Preparing for Climate Change

in the Upper Willamette River Basin of Western Oregon

Co-Beneficial Planning for Communities and Ecosystems

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Executive Summary

The Intergovernmental Panel on Climate Change (IPCC) reached a consensus in 2007 that the evidence is now "unequivocal" that the earth's atmosphere and oceans are warming and concluded that these changes primarily are due to human activities (IPCC, 2007). While reducing carbon and other greenhouse gas emissions is vital to stabilize the climate in the long term, excess emissions already concentrated in the atmosphere will produce significant changes in the global climate now and throughout the next century. These changes are expected to transform natural systems and pose new stresses on native species in the Upper Willamette River Basin. Changes in the Basin's natural systems will, in turn, modify the way the local economy functions and produce new stresses on infrastructure and buildings, human health, and the quality of life of the people who live in and enjoy the Upper Willamette River Basin.

Numerous initiatives already underway will have benefits that help prepare the Basin's communities, economy, and landscapes for these effects. However, few initiatives focus on the actions needed to prepare explicitly for climate change. Expanding existing activities, launching the additional climate preparation efforts described in this report, and continuing to develop new strategies in an integrated and co-beneficial manner can help build resistance and resilience to climate change across multiple scales in the Upper Willamette River Basin and enable the region to thrive over the coming century.

In the fall of 2008, the University of Oregon's Climate Leadership Initiative (CLI) and the National Center for Conservation Science & Policy (NCCSP), in partnership with the Mapped Atmosphere-Plant-Soil-System (MAPSS) Team at the U.S. Forest Service Pacific Northwest Research Station, initiated a project to assess the likely consequences of climate change for the Upper Willamette River Basin. The Basin is defined as the region from the confluence of the McKenzie and Willamette rivers south and east to the headwaters of the South Fork Willamette, Middle Fork Willamette, and McKenzie rivers. This report outlines a framework for climate preparation activities in the Basin, but specific details, locations and issues will need to be addressed by other groups, community leaders, and scientists.

This project began by considering projected changes in temperature, precipitation, fire patterns, and distribution of native vegetation for the Basin, based on the downscaling of three global climate models reviewed by the International Panel on Climate Change (IPCC) and a vegetation model developed by the MAPSS Team. The three global climate models applied in this study are considered to have high scientific credibility, although recent evidence suggests that the current suite of climate models reviewed by the IPCC underestimate the potential severity of climate change over the next 100 years (MWC, 2009; Schwartz, 2009). Regardless, basin-scale projections of future temperature and snowpack are considered to be more reliable than projections of precipitation and fire.

CLI and NCCSP convened a panel of scientists and land managers to determine the likely stressors to natural systems posed by projected changes in climate. This panel also was asked to make recommendations for increasing the capacity of ecosystems and species to withstand and adapt to climate induced stressors. Using these findings, a panel of policy experts then assessed the risks for built, human, and economic systems within the Upper Willamette River Basin. The policy panel also made recommendations for preparing these sectors for the adverse effects of climate change. This report summarizes the key findings and recommendations made by these panels.

Findings: Future Climate Conditions

Conditions in the Upper Willamette River Basin are projected to change substantially during the coming century due to changing global climate conditions.

Temperature

- Annual average temperatures are likely to increase from 2 to 4º F (1 to 2º C) by around 2040 and an additional 6 to 8º F (3 to 4º C) by around 2080.
- Average summer temperatures are likely to increase 4 to 6º F (2 to 3º C) by 2040 and an additional 4 to 8º F (2 to 4.5º C) by 2080, while average winter temperatures may increase 1 to 2º F (0.5 to 1º C) by 2040 and an additional 2 to 4º F (1 to 2º C) by 2080.

Precipitation and Snowpack

One model shows a slight increase in mean annual precipitation while the other two models show no real change.

- By 2040, all three models predict slightly less precipitation during spring, summer and fall and two models predict slightly more precipitation in winter.
- By 2080, precipitation patterns could range from a slight year-round decline to larger shifts that include monsoon patterns in the spring coupled with increased seasonal drought in the summer.
- Snowpack across the Pacific Northwest is likely to decline by 60% by 2040 and 80-90% by 2095 from current levels.
- As snow melts earlier in the spring, stream flows will peak earlier but at lower levels than typical flows in recent years, depending on the geology of the particular stream reach.

Storms and Flooding

- With warmer oceans and more available moisture in the atmosphere, storm events could increase in intensity, resulting in more flooding in all rivers in the Basin.

Wildfire

- One model projects conditions that may lead to more wildfire and a much greater proportion of area burned in the Basin, while the other two models anticipate little change from historic conditions.

Vegetation Change

- Although current conditions in much of the Basin are suitable for coastal spruce and fir, future conditions in the western portion may become more suitable for mixed pine, hardwoods, and oaks. Growing conditions in the eastern portion may best support ponderosa pine and Douglas-fir.
- Despite changes in growing conditions, plant and wildlife communities may take decades or centuries to adjust, making the timing of changes to dominant vegetation difficult to project. Fire is expected to be a major agent of vegetation change, even if fire incidence and size remain at approximately current levels.

Findings: Consequences of Projected Climate Change on Natural Systems

Based on the projected changes in climate conditions, the science panel identified the following likely consequences for aquatic and terrestrial systems and species in the Basin:

Aquatic Systems and Species

- Increased winter storm intensity, changes in seasonal precipitation patterns, and increased temperatures are likely to be detrimental to the reproduction and survival of many native fish and amphibians.
- Increasing temperature is likely to benefit warm water native species and non-native fishes and amphibians while harming native species that rely on cooler water. This will likely result in the decline of Chinook salmon, steelhead, and Oregon chub. Spring Chinook are likely to have particular problems in the lower Middle Fork due to higher temperatures.
- Spring-fed streams and riparian areas will be buffered somewhat from climate change due to mediated shifts in flow and temperature. The McKenzie is likely to remain the best stronghold for fish in the Upper Willamette. The Middle Fork also may see more moderate changes in flow.
- Because the McKenzie watershed is vital to Eugene municipal water supply in the summer months, increased summer drought and evapotranspiration could lead to seasonal water shortage.

Terrestrial Systems and Species

- The greatest risk to terrestrial systems and species is the potential for climate change to exacerbate existing stressors, such as fragmentation (e.g. loss of connectivity due to roads or land clearing), invasive species, and habitat loss. Warmer temperatures and drought stressed vegetation are likely to provide more favorable conditions for disease, insect pests, and invasive species that will negatively impact wildlife and wildlife habitat.
- The goods and services that humans gain from natural ecosystems, such as clean water and recreational opportunities, are likely to be negatively impacted and degraded as a result of climatic changes to the natural system. Some species will be especially at risk, including those at high elevations (alpine and subalpine species), species that depend on old-growth forests (e.g. northern spotted owl), moisture dependent species (e.g. waterbirds, some salamanders and land snails), species that already are rare and declining, and maritime evergreen associated species (e.g. marbled murrelet).
- Areas especially at risk include lower elevations of the Basin, notably including the Coast Fork, where stressors such as erosion, development, and logging already are higher. Areas at the interface between public and private lands, where management issues such as fire and invasive species control become problematic due to differing objectives, also will be particularly vulnerable.
- Invasive and exotic species that have evolved to colonize quickly following disturbance (such as fire) and those that are habitat generalists will gain a competitive advantage. For example, non-native blackberry and bullfrogs could become more common across the landscape. Some species that are not considered to be invasive under current conditions could become invasive as conditions change.

Recommendations: Prepare Natural Systems for Climate Change

The panels made the following recommendations to prepare aquatic and terrestrial systems for climate change:

- <u>Prioritize the following areas for protection</u> from development and degradation: areas that provide ecosystem services, such as recreation, flood control, water storage, and carbon sequestration; areas that provide “climate refuges” in the form of cooler local climate and less change to vegetation; and areas typified by intact or slightly modified ecosystems that currently have few external stressors.
- <u>Increase early detection and rapid response</u> efforts to identify, manage, and control invasive species. Standards should be developed for determining when species are considered invasive and when they are successfully shifting their ranges due to climate change.
- <u>Base resource management decisions on a thorough understanding of the entire ecological system, climate change projections for the area, and careful consideration of the outcome of alternative management actions.</u> Goals for all management decisions should include maintaining resiliency and flexibility.
- <u>Adopt new conservation priorities</u> based on a sound understanding of future climatic and ecological conditions in specific locations. Rather than continuing to manage to retain historical conditions and species, future goals will need to shift towards protecting and restoring key parts of the landscape that will be able to withstand the additional stress of climate change.
- <u>Update methods for resource monitoring and evaluation</u> continually in order to detect climate change impacts and trajectories while testing the efficacy of management action. Because ecological communities are expected to unravel, monitoring of individual species as well as ecological relationships within ecosystems will become increasingly important.

- Direct planners and managers to work across jurisdictions to develop interdisciplinary, co-beneficial strategies and policies that build resistance and resilience to climate change impacts.
- Replace the 'multiple use approach' to federal lands policy with a 'whole systems' approach that strives to maintain and enhance the processes and components of the landscape that are vital to sustaining water quality and availability, soil health, nutrient cycling, and other critical ecosystem services. This will facilitate decisions that allow forests, wetlands, and other natural systems to withstand and adapt to climate change.

Findings: Consequences of Projected Climate Change on Built, Human, and Economic Systems

Based on the projections of likely changes to the climate system and assessments by the science panel of the impact of such changes on natural systems, the policy panel identified the following risks to built, human, and economic systems in the Upper Willamette River Basin:

Infrastructure, Transportation and Buildings

- Increased flooding and wildfire is likely to produce greater risks for buildings, transportation systems, and other public infrastructure, especially in floodplains and areas within the wildland-urban interface.

Energy Systems

- Reduced snowpack and summer water storage in reservoirs behind generation facilities is likely to diminish hydroelectric generation.
- A possible increase in the number of acres burned by wildfire may threaten power lines in some locations.
- Wildfire and persistent summer drought may reduce the supply of biomass for new large-scale biomass energy power plants.

Public Health and Emergency Services

- Increases in ground level ozone, increased allergens, degraded air quality, and potentially increased wildfire will likely cause higher rates of asthma and other respiratory diseases.
- Warmer waters and more mosquitoes and ticks are expected to lead to an increase in vector-borne diseases (those transmitted through another organism, such as a mosquito) such as West Nile Virus, as well as water-borne disease such as cryptosporidiosis, a parasitic disease of the intestinal tract.
- Higher temperatures will likely lead to increased heat stroke and cardiovascular disease, particularly for those without air conditioning.
- Warmer temperatures may lead to more food contamination.
- Higher concentrations of people due to population growth and climate refugees (i.e., people coming to Oregon to escape greater climate stress in other areas) may create conditions for communicable disease outbreaks.

Agriculture and Forestry

- Reduction in snowpack will diminish water supplies from streams, reservoirs, and groundwater available for irrigation.
- Crops sensitive to higher day and nighttime temperatures, such as some varieties of wine grapes, will lose viability. Other crops may benefit from a longer growing season.
- The possibility of increased acres burned by wildfire, increased disease, and persistent drought may reduce levels of sustainable green tree timber harvest due to lower productivity.

Manufacturing, Retail and Service Sectors

- Energy prices may rise as hydroelectric production declines and energy sources shift to new technologies rather than carbon-based fuels.
- Reduced snowpack and warmer winter temperatures will impair winter recreation, but spring and summer recreational opportunities may expand due to warmer temperatures.
- Increased flooding and acres burned by wildfire may isolate certain smaller communities and homeowners as well as disrupt transportation systems.
- Increased stream runoff rates may increase costs of treating public water supplies.
- Because the food system currently is heavily reliant on imported foods, disturbances to transportation systems due to increased storm activity could threaten local food security.

Recommendations: Prepare Built, Human, and Economic Systems for Climate Change

The policy panel made the following recommendations to prepare human, built, and economic systems for climate change:

Local Government Planning, Public Infrastructure, and Building Agencies

- Prevent expansion of residential development into forested areas and floodplains to reduce risks of property damage and loss of life from increased flooding and wildfire, and retain the capacity of the land to moderate flooding and fire.
- Account for projected climate change impacts in land use planning, regulation, and zoning. Reduce development that increases vulnerability to flood and fire and increases demand for emergency services.
- Incorporate energy efficiency and waste reduction in all new and existing buildings.

Emergency Management Agencies

- Implement educational outreach to private landowners to provide information on risks and methods for protection so they can take protection of homes and selves from extreme weather events and fires into their own hands.

Public Health Agencies

- Initiate programs to monitor and develop appropriate responses to the likely increase in heat related illnesses.
- Build cooling centers for public use during extreme heat events and develop means for transporting vulnerable populations to the centers.
- Develop an expanded approach to the likely increase in asthma and other respiratory diseases.
- Expand vector-borne disease control programs to develop strengthen monitoring, early warning and management of outbreaks.

Agriculture and Forestry

- Research and develop new crop varieties suitable for a warmer climate that may be wetter in the winter and drier in the summer.
- Encourage local food production to build resistance to transportation disruptions.
- Embrace local, state, and federal policies that protect land from urban sprawl and encourage water use efficiency.
- Reexamine the existing water rights system, assess groundwater resources and well capacity, and reevaluate existing permits in light of future potential water limitations to avoid over-appropriation.
- Research how transitions in growing conditions will affect reforestation decisions and how resilience to climate-induced impacts can be enhanced with revised management strategies on private, state, and federal lands.
- Link preparation strategies to economic development opportunities. For example, integrate efforts to reduce wildfire fuels near homes with biomass energy production (i.e. use brush near homes to create electricity).

Manufacturing, Retail, and the Service Sectors

- Implement energy and water use efficiency strategies to encourage a reduction in demand so that systems are not stressed during extreme weather events.
- Install on-site renewable energy systems like solar photovoltaics to provide energy security and insulate businesses from power outages due to storms or wildfire as well as price fluctuations of traditional fuels.
- Institute widespread outreach and education to businesses on climate associated health risks for employers to help protect workers.

Recommendations: Adopt Governance Systems Appropriate for Rapidly Changing Climatic Conditions

A consistent theme heard from the panels was the need for new types of information, resource allocations, and decision-making mechanisms. In short, because future conditions will be very different from the historic conditions that our current systems were based on, the panels called for new and expanded forms of governance. Specific recommendations include:

- Adopt governance models that cross traditional boundaries. For instance, governance based on counties and cities should expand to encompass structures based on watersheds or climatic regions. In addition, preparation strategies should seek to provide benefits for all regions and sectors.
- Focus planning and decision-making teams on inclusive participation and diverse stakeholder representation. Climate change expands the realm of the issues and people that may be affected by projects and policies.
- Use scenario planning to consider management options across the full range of possible future conditions. Analyze current data gathering and monitoring systems and adopt mechanisms that are better suited for rapidly changing conditions.

Introduction and Background

The Intergovernmental Panel on Climate Change (IPCC) concluded in 2007 that the evidence was “unequivocal” that the earth’s atmosphere and oceans are warming primarily due to human activities, including the emission of carbon dioxide (CO_2), methane, and other greenhouse gases, along with land conversion and deforestation (IPCC, 2007). Left unchecked, rising global temperatures and the changing climatic patterns they cause will affect ecological systems and species and thus undermine economic and social prosperity and security in Oregon, the nation, and abroad.

This report describes the likely consequences of climate change, as projected by a set of IPCC-reviewed climate models, on natural, built, human, and economic sectors in the Upper Willamette River Basin of Western Oregon. (The Basin is defined as the portion of the Willamette Basin from the confluence of the McKenzie and Willamette rivers upstream to the headwaters.) This report also describes a suite of strategies and policies recommended by panels of scientists and policy experts for building resistance and resilience to the anticipated climate-related changes in the four sectors mentioned above.

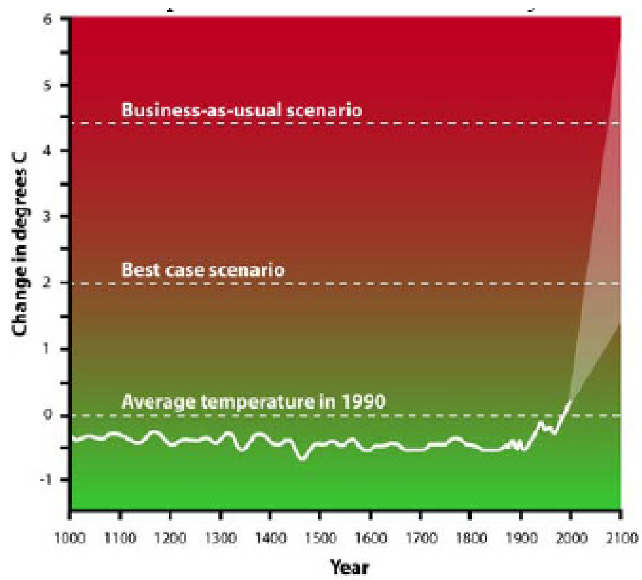


Figure 1. The last 1,000 years of global mean temperature, in comparison to projected temperature for 2100. Drastic cuts in greenhouse gas emissions would lead to an increase of about 2˚ C by 2100, while the current trajectory will lead to an average increase in temperature closer to 4.5˚ C, and as high as 6˚ C (adapted from IPCC, 2001).

Preparation, as used in this context, means to proactively reduce the vulnerability of natural, built, human and economic systems to the negative impacts of climate change.

Resistance strategies seek to increase the capacity of systems to withstand the negative effects of climate change.

Resilience strategies are aimed at building the capacity of systems to recover from the climate change impacts they cannot withstand.

The report outlines an initial framework for climate preparation activities in the Upper Willamette River Basin. Because it is the first assessment of the likely effects of climate change on the region, many details on specific locations, actions, or agency responsibilities required to effectively implement climate change preparations strategies are absent. These types of particulars will need to be identified through more rigorous examination of specific issues and regions by public, private, nonprofit, and academic organizations.

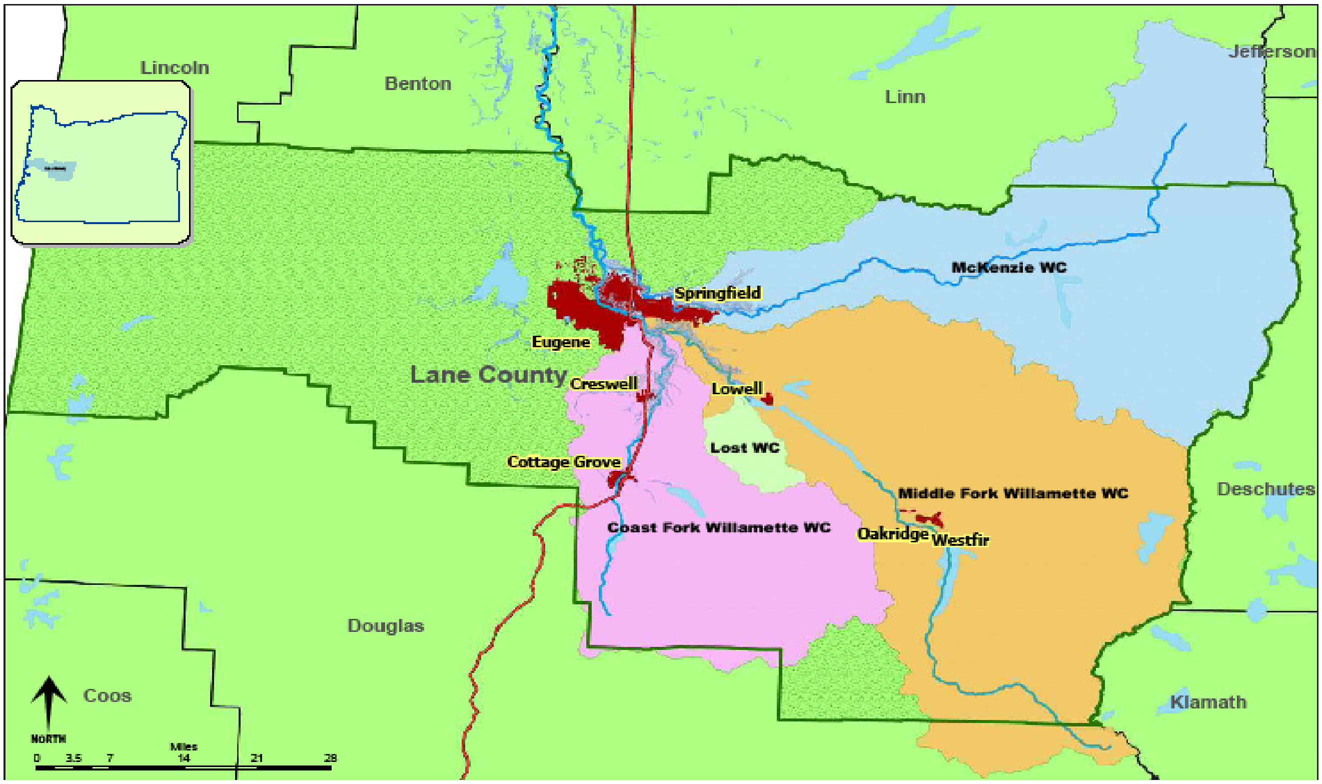
The effects of climate change are not restricted to the Upper Willamette River Basin; climate change is a global problem and no region in Oregon or elsewhere in the world is immune from its impacts. However, taking action within our communities to prepare for the local impacts of climate change can help minimize the negative effects on local communities, economies, and the environment.

This assessment is one of four produced by an initiative aimed at establishing a common method for developing integrated climate change preparation plans and policies. The project is coordinated by the Climate Leadership Initiative (CLI) in the Institute for Sustainable Environment at the University of Oregon and the National Center for Conservation Science & Policy (NCCSP), in partnership with the Mapped Atmosphere-Plant-Soil-System (MAPSS) Team at the U.S. Forest Service Pacific Northwest Research Station (PNW). In addition to the Upper Willamette River Basin, a climate preparation assessment already has been developed for the Rogue River Basin of Southwest Oregon (& NCCSP, 2008). Assessments for the Klamath and Umatilla basins and possibly others will be completed in 2009.

This work is intended to jump-start preparation efforts in the pilot basins and identify strategies and policies for collaborative efforts that will increase the resistance and resilience of natural, built, human, and economic sectors to climate change across Oregon and, eventually, the United States.

The Need for Climate Change Preparation

Global mean surface temperatures already have risen by 1.3º F (0.7º C) since the early part of the twentieth century (Fig. 1). In the Pacific Northwest, temperatures have risen by 1.5º F (0.8º C) over this same time period. Scientists have teased out natural from human-related drivers of this warming and the strong consensus is that solar variability,



Map Developed by Ray Neff, 2009

volcanic activity, and other natural events cannot account for current levels and rates of change (IPCC, 2007). Only when the human contributions to atmospheric concentration of carbon dioxide, which has risen more than 35% since pre-industrial times, methane, which is up 155%, and other greenhouse gases are taken into account do climate models replicate observed warming. The bottom line is that global surface temperatures indisputably are rising, humans are the primary cause, and warming will have serious consequences for the world's climate systems.

While much attention is appropriately being focused on reducing U.S. greenhouse gas emissions by more than 80% of 1990 levels, the long residence time of emissions already built-up in the atmosphere means that even once emission cuts are made the climate will not restabilize for at least 50-100 years (IPCC, 2007) and global mean temperature will continue to rise for many more decades. Thus, local, state, and federal governments, the private sector, and individual households worldwide have two primary responsibilities: (1) to reduce emissions; and (2) to prepare natural, built, human, and economic systems to withstand and adapt to the now unavoidable consequences of climate change.

This report provides an initial set of guidelines to prepare for climate change in the Upper Willamette River Basin. It should be considered a starting point for climate preparation efforts in the Upper Willamette River Basin, not a final outcome. It is our hope that all levels of government, the private sector, and individual households will use the information and recommendations as a platform for expanding their knowledge and influencing efforts to develop continuously improving climate preparation practices, strategies, and policies. The recommendations offered in this report are just a few initial ideas to get the process of preparation moving and spur the imagination of Upper Willamette River Basin residents in developing innovative, co-beneficial, and effective strategies that allow them to thrive and prosper as the climate changes.

The Upper Willamette River Basin Project

The Upper Willamette River Basin (Fig. 2) encompasses nearly 2 million acres, of which 90% is forested, and approximately 43,344 acres of incorporated cities (based on data compiled by Ray Neff from LCOG). It spans four major subbasins: The McKenzie, Mohawk, Middle Fork Willamette, and Coast Fork Willamette. The Basin borders the Coast Mountain Range to the west and the headwaters of the Cascade Mountains to the east. The land in the higher elevation portions of the subbasins is mostly under public ownership. The Bureau of Land Management has a few patches of land in the lower parts of the Basin, but otherwise, these lands mostly are privately owned. The land area in the Mohawk watershed, a tributary of the McKenzie, is virtually all in private ownership. National forest land covers roughly 60% of the McKenzie River Subbasin, 80% of the Middle Fork of the Willamette, and 20% of the Coast Fork Subbasin (data provided by Ray Neff, 2008).

Cities in the Basin include Eugene, Springfield, Oakridge, Cottage Grove, Westfir, Marcola, Lowell, Santa Clara and Creswell. The Upper Willamette River Basin is home to approximately 225,680 people, about 6% of Oregon's population, and population growth rates are higher than the rest of Oregon by approximately 1% (LCOG, 2008). Eugene and Springfield are the largest urban areas, while over a quarter of the population lives in unincorporated areas outside urban growth boundaries (LCOG, 2008).

The likely consequences of climate change in the Basin were assessed by applying three global climate models operated under the ‘high emission’ scenario assumptions developed by the Intergovernmental Panel on Climate Change (IPCC, 2007) to project future conditions specific to the Basin. The results were mapped for two time periods: 2035-2045 and 2075-2085. In addition, time series graphs were plotted for some variables, such as temperature and precipitation, to show how conditions are likely to change both annually and seasonally through 2100. The three downscaled global climate models were also used to run a dynamic vegetation model, called MC1, to project the dominant types of vegetation that the climate would be suitable for in the future. Finally, the results from a study of future snowpack in the Cascades (Nolin & Daly, 2006), and another study of snowpack in the West (McCabe & Wolock, 1999), are presented to supplement the model output.

On the basis of regional climate and vegetation projections, a panel of scientific experts assessed the likely impacts of climate change on fish, wildlife, and plant species, ecological communities, and ecosystem function and structure (see Appendix A for participant list). The natural system assessment was used as the basis for a subsequent evaluation by a panel of managers and policy experts (see Appendix B for participant list) that identified the likely risks posed by potential changes to built, human, and economic systems. Both panels made recommendations for increasing resistance and resilience in their respective sectors, as well as noting research and monitoring opportunities that would lead to a better understanding of impacts and facilitate ongoing learning and adaptation in rapidly changing circumstances. These workshops along with subsequent research form the basis of the recommendations found in this report.

The ‘A2’ Future

The IPCC emission scenario used in this assessment was the A2 or “business as usual” high emissions path that most closely follows the current global emissions path (Fig. 1). In fact, emissions of carbon dioxide and other greenhouse gases have been growing at 3.5 percent per year since 2000, a sharp rise from the 0.9 percent annual rise in the 1990s. As a result, emissions have exceeded the projections assumed by the IPCC’s A2 scenario, a situation that a leading climate scientist has indicated will be remedied with the next iteration of the IPCC Report, expected in 2014 (MWC, 2009; Schwartz, 2009). This suggests that without major cuts in the growth of emissions, the results of this assessment are likely to significantly underestimate the extent of change.

In the A2 scenario, the IPCC assumes that most countries fail to act individually or collectively to reduce greenhouse gas emissions. Countries preserve self-reliance and national identities, following the lead of the United States, India, and China. Global population continuously increases, reaching 15 billion by the end of the century. The world population produces and consumes much more than today, with a Gross World Product 26 times the present amount by 2100, but economic growth is fragmented and technology change is slow. Emissions caused by clearing of land increase, driven by deforestation and conversion of forests and other lands to agriculture to support population growth. Despite agriculture expansion, productivity gains are low due to poor growing conditions.

On a global scale, surface temperatures increase about 1.8º F (1º C) by 2025 to 8º F (4.5º C) by 2100 (Fig. 1). As ocean waters warm, water expansion from warming alone causes sea levels to rise on average from 0.75 ft (0.23 m) to 1.7 ft (0.51 m). Substantial additional rise in sea levels could occur due to polar ice-sheet melting, with the IPCC predicting a rise of 3 ft (0.9 m) by the end of the century. Additional rise is difficult to predict, as ice sheet dynamics are poorly understood, but a recent study suggests up to 21 feet (6.4 m) in some areas (Mitrovica et al., 2009), although a time frame was not given.

The Climate Models

The three global climate models used in the Upper Willamette River Basin project (CSIRO, MIROC and Hadley) are known as Atmosphere-Ocean General Circulation Models and are based on equations describing the atmosphere, land surface, cryosphere (ice and snow), and oceans. These models were chosen because they best represent a range of possible future changes in temperature and precipitation in the Pacific Northwest region.

Limitations of Climate and Vegetation Models

All future climate projections come with some uncertainty stemming from the components of the model itself. A model, by necessity, is a simplified representation of complex processes. Other uncertainty stems from the variable nature of climate processes. Because the climate system is chaotic, small changes in one variable can lead to large effects elsewhere in the system. Finally, additional uncertainty stems from the geographic location of the Upper Willamette River Basin, which resides in between an area expected to become wetter (northern Oregon and Washington) and an area expected to become drier (California and the Southwest). There is great ambiguity regarding the point of transition between these growing extremes. Climate models constantly are being improved to decrease the level of uncertainty due to oversimplification of climate processes, but uncertainty from natural, chaotic processes always will remain.

The models also have difficulty forecasting the effects of changes in the amount of solar radiation reflected from the earth’s surface back to the atmosphere (albedo effect) and with the strength of water vapor in warming the planet. The latter issue is especially important because increased water vapor is linked to rising temperatures and in fact may account for 50% of warming. In general, all three models are better at projecting changes in temperature than in precipitation. The Japanese MIROC model projects warming by the end of the 21st century in the Pacific Northwest region of up to 12º F, while the Australian CSIRO model projects half that increase. The CSIRO model projects a much wetter Pacific Northwest while the British Hadley model projects a drier climate compared to the recent time period.

Adding to the uncertainty is the fact that the models were created at global scales and this study "downscaled" and applied them to the Upper Willamette River Basin. The downscaling process provides the opportunity to look at local and regional trends, but global uncertainties inherent in the models could potentially limit the accuracy of the downscaled results.

The dynamic global vegetation model, MC1, was run based on the downscaled projections produced by the three climate models described above. MC1 uses a set of rules based on physiology (the functioning of organisms) and biogeography (the geographical distribution of organisms) to determine the most appropriate dominant vegetation type for the projected climate. Because vegetation can take decades or centuries to adjust to a changing climate, due to limitations in seed dispersal and the time it takes for vegetation to reach maturity, the results from MC1 are not predictions of the type of vegetation that will be found in a specific location at a specific time. Rather, a MC1 projects suitable future growing conditions for certain types of vegetation in the Willamette Basin.

Climate change may have a short-term positive impact on net vegetation growth because plants respond positively to higher concentrations of CO_2 in the air. They are able to grow faster and use water more efficiently when levels of CO_2 are higher. However, scientists still do not fully understand which types of plants respond to CO_2 enrichment and at what level CO_2 saturation occurs, thereby limiting any further benefit to plants. The MC1vegetation model included this short-term benefit to vegetation growth when projecting wildfire and growing conditions for specific types of vegetation in the coming decades.

Given the uncertainties outlined above, model projections should not be considered absolute. Instead, they are a credible portrayal of a range of possibilities for the Upper Willamette River Basin given the projected global emission path and climate change relationships. Many experts predict an increase in the variability of climate patterns from decade to decade, which the varied outcomes of the models seem to support. This suggests that many effects described for the Upper Willamette River Basin by the different models could occur at different times in the future. Rather than debating the merits of any particular climate model or outcome, it is more reasonable to plan with the full range of possible future projections in mind.

The Effects of Climate Change on the Upper Willamette River Basin

The three climate models and the vegetation model projected changes for the Upper Willamette River Basin in temperature, precipitation, biomass consumed by fire, and distribution of growing conditions suitable for different vegetation types. Appendix C includes the maps and graphs produced from the models. Results from two other studies that investigated the change in snowpack (Nolin & Daly, 2006; McCabe & Wolock, 1999) also are included in Appendix C. While projections for increasing temperatures and declining snowpacks are associated with a high level of certainty, those for precipitation patterns, wildfire patterns, and vegetation distributions are highly uncertain.

Temperature

All three models project a significant increase in annual average temperature in the Upper Willamette River Basin (Fig. 3), ranging from 2 to 4° F (1 to 2º C) by around 2040, and another 6 to 8° F (3 to 4˚ C) by around 2080. Summer temperatures in the Basin are projected to reach 4 to 6° F above baseline by 2040 and another 4 to 8° F by 2080. Winter temperatures are likely to be an average of 4° F warmer by 2080 than during the past century.

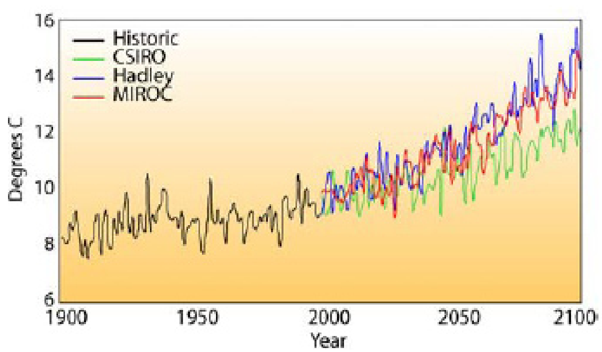


Figure 3. Mean annual temperature in the Upper Willamette River Basin, historically and projected through 2100 with three different climate models.

Precipitation, Snowpack, and Storms

Mean annual precipitation is projected to remain similar to today, with possibly a slight increase over the next century (Fig. 4). It is important to note that even if precipitation levels are comparable to historic levels, higher temperatures in the coming century will lead to lower soil moisture and increased evaporation from streams and lakes. Therefore, mean annual "effective precipitation" will be reduced.

By 2040, slightly less precipitation is expected during spring, summer and fall (-10 to -29 mm/mo. or -0.5 to -1 in/mo.). In the winter, precipitation may remain constant, or increase slightly (10 to 70 mm/mo. or 0.5 to 3 in/mo.) (Table 1).

By 2080, two models project a significant increase in winter precipitation (10 to 121mm/mo. or 0.5 to 5 in/mo.) but the third projects a gradual decrease (-10 to -49 mm/mo. or 0.5 to 2 in/mo.). Spring, summer, and fall precipitation varies substantially among the different models, from a spring monsoon to late-summer drought.

Data on precipitation patterns is highly uncertain, but warmer oceans and more available moisture in the atmosphere are expected to increase the intensity of storm events. More flooding could occur in all rivers in the Basin. On the other hand, a reduction in snowpack is likely to lead to extended low summer flows.

Table 1. Precipitation projections for the Upper Willamette River Basin. Baseline values are from 1910-2000.

Time period	CSIRO	MIROC	Hadley
Annual baseline = 55 in.			
2035/45	No change	No change	No change
2075/85	No change	No change	- 0.8 in.
July baseline = 0.5 in.			
2035/45	No change	No change	No change
2075/85	No change	No change	No change
December baseline = 7.5 in.			
2035/45	No change.	+ 1.2 in.	No change
2075/85	+ 2.4 in.	+ 3.1 in.	- 0.6 in.

According to Nolin and Daly (2006), a 3.5º F (2º C) increase in winter temperatures would likely convert much of the winter precipitation from snow to rain. This study concluded that approximately 22% of the area in the Cascades now covered by snow in the winter would receive no snow accumulation by 2040.

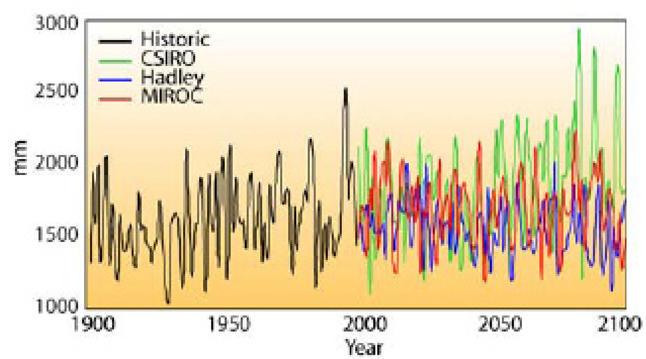


Figure 4. Mean annual precipitation based on historic data and three different global climate models, downscaled to the Upper Willamette River Basin

McCabe and Wolock (1999) also project diminished snowpack (Fig. 5); as much as 60% by 2040 and 80-90% by 080 compared to a 1961-1990 baseline.

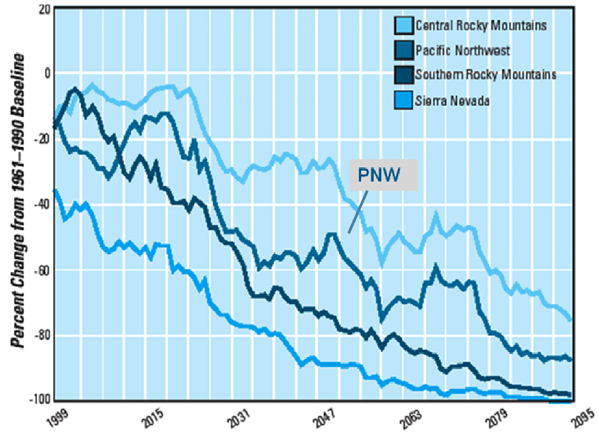


Figure 5. Snowpack is projected by a Canadian model to diminish by 80-90% over the next 85 years (McCabe & Wolock, 1999)

As snow melts earlier in the spring, increased streamflows will occur earlier but peak at lower levels than have been typical during the past century. Seasonal flow patterns will vary somewhat depending on the geology of the particular stream reach (Fig. 6; Tague & Grant, in review, 2009). Spring-fed streams and those with underground storage will be more likely to continue to support late summer flows while those in granitic areas will be more likely to run dry. The High Cascades have extensive underground storage.

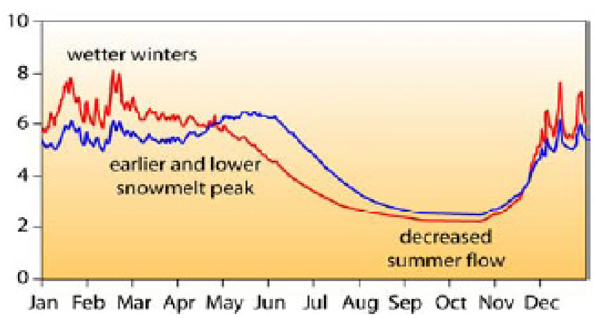


Figure 6. Future stream flow patterns (red) may differ from historical patterns (blue) in the High Cascade mountains. Stream flow, measured in mm per day, was modeled under a scenario of 1.5˚ C warming (Tague and Grant, in review, 2009).

Wildfire

Fire is a natural, though relatively infrequent, process in the forests of the Upper Willamette Basin. The effects of fire can be quite positive because it is one of the primary mechanisms leading to vegetation changes and adaptation to the new climate.

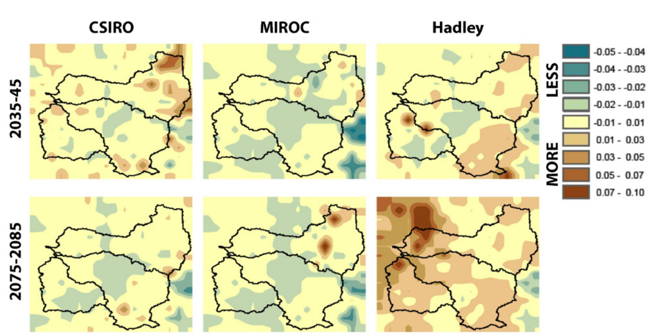


Figure 7. Change in the proportion of the Willamette Basin projected to burn in wildfires in 2035-45 and 2075-85, as compared to baseline (1961-1990), according to the MC1 vegetation model.

The models presented a range of possible fire conditions over the next century, from little change from current conditions (CSIRO, Fig. 7) to more fire and a much larger area burned (Hadley, Fig. 7).

Changes to Conditions for Vegetation Distribution

Three major vegetation types currently occur naturally in the Upper Willamette River Basin (Fig. 8). Conditions are projected to change over the next century, causing one or two types to eventually disappear while bringing in two new vegetation types to the area. Even when conditions change, however, individual species of vegetation do not respond immediately. The shift from current to future vegetation patterns might be a very long process (decades to centuries) for many reasons:

1. Many of the vegetation communities in the Upper Willamette Basin are dominated by long lived species like Douglas-fir that are relatively resilient to disturbance (e.g. trees with thick bark and high canopies and mature forests with a cool, moist microclimate).
2. The moderating influence of the Pacific Ocean results in a fire return interval that is fairly long.
3. Regenerative processes to some extent favor existing vegetation. For example, after disturbance, the existing species may continue to dominate because seed sources are lacking for new species and existing species are still producing seeds and sprouts.

The most significant change from current conditions is likely to be a shift that will favor the replacement of maritime evergreen needleleaf (spruce and fir species) with warm maritime evergreen needleleaf (mixed pines and hardwoods, madrones and live oaks) across much of the Basin (Fig. 8). Plant and associated wildlife communities may take decades or centuries to adjust to changes in growing conditions, making it difficult to project when changes to dominant vegetation actually will occur. Rising temperatures, fewer days of freezing, and changes in precipitation could create conditions that would encourage pines and hardwoods, for example, to populate up to 10% of the region by 2040 and up to 55% by 2080. Conditions that support temperate deciduous broadleaf forest (oaks, maples and ash) also are projected to expand from almost no historical presence to up to 20% of the area by 2080. In contrast, subalpine forest conditions are likely to be completely eliminated from the region by 2040.

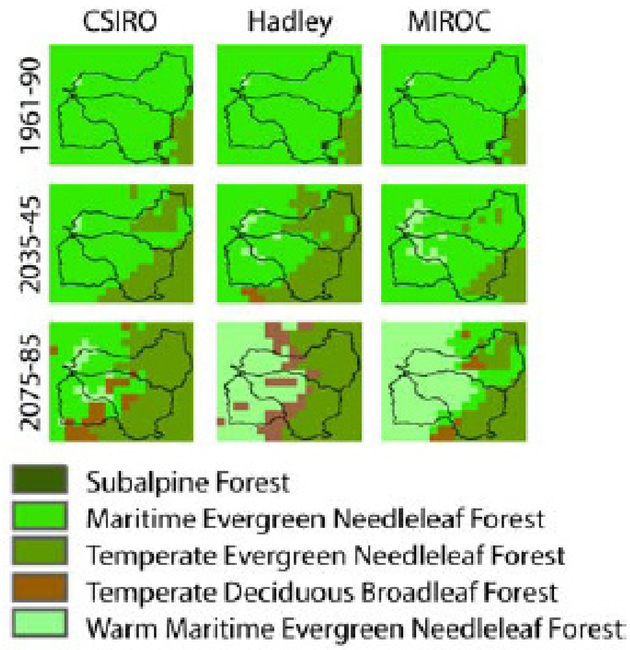
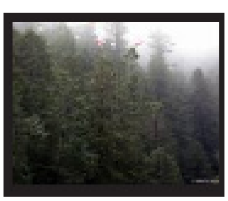


Figure 8. The vegetation model, MC1, projects major changes in growing conditions in the Upper Willamette Basin, with shifts from climate suitable for maritime spruce and fir to a climate more suitable for mixed pines and hardwoods (see box for forest type descriptions). Note that this figure reflects vegetation patterns consistent with modeled growing conditions, not the actual distribution of vegetation which would reflect impacts from forest clearing and other land management activities.

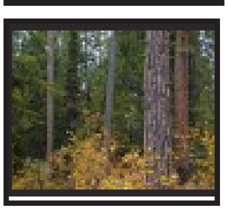
Upper Willamette Basin Forest Types

Maritime Evergreen Needleleaf - Coastal spruce and fir.

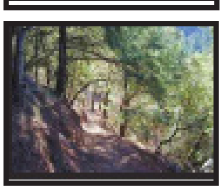
Subalpine Forest –
True firs (e.g. Pacific, silver), Englemann spruce, cedar (Alaska and incense), pine (lodgepole and western white) and quaking aspen. Photo from oregonforests.org



Temperate Evergreen Needleleaf- Douglas-fir, true firs, and ponderosa pine.



Temperate Deciduous Broadleaf-
Oaks, maples, ash and other deciduous trees.



Warm Maritime Evergreen Needleleaf- Very diverse mixed pines and hardwoods, some frost sensitive species such as madrone and evergreen oaks.

Risks to Species and Ecosystem Function

The ecological changes projected by the three climate models, the vegetation model, and the snowpack and streamflow studies are likely to magnify existing stresses and pose significant new risks to both aquatic and terrestrial species. In the Upper Willamette River Basin these changes will alter the structure of ecosystems and the way they function (see box).

Panels of scientists and natural resource managers were convened to evaluate the likely effects of future climate conditions, as projected by the models, on natural systems. The panelists also were asked to identify areas of the Basin most likely to be susceptible to, or buffered from, projected climate impacts. Through these assessments, panelists anticipated the risks to species and to ecosystem function posed by potential impacts of climate change.

One of the greatest concerns transcending all risks was the potential exacerbation of existing stressors by climate change. Aquatic and terrestrial species that already are at risk due to habitat loss, pollution, lack of movement corridors, and other stressors will become more strained as climate change worsens existing stressors. For example, a population already stressed by a lack of connectivity and gene flow due to habitat fragmentation, whether that fragmentation is due to roads, logging practices, land development, or instream barriers, is likely to become additionally stressed as climate change increases the need for individuals to move to find newly suitable habitat.

Ecosystem function - the characteristic actions or normal activities of the ecosystem; such as the movement of nutrients, water, and sediment through the environment, or the control of prey populations by predators.

Ecosystem structure - the relationship, arrangement, and/or age of the species and physical features that make up an ecosystem.

Risks to Aquatic Species and Systems

The scientific panel determined that changes associated with shifts in runoff patterns, storm intensity, stream flows, temperature, and water quality were likely to be the most significant climate change risks to rivers and streams and the fish, amphibians, and other species that rely on them. Many of these impacts were difficult to predict, due to high uncertainty associated with the precipitation projections.

Higher runoff and more flooding - If winter storm intensity increases as projected with rainfall and snowmelt concentrated into shorter time periods, the Basin is likely to experience higher runoff patterns and more flooding. Greater sediment input, debris flow, and landslide risks are likely, especially in areas with road networks, extensive timber harvest, and other intense land uses. While periodic floods are necessary for maintaining stream health because they create and maintain deep pools, clean spawning gravels, and recruit large wood to the stream, floods that are too frequent or intense can cause shortages of woody debris and increase sparseness of wood distribution, scour gravel deposits and dislodge the egg masses of salmonids, or otherwise compromise stream structure and function.

Decreased flow and warmer water - Higher air temperatures in the coming century will lead to lower soil moisture and increased evaporation from streams and lakes. As a result, the "effective precipitation" will be reduced significantly even if there is no decline in total precipitation. Decreased flow during summer and an expansion of the low flow period into the spring and fall is likely to lead to warmer water. Blooms of cyanobacteria (blue-green algae), the spread of disease, and a reduction in the amount of dissolved oxygen are likely to be driven by warmer water temperatures. A decline in water quality is likely to harm fish and amphibian survival as warmer temperatures make these species more susceptible to disease and may exceed their range of tolerance. Temperature changes also will impact fish spawning habitat availability and suitability, ultimately reducing spawning success. Extreme maximum temperatures and increases in minimum temperatures are likely to have a greater impact than changes in mean temperature. Some native fish species likely will thrive under the warmer water temperatures and lower base flow conditions predicted by climate change for the Upper Willamette. These fishes include largescale sucker, northern pikeminnow, and threespine stickleback.

Erosion and loss of water storage - Climate scientists suggest the potential for a shift to extended periods of wet weather followed by extended periods of drought on an approximately inter-decadal schedule. Such a pattern of precipitation would make it more difficult for stream systems to maintain their structure and function. River systems would be susceptible to severe erosion, loss of riparian cover, and isolation from an effective floodplain. These climate change susceptibilities, in combination with the effects of expanded human development of the floodplain, are likely to severely degrade the natural capacity of the land to store excess water during flood and slowly release it during drought.

Increased water conflict - Future water shortages, due both to a decline in the land's capacity to store water and a decline in "effective" precipitation as well as to increasing demands from a growing human population, could make conflicts over allocation among stakeholders more frequent and intense. Because current water allocations and decisions are based on historical flow quantities and patterns, and do not include a mechanism to modify rights to account for climate change impacts, conflicts are expected to increase in the future unless regulations and policies are modified.

Impacts from changes in upland vegetation - As forests respond to changes in growing conditions, large-scale vegetation change is anticipated, mediated in large part by drought stress, fire, insect, and disease. Vegetation changes will lead to changes in the timing of peak and low flows, and directly impact timing of spawning, hatching, and migration of young salmon and steelhead to the ocean. In addition, streams are likely to suffer a loss of large diameter wood, which is important for fish habitat, especially if forests currently dominated by mature conifers are replaced by young broadleaf trees. Finally, if the forest management response to the shift in vegetation patterns results in fire suppression efforts, post-fire logging, or increased road construction, stream health will be significantly compromised.

Aquatic Species and Systems Most Vulnerable to Changing Climate Conditions

The science panel identified the following areas and conditions as particularly vulnerable to projected climate related changes within the Basin:

- Stream reaches where water rights currently are fully or over-allocated, including Lost Creek and the Calapooia.
- Reaches already experiencing temperature problems, including the middle and upper forks of the Willamette as well as Salmon Creek (that flows into Oakridge) and Anthony Creek (in the Lost Creek River Basin) that already are listed as water quality limited.
- Aquatic systems likely to become more "flashy," (i.e. intense surges in short amounts of time) including waterways in the mid to low Cascades, mid to low McKenzie River, and the Middle Fork of the Willamette River as well as major tributary junctions throughout the Basin.
- Areas where pollution is already a problem, including the mainstem Willamette River, where agricultural and urban development provides numerous inputs. These reaches will experience reduced capacity for pollutants to be diluted due to climate change-driven reductions in stream flow.
- Streams whose size, shape, or substrate make them particularly vulnerable to dramatic change, including east side Upper Basin fine sediment streams.
- Headwater streams that are increasingly likely to be vulnerable to scouring down to bedrock during high flow events. These same streams are likely to experience increased water temperatures in permanently flowing reaches during reduced flow periods as the entire stream network contracts during summer months.
- Unique and isolated habitats, including wetlands and Montane meadows, that will be difficult to maintain or reestablish.
- The Coast Fork Willamette, which is already a warm water stream. Due to the area's sandstone dominated geology as well as significant human development pressure the Coast Fork Willamette is inherently drier than other sections of the Basin.

The science panel identified the following species or groups of species as particularly vulnerable to projected climate-related changes within the Basin:

- Fish, such as the Chinook salmon in the Upper Willamette River Basi,n are likely to be most affected by high flow scouring, while Chinook, steelhead, and Oregon chub throughout the region will be impacted by the change in timing of spawning conditions and the interaction of climate change with barriers to upstream movement. Spring Chinook are likely to have particular problems in the lower Middle Fork due to higher temperatures.
- The foothill yellow-legged frog population will be impacted by further increase the impacts of contaminants and water diversions that are already affecting the species. Yellow-legged frogs are an important element of aquatic systems and are prone to losing their eggs when water releases allow scouring of the stream bank. Climate change-related storm events and flooding could exacerbate this stress.
- Northern red-legged frogs, especially in the Middle Fork, are likely to come under increasing pressure as rising temperature assists the spread of non-native bullfrogs that may compete with or feed on native frogs and other native species.
- Invasive species also are likely to threaten native species with small or declining populations, such as tailed frogs and torrent salamanders. This shift in competitive advantage toward non-native fish and amphibians is likely to result in declining native

species populations. Turtles and amphibians could experience a significant shift in the ratio of males to females, as gender determination in these species is dependent on temperature. This shift could impact long-term reproductive success.

- Species that must shift their range to find more suitable conditions in response to climate change, as they will tend to move northward or to higher elevations in order to find areas with newly suitable conditions. Aquatic species are at a disadvantage because they cannot move over land or stream barriers in order to find cooler water. The Upper Willamette River Basin is unique because it runs mostly south to north, and, if cool water refugia are maintained in the mainstem, there may be a greater opportunity for species to migrate north to new areas that are cooler than is typical in river systems that run east/west. However, the Basin may not be big enough for this effect to be significant and off-set the warming trend downstream.

Aquatic Species and Systems Most Buffered from Changing Climate Conditions

- The McKenzie and Middle Fork Willamette Rivers, as stream temperature increases at higher elevations may be less extreme than those at mid and lower elevations. As a result, despite a high likelihood of lower flows and a shift in the timing of flows resulting from changing snow pack patterns, the McKenzie River is likely to remain the best stronghold for native fish in the Upper Willamette River Basin, especially because it is spring-fed rather than relying on surface flows. The Middle Fork Willamette also may see more moderate changes in flow.

- In general, spring-fed streams and riparian areas will be buffered somewhat from changes in flow and temperature. For example, the high Cascades may not be particularly vulnerable to changes in groundwater temperature because the ground is so porous that water infiltrates deeply and quickly.

- Streams on federal public lands can be expected to be somewhat more resilient to climate change conditions and may provide a climate refuge for cool water dependent species. This is because land management practices on USDA Forest Service lands are likely to continue to have a less detrimental impact on stream systems than the generally more intense practices on private and state timber lands.

- Trout which are currently restricted mostly to spring-fed cold streams as these streams and associated riparian areas are reasonably buffered from climate change impacts to flow and temperature. The overall magnitude of change may be greater in the McKenzie subbasin than in other major tributaries in the Upper Willamette River Basin; however it is likely that cold spring sources will maintain minimum temperatures even as flow is reduced. Therefore, trout in the McKenzie subbasin are likely to be less susceptible to climate change losses than those in the Middle Fork of the Willamette.

- Native fishes that thrive in warmer water, such as largescale sucker, northern pikeminnow, and threespine stickleback, are likely to increase in population and out-compete colder water species.

Risks to Terrestrial Species and Systems

The expert panelists determined that the likely risks to terrestrial species posed by climate change under the three models are varied and numerous due to potential broad-scale changes in vegetation, precipitation, and species relationships and distributions.

Existing terrestrial stressors become worse – As mentioned previously, the greatest identified threat to both terrestrial and aquatic systems is the potential for climate change to make stressors that are already impacting wildlife, wildlife habitat, and ecosystem function worse. Climate change has the potential to severely exacerbate such stressors as pollution, fragmentation, loss of habitat, and the encroachment of invasive species.

Decline in specialized habitats - Due to the lag time between the decline of one species and the increase or immigration of another, the number of species of plants and wildlife in the Basin, and the ecological functions they serve, are expected to decline with climate change. Maritime evergreen forests, for example, are expected to decline, along with numerous associated species that depend on these forests including spotted owl, red tree vole, and long-eared myotis (a bat). As maritime evergreen trees are replaced by oak and other hardwoods this will create mixed habitat. This period of transition is likely to benefit generalist species such as barred owls (increasing competitive pressure on spotted owls) and mule deer over specialists that are associated with specific habitats.

Fast rate of change - The rate of climate change projected for the Upper Willamette Basin is substantially faster than species traditionally have dealt with and may exceed their ability to adapt. Evolutionary changes that allow species to adapt to changes in their environment generally occur on a much longer timescale, so plants and animals will have to move to new locations to respond to changing climatic conditions, rather than evolve in place. Unfortunately, many species will have difficulty relocating due to inherent limitations in their ability to move great distances and limitations in habitat connectivity resulting from development and land-use pressures. As temperature, available moisture, and vegetation patterns shift, local populations of species with low dispersal abilities or habitat types that are uncommon on the landscape are likely to be eliminated unless wildlife managers intervene.

Drought stress of vegetation - One of the climate models used in this assessment suggests that climatic patterns will shift to include extended interdecadal wet/dry periods. If decade long wet periods followed by decade long dry periods become more common, a build-up in vegetation followed by broad-scale die-off, disease, and fire can be expected. The frequency, intensity, and size of fires all are expected to increase substantially in such a scenario. The variety of species in the Basin would become depleted as more dry-adapted species die off during wet periods and more wet-adapted species, such as Douglas-fir, die off during dry periods. Mature forests would be reduced due to increasing fire events during periods of drought.

Increase in native and non-native invasive species - The projected changes in climate in the Basin are likely to lead to an increase in invasive species. Many exotic and weedy species already in the Basin, such as bullfrogs, feral pigs, and scotch broom, are better colonizers than most native species, making them more likely than native species to become established and spread in areas when native species decline. Exotic species like kudzu are likely to invade the Basin as the climate warms and join the plethora of weeds already disrupting the landscape. In contrast, leafy spurge may contract its range in Oregon due to climate change (Bradley et al., 2009). Some native species also could become invasive under climate-changed conditions as they shift their ranges to new areas with fewer competitors. Even some plant species used in landscaping, and potentially some agricultural crops, may become invasive as the climate shifts.

Increase in disease and pests - Disease and pest problems in wildlife, native vegetation, and agriculture, are likely to increase, especially diseases and pests that typically are controlled by freezing temperatures in the winter. As diseases move into new areas, local species will be especially susceptible due to a lack of previous exposure. Higher winter temperatures will allow many pests to survive the winter and increase their overall reproduction, as spruce budworm and pine beetles already are doing in some parts of Oregon and much of the West.

Degraded ecosystem services - Ecosystem services, such as the ability of natural systems within the Basin to control flooding or provide clean water and air, are expected to diminish with climate change. Changes in climate also may impair the ability of older forests to absorb carbon dioxide and help in regulating climate, a service that is critical for helping prevent climate change from growing worse. To understand how climate change and diminishment of ecosystem services are linked, consider the fact that climate change in the Basin may lead to the death of a dominant tree species, which in turn could cause the landscape to release CO_2 and to be more exposed to erosion during severe storms. Increased tree death attributable to climate change already has been documented across the Pacific Northwest (van Mantgem et al., 2009), and widespread loss of dominant species such as lodgepole pine has been seen in the Rockies and elsewhere. The loss of forest could lead to a loss of cover for deer and other wildlife, therefore impacting hunting opportunities, while increased erosion may lead to lower water quality in a reservoir or stream used for drinking water or salmon spawning. As individual pieces of an ecosystem are degraded, a large variety of interconnected ecosystem services are lost.

Terrestrial Species and Systems Most Vulnerable to Changing Climate Conditions

The science panel identified the following species, habitats, and areas as particularly vulnerable to projected climate related changes within the Basin:

- Species that rely on mature and old-growth forest, such as the red tree vole, northern spotted owl, and southern torrent salamander, are expected to experience accelerated reductions in habitat in the Basin. Old growth reserves, such as late-successional reserves established by the Northwest Forest Plan, that provide critical habitat for these species increasingly may be at risk due to changing climate conditions. Inter-decadal variation in precipitation is one factor that may lead to the decline of older forest habitat. Even without 10-year shifts in climate, however, mature forest could decline and be replaced by younger stands, placing an even greater premium on the ecological value of the mature forests that remain. Mature and old-growth forests are at risk because it takes so long to replace them once they are lost, but they also are discussed in the next section as being highly resistant to fire, drought, and other disturbance, thereby providing them with some level of buffering against climate change.

- Terrestrial species found in the Basin that already are at risk of extinctions, such as marbled murrelet and northern spotted owl, are especially vulnerable to the impacts of climate change. Species with already reduced populations may be further impacted by invasive native and non-native species. One example of this is the presumed competition between related owl species – barred owl and the threatened northern spotted owl. A combination of climate related effects (increased winter precipitation that leads to lower reproductive success in spotted owls), along with competition among closely related owl species, and ongoing logging, could cause the spotted owl to disappear from the Basin.

- Maritime evergreen dependent species, such as marbled murrelet, which already is experiencing range-wide declines of up to 70% due to excess logging, oil spills, and declines in near shore fish resources, could be especially hard-hit by the reductions projected by all three models in the amount of the Basin with growing conditions suitable for the forest community upon which they rely. Maritime evergreen tree species, especially the younger age classes, could become drought stressed and prone to fire and disease as conditions change.

- High elevation alpine and subalpine habitats and associated species are projected to disappear completely from the Basin, according to the vegetation model. Engelmann spruce, subalpine fir, and whitebark pine are at risk, along with other subalpine vegetation, and the wildlife that depends on them for food and shelter. Examples of associated wildlife species that are likely to be at risk include the Cascade frog, long-toed salamander, spotted frog, and hoary marmots.

- Areas with new volcanic soils, which are unable to store water in surface and near-surface soils and therefore more at risk of drying during drought. The plant and wildlife species inhabiting these areas therefore are particularly vulnerable to impacts from climate change.

- The lower elevations of the Basin and the Coast Fork of the Willamette River are likely to experience greater impacts from rising temperatures as well as additional stresses from increased population growth. Douglas-fir in lower elevation areas could be replaced by ponderosa pine, and fire is expected to act as a primary catalyst of change. Douglas-fir, a commercially valuable species, also could be replaced by invasive species in many areas.

- The interface between public and private forestlands will be especially vulnerable to stress, including high intensity wildfire, due to the challenge of integrating management of prescribed fire, fire prevention, and fire suppression across land ownership boundaries. As the human population continues to grow, continued encroachment into forested lands increasingly has complicated and limited the tools available for managing fire. Without a significant policy response, this trend is likely to continue.

Terrestrial Species and Systems Most Buffered from Climate Change

Not all terrestrial species will be negatively impacted by climate-induced changes, as some species may benefit or be resilient to a changing climate. The workshop participants identified the following terrestrial species and systems as most likely to be buffered from climate change impacts.

- Douglas-fir may be maintained at mid-elevations where shifts from one vegetation type to another are predicted. This is due to this fir's prevalence across elevational gradients and its presence in both current and future projected forest types. Old-growth forest at these mid elevations is likely to be buffered from climate change impacts and its maintenance is especially important to ensure these forests provide habitat for old-forest dependent species, and connectivity for species migrating up in elevation to escape warmer basin temperatures. Specifically, Douglas-fir may be important to maintain in the eastern (upper) portions of the McKenzie and Middle Fork Willamette subbasins where it will continue to provide habitat for old-forest associates as other tree species shift over time.

- Intact ecosystems, such as roadless areas, late-successional reserves enacted by the Northwest Forest Plan, parts of the HJ Andrews Experimental Forest in the central Cascade Range, streams without diversions, and other areas that remain ecologically protected and intact, are likely to be more able to withstand climate change. Older forests, for example, maintain higher moisture levels compared to younger forests due to greater shading, deeper root systems, and abundant moisture absorbing logs on the forest floor. Older forests have some level of inertia due to their thick bark, plentiful and diverse seed bank, moisture-preserving microclimate, and intricate species webs. As a result they may be more buffered from climate impacts than younger forests and continue to provide suitable microclimates for species seeking cooler locales and specific habitats.

- Some higher elevation areas will benefit from an increase in the length of the growing season. As plant species from lower elevations move upslope, these areas also will provide refuge for wildlife seeking new habitat.

- Species that use post-fire habitat or new stands, such as the olive-sided flycatcher and pileated and downy woodpeckers, might expand under the projected changes to climate; however, this will depend on whether post-fire forests are allowed to recover on their own or are logged. In general, post-fire logging diminishes the ability of the landscape to support fish and wildlife species and inhibits forest recovery (Donato et al., 2006). After disturbance, forest composition is likely to change, and Western bluebirds may benefit as oak woodlands replace conifer.

- Species with large population sizes that occupy diverse habitats, such as great-horned owl, mallard, coyote, barred owl, and striped skunk, are likely to persist or expand under the projected climate changes. Species with large populations and high genetic diversity have a greater likelihood of having offspring that are able to reproduce and thrive under a changing climate.

Risks to Individuals, Communities, and the Economy

The projected climate-induced ecological stresses in the Upper Willamette River Basin are likely to significantly affect all aspects of communities including public health, infrastructure and the built environment, and the economy. In October 2008 a panel of government officials, business leaders, and citizens examined the likely climatic and ecological changes projected for the Upper Willamette River Basin and determined the likely consequences to social and economic well-being in the region. Prior to the workshop, participants received information on existing water, transportation, energy, and economic infrastructure and activities specific to the Upper Willamette Basin, a summary of which is provided here. Our intent was to provide a basis for analyzing how climate change impacts will affect existing structures and activities, and how preparation strategies in one sector might complement or negatively interact with activities in other sectors (see Appendix D).

Risks to Infrastructure and the Built Environment

The projected climate impacts are likely to threaten the integrity of buildings, transportation systems, and energy facilities in the Basin. Hydroelectric generation in the McKenzie Subbasin is likely to diminish with reduced snowpack and summer water storage, and wildfire increasingly may threaten power lines in the upper portions of the Basin. Renewable biomass electrical generation supply may become intermittent if periods of drought reduce vegetation growth.

Fire

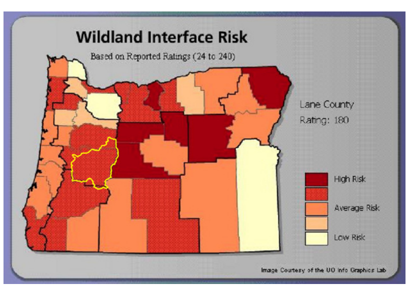


Figure 9. The Wildland Interface Risk map shows Lane County currently at above average risk for wildfire, with the Upper Willamette River Basin outlined in yellow. From UO Info Graphics Lab

Most of the Basin (90%) is covered by forestland, and one model suggests a high risk of increased wildfire, in terms of proportion of area burned by 2080, while the other models show little change in wildfire. It should be noted, however, that the Basin already is above the state average for wildfire risk (Fig. 9) with nearly 2 million acres of land considered to be at high risk (Lane County Community Wildfire Protection Plan, 2005). Lane County, which encompasses much of the Upper Willamette River Basin, was ranked by a national report as a high-risk place for fire in the wildland-urban interface. Of the top 25 at-risk counties in the 11-state region, the study ranked Lane County third, behind Josephine and Jackson counties (in the Rogue River Basin), in terms of the number of square miles developed within the wild-urban interface (WUI) (Headwaters Economics, 2007; Palmer 2007). The costs associated with fire fighting and fire control are likely to rise dramatically over the coming decades (CLI, 2007).

With increased growth in the WUI and projected increases in area burned by wildfires, protecting private property from wildfires eventually is expected to consume a larger proportion of all firefighting costs. The interface between public and private forestlands is where the greatest threat will exist because of the challenges to fire management on private lands (e.g. there currently are no laws for mandating shrub clearing around houses in the WUI). Further expansion into the WUI driven by rising population growth will make fire management even more complicated. Midelevation areas and urban-rural interface areas are likely to be most susceptible to fire due to a combination of warmer and drier conditions and the potential for human-caused ignition.

Flooding

The Basin has nearly $32 billion in taxable property ($23.5 billion in Eugene, $6.27 billion in Springfield, and $1.9 billion in the rest of the Basin). Of the 47,600 acres of land that are on taxable lots, nearly 33,450 acres of land are in the floodplain (based on data compiled by Ray Neff from LCOG). Many buildings, roads, and other infrastructure located on these floodplains will be at greater risk if flood frequency and intensity increases with a changing climate and the natural "sponge" of the Basin's floodplain increasingly degrades with development. For example, the 1996 flooding in the Upper Willamette River Basin resulted in $500 million in property damage (NOAA, 1996).

Floodplain: The area adjoining a river or stream that has been or may be covered by floodwater. For insurance purposes, floodplains are evaluated by their 100-year and 500-year flooding potential. These time periods may need to be reevaluated under climate change.

Floodway: The channel of a river or stream and the parts of the floodplain adjoining the channel that are reasonably required to efficiently carry and discharge the flood water or flood flow of a river or stream.

Source: Tinleypark.org, National Flood Insurance Program

Case Study: Cottage Grove

Cottage Grove is a community of 9,300 people with timber and manufacturing as major industries. It is located in the most southern portion of the Upper Willamette Basin and is threatened by flooding and wildfires. The current risks of wildfire and flooding are expected to increase with climate change.

Part of the city of Cottage Grove is within the floodway.[1] There are at least 25 buildings in the floodway, and a minimum of 137 buildings in the 100-year floodway[2], all of which are at risk for damage should flooding occur. The average value of each building is approximately $136,000: flooding would cost millions in damage to this small community. In addition, 10% of the community resides in the wild-urban interface and is at risk for wildfire. As both population and the risk of wildfire increase, so will the risk to infrastructure and human lives.

Source: Cottage Grove Natural Hazard Mitigation Plan and personal communication with city planner, 2008.

[2] *100-year floodway*: area with a 1% annual chance of being flooded. http://www.fema.gov/plan/prevent/floodplain/nfipkeywords/floodway.shtm

Transportation

Road, rail, and air transportation is vital to the Upper Willamette River Basin's diverse economy. The Basin has nearly 1162 miles of paved road and approximately 1450 miles of unpaved road (based on data from AOC, 2007; Ray Neff from LCOG data).

Train in Oakridge. Cartracks.com

The economy of the Basin is linked to a network of states and Pacific Rim trade; Interstate 5, the Union Pacific Railroad, and the Eugene airport are the major transportation routes for trade. The Eugene-Springfield area serves as a marketing center for Central and Southern Oregon, connecting other counties to the world. The Eugene Airport serves six major cities, while Interstate 5 and rail lines connect Lane County to states around the northwest, the nation, Canada, and Mexico. Use of Interstate 5 in Lane County has increased by 20 - 24 % over the past 10 years and is expected to continue to increase (LCOG, 2008). Use of the Eugene airport also is growing, with over 750,000 passengers traveling through the airport in 2007 (LCOG, 2008). The Basin also is well connected to water-based export trade routes, such as the Port of Portland and Coos Bay.

Severe flooding caused by more frequent and severe storm events as well as increased forest fires are likely to impact roads and the railroad and impair movement of persons and equipment during storm and fire emergencies. The most susceptible roads will be those bordering rivers and streams as well as those in the vicinity of unstable slopes. Air transport also may be affected by increased storms and smoke intrusion from wildfires.

Water Supply

The Upper Willamette River Basin contains thousands of waterways, the quality of which is affected by adjacent land uses. There are many different types of waterways in this region including a higher elevation network of rushing forest streams, channelized urban stormwater conduits, agricultural irrigation ditches, rural roadside ditches, mid-sized tributary rivers, and the beginnings of the broad, meandering Willamette River.

Municipalities and utility providers including Westfir, Lowell, SUB, EWEB, Creswell and Cottage Grove all rely on surface water supply to provide drinking water to serve citizens in the Upper Willamette River Basin. As flooding and runoff increase in the basin, costs associated with water supply treatment will increase as well. More frequent higher intensity rain events with higher flows and more runoff are likely to reduce water quality as sediments and chemicals leech from the soil and impervious surfaces such as roads, parking lots, and rooftops. The increased costs come from removing turbidity (a measurement of water quality which refers to the cloudiness of water caused by individual particles / suspended solids similar to smoke in air), removing chemical contaminants, inactivating biologic pathogens, addressing increased algae loading that impact filtration, and taste and odor issues. Treatment for possible neurotoxins, associated with cyanotoxins released when certain algaes and bacteria die during blooms, also may be required.

The demand on groundwater is not expected to increase dramatically in the future due to lower rural population growth and increased urbanization; most urban areas rely on surface water. Water scarcity, disruptions, and conflict are likely to increase due to reduced snowpack and increased periods of drought, especially on a seasonal basis. For example, Gordon Grant's research with the USFS PNW Research Station predicts that even the McKenzie River, which is vital to Eugene municipal water supply in the summer months, once was thought to be immune to the impacts of reduced snowpack but is now projected to experience a loss of summer streamflows. These changes increasingly will challenge the physical capacity for water storage and allocation in the Basin.

Pressure on already limited off-stream water storage will likely increase with climate change, particularly in the summer months. Increasing competition for limited water supplies may lead to more rural-urban, and intra-group tensions over the historical legacy of water rights, apportionment, and pricing policies. There likely will be more pressure to limit surface and groundwater withdrawals in favor of enhancing streamflows for fish and other ecosystem services.

The Upper Willamette River Basin often faces periods of warming (heatloads), to the point where cold-water fish spawning and migration may be affected. Even with the standards set by the DEQ, natural occurrences such as changes in stream flow or hydrology, may lead to warming in the Willamette River and its tributaries during certain periods of the year. Increases in temperatures and changes in snowpack from climate change may lead to additional warming in the future. Furthermore, the majority of land in the Basin lies outside of urban areas and heat loads often are not controlled. Runoff from agriculture or septic system failure, for example, can influence the water temperature and other water quality parameters in the Basin.

[1]Heat loads (heat that enters the river from human point and nonpoint sources of pollution) are established and allocated by the Department of Environmental Quality (DEQ) and limited based on how much heat the river can accept without affecting water quality and species' habitat. Heat loads occur from vegetation loss, ambient air temperature, direct solar radiation, water diversion, and wastewater inflow from industrial and municipal facilities.

Energy Systems

The electrical power and transmission sectors play important roles in delivering a reliable supply of energy that is vital to support the Upper Willamette River Basin's growing population and diverse economy. The regional power grid is likely to face increased stress due to the likelihood of more intense storms, heat waves, fires, and drought. Problems related to these issues have appeared in the past, for instance in 2001 when power shortages and high electrical costs caused in part by decreased hydroelectric reservoir storage forced some Oregon manufacturers to curtail production.

Lane County Co-Op

Utilities operating within the Basin provide relatively clean power at among the lowest rates in the country due to the abundance of hydropower. Electricity is furnished at less than a nickel per kilowatt-hour for industrial users, and hydroelectric dams provide electricity year round. Natural gas is provided by Northwest Natural, the largest supplier of natural gas in the Northwest.

Utility service for rural communities includes:

- Blachly-Lane Electric Co-op, which purchases the majority of its power from Bonneville Power Administration (BPA).[1] BPA uses a power mix primarily hydroelectric, with nuclear and other sources mixed in.
- Emerald People's Utility District's territory covers 555 square miles, in a patchwork "donut" around the Eugene-Springfield metropolitan area. As of June 2008, they had almost 20,000 members. There are 1,918 miles of distribution line and 21 miles of transmission line in EPUD's district, with 24,874 distribution poles and 387 transmission poles. EPUD's source of electrical power is primarily hydroelectricity from BPA.
- Lane Electric Cooperative, which provides rural electric service on a cooperative basis to areas in Lane County. Lane Electric's service territory covers 2,600 square miles including Forest Service land. As of 2007, they had 12,808 electric accounts, over 1,456 miles of power lines, including 54 miles of high voltage transmission lines which would be vulnerable to fire, storm damage and large scale outage Their power comes from BPA and is primarily hydroelectric.

Utilities Serving the Eugene-Springfield Metro Area include the following:

- The Eugene Water & Electric Board (EWEB), which serves Eugene and residents along portions of the McKenzie River. EWEB is Oregon's largest customer-owned utility and provides electricity, water and steam to more than 86,000 homes, business, schools and other customers in Eugene, serving an area of 235.6 square miles. EWEB purchases 47% of its power from BPA, 11% of power is generated by EWEB-owned power plants, and the remaining power comes from other suppliers, mostly across the Northwest. EWEB has over 50,000 water customers, who consume 9.6 billion gallons on average per year, and 90 steam customers. EWEB's power sources include wind (2%), biomass (5%), nuclear (7%), natural gas (3%), coal (3%), efficiency (12%), and hydro (68%).
- The Springfield Utility Board serves the City of Springfield and covers over 25 square miles of territory. SUB has over 56,000 customers, 240 miles of overhead line, and 121 miles of underground line. Power is sourced from BPA and is primarily hydroelectric. Water service includes just under 20,000 customers, with a majority of the water taken from a system of seven wellfields that tap groundwater from beneath Springfield and the remaining 7% comes from the Middle Fork Willamette River.
- The Metro Wastewater Commission is responsible for sewer and stormwater management in the Eugene-Springfield area. They manage the Water Pollution Control Facility (regional treatment plant), the Biosolids Management Facility, Biocycle Farm, and more than 800 miles of sewer lines and 50 pump stations.[2]

EWEB's McKenzie River hydroelectricity system is likely to face significant challenges in coming years due to increasing seasonal variability of water. Summer power capacity likely will be reduced as streamflows are reduced and reservoirs depleted during summer droughts due to reduced snowpack and earlier snowmelt. At the same time, demands for electricity in the summer will likely increase

1 The Bonneville Power Administration is a federal agency based in the Pacific Northwest. Although BPA is under the U.S. Department of Energy, it is self-funding and covers its costs by selling its products and services at cost. BPA markets wholesale electrical power from 31 federal hydro projects in the Columbia River Basin, one nonfederal nuclear plant and several other small nonfederal power plants. About one-third of the electric power used in the Northwest comes from BPA.

2 Lane County's Community & Economic Development Program is collaborating with a wide array of local and regional entities to study the feasibility of turning local waste streams into renewable energy. This collaborative partnership has already been awarded one federal and two state grants totaling $400,000.

as rising temperatures expand the use of air conditioning. Utilities that purchase power from BPA, such as Springfield Utility Board, may be especially vulnerable to these effects because sourcing is dominated by hydroelectricity. In contrast, the per-capita demand for natural gas may decline as people need less heat in the winter, but overall demand still will rise due to population growth.

Increased proportion of area burned by wildfires also is likely to affect hydroelectric supply due to increased sediment deposition into rivers and streams that over time reduces reservoir capacity. Also, increased extent of acres burned may reduce the supply of forest and agricultural residues needed to fuel biomass-based energy production. Both increased storm activity and wildfires may impair high voltage electrical transmission lines and distribution systems. All three climate models project an increase in wildfire in the Upper McKenzie Basin where EWEB power generation facilities and transmission lines are located (see Figure 7). In addition, higher surface air temperatures will decrease the efficiency of electrical distribution wires in some locations.

Demographic changes such as the rising number of people moving to the Upper Willamette River Basin, as well as economic changes, such as possible growth of plug-in-electric (PEV's) vehicles that leads to increased electricity needs, would place even greater stress on local energy systems.

Risks to Economic Systems

Historically, the economy of the Upper Willamette River Basin has been dominated by timber and agriculture. However, over the past few decades the Basin's economy has become more diversified. Approximately 117,600 individuals are employed in the Basin, with Table 2 providing a breakdown by sector with estimates of employees. Employer categories are based on national categorizations.[3]

In the coming decades, economic growth is expected in sectors such as services, manufacturing, printing, publishing, and technology, while forestry and agriculture are likely to continue the declines of the last century but at an even more accelerated trajectory unless these sectors adapt to changing climate conditions.

The economy of the Upper Willamette River Basin, whether manufacturing, services, agriculture, forestry, or tourism, is highly dependent on stored water for hydroelectricity, irrigation, and municipal water supply. With warmer temperatures and more extended dry periods predicted by the climate models, ample supplies of hydroelectricity and water may become increasingly less stable. The local economy also is dependent on readily available in-basin, regional, and national transportation. As previously mentioned, road, air, and rail transportation are likely to face disruptions due to increased storm events (locally and elsewhere), flooding, and wildfires.

In this section, we focus on the impacts of projected climate change on one of the largest sectors in terms of employment - manufacturing, retail, and tourism- and two sectors likely to be greatly affected by climate change- agriculture and forestry.

Table 2. Approximate number of employees in various employment sectors for the Upper Willamette River Basin (incorporated cities only). Based on national categorization of employer sectors. Data from LCOG, 2008.

Sector	Employees
Accommodation and Food Services	10,460
Administrative and Support and Waste Management and Remediation	7,525
Agriculture, Forestry, Fishing and Hunting	630
Arts, Entertainment, and Recreation	1,955
Construction	5,160
Educational Services	10,940
Finance and Insurance	4,150
Government	5,682
Health Care and Social Assistance	17,022
Information	3,280
Management of Companies and Enterprises	13,820
Mining	60
Other Services	4,570
Professional, Scientific and Technical Services	5,390
Real Estate and Rental and Leasing	2,184
Retail/Trade	16,375
Utilities	734
Wholesale Trade	4,700
Transportation and Warehousing	3,103

Manufacturing, Retail and Service Sectors

Manufacturing and retail are major employers in the Basin. Wood product manufacturing employment is six times higher in the Basin compared to the rest of the country, and 1.5 times higher than in other areas of the state (LCOG, 2008). However, wood product manufacturing also is predicted by the Oregon Employment Department to decrease steadily in the coming decade.

Rising fuel costs due to potential greenhouse gas mitigation measures, and higher power costs due to reduced hydroelectric supply will likely produce increased stress for many facets of the manufacturing, retail, and service economy. In addition, transportation disruptions due to climate related extreme weather events along with more restrictive use of water are likely to affect these sectors.

Hotter summer temperatures, increased allergens, and

3 These numbers are only available for incorporated cities. Based on data from Bob Denouden, LCOG, 2008.

reduced air quality (due to rising temperatures and smoke intrusion from wildfire) are likely to adversely affect the health of the local workforce and visitors alike. The smoky air that permeated the region in the first few days of the 2008 Olympic Trials may be a sign of things to come. In addition, the predicted increase of fires in other regions, such as the Rogue Basin, could affect air quality in the Upper Willamette Basin (CLI & NCCSP, 2008). These concerns also may impair living conditions now favorable to attracting retired persons.

Tourism is expected to grow given Lane County's proximity to the rivers, ocean, and mountains. Tourism was a $ 552.8 million industry in Lane County in 2005 (these numbers are only available at the county level, which expands to the coast, not for the Basin alone). However, reduced snowpack is likely to affect winter sports, while increased incidence of forest fires may lead to longer closures of national forests and increased smoke intrusion may make summer camping, hiking, recreational fishing and other recreational forest use less desirable. Reduced summer streamflows also may affect commercial and recreational boating and fishing.

The optimal tourist season may shift as rising temperatures make summers less attractive to people, while milder fall, winter, and spring temperatures may prove more attractive. In the summer months, these changes would affect the entire service sector and their suppliers, including motels, hotels, and restaurants.

Motor coach (i.e. large recreational vehicles and tour buses) and bicycle manufacturing are located in the Basin; in 2004, motor coach manufacturing employed 3,663 and bicycle manufacturing employed 169. Motor coach manufacturing traditionally has been cyclical and has had two recent large employment increases – once in the late 1990s and again from 2004 to 2005 (Monaco Coach Corp. and Country Coach Inc). With the baby boomer generation entering into retirement years, sales in recreational vehicles were predicted to increase (Oregon Employment Dept, 2005). However, this could be greatly affected by the price of gasoline, restrictions on, or greater awareness of, vehicle emissions that contribute to climate change, and from the current economic downturn that limits the sale of this type of luxury item. Innovations that greatly reduce emissions from RVs could transform the industry due to the demand that is likely to exist if retiring baby boomers regain recently lost financial security. Bicycle manufacturing also may increase greatly as incentives are developed for alternative forms of transportation to automobiles.

Agriculture

Agriculture always has played an important role in the economy of the Upper Willamette River Basin. Agricultural sales brought in about $119 million supported by $20.4 million in payroll for all of Lane County, much of which lies within the Basin (OED, 2008). Crops produced include oilseed, wheat, grain, corn, vegetables and melons, non-citrus fruit, treenuts, nursery and floriculture, and hay. The Basin also produces beef and dairy cattle, hogs, pigs, chickens and eggs, turkey, poultry, sheep, and goats (OECDD, 2008). While extensive agricultural landholdings lie outside the boundaries of the Upper Basin, the Eugene-Springfield area is a supply center for services and products for the entire southern Willamette Valley.

Rising land prices caused by accelerating population growth and development have placed increased stress on local farmers. Climate change is likely to add additional stresses. Higher temperatures, especially warmer night time temperatures, could stress certain crops. Farmers also are likely to need more water for crops, which will raise costs and also possibly become problematic as reduced water availability forces farmers to compete with municipal and other users for available supplies. Increased atmospheric CO_2, on the other hand, may increase crop productivity in the short term, and a longer growing season could increase crop harvest.

Pollinators may be affected by disease pathogens that increase with warmer temperatures or by pesticides and herbicides used to kill off the higher numbers of agricultural pests and invasive plants that are expected to emerge with rising temperatures. Increases in pesticide and herbicide use also may reduce water quality. Large and small growers alike may be vulnerable to these changes. Large farms with monocultures will be more susceptible to disease, while farms that rely on single crops are likely to be more at risk financially than those with a diverse array of crops. Growers may need to shift to different, more diverse crops, and new varieties and types of crops may need to be developed and planted. Production of specific crops may need to be shifted to cooler, higher elevations. This would require changes in land-use patterns and regulation.

Viniculture and production of specialty foods are growing steadily throughout the Upper Willamette River Basin. Production of agricultural products such as grapes, honey, and organic and natural foods is likely to experience the effects of climate change. The methods, varieties, or areas of production may have to shift in order for these products to continue to be produced. However, if interest in reducing the size of the carbon footprint of food increases, the organic and natural food movement likely will grow. Climate influences the style of wine that a region can produce for optimum quality and production each variety generally is grown in specific regions and narrow climatic zones. Wine varieties in their optimum zones have consistent sugar levels, ripe flavors, and balanced taste. Warmer and longer growing seasons, while reducing frost damage, will alter ripening profiles and increase sugar levels resulting in excessive alcohol content. Reduction in soil fertility and erosion also may be anticipated. Viable zones in the Willamette Valley will shift northward, to the coast, or upward in elevation. High value Pinot Noir and Chardonnay varieties may be replaced by lower value Merlots and Grenaches (Jones, 2007), and California growers may decide to move their vines to Oregon. Fig. 10 illustrates the effect of a moderate 2.3° F warming on suitable grape varieties.

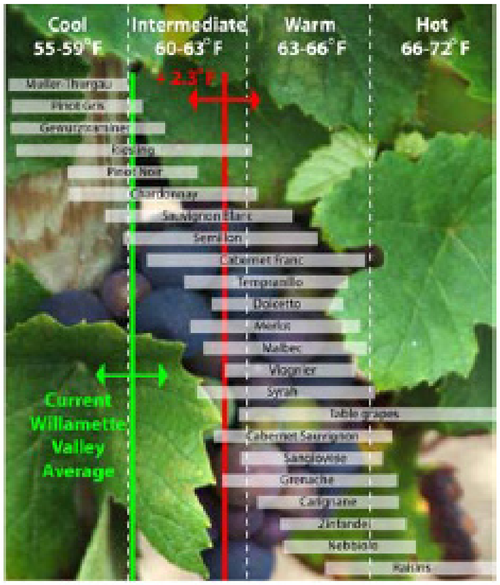


Figure 10. Predicted changes for grapevine climate and maturity groupings for the Willamette Valley showing average growing season temperature (adapted from Jones, 2007).

Forestry

Employment in the forestry industry in the Basin has been decreasing sharply since 2001 (OED, 2008). Forestry operations in the Basin include timber operations (e.g. silviculture, controlling erosion, surveying, and removing diseased or damaged trees), logging, and forest nursery and gathering of forest products. Payroll for the forestry sector in Lane County was $24 million in 2006 (OECDD, 2008). Data specific for the Upper Willamette River Basin portion of the county was not available.

Forestry is likely to be under increasing stress from a number of climate-related factors. Reduced snowpack, rising temperatures, and the increased occurrence of drought likely will decrease soil moisture, weaken trees, and increase disease. In fact, increased tree mortality attributable to climate change has already been documented throughout the Pacific Northwest (van Mantgem et al., 2009). These forces will make forests more susceptible to wildfires, which likely will cause forest production to decline. Longer wildfire seasons may narrow the window of time in which tree harvest is possible, although a longer snow-free period may negate this impact by extending the harvest season. Conflicting social pressures to rely on forests for carbon sequestration and for producing energy from woody biomass may complicate the economics of more traditional forestry. Increased frequency and intensity of wildfire may place supply limits and higher costs on the production of biomass energy and limit carbon sequestration levels. Both newly emerging forest uses will need to be carefully regulated to ensure that sustainable practices are followed.

Risks to Public Health and Emergency Services

Public Health Services

Rising summer temperatures will likely produce higher incidences of heat-related illnesses such as heat stroke and exhaustion. Many homes today in the Upper Willamette River Basin lack air conditioning, which may exacerbate the incidence of heat-related illness. Elderly, infirm, and low income individuals are likely to be most at risk because they may lack funds to pay for air conditioning or health care, and because increased warming and air pollution may exacerbate pre-existing diseases and illnesses. Higher use of air conditioning may raise the costs of energy for these populations.

Higher rates of asthma and other respiratory diseases from ground level ozone, increased allergens, degraded air quality, and increased wildfires also are likely (PSR, 2002; WHO, 2005). Current occurrence is considerably higher in Oregon than the national average. In 2005 there were 2,446 hospitalizations for asthma costing $23.5 million, although this number appears to be decreasing. In Lane County about 10.5% of adults are estimated to have asthma (based on known cases and estimated untreated cases) and almost 1000 hospitalizations for asthma occurred between 2001-2005 in Lane County (Oregon Asthma Surveillance Report, 2007).

Vector (i.e. carriers, such as a mosquito or tick) and water-borne diseases may increase with changes in temperature and precipitation. Warmer waters and increased flooding are likely to produce elevated numbers of mosquitoes that may carry diseases such as West Nile virus and malaria, which was endemic in the Upper Willamette River Basin in the 19th century. Infection most frequently occurs between May and November, with peak incidence in June and July. Infectious diseases that are currently found further south, such as dengue fever, could become viable in Oregon over the long term.

Lyme disease is a multisystem inflammatory disease caused by the bite of the western black-legged tick. The Center for Disease Control (CDC) reports that Lyme disease is grossly under-diagnosed by at least 10-fold. In 2006 Oregon saw 19 human cases with 17 (89%) occurring west of the Cascades. The five-year annual average for reported Lyme disease cases in Lane County is 1.5 (Oregon DHS, 2006).

West Nile virus (WNV) is carried by mosquitoes and can infect humans, horses, and birds. Across the state, 27 humans, over 70 animals ranging from birds to horses, and 32 mosquito ponds were diagnosed or identified in 2007 as being infected by WNV. Warmer water temperatures are likely to increase the months of the year that will support high adult mosquito populations. West Nile Virus has not yet been detected in Lane County, but has been found in Eastern Oregon. Lane County Public Health is working with the state and CDC to prevent WNV. However, with warming temperatures and more major rain events projected, WNV may become more common in the Upper Willamette River Basin.

Flooding, which likely will increase under the predicted scenarios, also may have severe impacts on mental health and increased stress from displacement, as well as reduced ability to transport medical supplies due to road damage (Longstreth, 1991).

Even with the potential impacts, Oregon is likely to be less affected initially by climate change than other parts of the country and world. Therefore, an influx of climate "refugees" to the Basin (individuals escaping areas at high risk for climate change impacts, such as those living in areas affected by sea level rise or more frequent hurricanes), seems a likely possibility. Crowding, higher rates of communicable disease spread, rising land and property prices, competition over energy, water, land and other resources, and increased pollution in urban areas may result from the in-migration (WHO, 2005).

Increased forest fires pose a public safety hazard in itself, but also degrades air quality. The two extremes of more flooding and longer periods of drought will degrade water quality both for municipal water supplies and groundwater. These factors may affect water quality for human consumption.

Emergency Services

Increased storm intensity, flooding and wildfire are likely to place greater demands on emergency service providers in the Upper Willamette River Basin. A major demographic shift would exacerbate these pressures as drought, fire, flooding, and other extreme weather events encourage people to move from rural to urban areas to be closer to emergency services.

Populations Most Vulnerable to Climate Change

Low income populations in rural areas may have an increasingly difficult time coping with hotter summers and the projected rise in major storms, flooding, and wildfire due to lack of healthcare and property insurance. The elderly and low-income families may not be able to relocate or rebuild following extreme weather events. Elderly populations, which are predicted to increase significantly over the coming decades, will be at higher risk for heat strokes and more susceptible to disease. Individuals with suppressed immune systems also may be more vulnerable to a changing climate and more susceptible to heat and disease. Higher fuel prices, due to instability in the Middle East, high demand for oil, increased taxes on carbon-based fuels, or the shift to renewable fuels, may raise the cost of travel for low-income rural residents and further contribute to the vulnerability of rural populations.

Populations Most Buffered from Climate Change

Some sectors of the population will be less vulnerable to the impacts of climate change. High-income persons are likely to carry adequate health, fire, and flood insurance and be better informed about strategies to cope with stressors. Individuals, families, and communities that are self-sufficient in food, energy, and water will be more resilient. Populations in larger urban areas, while vulnerable to flooding in the Upper Willamette River Basin, may have better access to quality city services. Generally, those communities that are well connected to each other through reliable transportation and communications systems and that have strong social bonds will be most buffered from climate change impacts.

Summary of Risks to All Sectors

The effects of climate change such as higher temperatures, more extreme weather, reduced snowpack, longer periods of drought, and changes in wildfire risk will likely have substantial impacts on natural, built, human, and economic systems in the Basin. If no action is taken to prepare for the likely stresses, damages could amount to millions of dollars in direct costs. The indirect costs, along with reduced quality-of-life, undoubtedly will be many times greater than this amount.

Many climate impacts already are taking place and exacerbating stresses to all four systems. These stresses include increased tree death, invasive species impacting already vulnerable native species, increased allergens, and unsuitable growing conditions for some crops. Globally, the incidence of natural disasters has increased fourfold over the past three decades, growing from fewer than 100 in 1975 to more than 400 in 2005 (UNEP/GRID-Adrendal, 2005). The added climate stresses will increase the vulnerability of native species and ecosystems, buildings and infrastructure, the economy, and human health due to heat and drought stress, possible increases in flooding and wildfire, declines in ecosystem services like clean water and forest products, and increased disease, invasive species, and pests. Government, citizens, and private landowners are not strangers to dealing with these impacts, but the impacts may start to overwhelm normal economic and social function.

Local governments, private companies, nonprofit organizations and individual households can begin to prepare for these impacts in many ways and having a sound understanding of the potential changes ahead will help them to develop suitable strategies and actions. Preparation will help lessen negative impacts, while also increasing the capacity of the land to buffer against increased disturbances. Preparation also will reduce the direct production of greenhouse gas emissions and increase the capacity of forest and agricultural lands to sequester emissions, and thus will help restabilize the climate.

Recommendations for Preparing for Climate Change

Preparing for the likely consequences of climate change should become a priority for government, businesses, and households within the Upper Willamette River Basin. Preparation should begin by making it standard policy to consider and incorporate the likely effects of climate change into ongoing and future planning processes, practices, projects, and policies. The goal should be to proactively build resilience and resistance in an integrated, co-beneficial manner so that natural, economic, built, and human systems can withstand and adapt to growing climate stressors.

Recommended Preparation Strategies for Natural Systems

A number of strategies should be employed in the Upper Willamette River Basin to build resistance and resilience to climate change within aquatic and terrestrial plant and animal species and ecosystems. Current and future management actions and strategies should reflect an understanding of how climate change already has impacted natural systems and how both human activities and climate change are expected to change ecological relationships in the future. Preparation efforts should focus on protecting, and as needed, restoring the functional and structural characteristics of ecosystems so they recover from disturbance, support biological diversity, and continue to provide ecosystem services. The expert panelists identified the following as the most important and effective approaches to preparation of natural systems.

1. ***Protect Native Species and Intact Habitats.*** Protecting native species and their habitats, especially intact ones, is one of the most widely applied approaches to conservation. The panelists argued that this successful approach needs to be applied across broad geographic scales and diverse ecosystems at a much faster pace due to the imminent threat of climate change. Traditional conservation strategies, like the design of reserves or protected areas, have not been set up to address climate change risks. New measures of prioritization for conservation areas and species will need to be carefully developed. Panelists suggested that the following areas or species in the Basin be considered high priority for conservation in a changing climate:
   a. *Floodplains, riparian areas, and other areas and species essential for ecosystem services* - These include areas that provide basic services that communities depend on, such as water filtration, hunting and fishing opportunities, moderation of flood and drought, carbon sequestration, etc. For example, panelists recommended protection of floodplains and riparian zones (especially in the lower Middle Fork subbasin, along the Willamette River mainstem, and in the area of Dexter and Cottage Grove dams) to enhance the capacity of the land to moderate flood and drought. In addition, areas essential to ensure ecosystem resilience, such as mature and old-growth forests, areas with low road density, unique habitats that support biodiversity, should be protected to maintain ecosystem services. As snowpacks decline and precipitation patterns change, high elevation forest service lands in the Upper Willamette Basin are likely to become more vital for providing water for downstream communities (Grant 2007). Improving forest management (retaining old growth, reducing clearcuts, increasing forest diversity, and decommissioning failing roads) in high elevation areas of the eastern Basin now to ensure future water supply is recommended.

   b. *Climate refuges* – The spatial distribution of climate change impacts will be patchy, and some areas are expected to experience less climate stress and change than others. Areas that are expected to undergo little change are called "climate refuges", and they should be identified and given additional protection due to their importance in harboring native species, biological diversity, and functional ecosystems over the long term. For example, it is likely that critical tributary junctions and deltas in upper portions of the McKenzie and Middle Fork Willamette subbasins will serve as climate refuges for fish and amphibians, because their waters may not become as warm as other rivers and reaches. Panelists also noted the importance of cold-water areas in lower portions of all three basins, especially downstream of Eugene, and recommended that these reaches be maintained and protected. Douglas-fir forests found at mid- to high-elevations will also be more likely to persist over the long term, providing valuable habitat as lower elvations and other forest types experience increased climate stress. Other potential climate refuges will need to be identified, and some areas may need to be restored if they have been degraded.

   c. *Intact ecosystems, centers of large populations, and neighboring areas* – Intact and functioning ecosystems with high diversity within and among species will have the greatest capacity to resist climate change and recover after disturbance. This generally includes roadless areas, unlogged old forests, streams not dammed or disconnected from their floodplain, riparian areas that have not been degraded, areas of groundwater upwelling into rivers and streams, and other areas not significantly degraded by past land use, such as logging or grazing. Also included are strongholds of fish populations and areas with viable populations of species that may be at-risk or declining elsewhere. Unfortunately, protecting just the areas where species are still viable will not be good enough to ensure long-term persistence. In addition, protecting neighboring areas with cooler temperatures and connections to these areas will be necessary to allow for large population centers to shift as the climate changes. Maintaining intact and connected areas along elevational gradients will be especially important.

2. *Maintain and Restore Ecosystem Function and Connectivity.*

Maintaining and enhancing the functionality and connectivity of ecosystems increases their resilience to climate change impacts. Panelists consistently pointed out that natural resource managers have a long history of maintaining and restoring ecosystem function and connectivity, but that such management strategies need to be applied across broad geographic scales and implemented under short time frames due to the threat of relatively rapid climate change. Previous efforts, however, have been aimed at restoring historical patterns of vegetation, wildlife, fire, and other variables. Future efforts will need to focus on restoring and maintaining ecosystem function under likely future climate and ecological conditions and on keeping systems as resilient as possible. The panelists proposed five specific examples of potential management action for the Upper Willamette River Basin, with climate change in mind.

a. *Mid- to high-elevation water storage* should be maintained and restored, especially by reintroducing beavers to areas where they were eliminated, to enhance water storage and stream flow as the snow pack declines. Beavers not only provide water storage, but also create wetland habitat, songbird habitat, and a diversity of ecological communities on the landscape. Other approaches to water storage include snow banking and snow fences that capture high elevation snowpack and direct it towards rivers and reservoirs. Such measures would only be effective in concert with intensive efforts to conserve water by residents, agricultural users, and industrial users.

b. *Forested areas with uncharacteristically high fuel loads and a history of suppression* should be considered for judicious thinning to reduce drought stress and prevent broad scale vegetation dieback due to climate change. Forest types that may be appropriate for thinning will primarily be stands that are already intensively managed for timber. Many commercial stands, especially on private property, are young and very dense. These stands currently have little resilience to fire or drought. Thinning projects should be designed and implemented carefully to avoid damage to the functionality of the landscape and impacts to aquatic systems. Because thinning often involves road-building, the benefits will need to be weighed against the potential negative impacts when deciding whether such action is advisable. Thinning alone may not greatly increase the resilience of such heavily managed stands. By also planting with greater species diversity and increasing the age of stands prior to harvest, commercial forestry practices could contribute both to increased carbon sequestration and increased forest resilience. Intact, mature, old forests with moist microclimates should **not** be thinned.

c. W*ild fish populations* should be recovered by restoring natural habitat and managing harvest to protect weak stocks. Reliance on hatchery fish reduces the overall genetic diversity of local fish populations, increases the likelihood of disease introduction, and reduces native fish resilience. High genetic diversity of native populations increases the chance that some individuals will survive and thrive in changing conditions.

d. *An aggressive program to reduce instream barriers, restore connectivity between waterways and their floodplain, and minimize impervious surfaces* should be instituted. Instream barriers, including those created by dams, diversions, culverts, and road crossings, impair up- and downstream connectivity, preventing fish from accessing spawning grounds and other important habitat, and from expanding their ranges to cooler waters in response to climate change. Isolating a river from its floodplain reduces fish reproduction and makes the entire system more vulnerable to impacts from flood and drought. Impervious surfaces such as roads and other pavement prevent water from filtering slowly into streams and groundwater, exacerbating the problems of rapid runoff, including flooding, erosion, and movement of contaminants, and reducing the resilience of the floodplain. Efforts to relocate existing floodplain development, reduce migratory barriers, remove roads, especially those in steep terrain and minimize and mitigate other impervious surfaces will enhance watershed function.

e. *Connectivity (which ensures that species can move to new areas) should become a priority of forestry and other land management practices*. Strategies to enhance connectivity (for example, by landscape-level planning and coordination), facilitate movement of species to higher, cooler elevations, identify, protect, and restore areas along elevational gradients, and protect known movement corridors for wildlife should be key elements of a landscape connectivity plan. Consideration of the potential increase of acres burned by fire, disease, or invasive species will be important when developing connectivity recommendations.

One area in the Upper Willamette Basin that will need to be targeted for conservation, in order to provide connectivity, is the last forested lowland connector between the Coast and Cascade ranges, just south of Eugene. This important corridor for wildlife consists of checkerboard BLM and private land ownership, which complicates management. New avenues of collaborative management across jurisdictions and ownership will need to be developed.

f. *Managers should continue to implement the Northwest Forest Plan* (NWFP). The NWFP attempts to restore functional, integrated old-growth forest ecosystem by establishing a system of connected reserves with connectivity provided both north-south along the Cascades, as well as along east-west elevation gradients. The southern end of this Basin is identified as an important east-west link between the Cascades and Coast Range. The NWFP Aquatic Conservation Strategy wisely provides stream buffers, identifies "key watersheds" which serve as salmonid strongholds, and requires watershed analysis that can act as an early warning system for climate impacts.

2. *Increase Early Detection and Rapid Response Efforts for Invasive Species*

Early detection and rapid response efforts to control establishment of new invasive species should be enhanced and expanded. This effort will need to be coordinated at the level of counties, or higher. As non-native invasive species are introduced to the Upper Willamette River Basin, and the rest of Oregon, early detection would lead to greater success in control and eradication. One complication will be in understanding when a newly arrived species should be controlled as an invasive and when it should be conserved as a climate change refugee (a species forced to disperse from another locale due to climate change). Modification to the definition of what constitutes an invasive species, and protocols for determining when and how to control them under a changing climate, will need to be developed.

To avoid human contributions to the spread of invasive species, panelists recommended that all stocking of exotic fishes in high mountain lakes be halted, and opportunities to eradicate stocked populations be examined to determine the feasibility of restoring native high mountain lake communities. Panelists also suggested that the use of native species, seed sources, and materials be required in forestland management. Further, nursery plants and agricultural crops should be assessed and the availability of plants likely to become invasive under climate-changed conditions should be severely restricted. The state's Forest and Agricultural Practices acts should be updated to include new regulations in this regard.

3. *Update Monitoring and Evaluation Procedures.*

Existing resource management protocols (those aimed at species and habitat management) should be evaluated for effectiveness under changing climate conditions. Managers will need a new decision-making framework that helps them determine when to take action, what action to take, and how to set priorities. The first tenet of such a framework should be to "do no harm". All management strategies will need to be based on a thorough understanding of the likely consequences of climate change, the best available science, a full understanding of ecosystem components that will be affected and that have an impact on other systems, and a strategic analysis of intervention points and actions. New or unusual approaches should not be discounted, and even some approaches that have been shunned in the past may become appropriate in the future. By following a well-formulated framework, managers will be able to move past the current roadblock of uncertainty and begin to take action.

a. While past management strategies focused on maintaining historical patterns, *future management will need to be based on the best current knowledge and data* that are available regarding likely future conditions. "Adaptive management" incorporates the collection of data with the management of natural resources, thereby informing the process as it is carried out. Monitoring protocols that explicitly and rapidly detect climate-induced shifts in wildlife and habitat, track climate change trajectories, and assess effectiveness of management actions will need to be developed and implemented. Adaptive management has lost some of its rigor in recent years as it has been applied haphazardly and without sound monitoring protocol or experimental design. This practice needs to be rectified by revisiting the requirements for a robust adaptive management protocol.

b. Monitoring strategies also will need to include the *identification and monitoring of climate-sensitive species;* that is, species expected to respond most quickly to changes in the climate or associated ecological responses. Many ecological communities are expected to unravel under climate change, because different species will react in different manners to the myriad changes that are expected. Individual species could disappear quickly, even if other closely associated species appear stable. Close monitoring will be needed to prevent unexpected extirpations.

c. *Finally, laws and regulations developed in the past century should be reevaluated;* some may need to be adjusted to provide the needed flexibility in planning and rapid response to attain conservation goals under climate change pressures. Many new management and policy approaches will need to be developed as new natural resource issues arise. One issue that will need to be addressed is the conservation of plant, fish, and wildlife species with restricted distributions (i.e., endemic species that are restricted to a given location) that do not have the capacity to shift their distributions rapidly in a changing climate. Translocation of species is an issue that needs to be carefully considered and guiding principals will need to be developed because of the high potential for unintended consequences.

5. Implement Cross-Jurisdictional Planning for Protecting Natural Systems

Cooperation and coordination across jurisdictions and ownerships will be vital to successful climate preparation. Regional planning needs to be multi-jurisdictional and across governments. Collaborative effort, similar to the concept of watershed councils, will be needed at larger scales, with greater participation by private landowners, and possibly with greater authorities. In order for groups to coordinate, a level of trust among different stakeholders will need to be built. While management actions can be legislatively or administratively directed on public lands, they may need to be encouraged with incentives on private lands. Within the context of co-beneficial planning, the following approaches were recommended:

a. *Measures that provide co-benefits for both climate change preparation and climate change mitigation* (measures to reduce the concentration of greenhouse gases in the atmosphere, and thereby limit climate change) should be given priority over measures that potentially conflict with one another. If land owners are to receive "carbon credits" for sequestering carbon, for example, higher value should be assigned to lands that sequester carbon using intact ecosystems, extended timber rotations, and native species than to those that use plantations, short-rotation logging, and non-native species.

b. Instead of promoting increased storage, policies should *favor development of programs to increase water efficiency in agriculture, industry, and residential areas*. Restoring wetlands, riparian areas, and floodplains also should be encouraged as measures to help sustain water yields. Increased water shortages during much of the year, coupled with potential increases in storm and precipitation intensity could otherwise lead to an increased demand for water diversions, potentially having negative impacts on fish and other aquatic species that already will be stressed by changes to their habitat.

c. Promoting the planting of diverse stands by the timber industry not only would benefit wildlife and native species, but also would protect foresters from potentially devastating climate change impacts. Monocultures (single species stands) lack the resilient properties that are gained from species and genetic diversity and are at greater risk of broad-scale decline and disease than diverse stands.

6. Pursue Additional Research on Large Scale Forest Thinning Forest Thinning.

The idea that thinning of Oregon's forests will keep them below their water-limited carrying capacity and help them persist through droughts has been gaining traction in recent years. This approach may be suitable in the dry forests of eastern and southern Oregon, but the same approach makes little sense on the wetter west-side forests in the Cascades and coast range. Many scientists agree that even the most well-intentioned thinning comes with a price in terms of forgone opportunities to store carbon in the forest and loss of the moist microclimate provided by intact forests. The lack of agreement on large scale thinning suggests that more research is needed before any decision is made to launch such a program.

7. Management Direction Should Shift To Whole Systems Approaches Rather Than Multiple Use

An important policy change recommendation by the panelists is that federal lands policy should shift from "multiple use" to a landscape level and "whole systems approach" that prioritizes conservation and management of ecosystem services and intact ecological communities. Federal and state agencies may want to take individual approaches to climate change preparation in order to test those that are most successful. Consequently, multiple use policies may not necessarily provide the whole systems approach necessary to achieve resistance and resilience to climate change. By trying to satisfy the short run demands of different and often diametrically opposed interest groups, for example livestock grazing and wildlife viewing interests, multiple use approaches may actually exacerbate climate impacts by adding stressors at a time of rapid climate shifts. On the other hand, a whole systems approach may discover shared values that can have long-term co-benefits for apparently conflicting purposes while building resilience and resistance to change.

To ensure a whole systems approach, climate change mitigation and climate change preparation policies must be integrated and steps taken to ensure that they do not conflict with one another. Policies should be integrated across related fields, including fire management, carbon storage, water conservation, and wildlife management, in order to develop cohesive climate change policy and avoid competition, redundancy, and disruption of efforts in one field by those in another. Stakeholder involvement in decision making may lead to cooperative protocols and partnerships that among formerly conflicted interest groups. Care must be taken, however, to ensure that the overall goal of restoring resilience and resistance through a whole systems approach is not lost.

8. Conduct a "Life-Cycle Analysis" to Prevent Secondary Impacts

Climate change preparation and mitigation must also be harmonized. Natural systems play a dual role in climate change - acting both as part of the carbon cycle that can cause or remedy climate change depending on the approach, and the source of ecosystems services that will be affected by, and must adapt to, the changing climate. Many actions being proposed to increase carbon sequestration or decrease greenhouse gas emissions could unintentionally sabotage efforts to increase the resilience and resistance of natural systems to climate change. A less resistant ecosystem is also less able to function, and carbon storage may be one of many vital functions lost. Conducting a thorough "life-cycle-analysis" (an assessment of all the potential inputs and effects, including secondary effects, of a proposed action) prior to implementing new mitigation actions to determine the true costs and benefits can prevent unintentional secondary impacts.

Recommended Preparation Strategies for Economic Systems

Panelists recommended a number of strategies to enhance resistance and resilience to climate impacts for the economic systems, including careful consideration for land-use management and planning, limiting development, and careful consideration for the use of alternative fuels.

1. Incorporate Climate Change Considerations into Land-use Management and Planning Decisions

All aspects of land use planning will need to incorporate future climate change considerations, including expansion of the urban growth boundaries, building codes, and zoning. All current uses including agricultural, urban and suburban development, and water supply will need to be reconsidered in light of likely changes in temperatures, snowpack, storm events, flooding, wildfires, and other climate changes. Best Management Practices (BMPs) of the past are no longer likely to be appropriate and new or expanded BMPs will be needed. Of special importance will be efforts to prevent further development in floodplains and forested areas. Also important will be incorporating into planning the need to develop and enhance ecological connectivity and function throughout the Basin.

Energy sources and infrastructure are needed to support a growing human population while reducing greenhouse gas emissions and without compromising climate change preparation strategies. Renewable energy infrastructure such as rooftop solar panels and small-scale onsite biomass heating may be one way to accomplish these multiple goals. Large-scale renewable resources such as wind, biomass generation, and wave energy will also be required and will likely need long distance high voltage lines to supply the Basin's energy needs from remote locations and to reduce carbon emissions at the same time. As alternative energy sources and infrastructure are expanded, it may also be essential for energy efficiency and conservation to be deployed on a large scale.

When decisions are made for urban and suburban planning, policy makers should consider a number of issues including:

- The potential impacts of their actions on the emission of greenhouse gases and on the capacity of natural, built, human, and economic systems to withstand and adapt to climate change;
- How climate change will impact the outcome of any policies or decisions; and
- How decisions or policies may impact other actions being taken to mitigate or prepare for climate change.

Government agencies will need to prepare for unexpected storm, fire, drought, disease outbreak, and other events stemming from a changing climate. In order to prepare for the unexpected, and enhance the capacity to respond, establishing a "rainy day fund" will be important. Also important will be the training of individuals involved in natural resource management and emergency response. Sufficient funds to support trained and knowledgeable individuals would provide the capacity to respond effectively to the unexpected impacts to people and ecosystems that climate change is likely to bring to the Upper Willamette River Basin.

B-Cru

2. Institute Efficiency Strategies in the Manufacturing Sector

Manufacturers in the Basin will need to develop strategies to ensure a stable source of low carbon energy, reduce their dependence on water, and increase resilience to projected disruptions in transportation and feedstocks. In addition, they will need to consider ways to protect their workforce from possible health and stress effects of climate change.

Instituting aggressive energy, water, and materials conservation and efficiency strategies may make firms less susceptible to rising costs for and disruption in the supply of energy and raw materials. The installation of on-site energy production such as solar PV or high-efficiency thermal biomass systems can provide valuable backups in times of blackouts or other disruptions in energy supplies while also acting as a counterforce to rising energy prices. The use of solar hot water systems can substantially cut energy consumption for the heating of hot water. The incorporation of (gently sloped, vegetated ditches that slow the flow of rainwater runoff into the sewer system) and other approaches to minimize surface water runoff from new buildings and developments, and the retrofitting of such mechanisms into existing construction would reduce the intensity of flooding in the Basin. These steps also would promote the growth of "green jobs" in the Upper Willamette River Basin.

Shortening and developing redundant supply chains can help protect manufacturers from disruptions in material and transportation brought about by storms and other climate change related disturbance events. Firms that take proactive steps to ameliorate the likely health threats posed by climate change for their employees are likely to experience decreased absenteeism and increased commitment and productivity.

3. Expand Tourism Season

While there may be seasonal shifts in the tourism industry due to a warming climate and the likely increase in major storm events, flooding, drought, and wildfire, the industry as a whole is likely to continue to do well if it adjusts to changing climate conditions. With likely increases in wildfire and temperatures in the summer, and a decreasing snowpack in the winter, the industry might, for example, consider expanding spring and fall activities to accommodate likely increases in tourism during the milder seasons.

4. Increase Water and Energy Efficiency of Agriculture and Start to Develop New Crop Varieties

Aggressive incentive and regulatory programs should be developed to encourage more energy and water efficient agricultural practices, establish and maintain sufficient riparian buffers, shift to more water efficient crops, and expand no-till agriculture where feasible. Local food production capacity in the Basin should be maintained and expanded to enhance food security. Winter snow banking in groundwater regions should be examined as a possible way to provide additional water resources in the longer periods of dry summer months.

The agriculture sector likely will benefit by maintaining production of existing crops as long as possible, while also initiating research into new crops and markets prior to the time when changing climate conditions force the need to transition to new crops. Introduction of more drought tolerant crops is likely to be key. Of course, knowing when a transition to new crops will be mandatory will be difficult, so research and assessment efforts should begin immediately.

Farmers should consider embracing land and water use policies that protect agricultural land from urban/rural sprawl and encourage efficient water use (e.g., efficient irrigation practices and low water demand crop selection). Policy makers should consider policies that expand sustainable agricultural practices; especially those that reduce pesticide, herbicide, and water use, and that reduce erosion and stream sedimentation (e.g., no-till farming). Congress should remove federal subsidies for large-scale monocultures. Incentives to support the development and maintenance of a local food supply should be considered at all levels of government as climate change reduces food production in the some areas of the nation and world and increases the risk of disruptions in transportation of incoming goods.

The existing water rights system should be reexamined, groundwater resources and well capacity reassessed, and existing permits and licenses reevaluated to avoid over-appropriation. Current policies and allocations are based on historic conditions. However, future conditions are certain to be very different as the Upper Willamette River Basin experiences the effects of climate change. Adjustments to water laws and allocation systems are likely to be needed. It will be essential to establish a rational, integrated allocation of ground and surface water resources that is consistent with climate change predictions for changes in snowpack, soil moisture, and stream flows.

Lane County Farmers Market

5. Adjust Commercial Forestry Practices to Increase the Resilience of Natural Systems

Changes to planting techniques, especially for private timber owners, will be needed to increase seedling survival. Future climatic conditions should be considered when making decisions regarding the types of species to be planted after logging or disturbance. Seed source should also be considered, as managers will be tempted to plant new species that may survive better in new climate conditions. However, these species may also act as invasive species that could threaten the integrity of the entire Basin's plant communities and ecosystems. Federal and state governments may need to adopt seed source policies to ensure that this does not occur.

Agency, university, and timber industry research scientists will need to be engaged in discussions as to whether, when, and how mechanical thinning and/or the use of prescribed burning will be effective means for reducing drought stress and uncharacteristically severe fire in forests. Whether it will be possible to thin forests in an ecologically sound way in order to prevent larger and more intense wildfires is still under debate. Some argue that mechanical thinning and prescribed fire could be used to reduce water use and loss by forests to levels below the available moisture levels, thereby reducing drought stress and the risk of wildfire. On the other hand, many scientists argue that fire is an important component of western forests and that the negative ecological impacts and carbon emissions produced by mechanical thinning often are equal to or greater than the negative effects of wildfire. In fact, wildfires in the western Cascades do not produce as much CO_2 as many believe (per communication Olga Krankina & Bev Law, 2008).

Because fire is a natural and ecologically necessary component of western forests and creates wildlife habitat and forest diversity, many researchers argue that fire patterns do not need to be artificially controlled. Most scientists agree, however, that intensively managed, single-age, commercial monocultures could benefit from a shift to management focused on reducing potential fire intensity and increasing stand resilience to both fire and drought. These issues need to be sorted out through additional research and ecologically sound policy adopted before a large-scale mechanical thinning program is launched.

Research efforts should focus on evaluating how predicted climate-induced changes in vegetative patterns will impact the ongoing transition to smaller diameter milling needed for most thinning operations. Forestry management practices should be adjusted to ensure that they address climate-induced changes and enhance, rather than degrade, the landscape's ability to provide a buffer against greater seasonal, annual, and decadal variability in temperature and precipitation as well as against the increased likelihood of severe storm events and fire.

There is a consensus that mechanical thinning makes sense to reduce the risks to buildings and property in the wild-urban interface by creating "defensible space". Creating a jobs program at the state, local, and national level to establish defensible space around homes and other infrastructure in these areas would protect property and people, and generate jobs. Large-scale thinning would need to be regulated by ecological considerations that include maintaining biological diversity, sensitive and important habitats like riparian areas, mitigating soil damage and the spread of invasive plants, and avoiding new road construction.

Old growth and mature forests should be maintained as reserves to serve as protections for biodiversity, carbon sinks, connectivity corridors, and relatively fire resistant core habitat areas. Areas adjacent to old and mature forests also should be managed in a way to allow for ecosystem services, species and genetic diversity, and connectivity. Surrounding mature forest reserves, for example, with young, dense, plantations, unnecessarily increases the risk of fire and disease in the reserve. To ensure that these essential and rare older forests are maintained for their biodiversity values and public benefit, collaboration among state and federal agencies, conservation interests and commercial forestry is vital.

Current forest conservation and restoration practices that do not consider climate change will need to be updated. For the time being, and until plans can be updated to incorporate climate change conditions, the Northwest Forest Plan should be adhered to in order to maintain multiple forest types at different elevations, as well as functional aquatic and riparian corridors.

6. ***Fully Account for Costs and Benefits Before Implementing Biomass Energy Production Systems***
   Great caution should be given to the development of large-scale forest biomass energy facilities in the Basin. There may be situations where conversion of biomass for energy is a viable option, but it could be the case that the energy costs of removing, transporting, and converting the biomass on a large scale outweigh any benefits. Using native forests for energy production is unlikely to be an economically viable enterprise over the long term, and is also likely to undermine ecological health. Limited resources would be better spent elsewhere, such as on wind or solar power, biomass facilities that use waste products, or energy conservation. In addition, any large-scale biomass energy development should be preceded by a complete life cycle analysis to ensure that the energy costs of biomass extraction do not exceed the energy benefits anticipated from biomass energy generation. It should also include the adoption of ecological guidelines to ensure sustainable biomass harvesting and set standards for protection of soil, wildlife, nutrient cycling and other natural resources. If large-scale forest biomass energy development is deemed economically viable and feasible, clear and strong policies should be adopted to protect the landscape and integrate fuel reduction efforts (to reduce fire risk) with small-scale agriculture and other waste biomass energy production. A more economically and ecologically viable alternative fuels strategy may be the development of small-scale biomass facilities that use agricultural, and residential, and other waste materials as well as woody materials from ecologically sound thinning in the urban-rural interface.

7. ***Integrate Climate Change Preparation and Economic Development***
   Climate preparation and economic development should be integrated so that one enhances the other. For example, emphasis should be placed on creating jobs that reduce the vulnerability of local residents to projected climate impacts. Opportunities to forge a link between greenhouse gas reduction projects and climate preparation also should be taken advantage of in the near future. For example, strategic fuels reductions programs in the urban-rural interface can provide fuel for small-scale biomass energy production and create jobs. Federal tax money could support the start-up of small-scale renewable energy facilities, especially if program policies provide guidelines that facilitate stewardship forestry practices and assist with preparation efforts.

Maintaining and expanding local food production capacity in the valley could build resilience in the event of transportation disruptions and in keeping with local bioregional integrity. Maintaining local food production also contributes to reducing the carbon footprint of the food system by reducing "food miles" (distance from farm to plate) traveled.

Recommended Preparation Strategies for Infrastructure and the Built Environment

The built environment includes a number of divergent elements that will require distinct preparation strategies. The panelists focused explicitly on developing preparation recommendations for the rural-urban interface, transportation, water supply, and energy systems.

1. Limit Further Development in The Urban and Rural Interface

Government agencies should adopt a policy to maintain the rural and urban interface as functioning ecosystems in order to buffer likely effects of climate change such as increased wildfires. Further expansion in the urban-rural interface should be limited in order to protect wildlife areas and reduce losses to human structures from wildfire. Land use laws and zoning ordinances that account for the projected climate impacts should be used to control sprawl and avoid further stress on key floodplain and forest areas. Local and state government agencies rapidly should consider which areas are the least likely to be impacted, and which are most vulnerable, and plan accordingly.

In addition to zoning, local governments should examine their building codes and development standards to determine whether they provide enough protection from increased storm events, rising temperatures, and flooding likely to occur due to changes in climate.

2. Improve Resilience and Resistence in the Built Environment.

Monitoring and data gathering on storm intensity and precipitation, seasonal water availability, energy supply (locally and across the western electrical grid), public health risks, and other issues will be important for informing planners and builders on how to incorporate resistance and resilience strategies. Through monitoring programs, areas that are most prone to vulnerability can be identified and early warning systems developed. Through information collected from monitoring and data gathering, infrastructure can be constructed to resist anticipated threats and increased intensity of extreme weather events(e.g., efficient cooling systems for heat waves or structures resistant to flooding).

Recommended Preparation Strategies for Transportation, Water, and Energy Systems

Panelists recommended a number of strategies to enhance resistance and resilience to climate change for transportation, water, and energy systems. In all cases better planning that incorporates climate projections combined with more efficient use of existing infrastructure will be essential.

1. Expand Public Transit System

Using the Eugene-Springfield EmX as an existing model, panelists suggested planning for transit oriented development linking density planning with public transportation planning. They suggested closer cooperation between city and county governments to plan new EmX corridors including supporting a 2009 state legislative proposal on a "buildable lands" study. Expansion of these corridors would facilitate more efficient density planning and also reduce greenhouse gas emissions from private automobile use. There was agreement that public transportation financing should focus on increased mass transit like the EmX bus line between Eugene and Springfield and less on building more highway arterials.

2. Recycle Waste Water for Re-Use by Homes, Agriculture, and Industry

Panelists made recommendations for decentralized waste water treatment and reuse for the purpose of maintaining in-stream flows for fisheries, hydroelectric production, irrigation, and domestic water use. Biosolids (sludge, a byproduct of domestic and commercial sewage and wastewater treatment) may be used for soil nutrients for agriculture, landscaping and golf courses, and constitute a revenue source for the producer. Bioswales and other green building techniques should be required in building and planning codes for new construction. Affordable housing opportunities that incorporate these water efficiency improvements should be identified given the anticipated increase of climate refugees to the Basin.

3. Plan for Future Energy Demands

Demographic changes such as the rising number of people moving to the Upper Willamette River Basin, as well as economic changes, such as possible growth of plug-in-electric (PEV's) vehicles that leads to increased electricity needs, would place even greater stress on local energy systems. Power to charge PEV's would need to be drawn off-peak during nighttime hours to avoid possible energy shortages given current supplies.

Recommended Preparation Strategies for Public Health and Emergency Services

Panelists recommended a number of resistance and resilience strategies to prepare human systems for the impacts of climate change. Resistance strategies would reduce the exposure of human populations to disasters (e.g., reducing the number of wild-urban interface area homes and/or increasing the establishment of defensible space around interface homes). Resilience strategies would build the capacity of emergency services to respond to increased needs (e.g., expanding the capacity to fight fire around interface area homes and/or to provide emergency shelter and food to families displaced from their interface area homes during wildfire).

1. Reduce Community Susceptibility

Land use planning should focus on reducing community susceptibility to climate risks by prohibiting new development in floodplains and high-risk fire locations of the urban-rural interface. Reconstruction of facilities that support human habitation in burned or flooded areas should be restricted, for example by making the receipt of government disaster relief Flood and fire insurance should be contingent upon relocation to less susceptible areas following loss. To facilitate these population shifts, local, state, and national policies should restrict development in high-risk areas and be supported with appropriate funding. Policies that more fully incorporate the consequences of climate change into energy pricing also could be used as an incentive to reduce rural sprawl.

Breeding grounds for mosquitos and other disease vectors can be eliminated or natural predators can be introduced to eradicate them to forestall public health threats.

2. Update Emergency Management Plans

Emergency service resources and responsibilities may need to be redirected. As the likelihood of flood and wildfire increases, the demand for emergency services may grow and stretch beyond capacity unless significant shifts are made in human habitation patterns. While local fire agencies currently provide rural fire protection, it is conceivable they will not be able to maintain the financial and personnel resources to support these services in the face of climate change impacts. Updated emergency management plans may be necessary. Updating of plans must be accompanied by significant outreach to educate existing and new rural residents about their responsibilities and the limits of governmental obligations. Existing outreach programs directed at educating the public on the details of how to establish a defensible space to reduce the risk of loss during wildland fire provide a good illustration of the kinds of education tools available. However, these outreach efforts need to be broadened and expanded.

Forest and floodplain management policies should be reexamined to ensure that the focus is placed on reducing susceptibility to the likely increase in flooding and wildfires brought about by climate change. Existing patterns of human habitation in the urban-wildland interface and in floodplains are well established, and will take time to change even with aggressive policies. New policies and incentives aimed at consolidating human populations onto less risky portions of the landscape (i.e., areas not prone to flooding or wildfire) should become a priority.

3. Protect Water Quality

Water quality protections should be strengthened and expanded. As climate change extends the period of low "summer" base flows, it increasingly will become important to prevent the contamination of shallow wells and to protect surface water quality. Contamination from nonpoint sources (including urban and agricultural runoff) will have greater detrimental impacts as storm event and hydrologic runoff patterns change and less water is available to dilute pollution in the streams.

4. Anticipate and Plan For Increased Heat-Related Illnesses and Stress

Strategies to anticipate new climate change induced health service needs, especially for vulnerable populations, should be considered. As summer temperatures rise, the incidence of heat related illness is also likely to increase. The need for cooling centers for extremely hot days should be planned for, and the logistical challenges of making centers available to those in need anticipated (e.g., developing a system for transporting the elderly to the centers). Outreach and education on the use of air conditioning and what to do in the case of extreme temperatures should occur for elderly populations. In addition, asthma and other respiratory related diseases are likely to rise with increased heat, allergens, and pollutants, and plans should be made to respond to these needs, such as providing warnings to susceptible individuals when they should not go outside and supporting access to low-cost medications. Warmer temperatures are also likely to increase the risk of food contamination during transportation and storage and measures to assure reliable refrigeration will be required.

5.Improve and Expand Vector Control Programs

Most vector-control programs in the Basin currently focus on the impacts on agriculture, not human health. The existing programs should be evaluated to ensure that they can adequately address the rising risks of climate-related increases in vector-borne diseases. The secondary impacts of vector-control programs on wildlife, including waterbirds, will also need to be weighed when developing and implementing new programs. Early warning systems for vector- and water-borne disease should be developed to alert communities when an outbreak occurs in the Basin.

6. Educate the Public on the Health Risks Associated with Climate Change

Public education about the causes, trajectory and potential health risks associated with climate change will be essential, as will education about the variety of actions available to reduce emissions and prepare for climate change. The more informed people are the more likely they are to be motivated to make wise choices and support climate change preparation measures. Detailed scenarios of local climate change projections should be presented to individuals and communities in order to facilitate the climate change preparation process. Information also should be provided on a regular basis about the speed and trajectory of changes caused by climate-induced stresses.

7. ***Educate Public Health Professionals***
Public health professionals are primarily focused on current health threats, and do not currently have the capacity, funding or necessary resources to implement a preparation strategy. However, the public health sector in the Basin does have programs that can be built and expanded on to manage climate change health risks. Public health professionals should be trained on Basin specific health threats, how to communicate effectively with their clients and mangers to bring climate change and health on the radar, and trained in methods for developing a preparation strategy for their department. By involving the public health sector in climate change preparation planning they can more effectively initiate intensive outreach and education campaigns during times when people are most at risk (high incidences of WNV, summer months, etc). Public health workers should also be trained on the best means for communicating risks and preparation strategies to individuals and communities as to not provoke fear.

Recommended Preparation Strategies for All Systems

Panelists from the natural systems and built, human and economic workshops provided recommendations that could be integrated across all systems. These recommendations call upon researchers, individuals, policy-makers and planners to shift their thinking, decision-making processes, and short- and long-term planning strategies.

1. ***Improve Data Gathering and Monitoring Systems***
The responses of people, infrastructure, economies, and natural systems to climate change will be inherently chaotic and uncertain. Many changes will occur more rapidly than anticipated and surprise events are likely. Improved monitoring of the types, extent, and effects of those changes will be vital to the development and implementation of agile, responsive preparation plans and policies.

A greater understanding of the relationship between climate projections and fire impacts through use of a finer resolution analysis of the interaction of fire, vegetation, and wildlife responses in forests should be developed. In addition, there is also need for a finer resolution analysis of the intensity and frequency of high stream flow events and the impact of such events on ecosystem integrity, stream function, and survival of the various life history stages of our native fishes. A clearer understanding and awareness of the response of mobile, invasive, native and non-native species to climate change may also support prevention and management strategies. Climate induced changes in fire and flood behavior and invasive species responses clearly also are of critical importance to preparation planning for human communities.

Improved monitoring on storm intensity and precipitation, seasonal water availability, energy supply (locally and across the western electrical grid), public health risks, and other issues will be important to building increasingly effective resistance and resilience strategies.

2. ***Encourage Action by Individuals and Households***
Individuals and households cannot depend on government or private businesses alone to protect them from all threats from climate change impacts. Property owners are best suited to take measures to protect structures from wildfire by creating defensible space if residing in the urban-wildland interface, or from flooding by planting or leaving vegetative buffers if their home is located near a streambank. Through frequent clearing and planting only native species, property owners can prevent encroachment from exotic invasive species which may thrive in an environment with warmer temperatures and higher levels of carbon dioxide.

Individuals could also become better informed and active participants in volunteer emergency service procedures and organizations in their communities. By doing so, they can assist more vulnerable populations in the event of extreme weather events or fires. Individuals can also engage in, or financially contribute, to conservancy efforts to restore natural habit or create refuges for species endangered by climate impacts.

Individuals can also support preparation planning by changing their lifestyle choices, such as purchasing or building homes in low-risk areas and that do not harm critical habitats, taking public transportation, and encouraging elected officials to adopt climate change preparation strategies.

3. ***Use Both Short Term Actions and Long Term Planning***
Many climate change preparation strategies entail measures that can be implemented immediately and in fact have been used to buffer natural and human systems from development pressures as well as past extreme weather events. These include measures such as restoring flood plains to natural conditions so they can absorb excessive stream flows, removing fuels adjacent to structures (e.g., dry brush near homes in fire-prone areas), and maintaining corridors for species migration in fragmented landscapes. These and many other immediate preparation strategies have been practiced by individual property owners and land managers for decades and can easily be implemented and expanded to cope with climate impacts in the short term. Efforts should not depend solely on long term objectives, such as shifting paradigms in planning and governance, as this may impede implementing measures currently known to be effective in dealing with threats to natural and human systems.

As the impacts of climate change already are being felt in portions of the Basin, it is essential that immediate action takes place before the systems are further degraded.

While short term action is essential, the Basin may also need to develop long term preparation planning and adaptation strategies. Some actions, such as creating new land use planning boundaries based on watersheds and developing monitoring systems to better assess climate impacts and vulnerabilities, may take some time due to the need to overcome political inertia, conduct further research, or collect additional information. These long term strategies will need to be well thought-out, involve wide-spread participation, and be incorporated into all future decision-making in the Basin.

4. Develop Integrated and Co-Beneficial Strategies
Integrated, co-beneficial climate preparation strategies, plans and policies should become a priority for all levels of government, private, nonprofit and faith-based organizations, academic institutions, and households in the Basin. This means that efforts to prepare one system or sector for climate change should enhance and not undermine preparation efforts in other areas. Integrated preparation plans and policies should be coordinated with, and provide co-benefits for, other preparation efforts as well as mitigation efforts (i.e. efforts to reduce greenhouse gas emissions and increase carbon sequestration). Well-intentioned efforts to build resistance to likely future irrigation water shortages, for example by building dams or stream diversions, very easily can undermine efforts to allow native fish populations to shift their ranges to cooler parts of a river system in response to climate change.

A concerted effort should be made to ensure that current management plans and policies, including federal forest plans and city development plans, as well as future climate preparation strategies are well coordinated, ecologically sound, and provide co-benefits across all four systems and regions within the Upper Willamette River Basin. Decisions to allow further development in floodplains due to population pressures, for example, without considering the potential for changes in precipitation patterns, could lead to increases in flood damage, expense, and human suffering.

Summary

Government agencies, businesses, and households in the Upper Willamette River Basin should all anticipate climate change impacts in their planning and investment decisions. Climate stressors call for proactive engagement in crafting innovative and creative strategies to increase the capacity of systems to withstand damage from climate impacts and strategies to develop the capacity to recover from these impacts.

All levels of society – individuals, households, the health sector, government, private companies, faith organizations, and the nonprofit sector- will need to prepare for climate change. Short term solutions for mitigating further impacts of climate change and adapting to changes that occur should be developed in coordination with long term planning for different climatic conditions.

In order for effective development and implementation of climate change preparation strategies, panelists made the cross-cutting recommendation of developing new and expanded forms of governance. Strategies for doing so are discussed in the next section.

Recommendations for New and Expanded Systems of Governance

A consistent theme that emerged from the expert panels was the need for new information, expanded funding and resource allocation, and decision-making mechanisms that are better suited for future climate conditions. These are the core factors of governance. Boards, commissions, and legislative bodies are merely the 'containers' in which governance occurs. It is the type and ways in which information is gathered and distributed, resources are allocated, and decisions are made that actually determine how governance systems function and what issues are given priority. This section outlines and reiterates the recommendations made by the expert panels for new and expanded systems of governance.

1. Incorporate Climate Preparation into all Public and Private Plans and Policies

One of the primary reasons new forms of governance are needed in the Upper Willamette River Basin is that ongoing and future planning and decision-making must take climate change into account. New types of information will need to be gathered (e.g., effects of climate on organisms and on transportation infrastructure), new resources allocated to different types of programs and policies (e.g., to those that build resistance and resilience in each sector), and stakeholder involvement expanded (e.g., landowners downstream of proposed dams or stream barriers) and interests (e.g., future generations) included or considered in policy development. As part of this effort, governments should consider inventorying their current policy and funding priorities to determine if they incorporate, enhance, or undermine climate change preparation efforts. They should reprioritize policies and budgets as needed.

For example, local governments should ensure that disaster relief funds be used to relocate people from fire and flood disaster prone areas. Every public agency, private company, nonprofit organization, and individual household should complete energy audits and greenhouse gas inventories and implement appropriate energy conservation and efficiency measures. Mass transit and runoff retention should be incorporated into new developments and public transportation projects. Incentives to expand use of telecommuting should be implemented by businesses and governmental agencies.

2. Manage for the "Future Range of Variability"

Climate projections in the Upper Willamette River Basin indicate that the ecological, social and economic conditions of the past no longer are reliable indicators of future conditions, and that a future-oriented perspective needs to be adopted. Planning for likely future changing climatic conditions will require different types of information, changes in monitoring protocols, new funding and personnel allocation, and new decision-making mechanisms. Managing for Future Range of Variability also will require flexibility in setting goals and priorities because conditions are likely to change continuously, and new conditions are highly uncertain. The whole systems approach mentioned previously will need to be based on careful assessments of how shifts in one aspect of the natural or human environment are likely to affect other aspects. This approach is likely to enhance the capacity of every system to withstand and adapt to changing climate conditions.

3. Use Scenario Planning

One of the most helpful tools when planning for an uncertain future is "scenario planning." Although model downscaling provides a reasonable projection of the range of conditions likely in a climate changed future, it is not possible to know exactly how climate change will play out in the Upper Willamette River Basin. Decision makers will benefit by developing a suite of possible future scenarios, analyzing potential vulnerabilities, identifying the gaps that exist in the capacity of existing programs and policies to respond to those vulnerabilities, and developing strategies and policies to increase resistance and resilience of local systems under most or all of those future conditions. Fig. 12 outlines the steps in a scenario planning process.

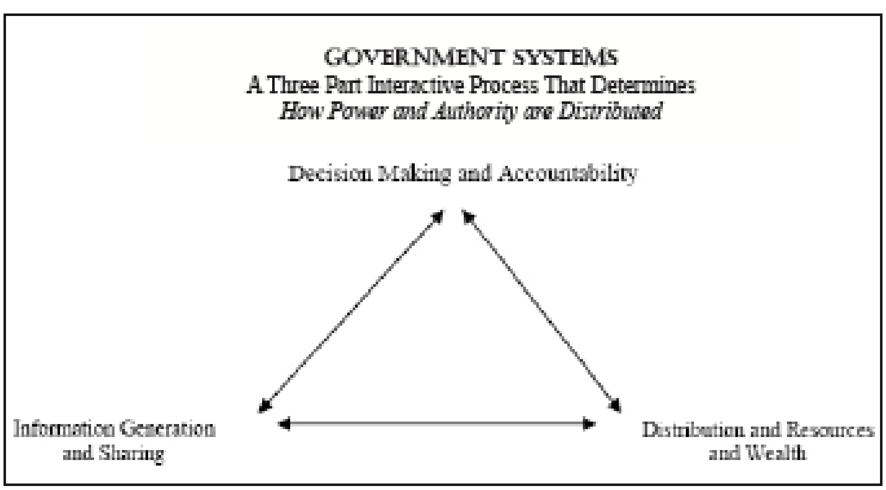


Figure 11. From Doppelt 2003

Scenario building, such as that described in this report, is a common practice used within the business community, but it lends itself quite well to conducting climate change planning exercises. The Nike Corporation provides a good example of integrating climate change preparation with business planning using a scenario approach. Resources on adaptation and preparation can be obtained from the web and in many books

4. Expand Goal-Setting and Decision-Making to the Landscape Level

Changing climate conditions mean that individual projects that on first glance appear to have little consequence beyond the specific location in which they take place may, in fact, have significant cumulative effects on natural, built, human, and economic systems elsewhere in the Upper Willamette River Basin. This new reality means it is even more important in the future than it has been in the past that management goals, policies, and projects no longer be planned or implemented in isolation. Their effects on the entire landscape should be considered. This is especially the case in the Upper Willamette Basin where patchwork landownership leads to conflicting management practices tightly interspersed across the landscape. Even federal agencies, such as the USFS and BLM have conflicting management goals, although the Northwest Forest Plan has lead to greater collaboration and landscape-level planning. Landscape level climate and ecological management means that federal land management plans should be updated to account for likely climate futures. Existing watershed plans and landscape level analyses also should be updated to include likely future climate conditions.

The scientific panel also acknowledged that the traditional segregation between the management of public and private lands, and between forested, agricultural, and urban areas, should shift to a more integrated approach. A more integrated approach will help identify potential barriers to the implementation of preparation activities. Landscape level planning and management will likely foster the identification of opportunities for leveraging efforts through involvement with multiple partnerships.

5. Seek Co-Beneficial Preparation Strategies

Many climate preparation actions focused on one resource or region in the U Basin can offer co-benefits for others. For example, groundwater storage in upper stream reaches of the Basin will provide enhanced water supply and increased water quality for both fish and municipal drinking water. By always seeking co-beneficial strategies a self-reinforcing system will be established that continually enhances natural, built, economic and human systems. Appendix D offers examples of how climate preparation activities in one sector can provide benefits in other sectors.

6. Expand Participation on Planning and Decision-Making Teams

Because climate change expands the realm of the issues and people that may be affected by projects and policies, planning teams often will benefit from expanded stakeholder participation. For example, aquatic scientists should be included in planning and decision-making regarding forest thinning projects because may have significant implications for aquatic species and systems, particularly through road construction, and road and culvert maintenance. Similarly, infrastructure projects implemented upstream in the Upper Willamette River Basin may have significant implications for natural systems, public safety, or public health downstream. Unintended negative consequences often can be avoided by expanding the types of expertise of people involved in planning and decision-making.

All counties in Oregon have natural hazard plans for preventing loss of life and reducing injuries and property damage during extreme weather events. The plans are developed collaboratively, in conjunction with various partners throughout the county, fire departments, transportation and development departments, soil and water conservation districts, national forest departments, and planning departments. The Partners for Disaster Resistance and Resilience: Oregon Showcase State Initiative is a coordinating body that leverages human and financial resources for risk reduction throughout Oregon. Many other types of collaboration similar to this one are possible.

Watershed councils that include multiple stakeholders are an example of new governance mechanisms that could be built upon and vested with authority to coordinate and integrate ecological climate futures planning at the landscape level.

Steps in a Vulnerability/Opportunity Assessment

1. **Develop/utilize climate change impact scenarios**
2. **Assess existing systems against climate impact scenarios and identify risks and opportunities**
3. **Estimate the gaps between existing capacity and what will be need to build resistance and resiliency under different climate scenarios**
4. **Identify and assess strategies for closing gaps and taking advantage of opportunities**
5. **Choose a strategy and implement a plan**
6. **Monitor and evaluate**
7. **Continually improve and adapt your plan**

Figure 12. Adapted from *Curbing and Preparing for Climate Change: Handbook for Rural Governments in the Pacific Northwest*, UO Climate Leadership Initiative, 2007.

Conclusions

No matter how fast human-produced greenhouse gas emissions are reduced during the coming years, changing climate conditions will continue to transform the natural systems of the Upper Willamette River Basin for several decades. These shifts will in turn stimulate considerable change in how the local economy functions, the capacity of the built environment to support local communities, human health, and the overall quality of life of the people who live in and enjoy the Upper Willamette River Basin. Numerous planning and policy initiatives currently exist in the Basin that can help increase climate resistance and resilience Examples of these initiatives include: wetland recovery projects initiated by the City of Eugene and Lane County; riparian vegetation rules adopted by the Lane County to buffer structures from flood damage, prevent erosion, and provide habitat for aquatic species; and fire ordinances in the Eugene and Lane County codes that require homeowners to remove brush that may cause wildfire to spread to structures.

The people and institutions of the region have the capacity to make the adjustments needed to effectively prepare for climate change. Proactive steps to upgrade and expand preparation efforts for natural, built, human, and economic systems for the likely future consequences of climate change can help the people, communities, and the natural systems they depend on within the Basin a thrive in the future.

This report should serve as a beginning, not an ending point, for the development of climate preparation programs and policies in the Upper Willamette River Basin. It is our hope that the City of Eugene, City of Springfield, Lane County, Lane Council of Governments, local utilities, watershed councils, state and federal agencies, as well as private companies, nonprofit organizations and individual households will use the information as a platform for developing additional and more extensive plans and strategies. While this report provides numerous recommendations, specific details and actions will need to be identified by a diverse and inclusive group of stakeholders. Only with extensive community involvement will climate change preparation plans be successfully developed and implemented.

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Appendix C. Graphs and Figures

NOTE: Due to document size limitations, the graphs and figures are available in a separate document.

Appendix D. Co-benefits from select recommendations

Recommended Strategy/ Policy	Natural Systems (NS)	Human Systems (HS)	Built Systems (BS)	Economic Systems (ES)
NS 1 Expand monitoring and evaluation programs		May act as early warning system for flooding and disease outbreak (+)	May identify areas where buildings should be limited or removed (-)	Costly (-)
NS 2 Manage runoff		Improves municipal water quality (+)	Reduces water treatment costs (+)	
NS 3 Protect groundwater				Enhances water storage and supply for all purposes (+)
NS 4 Reduce current stressors to natural systems		Steady supplies of clean water for humans (+) Clean air, plant pollination, flood control (+)		Limits development in forests and flood plains (-)
NS 5 Maintain forest health through strategic use of fire		Potential health hazard (-)	Limits development on forest land (-)	Enhances forest productivity (+)
NS 6 Protect remaining intact ecosystems				Limits development in forests and flood plains (-)
NS 7 Maintain habitat connectivity				Limits development in forests and flood plains (-) Enhances recreation and tourism (+)
NS 8 Protect species and habitats that are essential for ecosystem services		Steady supplies of clean water for humans (+) Clean air, plant pollination, flood control (+)	Flood control (+)	Limits development in forests and flood plains (-) Flood control (+)
NS 9 Minimize risks from invasive species		Early detection and rapid response may prevent risks that some invasives pose to human health (+)		Early detection and rapid response may protect agriculture and timber supplies (+) May reduce some recreational opportunities by preventing the stocking of exotic species in lakes (-)
NS 10 Change land use planning policy			Limits development in forests and flood plains (-)	

Recommended Strategy/Policy	Natural Systems (NS)	Human Systems (HS)	Built Systems (BS)	Economic Systems (ES)
HS1 Concentrate human populations onto less risky portions of the landscape	Protects riparian areas (+)		Reduced damage to residential and commercial buildings (+) Limits development in forests and flood plains (-)	Good for future economy (+)
HS 2 Redirect emergency services resources and responsibilities				More efficiency use of resources and good for future economy (+)
HS 3 Develop early warning communication networks for extreme weather events				Prevents expeditures for hospital visits (+)
HS 4 Develop subsidy programs to provide air conditioning and fans to low income families				Prevents expeditures for hospital visits (+)
HS 5 Intensify and adapt vector control for diseases				Enhances viability and resilience of work force and economy (+)
HS 6 Strengthen and expand water quality protections	Protects and enhances integrity of species and ecosystems (+)			Enhances recreation and tourism (+)
HS 7 Develop strategies to anticipate new, climate change induced health service needs and provide them to vulnerable populations				Enhances viability and resilience of work force and economy (+)
BS 1 Revisit transportation strategies, for instance expand road culverts, reduce forest roads, and enhance storm run-off protection	Protects rivers from sedimentation and forests from mudslides (+)	Protects municipal water quality (+)		Reduces insurance costs (+)
BS 2 Protect energy systems and water supply	Reduces greenhouse gas impacts (+)	Improves air quality (+)		Reduces business costs and reduces wealth export (+)
BS 3 Develop zoning and building codes that consider implications of climate change and reduce their emissions.	Reduced impact on natural systems (+)			Good for future economy (+) May be unaffordable to some Businesses.
ES 1. Maintain production of existing forestry and agricultural products as long as possible, while also initiating research into new crops	May harm forest ecosystems (-)			
ES 2 Embrace land and water use policies that protect agricultural land from urban/rural sprawl and encourage efficient water use		Protects municipal water quality and agricultural land (+)		
ES 3 Develop and adopt policies that focus on locally grown food production.	Reduces impact on water and land ecosystems (+) Less emissions from transportation (+)	Less vulnerability to food-borne diseases from imported foods (+)		
ES 4 Development planning should consider changing demographics and the likelihood of "climate refugees" coming to the Basin	May reduce some building in vulnerable areas (e.g. floodplains) (+)	May reduce risk of communicable diseases (+) May limit living options for individuals or impose population controls/urban growth boundaries for some areas (-)	Will affect how and where buildings are constructed (+/-)	

Recommended Strategy/ Policy	Natural Systems (NS)	Human Systems (HS)	Built Systems (BS)	Economic Systems (ES)
ES 5 Develop a rainy day fund to respond to unexpected events	Better able to respond to disease outbreaks in aquatic or terrestrial systems (+)	Better able to respond to disease outbreaks or health risks associated with extreme weather events (+)	Better able to responde to infrasturture destricution from extreme weather evetns (+)	
ES 6 Reexamine existing water rights system, groundwater resources and well capacity, and reevaluate existing permits and licenses to eliminate over-appropriation.	Enhances ecosystem function and integrity (+)			
ES 9 Expand research and production of small-scale biomass and cellulosic ethanol	May harm ecosystems and species (-) Reduced emissions generation (+)	Reduced emissions generation, which can affect individuals with respiratory illness (+)		
ES 10 Develop strategies to protect manufacturing energy supplies, reduce dependence on water, increase resiliency to projected disruptions in transportation, and consider ways to protect workforce from possible health and stress effects	May harm ecosystems and species (-)			
ES 13 Consider expanding spring, winter and fall activities to accommodate for likely increases in tourism during the milder seasons as climate change unfolds	May stress wildlife during mating and rearing seasons (-)			

Appendix E. Resources

Websites:
www.epa.gov/climatechange/effects/adaptation.html (provides list of references at end)

www.climateadaptation.net

www.undp.org/gef/adaptation.index.htm

www.climatechange.ca.gov/adaptation/index.html

http://www.heinzctr.org/Press_Releases/adaptation_survey.shtml

http://www.pewclimate.org/docUploads/Adaptation_0.pdf

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Easterling, W., Hurd, B., and Smith, J. 2004. Coping with Global Climate Change: The Role of Adaptation in the United States. Pew Center on Global Climate Change.

IPCC. 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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Climate Change and Adaptation by Neil Leary, James Adejuwon, Vicente Barros, and Jyoti Kulkarni (Paperback - Dec 2008)

The Earthscan Reader on Adaptation to Climate Change (Earthscan Readers Series) by Lisa Schipper and Ian Burton (Paperback - Feb 2009)

Climate Change and Adaptation Strategies for Human Health by Bettina Menne and Kristie L. Ebi (Paperback - Jan 9, 2006)

Understanding Climate Change Adaptation: Lessons from Community-based Approaches by Jon Ensor and Rachel Berger (Paperback - May 31, 2009)

Fairness in Adaptation to Climate Change by W. Neil Adger, Jouni Paavola, Saleemul Huq, and M. J. Mace (Paperback - May 12, 2006