The Oregon Climate Change Adaptation Framework

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Preface

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Climate variability and change already affect Oregon, including Oregon's marine environments, forestlands, agriculture, and transportation infrastructure. Over the next few decades, indicators show that Oregon's natural resources, infrastructure, and people will likely face more severe impacts from climate change.

Oregon's climate is marked by variability, and that variability alone has caused or contributed to significant ecosystem and economic damage to infrastructure through floods, landslides and forest fires. In addition to the effects of normal variability in Oregon's climate, significant changes in temperature, precipitation patterns, and other climate factors like ocean conditions are expected to increasingly affect Oregon's communities, natural resources, and economy. As with the effects of climate variability, long-term changes in climate conditions have the potential to result in very costly conditions and outcomes. Natural hazards, water supply problems, drought, habitat changes and loss of ecosystem services will all affect Oregon's citizens, communities, and economy. Fortunately, many of the potential costs and consequences of climate change may be anticipated and planned for. As such, it is both prudent and important to develop measures to reduce the costs of climate variability and change on Oregon.

In October 2009, Governor Kulongoski asked the directors of several state agencies, universities, research institutions and extension services to develop a climate change adaptation plan. Among other things, the plan would provide a framework for state agencies to identify authorities, actions, research, and resources needed to increase Oregon's capacity to address the likely effects of a changing climate.

Given the broad range of expected changes to Oregon's climate in the coming decades, the breadth of state-level responsibilities, authorities, and programs that will likely need to respond to the effects of future climate conditions, and limited time, it has only been possible to begin the development of a climate change adaptation strategy for Oregon. This report constitutes a *framework* for the continued development of strategies and plans to address future climate conditions. This Climate Change Adaptation Framework provides context, identifies risks, lays out short-term priorities, and provides momentum and direction for Oregon to prepare for future climate change.

The framework has been developed in parallel with the Oregon Climate Assessment Report (OCAR) by the Oregon Climate Change Research Institute (OCCRI). The OCAR and this framework are intended to complement each other. The OCAR identifies the most likely impacts from climate change, which will help the state prioritize resources to prepare for and adapt to a changing and variable climate. The OCCRI assisted in the development of this Framework.

This Framework lays out expected climate-related risks, the basic adaptive capacity to deal with those risks, short-term priority actions, and several steps that will evolve into a long-term process to improve Oregon's capacity to adapt to variable and changing climate conditions. It will be necessary to continue to develop adaptation strategies and plans, in particular at the regional and local level. Finally, more effort needs to be made to identify resource management and economic opportunities that climate change might present for Oregon. This Framework positions Oregon to take effective early steps to avoid some of the most costly potential consequences of climate change.

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The Oregon Climate Change Adaptation Framework

Summary of Key Findings and Recommendations

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There is abundant evidence that Oregon is already experiencing the effects of climate change. The Oregon Climate Assessment Report documents these effects and describes the more pronounced changes that are expected to occur in the coming decades. Climate change will affect all Oregonians, all Oregon communities, our natural resources, and our businesses.

At the same time that climate change is beginning to affect us, state, local and private resources to begin to prepare for these changes are under historic stress. This interim report by the state recognizes these fiscal realities, and (as a result) focuses on providing decision-makers with information about what things are most important to do (or avoid doing) in an era of very limited resources. Only actions that involve little or no cost are proposed at this time, even though we also recognize that investments now may yield very substantial long-term benefits

This introduction to the Oregon Climate Change Adaptation Framework summarizes the key findings and recommendations of the participants in this initial effort to review the emerging science on climate change and evaluate what our priorities should be at a state-wide level in terms of preparing people, communities and resources for the coming changes. Among the key recommendations is that we broaden this work to include private sector interests along with our federal, tribal, and local counterparts. A major determinant of what new actions to recommend is our initial assessment of costs and benefits.

History and Purpose

In early 2008 the Governor's Climate Change Integration Group (CCIG), made up of state, federal, and local government representatives, industry leaders, and nonprofit organizations, produced Oregon's *Framework for Addressing Rapid Climate Change*. The CCIG's framework presented the broad scope of needed work related to climate change in four elements: preparation and adaptation; mitigation; education and outreach; and research. At the time, Oregon had already made some progress in mitigation, and had begun to invest in research. Since then, there has been some further progress in mitigation and research, and some initial efforts related to preparation and adaptation.

In October 2009, Governor Kulongoski asked state agencies and partners in Oregon's University System to develop an initial framework for determining what the most important risks are to the state related to climate change, and initial recommendations for how to begin preparing for those risks. This Framework is the result of that initiative. The Climate Change Adaptation Framework is the first step in a long-term process to identify key risks and measures to reduce Oregon's vulnerability to the effects of climate variability and change. This framework presents a broad-scale qualitative assessment of risks to people, infrastructure, communities and natural resources that are expected to result from the effects of variable and changing climate conditions. More importantly, this framework identifies several concrete actions the state should consider taking to begin to prepare for and adapt to the effects of climate variability and change.

The purposes of this framework are to

- Identify likely future climate conditions that pose major risks for Oregonians.
- Assess the capacity of state programs to effectively address climate-related risks to people, communities, infrastructure, and natural resources.
- Identify short-term and low- or no-cost priority actions to prepare for those risks.
- Provide context and initial direction for additional coordination and planning for future climate conditions.

In developing this framework, Oregon has begun to address several of the CCIG's recommendations, including the following:

- Determine how climate change will affect Oregon's diverse regions.
- Assist Oregon institutions and individuals in responding to climate change.
- Transform our planning processes to deal with climate change.
- Incorporate the public health implications of climate change.
- Continue to develop and refine a climate change research agenda for Oregon.

This framework is only an initial step; it by no mean completes the work needed to fully implement these recommendations. Considerable work will be needed, especially in collaboration with Oregonians, local governments, Native American tribal governments, and federal agencies, to fully address climate risks to Oregon.

Scoping Climate Risks

In late 2009, an interagency work group was convened to develop this framework. The work group's first two tasks were to identify likely changes in Oregon's climate conditions and the likely consequences of those changes over the next 40 to 50 years. The work group identified several dozen likely changes in four areas: built and developed systems, ecosystems, public health and safety, and Oregon's economy. In consultation with the Oregon Climate Change Research Institute (OCCRI) and state agencies, the work group ultimately combined the likely changes in Oregon into eleven categories that are likely to occur over the next four to five decades. In this framework, these likely changes are defined as *climate risks.*

As the work group refined the inventory of risks, characterizing the risks to economic systems became more and more difficult. More to the point, very little information is available on the likely *economic* effects of climate change in Oregon. Risks to Oregon's economy that were identified by the work group were really risks to other systems restated in very general economic terms. In other words, climate-related risks to Oregon's economy reflected the economic consequences of risks to natural systems, built and developed systems, and public health and safety. In the end, while this framework attempted to include the economic effects of future climate conditions within its scope, there is little information available to do so with confidence at this point in time. Further collaboration with economists and organizations outside government is necessary to improve the assessment of the possible or likely economic consequences of climate change on Oregonians and the state at a whole.

The eleven climate risks listed below and in the table later in this Summary of Key Findings and Recommendations constitute the substantive foundation for the adaptation framework. Climate risks have varying degrees of likelihood; that is, not all the identified climate risks are equally likely to occur in Oregon. The risks are listed according to likelihood levels; the three levels of *Very likely*, *Likely*, and *More likely than not* correspond roughly to 90 percent, 66 percent, and 60 percent confidence levels, respectively. In planning for future climate conditions, it will be important to recognize variability and uncertainty in climate risks.

Potential Consequences of Climate Risks

The work group compiled a survey of likely consequences for each climate risk. Some of the consequences are summarized below. The summaries are by no means exhaustive, but rather are intended to help identify state responsibilities and programs that will likely need to prepare for and adapt to the effects of climate change.

Risks that are *Very likely* to occur

Risk 1. Increase in average annual air temperatures and likelihood of extreme heat events.

Overall, increased average air temperatures will result in increased water temperatures and reduced flows in streams, which over the long term will cause shifts in aquatic habitats, species, and communities. There is serious risk that increased average air temperatures will affect water temperatures and aquatic habitats to the extent that important core populations of salmonids will go extinct.

Heat waves will result in increased deaths and illness among vulnerable human populations. The elderly, infants, chronically ill, low income communities, and outdoor workers are the main groups threatened by heat waves. Higher temperatures increase the threat of human illness from both waterborne diseases and vector borne illnesses. In addition, heat waves, drought and changes in hydrology will contribute to an increase in the threat of wildfire, which will result in increased exposure of vulnerable populations to smoke. (See risk 8).

Risk 2. Changes in hydrology and water supply; reduced snowpack and water availability in some basins; changes in water quality and timing of water availability

Changes in hydrologic patterns in some Oregon basins will affect supplies of water for all uses, and will contribute to increased water quality problems. Reduced availability of water will affect junior irrigators, change water supply planning in many basins, and affect the quality and availability of water for some public drinking water systems. Proposals for surface water storage may increase.

Changes in the timing and quality of available water will affect aquatic, wetland, and riparian ecosystems and species, especially species that need adequate water in stream to survive and populations that are already identified as threatened or endangered. Hydrologic changes will exacerbate temperature-related water quality problems.

Water users suffering the most adverse consequences will be irrigators. Irrigated agriculture is a primary economic driver in Oregon, so without careful planning for the consequences of climate change, the Oregon economy may suffer significantly. Changes in hydrology have the potential to significantly affect agricultural productivity until crops suited to new hydrologic conditions are developed.

Risks that are *Likely* to occur

Risk 3. Increase in wildfire frequency and intensity

Increased temperatures, the potential for reduced precipitation in summer months, and accumulation of fuels in forests due to insect and disease damage (particularly in eastside forests) present high risk for catastrophic fires. An increase in frequency and intensity of wildfire will damage larger areas, and likely cause greater ecosystem and habitat damage. Larger and more frequent wildfires will increase human health risks due to exposure to smoke.

Increased risk of wildfire will result in increased potential for economic damage at the urban-wildland interface. Wildfires destroy property, infrastructure, commercial timber, recreational opportunities, and ecosystem services. Some buildings and infrastructure subject to increased fire risk may not be adequately insured against losses due to fire. Increased fire danger will increase the cost to prevent, prepare for, and respond to wildfires.

Risk 4. Increase in ocean temperatures, with potential for changes in ocean chemistry and increased ocean acidification

Ocean acidification will have a negative effect on some marine species and could result in dramatic changes in marine and estuarine ecosystems. Changes in temperature and upwelling may be positive for some species and negative for others off of Oregon. If there are large increases in hypoxia, there is a potential for significant restructuring of the ecological communities on the ocean floor off of Oregon. Population variation of many marine species is likely to increase due to direct biological effects of climate change and indirect cascading ecological effects.

Risk 5. Increased incidence of drought

Longer and drier growing seasons and drought will result in increased demand on ground water resources and increased consumption of water for irrigation, which will have potential consequences for natural systems. Droughts affect wetlands, stream systems, and aquatic habitats. Drought will result in drier forests and increase likelihood of wildfire.

Droughts will cause significant economic damage to the agriculture industry through reduced yields and quality of some crops. Droughts can increase irrigation-related water consumption, and thus increase irrigation costs. Drought conditions can also have a significant effect on the supply of drinking water.

Risk 6. Increased coastal erosion and risk of inundation from increasing sea levels and increasing wave heights and storm surges

Increased wave heights, storm surges, and sea levels can lead to loss of natural buffering functions of beaches, tidal wetlands, and dunes. Accelerating shoreline erosion has been documented, and is resulting in increased applications for shore protective structures. Shoreline alterations typically reduce the ability of beaches, tidal wetlands, and dunes to adjust to new conditions.

Increasing sea levels, wave heights and storm surges will increase coastal erosion and likely increase damage to private property and infrastructure situated on coastal shorelands. Coastal erosion and the common response to reduce shoreland erosion can lead to long-term loss of natural buffering functions of beaches and dunes. Applications for shoreline alteration permits to protect property and infrastructure are increasing, but in the long term they reduce the ability of shore systems to adjust to new conditions.

Risk 7. Changes in abundance and geographical distributions of plant species and habitats for aquatic and terrestrial wildlife

Changes in temperature and precipitation regimes will result in a gradual migration of some species and habitats north and to higher elevations. Species that cannot migrate or shift their range quickly enough to respond to climate change, or that have specific life-history needs that cannot be met through migration, will likely experience a decline in population numbers, potentially leading to extinction.

Changes in temperatures and hydrology will affect aquatic, wetland, and riparian ecosystems and species, especially species or population units that are already identified as threatened or endangered.

Risk of damage by insect and plant pests, which can result in significant damage to native species and communities, will increase with warmer temperatures. Alterations to the species composition of native ecosystems will likely result in a decline in important ecosystem services, including water quality and quantity, carbon storage, soil stabilization, flood control, and nutrient cycling.

Risk 8. Increase in diseases, invasive species and insect, animal and plant pests

Invasive species can negatively impact native plants, fish, and wildlife in agricultural ecosystems by displacing native species, changing habitat characteristics, consuming significant amounts of water, and changing fire regimes. Invasive species are already very costly to Oregon’s forests, grasslands, and wetlands, and agricultural economy.

Spread of infectious diseases in the United States and in the Pacific Northwest is occurring, with increased vulnerability of human populations to existing and emerging conditions. The West Nile Virus, Hanta Virus and Cryptococcus Gattii have all emerged recently in the Pacific Northwest.

Risk 9. Loss of wetland ecosystems and services

Wetlands play key roles in major ecological processes and provide a number of essential ecosystem services, such as flood reduction, groundwater recharge, pollution control, recreational opportunities, and fish and wildlife habitat, including for endangered species. Only about 38 percent of the wetlands that were in Oregon at the start of European settlement remain as wetlands today, because of conversions for various other land uses. As such, increases in air temperature and changes in hydrology will exacerbate impacts to already degraded and fragmented wetland ecosystems. The consequences for losing wetland ecosystems and their associated services will potentially affect all of Oregon's systems—natural, built and developed systems, public health and safety, and Oregon's economy.

Examples of the effects of a loss or reduction in wetland ecosystem services include increased flood damage to residences, commercial buildings, bridges, culverts, and roadways; increased need for new and expanded drinking water treatment facilities; and increased need for water storage facilities for flood control and to meet seasonal water demand.

The loss of wetland ecosystems and services will have indirect consequences on a range of economic activities. Loss of coastal wetlands that provide habitats can eventually reduce the value of Oregon's commercial and recreation fishing industries. Loss of seasonal wetlands and coastal wetlands will impact waterfowl and shorebird populations and may reduce the revenue generated from hunting, birding, and other recreation activities. Loss of wetlands that provide flood protection may result in higher damage costs as a result of increased flood related damages. Loss of wetlands that purify water may result in the need for expanded or additional drinking water treatment facilities. Loss of wetlands that provide water storage may result in the need for the construction of expanded and additional infrastructure to prevent flooding and to meet summer time water demands.

Risks that are *More likely than not* to occur

Risk 10. Increased frequency of extreme precipitation events and incidence and magnitude of damaging floods

Extreme precipitation events have the potential to cause localized flooding due partly to inadequate capacity of storm drain systems. Extreme events can damage or cause failure of dam spillways. Increased incidence and magnitude of flood events will increase damage to property and infrastructure, and will increase the vulnerability of areas that already experience repeated flooding. Areas thought to be outside the floodplain may now experience flooding. Many of these areas have improvements that are not insured against flood damage, and thus floods will probably result in catastrophic property damage and losses. Finally, increased flooding will increase flood-related transportation system disruptions, thereby affecting the distribution of water, food, and essential services.

Risk 11. Increased incidence of landslides

Increased landslides will cause increased damage to property and infrastructure, and will disrupt transportation and the distribution of water, food, and essential services. Widespread damaging landslides that accompany intense rainstorms (such as "pineapple express" winter storms) and related floods occur during most winters. Particularly high-consequence events occur about every decade; recent examples include those in February 1996, November 2006 and December 2007.

Selecting Short-Term Priority Actions

Once the work group finalized its inventory of climate risks, the next tasks were 1) to assess the basic state agency capacities to address the identified risks; and 2) to compile a list of immediate or short-term actions that are needed to improve Oregon's capacity to address the risks. This effort was primarily an initial scoping exercise. Over the course of about two months in early 2010, the work group listed about 120 mostly short-term actions that are needed to effectively address the identified risks. Finally, resource considerations made it paramount to limit the list of needed actions to a few relatively low-cost actions. All the identified actions are listed in summary form under each risk in section 2 of the framework.

Clearly, given the state general fund budget situation that has developed since early 2010, new resources are not likely to be available to implement any more than only a few of the needed actions, if any. It thus became necessary to identify a limited set of *top priority, short-term, low-cost actions* from the list. In consultation with agency directors, the work group prioritized needed actions according to the estimated costs and benefits of each one relative to all the other actions. In selecting priority actions, the work group based its assessment on a very general idea of the *relative magnitude of the costs and benefits* for each of the actions. In attempting to narrow its focus on low cost, high benefit actions, the work group assigned high, medium, and low cost and benefit values to each action, *relative* to the costs and benefits of the other actions, using the following guidelines in the evaluation:

Costs

- Costs to the state: The approximate personnel cost to implement the action.
- Costs to private landowners and businesses: Costs to private parties and businesses of implementing the action.
- Costs to the public *and* to particular communities: All other costs to the public, including infrastructure costs and costs to local governments.

Benefits

- Higher priority actions respond to *higher* likelihood of risks.
- Avoided costs: Reduced losses and damage from climate conditions that will be achieved in a 30-40 year timeframe if the actions are implemented now.
- Higher priority actions address the effects of more than one risk.

Finally, after compiling the information on risks, needed actions, and the relative costs and benefits of a set of "first cut" needed actions, the agency directors overseeing development of the framework made a final selection of *short-term priority actions*, which are central to the framework, for implementation in the 2011-2013 biennium.

More time and considerably more detailed information about the costs and likely benefits of needed actions are needed to improve the process of identifying priority actions. The work group's inventory of gaps and actions is by no means exhaustive, nor is it intended to be the last word in identifying climate change adaptation priorities. This framework represents a starting point and initial assessment of state capacity to deal with present and future climate risks.

The table below lists the short-term priority actions needed to improve Oregon's capacity to address the identified climate risks.

Climate Risks and Short-Term Priority Actions	
Very likely to occur	
1.	**Increase in average annual air temperatures and likelihood of extreme heat events**
	Enhance and sustain public health system capacity to prepare for and respond to heat waves and smoke emergencies, and improve delivery of information on heat events and cooling centers, especially for isolated and vulnerable populations.
2.	**Changes in hydrology and water supply; reduced snowpack and water availability in some basins; changes in water quality and timing of water availability**
	Maintain the capacity to provide assistance to landowners to restore wetlands, uplands and riparian zones to increase the capacity for natural water storage.
	Improve real-time forecasting of water delivery and basin yields to improve management of stored water.
	Improve capacity to provide technical assistance and incentives to increase storage capacity and to improve conservation, reuse, and water use efficiency among all consumptive water uses.
Likely to occur	
3.	**Increase in wildfire frequency and intensity**
	Include wildfires in planning to reduce vulnerability to natural hazards.
	Restore fire-adapted ecosystems to withstand natural recurring wildfires.
	Develop short- and medium-term climate change adaptation strategies for forests and other fire-prone habitats, and improve development standards to reduce exposure to fire risk at the urban-wildland interface.
	Improve the capabilities of public health agencies to plan for and respond to the public health and safety risks of wildfire emergencies.
4.	**Increase in ocean temperatures, with potential for changes in ocean chemistry and increased ocean acidification**
	Increase research on the impacts of changes in ocean temperature and chemistry on estuarine and near-shore marine habitats and resources, including commercial and recreational fisheries.
5.	**Increased incidence of drought**
	Improve capacity to provide technical assistance and incentives to increase storage capacity and to improve conservation, reuse, and water use efficiency

	among all consumptive water uses.
6.	**Increased coastal erosion and risk of inundation from increasing sea levels and increasing wave heights and storm surges**
	Inventory and map coastal shorelands that are at risk of erosion or inundation, or are barriers to shoreline migration, and develop long-term state and local adaptation strategies for shorelands.
7.	**Changes in the abundance and geographical distributions of plant species and habitats for aquatic and terrestrial wildlife**
	Identify ways to manage ecosystems that will improve their resilience to changes in climate conditions.
8.	**Increase in diseases, invasive species, and insect, animal and plant pests**
	Increase monitoring, detection and control measures for pest insects and plant and wildlife diseases.
	Increase surveillance and monitoring for climate-sensitive infectious diseases to humans.
	Increase outreach and community education about disease and invasive species prevention measures.
	Seek new means of securing resources to detect and combat diseases and invasive species.
9.	**Loss of wetland ecosystems and services**
	Support implementation of priority actions for Risks 2, 5, 6, 7, and 10 related to hydrologic changes, drought, coastal erosion and inundation, habitats, and flooding.
More likely to occur than not	
10.	**Increased frequency of extreme precipitation events and incidence and magnitude of damaging floods**
	Inventory past flood conditions and define and map future flood conditions.
	Improve capability to rapidly assess and repair damaged transportation infrastructure, in order to ensure rapid reopening of transportation corridors.
11.	**Increased incidence of landslides**
	Develop public education and outreach on landslide risks and how to adapt to landslide risks.

Existing Adaptive Capacity

The state and local communities are not without resources already to begin to adapt to the effects of climate change. Important elements of Oregon's basic capacity to adapt to the effects of future climate conditions include the following:

- Oregon has a strong capacity at present to respond to wildfires.

- Oregon is making investments to restore and protect ecosystem services like habitats, riparian structure, and wetlands, which will reduce or mitigate the effects of future climate conditions on people, communities and infrastructure.
- Oregon's wetland and waterway regulatory program protects important ecosystem services that will become increasingly important in a changing climate.
- There is some capacity at the state and local level to respond to emergency events like floods, fires, and windstorms to reduce damage and loss of life.
- Local land use plans are required to identify significant natural resources—including wetlands and riparian areas—that help reduce or mitigate the effects of future climate conditions on people, communities and infrastructure.
- Local land use plans are required to identify natural hazards that are subject to climate change, like flood, landslides, and coastal erosion.
- Oregon has an extensive network of state and county public health officials and authorities.

The current and future ability to successfully adapt to climate risks will rely in part on maintaining these and other program capabilities at the state level.

Implementing the Framework

Implementing the short-term priority actions will get Oregon started on a long-term path to improve community resilience across the state. Implementing the priority actions will begin the process of factoring information on climate risks into a broad suite of decisions at the federal, tribal, state and local level that affect land use, infrastructure, and natural resources over the next 30 to 40 years. But if implementation of the framework is limited to just the priority actions, several important issues will remain unaddressed. The framework includes a series of recommendations related to these issues, which themselves are not tied exclusively to any one risk.

1. *Identify Research Needed for Management*

Just like all planning efforts, the anticipated future conditions that form the foundation for the framework involve some uncertainty. Further planning for climate change should involve continued identification of needed research to help ensure that measures being considered are the most appropriate measures. In particular, research is needed on the potential economic costs and benefits of alternative adaptation strategies.

Recommendation for Research

- Compile an inventory of research needed to improve the effectiveness of adaptation measures at the state and local levels.

2. *Monitoring for Management*

Monitoring is an underappreciated element of effective resource management. Oregon agencies draw on information from many sources, and may monitor a variety of conditions, to improve agency efficiencies and the management of resources. The foundation of information for managing natural resources and state infrastructure could be improved, however, and such improvements will almost invariably improve Oregon's ability to respond to the effects of future climate conditions.

Recommendation for Monitoring

- Compile an inventory and maps of current surveillance (for diseases) and monitoring (for environmental conditions) efforts, and assess the feasibility of integrating different monitoring efforts into a statewide monitoring system.

3. Agency Program Assessments

State agencies already have some important capacities to prepare for, respond, and adapt to the effects of future climate conditions. However, the challenge that climate variability and change present to Oregon agencies is that conditions are changing faster than has generally been experienced before. Therefore, it is important that agency policy, program, and permit choices in the future incorporate information about likely future climate conditions, so as to avoid policies that might have clear climate-related future costs.

Recommendation for Agency Program Assessments

- State agencies should undertake an initial broad-scale assessment to identify policy and program elements that could result in decisions that place people, resources or infrastructure at risk.

4. Integrating Economic Information into Adaptation Planning

Development of this framework has been somewhat hampered by the absence of reliable information about either 1) the economic costs of projected changes to Oregon's climate, especially over time; and 2) the likely cost to effectively respond to such changes, especially at the local level. The framework had to be developed on the basis of the estimated magnitude of costs—of both the effects of climate conditions and actions to address those effects—relative to other effects and actions. It is necessary to improve the economic foundation for future adaptation planning.

Recommendation for Economic Information

- Agencies should work with economists and climate adaptation specialists and existing groups or institutes with expertise in economics to compile a white paper to frame the economic questions, analyses, and data that can be used to improve the effectiveness of planning for climate variability and change.

5. Mainstreaming Adaptation

Climate variability and change will affect all of the agencies that developed this framework and nearly every sector of Oregon's economy in the coming decades. Mounting and maintaining an effective response effort within state government will require ongoing coordination and collaboration between agencies. Given the continuing long-term challenge, climate preparation and adaptation needs to be 'mainstreamed' into agency programs and operations.

Recommendation for Mainstreaming Adaptation

- The agency directors' group and the interagency work group that have developed the framework should be formalized. The directors, as a steering group, should provide oversight for the coordinated implementation of the short-term priority actions and the implementation recommendations outlined here.

6. *Intergovernmental Coordination*

Building resilience to the effects of climate change will require coordination among all levels of government, and should include non-government entities as well. The most effective adaptation strategies will be implemented at the local or regional level, but may well be a function of state or federal initiatives. The private and non-profit sectors will also be actively engaged at the local, statewide, and national scale in building resilience in areas such as the economy and social welfare. Activities at all levels will need to be coordinated to assure cost effectiveness and to avoid working at cross-purposes.

Recommendation for Intergovernmental Coordination

- Oregon state agencies should consult with federal agencies, Native American tribal governments, representatives of local governments, and the private and nonprofit sectors to identify ways to coordinate the implementation of climate adaptation initiatives.

7. *Integrating Adaptation and Mitigation Strategies*

There is very little in the way of credible scientific challenge to the conclusion that much of the change in climate at the global scale is being driven by increased carbon dioxide emissions from the combustion of fossil fuels. One of the priority overarching actions of an adaptation framework should be to renew the commitment to reducing the generation of greenhouse gasses. Implementation and future revisions of the Framework should involve collaboration with the bodies that have principal responsibilities for implementing Oregon's Roadmap to 2020 developed by the Oregon Global Warming Commission.

Recommendation for Integrating Adaptation and Mitigation Strategies

- Over the next year, state agencies and the OGWC should assess existing emission reduction strategies to determine how best to incorporate climate change preparedness considerations.

8. *Communications and Outreach*

Given the breadth of Oregon's exposure to the effects of climate variability and change, the somewhat unpredictable nature of some climate-related events, and the potential to make decisions that increase vulnerability to various effects of climate change, it is critical to increase communications and outreach with the public about preparing for climate change. Communication and outreach efforts to inform Oregonians about the likely effects of future climate conditions should include information on how individuals and communities can reduce exposure to climate-related risks, and on how individuals can become involved in community-level efforts to prepare for climate change.

Recommendation for Communications and Outreach

- State agencies and the OGWC should collaborate on ways to improve messaging and outreach to the public related to preparing for climate change.

These next steps are designed to build the long-term infrastructure within Oregon state government needed to address climate impacts that will continue to affect Oregonians in the coming decades. These next steps, in conjunction with the short-term priority actions, represent the beginning of Oregon's effort to build resilience into every element of Oregon's economy and the natural and governance systems that sustain it.

The Framework Report

The Climate Change Adaptation Framework report contains more information than can be presented in this brief Summary of Key Findings and Recommendations. Please refer to the framework report for additional detail on

- The need to plan for variable and changing climate conditions.
- A summary of the scientific research related to each risk.
- Information on the time scale for the risk.
- Additional likely consequences of the risk.
- Agency actions that address the risk.
- Additional needed actions.
- Details on implementing the priority actions.

The Framework is an important first step in a collaborative state-level effort to address the challenges of preparing for and adapting to variable and changing climate conditions in Oregon. It lays the groundwork for expanded collaboration and coordination at all levels of government, and with citizens and the private and nonprofit sectors.

1. Introduction and background

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Climate is a fundamental element in people's consideration of where to live; in the productivity of natural systems; in the design and construction of infrastructure; and in the economies that help sustain people and communities across the state. Everyday decisions of individuals, organizations, governments, and businesses can involve deep assumptions about climate conditions. Events and conditions like floods and drought that fall outside the fundamental assumptions about climate can result in costly consequences for individuals, communities, and the state.

Preparation for and adaptation to the effects of a variable and changing climate will be an ongoing challenge for individuals, communities, state agencies, and the federal government. Not the least of the challenges is acting in the face of uncertainty about specific future climate conditions and how those conditions will affect Oregon's natural systems, built and developed systems, and human health. It's even less clear how Oregon's economy, which relies on and responds to changes in those same three areas, will respond to changes in Oregon's climate. If Oregon wants to maintain or even improve its economic resilience into the 21st Century, it needs to be prepared for, and take measures to adapt to, the effects of variable and changing climate conditions.

Several state authorities and programs that are based on the protection of public health and safety have a responsibility to anticipate and avoid or minimize the negative consequences of variable and changing climate conditions. The Climate Change Adaptation Framework is intended to initiate an ongoing process among state agencies, and eventually agency partners, to identify priorities and measures to reduce the vulnerability and promote the resilience of Oregon's citizens, communities, infrastructure, and natural systems. The framework is based on a broad-scale qualitative assessment of risks to people, infrastructure, communities and natural resources related to climate conditions. The purposes of this framework are to

- Identify likely future climate conditions that pose some risk for Oregonians.
- Assess the capacity of state programs to effectively address climate-related risks to people, communities, infrastructure, and natural resources.
- Identify short-term priority actions to prepare for those risks.
- Provide context and initial direction for additional coordination and planning for future climate conditions.

Preparation for and adaptation to the likely effects of climate variability and change is only one important element of a complete state-level response to challenges related to climate. The other critical element is often referred to as *mitigation*, which refers to the need to mitigate the effects of increased concentrations of greenhouse gasses in the atmosphere. Oregon has already been working for several years to address the need to reduce greenhouse gas emissions. As recently as late October 2010, the Oregon Global Warming Commission adopted a series of strategies to achieve targets for reducing greenhouse gas emissions. *The scope of this framework does not extend to initiatives that are primarily designed for mitigating greenhouse gas emissions.*

The principal long-term challenge of adapting to future climate conditions is to identify the most effective investment of scarce resources to reduce vulnerability and increase resilience at the individual, community, regional, and state level. Fortunately, Oregon already has some basic capacity to address many of the anticipated future climate conditions at the state and local level. Adapting to the effects of climate change does not necessarily mean there is a need for *new* programs, but rather that there is a need to implement some programs *differently*. Given the breadth of potential impacts of climate change and the scope of actions needed to address them at the state level, implementation of this framework is going to take some time.

This framework provides a starting point for Oregon in planning for the future effects of climate on people, places, and the built environment. In order to make real progress at the state and local level in preparing for and adapting to the effects of climate, several broad things need to occur.

- First, the criteria for state and local decisions about land use, infrastructure investments, and management of natural resources must be reviewed to ensure that today's decisions are not setting individuals or communities up for predictable future losses.
- Second, similar climate change scoping efforts must be undertaken at the regional, and in some cases, local level.
- Third, the efforts of citizens, local governments, state agencies, academia, NGOs, and federal agencies need to be coordinated and integrated.
- Finally, far more needs to be done to fully integrate economics into planning for future climate conditions.

Oregon's Previous Work on Adaptation

This framework was essentially initiated in early 2008 with the publication of Oregon's *Framework for Addressing Rapid Climate Change* by the Governor's Climate Change Integration Group (CCIG). The *Framework for Addressing Rapid Climate Change* presented the scope of needed work in four elements: preparation and adaptation; mitigation; education and outreach; and research. Each element in the CCIG's framework contains several recommendations. CCIG's key recommendations for preparation and adaptation include:

- Immediately begin preparing for climate change.
- Determine how climate change will affect Oregon's diverse regions.
- Assist Oregon institutions and individuals in responding to climate change.
- Transform our planning processes to deal with climate change.
- View responding to climate change as an economic development opportunity.
- Incorporate the public health implications of climate change.
- Continue to develop and refine a climate change research agenda for Oregon.
- Provide funding for key actions.

In laying the groundwork for preparation and adaptation to climate change, the CCIG also identified several key principles that should be applied in preparation and adaptation planning:

- Prevention should be the first priority.

- Prioritize the most vulnerable.
- All government agencies should adopt preparation plans.
- Redesign planning tools.
- Plan at larger scales to ensure that climate preparation in one sector or region does not affect preparation elsewhere.
- Link climate preparation to existing economy and to new economic development efforts.
- Limit non-climate stresses.
- Use and continually improve adaptive management processes and contingency planning.
- Assess existing capacity and develop governance systems appropriate for the rate and scale of change.
- Assess existing finance mechanisms and develop new funding options as needed.
- Coordinate research agendas across states and regions.

To the degree possible within the time available and at the state-wide scale, these principles have been integrated into this Framework. At the same time, it will be necessary to attend to their continued integration into adaptation plans as the Framework is implemented through further planning efforts at the state, regional, and local scale.

At a broad state-wide scale, the Climate Change Adaptation Framework furthers the CCIG's work by identifying likely risks associated with future climate conditions; assessing the capabilities of state agencies to address those future conditions; and identifying priority short-term actions to reduce the potential for costly consequences for life, property, resources, and infrastructure from the effects of climate change.

Basic Adaptive Capacity

Oregon is not without considerable resources and capabilities to prepare for the effects of climate variability and change. The state has basic capacity to address several of the effects of anticipated future climate conditions, and agencies are already beginning to adjust management approaches in response to climate conditions. State agencies and local governments already implement several authorities that will continue be useful in responding to future climate conditions. Principal elements of Oregon's basic capacity to adapt to the effects of future climate conditions include the following:

- The state and national forests have a robust capacity to respond to wildfires.
- Oregon has an extensive network of state and county public health officials and authorities.
- Oregon is making investments to restore and protect ecosystem services like habitats, riparian structure, and wetlands that will reduce or mitigate the effects of future climate conditions on people, communities and infrastructure.
- Oregon's wetland and waterway regulatory program protects important ecosystem services that will become increasingly important in a changing climate.
- There is some capacity at the state and local level to respond to emergency events like floods, fires, and windstorms to reduce damage and loss of life.

- Local land use plans are required to identify significant natural resources—including wetlands and riparian areas—that help reduce or mitigate the effects of future climate conditions on people, communities and infrastructure.
- Local land use plans are required to identify natural hazards that are subject to climate change, like flood, landslides, and coastal erosion.

Oregon has some basic capacity to anticipate and respond to the likely effects of future climate conditions. Agency programs and actions that address climate risks are summarized under each risk in Chapter 3, "Foundation for the Framework." It is imperative that Oregon's adaptive capacity be maintained and actively managed to ensure that climate variability and change are factored into everyday state decisions.

Process of Developing the Framework

In late 2009, Governor Kulongoski initiated the process of developing an adaptation plan. In early 2010, the Oregon Climate Change Research Institute (OCCRI) began to compile the first Oregon Climate Assessment Report (OCAR), to be completed in time to present to the 2011 Legislative Assembly. The two efforts have distinctly different purposes, but have been developed in parallel. This Climate Change Adaptation Framework has been developed in close consultation with the OCCRI to ensure that it is firmly based on sound science and the best available expertise about the likelihood and timing of climate changes in Oregon.

Shortly after an initial meeting of Governor Kulongoski and state agency directors and others in October 2009, a work group was convened by representatives of all the participants. The work group's first task was to identify likely changes to occur in Oregon's climate conditions, and the likely consequences of those changes. In consultation with the OCCRI and the agency directors, the work group ultimately identified eleven *likely changes in climate conditions in Oregon in the next three to five decades*, which are defined in this framework as *risks*. These risks, listed in Table 1, provide the substantive foundation for the entire framework.

Not all the identified climate risks are equally likely to occur everywhere. Each risk was identified as posing a significant threat to Oregon, but each one varies in the likelihood of its occurrence. A determination of the likelihood of each risk impacting the state through 2050 was based on the amount of literature available about that risk, and the scientific confidence to make such a determination. Following the IPCC's usage, categories of very likely, likely, or more likely than not were assigned to each risk; these designations reflect the best judgment of the scientific community related to the risk. A designation of *very likely* indicates that the change is almost certain to occur in Oregon. *Likely* indicates a fairly high level of probability that the risk will occur in Oregon. *More likely than not* indicates there is some spatial or temporal uncertainty involved, or that there is a lack of Oregon- or Pacific Northwest-related research available to confidently quantify the risk as almost certain. These designations roughly translate to greater than 90 percent, greater than 66 percent, and greater than 50 percent probabilities of occurrence.

Table 1. Likelihood of climate risks for Oregon		
1.	Increase in average annual air temperature and likelihood of extreme heat events	Very likely
2.	Changes in hydrology and water supply; reduced snowpack and water availability in some basins; changes in water quality and timing of water availability	Very likely
3.	Increase in wildfire frequency and intensity	Likely
4.	Increase in ocean temperatures with potential for changes in ocean chemistry and increased ocean acidification	Likely
5.	Increased incidence of drought	Likely
6.	Increased coastal erosion and risk of inundation from increasing sea levels and increasing wave heights and storm surges	Likely
7.	Changes in abundance and geographical distributions of plant species and habitats for aquatic and terrestrial wildlife	Likely
8.	Increase in diseases, invasive species and insect, animal and plant pests	Likely
9.	Loss of wetland ecosystems and services	Likely
10.	Increase incidence and magnitude of damaging floods and frequency of extreme precipitation events	More likely than not
11.	Increased incidence of landslides	More likely than not

The work group's next step was to identify the likely effects of all the climate risks on people, communities, resources and infrastructure over the next 40 to 50 years. It produced a high-level survey of the likely effects of climate change on public health and safety, built and developed systems, ecosystems, and Oregon's economy.

The high-level survey of the effects of climate change on Oregon and Oregonians provided the basis for an equally high-level assessment of state agency capacities to effectively manage and protect Oregon's public health and safety, built and developed systems, ecosystems, and economy against the adverse effects of future climate conditions. Finally, each agency compiled information on current and planned actions (through the 2011-2013 biennium) to address the identified risks. This effort laid the groundwork to identify opportunities to coordinate programs and to avoid duplicating efforts and state-level measures.

Finally, considering risks, agency capacities, and planned actions, all of the agencies identified gaps in state capacity and actions needed to fill those gaps. The identified gaps and needed actions only represent an initial assessment of Oregon's preparedness for the effects of future climate conditions. As state agencies expand their understanding of the timing and likely effects of future climate conditions on people, resources and communities, their understanding of gaps in capacity and needed actions will also continue to be refined. The Framework anticipates a continued, more rigorous, assessment of state capacity to address the effects of future climate conditions over the next 30 to 50 years.

Structure of the Framework

The Framework consists of three principal elements and an appendix. The three principal framework elements are a summary of climate risks; short-term priority actions; and recommendations for implementing the framework. Because the most important element of the framework is the set of short-term priority actions, they are presented first.

Short-term priority actions

The work group identified 119 state agency actions needed to fill gaps in Oregon's capacity to effectively respond to identified climate risks. Clearly, given the state general fund budget situation that has developed since early 2010, new resources are not likely to be available to implement any more than only a few of the needed actions, if any. It thus became paramount to identify *top priority, short-term, low-cost actions* from the list. In consultation with the agency directors, the work group identified a couple of dozen "first-cut" priority actions, which was further refined. In selecting priority actions, the work group based its assessment on a very general idea of the *relative magnitude of the costs and benefits* for each of the actions. This was not a quantitative assessment, since data for that kind of analysis are not available. Rather, the work group assigned high, medium, and low cost and benefit values to each action, based on the guidelines below. It must be emphasized that this assessment was not based on a rigorous quantitative analysis, but rather assigned cost and benefit values *relative* to the costs and benefits of the other actions. The guidelines that were used to assign relative costs and benefits are:

Costs

- Costs to the state: The approximate personnel cost to implement the action.
- Costs to private landowners and businesses: Costs to private parties and businesses of implementing the action.
- Costs to the public *and* to particular communities: All other costs to the public, including infrastructure costs and costs to local governments.

Finally, in order to make the cut, actions need to be capable of being implemented in two to three years, even if their effects might not be realized for some time.

Benefits

- Level of risk: Assign benefits according to the relative magnitude of the risk; that is, priority actions respond to *higher* risks.
- Avoided costs: Reduced losses and damage from climate conditions that will be achieved in a 30-40 year timeframe if the actions are implemented now.

- Co-benefits: Priority actions will address the effects of more than one climate risk.

In order to evaluate if some of the 119 actions clearly were a priority for all agencies, each agency also identified fifteen priority actions. Finally, the work group's list of priority actions was forwarded to the agency directors for their consideration as a central element of the framework.

Summary of Risks

The foundation of the framework is in an informed understanding of the anticipated effects of future climate conditions, referred to throughout the framework as *climate risks*. The next section of this report provides a survey of several planning-related aspects of each of the eleven climate risks. Each risk summary includes several components:

- A summary of the scientific research related to the risk.
- A brief description of the timing and the geographic breadth of the risk.
- An identification of other risks that are related to the risk.
- A summary of the consequences of the climate risk on Oregon's ecosystems, built and developed systems, public health and safety, and (where such information is available) economy.
- A summary of present agency capacity and actions to address the risk.
- Gaps in state capacity to address the risk.
- Actions needed to fill the gaps in state capacity, including priority actions.
- Considerations for implementing priority actions.

It is anticipated that this summary of risks will provide a foundation for adaptation planning at the regional, watershed, and community scales.

Implementing the Framework

In order to reduce the potential costs of future climate conditions and events on Oregon and Oregonians and to avoid decisions today that could place people, resources and infrastructure at risk of damage or loss, this Climate Change Adaptation Framework needs to continue to be developed and implemented. In particular, considerably more work needs to be done in the area of economics. Perhaps most importantly, this framework also needs to be scaled down and implemented at the regional level and at the level of Oregon's communities. The state-level risk assessment provides valuable context for more accurate scaled-down assessments of risk at the community and regional scale.

There will always be some degree of uncertainty in planning for future environmental and climate conditions. But uncertainty can't be used as a reason to postpone planning for future climate conditions. The estimated likelihood of climate risks is sufficiently accurate to support adaptation planning at the state and local level. Different climate risks occur at different time scales. For example, loss of some wetland ecosystem services and habitat shifts will occur over longer time spans than will the effects of increased storm wave heights. Ultimately, each climate risk involves spatial and temporal considerations that will influence state, local, and individual responses. Continued work on the framework will help frame these various levels of response.

In the end, a framework is not a plan, and plans are needed—particularly at the regional and local level—to identify specific strategies and actions that will reduce exposure to risk; to avoid increasing the potential for loss; and to provide for response and rapid recovery during and after significant climate events.

The last section on implementing the framework contains information on several issues that are not related to a single specific risk, but are important to address in a state-level adaptation effort. Among other things, these issues include

- Research and monitoring.
- Agency program assessments.
- Integrating economic information into adaptation planning.
- Intergovernmental coordination.

This framework represents an important start on what will likely be an extended effort to address climate risks in Oregon in the coming years and decades.

2. Short-term priority actions

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One of the most important elements of the framework is a set of short-term priority actions to improve the state's capacity to address the effects of future climate conditions. The short-term priority actions represent low-cost beneficial actions the state can take to begin a longer-term process of preparing for the effects of a variable and changing climate.

The framework also sets the stage and direction for a range of subsequent efforts, including the continued identification of priority gaps in state capacity to address climate risks as our understanding of those risks improves.

Low-cost, high-benefit actions

The short-term priority actions that are the first concrete outcome of the framework represent only a first-cut analysis. They are intended to make some progress in addressing climate risks and to set the stage for additional agency planning and coordination through the 2011-2013 biennium. Selection of these priority actions was constrained by the understanding that resources for new initiatives will be scarce for at least the 2011-2013 biennium. The priority actions were selected partly on the basis that they were among the lowest cost actions to implement, and that they would benefit the state by improving its capacity to address the effects of climate change.

The scope of this first-cut analysis is limited to present state agency authorities, responsibilities and capacities. A more thorough analysis will provide a detailed understanding of where state capacity needs to be improved to reduce vulnerability to climate risks. Potential improvements in state capacity to address climate risks may range from a need for new authority to changes in design criteria for infrastructure. In addition, a more thorough analysis would be broadened to identify where federal and local authorities can more effectively address climate risks in Oregon.

While identifying needed changes in federal, state and local capacity to reduce vulnerability to risk is one thing, fully integrating such changes into programs is another. More effort and some additional resources will be needed to fully integrate climate change into the criteria for agency decisions, and to coordinate agency programs and actions to improve Oregon's overall effectiveness in preparing for climate change.

This effort initially set out to identify climate-related risks to people, places, infrastructure and resources as the foundation for adaptation planning. Over time, the broad range of risks and likely effects were compiled into about a dozen risks. In this framework, *risks* are defined as ***changes in climate conditions and the likely effect of changed conditions on people, communities, resources, and infrastructure***. In the early stages of developing the framework, over 60 likely effects of future climate conditions on ecosystems, built and developed systems, and human health and safety were identified. This list of risks was revised down to 18, and eventually collapsed into a set of eleven climate *risks*. Ultimately, of course, in physical science terms, all the risks associated with climate change could be collapsed into a single risk for *increased average annual air temperatures*, since increased temperatures are driving all the other changes in climate that are expected to affect Oregon. However, collapsing all the risks into a single risk for increased temperatures would limit the view of how other, temperature-driven climate-related phenomena will affect the health, safety and welfare of Oregonians.

The framework was originally intended to include the effects of future climate conditions on Oregon's economy. Unfortunately, the effects of climate variability and change on Oregon's economy are difficult to pin down with any degree of certainty. Risks to the economy are essentially risks to natural systems, built and developed systems, and public health and safety stated in economic terms. Assigning economic value to *potential* changes involves several huge assumptions and considerable speculation. Any effort to identify the consequences of climate change in economic terms needs far more specialized knowledge than what was available for this effort. Improved knowledge about economic consequences will be necessary to more effectively prepare for the consequences of future climate conditions in Oregon.

Process and criteria used to identify priority actions

As with the attempt to identify the economic effects of future climate conditions, the process used to select priorities was hampered by a lack of solid quantitative information about the costs and benefits of specific strategies and actions. Without reliable economic data, the evaluation had to rely on the estimated costs and benefits of an action *relative to the estimated costs and benefits of other possible actions*. The recommended short-term priority actions are thought to be the most effective *low-cost* or essentially *no additional cost* actions that can be put in place immediately or within a relatively short time.

Evaluation of the costs and benefits of possible short-term actions initially involved 1) estimated cost to the state to implement the action; and 2) estimated benefits in reduced vulnerability and reduced damage or loss of property, infrastructure and resources. However, this initial evaluation was judged to be too limited, since potential costs of implementing some actions had not been fully considered. Possible short-term actions were re-evaluated, using broader definitions of costs and benefits. In the revised evaluation, the estimated costs of possible actions included:

- Estimated cost to the state to implement the action.
- Cost to and effect on private landowners and businesses.
- Costs to the public in general.
- Costs to particular communities.

Finally, the evaluation considered whether the action is capable of being implemented in two to three years.

The revised evaluation of the benefits of possible actions considered:

- Magnitude of the risk to be addressed (i.e., the benefits of an action that addresses a risk with a high likelihood of occurrence are greater than the benefits of an action that addresses a lower risk).
- Avoided costs and benefits that will be achieved in 30 to 40 years if the action is implemented now.
- Co-benefits, which reduce vulnerabilities associated with more than one risk.

Finally, once the evaluation of the costs and benefits of possible priority actions was completed, the agencies also identified actions that they considered the highest priorities in terms of their responsibilities and mission. The short-term priority actions to prepare for each risk are summarized in Table 2.

Table 2: Climate Risks and Short-Term Priority Actions	
Very likely to occur	
1.	**Increase in average annual air temperatures and likelihood of extreme heat events**
	Enhance and sustain public health system capacity to prepare for and respond to heat waves and smoke emergencies, and improve delivery of information on heat events and cooling centers, especially for isolated and vulnerable populations.
2.	**Changes in hydrology and water supply; reduced snowpack and water availability in some basins; changes in water quality and timing of water availability**
	Maintain the capacity to provide assistance to landowners to restore wetlands, uplands and riparian zones to increase the capacity for natural water storage.
	Improve real-time forecasting of water delivery and basin yields to improve management of stored water.
	Improve capacity to provide technical assistance and incentives to increase storage capacity and to improve conservation, reuse, and water use efficiency among all consumptive water uses.
Likely to occur	
3.	**Increase in wildfire frequency and intensity**
	Include wildfires in planning to reduce vulnerability to natural hazards.
	Restore fire-adapted ecosystems to withstand natural recurring wildfires.
	Develop short- and medium-term climate change adaptation strategies for forests and other fire-prone habitats, and improve development standards to reduce exposure to fire risk at the urban-wildland interface.
	Improve the capabilities of public health agencies to plan for and respond to the public health and safety risks of wildfire emergencies
4.	**Increase in ocean temperatures, with potential for changes in ocean chemistry and increased ocean acidification**
	Increase research on the impacts of changes in ocean temperature and chemistry on estuarine and near-shore marine habitats and resources, including commercial and recreational fisheries.
5.	**Increased incidence of drought**
	Improve capacity to provide technical assistance and incentives to increase

	storage capacity and to improve conservation, reuse, and water use efficiency among all consumptive water uses.
6.	**Increased coastal erosion and risk of inundation from increasing sea levels and increasing wave heights and storm surges**
	Inventory and map coastal shorelands that are at risk of erosion or inundation, or are barriers to shoreline migration, and develop long-term state and local adaptation strategies for shorelands.
7.	**Changes in the abundance and geographical distributions of plant species and habitats for aquatic and terrestrial wildlife**
	Identify ways to manage ecosystems that will improve their resilience to changes in climate conditions.
8.	**Increase in diseases, invasive species, and insect, animal and plant pests**
	Increase monitoring, detection and control measures for pest insects and plant and wildlife diseases.
	Increase surveillance and monitoring for climate-sensitive infectious diseases to humans
	Increase outreach and community education about disease and invasive species prevention measures.
	Seek new means of securing resources to detect and combat diseases and invasive species.
9.	**Loss of wetland ecosystems and services**
	Support implementation of priority actions for Risks 2, 5, 6, 7 and 10 related to hydrologic changes, drought, coastal erosion and inundation, habitats, and flooding.
More likely than not to occur	
10.	**Increased frequency of extreme precipitation events and incidence and magnitude of damaging floods**
	Inventory past flood conditions and define and map future flood conditions.
	Improve capability to rapidly assess and repair damaged transportation infrastructure, in order to ensure rapid reopening of transportation corridors.
11.	**Increased incidence of landslides**
	Develop public education and outreach on landslide risks and how to adapt to landslide risks.

The recommended short-term priority actions are not the only actions Oregon should take to improve its ability to effectively address the effects of variable and changing climate conditions. They are only a starting point; additional effort and resources will be needed, in particular to expand the assessment of vulnerabilities and capabilities at the local level, and to involve federal agencies in planning for future climate conditions.

3. Foundation for the Framework: Climate Risks, State Capacity, and Needed Actions

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Preparation for and adaptation to the effects of climate variability and change involves several factors and uncertainties, especially when doing so for such a large area as the State of Oregon. The first challenge in planning for future climate conditions essentially comes down to the inherent uncertainty about future events and conditions. Planning for climate change should not be deferred until perfect information about future conditions is available. Such information will never be available, and the costs of *not* planning for future climate conditions are potentially high.

In order to begin preparing for climate change even in the face of uncertainty, this section provides an overview of several climate risks in Oregon and the likelihood of their occurrence. Information about future climate conditions provides the basis for Oregonians to begin to analyze where they and their communities may be vulnerable to the effects of climate change.

These risk summaries are intended to begin a process to assess future climate risks at regional and local scales. These are the events and conditions that should be used as the foundation for local climate adaptation planning. Further refinement and implementation of the framework will require that each risk be more clearly defined and addressed at the local scale.

Each of the risk summaries contains information as outlined below.

1. **Risk assessment**

   For each risk, there is a summary of the scientific research pertinent to the Pacific Northwest or specifically to Oregon, and the likelihood that the risk will occur.

2. **Timing and geography of the risk**

   Climate risks will occur over different timeframes and at different geographic scales. For example, average annual air temperatures will increase over the entire state, but the hydrologic effects of increased temperatures will likely be more pronounced in river basins where the hydrology is now dominated by snowmelt. The timing of some risks is episodic—for example, precipitation, floods, coastal erosion, and landslides are generally localized short-term events for which some increase in event magnitude or frequency (or both) is expected to occur gradually over several decades. This section provides some idea of the geographical and the timing elements of the risk.

3. **Related risks**

   Every climate risk relates in some way to one or more other risks. Ultimately, all the risks described in this section are associated with increased average air temperatures and concentrations of CO_2 in the atmosphere. Increased air temperatures are driving all the other risks. Nevertheless, in order to more effectively lay the groundwork for local adaptation planning efforts, this framework includes "second order" risks—those risks that are caused primarily by first order risks like increased temperatures.

4. **Summary of consequences of the risk**

   Each risk summary provides a brief overview of some of the kinds of changes that are anticipated to occur as a result of the identified risk. This survey of consequences provides some perspective on what the risk represents to individuals, communities and the state as a whole. The summary is by no means exhaustive or even complete. Rather, it is intended to simply focus the framework on the state agency programs that are in place to address the effects of climate conditions, and to further identify where additional capacity needs to be developed. The summaries provide information on consequences for ecosystems, built and developed systems, public health and safety, and Oregon's economy.

5. **State agency actions to address the risk**

Oregon already has several authorities and programs in place that address the effects of climate conditions to one degree or another. These authorities and programs range from the capacity to respond to floods and wildfires to programs to reduce the spread of invasive species. Each risk summary provides a survey overview of the state capacities in place that can address at least some aspect of the consequences of the risk. This summary provides context for the next two sections

6. **Gaps in state capacity to address the risk**

At a similar scale to the preceding summary of existing authorities and programs in place to address the risk, each risk summary provides an overview of gaps in state capacity to address the risk.

7. **Needed actions, including priority actions**

The most important outcome of developing this framework has been to identify where state capacity to address climate risks needs to be improved. Each risk summary provides a list of actions needed at the state level to improve Oregon's capacity to address the risk. Note that the listed actions are in abbreviated form, and that the list is by no means exhaustive. The list represents a 'first cut' survey of state capacity; considerably more analysis will be needed to flesh out a full understanding of Oregon's capacity to address climate risks. In particular, the capacity of programs and capacities at the local and federal levels, and the effect of local, state and federal coordination need to be integrated into a more rigorous analysis of needed actions.

Over 100 needed actions were identified across all the risks in this first cut. Since all the needed actions cannot be implemented in the near term, it was necessary to select a set of suitable early actions. Under each risk, at least one action has been selected as a 'short-term priority action,' based on estimated magnitude of costs and benefits relative to all the other needed actions under each risk. The list of needed actions identifies *priority actions* and *additional needed actions*.

8. **Implementing the priority actions**

Finally, the risk summaries list what needs to be done to implement the priority actions for the risk. This discussion provides a list of the next steps to implement the action; identifies research and monitoring that may be needed to effectively implement the action; lists state and federal agencies and others that are likely to have some role in implementing the action; and resource requirements to fully implement the action. Again, in keeping with the 'first cut' nature of the framework, this summary is not meant to be absolute or exhaustive, but rather to initiate momentum toward building state capacity.

Risk 1: Increase in average annual air temperatures and likelihood of extreme heat events [Return to Table of Contents]

1. **Risk assessment**

   There is a high level of scientific confidence in the accuracy of projected increases in annual average air temperatures. An analysis of the global climate models used in the 2007 Intergovernmental Panel on Climate Change (IPCC) assessment show an increase in annual average air temperatures in the Pacific Northwest through the end of the 21^{st} century (Mote and Salathé, 2010). Future regional change will likely be marked by increases in temperature of around 0.3˚ C per decade, which could be lower if greenhouse gas emissions are lower than expected. Average air temperatures will very likely increase over the next century. The magnitude of the increase is dependent on global greenhouse gas emissions. Seasonal changes in temperature often have greater societally-relevant impacts than annual averages. Future seasonal change will likely be marked by an accentuated warming in the summer months (Mote et al., 2010). On the episodic scale, Meehl and Tebaldi (2004) found that areas such as the northwest United States could see an increase in heat wave intensity in the 21st century. These heat waves could impact this region more severely than other regions that are well-adapted to extreme heat.

2. **Timing and geography of the risk**

   Air temperatures are projected to continue to increase across all of Oregon and the Pacific Northwest over the next century. Temperatures have already increased across the region in the recent past. An analysis of United States Historical Climatology Network stations in the Pacific Northwest for the period 1920-2000 indicated a warming of 0.8˚C (1.5˚F)/century (Mote, 2003).

3. **Related risks**

   Increasing average air temperature (annual, seasonal, and episodic) acts as a driver for other risks. Risks related to increased temperatures include, but are not limited to, loss of snowpack and changes in hydrology; increased incidence of drought, which is often a result of a below-average winter snowpack in Oregon; changing distribution of habitats and species as temperatures may become more or less hospitable for various plant and animal species; an increase in wildfire frequency and intensity; and increases in diseases and pests.

4. **Summary of consequences of increased air temperatures**

Ecosystems

Overall, increased average air temperatures will result in increased water temperatures and reduced flows in streams, which over the long term will cause shifts in aquatic habitats, species, and communities. Urban streams are particularly vulnerable; natural vegetation is usually lacking in these areas. The ability of aquatic systems and habitats to support fish species and populations and provide other landscape functions will be reduced. Blue-green algae blooms are increasing in frequency, and water temperature violations are already occurring.

Increased average air temperatures may also affect the growing season, the timing of blossoms, the length and severity of cold spells, and other factors that affect species and habitats. Higher winter temperatures can result in increased activity of bark beetles, especially at higher elevations. In general, habitats and species will respond to higher temperatures by migrating poleward and/or to higher elevations. Risk of infestation by insect and plant pests, which can result in significant damage to native species and communities, will increase with warmer temperatures.

Built and developed systems

Extreme heat events can affect transportation infrastructure such as bridge expansion joints and pavement integrity, and can result in rail-track deformities.

Economic systems

Increased temperatures will increase use of air conditioning. Higher temperatures reduce the efficiency of electrical transmission networks. Increased average air temperatures will affect the productivity of Oregon forests, and therefore the economic health of rural communities.

Public health and safety

Higher average air temperatures will increase air pollution and pollen counts, both of which adversely affect the health of some populations and people. Higher average temperatures will reduce the quantity and quality of drinking water and increase episodes of algal blooms. Increased temperatures may increase the threat of food insecurity, particularly among low income populations. Higher temperatures increase the threat of human illness from both waterborne diseases and vector borne illnesses. Heat waves will result in increased deaths and illness among vulnerable populations. The elderly, infants, chronically ill, low income communities, and outdoor workers are the main groups threatened by heat waves. Increased pollen production from extended blooming seasons and invasive plants will likely make allergies more severe.

5. Agency actions to address the risk of increased temperatures

State authorities cannot directly address the increase in average annual air temperatures. However, some state authorities do address some of the drivers and consequences of increased air temperatures. State authorities that address various effects of increased average temperatures include:

- DEQ has programs and authorities under the Clean Water Act and state laws to address increased water temperatures.
- OPRD monitors water quality at critical water bodies (listed species habitat, reservoirs).
- ODF administers forest practice rules requiring vegetation retention along streams.
- ODA supports the development of agricultural water quality management programs that work with producers to protect water quality from the effects of agricultural practices.
- OWEB, federal agencies, and local organizations fund and work with producers to restore riparian ecosystems and make other water quality improvements.
- State efforts to reduce greenhouse gas emissions will help reduce the rate of increase in CO_2 in the atmosphere, and thus in turn reduce the rate of global

temperature increases. Oregon's contribution to reduced generation of greenhouse gases is likely to be relatively small, but necessary.

- ODOE accounts for increased demand for building cooling in energy policies and consumer programs for the state.

6. Gaps in state capacity to address the risk of increased temperatures

- The state and local governments have limited capacities to prepare for and respond to heat waves.
- Statewide or system-wide standards for riparian protection are needed to reduce the effects of increased air temperatures on surface water temperatures and aquatic habitat.
- There is a need to monitor respiratory conditions and levels of airborne contaminants and pollen.
- For many of Oregon's more than 250 crops, it is unknown how the increase in annual average temperatures, combined with the CO_2 fertilization effect, will affect crop quality and crop production, as well as vulnerability to pest and invasive species.

7. Needed actions

Priority action

Enhance and sustain public health system capacity to prepare for and respond to heat waves and smoke emergencies, and improve delivery of information on heat events and cooling centers, especially for isolated and vulnerable populations.

Additional actions

Improve protection of wetlands, streams and riparian corridors.

Protect and expand urban green spaces to reduce the urban heat island effect.

Develop and use capacity at OPHD to identify, track, analyze and prevent adverse health impacts (illnesses and injuries) from priority climate-related hazards (including excess heat events, wildfires, floods and other extreme storms, and emerging vector-borne diseases).

Develop early warning systems to alert high-risk populations about threats from heat waves.

Develop tools and provide resources to improve implementation of water quality plans for reducing in-stream water temperatures.

Develop plans to respond to air contaminant and pollen emergencies.

Assess air temperature effects on infrastructure, particularly transportation infrastructure.

Support research into better-adapted crop varieties and new crops that may become available in warmer climate conditions.

Improve capacity to monitor air quality conditions affected by warmer temperatures.

Assess need for cooling centers in urban areas.

8. Implementing the priority action

Next steps

- Work with local health departments and tribal officials to assess or develop heat-health action plans to respond to heat wave episodes.
- Work with local health departments and tribes to develop messages to help raise awareness of the dangers of extreme heat, and encourage targeted outreach to those at highest risk, about steps they can take to minimize their risk.
- Work with officials in the National Weather Service to coordinate early notification when heat waves are predicted, and issue timely warnings and alerts to the public about extreme heat events.
- Inform people about the warning signs of heat-related illness in themselves and others.
- Work with health care and social services providers to ensure their ability to provide appropriate services during extreme heat events.
- Work with local health departments, tribes and local offices of seniors and people with disabilities to assess the need for and coordinate the operation of cooling centers that are readily accessible, especially for vulnerable populations (such as the elderly, disabled and homebound individuals).

Research and monitoring

- Identify appropriate sources of data that measure and characterize the impact of past and current extreme heat events, and develop agreements for timely access to these data.
- Assess the need for administrative rule or other policy changes to facilitate access to information about illnesses and deaths associated with extreme heat.
- Monitor changes in reported illnesses and deaths associated with extreme heat events over time to measure the impact of prevention and adaptation efforts.

Coordination

- Primary coordination will be with local health departments and tribal authorities to develop or enhance planning efforts to effectively prepare for and respond to extreme heat events.
- Coordinate with the Departments of Human Services and Employment and the Oregon Health Authority to determine ways to identify and reach vulnerable populations at increased risk from extreme heat events.
- Coordinate with state agencies and other providers of cooling center services to plan for adequate services, including transportation to cooling facilities.
- Coordinate with the National Weather Service to assure access to early and accurate information about extreme heat events.
- Coordinate with health care system providers, social service providers, Emergency Medical Services, public safety agencies, 411 Information providers and others to develop timely access to the data needed for assessing

and characterizing the impacts of extreme heat events and to measure the values of prevention efforts.

Risk 2. Changes in hydrology and water supply; reduced snowpack and water availability in some basins; changes in water quality and timing of water availability

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1. Risk assessment

Climate change will likely impact the hydrology in Oregon in terms of water quantity, water quality, water supply, snowpack, and water availability in some areas. Increasing winter temperatures will affect snowpack in the Cascades, which will affect the timing of runoff and water availability in large areas of the state.

A study completed by the Climate Impacts Group at University of Washington indicates that approximately fifty percent of Oregon water users are located in areas of the state that are "snowpack dependent." This means that water use significantly depends on the use of natural storage, with water becoming available during heavy use periods as a result of snow melt. Loss of natural storage will mean less water will be available for users during summer and fall months. This issue will be compounded by warmer summer months and a longer growing season (Climate Impacts Group, 2009; Elsner et al., 2009). Significant declines in snow water equivalent (SWE) in the Pacific Northwest and a shift in precipitation from snow to rain coinciding with increases in air temperature since the 1950s are well documented (Mote, 2003b; Mote et al., 2005; Knowles et al., 2006, Chang et al., 2010).

2. Timing and geography of changes in hydrology

Cascade snowpacks are projected to be less than half of what they are at the beginning of the 21st century (Leung et al., 2004).

Hydrologic patterns vary annually and seasonally throughout the state. In general, however, basins are either snow-dominated, where the hydrologic pattern is marked by the majority of runoff occurring as a function of spring snowmelt, or rain-dominated, where the hydrologic pattern closely reflects the seasonal precipitation pattern. In other words, in snow-dominated basins, the peak runoff lags behind the period of the peak period of precipitation, since much of the precipitation occurs as snow, and is stored until springtime temperatures rise above freezing.

As average temperatures increase across the state, the amount of precipitation that falls as snow will decrease, and timing of the peak runoff period will begin to shift to earlier in the year. Lower elevation snowpacks are expected to show the greatest differences in timing and magnitude of snowmelt; much of the snow in the Cascades accumulates close to the freezing point (Hayhoe et al., 2004; Payne et al., 2004; Nolin and Daly, 2006; Oregon Climate Change Research Institute, 2010).

3. Risks related to changes in hydrology

The shift to warmer winters, which is what will cause the changes in hydrology, could result in some increase in winter flooding in basins that otherwise may experience flooding related to spring snowmelt runoff.

4. Summary of consequences of changes in hydrology

Ecosystems

Changes in hydrology and water supply will reduce water for instream uses like recreation and aquatic habitat, and could lead to increased proposals for surface water storage. Reduced snowpack and changes in precipitation regimes have the potential to increase forest damage from insects and pathogens. Changes in hydrology will potentially result in increased pollutant loads. Hydrologic changes will reduce the ability of wetland and aquatic systems and habitats to support populations of native fish species and provide other landscape functions. In particular, changes in the hydrology of streams important for coho salmon may reduce the viability of some coho populations. Over the long term, changes in streamflows will cause shifts in wetland and aquatic habitats, species, and communities, and may cause changes in terrestrial ecosystems. Freshwater systems in eastern Oregon are already under stress due to limited water quantity and quality.

Changes in hydrology will exacerbate water quality problems caused by increased average air temperatures, and potentially cause shifts in aquatic habitats, species, and communities. Changes in hydrology will reduce the ability of wetland and aquatic systems and habitats to support fish species and populations and provide other landscape functions.

Built and developed systems

Reduced water availability will reduce water available for junior irrigators and change water supply planning in many basins. Proposals for surface water storage may increase. Changes in hydrology have the potential to affect navigation at both high and low water levels.

Public health and safety

Reduced water availability can reduce the quality and quantity of available drinking water, and can also contribute to vector-, food-, and water-borne diseases. It can also threaten food production, thereby contributing to food insecurity, especially for low income populations. Native American Tribal Nations that rely on fish as an important part of their diet would be affected by reduced fish populations.

Economy

Water users suffering the most adverse consequences will be irrigators. Irrigated agriculture is a primary economic driver in Oregon, so without careful planning for the consequences of climate change, the Oregon economy may well suffer significantly. Changes in hydrology have the potential to significantly affect agricultural productivity until crops suited to new hydrologic conditions are developed. Reduced water availability can increase the cost to produce agricultural and manufactured goods. Water quality problems will increase the cost of domestic, commercial and industrial water supply and waste disposal. Public water systems may have to invest capital to assure adequate availability of drinking water. Reduced water quality and/or availability could affect demand for water recreation.

5. Agency actions that address changes in hydrology

- OWRD is developing an Integrated Water Resources Strategy with the participation and consultation of several state agencies. WRD, as the leader of this effort, is charged with including considerations of climate change in development of the Strategy.
- WRD monitors groundwater and surface water levels and manages the Umatilla Below Ground Storage Pilot Project.
- OPRD implements water conservation at water-limited facilities.
- DEQ has programs and authorities under the Clean Water Act and state laws to address water quality problems, including increased water temperatures.
- DEQ promotes recycled water use; DEQ has rules for recycled water and also is developing rules for the use of graywater.
- Local organizations such as Soil and Water Conservation Districts and Watershed Councils work with agricultural producers to implement irrigation efficiency projects, with support from state agencies including OWEB and ODA.
- OPHD and DEQ have assessed land use-related vulnerabilities to drinking water sources throughout the state, and provided these assessments to system operators.
- DSL issues permits and requires mitigation for earthwork in wetlands and waterways, which impacts the spatial and temporal distribution of water within a watershed.

6. Gaps in state capacity to address changes in hydrology

- Oregon needs reliable assessments of the effect of long-term shifts in temperature and precipitation on hydrology and water availability at the scale of the state's eighteen hydrologic basins.
- The technical assistance and incentives that are available are insufficient to improve the efficiency of agricultural, residential, industrial and commercial water use.
- Oregon lacks a comprehensive plan to address water availability and water quality issues.
- Oregon lacks a financing tool to assist the 900+ public water systems not eligible for federal capital assistance.
- Oregon lacks rules promoting water quality trading as a mechanism for supporting riparian habitat restoration projects.
- Oregon needs to complete development of the Integrated Water Resources Strategy that will include clear policies to provide sufficient water for both human and natural resource needs.
- Measurement is a critical tool to insure equitable and more efficient management of Oregon's water resources. Technology is available to increase monitoring of instream flows and diversions, but the resources are not available for implementation.

7. Needed actions to address changes in hydrology

Priority actions

Maintain the capacity to provide assistance to landowners to restore wetlands, uplands and riparian zones to increase the capacity for natural water storage.

Improve real-time forecasting of water delivery and basin yields to improve management of stored water.

Increase capacity to provide technical assistance and incentives to increase storage capacity and to improve conservation, reuse, and water use efficiency among all consumptive water uses.

Additional actions

Find resources to support both the loan program and the grant program authorized under HB 3369 for water supply infrastructure.

Develop planning standards for municipal water supply based on anticipated future hydrologic conditions.

Develop policies and incentives to maintain in-stream flows sufficient to support healthy fish and wildlife populations.

Increase institutional capacity for water supply planning and regulation.

Create a revolving fund to assist public water systems not eligible for federal capital loans and grants.

Complete the water right adjudication process.

Complete groundwater investigations.

Conduct a statewide assessment of long-term changes to basin hydrology.

Improve capacity to monitor surface water, ground water, and water use along with changes in water quality.

Develop rules for water quality trading.

8. Implementing the priority actions

Next steps

- Establish a coordinated program for implementing water conservation efforts statewide, and identify experts to provide assistance to water users and to assess projects.
- Develop criteria and funding for high priority water conservation efforts.
- Work with water interests to establish a unified approach to implement conservation measures.

Research and monitoring

Research and monitoring needed to increase technical assistance for water conservation include:

- Develop a comprehensive inventory of water conservation projects with estimates of costs and water savings.
- Develop standards for measurement and reporting protocols to validate conservation efforts.
- Assess the state's current water monitoring network to determine if improvements in location, type and method of measurement are necessary for adapting to climate change impacts.
- Complete basin yield analyses to provide management tools for future water allocations. Basin yield analyses will statistically establish water amounts available for storage, appropriation, and for instream flow protections.
- Estimate the benefits of technical assistance and incentive programs using data in available records.

Coordination

- Agencies involved in the priority actions include OWEB, OWRD, USFWS, DEQ, and OPHD's Drinking Water Program.
- Coordinate with USDA-NRCS and FSA to communicate that water-saving projects are among the state's highest priorities for Farm Bill conservation program funding.
- Coordinate with USBOR and communicate the value of BOR programs for water savings for irrigation districts.
- Coordinate with SWCDs and Watershed Councils to ensure they have the technical expertise and resources to assist the agricultural (and in many cases residential) sectors with water saving projects.
- Coordinate with irrigation districts to encourage water conservation projects in irrigation water delivery systems.
- Coordinate with the Freshwater Trust and other private partners who may provide incentives for keeping water instream.
- Enhance existing technical assistance and incentive programs by including information about climate change adaptation when working with local governments and stakeholders.

Resource requirements

- Maintain existing funding at OWEB, OWRD, and other state agencies for incentives for water use efficiency.
- Maintain existing technical resources at state agencies, SWCDs, and watershed councils to assist agricultural (and in some cases, residential) land managers on water use efficiency.
- Provide additional technical assistance program staff.
- Invest in improvements to the monitoring network and information delivery systems.
- Establish a tax credit program for projects that save at least 10 percent of the water used in an industrial, agricultural, or commercial process, and provide staff to manage the program.

- Funding for a small grant fund.
- Funding for revolving fund for state-regulated public water supply systems.
- Funding for basin yield analyses.
- Funding to expand the system for monitoring instream flows and diversions.

Risk 3. Increase in wildfire frequency and intensity

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1. Risk assessment

Strong relationships exist between climate and fire across the western U.S. but those relationships vary with the interaction among type of vegetation and climate (Littell et al., 2009). Analyses of fire history reveal a strong correlation of fire activity and decadal-scale natural climate variation (e.g., Pacific Decadal Oscillation), with larger areas burnt during warm/dry phases (Mote et al., 2003; Pierce et al., 2004; Gedalof et al., 2005; Trouet et al., 2006; Kitzberger et al., 2007). A recent study found that both the frequency of large wildfires and the duration of the fire season increased sharply in the mid 1980s in the western U.S., an increase that could largely be explained by changed climatic drivers (Westerling et al., 2006). Critical climate-sensitive processes, however, differ by ecoregion and vegetation type. In mesic forest types (i.e., predominately west of the crest of the Cascade Range), dry and warm summers exert the strongest climatic influence on forest area burnt, depleting fuel moisture and creating favorable conditions for fire spread (Littell et al., 2009). In contrast, in drier forest types in eastern Oregon the main climatic influence on wildfire activity is via facilitation of vegetation growth in winter(s) prior to the fire (i.e., fuel availability is an important limiting factor for fires) (Littell et al., 2009). Four critical factors—earlier snowmelt, higher summer temperatures, longer fire season, and expanded vulnerable area of high elevation forests (see below)—are combining to produce the observed increase in wildfire activity.

The likelihood of increased frequency and intensity of wildfire is very high.

Despite there being different drivers for wildfire for different forest types in Oregon, an increase in fire activity is expected for *all* major forest types in Oregon and the western U.S. under the climatic changes expected for the coming decades (Bachelet et al., 2001; Whitlock et al., 2003; Keeton et al., 2007). A 78 percent increase in forest area burned by the middle of the 21st century is estimated for the Pacific Northwest (Spracklen et al., 2009). Variability of these estimates depends on the climate scenario and estimation method used; local values range from 0 to 600 percent (McKenzie et al., 2004; Littell et al., 2009; Spracklen et al., 2009).

The actual incidence of future fires is not only driven by favorable climate conditions but also requires a source of ignition (usually lightning or human ignition sources) and a mechanism for rapid spread (strong winds and topography). The latter factors are strongly influenced by local conditions; firm projections that can use data on local conditions under climate change are not yet available. However, growing evidence points towards increasing lighting activity over the western U.S. under climate change (Price and Rind, 1994; Del Genio et al., 2007).

Westerling et al., (2006) come to a discomfiting conclusion for wildfires. They show that warmer temperatures appear to be increasing the duration and intensity of the wildfire season in the western United States. Since 1986, longer, warmer summers have resulted in a fourfold increase of major wildfires and a six-fold increase in the area of forest burned, compared to the period from 1970 to 1986. A similar increase in wildfire activity has been reported in Canada from 1920 to 1999

2. Timing and geography of increased frequency of wildfire

Predicting where and when wildfire will occur is still an imprecise science. Nonetheless, Littell et al., (2009) found that over the last century climate has been the strongest determinant for the amount of wildfire area burned in the Western United states. With respect to timing, when there is low precipitation, high temperature, and high drought severity immediately preceding and during the current year the amount of wildfire area burned is likely to higher than average. Westerling et al., (2006) used the most comprehensive data set of wildfire occurrences yet compiled for the western United States to analyze the geographic location, seasonal timing, and regional climatology of the 1166 recorded wildfires with an extent of more than 400 ha. They found that the length of the active wildfire season (when fires are actually burning) in the western United States has increased by 78 days, and that the average burn duration of large fires has increased from 7.5 to 37.1 days. Based on comparisons with climatic indices that use daily weather records to estimate land surface dryness, Westerling et al., (2006) attribute this increase in wildfire activity to an increase in spring and summer temperatures by about 0.9°C and a one- to four-week earlier melting of mountain snowpacks. Years with early snowmelt had five times as many wildfires as years with late snowmelt. With respect to geography they found that high elevation forests between 1680 and 2600 meters (~5500 to 8500 ft) that have been previously protected from wildfire by late snowpacks are becoming increasingly vulnerable. Thus four critical factors—earlier snowmelt, higher summer temperatures, longer fire season, and expanded vulnerable area of high elevation forests have been found to be the primary variables that will continue to influence wildfire activity.

There was an increase risk of wildfire from less moisture availability between 1970 and 2003 (Westerling et al., 2006). If this trend continues or becomes magnified in the future, most forested areas in Oregon will be at greater risk of wildfire. Adaptation planning for the risk of wildfire must include continuous monitoring of current and cumulative weather conditions, in addition to the abundance and moisture status of fuel in forested and highly vegetated areas near human infrastructure.

3. Risks related to increased wildfire

Higher average temperatures will increase the potential for more drought conditions, and thus increase environmental stress on forest ecosystems from drier conditions. The added stress also increases the risk of insect and disease infestations of trees, which leads to excessive mortality and effectively increases their flammability and the probability of fire. Large disturbances such as intense fire combined with altered climatic conditions are expected to rapidly transform forest ecosystems to new structural conditions and plant and animal compositions.

Naturally, any urban areas or areas containing human infrastructure that interfaces with forests with increased vulnerability are at risk of burning if a fire does occur.

Increased risk of wildfire will require additional human and financial resources to monitor fire activity, plan and implement more advanced prevention measures, purchase and maintain additional fire fighting equipment, coordinate and implement control efforts for active fires, and carry out restoration policies.

4. Summary of consequences of increased frequency of wildfire

Ecosystems

Increased temperatures and the potential for reduced precipitation in summer months, in addition to accumulation of fuels in forests due to insect and disease damage (particularly in eastside forests) present high risk for catastrophic fire. An increase in frequency and intensity of wildfire will damage larger areas, and likely cause greater ecosystem and habitat damage; loss of nutrients, biomass, and forest structure; and increased erosion.

Built and developed systems

Increased risk of wildfire will result in increased risk of property damage at the urban-wildland interface. Increased risk of wildfire may affect areas where wildfire has not been experienced in the recent past. Wildfires damage transportation infrastructure through direct heat damage and subsequent erosion events due to loss of vegetative cover that stabilizes slopes near roadways. Fires can disrupt transportation access, mobility and the movement of essential goods and services.

Economy

Increased risk of wildfire will result in increased potential for economic damage at the urban-wildland interface. Wildfires destroy property, infrastructure, commercial timber, recreational opportunities, and ecosystem services. Some buildings and infrastructure subject to increased fire risk may not be adequately insured against losses due to fire. Increased fire danger will increase the cost to prevent, prepare for, and respond to wildfires. Changes in forest ecology, forest health, species mix and forest productivity will all affect the economic productivity of Oregon forests and the economic health of rural communities.

Public health and safety

Increased incidence of wildfire will result in greater potential for injury and loss of life at the urban-wildland interface. Wildfire may affect areas where it has not been experienced in the recent past, thus potentially placing unprepared communities at risk. Fire-caused road closures reduce access, mobility, and the movement of essential services. Populations downwind from wildfires will be at risk for fire-related illness, injuries, and displacement. Fire control crews are at risk from fire-related injuries and illness. Increased air pollution from wildfires will result in greater incidence of asthma and increase severity of emphysema, cardiopulmonary disease and other respiratory illnesses.

5. Agency actions that address increased frequency of wildfire

- ODF maintains fire detection and suppression capabilities; a forest health monitoring and mapping program; administers the Oregon Smoke Management Program to manage prescribed burning on forestland; and manages forest thinning on state and private forestlands for fuels management and ecosystem health.
- The Forest Biomass Working Group is investigating opportunities to improve forest health and carbon sequestration while meeting renewable energy goals.
- ODF is incorporating adaptation to climate change in the new Forestry Program for Oregon.

- ODF is partnering with OSU to further develop and apply forest landscape modeling to quantify changes in forest carbon due to fire.
- OSU developed MC1, a model to predict vegetation distribution, natural fire frequency, and carbon pools and fluxes in response to alternative climate change scenarios.
- ODF supports the Federal Forestlands Advisory Committee to improve forest health and sustainability and reduce the high potential for catastrophic fire on federal forestlands through active management of fuel buildup.
- DEQ administers programs to reduce air pollution and manage prescribed burning. DEQ can provide special air quality monitoring to communities affected by smoke intrusion.
- DEQ and OPHD have partnered to provide health risk information regarding wildfires.
- OWEB provides grant funding for forest resiliency restoration programs, including prescribed burning and thinning.

6. Gaps in state capacity to address increased frequency of wildfire

- Oregon lacks a comprehensive and quantitative assessment of future wildfire risk.
- Oregon lacks a coordinated, interagency plan for fighting potentially more severe and frequent wildfires.
- Oregon's land use planning Goal 7 for Natural Hazards does not include wildfire as a natural hazard.
- Oregon's capacity for effective response to wildfires is insufficient for larger, more intense, or more frequent wildfires.
- Oregon does not have policies or mechanisms to influence wildfire mitigation on federal lands.
- The state and most local public health agencies have very limited capacity to track adverse health effects of wildfires.

7. Needed actions

Priority actions

Include wildfires in planning to reduce vulnerability to natural hazards.

Restore fire-adapted ecosystems to withstand natural recurring wildfires.

Develop short- and medium-term climate change adaptation strategies for forests and other fire-prone habitats, and improve development standards to reduce exposure to fire risk at the urban-wildland interface.

Improve the capabilities of state and local public health agencies to plan for and respond to the public health and safety risks of wildfire emergencies.

Additional actions

Provide resources to develop local climate adaptation plans that address all climate-related hazards.

Inventory and map areas vulnerable to wildfire.

Improve capacity to respond to fires near developed areas.

Include wildfires in planning to reduce vulnerability to natural hazards.

Assess the frequency, intensity and location of past fires.

Interagency coordination and plan for fighting wildfires.

Improve monitoring systems for smoke intrusion.

Conduct inventories and planning for fuels, fire and pest management in forests and other fire-prone habitats.

Assess the capabilities of state agencies to respond to wildfire emergencies.

Assess the need for short term inhalation air quality standards for smoke from wildfires.

8. Implementing the priority actions

Next steps

- Improve siting and fuel management standards for existing and new property developments to reduce risk of fire within the urban-wildland interface.
- Identify barriers to developing and implementing adaptation alternatives.
- Maintain Community Wildfire Protection Planning to identify additional areas that can benefit from reducing fire hazards.
- Develop policies, tools, practices, monitoring and adaptive management systems that identify and allocate forest areas for managing as long-term carbon sinks, carbon neutral sources of wood production/biomass, and as short-term sources as a means to reduce risks from insect, disease and wildfire.
- Develop a standardized approach for monitoring carbon stocks in Oregon's forests (including stocks in wood products) and their fluxes to track where forests are net sinks, net sources or neutral to atmospheric carbon dioxide.
- Foster homeowner, community and local or regional government understanding of the importance or Oregon's urban-rural forests to habitats along streams, wildlife corridors and parks and other open space.
- Develop innovative approaches to reduce forest fragmentation and reduce dispersed and low impact residential and other building development in rural-urban forest areas.
- Plan, conduct and monitor landscape scale thinning, slash treatment, prescribed burning and other treatment projects on private lands to restore the role of wildfire in forest ecosystems and to improve forest health and safety.

Research and monitoring

- Maintain capability to monitor, map, and report forest mortality from insect, disease, and drought conditions that increase flammability and probability of fire.
- Identify future research that addresses the effectiveness of proposed adaptation strategies.

- Monitor forest fuel loading in forestlands at the urban-wildland interface.
- Monitor succession and recovery of forestlands currently experiencing high rates of mortality from insects and disease.
- Maintain regular monitoring and reporting of the Energy Release Component estimates by ecoregion and forest zoning during fire season.
- Integrate forest fire research and monitoring within a policy planning framework based on the principles of adaptive management.
- Analyze current-year fire frequency and sizes with fire history regime to inform forest policy and planning efforts.

Coordination

- USFS, BLM, ODF, DSL, and city and county governments.
- Continue coordination across land ownership for forest resiliency treatments and fire protection.

Resource requirements

- Provide financial, technical, and other assistance to State Foresters to organize, train and equip rural fire departments to prevent and suppress wildfires.
- Fully integrates the occurrence of extreme fire events into planning for future fire risk.
- Pursue significant improvements to the structure and funding of the Oregon Department of Forestry's budget.
- Ensure active management of urban forests through inventory, planning, tree care, management and monitoring.

Risk 4. Increase in ocean temperatures, with potential for changes in ocean chemistry and increased ocean acidification

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1. Risk assessment

Ocean temperature

Ocean heat content and average sea surface temperature have been increasing on a global-ocean scale (Bindoff et al., 2007; Trenberth et al., 2007). There is considerable variation in basin-scale and Oregon coastal-scale temperature changes. Models predict Pacific Northwest coastal sea surface temperatures to increase by 1.2°C by the 2030-2059 period (Mote and Salathé, 2010). However, coastal upwelling dramatically affects Oregon's nearshore ocean temperatures as cold, nutrient rich subsurface waters rise to the surface in spring and summer. Average sea surface temperature in near-coastal environments varies by about 8°C seasonally (Mote and Salathé, 2010). If changes in climate alter the frequency, duration, or intensity of upwelling, there could be decreases in average nearshore temperatures during upwelling events and more dramatic temperature swings in the transitions between upwelling events and seasons. Higher ocean temperatures overall will result in species range shifts to the north.

Ocean acidification

As carbon dioxide concentrations increase in the atmosphere, the oceans absorb more and more of the gas, buffering the earth from some of the climate effects of atmospheric carbon dioxide, but also making ocean waters more acidic. Since the beginning of the industrial era, the oceans have absorbed approximately one-third of human-caused carbon emissions, lowering global average seawater pH by about 0.1 unit (Feely et al., 2008; Feely et al., 2009). Modeling based on climate scenarios suggests that surface-water pH could decrease by about 0.4 units by the end of the 21st century, putting both marine ecosystems and human societies at significant risk (Feely et al., 2008; Feely et al., 2009). For perspective, there is no evidence that ocean pH has been lower than 0.5 units below present values for at least the past 300 million years (Bindoff et al., 2007). These changes are expected to persist for centuries, even if atmospheric concentrations return to pre-industrial levels. Parts of the Oregon nearshore environment are particularly susceptible because seasonal upwelling brings deeper, more acidic waters to the coast, making coastal waters more acidic than the overall average (Bindoff et al., 2007; Feely et al., 2008). Some consequences of acidification, for example failures in cultured oyster recruitment, have already been documented in the Pacific Northwest (Miller et al., 2009). Similar consequences to other organisms are likely (e.g., Dupont et al., 2008), but the species and precise nature of the consequences are difficult to predict (Doney et al., 2009). Oregon may see direct reductions in shellfish species abundance and potentially dramatic indirect cascading ecological effects as lower trophic levels become significantly impacted.

Potential changes in coastal-scale circulation patterns

Potential changes in coastal upwelling and related circulation patterns can lead to dramatic species and habitat impacts. There is significant uncertainty in predicting changes in upwelling. While current models do not predict changes in along-shore coastal winds that drive upwelling (Mote and Salathé, 2010), the scale of current models is too coarse to adequately reflect the complexities of coastal circulation (Mote and Salath,é 2010). There is some concern that spring and summer north winds will increase due to a larger differential between land and sea temperature (Bakun, 1990), thus increasing the frequency, duration, or intensity of upwelling. A change in wind and upwelling patterns could also change the timing of the spring and fall transitions and affect the magnitude of related currents such as the coastal jet. Climate models project a delay in spring transition and more intense upwelling later in the season (Snyder et al., 2003), with potentially profound changes in productivity and recruitment of many organisms in the nearshore environment (Barth et al., 2007). The consequences of increased upwelling could be large in both a positive and negative direction, including increased phytoplankton production, an increase in hypoxia events, changes in larval transport and recruitment processes, and changes in the synchronicity of organisms' food supplies. Upwelling is a highly variable process and is driven by both large- and small-scale climate processes, and it will be difficult to detect changes beyond the current interannual and inter-decadal variation.

Potential increase in hypoxic conditions

Hypoxic conditions appear to be increasing in intensity, duration, and spatial scale on the Oregon and Washington continental shelf. Hypoxia off of Oregon results from a combination of locally intense upwelling periods and a global-scale reduction in oxygen levels of deep ocean waters (the source of upwelled water) (Grantham et al., 2004; Chan et al., 2008). It is unknown if upwelling will intensify, but the continued reduction of deep ocean oxygen levels has a high degree of certainty. If the increased hypoxia trend continues, it is likely there will be continued and intensified negative impacts to commercially and ecologically important fish and invertebrate species.

Potential increases in harmful algal bloom events

The frequency of harmful algal bloom events is on the rise globally (Anderson et al., 2010; Gilbert et al., 2005) and appears to be increasing Oregon nearshore waters. It is difficult to establish the link to global climate change due to the lack of long-term datasets on algal blooms. Ocean climate change factors, including increases in temperature, increases in stratification, and changes in upwelling can influence the frequency, intensity, and species in harmful algal bloom events. For example, increases in temperature elevates the growth of genera such as *Alexandrium* (paralytic shellfish poisoning), and could expand the range of warm water species northward (Moore et al., 2008). Increases in ocean stratification would favor dynoflagellates such as *Alexandrium* over non-motile phytoplankton species (Moore et al., 2008). Harmful algal bloom events pose both human health risks and risks to fish and wildlife species.

2. Timing and geography of climate-related changes that may affect Oregon ocean waters

The timing of potential changes summarized above varies in level of certainty. Some changes such as ocean acidification are already occurring.

Models predict Pacific Northwest coastal sea surface temperatures to increase by 1.2°C by the 2030-2059 period (Mote and Salathé, 2010). There is already some evidence of northward shift in distribution of some marine species such as Pacific hake (Phillips et al., 2007), pink shrimp (Hannah, in press), northern and flat abalone (Rogers-Bennett, 2007), and jumbo squid (Field et al., 2007).

Ocean pH has decreased (acidified) by 0.1 unit since the beginning of the industrial age, and models suggest a total decrease of 0.4 units by the end of the 21st century (Feely et al., 2008). However, upwelling systems are particularly vulnerable to acidification due to deeper, more acidic waters being brought to the surface. The California current system (which includes Oregon waters) will reach more critical levels of acidification decades before the prediction for the overall average for the ocean (Hauri et al., 2009)

The timing of potential changes in coastal circulation, hypoxia, and harmful algal blooms is uncertain.

The geography of changes depends on a number of factors, some of which have a high degree of uncertainty. Geographic differences in climate related changes in Oregon's ocean waters will be more evident and more variable in nearshore and shelf waters compared to waters farther offshore, due to effects of upwelling and associated circulation patterns. Areas of more intense and/or longer upwelling events may have lower temperatures during the upwelling season compared with today. Since the non-upwelled water will be warmer, these areas will display larger temperature variations between upwelling events. Waters off of Oregon are currently acidification "hot spots" because upwelled waters have a lower pH than the average for surface waters (Feely et al., 2008). Virtually the entire Oregon coast experiences upwelling; the strongest upwelling occurs south of Cape Blanco. The most frequent and severe hypoxia area is currently inshore of Heceta Banks on the central Oregon Coast. During years of severe hypoxia, hypoxic waters can encompass large portions of the Oregon continental shelf (Grantham et al., 2004; Chan et al., 2008). If hypoxic events increase in the future, expansion of hypoxic conditions to larger areas of the shelf is likely. Harmful algal blooms can occur anywhere on the coast.

Oregon estuaries and their biota will be impacted by the changes in ocean temperature and chemistry, especially in the more marine-influenced lower and middle estuary areas. Climate change factors discussed elsewhere in this document, such as sea level rise and changes in precipitation, will likely increase the entrainment of ocean water into estuaries and the total estuarine area impacted by ocean water changes. In addition, increases in river water temperatures and changes in timing and amount of precipitation will impact estuary habitats and species from the freshwater input side.

3. Risks related to changes in ocean temperatures and chemistry

Changes in habitat and species that may result from changing ocean conditions would vary considerably, depending on the intensity and timing of factors described above. Increases in overall ocean temperature will likely result in a northern shift in species ranges. Examples of apparent northward shifts in Pacific hake, pink shrimp, two abalone species, and jumbo squid are stated above. Ocean acidification could affect recruitment and survival of shellfish species, and can affect organisms at the base of the food chain such as coccolithophores and pteropods (Hauri et al, 2009; Cooley et al., 2009). Potential increases in upwelling could increase primary production, favoring organisms and food webs that could take advantage of the increased production. Changes in upwelling and related coastal circulation could also alter patterns of larval transport, changing recruitment dynamics of many marine species and altering the mix of dominant species (Parrish et al., 1981). Increases in hypoxia could alter benthic ecosystems, either due to direct mortality or through changes in food supplies in these habitats. Increases in harmful algal blooms can cause increased mortality to fish and wildlife vulnerable to the toxins.

4. Summary of consequences of changes in ocean temperatures and chemistry

Ecosystems

As described above the combination of climate change-related factors will lead to changes in species abundance and distribution in unpredictable ways. Shifting species ranges can dramatically affect existing communities. For example, the range expansion of the jumbo squid could lead to impacts on its primary prey species, including economically important Pacific hake, rockfish species, and salmon (Field et al., 2007). It is likely that ocean acidification will negatively impact some species and could result in dramatic changes in the ecosystem. Acidification can negatively affect growth, reproduction and survival of organisms which rely on calcium carbonate processes for shell or body parts, such as mollusks and echinoderms. Impacts to primary producers such as coccolithophores and organisms such as pteropods (important food item for fish) can have cascading ecosystem effects (Hauri et al., 2009). Changes in temperature and upwelling may be positive for some species and negative for others off of Oregon. If there are large increases in hypoxia, there is a potential for significant restructuring of benthic systems off of Oregon. In addition to human health concerns, harmful algal blooms directly impact marine fish and wildlife through direct mortality or decreased reproductive success (e.g., Hall and Frame 2010; Lefebvre et al., 2010; Levin et al., 2010). Population variation of many marine species is likely to increase due to direct biological effects of climate change (described above for several factors) and indirect cascading ecological effects. Variability in exploited species in particular will have socioeconomic ramifications for their associated fisheries.

Built and developed systems

Changes in ocean temperatures and chemistry are not expected to have direct consequences on built and developed systems.

Public health and safety

An increase in harmful algal blooms would increase risks to public health and safety. Increased toxic events would increase risk of poisoning from ingestion of shellfish. More events and potentially more different species of toxin-producing algae, could increase the number of seafood species subject to food safety concerns. Some species of algae can produce toxins dangerous for direct water ingestion or skin contact by humans (currently no record of these in Oregon ocean waters). If these species were to become established in Oregon, there would be an increase risk to swimmers, waders, anglers, etc.

Economy

Coastal recreation, commercial and sport fishing, wildlife viewing, and related tourist activities form a large part of Oregon's coastal economy. Changes that reduce fish populations or affect seafood or water recreation safety will negatively impact coastal economies. Oregon's commercial ocean fishery contributes approximately $220 million per year to Oregon's economy (not counting the distant waters fleet) (The Research Group 2007, 2010). Recreational fishing and wildlife viewing activities in the five coastal counties contribute $873 million to the Oregon economy, accounting for over one-third of the statewide economic contribution of these activities (Dean Runyan Assoc. 2009).

5. Agency actions that address ocean conditions

ODFW currently does not have a program with a direct objective of examining ocean climate change effects. However, existing programs with ODFW's Marine Resources Program monitor fisheries and other aspects of the ocean environment, and could contribute toward detecting and monitoring climate change effects. These include:

- Ongoing sport and commercial fishery monitoring, which records changes in fished marine species abundances, distribution, and life history characteristics. The monitoring program maintains constant communication with fishing fleets, whose members would likely be the first to observe new species moving into Oregon waters.
- Seafloor habitat inventory work and ongoing research on nearshore reef fish abundance, distribution, and habitat relationships.
- Estuarine shellfish and habitat assessments, and related shellfish biological research.
- Harmful algal bloom monitoring program (currently in its last year, unless additional funding is secured).
- DEQ and OPHD partner to sample near-shore waters for bacterial contamination, and communicate risks of water contact.

ODFW developed a Nearshore Strategy as part of the Oregon Conservation Strategy, with the express objective of conducting long-term research and monitoring of nearshore species and habitats to characterize them and monitor changes over time. Lack of funding has prevented full implementation of this program.

ODFW is also working with DLCD, DSL, OPRD and others on a process to designate and implement marine reserves in Oregon's ocean waters. Two pilot marine reserves have been designated and four additional areas are being evaluated for possible marine reserves. Continued implementation of the reserves is dependent on obtaining on-going funding. One of the primary purposes of the reserves will be to use them as reference areas (no extraction allowed) to conduct ongoing research and monitoring of reserve conditions, effectiveness, and the effects of natural and human induced stressors. On-going monitoring of the reference areas would be vital toward detecting and understanding climate-related changes in the nearshore system. Reference areas allow the ability to discern changes in species and habitats due to extraction vs. changes due to natural or climate-related shifts and variation.

6. Gaps in state capacity to address ocean conditions

- Incomplete inventory and assessment of nearshore and estuarine habitats and communities to inform management decisions.
- Lack of a program to implement the Oregon Nearshore Strategy.
- Lack of fishery-independent monitoring of nearshore species, which is needed to detect and monitor changes in species abundance and distribution; marine reserves, if implemented and funded, will fill part of this gap.
- Lack of predictive information on coastal-scale oceanographic changes likely to occur from climate change.
- Lack information on the impact of climate change on near-shore marine habitats, marine populations and marine communities.

7. Needed actions

Priority action

Increase research on the impacts of changes in ocean temperature and chemistry on estuarine and near-shore marine habitats and resources, including commercial and recreational fisheries

Additional actions

Implement Oregon's Nearshore Strategy.

Develop and implement a long-term monitoring program to characterize the communities and habitats in Oregon's nearshore waters, and use the information in conjunction with fisheries monitoring data to adapt management strategies to ensure sustainable commercial and sport fisheries.

Inventory estuarine wetlands and identify barriers to wetland migration in response to increased sea levels.

Expand estuarine shellfish and habitat monitoring.

Continue funding of the harmful algal monitoring program.

8. Implementing the priority action

Next steps

- Implement Oregon's Nearshore Strategy by developing and funding a program within ODFW to carry out recommendations of the strategy, including research and monitoring of nearshore species and habitats (see Research discussion below), adaptive resource management, and public process and information.
- Continue and expand existing monitoring programs within ODFW, including fishery monitoring programs, harmful algal bloom monitoring, estuarine shellfish and habitat assessments, and marine reserves monitoring.
- Develop a coordination mechanism for regional research and monitoring concerning ocean and estuary climate change affects, possibly through the West Coast Governors' Agreement on Ocean Health.

Research and monitoring

The big gap in the federal and university programs is Oregon nearshore species and habitat monitoring; ODFW is the best entity to fill that gap due to existing programs, planned future programs, and overall experience in the area.

- Continue and expand existing fishery monitoring programs.
- Continue and expand the harmful algal bloom monitoring program.
- Continue and expand estuarine shellfish and habitat assessments.
- Implement a nearshore species and habitat monitoring program to characterize nearshore species and habitats and monitor changes and variation in abundance, distribution, life history characteristics, and ecosystem processes.
- Implement marine reserves monitoring program as part of the overall nearshore program to determine natural vs. anthropogenic changes in the system.

Coordination

Federal agencies and universities have large monitoring programs that, in coordination with an ODFW program, could provide the information necessary to adaptively manage Oregon's marine resources for sustainability.

- NOAA monitors groundfish and other species on the outer continental shelf and slope on a periodic basis.
- A new ocean monitoring system is currently being installed on the continental shelf of the West Coast. Oregon's component will be administered by OSU. The system will provide continuous, real time oceanographic data and will significantly advance our understanding of oceanographic processes and ocean changes due to climate off the west coast.
- OSU's COAS and PISCO programs study and monitor nearshore coastal oceanography and rocky intertidal communities.

Resource requirements

- New resources will be required to undertake the steps and monitoring actions listed above.
- Implementing nearshore species and habitat monitoring would require a program to implement Oregon's Nearshore Strategy. New staff will be required to undertake biological resource monitoring in the marine environment.
- ODFW currently has a harmful algal bloom monitoring program, it is funded by a federal grant that will end in 2011. Continuation of this program would require obtaining a new source of funding.
- Expanding other existing ODFW monitoring programs to enhance monitoring related to ocean climate change affects will require additional staff for at-sea field work.

Risk 5. Increased incidence of drought

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1. Risk assessment

Drought has historically been an issue in Oregon; precipitation in the Pacific Northwest is highly seasonal. Most of the precipitation for the year falls in the period from October to March (Oregon Climate Service, pers. comm.). The Pacific Northwest is prone to three types of drought: low winter precipitation, low summer precipitation and lack of snowpack due to warm winter temperatures (Bumbaco and Mote, 2010). Due to the annual variability of precipitation in the Northwest, not all drought can be attributed to climate change. However, with more winter rainfall, declining snowpack and earlier spring snowmelt as a result of increasing air temperatures, drought is likely to increase through the next century.

2. Timing and geography of increased drought

The threat of drought in the state is a short term (now) as well as a long term concern; both rain- and snow-dominated basins are prone to drought in Oregon. Hotter, drier summers will impact rain dominated basins and snow dominated basins will be affected by earlier spring snowmelt and a declining snowpack. An analysis using eight global climate models show 3-6 month drought increasing highly in the Willamette Valley and Western Cascades through the end 21st century (Chang and Jung, 2010; Oregon Climate Change Research Institute, 2010). The inherent variability in precipitation in Oregon means that drought in the future may be driven by greenhouse gases or natural interannual variability. Additional stressors, such as increased water usage in increasingly hot and dry summers (either urban, residential or agricultural) may exacerbate drought conditions in the future (Oregon Climate Change Research Institute, 2010).

3. Risks related to increased drought

Drought will result from changes to hydrology and increasing average air temperature, both of which will affect water availability, soil moisture, and evapotranspiration rates. Drought conditions will likely increase the possibility of wildfire.

4. Summary of consequences of increased drought

Ecosystems

Longer and drier growing seasons and drought will result in increased demand on ground water resources and increased consumption of water for irrigation, which will have potential consequences for natural systems. Droughts affect wetlands, stream systems, and aquatic habitats. Drought will result in drier forests and increase chances for wildfire. Drought-related insects such as fir engravers and ash borers will cause an increase in the area of forestland with above normal rates of tree mortality. Droughts may affect the viability of some habitats, and over the long term could result in permanent change of certain habitats. Expansion of drought-tolerant species into new regions may stress plant and wildlife communities significantly.

Built and developed systems

Droughts will cause an increase in conflicts among irrigators and the need for oversight over water distribution. Droughts reduce water availability for domestic, commercial, and industrial uses.

Public health and safety

Droughts will reduce drinking water quality and quantity, and increase the risk of water-borne diseases. Droughts may also reduce food production and the viability of subsistence fisheries, and thus contribute to food insecurity.

Economy

Droughts will cause significant economic damage to the agriculture industry through reduced yields and quality of some crops. Droughts can increase irrigation-related water consumption, and thus increase irrigation costs. Droughts can reduce opportunities for water-based recreation, and thus reduce income for some rural communities. Droughts can increase stresses on forests, and changes in forest ecology, forest health, species mix and forest productivity will all affect the economic productivity of Oregon forests and the economic health of rural communities. Public water suppliers facing drinking water availability shortages will have to invest in capital improvements to acquire, treat, and distribute water from new sources.

5. Agency actions that address drought

Agencies and actions identified under Risk 2 for changes in hydrology also apply to the increased likelihood of drought.

- The OWRD manages water use and water rights throughout the state, which becomes far more critical in periods of reduced water availability.
- OWRD is developing an Integrated Water Resource Strategy (IWRS) with the participation and consultation of several state agencies.
- OWRD monitors groundwater and surface water levels and manages the Umatilla Below Ground Storage Pilot Project.
- OWRD participates in the Drought Council, and leads the Water Availability Subcommittee.
- OPRD implements water conservation at water-limited state-owned recreational facilities.
- DEQ administers water quality programs, where low-flow permit conditions in discharge permits for wastewater treatment plants may need to be in place for longer periods, which could require operators to implement alternatives to surface water discharge. Lower flows will result in more stringent effluent limits in water quality permits.
- OWEB provided funding for an OSU study on surface water availability and summer streamflow.
- ODA creates the initial requests to USDA for disaster declaration, which can make additional emergency resources available to agricultural producers; determines economic impact of a drought on agriculture, in collaboration with OSU and USDA; ODA assesses immediate, ongoing, and long-term needs of the affected agricultural community, and works with state and federal agencies to address needs.
- OWEB provides grant funding for water conservation projects and water leasing including temporary leases during drought and low water periods.

6. Gaps in state capacity to address increased drought

- For many of Oregon's 250+ crops, it is unknown how drought, combined with the CO_2 fertilization effect, will affect crop quality, overall crop production, and disease and pest risk to crops.
- Oregon needs to determine how increased drought will affect ground water resources.
- Oregon lacks a comprehensive water plan for extreme drought conditions.
- More information is needed on likely drought-related impacts to natural habitats, including seasonal wetlands, springs and seeps, and the wildlife that depend upon these resources.
- Oregon's public health system has very limited capacity to track adverse health effects of drought on communities and susceptible populations.

7. Needed actions

Priority action

Increase capacity to provide technical assistance and incentives to increase storage capacity and to improve conservation, reuse, and water use efficiency among all consumptive water uses.

Additional actions

Restore wetlands and riparian zones to increase the capacity for natural water storage.

Increase the network of monitoring stations (streams and precipitation).

Develop policies and incentives to maintain in-stream flows sufficient to support healthy fish and wildlife populations.

Identify areas of the state most likely to be critically affected by drought.

Develop a comprehensive water management plan for extreme drought conditions.

Assess the vulnerability of groundwater resources to prolonged drought conditions.

Support research into better-adapted crop varieties and evaluate the combined effects of drought and CO_2 fertilization on crops.

Conduct or promote research on the likely impacts of increased drought to fish, wildlife, and habitats; and human populations.

Improve the capabilities of state and local public health agencies to plan for and respond to the public health and safety risks drought.

Increase state water management capabilities.

8. Implementing the priority action

The short-term priority action for the risk of drought is also one of the actions for the risk related to changes in hydrology. The next steps outlined below are also among the next steps for the hydrology risk above.

Next steps

- Establish a coordinated program for implementation of conservation efforts statewide, and identify experts to provide assistance to water users and to assess projects.
- Develop criteria and funding for high priority water conservation efforts.
- Maintain existing technical resources at state agencies, SWCDs, and watershed councils to assist agricultural (and in some cases, residential) land managers on water use efficiency.
- Maintain existing funding at OWEB, OWRD, and other state agencies for incentives for water use efficiency and water right purchases and leases.

Research and monitoring

Research and monitoring needed to increase technical assistance on water conservation include:

- Work with water interests to establish a unified approach for implementation of conservation measures.
- Estimate the benefits of technical assistance and incentive programs using data in available records.
- Assess the acceptance and utilization of new techniques and technologies to improve water use efficiency.
- Establish thresholds of maximum use during drought periods for surface and groundwater use in areas where there is a strong intermingling ground and surface waters.

Coordination

- Agencies involved in water conservation include OWEB, OWRD, USFWS, DEQ, and OPHD’s Drinking Water Program.
- Coordinate with USDA-NRCS and FSA and communicate that water-saving projects are among the state’s highest priorities for Farm Bill conservation program funding.
- Coordinate with SWCDs and Watershed Councils to ensure they have the technical expertise and resources to assist the agricultural (and in many cases residential) sectors with water saving projects.
- Coordinate with the Freshwater Trust and other private partners who may provide incentives for keeping water instream.
- Coordinate with USBOR and communicate the value of BOR programs for water savings for irrigation districts.
- Coordinate with irrigation districts to encourage water conservation projects in irrigation water delivery systems.

Resource requirements

Resources needed to increase technical assistance on water conservation include:

- Additional technical assistance program staff.

- Funding for a small grant fund.
- Establish a tax credit program for projects that save at least 10 percent of the water used in an industrial, agricultural, or commercial process, and provide staff to manage the program.

Risk 6. Increased coastal erosion and risk of inundation from increasing sea levels and increasing wave heights and storm surges [Return to Table of Contents]

1. Risk assessment

The coast is vulnerable to a number of climate-related impacts. Oregon's winter storms have been the primary factor for coastal erosion and flooding (Ruggiero, 2008). Maximum wave heights have increased significantly from the period of the late 1970s to 2005, from 9 meters to about 12 meters. Winter is the dominant season for storms that produce significant waves on the Oregon coast. There is some evidence that these storms will increase in frequency, but not intensity in the future. It is unclear if the increasing wave heights trend observed in the late 20th century will continue into the future, though the combination of the possibility of increasing storm-generated wave heights and the likely trend of rising sea levels may present a substantial threat to the Oregon Coast (Ruggiero et al., 2010).

Rising sea levels are also a primary mechanism through which climate change will affect coastal erosion. Sea levels are generally increasing through two mechanisms, by melting glaciers and ice caps, and through the expansion of ocean waters as they warm. Sea level rise at the local scale is a result of the combined effects of global sea level rise, vertical land movement, and seasonal ocean elevation changes (Mote et al., 2008). From 1961 to 2003, the average rate of global sea level rise was 1.8 +/- 0.5 mm/year (IPCC SPM, 2007). There is near certainty that the rate of sea level rise will increase in the future as a result of global warming, with the potential of greater than 1.0 meters expected by 2100. Evaluating the consequences of intensified and more frequent hazards is complicated by Oregon's tectonic setting; some parts of the coast are increasing in elevation, and some are subsiding, due to tectonic forces. While it is certain that sea level will rise with increasing temperatures, some uncertainty lies in the magnitude of the increase, given the complexities of glacier dynamics and total ice melt contribution. However, all approaches suggest a significant increase in sea level rise through the end of the century (Ruggiero et al., 2010, Oregon Climate Change Research Institute, 2010).

2. Timing and geography of increased coastal erosion

Sea level rose globally through the 20th century and is expected to continue to rise in small increments through the 21st century. Along the Oregon coast, the amount of apparent sea-level rise will vary considerably because of local processes of land subsidence and uplift. On the central coast, sea level rise has displaced vertical land movement. However, in southern and northern Oregon, upward vertical land movement has been greater than that of sea level rise. By 2050, sea level rise should be greater than vertical land movement along the entire Oregon coast (Ruggiero et al., 2010). There is some evidence in global climate models that the storm track may shift poleward in the future, but uncertainties regarding natural variability and model limitations remain (Yin, 2005).

3. Risks related to increased coastal erosion

The global increase in average annual air temperatures is one of the factors contributing to sea level rise.

4. Summary of consequences of increased coastal erosion

Ecosystems

Higher sea levels and more powerful storms will alter coastal shorelines, shorelands, and estuaries. Increased wave heights, storm surges, and sea levels can lead to loss of natural buffering functions of beaches, tidal wetlands, and dunes. Accelerating shoreline erosion has been documented, and is resulting in increased applications for shore protective structures. Shoreline alterations typically reduce the ability of beaches, tidal wetlands, and dunes to adjust to new conditions. Under a combination of high tide, storm surge and high waves, coastal spits can be breached or overtopped, which in turn will dramatically change estuarine circulation and productivity. Estuarine shorelines will likely shift with changes in sea level, but the nature, rate and magnitude of such changes in Oregon's estuaries are not well understood. Tidal wetlands, including some wetland restoration and mitigation sites, may be lost because they aren't able to migrate inland due to hardened shorelines and bulkheads. Estuarine intertidal areas may be lost if sediment inputs are insufficient to maintain equilibrium with increased tide levels. Intertidal communities and habitats will shift in response to changes in the frequency of inundation, salinity, and water depth, all of which can be affected by erosion and changes in sea level.

Built and developed systems

Increasing sea levels, wave heights and storm surges will increase coastal erosion and likely increase damage to private property and infrastructure situated on coastal shorelands. Coastal erosion and the common response to reduce shoreland erosion can lead to long-term loss of natural buffering functions of beaches, tidal wetlands, and dunes. Applications for shoreline alteration permits to protect property and infrastructure are increasing, but in the long term they reduce the ability of shore systems to adjust to new conditions. Coastal erosion can affect transportation infrastructure and thus restrict mobility, access, and delivery of essential services. Some of Oregon's largest and most popular ocean parks are at risk from coastal erosion. By mid-century, more areas are likely to become regularly inundated by high tides or storm surges.

Economy

Property and infrastructure at risk of damage due to coastal erosion and inundation will eventually need to be protected, repaired, rebuilt, or relocated.

Public health and safety

Higher sea levels could eventually result in saltwater intrusion into coastal aquifers used to supply domestic and agriculture uses. Higher waves and storm surges can increase risk of injury and death to residents of shoreland properties. High waves increase the potential for increased storm-related injuries and death.

5. Agency actions that address increased coastal erosion

Several state agencies have programs or authorities that address coastal erosion.

- DOGAMI is partnering with NOAA, the University of Washington, OHSU, OSU, DLCD and OPRD in developing and maintaining the Oregon Beach and

Shoreline Monitoring and Analysis Program (OBSMAP), which includes a monitoring network and the development of shoreline change model.

- In partnership with researchers at OSU, DOGAMI is examining wave climate trends and historical storm surge and sea level trends from existing tide gauges to establish the best documentation available of West Coast wave climates, including their extremes, and how they depend on the changing climate.
- DOGAMI is also collaborating with OSU in modeling 1.0 percent and 0.2 percent annual probability wave runup models in Oregon for FEMA. DOGAMI is developing techniques to model the “500-year” flood as part of FEMA RiskMAP.
- OWEB provided funding for a west coast-wide sea level rise study by the National Academy of Sciences under the West Coast Governors’ Agreement, which will produce estimates of sea level rise and changes in storminess along the west coast for 2030, 2050, and 2100. OWEB also provides grants and funding for coastal restoration and protection, including estuaries and wetlands.
- DLCD is partnering with NOAA to develop a proof-of-concept and scope of work for a web-based Climate Adaptation Planning Information System (CAPIS) for local adaptation planning in coastal areas. CAPIS is being designed to provide access to information about sea level rise, storm surge, and inundation in coastal communities.
- DLCD provides funding to DOGAMI to monitor beach erosion rates.
- DLCD is developing an inventory of the location, condition, and legal status of dikes, levees, and other reclamation infrastructure around Oregon’s outer coast estuaries.
- OPRD is implementing measures to stabilize, abandon or relocate threatened coastal facilities and infrastructure.
- OPRD is managing more permit applications for coastal stabilization projects.
- ODOT is preparing scour analyses of 69 coastal bridges under its jurisdiction; forty-two (42) bridges have been analyzed and are considered very stable.
- DSL issues permits for bank stabilization projects in Oregon’s estuaries.

6. Gaps in state capacity to address increased coastal erosion

- The available maps and data on potential inundation zones along coast, including maps of built infrastructure and natural environment, are imprecise.
- There is a lack of reliable information on rates of sea level rise (‘relative sea level rise’) at the community level.
- Long-term sea level rise is not a principal factor in Goals 17 and 18, although it should be for land use planning for coastal and shoreland areas.
- Oregon lacks information about the cumulative effects of beachfront and estuarine shorelines protective structures.
- Oregon lacks a policy framework to use restoration of natural habitats and features as a strategy to buffer the effects storms, waves, and higher sea levels.
- Oregon does not have a policy framework for managing retreat from areas subject to increased threat of climate-related hazards.

7. Needed actions

Priority action

Inventory and map coastal shorelands that are at risk of erosion or inundation, or are barriers to shoreline migration, and develop long-term state and local adaptation strategies for shorelands.

Additional actions

Adopt coast-wide shoreland setback requirements based on anticipated 50 year shoreline retreat due to increasing chronic coastal erosion.

Develop policies that help limit development and post-disaster reconstruction in hazard-prone areas.

Provide resources to develop local climate adaptation plans that address all climate-related hazards.

Identify and protect lands that will allow for up-slope migration of tidal wetlands in response to sea level rise.

Complete the development of a beach transect monitoring system (OBSMAP).

Develop BMPs and guidelines to mitigate shoreline erosion and stabilize development at risk of coastal erosion.

Develop maps on how sea level rise will affect river levels around Oregon.

Develop a long-term policy framework and plan for moving infrastructure and the geographic footprint of communities at risk of damage and loss due to shoreline change.

Strengthen the policy framework and standards to increase the protection of natural resources and landscape functions that buffer the effects of storm surges, waves, and higher sea levels.

Increase network of tide gauges.

Develop an incentive-based shoreline erosion hazard mitigation fund.

8. Implementing the priority action

Next steps

- Inventory and map areas and infrastructure subject to inundation and erosion due to storm surge, waves and sea level rise, including likely timing, vulnerability maps.
- Develop state-level, coast-wide, and local strategies for response to the threat of sea level rise and coastal erosion.

Research and monitoring

- Inventory and map estuarine shorelands and intertidal lands, including ownership, to identify possible barriers to migration of tidal wetlands in response to sea level rise.

- Establish sea-level rise and erosion scenarios that allow for emergency management training and preparation as well as priorities for land acquisition and protection.

Coordination

- Continue to use the Coastal Natural Hazards and Processes Working Group as a forum to monitor conditions and assess approaches for managing areas subject to erosion and other hazards.

Resource requirements

- Maintain the efforts of the Oregon Coastal Management Program, which includes all state agencies and local governments with some responsibility for managing coastal resources, to provide technical assistance, grant funds, and coordination for efforts to reduce vulnerability and exposure to coastal hazard risks.
- Compete for federal disaster preparedness and coastal management funds to improve the ability of local communities to prepare for and respond to coastal hazards and the effects of climate change.

Risk 7. Changes in the abundance and geographical distributions of plant species and habitats for aquatic and terrestrial wildlife

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1. Risk assessment

Vegetation has responded to recent climate change over the last century, with rapid changes since the mid-1970s (Shafer et al., 2010). Climate has long been identified as a primary control on the geographic distribution of plants (Forman, 1964; Box, 1981). Research from a variety of ecosystems and spatial scales has described the effects that climate has on plant species distributions and ecosystem type (Davis and Botkin, 1985; Overpeck et al., 1990; Guisan and Zimmerman, 2000). The paleoenvironmental record provides clear evidence that species respond individualistically to climate change, and supports the current scientific consensus that the geographical distributions of plant species will change as climate changes (Walther et al., 2002; McLachlan et al., 2005; Wang et al., 2006; Bachelet et al., 2001; Lawler et al., 2009; Shafer et al., 2001; Thuiller et al., 2008; Xu et al., 2007; Pitelka, 1997; Araujo et al., 2005; Jurasinski and Jurgen, 2007; Jackson and Overpeck, 2000; Sans-Elorza et al., 2003; McKenney et al., 2007; Higgens et al., 2003; Huntley, 1991; Hansen et al., 2001; Rehfeldt et al., 2006).

A number of different types of uncertainties (Giorgi, 2005) are associated with the scientific community's understanding of how Oregon's vegetation may respond to potential future climate changes.

Some plant species in Oregon, particularly those with economic value such as Douglas-fir, have received a significant research attention (Shafer et al., 2010). However, for many other plant species, relatively little is known about how they may respond to future climate changes. Numerous studies in Oregon and elsewhere are contributing to improved understanding of how plants will respond to future climate conditions. Insights gained from such studies will be incorporated into models to improve vegetation simulations. Vegetation models have some limitations, particularly in the inability to project changes in amount and variability of precipitation.

Given rapid changes in Oregon's vegetation in recent past, coincident with the period of enhanced warming in Oregon, the likelihood that the geographic distribution of many plant species will change in response to changes in climate conditions is very high. A number of changes in the distribution of species considered invasive have been documented, and the fossil record shows that historic changes in plant and animal distributions were highly correlated with changes in climate.

2. Timing and geography of the shift in habitats and species

Changes in vegetation are relatively continuous through time with different rates of change for each species. Estimates have been made that the geographical range of many North American tree species will have to expand at rates of 100-1000 meters per year in order to successfully adapt to changes in climate conditions projected for this century (Davis and Zabinsky, 1992; Iverson and Prasad, 2002). As conditions warm, species are generally expected to move both toward the poles and to higher elevations, although complex topography, interspecies relationships, and feedback processes can cause shifts in other directions. There is general agreement in vegetation models that high elevations of subalpine forest and tundra as well as shrublands in Eastern Oregon will contract under future climate change.

Along the Oregon coast, the amount of sea-level rise will vary considerably because of local processes of land subsidence and uplift, which will determine the impact on coastal species. In some locations, particularly the area around the mouth of the Columbia river and the coast south of Florence, the land is lifting; in some areas this uplift seems to roughly counterbalance global sea-level rise in the short-to medium-term, resulting in little or no local apparent sea-level rise. The north-central coast, in contrast, is subsiding and may experience local sea-level rise that is greater than the global average as a result. Elsewhere on the coast, land movement is minimal, and sea-levels are expected to roughly track the global average (Lawler et al., 2008).

Conclusive evidence of changes in terrestrial species distributions that are correlated with changes in climate is not available for Oregon. However, California's indicator of climate change for species distributions—Forest Vegetation Patterns—reports that the lower edge of the conifer-dominated forests of the Sierra Nevada has been retreating upslope over the past 60 years, transitioning to oak-dominated and chaparral vegetation. The contraction and transition is consistent with predicted forest responses to future climate conditions (Lenihan et al., 2003).

3. Risks related to the shift in habitats and species

Long-term shifts in habitats will be driven by changes in both temperatures and hydrologic regimes. More geographically limited changes in habitats will occur as a result of particular climate-related events like increased intensity of precipitation, droughts, landslides, and floods. Increased insect and plant pests have the capacity to change species mixes and habitats. The loss of wetland ecosystems will directly affect several species and habitats.

4. Summary of consequences of the shift in habitats and species

Ecosystems

Changes in temperature and precipitation regimes will result in a gradual migration of some species and habitats north and to higher elevations. Species that cannot migrate or shift their range quickly enough to respond to climate change, or that have specific life-history needs that cannot be met through migration, will likely experience a decline in population numbers, potentially leading to extinction. Changes in the range of some species are already being observed. Climate-sensitive species already under stress (e.g., the Oregon chub) may be lost as habitat dwindles.

Invasive species can reduce habitat quality and decrease biodiversity. Species identified for special management under state or federal endangered species laws that are currently under environmental stresses could be lost. Risk of damage by insect and plant pests, which can result in significant damage to native species and communities, will increase with warmer temperatures. Alterations to the species composition of native ecosystems will likely result in a decline in important ecosystem services, including water quality and quantity, carbon storage, soil stabilization, flood control, and nutrient cycling (Hooper et al., 2005).

In coastal wetlands, rising sea levels have historically been counterbalanced by vertical gain through sedimentation; sediment and organic matter that is brought into the estuary system accumulates, raising the elevation of the wetland floor itself. However, in at least some estuary systems future sea level rise may be too rapid to allow for this kind of adaptation. In that case, these habitats and the ecosystem services they provide will persist only if they have room to "migrate" landward to accommodate the rising sea level (Burkett and Kusler, 2000). In many developed areas of the coast, however, bulkheading and other kinds of shoreline armoring will prevent this landward migration.

Public health and safety

Changes in habitats and species have the potential to affect human health through pollen production (allergies/respiratory illness); poisonous plants (adverse reactions); habitat for new disease vectors (emerging infections); and encounters with wildlife near residences (injuries).

Economy

Risk from insect and plant pests will intensify with warmer temperatures. Plant pests may also become more competitive, which can potentially result in significant economic damage to crops and livestock. Climate change impacts to fish, wildlife, and habitats are likely to negatively affect the estimated $2.5 billion spent annually on fish and wildlife-based recreation in Oregon (Dean Runyan and Associates, 2009).

5. Agency actions that address the shift in habitats and species

- The Oregon Department of Forestry is developing an inventory of current forest tree and other plant species distributions, which will provide a monitoring baseline by which actual changes in species geography can be quantified and mapped.
- ODF is also maintaining monitoring and control of invasive species.
- ODF collaborates with USFS and BLM on assessing the effects of climate change on the geographical distribution of tree and other plant species.
- ODF also continues to implement forest insect and disease monitoring in cooperation with the U.S. Forest Service, forest landowners, and other cooperators.
- ODF continues as a member of the Oregon Invasive Species Council and support council activities.
- In collaboration with ODA and other cooperators, ODF assists forest landowners in identifying, preventing, and controlling forest insects, diseases, and weeds.
- The Oregon Department of Fish and Wildlife has prepared a report to the Global Warming Commission on the likely impacts of future climate change on the state's fish, wildlife, and habitats and some suggested policy and management strategies for adapting to these changes.
- ODFW is working to update the Oregon Conservation Strategy and the Oregon Nearshore Strategy to include information on climate change impacts and adaptation strategies.

- DSL considers ecological priorities as identified in watershed prioritizations, the Oregon Conservation Strategy, and/or other assessments in permit and mitigation decisions.
- Implement a Collaborative Planning, Monitoring, and Management project with stakeholders and landowners.
- OPRD is modifying restoration and planting plans to favor simpler, robust communities; expanding habitat areas anticipating loss of key species. Enhance and restore habitat for threatened and endangered species currently under stress. Acquire adjacent lands providing connectivity for wildlife.
- OWEB provides grants and funding for the protection of key wildlife habitats, species and habitat status and trends monitoring and evaluation, and floodplain restoration and protection.

6. Gaps in state capacity to address the shift in habitats and species

- The Oregon Conservation Strategy provides a good framework for increasing the adaptive capacity of Oregon' fish, wildlife, and habitats, but additional policy tools are needed to support implementation of the strategy.
- More information is needed on current conditions of native species and habitats, projected climate impacts on species and habitats, and strategies for improving the resilience of species and habitats to climate change.
- Ecological predictions for the effect of climate change on the full set of native species and habitats are incomplete for developing effective adaptation policies.
- Large scale vegetation sampling is currently relatively coarse across the state of Oregon and will need supplemental sampling locations to sufficiently detect, quantify, and effectively monitor the actual changes in species distributions.

7. Needed actions

Priority action

Identify ways to manage ecosystems that will improve their resilience to changes in climate conditions.

Additional actions

Improve protection of riparian areas, wetlands and wildlife habitats in local land use plans.

Develop incentives and other policy tools for conservation of native fish, wildlife, and habitats.

Identify critical habitats and migration corridors that need increased protection against long-term degradation.

Improve ability to monitor change in natural systems, and to monitor and map plant species distributions.

Increase research on impacts of climate change on fish, wildlife, and habitats, including plant and wildlife diseases.

Re-evaluate Oregon's Endangered Species Act to consider how the act will deal with species moving into and out of the state in response to climate change.

Develop research and methods to predict and validate changes in habitats, species, forests, crops, and plant health in response to changing climate conditions.

8. Implementing the priority action

Next steps

- Research habitat resilience initiatives in other western states to identify possible strategies for consideration in Oregon.
- Integrate climate factors into the revised Conservation Strategy for Oregon.
- Continue funding of priority habitat protection and restoration programs and invasive species management programs through OWEB, ODA, ODFW, ODF and other state agencies.

Research and monitoring

- The information base for developing adaptation policies needs mapped data on actual species distributions and species distribution modeling. Develop distribution maps based on likely climate change scenarios to inform habitat and species management decisions.
- Analysis of change in species distributions will help invasive species management efforts. Monitoring change in species distributions will require supplemental sampling in existing federal vegetation monitoring systems.
- Expand research projects to model and map species distributions from existing inventory data. Develop research and methods to validate current predicted changes in habitats, species, forests, crops, and plant health in response to changing climate conditions.
- Organize a technical workshops and conference within the forest and rangeland science community to develop long term research plans for inventory, monitoring and analysis with the goals of quantifying actual changes in species distributions predicted to occur from climate change.
- Evaluate effectiveness and sufficiency of existing inventory systems to detect, quantify, and account for actual changes in the distribution of individual forest and rangeland plants.
- Inventory existing and current vegetation sampling for species distribution modeling and mapping.

Coordination

- USFS, Forest Inventory and Analysis (FIA), BLM, ODF, DSL, county and city governments, OCCRI, OUS.
- Mapping and modeling will require partnerships, collaborations, and integration among all federal and state natural resource agencies and universities.

Resource requirements

- Monitoring and mapping is an iterative process that will require long-term contributions among federal and state natural resource agencies, universities, environmental organizations, natural resource-based industries, and private stakeholders.

- Allocate resources for long term monitoring and analysis of forest inventory data.
- Establish a fully funded program within OCCRI to model and map species distributions and perform comparisons among multi-temporal inventories.
- Organize a technical work group to address funding shortfalls within FIA, which collects data on vegetation that includes non-tree plant species, which are more sensitive than trees to changes in climate.

Risk 8. Increase in diseases, invasive species, and insect, animal and plant pests

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1. Risk assessment

Trends in human diseases associated with vector-, water-, and food-borne diseases have been increasing in recent years. Human infections from West Nile virus and *Cryptococcus gattii* have only been identified in the Pacific Northwest during the recent years. Algae blooms in fresh water systems have increased in number and duration of occurrences in Oregon during the last five years.

Other diseases, along with insect and plant pests, affect primarily agricultural crops. Climate change is expected to enhance invasion risk from many crop diseases, pests, and weeds (Bradley et al., 2009), ultimately increasing the stress on crop plants and requiring more attention to pest and weed control. Higher atmospheric CO_2 levels can also preferentially benefit some invasive species over native or beneficial species.

Human diseases

Many vector-borne pathogens are sensitive to temperature. West Nile virus (WNv) infection, for example, already exhibits strong seasonality with peak transmission in late summer in the Northwest; longer summers with higher temperatures may substantially increase the incidence of WNv fever and encephalitis in Oregonians. Warming waters in the Pacific Northwest could lead to higher concentrations of *Vibrio* spp. in shellfish beds and more prolonged periods of summer risk. Flooding events may lead to the washing of *Cryptosporidium parvum*, a protozoan agent of diarrhea in cattle, along with other animal intestinal indwellers, into drinking water reservoirs (National Research Council, 2001).

The fungus *Cryptococcus neoformans* lives in dead or rotting trees and has been notorious as a cause of meningitis in patients with organ transplants or AIDS, but one variety has shown a particular ability to infect even healthy hosts (Speed and Dunt, 1995). This variety, known as *gattii*, was thought to have been restricted to tropical and subtropical areas, but caused an outbreak on Vancouver Island beginning in 1999. A novel genotype of *C. gattii*, VGIIc has recently emerged in Oregon (Brynes et al., 2010) and infections appear to be more virulent and have a more complicated clinical course than the more common *C. neoformans*. Researchers hypothesize that the establishment of the fungus in this area may have been due to climatic changes (Kidd et al., 2004).

The net effect of climate change on communicable diseases cannot be predicted. However, given the dynamic interplay among reservoirs, vectors, human hosts, and the environment, there is a high degree of confidence that communicable disease patterns will change.

Incidence of waterborne disease can be affected by changes in water temperatures and the frequency and intensity of precipitation (Portier et al., 2010). Infectious microorganisms that can cause waterborne disease include parasites that cause *cryptosporidiosis* and *giardiasis*, bacteria that cause *legionellosis* and cholera, viruses that cause viral gastroenteritis, amoebas that cause dysentery and amoebic meningoencephalitis, and algae that cause neurotoxicity. These microorganisms can be found in water used for drinking and food preparation, cleaning, irrigation, and recreation. The effects of climate change are anticipated to increase the frequency and range of waterborne diseases with rising temperatures and more incidents of flooding.

Insect and plant pests and plant disease

Climate change, as well as increases in atmospheric carbon dioxide concentrations, can affect insect and plant pest and disease populations in several ways. Some insect pests are able to expand their ranges as warmer temperatures expand northward, and invade areas where they were previously not a problem. Conversely, some insect pest populations may decrease if warmer growing conditions are no longer suitable to support them. Increased temperatures may benefit species such as the Argentine ant, some warm-water North American fish species, and shrubs (Dukes and Mooney, 1999). Models have also predicted that ranges of certain invasive species will contract under climate change (Dukes and Mooney, 1999).

Higher CO_2 concentrations in combination with changing climate conditions can also preferentially benefit some invasive species over native or beneficial species. For example, several researchers have suggested that juniper expansion across the arid west has accelerated in part because it can effectively exploit rising CO_2 levels (Hatfield et al., 2008).

Longer growing seasons and warmer winters can allow for additional generations of insects within a single growing season (Hatfield et al., 2008). In addition, higher carbon dioxide concentrations and sugar content in plant tissues can increase insect pest predation. Free-air concentration enrichment (FACE) experiments showed 57 percent more insect pest damage to soybeans in higher CO_2 concentrations, which researchers hypothesized was due to the increases in levels of simple sugars in the leaves. Aphid populations have also been shown to increase under higher CO_2 concentrations, independent of temperature changes (Bezemer et al., 1998; Doherty et al., 1997; Salt et al., 1996).

Invasive plants may also expand or contract their ranges based on changing temperatures. Invasive plants often possess characteristics that allow them to adapt to changing climate conditions and higher carbon dioxide concentrations more successfully than other plants. Dukes and Mooney (1999) and Smith et al. (2000) also suggest that many invasive plant species share traits that could increase their dominance in a changing climate.

Several factors can promote increased plant disease under changing climate conditions. If populations of insect pests increase and plants experience higher rates of predation, they are left more vulnerable to disease. Higher carbon dioxide concentrations can promote more vigorous plant canopy growth, which in some cases can promote disease transmission between plants or portions of a plant. Changing climate conditions can also help an accidentally-introduced insect or plant pest or disease take hold in a region where conditions may have been inhospitable in the past. (Coakley et al., 2010)

2. Timing and geography of increased diseases and pests

Mosquito-borne diseases tend to increase in incidence during warmer months. The prevalence of mosquitoes increases following precipitation events during the warmer months. Tick-borne diseases are also reported more frequently during warmer months. Thus far tick-borne diseases appear to be concentrated in the southern parts of the state, but that could expand as temperature and habitat conditions change. Fresh water algae blooms tend to occur during the warmer months, and have been reported in all areas of the state.

A new crop or livestock disease, plant pest, or insect pest may be introduced into Oregon at any time during the year throughout the state. For invasive species that are already established, the previous year's climate, as well as past eradication and control efforts and early-season surveys, can help predict the severity of an outbreak in the coming year.

3. Risks related to increased diseases and pests

Risks of most of the diseases of concern are associated with warmer temperatures. As temperatures warm, the season of mosquito breeding is likely to lengthen, making mosquito-borne diseases a threat for more months of the year. Algae blooms are associated with increases in surface water temperatures, and can be impacted by flooding or drought.

Increased average annual temperatures, and especially warmer winters, can increase the risk of insect pests. Warm, wet spring and early summer seasons can increase risks from certain plant pests and diseases. Warmer temperatures can also make pest control more challenging. Drought can weaken crops, rangelands, and livestock so they are more vulnerable to disease and pests.

4. Summary of consequences of increased disease and pests

Ecosystems

Many agricultural ecosystems, including croplands, rangelands, streamside areas and forests adjacent to agricultural lands, support diverse plant and wildlife species. Invasive species can negatively impact native plants, fish, and wildlife in agricultural ecosystems by displacing native species, changing habitat characteristics, consuming significant amounts of water, and changing fire regimes. More generally, invasive species negatively affect Oregon's forests, grasslands, and wetlands.

Economy

Invasive species are already very costly to Oregon's agricultural economy. Cusack, Harte, and Chan (2009) estimate the impacts from 21 noxious weed species in Oregon at $125 million per year, and the control costs of the current sudden oak death outbreak to be $7 million annually. The authors note that the economic impacts to ecosystem function and human health have been less well studied at both state and national levels. Additional successful invasions or outbreaks facilitated by changing climate conditions could have severe economic impacts.

Public health and safety

Spread of infectious diseases in the United States and in the Pacific Northwest is happening, with increased population vulnerability to existing and emerging conditions. Some examples include West Nile Virus, Hanta Virus and Cryptococcus Gattii—all of which have emerged recently in the Pacific Northwest. Oregon began monitoring algae blooms in 2005, and steady increases in the number and duration of these episodes have been seen throughout the state. In addition, cardiac, pulmonary and respiratory conditions have all been linked to climate change, while obesity and other chronic conditions weaken individual resilience to these increased burdens.

5. Actions that address increased disease and pests

- The Public Health Division (PHD) tracks reports of vector-, food- and water-borne diseases through medical provider reports and laboratory confirmed case reports. All multi-case outbreaks are investigated. As the PHD becomes aware of new diseases, it works with clinicians and laboratories to assure reporting and to expand tracking.
- PHD tracks fresh water algae blooms, based on local, state or Federal monitoring data, and issues public advisories. PHD tracks and investigates reports of human and animal illnesses associated with harmful algae blooms. PHD tracks marine algae blooms and shellfish advisories issued by the Oregon Department of Agriculture, as well as reports of associated human illness.
- A number of diseases are reportable under Oregon Administrative Rules (OAR) Chapter 433 (433.001-035) and Chapter 333, Divisions 18 (Health services) and 19 (Investigation and control of diseases).
- DEQ is part of a response team when green algae blooms become a problem.
- DEQ is drafting a water quality permit to regulate application of pesticides on or near water bodies.
- The Oregon Department of Agriculture monitors and works to prevent and eliminate certain invasive species, including insect pests, plant pests, and diseases, that present significant threats to Oregon's ecosystems and working lands. ODA also offers certification services to Oregon's agricultural industry to verify that plants are free of certain diseases.
- The Oregon Invasive Species Council (OISC) conducts a coordinated and comprehensive effort to keep invasive species out of Oregon and to eliminate, reduce, or mitigate the impacts of invasive species already established in Oregon. The Council helps address gaps in authority to deal with certain invasive species.
- OWEB provides grant funding for priority weed, invasive species and pest treatment programs.
- ODFW has identified management of invasive species as one of the six key statewide concerns in the Oregon Conservation Strategy. ODFW implements regulations regarding importation, transportation and sale of wildlife, and works with the Oregon State Marine Board to implement the Aquatic Invasive Species Prevention Program. ODFW also works with ODA to identify potentially invasive species of concern.

- The Oregon State Marine Board manages a waterborne invasive species control program to reduce the spread of aquatic invasive species.

6. Gaps in state capacity to address increased disease and pests

- Vector control structures are very limited around the state.
- There is limited surveillance capability for targeted vector-borne infectious diseases.
- There is insufficient funding for emergency response to invasive species detections.
- Risk assessments have not yet been conducted for many of Oregon's worst potential invasive species.
- There is insufficient ability and capacity to predict and detect future invasive species and to evaluate risks of those species to humans, natural resources, and economic systems.
- Biocontrols are not available for many of Oregon's worst existing or potential invasive species.
- The border inspection program for invasive species is insufficient to effectively prevent the introduction of invasive pests.
- Community-level hazard vulnerability assessments do not identify and prioritize human health risks related to changing climate conditions.

7. Needed actions

Priority actions

Increase monitoring, detection and control measures for pest insects and plant and wildlife diseases.

Increase surveillance and monitoring for climate-sensitive infectious diseases to humans.

Increase outreach and community education about disease and invasive species prevention measures.

Seek new means of securing resources to detect and combat diseases and invasive species.

Additional actions

Increase surveillance and monitoring for new insect species and organisms that could be capable of transmitting disease to humans, other mammals and birds.

Complete invasive species assessments.

Maintain and increase support for the Invasive Species Emergency Response Fund.

Improve staff and facilities for accelerated biocontrol development.

8. Implementing the priority actions

Next steps

- OPHD is convening a division-wide Steering Committee on climate change impacts on public health, to include representation from local health departments and all disciplines in public health, to build a common vision and coordinate actions.
- Educate state agency staff and health care providers to recognize and report findings of new or unusual illnesses.
- Implement a new grant-funded project to build local capacity to include climate change threats in planning and responding to hazard emergencies.
- Create opportunities to inform the public about early detection of, and rapid response to, invasive species.
- Continue regional outreach campaign about firewood as a vector for invasive species.
- Lead a statewide summit on invasive species and co-host, with Washington, Idaho, and California, a regional summit on invasive species.

Research and monitoring

- Monitor public awareness through surveys to determine effectiveness of education and outreach efforts.
- Track changes in currently reportable diseases to determine if there are observable patterns that may be linked to changes in climate over time.
- Monitor changes in animal diseases among wild and domestic species. Expand and provide consistent funding for bird monitoring, including flocks of sentinel chickens.
- Expand insect sampling for diseases; increase the number of monitoring stations throughout the state.
- Expand monitoring of fresh water systems for algae blooms.

Coordination with local governments, federal agencies, and other partners

- Coordinate with Centers for Disease Control and Prevention (CDC) on information about changes in vector- water- and food-borne diseases across the country.
- Expand contacts with veterinarians and wildlife biologists to better detect changes in animal diseases.
- Continue coordination with local and tribal public health agencies around disease reporting, outbreak investigation, and information sharing and dissemination.
- Increase coordination between medical laboratories and the Public Health Laboratory to assure rapid data sharing and confirmation sampling for key vector-borne and other infectious diseases.
- Increase coordination between the Department of Agriculture laboratory and the state Public Health Laboratory on identification of new species and diseases of common relevance.

- Keep health care providers informed about changes in disease patterns that may be linked to changes in the environment.
- Coordinate with federal natural resource agencies, state agencies, local county weed boards, SWCDs, and watershed councils, and media, to disseminate information about terrestrial and aquatic invasive species.

Resource requirements

- Maintain staff support for the Oregon Invasive Species Council.
- Increase training of public health practitioners about threats from climate change.
- Expand the capacity to track disease and injury patterns that may be linked to climate.
- Expand the capacity to educate health care providers to recognize and report new or unusual patterns of illnesses and injuries, and to inform the public about preventive actions they can take.

Risk 9. Loss of wetland ecosystems and services

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1. Risk assessment

Sufficient scientific evidence suggests that climate change is now having and will have significant impacts on millions of coastal, estuarine, and freshwater wetlands throughout the country due to increased temperatures, changes in precipitation, and sea level rise.

Wetlands play key roles in major ecological processes and provide a number of essential ecosystem services: flood reduction, groundwater recharge, pollution control, recreational opportunities, and fish and wildlife habitat, including for endangered species. Wetlands are among the most biologically productive and species-rich habitats in Oregon, and occur in and nearby most Oregon communities. As a result of land use practices since 1850, Oregon has lost an estimated 38 percent of its original wetlands and many of the remaining wetland ecosystems are fragmented and degraded (Morlan, 2000). Wetlands are more sensitive to small changes in precipitation and temperature than other ecosystems (Erwin, 2009) and thus may be degraded or lost as a result of future climate conditions.

Available sea level rise (SLR) model predictions for Oregon wetland refuges indicate different types of impacts across different estuaries or estuarine segments. Recent analyses indicate that the Bandon Marsh National Wildlife Refuge (NWR) is predicted to lose between 19 and 92 percent of its swamp by 2100 depending on the SLR scenario utilized (Clough and Larson, 2010a). Simulations for the Siletz Bay NWR using the Sea Level Affecting Marshes Model (SLAMM) indicate dry land loss rates to range from 12 to 40 percent by 2100, again depending on the SLR scenario used in modeling future sea levels (Clough and Larson, 2010b). In the Nestucca Bay NWR, SLAMM predicts that the non-diked portions are vulnerable to SLR and 7 to 30 percent of the dry land is predicted to be lost (Clough and Larson, 2010c). Preliminary SLAMM results for the Yaquina Estuary based on 30 m digital elevation models (DEMs), recently updated NWI data, and a 1 meter SLR scenario by the year 2100, with no protection to developed areas, indicates a 74 percent reduction of tidal flat area, 94 percent reduction of irregularly flooded marsh, and a 85 percent increase in regularly flooded marsh from their initial areas (Reusser, in progress). It is important to recognize the limitations of SLAMM, both because of general model limitations and because of data gaps for Oregon estuaries (Oregon Climate Change Research Institute, 2010).

Consequences of the loss of the ecosystem services provided by wetlands are high. The importance of some wetland ecosystem services, such as fish and wildlife habitats; pollutant removal; buffering the effects of sea level rise, coastal storms and extreme precipitation events; protection of the source of drinking water supplies; flood water storage; and carbon sequestration, will continue to grow as the climate changes. Some climate change adaptation strategies—in particular those that emphasize the protection of infrastructure and property over managed retreat—can exacerbate the loss of valuable ecosystem services.

2. Timing and geography of loss of wetland ecosystems and services

Increased average air temperatures will generally increase evaporation and evapotranspiration across the entire state, so virtually all freshwater wetlands are at some risk, and will likely be at greater risk due to future climate conditions. The particular conditions of each wetland complex will determine how vulnerable it is to temperature increases and changes in basin hydrology. Loss of wetland ecosystems and services will be great for small, shallow wetlands such as vernal pools, where temperatures and evaporation rates may substantially increase without corresponding increases in precipitation. Vernal pools in Oregon occur in the Agate Desert around the Medford area and near The Dalles on the Columbia Plateau. Impacts will be great for montane wetlands with temperature-sensitive plant and animal species and little opportunity for such species to migrate. Over the longer term, loss of certain tidal wetland types due to rising sea levels could be particularly great, since steep topography, dikes and levees, sea walls, and other development all present barriers to upslope migration (Burket and Kusler, 2000). The rate of change in tidal wetlands will be affected by estuarine sediment budgets, about which very little is known in Oregon estuaries.

Oregon-specific projections of where losses will occur are not available for most wetland types. Some research has focused on the impact of sea level rise on estuarine habitat. Due to the differences of relative sea level rise along the Oregon Coast, coastal wetlands on the central and north coast are more susceptible to the effects of sea level rise than along the south coast, where tectonic uplift is outpacing the rate of sea level rise. Maximum wave heights will also increase, which will increase erosion in coastal areas and likely impact coastal wetlands.

3. Risks related to loss of wetland ecosystems and services

Increased average air temperatures will contribute to loss of shallow wetlands, which will affect the distribution of wetland-related habitats and species. Wetland loss in general has the potential to contribute to increased flooding, reduced water quality, and changes in water availability.

Increased sea levels are expected to force the upslope migration of tidal wetlands, or the loss of upper tidal wetland types where migration is prevented by development or landform. Increased ocean acidification could affect estuarine wetland functions and values, and thus estuarine wetland habitats.

Changes in hydrology (snowmelt to rain-dominated basins) will contribute to loss of montane wetlands.

Increased drought will reduce the extent of shallow wetlands. Changes in basin hydrology could result in loss of riverine wetlands.

4. Summary of consequences of loss of wetland ecosystems and services

Wetlands play key roles in major ecological processes and provide a number of essential ecosystem services, such as flood reduction, groundwater recharge, pollution control, recreational opportunities, and fish and wildlife habitat, including for endangered species. Only about 38 percent of the wetlands that were in Oregon at the start of European settlement remain as wetlands today, because of conversions for various other land uses. As such, increases in air temperature and changes in hydrology will exacerbate impacts to already degraded and fragmented wetland ecosystems. The consequences for losing wetland ecosystems and their associated services will potentially affect all of Oregon's systems—natural, built and developed systems, public health and safety, and Oregon's economy.

Ecosystems

Depending on the rate of sediment deposition, the nature of the shoreline, and rate of sea level rise, tidal wetlands are vulnerable to rising sea level and tidal elevations. Because most Oregon estuaries are sharply bounded by steep hillsides, dikes, levees, roads, or buildings, wetlands at the upper end of tidal influence may be unable to migrate landward in response to increased tidal elevations. Freshwater marshes and swamps could be converted to salt marshes or transitional marshes that experience frequent saltwater inundation. Significant losses in tidal flats and beaches are possible, depending on the rate of sea level rise and local factors. A loss in coastal marsh habitat will likely result in declining estuarine water quality, harm eelgrass beds, and contribute to hypoxia (low oxygen). Reductions in estuarine wetland productivity have the potential to affect the overall food web and negatively affect salmon, shellfish, waterfowl and shorebirds. Additionally, recent research has shown tidal marshes and eelgrass beds to be extremely effective at carbon sequestration with little methane gas production, even more effective than forests and peatlands.

In estuaries with snowmelt-dominated watersheds where changes to the timing and intensity of freshwater input are projected (the Umpqua, Rogue, and Columbia Rivers), increased runoff will result in warmer summer water temperatures, increased pollution, and sedimentation, all of which have deleterious effects on salmonids and other estuarine and marine populations.

Studies of the impact of climate change on Oregon's seasonal wetlands have not been undertaken. Seasonal wetlands in the Willamette Valley provide important habitat for migrating waterfowl and shorebirds, important flood storage, and water purification. While little is known about the vernal pools on the Columbia Plateau, the vernal pools of Agate Desert provide habitat for rare species, including two Oregon state-listed endangered plant species—the large-flowered woolly meadowfoam and Agate Desert lomatium—and the federally-listed (threatened) vernal pool fairy shrimp.

Montane wetlands are also projected to decrease in size due to the upslope migration of alpine areas. Baseline information about montane wetlands is fairly limited. The loss of montane wetlands may result in the loss of hydrologic storage function of these headwater wetlands, as well as the loss of potentially rare plant communities and associated wildlife habitat with little migration opportunities.

Built and developed systems

Loss of wetlands that mitigate flooding may result in increased damage to residences, commercial buildings, bridges, culverts, and roadways. Loss of wetlands that remove pollutants from surface water may result in a need for new and expanded drinking water treatment facilities. Loss of groundwater recharge wetlands may result in the need to dig deeper wells for drinking water and summer irrigation demands.

Public health and safety

Loss of wetlands that mitigate flooding may increase risk of flood injury and death. Large floods can overwhelm water treatment facilities causing outbreaks of waterborne illnesses. Loss of wetlands that purify water may degrade drinking water sources and recreational water use.

Economy

The loss of wetland ecosystem services will have indirect consequences on a range of economic activities. Loss of coastal wetlands that provide habitats can eventually reduce the value of Oregon's commercial and recreation fishing industries. Loss of seasonal wetlands and coastal wetlands will impact waterfowl and shorebird populations and may reduce the revenue generated from hunting, birding, and other recreation activities. Loss of wetlands that provide flood protection may result in higher damage costs as a result of increased flood related damages. Loss of wetlands that purify water may result in the need for expanded or additional drinking water treatment facilities. Loss of wetlands that provide water storage may result in the need for the construction of expanded and additional infrastructure to prevent flooding and to meet summer time water demands.

5. Actions that address loss of wetland ecosystem services

- DSL administers Oregon's Removal-Fill program, which regulates wetland losses and requires compensatory mitigation for permitted impacts to wetlands. DSL's wetland alteration permit and mitigation decisions are being reviewed to identify ways to incorporate the effects of climate change into permitting criteria and processes.
- DSL and DEQ are participating in EPA's National Wetland Condition Assessment 2011 to collect baseline wetland condition data, including data relevant to assessing climate change impacts, on twelve sites in Oregon.
- DSL participates in EPA's State and Tribal Climate Change Council to identify strategies for addressing climate change in state wetland programs.
- The South Slough Estuarine Research Reserve is partnering with stakeholders and landowners in the Coos Watershed to implement a Collaborative Planning, Monitoring, and Management project to address likely changes to coastal forests.
- OWEB provides grants and funding to acquire and restore wetlands, protect and restore floodplains, and protect key wildlife habitats.
- OPRD is increasing long-term monitoring at wetland sites (coastal marshes, fens) and implementing projects to improve existing aquatic habitat functions (removing fish barriers, restoring aquatic habitat, and increasing riparian area and quality).
- Oregon's Statewide Land Use Planning Program includes land use planning goal provisions and administrative rules to protect locally significant wetlands. Planning goals also provide for the protection, management, and restoration of estuarine areas, estuarine habitats, and coastal shorelands.
- DSL provides guidelines, methodologies, and technical assistance to help communities and property owners to identify, protect and restore wetlands.

6. Gaps in state capacity to address loss of wetland ecosystem services

- Oregon lacks both a) basic inventory and assessment data on montane and shallow wetlands and other climate-vulnerable wetland types and b) downscaled model projections depicting specific expected future changes on wetlands.
- Oregon lacks state-wide estuarine wetland regulatory buffers to allow for tidal wetland migration inland.
- Existing programs don't regulate earthwork of 50 cubic yards or less, and such work can result in loss of small, seasonal wetlands and all their functions.
- Existing regulations do not require wetland restoration and mitigation projects to address changes in hydrologic regimes or invasive species due to climate change, and don't regulate the removal of wetland vegetation. Further, current wetland mitigation ratios for permitted impacts are the same regardless of which wetland ecosystem services are being provided/impacted by alteration.
- Local estuary management plans are based upon historical and incomplete habitat maps, which may not reflect current locations of tidal wetlands, especially in the upper portions of the estuaries.
- Many local governments have not adopted Goal 5 wetland and riparian protections.
- Local floodplain protection programs do not integrate wetland protection and restoration.

7. Needed actions

Priority actions

Actions to address climate-related risks to wetlands will help reduce other climate-related risks, and *vise-versa*. Accordingly, the priority action to reduce risks to wetlands is to implement priority actions under Risks 2, 5, 6, 7, and 10 (related to changes in hydrology, increased drought, increased coastal erosion and risk of inundation, shifts in the distribution of habitats, and increased flooding) as they might affect wetlands.

Risk 2:

Maintain the capacity to provide assistance to landowners to restore wetlands, uplands and riparian zones to increase the capacity for natural water storage.

Risk 2, 5:

Increase capacity to provide technical assistance and incentives to increase storage capacity and to improve conservation, reuse, and water use efficiency among all consumptive water uses.

Risk 6:

Inventory and map coastal shorelands that are at risk of erosion or inundation, or are barriers to shoreline migration, and develop long-term state and local adaptation strategies for shorelands.

Risk 7:

Identify ways to manage ecosystems to promote resilience to changes in climate conditions.

Risk 10:

Inventory past flood conditions and define and map future flood conditions.

b. Additional actions

Require wetland mitigation and restoration plans to address projected changes in hydrologic regimes and invasive species due to climate change.

Update state rules for protecting wetlands to incorporate considerations for the effects of climate change into the definition of significant wetland and riparian resources.

Improve protection of riparian areas and wetlands in local land use plans.

Prohibit removal of wetland vegetation through local government ordinances.

Inventory and protect vulnerable wetland types.

Increase protection for wetlands affected by fills of less than 50 cubic yards.

Within the existing state wetland permitting program, provide incentives to protect wetland buffers and mitigation sites; to prioritize wetlands that provide ecosystem services important for adaptation to climate change, including carbon sequestration, flood mitigation, water quality purification, and groundwater recharge; and require wetland mitigation and restoration plans to include strategies for adapting to projected changes in hydrology and invasive species.

Prioritize protection of drinking water sources reliant on wetland purification over conflicting land uses.

Update estuary habitat maps and incorporate new information into local estuary management plans.

Incorporate the likely effects of climate change into local Goal 17 Coastal Shorelands Management plans.

Revisit wetland restoration, conservation, land acquisition priorities and other ecological priorities identified in watershed management plans to incorporate consideration for the likely the effects of climate change.

Coordinate wetland and riparian area planning and protection under Goal 5 with planning under Goal 7 for Natural Hazards to integrate protection of ecosystem services into local programs for flood plain management and protection.

8. Implementing the priority actions

The loss of wetland ecosystems and functions cuts across several risks, in particular risks associated with hydrology, drought, increased coastal erosion and risk of inundation, and habitats. Therefore, the priority actions for this risk emphasize actions under risks 2, 5, 6, 7, and 10. Improved agricultural, residential, industrial and commercial water use efficiency will result in less water withdrawals from aquatic ecosystems. Agency initiatives and actions related to improving the management and protection of wetlands that have a water storage function will also contribute to efforts to reduce flood risks. An inventory and map of estuarine shorelands and intertidal lands will help identify areas and infrastructure at risk of inundation and possible barriers to migration of tidal wetlands in response to sea level rise.

Next steps

- Continue to add to the statewide wetlands inventory by supporting local wetland inventory and other mapping efforts.
- Conduct outreach and education with local planning departments and the development community about climate change and the importance of wetlands.
- Review wetland restoration and conservation priorities by watershed, utilizing ecoregional projections of climate change.

Research and monitoring

Several research and monitoring initiatives are needed to improve the management and protection of wetland ecosystems and services, and thereby reduce flood hazards, improve habitat resiliency, reduce the effects of drought and mitigate the shift in hydrologic patterns anticipated to occur as a result of future climate conditions.

- EPA’s National Wetland Condition Assessment 2011 should be repeated, and should be intensified to include more sites.
- Estuarine wetlands and resources surrounding estuaries should be re-mapped; new maps of estuarine wetlands will be necessary to integrate information about climate-related future conditions into planning for estuarine restoration and shoreland development, and for managing estuaries to maintain important tidal wetland ecosystem services.
- Assessments of the current condition of montane and shallow wetlands and other climate-vulnerable wetland types.
- Increase the network of tide gauges in the upper portions of estuaries.
- Acquire detailed bathymetry data in Oregon’s estuaries and create integrated maps of estuarine bathymetry and the surrounding upland topography.
- Generate projections of expected future changes on wetlands by ecoregion and wetland type.

Coordination with local governments, federal agencies, and other partners

- Federal agencies with responsibilities or interests that may affect state actions to address the effects of climate change on wetlands, and which should be brought into the next cycle of climate change adaptation planning under the framework include the EPA, NOAA, U. S. Army Corps of Engineers, USFWS and NRCS.
- State agencies with responsibilities, information, or technical assistance to contribute to more effective measures to address the effects of climate change on wetlands include DSL, OWEB, ODFW, ODF, ODOT, DEQ, and DLCD. Improve coordination between DLCD and DSL’s Wetlands Program.

- Improve coordination among DSL's Removal-fill permit program, DEQ, ODF and ODFW to assess how to incorporate climate change into state wetland permitting.
- Include local governments in adaptation planning at the ecoregional and watershed scale to ensure the protection of wetland resources that potentially affect multiple jurisdictions.

Resource requirements

- Provide funding to local governments to complete Goal 5 planning for significant wetland and riparian resources.
- Provide funding to local governments to update Goal 5 wetlands and riparian areas with climate change impacts in mind. Wetlands and riparian area protection in accordance with Goal 5 should be a required element of local climate change adaptation plans.
- Local governments that have Goal 5 wetland and riparian protections in place do not have adequate funds to reevaluate the significance of Goal 5 resources, considering the anticipated effects of climate change.
- Coordinate programmatic changes to DSL's permitting program as a result of climate change effects with the U. S. Army Corps of Engineers Section 404 wetland permit program.

Risk 10. Increased frequency of extreme precipitation events and incidence and magnitude of damaging floods [Return to Table of Contents]

1. Risk assessment

There is confidence that flooding will increase in the 21st century, particularly in areas that have a history of chronic flooding, namely, urban areas (Chang and Jones, 2010)

There is not a clear climate change signal in annual precipitation trends in Oregon in recent past. Global climate models suggest that annual precipitation will continue to be dominated by natural variability in the Pacific Northwest, though there projections for seasonal changes, such as drier summers (Mote et al., 2010). Annual variability has caused significant flooding in the past. For example, the 2007 Vernonia flooding happened during a winter dominated by a strong La Nina, an area of cooler than average sea surface temperatures in the equatorial Pacific, which typically means colder, wetter winters in Oregon (Oregon Climate Service, pers. comm.).

Trends in extreme daily precipitation over the 1908-2000 period have been ambiguous and have not been statistically significant for any season in the Pacific Northwest (Groisman et al., 2004). An analysis of station trends in Oregon from 1948-2006 found a statistically significant decrease in Oregon (Madsen and Figdor, 2007). There is some evidence in global and regional climate models that extreme daily precipitation will increase in the 21st century in this region, though there is room for more research in this area. Such events are a primary driver of many flood events. An increase in extreme daily precipitation events will result an increase in the incidence and magnitude of damaging floods.

An increase in winter air temperatures due to climate change may lead to increased flood risk as more winter precipitation falls as rain, combined with possible rapid melting of winter snow.

2. Timing and geography of the risk of increased flooding

Flooding has been an issue in Oregon in the recent past, and will continue to be a concern through the 21st century, even if precipitation continues to be dominated by natural variability. Though one cannot tie single events to rising greenhouse gases, past significant flooding in the state has caused property damage, loss of life and economic loss. Flooding in Oregon generally occurs due to extreme precipitation events, rapid snowmelt or rain-on-snow precipitation events (Oregon Climate Service, pers. comm.). Extreme daily precipitation events may increase in the next few decades, but the basins where such events will occur cannot be predicted with any certainty. Areas that are already prone to flooding are most vulnerable to increased extreme precipitation events. Urban areas served by stormwater management systems that are at or near capacity today are likely to see an increase in the frequency of localized flooding. With the shift to warmer average temperatures affecting the hydrology of basins that are now dominated by snowmelt, there may be an increase in floods caused by rain-on-snow events. Damaging floods west of the Cascades tend to be associated with larger scale, more widespread events, while eastern Oregon will experience more localized, intensive events.

The increased incidence of damaging floods may already be seen in basins that now experience regular flooding.

3. **Risks related to increased flooding**

Increased incidence and magnitude of damaging floods will be caused in part by changes in precipitation patterns, in particular due to an increase in extreme daily precipitation events. Flooding in coastal basins can be exacerbated by coastal storm surges. Flooding results in erosion, and thus triggers increased landslides. Drought may increase wildfire, which can affect runoff and therefore increase flooding and trigger landslides.

4. **Summary of consequences of increased flooding**

Ecosystems

Increased frequency of extreme precipitation events and incidence and magnitude of damaging floods will result in fundamental changes in the morphology of streams, riparian areas, and wetland systems. Changes in stream system morphology will result in changes in fish and wildlife habitats. Floodplains will be fundamentally reshaped over time to reflect bigger floods, greater flood frequency, or both. Increased flooding will cause more landslides and increase sediment loads. Sedimentation regimes in wetlands and waterways will be changed. Channels and channel margins may become unstable for extended periods—essentially decades—until the stream system arrives at an equilibrium that reflects the new sediment load and peak flow regime. Streamside areas considered to be outside the floodplain may now experience flooding. Stream corridors with degraded riparian structure are likely to be more unstable than those with good riparian structure. Even though flooding is generally localized, some basins, particularly in the Coast Range Mountains, will experience repeat events. Flooding will potentially affect salmonid populations. Stream corridors with degraded riparian structure are likely to be more unstable than those with good riparian structure.

Built and developed systems

Almost every year, some Oregon community experiences a damaging flood, and in many years, floods cause damage in several communities. Increased incidence and magnitude of flood events will increase damage to property and infrastructure, and will increase the vulnerability of areas that already experience repeated flooding. Areas that are outside the historical floodplain may now experience flooding. Many of these areas have improvements that are not insured against flood damage, and thus floods will probably result in catastrophic property damage and losses. There will likely be modifications of waterways through permitted and unpermitted actions in order to protect property and infrastructure. The ‘base flood’ will need to be redefined in many communities, potentially resulting in increased cost to insure property in newly-defined floodplains. Existing structures now outside of the federal flood insurance program may become subject to federal flood insurance requirements. Floods cause reduced transportation mobility, access, and delivery of essential services. Stream systems that have been channelized and armored will require greater investment to maintain the present channel or level of streambank protection.

Extreme precipitation events have the potential to cause localized flooding due partly to inadequate capacity of storm drain systems. Extreme events can damage or cause failure of dam spillways. An increase in the frequency of extreme precipitation events has the potential to increase damage to property and infrastructure, including infrastructure for drinking water supplies. Increased flooding will increase transportation system disruptions, thereby affecting the distribution of food and essential services.

Public health and safety

Increased flooding will place large numbers of people and structures at risk. Some areas may experience repeat events, and areas once thought to be outside the floodplain may now experience flooding. The regulatory floodplain will need to be redefined in many communities; structures now outside the federal flood insurance program may become subject to federal flood insurance regulations. Increased flooding will increase risk of injuries, illnesses, death, and displacement.

Economy

Floods cause significant damage to Oregon's economy, and involve uninsured property damage and losses, lost productivity, and cleanup costs.

5. Agency actions that address flood risk

- DLCD provides technical and financial assistance to implement FEMA's National Flood Insurance Program (NFIP), and provides technical and financial assistance to local communities as requested to conduct planning for areas subject to natural hazards, including hazards related to climate. DLCD is also completing FEMA's map modernization program for Oregon communities participating in the NFIP, and is developing a five-year scope of work and plan to implement FEMA's new RiskMap program, as well as participating with DOGAMI on a pilot mapping project.
- DOGAMI is re-delineating flood hazards for FEMA in selected counties using high-resolution lidar elevation data; also developing protocols for modeling varying flood discharges using USGS StreamStats data and ArcGeoRas software. DOGAMI is also delivering a web-based map tool that will be capable of displaying a variety of geologic hazards, including earthquake, landslides, flooding, and coastal erosion.
- DLCD and OCCRI are co-hosting a Fellow under NOAA's Post-Docs Applying Climate Expertise (PACE) program to use downscaled climate data to map natural hazards under future climate conditions.
- The Oregon State University hosts the Oregon Hazards Explorer, a website and digital library for use by citizens, planners, public agencies, and community groups to learn and make informed decisions about known hazards in Oregon.
- OEM coordinates and facilitates emergency planning, preparedness, response and recovery activities in Oregon.
- The Oregon Partnership for Disaster Resilience at the University of Oregon leads a statewide initiative to build capacity to develop state, regional, and local hazard

mitigation plans and projects. Partners include OEM, DLCD, DOGAMI, FEMA Region X, and local governments throughout Oregon.

- OWEB provides grant funds for floodplain restoration and protection, water quality restoration and protection, and water quantity and quality monitoring.
- ODA, OWEB, Soil and Water Conservation Districts, watershed councils and the U.S. Department of Agriculture implement programs and projects that prevent erosion, build watershed resiliency, and may help reduce flooding.
- OSU faculty members are conducting watershed hydrology and modeling scenarios to assess the implications of evolving land use patterns and climate change. The OSU watershed extension program teaches participants about watershed processes.
- DSL issues permits for streambank stabilization and erosion control to protect property from damaging floods.
- OPRD is making park improvements designed to accommodate flooding.
- DEQ can deploy resources to assist in debris removal after major floods. DEQ currently issues stormwater permits; extreme participation events can affect how stormwater is managed to reduce flow and pollution.
- ODOT is installing automatic flood warning systems at Seaside and Cushman, and is conducting a high-level inventory of vulnerable areas and infrastructure using flood maps and historic data.
- ODOT is developing a Drainage Facility Management System (DFMS) for maintaining comprehensive, consistent, and up-to-date information on the type, size, location, and condition of culverts statewide.
- WRD manages a dam safety program; extreme precipitation events can affect dam spillways, resulting in dam safety issues.

6. Gaps in state capacity to address increased flooding

- Oregon lacks a comprehensive, integrated inventory and assessment of both historic and likely future extreme precipitation events and their impacts on the built and natural environments.
- Oregon lacks a baseline to monitor natural hazards, and land use change over time.
- Oregon lacks reliable assessments of likely future flood conditions and relative flood risk in areas where development and infrastructure improvements are likely to occur.
- Reliable information about likely future flood conditions is not required to be formally adopted into local land use plans.
- Several areas of the state are in need of restudy by FEMA’s floodplain mapping program.
- The NFIP regulatory floodplain will need to be redefined in many communities. FEMA’s capacity to incorporate climate change in their maps may lag behind Oregon’s needs; flood zone standards that exceed NFIP regulations for the state may need to be considered.

- Oregon is in need of better coordination between flood mapping, community response to the requirements of Goal 7, and Hazard Mitigation Plans.
- Oregon lacks a policy basis for determining when increased armoring is an appropriate response to damaging floods and when restoration of natural riparian habitat is preferable.
- Oregon's regulatory program for permitting streambank stabilization projects in waters of the state may be inadequate to efficiently respond to an increased demand due to increased flooding.
- There is an increasing need to evaluate capacity and performance monitoring of dam spillways.
- Oregon lacks a rapid assessment tool to assess damage to transportation infrastructure after extreme precipitation events, and there is minimal capacity to respond to transportation system and other infrastructure emergencies caused by extreme precipitation and other hazard events.
- The policy framework for managing land use and natural resources does not fully protect natural features and functions that buffer the effects of natural processes, including extreme precipitation events, on the built environment.

7. Needed actions

Priority actions

Inventory past flood conditions and define and map future flood conditions.

Improve capability to rapidly assess and repair damaged transportation infrastructure, in order to ensure rapid reopening of transportation corridors.

Additional actions

Develop an inventory and assessment of impacts on resources, built environment, human health and economic sectors of past extreme precipitation events.

Assess emergency response capabilities within state government for all hazard events.

Revise Goal 7 to require that new natural hazard inventory information be adopted into local comprehensive land use plans. Include extreme precipitation events in planning to reduce vulnerability to natural hazards.

Adopt standards for flood-prone development that exceed FEMA's minimum requirements and that restrict development in floodplains.

Provide resources to develop local climate adaptation plans that address all climate-related hazards.

Develop policies that help limit development and post-disaster reconstruction in hazard-prone areas.

Improve reliability of communication systems for use during and after extreme rainfall events.

Implement measures to protect and restore natural resource features and landscape functions, like riparian areas, wetlands, and floodplain connectivity, which will reduce and mitigate the effects of flood events.

Assess the capability of the Removal-Fill permit and enforcement program to manage an increase in shoreline armoring projects. Develop and adopt BMPs for streambank stabilization projects to protect or restore the natural buffering capacity of riparian areas.

Assess vulnerability of water supply and wastewater treatment infrastructure to floods.

Assess the capacity of bridges and culverts.

Develop planning criteria, guidelines, and engineering standards as appropriate for new and rebuilt infrastructure that account for increased incidence and magnitude of floods, and that minimize impacts on the adaptive capacity of human and natural communities.

Develop more effective methods to communicate varying probabilities of flood risk and incidence, and potential adaptation strategies, to a wide range of audiences.

Encourage, assist and support local public health agencies in developing or strengthening adaptation and evacuation planning among populations and businesses vulnerable to flooding.

Improve ability to monitor river levels and snowpack.

Develop capacity to provide emergency sewage treatment facilities.

8. Implementing the priority actions

Next steps

- Continue technical and financial assistance to implement FEMA’s National Flood Insurance Program (NFIP). Continue modernization of FEMA’s floodplain maps for Oregon communities participating in the NFIP, and identify areas in need of restudy due to changes in hydrology and development patterns.
- Create a historical flood baseline; research documented historic flood events in the state, and map locations to as much detail as possible.
- With FEMA and DOGAMI, remap watersheds with LiDAR coverage and establish flood depth grids.
- Assess current capacity to assess, repair, and reopen critical transportation corridors after flood events.
- Develop guidance for ODOT and other agency crews for what should be done after an extreme weather event that closes a major transportation corridor.

Research and monitoring

- Develop a complete inventory of natural hazards information in the state.

- Calculate annualized flood losses by watershed to establish a baseline for future planning.
- Use data on historical storms and floods to improve understanding of cause and effect in order to help model and predict the effects of global warming influenced storm events.
- Develop the ability to create uniform base maps for hazard planning, using data on tax lots, zoning, comprehensive plan designations, structures in areas considered vulnerable, and as-built infrastructure.
- Research best practices from other states on how they assess, repair, and reopen critical transportation corridors after flood events.

Coordination

- ODOT, Oregon State Police, DLCD, OEM, DOGAMI, cities, counties.

Resource requirements

- Maintain the current capacity to assess, repair, and reopen transportation corridors after a flood or other extreme event.
- Continue OWEB funding of riverine and wetland floodplain protection and restoration to retain critical watershed resiliency processes and off-channel storage.
- Continue to use LiDAR data to provide baseline for flood modeling.
- Complete natural hazards baseline mapping for the state.
- Complete digital flood mapping in areas that may not be scheduled by FEMA.

Risk 11. Increased incidence of landslides

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1. Risk assessment

There is some confidence in an increased incidence of damaging landslides.

The driver for landslides tends to be intense precipitation in some form: either on the one-day or event level (several days of precipitation).

2. Timing and geography of the increased incidence of landslides

Intense precipitation events forcing the landslides typically have a southwest-northeast long axis and can cover one-third of the state. The distribution of resultant landslides is also widespread over the event area.

3. Risks related to landslides

Intense precipitation causes increased landslides and flooding, which results in stream channel migration, which in turn can cause further landslides.

4. Summary of consequences of increased landslides

Ecosystems

Increased incidence of landslides will affect forest ecosystems and alter stream hydrology and aquatic habitats. Increased incidence and magnitude of damaging landslides will result in fundamental changes in stream morphology, riparian areas, and wetland systems. Changes in stream morphology will result in changes in aquatic habitats. More landslides will increase sediment loads. Channels and channel margins may become unstable for extended periods until the stream achieves an equilibrium that reflects the new sediment load and peak flow regime. Even though landslides are generally localized, some basins, particularly in the Coast Range Mountains, will experience repeat events. Landslides will potentially affect salmonid populations.

Built and developed systems

Increased landslides will cause increased damage to property and infrastructure, and will disrupt transportation and the distribution of water, food, and essential services.

Almost every year, some Oregon community experiences a damaging landslide, and in many years, landslides cause damage in several communities. Increased incidence and magnitude of landslide events will increase damage to property and infrastructure, and will increase the vulnerability of areas that already experience repeated land slides. Most insurance does not cover damage due to earth movement, and thus severe consequence events will result in catastrophic property damage and loss.

Widespread damaging landslides that accompany intense rainstorms (such as "pineapple express" winter storms) and related floods occur during most winters. Particularly high-consequence events occur about every decade; recent examples include those in February 1996, November 2006 and December 2007.

During December 1-3, 2007 northwestern Oregon and southwestern Washington were impacted over an area approximately 80 miles wide by 160 miles long. In Washington State some 1,940 landslides were mapped with a cumulative impacted area covering 2.34 square miles. On December 3rd several locations experienced 24-

hour precipitation records or near records, with these one-day rain totals in northwestern Oregon:

- Lees Camp: 9.90”
- Forest Grove: 3.66”
- Scappoose: 3.66”
- Hillsboro: 2.98”

The December 2007 storm resulted in approximately $180 million in damages and five fatalities in Oregon, including $57 million in damage caused by landslides and channel migration that destroyed the Tillamook Bay Railroad. The same storm caused $1 billion in damage and eight fatalities in Washington.

In 1996, damages from landslides totaled approximately $760 million in Oregon. Thus, annual damages from landslides will range from a few millions in the lightest winters to nearly 1,000 times that every two decades or so.

Public health and safety

Increased landslides will place people and structures at risk, increasing the potential for injury and death. Landslides can disrupt the distribution of food, drinking water, medicine and other essentials, and may limit access to medical services.

Economy

Landslides can disrupt the distribution of goods and services, and can cause significant damage to Oregon’s economy.

5. Actions that address landslides

- DOGAMI is mapping a landslide inventory for USGS and self-selected counties and cities using high-resolution lidar elevation data, and is developing a protocol for modeling landslide susceptibility. DOGAMI is also developing a web-based map tool that will be capable of displaying a variety of geologic hazards, including earthquake, landslides, flooding, and coastal erosion.
- DLCD manages a state-federal partnership that includes FEMA, DOGAMI, and OEM to conduct a pilot project to identify and map all natural hazards affecting a community. DLCD also provides technical and financial assistance to local communities to conduct planning for areas subject to natural hazards, including landslides. DLCD is developing a five-year scope of work and plan to implement FEMA’s RiskMap program.
- As manager of the Oregon Lidar Consortium, DOGAMI is the authorized purchaser of lidar data for the State of Oregon.
- ODOT has installed debris flow warning signs on I-84 that can be activated to warn motorists of landslides affecting the roadway.
- ODOT has an Unstable Slope Management System to track hazards, responses to landslides and rockslides, engineering information, and costs.
- ODF is using lidar to map landslides in state forests.
- ODF administers forest practice rules regulating timber harvesting and road building where down-slope public safety risk is involved.

- OWEB provides funding for grants to remove and improve problem roads and culverts as well as for the purpose of restoring upland watershed functions and processes.

6. Gaps in state capacity to address landslides

- Oregon lacks reliable data on future landslide susceptibility conditions.
- Oregon needs reliable assessments of relative landslide risk in areas where development and infrastructure improvements are likely to occur.
- Oregon lacks state-level emergency response to landslide hazards.
- Oregon lacks a state–level hazard mitigation plan for landslides.

7. Needed actions

Priority action

Develop public education and outreach on landslide risks and how to adapt to landslide risks.

Additional actions

Improve effectiveness of local hazard mitigation plans.

Provide resources to develop local climate adaptation plans that address all climate-related hazards.

Systematically identify and map landslide-prone areas statewide.

Develop BMPs, policies, and incentives for land management practices that reduce landslide risk.

Increase monitoring of landslide-prone slopes near transportation infrastructure.

Improve capacity to respond to landslide emergencies.

Help local public health agencies in emergency preparation and response planning for areas vulnerable to landslides.

8. Implementing the priority action

Next steps

- Partner with private corporations, counties and other local jurisdictions to develop outreach and education materials and programs for dissemination.

Research and monitoring

- Determine target audience, messages and best delivery methods of outreach and education efforts associated with landslide zones and risks.

Coordination

- Coordinate education and outreach messages and efforts among FEMA, OEM, DLCD, INR, DOGAMI, and local governments.

Resource requirements

- No specific resource requirements identified

4. Looking Ahead: Implementing the Framework [Return to Table of Contents]

This Climate Change Adaptation Framework is the result of an unprecedented level of collaboration among Oregon state agencies and institutes and offices in Oregon's University System. The most important function of this framework is to lay out the foundation, dimensions, and timing of several climate-related risks to people, places, resources and infrastructure, as a first step in developing approaches to address those risks at the individual, local and state level. The framework represents a significant first step in addressing the need to prepare for the effects of future climate conditions. However, it is only a first step. Implementing the short-term priority actions is necessary, but not sufficient, to begin preparing Oregon for the long-term effects of climate change.

In the process of developing the framework, it became clear that there was a need to include several elements that are not based on one risk or another. Integrating the need to prepare for and adapt to the effects of climate change into state programs will require focused attention over time, ongoing investments to build resilience, and the cultivation of a learning process within state agencies that will enable Oregon to devise appropriate solutions to future climate-related challenges. Most importantly, planning and implementing measures to prepare for and adapt to the effects of climate variability and change will require new resources.

This section briefly describes several overarching needs and recommendations that are central to the framework. In addition to implementing the short-term priority actions described earlier in this report through the 2011-2013 biennium, Oregon's executive branch agencies should continue to build Oregon's capacity to prepare for and adapt to changing climatic conditions.

Several key elements of the framework that will help build resilience in Oregon's natural systems, human and economic systems, and infrastructure systems, and recommendations related to each, are summarized below.

1. Identify Research Needed for Management

Just like all planning efforts, the anticipated future conditions that form the foundation for the framework involve some uncertainty. Further planning for climate change should involve continued identification of needed research to help ensure that measures being considered are the most appropriate measures. In particular, research is needed on the potential economic costs and benefits of alternative adaptation strategies.

Oregon has already begun to invest in climate-related research, most recently in establishing the Oregon Climate Change Research Institute (OCCRI). The OCCRI has provided considerable help in developing the adaptation framework, and will continue to provide great value to Oregon in several capacities. In September 2010, the OCCRI received two five-year federal grants to establish regional climate science centers, one from the National Oceanic and Atmospheric Administration and one from the U.S. Department of the Interior. These centers will establish and coordinate a regional consortium for climate variability assessment, research, and outreach focused on managing landscapes, watersheds, and other natural resources in a changing climate. In early 2011, the consortium will begin developing a research agenda in consultation with interested parties and institutions across Oregon, Washington, and Idaho.

State agencies should inventory the knowledge gaps that currently limit the potential to devise effective state-level program responses to future climate conditions. These gaps in present knowledge involve several fields of research in the natural and social sciences, and will form the basis for a summary of Critical Research Questions to be compiled by the end of 2011. Oregon's research community has demonstrated its commitment to providing policy-relevant research in the past; the Critical Research Questions Report will lay out a blueprint for continuing the fruitful collaboration between state agencies and Oregon's research and educational institutions.

Recommendation for Research

- Compile an inventory of research needed to improve the effectiveness of adaptation measures at the state and local levels.

2. Monitoring for Management

Monitoring is an underappreciated element of effective resource management. Oregon agencies draw on information from many sources, and may monitor a variety of conditions, to improve agency efficiencies and the management of resources. The foundation of information for managing natural resources and state infrastructure could be improved, however, and such improvements will almost invariably improve Oregon's ability to respond to the effects of future climate conditions. There may be opportunities to gain important data and information by just increasing the scope and coordination of monitoring for programs to manage forests, regulate harvests, manage water resources, identify serious disease outbreaks, and so on.

Efforts to increase or improve monitoring for management will likely support needed research, and will likely provide important data for modeling future climate projections.

State agencies should explore the feasibility of greater coordination in environmental monitoring efforts, in order to extend the capabilities of separate agency efforts and more efficiently achieve broader monitoring objectives. Oregon might consider the feasibility of establishing a statewide environmental monitoring network. Efforts to improve monitoring could simply involve establishing (or increasing) monitoring for important conditions—for example, early detection of diseases and invasive species. Or at a more ambitious level, Oregon could consider developing an integrated network of environmental monitoring stations. An integrated network has the potential to increase the efficiency of state agency monitoring programs; to provide an enhanced ability to understand how climate conditions are affecting natural resources; to gauge how adaptation measures are performing over time; and to detect the emergence of unanticipated conditions.

Recommendation for Monitoring

- Compile an inventory and maps of current surveillance (for diseases) and monitoring (for environmental conditions) efforts, and assess the feasibility of integrating different monitoring efforts into a statewide monitoring system.

3. Agency Program Assessments

The risk summaries in Section 2 demonstrate that state agencies already have some important capacities to prepare for, respond to, and adapt to the effects of future climate conditions. From one perspective, it's accurate to say that state agencies are already in the business of responding to climate change. Climate conditions can have significant effects on resources that are the basis for state management programs, including land use; coastal beaches, estuaries, and shorelands; and the management of forests, water supply, and habitats.

However, the challenge that climate variability and change present to Oregon agencies is that conditions are changing faster than has generally been experienced before. Therefore, it is important that agency policy, program, and permit choices in the future incorporate information about likely future climate conditions, so as to avoid policies that might have clear climate-related future costs. One obvious example would be siting new development in areas adjacent to floodplains; updated information might indicate that the area being considered for development is in fact likely to be flooded in the future.

State agencies should undertake agency-wide assessments to identify how existing programs as currently implemented build resilience to the effects of climate variability and change, and identify opportunities to improve resilience through changes in program design, decision criteria, and review processes, and coordination with other agencies and programs. And finally, these assessments should address areas where agency policies and programs may be working at cross-purposes with the programs and policies of other state agencies.

Recommendation for Agency Program Assessments

- State agencies should undertake an initial broad-scale assessment to identify policy and program elements that could result in decisions that place people, resources or infrastructure at risk.

4. Integrating Economic Information into Adaptation Planning

Development of this framework has been somewhat hampered by the absence of reliable information about either 1) the economic costs of projected changes to Oregon's climate, especially over time; and 2) the likely cost to effectively respond to such changes, especially at the local level. The framework had to be developed on the basis of the estimated magnitude of costs—of both the effects of climate conditions and actions to address those effects—relative to other effects and actions. There is considerable room to improve the economic foundation for future adaptation planning.

In the process of developing the framework, there were also assertions that the likely future effects of climate conditions would involve economic opportunities that in some degree would offset some of the economic costs. With the exception of one broad-scale report (Neimi et al., 2009), there are virtually no hard dollar figures available to help identify the most needed or the most effective actions that could be taken by the stat or local communities. Further, there is a lack of solid information on economic opportunities that may be generated by changing climate conditions. Again, there is significant need to quantify anticipated opportunities.

Economics has contributed much to the development of a range of policies designed to reduce greenhouse gases. However, the evolution of climate adaptation into a critical foundation for public policy has received far less attention in terms of economics. Analytical tools needed to assess the costs and benefits of adaptation measures are far less robust than tools used to assess the effects of mitigation policies. While important progress can be made on the basis of rough estimates of the relative magnitude of costs and benefits, a robust risk analysis requires real numbers. In particular, local planning for climate change, which will likely involve some level of risk analysis, will be more useful if real numbers and appropriate analytical tools are available.

Recommendation for Economic Information

- Agencies should work with economists and climate adaptation specialists and existing groups or institutes with expertise in economics to compile a white paper to frame the economic questions, analyses, and data that can be used to improve the effectiveness of planning for climate variability and change.

5. Mainstreaming Adaptation

Climate variability and change will affect all of the agencies that developed this framework and nearly every sector of Oregon's economy in the coming decades. Mounting and maintaining an effective response effort within state government will require ongoing coordination and collaboration between agencies. Given the continuing long-term challenge, climate preparation and adaptation needs to be 'mainstreamed' into agency programs and operations.

In an era of diminishing resources available to address threats to public health, safety and welfare, agencies must identify areas where collaboration and coordination can reduce the costs to implement state programs. Moreover, since agency programs represent some level of existing capacity to address the effects of climate change, it is likely that some climate risks can be addressed through collaboration rather than adopting new policies or program elements. In other words, the framework should be integrated into state agency operations in a way that will foster the continued development of strategies that cut across agency programs, rather than the development of independent, single sector-based initiatives.

Recommendation for Mainstreaming Adaptation

- The agency directors' group and the interagency work group that have developed the framework should be formalized. The directors, as a steering group, should provide oversight for the coordinated implementation of the short-term priority actions and the implementation recommendations outlined here.

6. Intergovernmental Coordination

Federal, state, and local governments and Native American tribal governments provide a broad range of services to Oregonians to address issues from public health and natural resource management to transportation and emergency management. Responses to climate change are being developed at all levels of government. Building resilience to the effects of climate change will require coordination among all levels of government, and should include non-government entities as well. The most effective adaptation strategies will be implemented at the local or regional level, but may well be a function of state or federal initiatives. The private and non-profit sectors will also be actively engaged at the local, statewide, and national scale in building resilience in areas such as the economy and social welfare. Activities at all levels will need to be coordinated to assure cost effectiveness and to avoid working at cross-purposes.

Recommendation for Intergovernmental Coordination

- Oregon state agencies should consult with federal agencies, Native American tribal governments, representatives of local governments, and the private and nonprofit sectors to identify ways to coordinate the implementation of climate adaptation initiatives.

7. Integrating Adaptation and Mitigation Strategies

In working to prepare for and adapt to the effects of climate change, it may be easy to lose sight of the fact that there is overwhelming evidence that changes in Earth's climate can be largely attributed to increased concentrations of atmospheric carbon dioxide and other greenhouse gasses. While there continues to be some resistance to the idea that there could be a connection between human activities and climate, there appears to be very little in the way of credible scientific challenge to the conclusion that much of the change in climate at the global scale is being driven by increased carbon dioxide from the combustion of fossil fuels. Other greenhouse gasses that are far more potent than CO_2 in terms of their capacity to absorb and re-radiate heat also have a role in increasing average atmospheric temperatures. Therefore, based on the idea that a way to reduce climate risks is to reduce, where possible, the drivers of climate change, one of the priority overarching actions of an adaptation framework should be a renewed commitment to reducing the generation of greenhouse gasses. Implementation and future revisions of the Framework should involve collaboration with the bodies that have principal responsibilities for implementing Oregon's Roadmap to 2020 developed by the Oregon Global Warming Commission.

Oregon should seek over time to develop and implement a fully integrated climate change policy designed to both reduce emissions of greenhouse gases and build resilience to impacts through preparedness and adaptation, and to manage the trade-offs between the two objectives. As noted earlier, Oregon has already made some progress in taking measures to reduce greenhouse gas emissions. As the state continues to reduce emissions, there is some risk that mitigation policies will be considered without sufficient appreciation for how those policies might perform under changing climate conditions, or whether they will restrict future choices of how to adapt to those changes. Some mitigation strategies can increase vulnerability to future climate impacts; for example, deforestation to plant biofuels to reduce emissions from petroleum use in the transportation sector may remove significant carbon sequestration capacity. On the other hand, adaptation strategies that involve increased use of energy can result in higher emissions. In the end, both mitigation and adaptation measures will need to consider their effect on both mitigation and adaptation objectives.

Recommendation for Integrating Adaptation and Mitigation Strategies

- Over the next year, state agencies and the OGWC should assess existing emission reduction strategies to determine how best to incorporate climate change preparedness considerations.

8. Communications and Outreach

Given the breadth of Oregon's exposure to the effects of climate variability and change, the somewhat unpredictable nature of some climate-related events, and the potential to make decisions that increase vulnerability to various effects of climate change, it is critical to increase communications and outreach with the public about preparing for climate change. Communication and outreach efforts to inform Oregonians about the likely effects of future climate conditions should include information on how individuals and communities can reduce exposure to climate-related risks, and on how individuals can become involved in community-level efforts to prepare for climate change.

Recommendation for Communications and Outreach

- State agencies and the OGWC should collaborate on ways to improve messaging and outreach to the public related to preparing for climate change.

These next steps are designed to build the long-term infrastructure within Oregon state government needed to address climate impacts that will continue to affect Oregonians in the coming decades. These next steps, in conjunction with the short-term priority actions, represent the beginning of Oregon's effort to build resilience into every element of Oregon's economy and the natural and governance systems that sustain it.

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Appendices

Appendix 1: Risks, Gaps, and Agency Actions

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Over several months in the first half of 2010, the Adaptation Framework Work Group went through an iterative process to compile information about the effects of climate variability and change, gaps in state programs for dealing with those effects, and possible agency actions to fill those gaps. This inventory of risks, gaps and actions drew largely on state agency staff's familiarity with scientific literature about climate change, state agency programs, and their professional judgment about the effectiveness of possible agency actions. Over roughly the same time period, the Oregon Climate Assessment Report was being drafted by the Oregon Climate Change Research Institute (OCCRI).

As noted in the body of the Framework, the work group initially compiled a list of over 100 different consequences of climate variability and change. A significant part of the work group's early effort consisted of collapsing and combining consequences into broad statements of likely changes in Oregon's climate, referred to throughout the framework as *risks*.

The work group achieved a milestone of sorts when it arrived at a list of distinct climate risks. However, since most of the risks overlap other risks, and since most of the consequences of climate change of concern to Oregon are related to other consequences, the scope of several risks continued to be slightly revised as the work group continued to develop the framework.

The tables in this appendix reflect the work group's understanding of climate risks about halfway through the process of developing the framework. Since then, in consultation with the OCCRI, these risks have been slightly revised. Therefore, these tables do not exactly coincide with the risks and actions as laid out in the body of the framework. Rather, they reflect the work group's preliminary understanding of climate risks. These tables are provided for reference only. For a more accurate understanding of risks, gaps and actions, the reader should refer to each of the risk summaries in the body of the framework.

Appendix 2: Participating agencies and work group members

Agency	Agency Directors Team	Work Group
Department of Agriculture	Katy Coba	Stephanie Page
Department of Energy	Bob Repine	Bill Drumheller
Department of Environmental Quality	Dick Pedersen	Annette Liebe
Department of Fish and Wildlife	Roy Elicker	Holly Michael Sara O'Brien (contract) Dave Fox
Department of Forestry	Marvin Brown	Andrew Yost
Department of Geology and Mineral Industries	Vicki McConnell	Don Lewis
Department of Human Services Public Health Division	Mel Kohn	Michael Heumann
Department of Land Conservation and Development	Richard Whitman Jim Rue	Bob Rindy Jeff Weber
Parks and Recreation Department	Tim Wood	Jim Morgan
Department of State Lands	Louise Solliday	Anna Buckley
Department of Transportation	Matthew Garrett	Margi Lifsey Elizabeth Hormann
Water Resources Department	Phil Ward	Barry Norris
Oregon Watershed Enhancement Board	Tom Byler	Greg Sieglitz
Oregon Climate Change Research Institute	Phil Mote	Kathie Dello
Climate Leadership Initiative	Bob Doppelt	Roger Hamilton Steve Adams
Oregon Sea Grant	Dr. Stephen Brandt	Pat Corcoran
Oregon State University Extension Service	Scott Reed	
Oregon State University Institute for Natural Resources	Lisa Gaines	Bobby Mauger
Global Warming Commission	Angus Duncan	
Office of the Governor	Mike Carrier	Ivo Trummer Christine Valentine
Business Oregon	Tim McCabe	