as sea level rises. Key impacts and issues for ports include:

- Increased maintenance and repair of port facilities.
- Increasing storm damage to piers and seawalls.
- Need to reconfigure or elevate freight handling yards.
- Increased corrosion of tanks and pipes, and increased leaching of contaminated soils.
- Opportunity to adapt during major facility updates.

Coastal and Infrastructure Planning and Adaptation Work Group Recommendations

The Coastal PAWG used these key impacts and issues to frame the design of the following recommendations, organized into four main strategies, which are described in greater detail below. The Coastal PAWG also recommended three overarching actions, which follow the description of the main four strategies. All of the recommendations advance the overall goal defined by the Coastal PAWG, which is to ***enhance the ability of state and coastal communities and ecosystems to prepare and adapt to impacts of sea level rise and other climate change impacts***.

1. Land use and hazard mitigation planning strategy

1.1. Incorporate the best available sea level rise and other climate change information into local government planning to promote resiliency of ecological systems and communities.

1.2. Revise state land use and shoreline planning statutes and regulations to effectively address sea level rise and other climate change impacts.

1.3. Pursue state funding for pilot projects in vulnerable developed shoreline areas to examine alternatives to reconstructing bulkheads.

1.4. Utilize Flood Control Assistance Account Program planning to address sea level rise and other climate change-related risks.

1.5. Inform property purchasers and investors regarding sea level rise risk that may affect coastal property.

1.6. Incorporate future sea level rise in prioritization, design, and post-project maintenance of toxic cleanup sites in shoreline areas.

2. Vulnerability characterization and monitoring strategy

2.1. Improve mapping and characterization of sea level rise vulnerability for all our

coasts.

3. Coastal nearshore habitat restoration and protection strategy

3.1. Direct state agencies to incorporate sea level rise into state-managed and supported coastal restoration and protection projects.

3.2. Develop guidelines for local governments, tribes, non-governmental organizations, and other stakeholders to address sea-level rise impacts in coastal habitat restoration and protection projects.

3.3. Include habitat reclamation opportunities in long-term management of armored/diked shorelines.

4. Coastal facility construction and maintenance strategy

4. 1. Include best available data on sea level rise in design of coastal facility construction and major repair projects.

4. 2. Require consideration of sea level rise in state infrastructure funding programs.

1. Land Use and Hazard Mitigation Planning Strategy

The goal of this land use and hazard mitigation planning strategy is to promote resiliency of ecological systems and communities by incorporating the best available information on climate change and sea level rise into existing land use and facility planning and permitting processes. The strategy builds on growing interest in local communities regarding planning for sea level rise/climate change.

The state needs to protect both natural systems and human communities, which are interconnected. It is vital that we address resilience of *both* in our coastal regions. Sea level rise will trigger an impulse by property owners and managers to "protect" shorelines through armoring or diking. The appropriateness of additional armoring or diking will vary, however, depending on existing infrastructure that may be at risk. Additional armoring directly threatens the ability of beaches and supporting shoreline processes to adapt to sea level rise. Hardening shorelines will lead to additional loss of vital shoreline habitat that provides critical functions for an array of important species. The state should discourage or preclude additional armoring whenever alternatives exist.

In urban areas, existing infrastructure investment will in some cases lead to decisions involving measures to protect near-shore facilities. The state should review policies and permit processes to accommodate protection of nearshore facilities (such as wastewater treatment plants) and low-lying urban core areas (including significant portions of downtown Olympia), in the context of utilizing the least impacting alternative for protection. Additionally, it is vital that sate and local governments avoid putting facilities and residences into relatively undeveloped areas that are at significant risk to sea level rise. The state should also need to examine risk to existing low-

density and urban development, and design adaptation plans that address long-term resilience of both natural systems and human communities.

Existing planning statutes partially – but not fully – accommodate consideration of sea level rise/climate change impacts. Both the Growth Management Act (GMA) and Shoreline Management Act (SMA) stress use of "all available information" in land use planning processes. The state and local governments should not lose the opportunity to include sea level rise/climate change impacts in existing planning processes. The departments of Community, Trade and Economic Development and Ecology – the state agencies responsible for implementation of these planning statutes – need to make the best information on sea level rise and climate change available to local governments.

The revised SMA rules provide a framework that discourages hard shoreline armoring, requiring that project proponents first look at softer alternatives, with hard shoreline armoring only as a last resort. The state also promotes softer shoreline alternatives through implementation of the Hydraulic Project Approval (HPA) program. Neither of these programs specifically address sea level rise impacts, and it is still important to identify potential revisions to statutes and rules to specifically include sea level rise in these processes. This is vital to ensuring the most effective use of our long-range planning tools to prepare for sea level rise and climate change.

The strategy has three complementary approaches:

- Maximize effective use of existing planning processes in considering sea level rise and climate change, in compliance with the Climate Change Executive Order. This includes incorporating sea level rise and climate change considerations into existing planning processes such as GMA, SMA, HPA, and the State Environmental Policy Act (SEPA), to the degree feasible, as well as long-range planning efforts by special purpose governments such as Drainage/Diking Districts and Port Districts.
- Update Washington's land use and shoreline planning and permitting statutes and rules to reflect the new imperative of sea level rise and climate change. Ensure that these issues are incorporated into our long-range land use, habitat protection, capital facilities and hazard mitigation plans and associated regulatory framework, including Critical Areas Ordinances (CAOs), Shoreline Master Program (SMPs) and HPAs.
- Carry out one or more pilot projects in vulnerable developed shoreline areas to demonstrate armoring alternatives, in light of sea level rise impacts and risks. Rising sea levels will likely increase desire to protect structures through hard shoreline armoring. This project will provide valuable information to local governments, state agencies, contractors, and property owners regarding techniques that provide property protection while protecting nearshore processes and habitats.

Recommendation 1.1: Incorporate the best available sea level rise and other climate change information into local government planning to promote resiliency of ecological systems and communities.

The state should compile and disseminate the best available scientific information and policy guidance on sea level rise/climate change impacts and planning as it relates to local planning. This should include policy and regulatory language that can be adapted to local circumstances. In addition, risk reduction guidelines should be developed to help communities deal with the challenges posed by existing development, while avoiding future actions that would increase risk. Key issues – such as the link between the level of certainty and the risks involved in a particular decision – need to be clearly outlined for local entities. Examples of existing processes that should incorporate preparation and adaptation to climate change impacts include:

- Shoreline Master Program (SMP) updates: The state is funding updates of all SMPs. Sea level rise projections and assessment of vulnerable shoreline features should be incorporated into SMP updates. The Cumulative Impacts Analysis, which is required for SMPs, may be a useful tool for examining long-term implications of sea level rise for a city or county. In addition, the Restoration Strategy, which is required for each updated SMP, should consider habitat resilience to sea level rise as a key factor in identifying priority actions. Public outreach efforts undertaken as part of SMP updates should include climate change/sea level rise discussions in order to inform the public of risks and opportunities.
- Growth Management Program (GMA) updates: Some governments are already including climate change issues within Comprehensive Plan updates. General policies and action strategies can be included in the Comprehensive Plan, to guide development of plans and action programs. Capital Facilities Plans for shoreline facilities should examine vulnerabilities and adaptation actions.
- SEPA: SEPA should be promoted as a tool to examine the impacts and risks of sea level rise and other climate change impacts on proposed development or non-project actions, and provide a framework for examining alternatives that promote community and ecological resiliency.
- Drainage/Diking and Port Districts: Sea level rise has particular relevance to some special purpose governments such as Drainage/Diking Districts and Port Districts. Outreach to small special purpose governments will be vital, as these organizations have very limited resources.

The state should provide funding for small and medium-sized local governments to support inclusion of climate change impacts into local planning, including affected special purpose governments such as Drainage/Diking and Port Districts. It is vital that these entities take a long-range comprehensive approach to deal with sea level rise implications for their infrastructure and mission.

Recommendation 1.2: Revise state land use and shoreline planning statutes and regulations to effectively address sea level rise and other climate change impacts.

Washington's community planning statutes should be updated to reflect the new imperative of considering impacts from climate change. GMA and SMA are the fundamental tools used by local government to plan for the future. Statutory update is needed to ensure that climate change issues are incorporated into our long-range land use, habitat protection, capital facilities and flood and geological hazard mitigation plans and regulations. Planning requirements of special purpose governments, including Drainage/Diking Districts and Port Districts, should also be updated to ensure that sea level rise and other climate change impacts are included in planning and operations of these entities.

Where the state has specific authority over land use or aquatic lands planning and permitting, rules and statutes need to be updated to address sea level rise. SMA and HPA rules should be revised to strictly limit new armoring and reduce the impact of reconstructed armoring. Ecology should update rules or guidance related to SMP updates to require characterization of erosion hazards and threats to shoreline functions due to sea level rise, and facilitate development of appropriate setback and/or buffer regulations that correspond to sea level rise forecasts. Permit application forms need revision to focus attention on climate change issues. The HPA process is a key law for protecting fish, shellfish, and their habitat in Washington state. Revisions to HPA processes are needed to ensure compliance with sea level rise policy objectives, such as requiring impact assessments for proposed armoring projects, consistent with SMP mitigation sequencing requirements (e.g., first avoid, then minimize, then mitigate) and consideration of cumulative impacts. Washington state should also examine innovative approaches, such as an impact fee for unavoidable armoring, that would contribute to a coastal habitat restoration fund.

Recommendation 1.3: Pursue state funding for pilot projects in vulnerable developed shoreline areas to examine alternatives to reconstructing bulkheads.

SMP update guidelines require that local plans limit armoring, and emphasize use of non-structural approaches where shoreline stabilization is an issue. Yet non-structural approaches have not been widely embraced by shoreline property owners or contractors, and hard armoring continues to be built and repaired. Interagency groups such as the Puget Sound Near Shore Restoration Program Shoreline Armoring Workgroup are beginning to address this issue. But we have little documented experience in alternative approaches in different geomorphic settings.

One or more bulkhead alternative pilot projects should be pursued with interested property owners. The most likely candidates are local and state governments. Pilot projects should be located in distinct geomorphic settings. Particularly important locations are drift cell(s)/reach(es) where shoreline processes are threatened due to rebuilding or continued presence of bulkheads. The projects would assist in developing practical methods to meet SMP regulatory requirements for alternatives to armoring that protect shoreline processes in consideration of an entire drift cell/reach. Lessons learned would be disseminated to other local governments and state

agencies, improving our ability to balance protection of property and protection of vital beach processes.

Recommendation 1.4: Utilize FCAAP flood hazard planning to address sea level rise and other climate-change-related risks.

Flood Control Assistance Account Program (FCAAP) planning funds have already been used to assist coastal communities in planning for risk of tsunamis. These funds could also support long-term climate change impact planning by local communities. These plans are vital to reducing risk to life and property, and to reducing long-term cost of responding to sea level rise and other climate change impacts. (FEMA-provided disaster mitigation funding will have limited ability to address sea level rise issues under current Federal rules.) Specifically:

- Eligibility and rating criteria for hazard planning programs should be updated in recognition of the growing awareness of sea level rise risk to our coastal communities.
- Funding levels for local grant programs should be reviewed, to assure that there is adequate funding to respond to the emerging need for sea level rise planning.

Recommendation 1.5: Inform property purchasers and investors regarding sea level rise risk that may affect coastal property.

Reduce the liability of government for building within sea level rise risk areas by ensuring that builders and purchasers are aware of risk. Potential mechanisms to achieve this increased risk awareness may include real estate disclosure forms provided to purchasers, and public information on emerging insurance industry responses to sea level rise and other climate change impacts.

Recommendation 1.6: Incorporate future sea level rise in prioritization, design, and post-project maintenance of shoreline toxic cleanup sites.

Cleanup of contaminated sites near Puget Sound are already a state-level priority. Future potential sea levels should be incorporated into the design of cleanup and maintenance projects. This will help ensure that these cleanups are sustainable in the face of climate change.

2. Vulnerability Characterization and Monitoring Strategy

The goal of this strategy is to provide the best available data and analytical tools to increase the resilience of coastal communities and shoreline processes. This strategy recognizes that climate change will have diverse effects on our 2,300 miles of coastline. Low-lying areas along the Pacific Coast and on river deltas around Puget Sound will be subject to flooding from storm

events and gradual inundation due to rising sea levels. Bluffs around Puget Sound will be subject to increased erosion events, as beach processes respond to rising sea levels. While these are very narrow shoreline areas, the supply of beach-forming material provided by these bluffs is vital to the Puget Sound ecosystem. At the same time, residences and transportation facilities near these bluffs may be threatened or damaged by erosion events.

We have a good sense of likely impacts of sea level rise and other climate change impacts, as identified elsewhere in the report. However, there exists significant uncertainty as to *where, how much, how fast,* and *why* these impacts will occur. In addition, we do not have adequate sea level rise vulnerability assessments and mapping. A related need is consistent information about vertical land movements and their potential affect on sea level rise impacts in various locations. Furthermore, these impacts will not be uniform in the wide range of landscapes along Puget Sound and the outer coast.

We need to support adaptation and preparation in our coastal communities by characterizing sea level rise vulnerability in various areas. We need to improve mapping of coastal areas, including more accurate elevation data. We need to improve information on predicted future sea level trends, and increase our ability to anticipate and prepare for impacts. We need to support the characterization or assessment of risk resulting from sea level rise and climate change on the state transportation corridors that connect communities and are essential to the movement of people and commerce. We also need to monitor the rates and magnitudes of sea level rise impacts to various parts of our coast, so that we can continually refine our adaptation actions over time.

With solid information and assessments, we can reduce risk to public safety. We can also reduce costs to agencies associated with costly emergency responses. Adequate investment in climate change assessment and evaluation is essential to adaptation and to increasing the resiliency of our coastal communities.

Recommendation 2.1: Improve mapping and characterization of sea level rise vulnerability for all our coasts.

There are several vital actions that support adaptation to sea level rise. First, the state should create a general characterization of sea level rise vulnerability for all shoreline types. This will include the entire range of natural settings – from low-lying spits and river estuaries to bluffs – and the varying types of land use from natural to urban. Vulnerability of coastal communities and shoreline habitat will be assessed based on current information and best available projections of sea level rise and the implications of changing conditions. ***This assessment is a vital underpinning of nearly all the recommendations in this coastal and infrastructure report.***

Sustained monitoring of sea level rise and its affects in the Puget Sound region should be established. Because of concerns by the communities on our outer coast, state and federal

agencies have several years of data collection and modeling addressing erosion and coastal processes. But we do not have a parallel level of sustained, comprehensive monitoring and forecasting for Puget Sound. We need tribes, state agencies, federal agencies, local communities and the private sector to work together on designing, initiating and sustaining such a monitoring and forecasting program. Although some of the pieces of this program are already in place, we need a comprehensive and sustained effort to support preparation and adaptation to sea level rise.

Nearshore elevation data control points to support sea level rise assessment should be improved. One specific and important action is to improve the elevation data control points along our coastline. We need to monitor and evaluate changes in sea level rise measured in inches. Our elevation control points need to be upgraded and maintained to provide a high level of accuracy to support sea level rise monitoring.

At some point, there may be a critical need for a comprehensive cost-risk analysis to comparatively evaluate all coastal risks. This would complement local jurisdiction risk assessments and risk management planning.

3. Coastal Nearshore Habitat Restoration and Protection Strategy

The goal of this strategy is to improve the long-term resilience of habitat protection and restoration projects to sea level rise and other climate change impacts. Permanent protection is the intent of conservation easements and habitat area purchases. Habitat protection and restoration investments in the coastal area should explicitly consider implications of sea-level rise and other climate change impacts to achieve the intended permanent protection of priority shoreline habitat. Additionally, opportunities for habitat restoration should be considered as part of long-term planning for armored and diked shorelines.

There are numerous public and private efforts (and significant investments) currently underway to restore and protect the Pacific Northwest's wetlands, beaches, and other coastal habitats, and the fish and wildlife species they support. The increased emphasis on ecosystem-based approaches and adaptive management principles in many of these plans will no doubt help the region deal with the multitude of stressors at play, including some climate change.

However, failure to explicitly take the effects of sea-level rise and other climate change impacts into consideration in the region's coastal habitat restoration and protection plans will make it much more difficult, if not impossible, to meet our important long-term conservation goals. For example, increasing the resiliency of coastal habitats to sea-level rise may require expanding the areas of restoration to accommodate for habitat migration, or restoring a greater diversity of habitat types in a given area to better support ecosystem functions.

For armored and diked shorelines, opportunities for improving habitat conditions and resilience should be considered when making long-term management decisions related to sea level rise. In

some cases, measures that improve the long-term resilience of diking and armoring may also improve or restore habitat. In other instances, it may be most prudent to relocate dikes or other facilities further inland, potentially allowing restoration of the intervening area.

While the relevance and effectiveness of specific strategies will vary by location, ecosystem types, respective organizational and agency jurisdictions, and the existence of other anthropogenic stressors, the state of Washington can and should provide important guidance through the following actions.

Recommendation 3.1: Direct relevant state agencies to incorporate sea-level rise into state-managed and supported coastal restoration and protection projects.

State agencies should incorporate sea level rise into state-managed and supported coastal restoration and protection projects (e.g., the Puget Sound Nearshore Ecosystem Restoration Project, the forthcoming 2020 Action Agenda of the Puget Sound Partnership, and the Comprehensive Wildlife Conservation Strategy). Resilience to longer term sea level rise should be a required criterion for state funding of local and private coastal habitat projects. Also, additional sources of dedicated funding should be identified and secured, specifically oriented to improving resilience of coastal habitat to sea level rise and other changes.

Recommendation 3.2: Develop guidelines for local governments, tribes, non-governmental organizations, and other stakeholders to address sea-level rise impacts in coastal habitat restoration and protection projects.

Nearshore areas adjacent to vulnerable coastal habitats for should be eligible for preservation, conservation easements and/or purchase by all conservation entities active in the coastal area. A broad set of government agencies, national and local non-governmental organizations such as land trusts, tribes and others are involved with property and easement acquisition to ensure habitat conservation. These groups need to consider the implications of sea level rise on their activities and mission. They should also provide funding for habitat projects that are partially or largely oriented toward adaptation to sea level rise.

Recommendation 3.3: Include habitat reclamation opportunities in long-term management of armored/diked shorelines.

The state, along with other agencies and non-governmental organizations involved in permanent habitat protection, should define an outreach strategy to diking districts and others responsible for maintaining diked areas. The initial objective should be informing the owners and operators of the dikes regarding the long-term challenge of sea level rise. Methods for including sea level rise projections in facility planning should be developed, especially methods tailored to use by small districts and other entities with limited resources.

4. Coastal Facility Construction and Maintenance Strategy

The state should routinely consider sea level rise and climate change impacts in planning for construction and major repairs to coastal facilities. A primary focus of the strategy is on state funds – funds used to construct and maintain state-owned coastal facilities, and funds provided to local governments for capital projects. Sea level rise should be factored into all state investments in coastal and nearshore facilities. The strategy also highlights the challenges and opportunities facing the entities responsible for diked and armored coastal shorelines. Multiple private and public entities own or maintain diked and armored shorelines. These shorelines will have significant vulnerability to sea level rise.

Consideration of risk is at the heart of this strategy. Specific sea level rise projections are fairly uncertain at this time and vary widely, but there is consensus that sea level *will* rise over the coming decades and beyond. The level of investment should drive consideration of risk from sea level rise. Significant long-term infrastructure investments near the shoreline should be based on a conservative approach based on the best scientific data.

Over time, guidance can evolve as projections related to sea level rise become increasingly definitive. Early examples of incorporating sea level rise risk into capital project planning will hopefully inform all parties contemplating facility construction or major maintenance in coastal areas. In addition, there will be points of significant opportunity for incorporating projected sea level rise into facility design, as existing shoreline facilities require periodic major maintenance or replacement.

Recommendation 4.1: Include best available data on sea level rise in design of coastal facility construction and major repair projects.

Sea level rise projections should be considered during capital project and major maintenance or replacement of publicly-owned coastal facilities. At this time, project-specific consideration of sea level rise appears to be the logical approach, due to uncertain and varying sea level rise projections. All state-owned capital and major repair projects involving coastal facilities should address sea level rise projections.

There should be a move towards design of sea level rise benchmarks and risk reduction guidelines for coastal facility planning. The engineering community should be encouraged to develop guidance and methods for considering sea level rise in construction and major repair. Tiers of recommendations based on level of risk over time to various types of facilities can be identified. These should be tied to improved mapping of potential sea levels in various areas of the ocean coast and Puget Sound as discussed in Coastal PAWG Strategy 2, *Vulnerability Characterization and Monitoring*.

Recommendation 4.2: Require consideration of sea level rise in state infrastructure funding programs.

The state has a host of funding programs that support local governments and other entities in facility construction and major maintenance. Coastal infrastructure projects should be required to consider future sea level in project analysis and design. As explained above, this should evolve from project-specific consideration at this time, toward facility planning sea level rise benchmarks.

Additional Considerations

The Coastal PAWG also recommended three key overarching actions:

Continue a multi-party coordinating group on this topic. One state agency should be designated as the convener of a continued group with membership similar to the PAWG. This group is vital to continue coordination and clarifying roles of various entities in research and action measures.

Conduct education programs and provide access to information. The state should conduct or sponsor climate change and sea level rise education programs, and provide access to information on these impacts and planning for the public, government officials, property owners and others.

Support coordination within and across agencies. The state should support coordination within and across agencies to help avoid an overly narrow response to the impacts of climate change and sea level rise, and support specific assignment of agency staff to focus on these issues. Both are vital elements for state agency success in helping coastal communities and ecosystems adapt to sea level rise and other climate change impacts.

FORESTRY

Projected 21st century changes in temperature and precipitation will affect forests differently depending on their elevation and proximity to the coast. The main impacts will be changes in tree growth, changes in establishment and regeneration, changes in disturbance regimes, and eventually, changes in species composition and range. Some of these changes have already been observed and are consistent with observed increases in temperature.

Increased summer temperature may lead to non-linear increases in evapotranspiration from vegetation and land surfaces. This effect would be exacerbated by decreases in growing season precipitation if they occur. Lower water availability, in turn, would decrease the growth, vigor, and fuel moisture in lower elevation forests (e.g., ponderosa pine, Douglas-fir and western hemlock) while increasing growth and regeneration in high elevation forests (e.g., subalpine fir, Pacific silver fir, and mountain hemlock).

Higher temperatures would also affect the range and speed up the reproductive cycle of climatically limited forest insects such as the mountain pine beetle. Other insects and pathogens whose northern or elevation ranges were previously limited by temperature can be expected to expand northward and upslope. Lower water availability also increases the vulnerability of individual trees to insect attack. Higher temperatures or decreased summer precipitation would likely increase the area burned by fire and fire frequency in both eastern and western Washington. Mountain Pine Beetle outbreaks in British Columbia and Idaho have resulted in large and possibly unprecedented landscape-scale mortality of forests. Fire severity may also increase, although this is highly dependent on site-level fuel characteristics.

The distribution and abundance of plant and animal species will likely change over time, given that paleoecological data show their sensitivity to climatic variability. This change may be difficult to observe at local scales or short time frames, except in cases where large-scale disturbances such as fire, insect outbreaks, or windstorms have removed much of the overstory, thereby "clearing the slate" for a new cohort of vegetation. The regeneration phase will be the key stage at which species will compete and establish in a warmer climate, thus determining the composition of future vegetative assemblages and habitat for animals.

The Forestry Preparation and Adaptation Work Group (Forestry PAWG)[13] examined the impacts of climate change for forestry and developed the following goals and strategies. The scope and complexity of potential effects of climate change on Washington's forests, along with limits on scientific understanding, present significant challenges to the development of effective preparation and adaptation strategies. Climate change itself may also affect the likely success of

[13] Members of the Forestry PAWG are listed in Appendix A.

the preparation and adaptation strategies employed in response to climate change, creating evolving conditions in which promising strategies lose their effectiveness. However, these recommendations have the potential, if undertaken soon, to create forest environments that are more resilient to change and that supply future generations with the ecosystem services we count on from Washington's forests.

Key Forestry Impacts and Issues for Washington State

The likely pattern of climate change in Washington will potentially have significant effects on the state's forests, forest ecosystems, and the benefits residents gain from forests. Key issues and impacts include the following:

Vulnerability to Insects and Diseases

Increased temperature, combined with the Pacific Northwest's characteristically dry summers, will directly stress trees in drier regions of the state, and will likely contribute to the increase of insect damage to trees. If summer precipitation also declines, which is not currently predicted for certain, these impacts will be greater. These effects, combined with more crowded and uniform forests due in part to decades of fire suppression and past management practices, are likely to make these forests more vulnerable to epidemics of forest insects and disease, such as the extensive bark beetle damage already evident in portions of Eastern Washington.

Size and Severity of Wildfires

The increased temperature and dryness, combined with widespread areas of dead or damaged trees due to insect infestations, and again combined with uniform and overcrowded forest conditions, make these forests vulnerable to the spread of large and/or severe forest fires. The high density of trees, especially dead or dying trees, contributes forest fuels that allow fires to burn hotter and spread farther more quickly. Recent large fires in Eastern Washington may be evidence of this trend, although large fires also burned in prior decades. Larger and more severe of wildfires also emit more carbon dioxide (CO_2) into the atmosphere, which may contribute to climate change. Carbon dioxide emissions from wildfires in Washington state have been found to be significant compared to total emissions from fossil fuel burning in the state. Forest fires could also contribute to human health effects, primarily smoke inhalation, and to damage to houses and public facilities. Many of these ancillary impacts will be analyzed by other Preparation and Adaptation Work Groups.

Runoff and Streamflow

Increased winter temperature and accompanying shift of winter snowfall to rainfall, and potential for increased severity of storms all raise the possibility of greater winter storm runoff and streamflow, especially in mountainous areas of Western Washington. Care will need to be taken that the extensive system of active and inactive forest roads is capable of handling increased flows without suffering damage or causing damage to salmon habitat and other conditions downstream. These watershed effects, accentuated by changes in forest cover and land use, have

the potential to cause major impacts. Streamflow changes also could contribute to changes for water supply and agriculture being analyzed elsewhere in this report.

Native and Non-Native Species

Predicted climate change may have largely unknown effects on individual populations of native and non-native plants and animals in Washington's forests. Individual species may experience changes in their physiology, ecological relationships with other species, and distribution within the state. Species with the potential for experiencing change as a result of climate warming include valuable timber species, species that are currently viewed as invasive pests or could become so, already at-risk species that have dwindled in numbers due to non-climate conditions, and species upon which many other species rely for important ecosystem functions. Some species may expand their range to higher elevations or more northerly latitudes, while other species may retreat. If species' suitable living conditions shift in location due to climate change, and human development or other conditions block a corresponding movement of the species themselves, those species may face declines. Particularly hard to predict are the possible ecological interactions among species that may newly encounter one another, or encounter one another in different locations or circumstances.

Forest Management

All the foregoing developments will have implications for management of Washington's working forests. As commercial timber species and other species change in direct or indirect response to climate change, traditional management guidelines and practices may become outdated. Effort will need to be spent updating management methods to make them more adaptive, although the future conditions that management must anticipate may remain uncertain.

In addition to working forests and commercial timber, Washington's critical network of forests protected in parks, wilderness areas, and other reserves will be stressed by climate change, due to all the factors discussed above. In the case of these protected areas, and the habitats they contain, adaptability to climate change may be limited by their fixed boundaries, by limited buffering from climate-induced changes outside those boundaries, such as fire, and by wide gaps between areas. In addition, restrictions on management intervention, while otherwise prudent, may limit actions that are adaptive to potential changes brought about by a changing climate.

Forestry Resources Preparation and Adaptation Working Group Recommendations

The Forestry PAWG developed five main strategies encompassing a number of specific recommendations to address potential impacts to forestry from climate change:

1. Forest health and fire strategy

1.1. Provide comprehensive data and information to landowners, policy makers, and the public about existing and developing forest health and fire hazard conditions.

1.2. Use new state authority to create forest health scientific advisory committees to assist decision-makers in responding to extreme forest health and fire hazard problems.

1.3. Fully fund and implement on-the-ground pilot programs.

1.4. Provide public financial and technical assistance to owners of small forestland parcels.

1.5. Implement an active communication and education strategy.

1.6. Foster a collaborative atmosphere across multiple jurisdictions, landowners, and stakeholders to promote agreement on forest health and fire hazard response approaches.

1.7. Improve coordination of regulatory requirements to remove unnecessary barriers while ensuring program objectives are being met.

1.8. Engage the private sector as a partner through market and investment opportunities.

2. Streamflow and fish strategy

2.1. Develop hydrologic models and watershed assessments for Washington rivers to forecast predicted water flows, especially in forested areas, and develop rapid technology transfer mechanisms to facilitate the use of modeling information in plans and prioritization.

2.2. Institutionalize ready access to best available science, from regional to site-specific scales, relating science to climate change impacts on stream hydrology and aquatic resources.

2.3. Institutionalize scientifically-based, function-centered goals and associated metrics to guide management prescriptions, monitoring and evaluation of aquatic communities and fisheries habitats.

2.4. Develop a clearinghouse for scientifically credible field-level best practices to address aquatic system responses to climate change.

3. Species physiology, ecology, and distribution strategy

3.1. Focus initially on both commercial and non-commercial forest tree species.

3.2. Develop a better understanding of likely impacts of climate change on tree species and evaluate strategies to minimize or adapt to those risks.

3.3. Keep forestland managers, policy makers, and the public informed with the current state of knowledge and the range of adaptation strategies being considered.

3.4. Begin to implement risk management strategies now to ensure the perpetuation of tree genetic resources.

4. Commercial timber management strategy

4.1. Focus adaptive management strategies on Washington's 12 million acres of commercial forestlands.

4.2. Improve scientific research into commercial tree species' physiological responses to climate change.

4.3. Develop physiological and ecological process-based growth and yields models for diverse commercial management scenarios.

4.4. Implement a genetic conservation program.

4.5. Promote investment of wood products or energy production infrastructure adapted to changes in commercial forest management associated with climate change.

4.6. Anticipate the development of markets for non-traditional products and services from commercial forests, including carbon storage.

5. Protected areas and habitat strategy

5.1. Complete a vulnerability assessment to identify specific species, habitats, landscapes, ecosystem functions, and cultural resources that may be most sensitive to climate change.

5.2. Identify potential forest "refugia" that may be capable of sustaining at-risk species and that themselves are likely to be viable in the face of climate-driven disturbance forces.

5.3. Maintain functional habitat networks and connectivity.

5.4. Attempt to maintain dominant native tree and shrub species, and promote species and stand structural and landscape diversity.

5.5. Develop strategies to respond to potential increases in undesirable exotic and invasive species, including triage strategies and rapid response to emerging circumstances.

5.6. Explore mechanisms for adjusting the size, boundaries, and location of protected reserves when required to maintain the full range of functions.

5.7. Develop guidelines for experimental translocation of individual species or genetic material in special circumstances.

1. Forest Health and Fire Strategy

The goal of this strategy is to sustain forest cover, forest resilience, and a broad range of ecological functions and services, in the face of climate-driven insect, pathogen, and severe fire stressors, which are currently more severe in Eastern Washington forests, by effectively shaping the trajectories of forests that are strongly affected by or highly vulnerable to those stressors. Many of the recommendations listed under this strategy can be found in the 2004 report, *A Desirable Forest Health Program for Washington's Forests*, by the Forest Health Strategy Work Group.

A good start has been made on many of these strategies. The Legislature has created a three-tier response system and provided initial funding. Other measures are contained in the Department of Natural Resources' (DNR) *Wildland Fire Strategic Plan*. A robust collaborative effort is underway in northeast Washington sponsored by U.S. Forest Service. Another good example is the Tapash Sustainable Forest Collaborative centered on the Naches River Basin, involving the US Forest Service, DNR, Washington Department of Fish and Wildlife, Yakama Tribes, and The Nature Conservancy. The Colville and Yakama Tribes have provided good models of integrated forest health, conservation, and commercial timber management on their respective reservation lands. Modest monitoring efforts exist that can be built on, and new GIS-based model development projects are underway in federal and academic research organizations.

Critical needs include funding for expanded data collection, storage, analysis, and distribution; on-the-ground pilot programs; expanded education and training; and broadened and replicated collaborative efforts. Addition needs include the development and refinement of models, identification of threshold levels for action, development of broadly accepted site-specific best practices, identification of regulatory barriers, and identification of key leverage points for public financial assistance.

Feasibility issues to consider when implementing this strategy include a current lack of site-specific information on stand conditions, stressors, and baseline trajectories; an inability to predict controlling environmental conditions in the future; an inability to confidently predict site-specific response to treatments in a changing climate, particularly the resilience of various post-treatment forest conditions; competing objectives regarding degree of acceptable management intervention on various ownership; issues around proprietary information; and a lack of venues for collaborative efforts.

Recommendation 1.1: Provide comprehensive data and information to landowners, policy makers, and the public about existing and developing forest health and fire hazard conditions.

Credible scientific information is needed as the basis for management and planning. Comprehensive data and information should be provided to landowners, policy makers, and the public about existing and developing forest health and fire hazard conditions, and areas of greatest treatment need identified. Regional forest health and fire hazard modeling capability should be developed that merges the available remote sensing and existing inventory data with existing GIS layers, and offers these data in downloadable form to assist in assessing current and projected risks, and in prioritizing treatment needs, including repaid response needs. Current monitoring programs should be strengthened, and the capacity to disseminate forest health fire hazard information to decision makers and the public increased. Without sufficient detail and timeliness of information to support site-specific treatment design involving multiple landowners with different objectives, at-risk forests will not be effectively treated to reduce risk of loss.

Recommendation 1.2: Use new state authority to create forest health scientific advisory committees to assist decision makers in responding to extreme forest health and fire hazard problems.

Credible information based on sound science, new regulatory authority to respond to extreme conditions may not be effectively used. Scientific advisory committees can also help ensure forestland managers are making land management decisions based on best available science. (See also recommendation 2.2 under *Streamflow and Fish Strategy*, below.)

Recommendation 1.3: Fully fund and implement on-the-ground pilot programs.

Fully fund and implement pilot programs in Eastern Washington to test site-specific forest health and fire hazard treatments in multiple broad multi-landowner areas in an explicit adaptive management context. On-the-ground pilot projects are the best method to demonstrate the efficacy of site-specific treatments so that landowners know how they can respond to extreme conditions and stakeholders know what to expect and can support needed actions. Northeast Washington is a major early priority.

Recommendation 1.4: Provide public financial and technical assistance to owners of small forestland parcels.

Provide public financial and technical assistance to owners of small forestland parcels to encourage their implementation of treatments demonstrated to be successful, and tailored to diverse landowner objectives, through science-based pilot programs. This includes support for targeted dissemination of information and training programs.

Recommendation 1.5: Implement an active communication and education strategy.

To help ensure the general public understands the nature of the forest health and fire hazard problem, its diverse causes, its future no-action trajectory, the costs of that trajectory (firefighting costs, etc.) and the rationale for the kind of treatment programs needed to change that trajectory, an active communication and education strategy should be implemented. Broad lack of understanding still exists about the consequences of past fire suppression and other forest management actions, linkages to climate change, and the potential for scientifically founded and well-targeted management intervention to reduce risk and achieve multiple future benefits. Public support is needed for successful implementation of adaptation strategies.

Recommendation 1.6: Foster a collaborative atmosphere across multiple jurisdictions, landowners, and stakeholders to promote agreement on forest health and fire hazard response approaches.

A collaborative atmosphere across multiple jurisdictions, landowners, and stakeholders should be fostered, with public and elected-official understanding and support, to promote agreement on forest health and fire hazard response approaches that are appropriate to the diverse circumstances of various private and public forestlands, and to manage collaboratively across ownership boundaries. It will be especially critical to institutionalize collaborative strategies in

order to respond to forest health and fire hazard circumstances at the broad geographic scale at which they are occurring, so that critically affected lands that could continue to pose a hazard to surrounding lands and communities as well as a continuing greenhouse gas emission hazard are not ignored. The search for collaborative solutions (e.g., on national forest lands) must be successful, and the state should focus its influence in this direction. Techniques may include workshops, focus groups, web-based communication, shared strategic plans, and collaborative demonstration projects that can develop a set of broadly accepted best practices. A particular focus on the wildland-urban interface will be critical.

Recommendation 1.7: Improve coordination of regulatory requirements to remove unnecessary barriers while ensuring program objectives are being met.

"Climate smart" laws and regulations are needed to facilitate adaptation. Coordination of regulatory requirements that may influence implementation of best practices should be improved, so as to remove unnecessary barriers while ensuring the objectives of those programs are met. These could include smoke management and reforestation requirements, among others.

Recommendation 1.8: Engage the private sector as a partner through market and investment opportunities.

The private sector must be engaged as a partner though enhancement of markets and investment opportunities. Promoting retention and development of local forest products and energy facilities could provide a market for small-diameter material and forest biomass that will likely result from forest health and fire hazard treatments, including thinning. A market provided by such processing facilities would provide additional private financial incentives for needed forest treatments, while also providing local economic benefits and reducing reliance on fossil fuel sources of energy. A specific need will be reliable long-term sourcing agreements with individual facilities.

2. Streamflow and Fish Strategy

The goal of this strategy is to maintain environmental conditions in and around streams to support the adaptation of viable aquatic communities to changes associated with climate change, especially precipitation, runoff, and soil movement patterns. This strategy complements strategies recommended by the Water Resources and Quality Working Group (see Chapter V).

This strategy takes into consideration the complex contributing factors including forest and non-forest environments in watersheds, and acknowledges multiple jurisdictions at the watershed scale. In particular, accessibility by the public and decision makers to scientific knowledge and science-based resource management practices relevant to forested streams and habitat for salmon and other aquatic species should be improved.

Not getting science quickly into the hands of managers is the biggest immediate barrier to planning and adapting to climate change, both in stream systems and the general forest environment. Models are available for some large river systems but not all, and not at a small enough scale. Science is available on climate change impacts on forest hydrology and aquatic systems, but will continue to develop over time. Authority to create expert panels to interpret science to managers is needed. Also, authority to build flexibility into regulatory systems may be crucial to the ability to take adaptive action in a timely and cost-effective way. State Forest Practices Rules are the mechanism into which adaptive flexibility must be incorporated, along with the state's Habitat Conservation Plan for those rules. Coordination with federal and tribal government is critical. Collaboration between government agencies, academia, landowners, and stakeholders will also be critical. Washington State already has an institutional structure for such collaboration in the Timber, Fish, and Wildlife process.

Feasibility issues to consider for implementing this strategy include institutional isolation and momentum, strong debate about regulatory flexibility, disputes over which practices are truly "best" in different circumstances, and the multiple scales in which scientific knowledge must be applied.

Recommendation 2.1: Develop hydrologic models and watershed assessments for Washington rivers to forecast predicted water flows, especially in forested areas, and develop rapid technology transfer mechanisms to facilitate the use of modeling information in plans and prioritization.

Reliable modeling information is foundational to design of roads, bridges, and culverts, and to predict effects on at-risk fish populations, and it is needed at smaller scales in Washington's forested watersheds. Current historical models may not be reliable predictors of the future. Distinctions should be made between groundwater-driven watersheds, and surface water-driven watersheds, which may be more susceptible to climate-induced precipitation changes. The University of Washington Climate Impacts Group (CIG) is developing hydrologic models at the watershed scale to assess and forecast water flows.

Rapid deployment of information is key to success in ensuring timely responses to changes. More effective information delivery systems are needed. The forest ecosystem, including aquatic components, will be more resilient in the face of climate change if we can reliably determine the best locations and designs of in-stream or near-stream facilities, and predict the most and least stable refugia for species.

Recommendation 2.2: Institutionalize ready access to best available science from regional to site-specific scales, relating science to climate change impacts on stream hydrology and aquatic resources.

Create independent interdisciplinary teams comprised of individuals with broadly accepted subject matter expertise to provide ready access to best available science relating to climate change impacts on stream hydrology and aquatic resources, at site-specific scales. Such access

to science is critical because of the complexity and diversity of forest aquatic systems, and the currently speculative nature of some predictions of climate change effects. Generic prescriptive measures are unlikely to be effective everywhere.

Recommendation 2.3: Institutionalize scientifically-based, function-centered goals and associated metrics to guide management prescriptions, monitoring and evaluation of aquatic communities and fisheries habitats.

Criteria and indicators need to be perfected to provide baseline information, along with threshold values triggering the need for management action. One example is the need to specify the criteria for functioning floodplains and floodplain forests.

Recommendation 2.4: Develop a clearinghouse for scientifically credible field-level best practices to address aquatic system responses to climate change.

A clearinghouse for scientifically credible field-level best practices will improve the application of scientific information in a timely manner while promoting public and stakeholder understanding and support, even when circumstances and knowledge about aquatic system responses to climate change are changeable and uncertain. Such best practices can be the foundation for collaborative approaches to aquatic resource management in forested environments. Best practices can include guidelines for owners of small forest parcels, can be the basis for expedited environmental review of public decisions, can guide forest infrastructure investments, can guide response to major disturbance such as fire, and can help ensure downstream water supplies and water quality.

3. Species Physiology, Ecology and Distribution Strategy

The goal of this strategy is to minimize the impacts of climate change on ecosystem functions by either attempting to maintain species composition similar to current species composition where current species remain physiologically and ecologically adapted to changing conditions, or maintaining similar forest ecosystem functions using alternative species. While the best way to meet the needs of species is to ensure they continue to be surrounded by their current associates, if and when that strategy results in loss of forested conditions due to species extirpation, then maintaining critical ecological functions with genetic variants of existing species or with different forest species better adapted to changing climate conditions is preferable to trying to force the retention of current species. This can only be done based on clear science-driven principles and carefully defined limits.

Existing research cooperatives currently exist, involving geneticists, silviculturists, and other needed disciplines, both within Washington and across the Pacific Northwest. These could be the foundation for expanded and targeted future efforts. A new institutional structure is needed to provide coordinated funding, and authorization to spend funds in ways outside the authority of

current separate jurisdictions. It is critical that spending be guided by principles of impartiality and regional focus.

Feasibility issues to consider regarding implementation of this strategy include inter-organizational science coordination, funding, and translation of developing scientific understanding to decision makers, resource managers, and the public.

Recommendation 3.1: Focus initially on both commercial and non-commercial forest tree species.

The initial focus should be on forest tree species, both commercial and non-commercial, because they form the dominant shaping influence over forest ecosystem structure and function. The strategies should be expanded to non-tree species as resources and knowledge permit. Invasive species are a particular concern; under some changing circumstances, native species may become invasive.

Recommendation 3.2: Develop a better understanding of likely impacts of climate change on tree species and evaluate strategies to minimize or adapt to those risks.

It may be possible to predict where certain existing species may be most at risk given anticipated climate changes. The most effective way to address this need for knowledge is to work across organizational boundaries to address these questions as a region, and take advantage of priorities, strategies, techniques, and knowledge that have proven useful elsewhere. There is an emerging, coordinated effort led by geneticists and silviculturists in the Pacific Northwest to understand impacts of climate change on native trees and to evaluate various approaches for adapting to the impacts of climate change. Providing financial and technical support for collaborative efforts will leverage existing knowledge, strengthen regional working relationships, and increase the speed of research.

Recommendation 3.2: Keep forest land managers, policy-makers, and the public informed with the current state of knowledge and the range of adaptation strategies being considered.

As information is generated, it is important to translate that into a dialogue with the people who will have to make or implement decisions, and those who must support those decisions. Funding targeted at organizations currently involved in outreach may prove cost effective.

Recommendation 3.3: Begin to implement risk management strategies now to the ensure the perpetuation of tree genetic resources.

Although adaptation strategies need to be informed by data, there are some useful activities that can be undertaken before additional knowledge becomes available. One obvious activity is a coordinated seed banking program with two initial goals: ensure the availability of adequate seed

and seedlings for reforesting areas projected to be especially vulnerable to increased fire activity; and provide ex-situ gene conservation for some of the disjunct populations or at-risk species that would be a conservation priority even in the absence of climate change.

This activity can involve a wide range of organizations, but needs some sort of coordinating body to avoid duplication of effort. This strategy also supports strategies aimed at other issues, including forest health and fire, timber management, and habitat and protected areas.

4. Commercial Timber Management Strategy

The goal of this strategy is to promote and maintain an economically and ecologically viable forest industry in Washington as climatic conditions change. The recommendations listed below are directed at encouraging and facilitating economically productive timber management, including providing incentives and assistance to owners of smaller forest parcels, so as to maintain large blocks of land in forested condition to provide forest products and ecological services, including carbon sequestration and storage.

Public and private research institutions need encouragement, funding, and incentives to develop models. Professional silvicultural experts need to be brought together to use the outcome of new modeling to develop silvicultural guidelines adaptive to anticipated climate conditions. Regulatory flexibility for critical research projects should be pursued on appropriate lands that advance understanding of commercial forest adaptation to climate change. Work should also be carried out with existing or broadened genetic conservation cooperatives to expand adaptive seed and seedling resources for out-planting.

Feasibility issues to consider in implementing this strategy include lack of coordination, competing economic priorities on commercial lands, lack of funding, difficulty securing regulatory flexibility, and difficulty guaranteeing supplies for new processing facilities.

Recommendation 4.1: Focus adaptive management strategies on Washington's 12 million acres of commercial forestlands.

Adaptive management strategies should be implemented on Washington's 12 million acres of commercial forestlands in industrial, institutional, family, tribal, and state ownerships, recognizing that management flexibility to employ new adaptive practices is greatest in these forests. A range of changes in species composition and stand structure that are likely to be resilient in the face of a variety of climate change scenarios and appropriate to site-specific ecological conditions should be identified. Such approaches, however, need a commitment to long-term monitoring. Specifically, active forest management should be used as a testing ground for applied research and demonstration programs, especially in relation to forest health and fire hazard.

Recommendation 4.2: Improve scientific research into commercial tree species' physiological responses to climate change.
Improve scientific research into commercial tree species' physiological responses to climate change across the range of genetic variability of those species to help determine adaptive patterns of reforestation on commercial timber lands.

Recommendation 4.3: Develop physiological and ecological process-based growth and yields models for diverse commercial management scenarios.
Based on applied research and analysis, develop physiological and ecological process-based growth and yields models for diverse commercial management scenarios including those involving multiple commercial species and structural complexity.

Recommendation 4.4: Implement a genetic conservation program.
Implement a genetic conservation program to protect the full genetic diversity of commercial tree species (this recommendation is supplemental to recommendation 3.3, above). This could involve expanded seed orchards and nurseries to provide adequate material for out-planting in the forest, especially following major disturbance events such as large wildfires. It will be necessary to inventory and maintain existing genetic material and fill gaps. Changes in current rules for transfers of material among seed zones may also be needed.

Recommendation 4.5: Promote investment of wood products or energy production infrastructure adapted to changes in commercial forest management associated with climate change.
For example, new commercial species may emerge, and new products may be feasible from forest materials resulting from forest health treatments. These may include an increased role for biomass for biofuels or refinery derivatives. Investment in new facilities must have multi-party strategic sourcing plans to guarantee supplies.

Recommendation 4.6: Anticipate the development of markets for non-traditional products and services from commercial forests, including carbon storage.

5. Protected Areas and Habitat Strategy

The goal of this strategy is to sustain Washington's biodiversity and cultural diversity by ensuring protection of key and at-risk species, natural processes, and ecological functions, and by

promoting appropriate human access, in working forests and protected areas. Responsibility needs to be assigned for strategic vulnerability assessments, refugia analyses, invasive species response plans, protected area boundary adjustment plans, and experimental translocation guidelines. Some of these efforts are underway, but need broader, and more broadly coordinated, attention.

Feasibility issues to consider in implementing this strategy include practical conceptual difficulties regarding what's "natural" under a changing climate, and especially considering past fire suppression and creation of ecologically unstable circumstances. The relative emphasis on more active management approaches and more protective management approaches as valid adaptation strategies will need careful consideration in a collaborative multi-party, science-based setting. Current laws and regulations governing species protection and reserve management may not be flexible enough to accommodate fully adaptive strategies that may be needed. Reserves and protected areas can play an essential role as "control" areas in an adaptive management context.

Recommendation 5.1: Complete a vulnerability assessment to identify specific species, habitats, landscapes, ecosystem functions, and cultural resources that may be most sensitive to climate change.

Consider especially the potentially changing patterns of major disturbance forces such as fire, wind, and flooding which may challenge past paradigms for protection. Locations that may be especially important nodes in movement patterns of species should be identified. A prior baseline assessment of current ecosystem services supplied by Washington forests would strengthen this strategy.

Recommendation 5.2: Identify potential forest "refugia" that may be capable of sustaining at-risk species and that themselves are likely to be viable in the face of climate-driven disturbance forces.

Recommendation 5.3: Maintain functional habitat networks and connectivity.

Functional habitat networks and connectivity should be maintained, especially for species with broad ranges. This includes maintaining networks of protected areas across environmental gradients at the landscape scale. Fragmentation in the changing context of climate change should be addressed.

Recommendation 5.4: Attempt to maintain dominant native tree and shrub species, and promote species and stand structural and landscape diversity.

Attempts should be made to maintain dominant native tree and shrub species, and to promote species and stand structural and landscape diversity in the matrix of working forests surrounding protected reserves, especially on federal lands. (Also see recommendation 5.6, below.) Native species may most reliably provide full ecosystem functions.

Recommendation 5.5: Develop strategies to respond to potential increases in undesirable exotic and invasive species, including triage strategies and rapid response to emerging circumstances.

Recommendation 5.6: Explore mechanisms for adjusting the size, boundaries, and location of protected reserves when required to maintain the full range of functions.

If and when climate change alters the circumstances for which protected reserves were created, and such adjustments are feasible and carefully defined, mechanisms for adjusting the size, boundaries and location should be explored. The basis for adjustments should be the full range of functions provided by the reserve.

Recommendation 5.7: Develop guidelines for experimental translocation of individual species or genetic material in special circumstances.

Where climate-driven ecological changes threaten a species' existence, especially species with a restricted range, and suitable habitat is emerging in locations not naturally accessible to the species, guidelines for experimental translocation of individual species or genetic material should be developed.

Priority Recommendations for Ongoing Research

Even though the science underlying general climate change effects and adaptation is beginning to mature, pointing the way towards important early actions, a great need continues for information upon which to base further actions. Several categories of information are needed, including inventory and data collection regarding resource conditions and changes, results of data synthesis and analysis, applying general research results and models to more local scale, and basic research on cause-effect relationships needed to understand climate change and the effects of adaptation actions. In addition, synthesis and dissemination of available information has been identified as a critical need. Some examples of the various needs are presented below.

Inventory

- Site-specific forest stand information, needed to help design pilot forest health treatments. Most useful will be GIS-based on-the-ground or remote sensing data (such as from LiDAR).
- Landowner database, to allow targeted dissemination of information and technical assistance.

Synthesis and Analysis

- Vulnerability thresholds for various species and ecological communities.

Scaling Down of Models

- Likely precipitation, runoff, and streamflow patterns in local watersheds, given specified climate change parameters.

Basic Research

- Carrying capacity of specific forest sites given changes in soil water balance.
- Species' physiological thresholds in response to changes in climate-influenced environmental conditions.
- Genetic variability of key species across their geographic ranges.
- Site-specific results of various thinning regimes in varying circumstances, in terms of community resilience to climate-induced stressors.

In addition to research and data collections, systems of adaptive management require carefully specified resource "indicators" of potential ecosystem change, intensive monitoring related to those indicators, early warning threshold criteria for those indicators, triggering a need for evaluation and possible action, and reliable systems for bringing such information to the attention of decision makers

Additional Considerations

The Forestry PAWG also identified several overarching considerations:

Early actions are needed while we improve scientific knowledge

In all the issue areas in the forestry adaptation sector, there is enough current scientific information and understanding to support specific recommended actions now, while simultaneously gaining understanding and capability to respond more completely over time based on emerging circumstances. A critical need is dissemination of current scientific information to decision makers, resource managers, stakeholders, and the public, to gain support for current action. Meanwhile, data needs to be gathered, models need to be built, pilot projects need to be implemented to demonstrate and develop diverse best practices, and a supportive institutional context for long-term adaptive action needs to be built.

Monitoring and adaptive management have never been more important

Biological and ecological systems are complex and dynamic and respond to climate change in unpredictable ways. Management actions designed explicitly as experiments, with appropriate scientific rigor and efficient monitoring of results, will be critical but challenge traditional institutional forces that value certainty. Laws, regulations and decision-making systems may need to become more flexible, and accept risk for the sake of learning and adaptive management. A collaborative approach can support the specification of acceptable risk, the design of threshold values of monitored indicators that will trigger management response, and the range of likely

management outcomes. While actions in the face of uncertainty are no doubt needed, humility regarding human ability to achieve predictable intervention in large environmental systems is also in order, and a precautionary approach will sometimes be preferred and feasible. In most cases, an inclusive process of decision-making will be needed to clarify broadly acceptable strategies.

Biological functions and processes are the center of attention
As biological systems change in response to a changing climate, it may not be possible to always expect forest species and structural conditions to respond as they have in the past. Therefore, the focus of forestry adaptation is on physiological and ecological system functions and services rather than on individual species. This could challenge our pre-conceptions about what's "natural," under altered climate conditions. The past is not an accurate guide to what will be most ecologically adaptive in the future.

Regional collaboration will allow for a more efficient response
Adaptation to climate change in Pacific Northwest forests is a regional undertaking crossing many jurisdictions and interests with multiple, sometimes divergent values and goals. Multi-party collaboration can bridge governmental jurisdictions, cover a broader geographic area, acknowledge multiple goals, and pool scientific information. A collaborative approach is therefore more efficient in the long run than a more fractured approach. However, collaboration requires a distinctive kind of shared leadership.

Maintaining Washington's forests is key to all forestry strategies
Past and current losses of forest cover can accentuate some of the problems driven by climate change and reduce options for adaptation. Forests also sequester and store carbon, making a crucial contribution to Washington's strategies to mitigate climate change.

The public will need dedicated education and outreach efforts
A well-informed and motivated public will be crucial to climate change preparation and adaptation, both to stimulate individual actions and to generate support for sometimes difficult public policy decisions. A sustained effort will be needed that allows the public to recognize the significance of climate change before obvious crisis conditions occur and while scientific understanding is still developing.

Major change is foreseeable in forests of eastern and western Washington. Greatest change may be triggered by characteristic major disturbance agents in these two distinct regions, such as fire, wind, and rainstorms.

Observed warming over the 20th century has resulted in substantial losses of snowpack in the last 60 years or so, particularly in the warmer areas west of the Cascades. In the Washington and Oregon Cascades, for example, spatially averaged losses of snowpack since the mid 1940s have been about 30 percent (Figure 1). Model simulations using both physically based models and statistical approaches have shown that at least two thirds of this decline is due to observed warming alone, with the remainder associated with reductions in precipitation. Changes in streamflow timing that are consistent with these changes in natural storage have also been observed in the Pacific Northwest and across the western U.S., since about 1950.

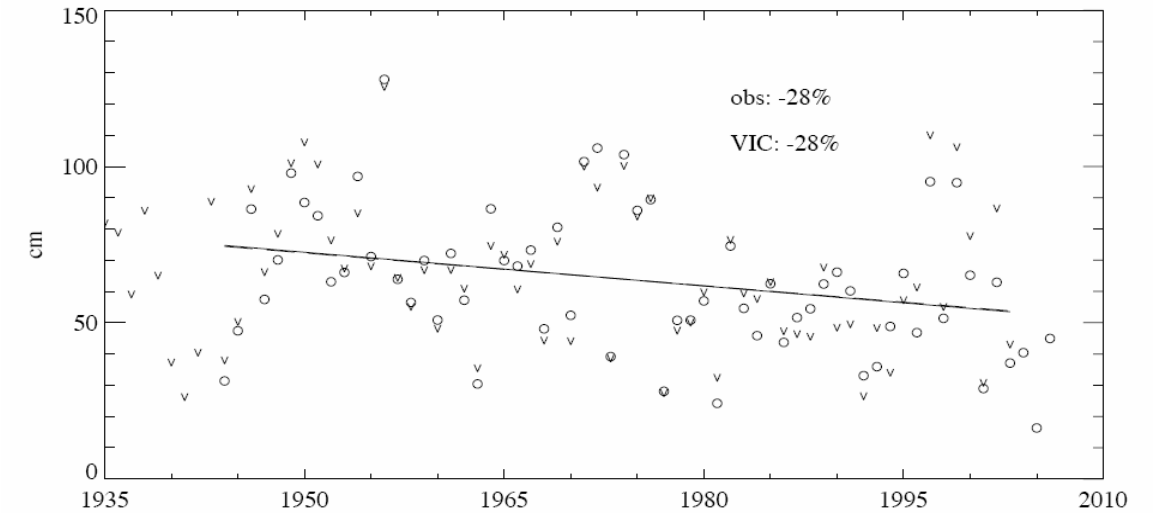

Figure 1: Linear trends in April 1 snow water equivalent averaged over the Cascades from a) area-weighted snow course observations (open circles) and b) VIC hydrologic model simulations (v symbols) (Source Mote et al., 2007: Has spring snowpack declined in the Washington Cascades?, Hydrologic Earth System Sciences Discussions, 4, 2073-2110)

Future projections of river flow in the Pacific Northwest using hydrologic models have shown pronounced changes in natural water storage (snowpack and soil moisture) associated with projected regional warming expected by the mid-21st century. In many mountain watersheds, loss of snowpack results in streamflow timing shifts from warm season (summer) to cool season (winter). In snowmelt dominant river basins, for example, warmer conditions would result in increased winter flows, earlier and reduced peak flows in the spring, and reduced summer flows (Figure 2). The extent of these changes in natural storage and seasonal water availability depends strongly on elevation and proximity to the coast which determine average winter temperatures in each particular basin. Colder areas (e.g., inland areas at higher elevations) are generally less affected than areas near freezing in mid-winter (e.g., near coastal areas at moderate elevation). These differences in hydrologic response highlight the need to produce

streamflow scenarios in individual river basins that account for each basin's unique sensitivity to warming.

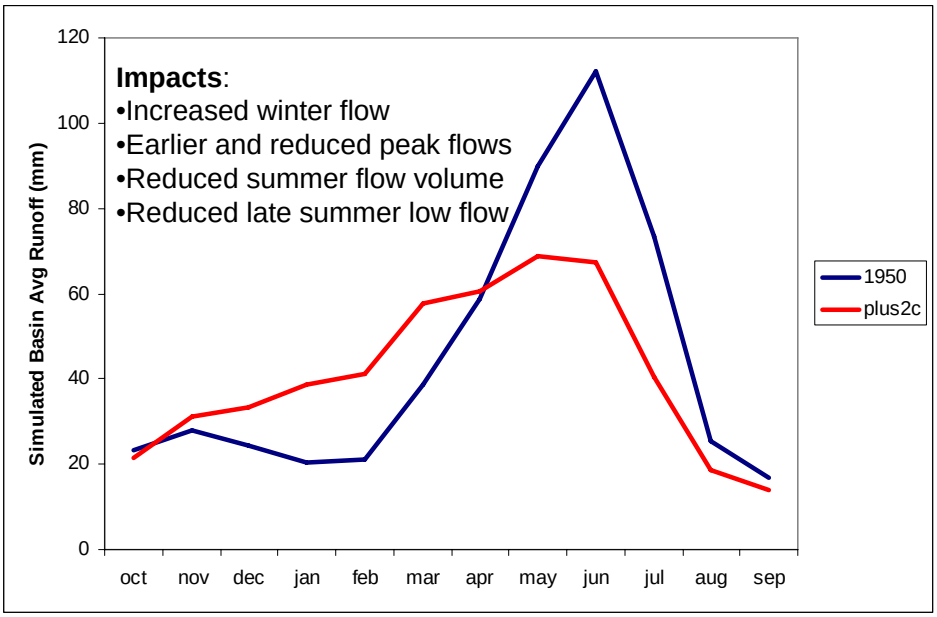

Figure 2: Simulated changes in long-term average natural runoff for the Naches River in the Yakima basin resulting from a 2 degrees C warming. The blue "1950" trace shows the average hydrologic response associated with mid-20th century temperatures, the red "plus2C" trace shows the average hydrologic response associated with temperatures 2 degrees C warmer than the late 20th century. The traces are the average for 88 years of simulation. Precipitation is identical in each case.

Although modeling studies and monitoring of water quality have so far been relatively limited in scope, significant changes in water quality are also expected to accompany regional warming, including increased water temperature and potential changes in sediment transport.

The hydrologic changes outlined above have many important implications for water resources management, planning, and policy in the Pacific Northwest, some of which are listed below.

Water Supply and Demand

- Changes in the seasonality of water supply (e.g. reductions in summer)
- Changes in water demand (e.g. potentially increasing evaporation)
- Changes in drought stress
- Increasing conflicts between water supply and other uses and users of water

Energy Supply and Demand

- Changes in the seasonality and quantity of hydropower resources
- Changes in energy demand
- Increasing conflicts between hydropower and other uses and users of water

Instream Flow Augmentation

- Changes in low-flow risks
- Changes in the need for releases from storage to reproduce existing streamflow regime.
- Changes in water resources management related to water quality (e.g., to provide dilution flow or to control temperature)

Flood Control and Land Use Planning

- Changes in flood risks
- Changes in flood control evacuation and timing
- Changes in design standards and land use planning
- Dam safety procedures

Estuaries

- Changing flood risk in low lying areas
- Impacts to ecosystem function as a result of changes in the timing and volume of freshwater inflows (e.g., increased winter peak flows, reduced summer low flows)
- Changes in land use policy and insurance as a result of changes in flood risk (e.g., coastal armoring, land ownership, FEMA maps)

Ecosystem Function

- Impacts to fish and aquatic ecosystems related to changes in the seasonality and intensity of flows (e.g., increased winter peak flows, reduced summer low flows)
- Changes in watershed function due to large-scale vegetation changes (e.g. , fire, insect damage)
- Changes in aquatic ecosystem function related to changes in water quality (e.g., changes in water temperature, sediment transport)

Long-Term Planning, Water Resources Agreements, Water Law and Policy

- Water allocation agreements in a non-stationary climate (e.g., water permitting)

- Appropriateness of the historic streamflow record as a legal definition of climate variability or water availability
- Need for new water planning and management frameworks in a non-stationary climate
- Transboundary implications (e.g., Columbia Basin, Snake River, Spokane Aquifer)

The Water Preparation and Adaptation Work Group (Water PAWG), drawn from state agencies, local and tribal governments and various water resource interests,[14] met between June and December 2006 to discuss preparation and adaptation to climate change in relation to the needs for water resources in Washington state. This report captures the findings and recommendations that emerged from these discussions.

Key Water Resources Impacts and Issues for Washington State

For the Pacific Northwest, climate change models indicate that a likely effect on water resources will be reduced snowpack and earlier runoff. Although overall precipitation may remain the same, more may fall as rain than as snow, with rain events likely to be more intense. Given the earlier snowpack melt, streamflows may be lower in summer and early fall, with in-stream temperatures higher due to higher air temperatures. This set of circumstances is likely to create significant pressures on water resources and on current tools and approaches used to manage water. That said, different watersheds across the state are likely to be affected differently by a changing climate.

The changes in climate experienced to date and expected future changes are likely to have significant effects on water supply, fish and wildlife, agriculture, flood and storm preparation, and hydropower (based on the timing and availability of water). Management systems for each of these sectors rely on past patterns of temperature and precipitation, which are now changing and will continue changing for the next half a century or more. The past is no longer a reliable predictor of the future. Management systems that have been designed around past relatively stable climate patterns will not readily accommodate the expected new extremes. Climate change is already forcing water resource managers and planners to evaluate complex tradeoffs and adapt their systems in a changing and unprecedented environment. Adaptive management approaches are already being adopted in many contexts.

While climate change is likely to impact the net amount of water that a basin receives, it is the uncertainty, variability and timing that have the greatest impact on water supply infrastructure. The impacts of climate change will also be compounded by increasing urban and suburban populations that will continue to stress water resources and water

[14] Members of the Water PAWG are listed in Appendix A.

management systems. Establishing the ability to continuously adapt as hydrologic regimes and water demands change will require time, planning, and long-term thinking.

A reliable supply of water is crucial for the communities, businesses, industries, ecology, and quality of life in Washington. Streams and aquifers rely on precipitation, which may be stored in snow, lakes or higher groundwater systems. As climate change shifts the timing and volume of streamflows, and reduces snowpack, more frequent low flows during the summer will make it more difficult to meet both in-stream and out-of-stream needs. Reduced groundwater recharge will also make it more difficult for water suppliers to meet the needs of consumers and preserve in-stream values in snowmelt-fed watersheds. Projected increases in air temperature will likely lead to warmer stream temperatures, especially during the summer.

Temperature changes and changes in the volume and timing of streamflows are likely to create environmental conditions that are detrimental to Pacific Northwest cold water fish populations. Salmon are at particular risk. Shifts in the amount and timing of streamflow will also affect hydropower. While increasing temperatures and rising CO2 levels may enhance potential crop production, soil moisture is projected to decrease, and crops could suffer more days of heat and moisture stress. Increased winter flows and lower summer flows are likely to reduce the availability of irrigation water when it is needed the most.

Changes in precipitation relative to temperature change are uncertain. Increases in temperature may cause more precipitation to fall as rain instead of snow, leading to an increase in flooding in winter even if total precipitation remains the same. If winter precipitation increases in the future, as some models suggest, the risk of flooding would be compounded for flood management systems designed to address historic events, and with major components aging. Likely climate change impacts on urban stormwater flooding are not well understood and require localized assessments and modeling. Many existing stormwater systems cannot handle out-of-the-ordinary deluges, as have recently occurred in some urban areas.

Water Resources and Quality Preparation and Adaptation Working Group Recommendations

The Water PAWG developed four priority strategies encompassing a number of specific recommendations to address the potential impacts of climate change. Additional priority areas, such as stormwater, hydropower, water quality, flood management, and dam operations, were not discussed by the PAWG due to time constraints, but are important to consider in the future. The Water PAWG suggests that the state authorize its continuation through 2008 to refine the four recommendations and provide additional recommendations for other priority areas. In addition, the Water PAWG suggests

providing a long-term venue for further comprehensive discussions about strategies for addressing climate change impacts on freshwater in Washington.

The Water PAWG offers the following recommendations, organized as four main strategies:

1. **Water resource management strategy**
   - 1.1 Identify and improve existing water resource policies, agreements and laws that limit the ability to manage and/or that exacerbate water resource challenges resulting from climate change.
   - 1.2 Evaluate options to meet water demand (considering potential climate change effects).
   - 1.3 Restore and protect natural watershed functions
   - 1.4 Create programs and incentives to encourage the consolidation or cooperative management of public water systems.
2. **Water conservation and efficiency strategy**
   - 2.1 Establish and fund a statewide water conservation program.
   - 2.2 Define guidance or standards for water conservation and related energy efficiency.
   - 2.3 Provide educational outreach on water conservation.
3. **Emergency preparedness and drought management strategy**
   - 3.1 Fund the drought preparedness and emergency water supply projects accounts and modify the utilization requirements therein.
   - 3.2 Remove the 10 percent allocation cap for non-agriculture uses for emergency drought relief.
   - 3.3 Create appropriate statewide drought management strategies that account for evolving drought risks in a warmer climate.
4. **Water resources planning and information strategy**
   - 4.1 Fund additional research and monitoring programs to improve understanding of available water supplies (surface and groundwater), water use, and linkages to climate variability and climate change.
   - 4.2 Incorporate climate change considerations into long range and emergency planning.
   - 4.3 Provide outreach to the public and others to plan and prepare for climate change.

Because the strategies overlap to some extent, the recommendations are separated in the interest of identifying specific discrete steps. Implementation steps for recommendations

to address the strategies are described below. No priority is assigned by the numbering. The Water PAWG believes that preference should be given to actions likely to have the lowest cost and environmental impact. Such actions generally can be implemented more quickly, with more agreement, and are less likely to be regretted at a later date.

The Water PAWG also recognizes that all of these strategies may not be relevant to all areas of Washington. Water resources vary significantly within the state and the effects of climate change and approaches to adaptation are likely to vary as well. The Washington State Legislature and departments of Ecology, Health, and Community, Trade, and Economic Development will play significant roles in implementing the following recommendations, in cooperation with local governments and watershed or other planning groups.

6. Water Resource Management Strategy

This strategy focuses on addressing current approaches to water resource management and allocation within Washington in preparation for and adaptation to the impacts of climate change. It addresses current barriers as well as identifies potential new approaches and means for sustainable water management in relation to the challenges of climate change.

Given the significant potential effects of climate change on water availability (including timing and amount), many existing serious challenges concerning appropriate allocations of water are likely to be exacerbated. The goal of the strategy is to examine various approaches to manage water supplies to meet both in-stream and out-of-stream demands, including public health and safety, in an increasingly unpredictable future. Access to water in the state is governed by various laws, regulations, programs, and policies that have divided the resource among many competing uses, including municipal drinking water supplies, energy and agricultural production, tribal rights, and fish and wildlife habitat. The major push in the past ten years to develop watershed plans in basins across the state, while beneficial, has not generally accounted for climate change impacts. Even without specific effects of climate change, in many parts of the state, the demand for water has exceeded available supplies. This situation is likely to grow worse and require increasingly rapid and adaptable responses to water management in some areas. The state's current management structures and decision-making processes are likely to be inadequate for the magnitude, scope and speed of water management decisions necessary to address climate change impacts.

Recommendation 1.1: Identify and improve existing water resource policies, agreements and laws that limit the ability to manage and/or that exacerbate water resource challenges resulting from climate change.

Given that the initial recommendations of this PAWG are by necessity very limited in scope, these preliminary efforts should be expanded and extended to encompass a wider range of important water resources issues that are likely to be affected by climate change, but which cannot be evaluated fully within the scope of the existing effort. For instance, the ability to adapt to the impacts of climate change on water resources as a whole, and to the regional variability of those impacts, will be directly affected by current water resources laws, policies, and agreements. In this context, the Governor and the Governor's Office are in a unique position to provide state-wide oversight and to take the leadership role in encouraging, mandating, facilitating, and funding the evaluation of current water resources policies, agreements, and water laws with the objectives of:

- Identifying additional areas of significant climate change vulnerability;
- Motivating appropriate agencies, groups, or individuals to take action to reduce these vulnerabilities via long-term planning, changes in water management policies, or other actions; and
- Institutionalizing the long-term and on-going process of climate change adaptation in the water sector.

Additional studies, with high level oversight in state government, could benefit areas of concern. For example:

- Comprehensively review dam safety and flood control operating plans to evaluate robustness in the face of a changing climate and make operational changes as needed to reduce impacts (keeping in mind the need to maintain and in many cases improve dam operations to minimize impact on fish and wildlife populations, which will also likely be stressed by climate change).
- Request that climate change be explicitly included in the proposed Columbia Basin comprehensive flood control review.
- Comprehensively evaluate the economic effects of changing hydropower resources due to altered run-off patterns from climate change in the context of changing fossil fuel markets, increasing cost-effective energy efficiency potential, and a growing portfolio of renewable energy sources such as wind power.
- Evaluate the sustainability of exempt wells in suburban development projects and other rapidly developing areas on a statewide basis.
- Evaluate and develop the means to achieve instream flow requirements in light of expected hydrological changes due to climate change.

One approach to do this is for agencies and representatives to evaluate existing implementation authority/ mechanisms that can be strengthened or adapted including the following:

- Watershed plans under the Watershed Planning Act
- Columbia Basin Water Management Program authorized in 2006
- Local or regional water management groups (e.g., groups in the Cedar River, Green River, Yakima Basin and Walla Walla)

- Groundwater management plans
- State authorities (water masters, metering, enforcement/compliance, utility planning and service area obligations, trust water program)
- Local authorities (GMA, flood management plans, emergency response plans)
- Water conservation and efficiency statutes, such as:
    - Plumbing Code (RCW 19.27.031)
    - Water Supply Facilities – Referendum 38 (Chapter 43.99E RCW)
    - Water Use Efficiency Rule (RCW 70.119.180)
    - Reclaimed Water Act (Chapter 90.46 RCW)
    - Water right permits for rainwater collection

Recommendation 1.2: Evaluate options to meet water demand (considering potential climate change effects).

The Department of Ecology should conduct/sponsor a study or evaluation, including a cost-benefit analysis and an assessment of environmental impact, that examines various options in use in Washington and elsewhere that improve the ability to meet demands for water. These may include examining approaches to flexibly transfer water among different users and uses of water, including pros and cons of water markets that create equity in the ability of various sectors to purchase water; options for addressing demonstrated water supply needs, including above and below ground to meet both in-stream and out-of-stream uses; and alternative water supply options such as desalination, greywater use and rainwater collection. The study should consider the potential development of an overarching infrastructure that provides a context and guidelines for water transfers and water supply development that supports the widest range of in-stream and out-of-stream uses.

Various storage studies—including the *2001 Report to the Legislature, Artificial Storage and Recovery of Groundwater* and those done as part of Chapter 90.82 RCW planning—should be expanded to account for climate change impacts. Other options to be investigated as means to meet water needs should include:

- Modification of existing infrastructure to meet multiple purposes (e.g., water supply, flood control, in-stream flows)
- New and expanded incentives and requirements for water conservation
- Use of reverse osmosis technology to desalinate water
- New water storage options, whether in-stream or off-channel, above or below ground, through techniques such as:
    - Aquifer recharge
    - Natural water storage (e.g., beavers, wetlands)
    - New impoundment structures (e.g., new storage facilities currently being assessed through the Columbia River Water Management Program)

Recommendation 1.3: Restore and Protect Natural Watershed Functions.

Natural watershed functions can provide a buffer against stream temperature increases while serving to maximize water retention and incremental release over the water year. The departments of Ecology, Fisheries and Wildlife, Natural Resources, and Community, Trade, and Economic Development and the Recreation and Conservation Office should use the tools they have available for planning and for habitat restoration and protection to restore natural watershed functions that decrease peak flows and increase base flows. These agencies should work together to identify the minimum flows necessary to restore and protect habitat and aquatic resources. This may entail setting in-stream flows for targeted watersheds and establishing specific strategies to improve and protect flows. Depending on the watershed, this may have connections to the water supply options in Recommendation 1.2. Some potential options for restoring natural watershed functions may include:

- Assessing statewide status, needs, and opportunities to restore and protect natural watershed functions;
- Restoring flood plain connectivity;
- Continuing to support the upgrading of roads to current standards, abandonment of roads not needed or that need to be move out of floodplains and replacement of undersized culverts or fish passage barriers;
- Allowing floodwaters to inundate the surrounding land to recharge soil;
- Acquisition of property; and
- Using of techniques to protect and restore soil storage capacity including canopy and duff re-establishment along with vegetation that slows and promotes water infiltration.

Recommendation 1.4: Create programs and incentives to encourage the consolidation or cooperative management of public water systems.

State agencies should create programs and incentives that encourage public water systems to consolidate or to cooperatively manage their systems. If these strategies would lead to increased water conservation and system efficiencies, they would help systems to meet climate change, public health and safety, and water supply challenges.

7. Water Conservation and Efficiency Strategy

Conserved water is likely to be the cheapest source of new water. The state should develop and implement a coordinated program of water conservation and efficiency activities targeting multiple water use sectors within the state – agriculture, municipal water supply, wastewater, and public sector supply.

The goal of the conservation and efficiency strategy is perennial efficiency and a system of water use that rewards consistency, as well as adaptability. The state should reduce water and related energy demands and replace existing practices over time with "more" and "most efficient" practices and infrastructure. Energy efficiency reduces the need to produce hydropower for local use, thereby potentially providing greater flexibility in water supplies. The net efficiency savings can provide a buffer for those years in which climate change and related water supply variability stress the state's capacity and resources. As conservation and efficiency are incorporated into normal practices, the state will be better positioned to balance or adapt to changes in water supply or demand. The state could also consider using mandatory regulations and codes to improve water and energy efficiencies. The goal of the strategy is to develop a coordinated program that will:

- Reduce overall water use by targeted water use sectors.
- Increase water use efficiency and related energy efficiency.
- Support the development of water and energy efficient infrastructure.
- Provide funding and support for conservation initiatives.
- Include regulatory support with standards, targets and, where appropriate, enforcement.
- Provide the public with a common vision for water conservation and efficiency across the state and across multiple sectors of government and businesses.

Recommendation 2.1: Establish and Fund a Statewide Water Conservation Program.

The Legislature should appropriate $10 million to fund conservation activities across multiple sectors. With this funding, a Cooperative Statewide Conservation Program would be established to competitively disperse funds, evaluate and track performance of expenditures, and disseminate lessons learned. State agencies should pool their resources and efforts to provide a coordinated front for all sectors and users of water resources, ranging across municipal, industrial, and agricultural water use. Water conservation and efficiency activities to be supported and funded may include the following:

- Market initiatives and tax credits
- Conservation incentive programs
- Infrastructure development, redevelopment or replacement
- Compliance and enforcement strategies against water misuse
- Development and application of new technologies, techniques and best management practices (e.g., goal setting, performance measures)
- Agricultural water use efficiency techniques, new technologies, and improved best management practices
- Landscaping techniques for urban settings such as urban forests, xeriscaping, etc.
- On-site use of stormwater and rainwater and low-impact development techniques

- Retrofits of existing development for on-site use of stormwater and rainwater
- Use of basic water use service meters in communities
- Use of reclaimed water, grey water, industrial re-use

Additionally, the state should aggressively pursue federal resources to support management strategies and decisions. For example, Senate bill, S. 1766, "The Low Carbon Economy Act," includes the creation of a Climate Adaptation Fund to facilitate planning, design, and construction of projects to conserve water and improve water use efficiency.

Recommendation 2.2: Define guidance or standards for water conservation and related energy efficiency.

The departments of Ecology, Health, and Community, Trade and Economic Development should determine the effectiveness of current rules or standards and identify where changes may be needed, and assess how best management practices and guidance can help achieve water conservation and efficiency across a range of sectors. For example:

- State agencies should promote sustainable development such as plumbing and infrastructure needed for appropriate use of reclaimed water, greywater and rainwater;
- The state should explore options/standards for decreasing energy and water use for wastewater treatment;
- The state should support stronger federal and state appliance efficiency standards;
- State agencies should provide incentives and support for municipal, industrial, and agricultural efficiencies; and
- State and municipal water suppliers should identify and remove barriers to water conservation and efficiency.

Recommendation 2.3 Provide educational outreach on water conservation.

State agencies should provide education on water conservation and efficiency tools and techniques to a variety of audiences from a range of sectors. Examples include:

- Outreach programs should encourage the adoption of more efficient water conservation equipment across a range of sectors.
- Agencies should provide incentives and education for communities to use less water and energy.

8. Emergency Preparedness and Drought Management Strategy

Some climate change forecasts predict that the Pacific Northwest will likely fluctuate between warmer and wetter and warmer and drier conditions. This means that the state must prepare for routine extreme events of both types—drought and stormwater/flooding— more as chronic conditions than as emergencies. This means shifting the focus of the state's activities to preparedness across all levels of government. Part of the state's strategy should include revitalization and stable funding for the drought preparation account; active preparation and planning for drought in all sectors; and rethinking the need for and definition of drought. The strategy does not include specific steps toward a coherent state strategy regarding flooding, which has generally been the responsibility of local and regional authorities. However, the state should at least assure that flood management and response strategies across the state are updated to include the higher risks from extreme events that climate change will likely bring.

Climate change is expected to result in increased frequency, severity, and persistence of low or drought-level water supply conditions in Washington state. The goal of the strategy is to enhance the state's capacity to adapt to emergency water supply conditions by shifting emphasis from emergency response to proactive preparation and management.

Recommendation 3.1: Fund the Drought Preparedness (DPA) and Emergency Water Supply Projects accounts and modify the utilization requirements therein.
The Legislature should authorize bonding for $10 million to fund the accounts. This would allow bonds to be sold on an "as-needed" basis to support a multi-year preparation and response. Use of the account would not require new legislation if applied within existing statutes and intent. Management and rule making authority for account use is delegated to Ecology per RCW 43.83B. Adequate guidance is available (Chapter 173-166 WAC) to provide for early and effective use of the funds, and their distribution to public bodies for agricultural, municipal, and fish and wildlife water infrastructure improvements during drought conditions. A significant number of smaller infrastructure improvements could be completed within an initial 5-year period. Examples include:

- Agriculture
    - Emergency wells, improved water diversion and delivery
    - Agricultural drought relief at the family farm or direct irrigator level
- Municipal
    - Small municipal systems upgrades, emergency wells and interties
    - More flexible application of "place of use" for water rights in emergencies.
- Fish and Wildlife
    - Hatchery water supply
    - Fish collection and passage facilities

Other considerations for the drought preparation funding should include options for loan programs for non-municipal supplies. Many water supplies in the state are non-profit but not legally a public entity. These include homeowner and community associations. A "refillable" source of low cost funds targeted for emergency preparedness would encourage small utilities to make the needed infrastructure adaptations. Existing funding programs do not preclude these types of projects, but they often fail to score high enough on the funding priority lists. Operator-owned utilities and other small non-municipal utilities have a very limit set of funding resources. Long-term infrastructure improvements often get overlooked for more immediate needs. A source of low-interest loans can be an important incentive to encourage better long-term assessments and preparations.

Recommendation 3.2: Remove the 10 percent allocation cap for non-agriculture uses for emergency drought relief.

WAC 173-166-090(6) states that "no more than 10% of total available funds will be allocated for nonagricultural drought relief purposes, including the preservation of the state's fisheries during a biennium." Stakeholders other than agriculture require emergency relief from drought. In the past, Ecology has dealt with the issues this cap creates by overriding this cap via an emergency rule and/or by transferring funds to the Drought Preparedness Account, which does not contain such limitations. Removing the 10 percent cap will ensure all stakeholders are assisted during a drought emergency and will eliminate the need to expend valuable agency time on procedural tactics used to circumvent the cap.

Recommendation 3.3: Create appropriate statewide drought management strategies that account for evolving drought risks in a warmer climate.

Currently, per RCW 43.83B.400, a "drought condition means that the water supply for a geographical area or for a significant portion of a geographical area is below 75% of normal and the water shortage is likely to create undue hardships for various water uses and users." The Department of Ecology should research the appropriate definition for "normal" to better define drought. In a pre-climate-change water policy world, it was easy to calculate "normal" – it was simply the mean of the historic record. As climate changes, historical records are less predictive of water availability. This recommendation would require further research to create a formula that would define drought to remove the bias associated with older historic data that is unrepresentative of typical conditions, even seen today. A new definition of drought would also be flexible. This flexibility will allow the state to declare drought in some regions and not in others based on different definitions of supply. Clarifying what "normal" means would not remove this flexibility. A rule that goes through the public process would demystify how the

75 percent of normal supply determination is calculated. Furthermore, such a rule would help push the trend away from emergency-based drought responses toward adaptive-management-based planning.

9. Water Resources Planning and Information Strategy

The strategy promotes the need to plan for and gather better data about the effects of climate change on water resources. It recommends the integration of climate change into a variety of planning environments, including short and long-range water resource and emergency planning, and the conduct of science and information gathering research.

The strategy recognizes that the profound effects of climate change require planning from every perspective. The goal of the strategy is to incorporate climate change into long-range and emergency planning through mandates. Additionally, improved monitoring, scientific information gathering, and data management will be implemented. The strategy also aims to engage and educate a cross-section of entities that will be affected by climate change, including the public, planning groups, and local governments, with the intent of helping them plan for the future.

Recommendation 4.1: Fund additional research and monitoring programs to improve understanding of available water supplies (surface and groundwater), water use, and linkages to climate variability and climate change.

The Legislature should augment current scientific research efforts, to establish a credible infrastructure of hydrologists and climate change scientists to provide increasingly finer resolution data and understanding (e.g., at watershed scales) of effects of climate change on water resources. This scientific infrastructure can also be used to study and develop data on hydrologic changes related to large-scale disturbances, such as fire and forest die-back.

The Legislature should direct state agencies to organize data, about water resources – including water use, water quality, return flows, extent of exempt wells, ground water availability, etc., and make this information available to a broad cross-section of users. A monitoring and data management program should be established to improve the monitoring of water rights, water use, water quality, ground water resources, return flows, exempt wells, and other areas, through improved metering and reporting. Agencies, in coordination with academic institutions, should monitor ice resources, such as glaciers, temperature, and precipitation in high elevations, and quantify their influence on the hydrologic cycle at the watershed scale. Better data such as floodplain maps should be developed for siting public and private infrastructure. Comprehensive data can provide the basis for water management decisions (e.g., work in Columbia basin and Walla Walla watershed). Methodologies for better projecting outcomes related to climate

change need to be developed and used by agencies in their work, such as for the design of infrastructure, and the development of TMDLs, for example. The state should also fund or support federal funding requests for improvements to weather forecasting for the state. This would help in emergency preparedness as well as water resource management and adaptation practices.

Recommendation 4.2: Incorporate climate change into long-range planning

State and local agencies and others with responsibilities for planning should examine where climate change strategies can be incorporated.

State agencies, including the departments of Health; Community, Trade and Economic Development; Ecology; and Fish and Wildlife should review and recommend to the Legislature modifications based on water issues to the Growth Management Act (GMA), State Environmental Policy Act (SEPA), Shoreline Management Act (SMA), State Wildlife Management Plans, Coordinated Water System Planning, and Watershed Planning, to require the incorporation of climate considerations if needed. These state agencies will identify needed changes and the Legislature should provide funding to address the changes. For example, the agencies should revise the assessments done in watersheds to account for climate change impacts on both supply and demand sides, and should include climate change as an element in studies supported by state funding and in planning activities (e.g., related to water permitting). Corresponding to the planning horizon, the state should also provide population and economic forecasts to support water demand forecasting, and these could correspond to the climate change scenarios

Local governments and planning groups should be required to review and comment on existing comprehensive plans to identify, prioritize, and address issues related to climate change. Local drought response plans should be developed that include approaches for water use savings (including curtailment) during low-supply periods. These could be incorporated into existing planning such as water utility planning and local government comprehensive plans. Assessment of potential changes in flood risk should be incorporated into land use planning. Water supply, watershed, and other significant water-resource-related planning activities should consider incorporating both "likely" and "worst case" scenarios relative to water availability and water demand.

Recommendation 4.3: Provide outreach to the public and others to plan and prepare for climate change.

State agencies should ensure that information gathered as part of planning and water resources investigations is made accessible to the broadest audience possible. Planning will be required by many organizations to adapt to climate impacts, and the more accurate the information and robust the tools, the more effective the planning. Agencies can do this by engaging more actively with watershed planning groups, as well as

developing tools, fact sheets, and brochures and conducting training with local groups, schools, local governments, and others.

Additional Considerations

The Freshwater PAWG developed these strategies as a first step in addressing the potential impacts of climate change on water resources in Washington state. The cooperative effort of all parties involved in this process generated an effective exchange of ideas and interests. The PAWG recommends that the state continue to initiate climate change discussions to develop these strategies further and to address additional priority areas not yet covered. The state, along with local governments, tribes and interest groups, must continue to focus on key issues in order to preserve and protect our valuable water resources from the potentially significant effects of climate change.

CLIMATE CHANGE IMPACTS TO FISH AND WILDLIFE RESOURCES

Supplemental Recommendations from the Washington State Department of Fish and Wildlife

The Washington Department of Fish and Wildlife (WDFW) participated in the development of recommendations for the Forestry Resources, Water Resources and Quality, and Coastal and Infrastructure Preparation and Adaptation Working Groups (PAWGs). These PAWGs addressed fish and wildlife impacts indirectly in several recommendations (e.g., restore and protect and enhance natural watershed functions, maintain habitat connectivity), but significant gaps remain. Therefore, WDFW has developed the following additional recommendations that are needed to more directly address the potential impacts of climate change on fish and wildlife species in Washington State.

Recommendations:

Vulnerability Assessments of Key Habitats

Ecosystems and habitats within Washington are susceptible to harm from climate change. It is critical to conduct assessments of how vulnerable key ecological systems may be to climate change, particularly habitats that support priority species or are known concentrations of high biodiversity. Building upon the eco-regional assessments that were recently completed and used as part of the Washington Biodiversity Strategy, we must identify which systems are the most sensitive to changes in climate or climate-driven processes (e.g., fire regimes, sea-level rise, species range expansions, hydrologic cycles) and where changes in climate and climate-driven processes will likely be the greatest.

This includes:

- baseline assessments of the extent of ecological services currently provided by natural ecosystems (e.g., carbon sequestration, flood control, physical buffer, etc.);
- assessing shifts in habitat types and locations associated with climate change;
- assessing the status of all protected lands in the state to determine if conditions are adequate for protecting at-risk species in light of climate change.

Baseline assessments are essential for accurate monitoring, preventing loss of services, and mitigating climate change impacts.

Preliminary Vulnerability Assessment of Key Species

As indicated above, climate change will impact key habitats. Current climate change models are more precise at predicting changes in the global climate but less so at the regional, local and microclimate levels. This makes predicting changes in vegetation and habitat more difficult. Consequently, projecting how these altered landscapes will affect species that may reside within them becomes even less predictable. However, with the recent work done to identify the species of greatest conservation concern in the Washington Wildlife Conservation Strategies, tying these species to specific habitats and ecoregions is possible. A preliminary analysis of species most susceptible to climate change is needed. This includes using the habitat assessment above to identify the species associated with these habitats that are most at risk from climate change impacts (e.g., alpine and sub-alpine species, species that require multiple habitat types, habitat connectivity and migration corridors, etc.).

Watershed-Specific Vulnerability Assessments

Partner with the University of Washington Climate Impacts Group (CIG) to conduct vulnerability assessments of watershed functions that provide necessary habitat for salmon, steelhead and other at-risk native fish populations. The CIG is developing watershed-specific models to predict how climate change will impact flows, runoff, moisture, etc. WDFW's partnership will provide the biological analysis of how these changes will affect individual watersheds and salmon recovery plans.

State Infrastructure Vulnerability Assessment

Conduct a vulnerability assessment of state facilities necessary for natural resource management. Assess how existing infrastructure may ameliorate or exacerbate the likely impacts of climate change. For WDFW, this would include assessing vulnerabilities and impacts of hatcheries, lands, roads, dams and water supply structures.

Economic Assessment of Climate Change on Fish and Wildlife

To date, economic assessments of the impacts to Washington associated with climate change have omitted fish and wildlife. The economic impact of fish and wildlife related recreation is widely recognized and a significant and growing component of the state's economy. The most recent survey data from the U.S. Fish and Wildlife Service indicate that fishing, hunting, and wildlife watching contribute over $2.6 billion to the state's economy annually. (*2006 National Survey of Fishing, Hunting, and Wildlife-State Overview; Preliminary Findings).* To gain a more comprehensive view of the economic impact of climate change in Washington, conduct an economic assessment of the impacts of climate change on consumptive (appreciative) uses of fish and wildlife species, including hunting, commercial and recreational fishing, and recreational wildlife activities.

State Agency Climate Action Plans

Following the guidance provided by the Climate Impacts Group and King County in *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments (September, 2007),* develop and implement state agency action plans on preparing for climate change. As outlined in the above guidebook, this would include conducting a climate resiliency study, identifying priority planning areas for action, developing preparedness goals and plans, implementing and updating the plans. For fish and wildlife, this would include amending the State's Comprehensive Wildlife Conservation Plan and expanding on the climate change aspects of the recently released Washington Biodiversity Strategy: *Sustaining Our Natural Heritage for Future Generations.*

For WDFW, key elements of the action plan would include: 1) dedicating a staff position to lead agency climate change activities and expand involvement in related national and regional projects, and 2) identifying existing and potential natural resource management agreements and decision-making processes that need to be (more) responsive to climate change impacts.

Coordinated Long-Term Monitoring Programs

Build on existing monitoring programs to develop a coordinated statewide long-term monitoring program to assess the progression of ecological impacts due to climate change. Identify key monitoring targets necessary to track climate impacts in terrestrial, freshwater and marine ecosystems. Initiate and provide stable funding for long-term monitoring that utilizes existing programs and develops new strategies to effectively track impacts. Include adaptive management elements so that as new data become available, climate action plans and strategies can be revised and improved.