CLIMATE CHANGE PREPARATION STRATEGY

RISK AND VULNERABILITIES ASSESSMENT

PREPARING FOR LOCAL IMPACTS
IN PORTLAND AND MULTNOMAH COUNTY | 2014

MULTNOMAH COUNTY

CITY OF PORTLAND, OREGON 1851

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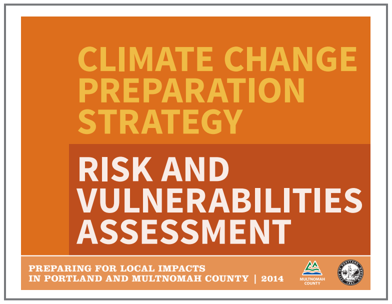
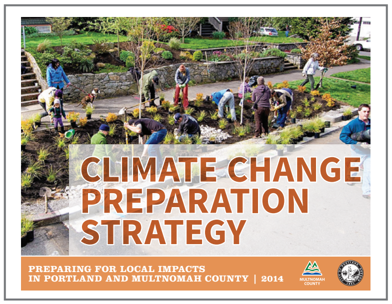
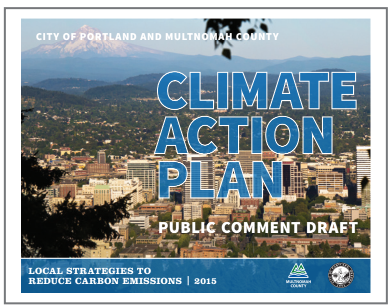


Portland's future climate is expected to include hotter, drier summers with an increased frequency of high-heat days and warmer winters with the potential for more intense rain events. This *Risk and Vulnerabilities Assessment* provides the foundation for Portland and Multnomah County's *Climate Change Preparation Strategy.*

RELATED PLANS



The *Climate Change Preparation Strategy* (separate document) uses this assessment as the foundation for identifying actions to prepare for the changing climate in two ways: 1) reduce climate-related vulnerabilities for residents and businesses, and 2) respond to impacts when they do occur. To view a copy of the action strategy, visit www.portlandoregon.gov/bps/climate.



Addressing the primary cause of climate change, greenhouse gas emissions, remains a crucial component of Portland and Multnomah County's climate change preparation work. This assessment report, and the associated *Climate Change Preparation Strategy* (separate document), are fundamentally linked to the City and County Climate Action Plan, which integrates the work to slow the effects of climate change while also preparing for the impacts that we will experience.

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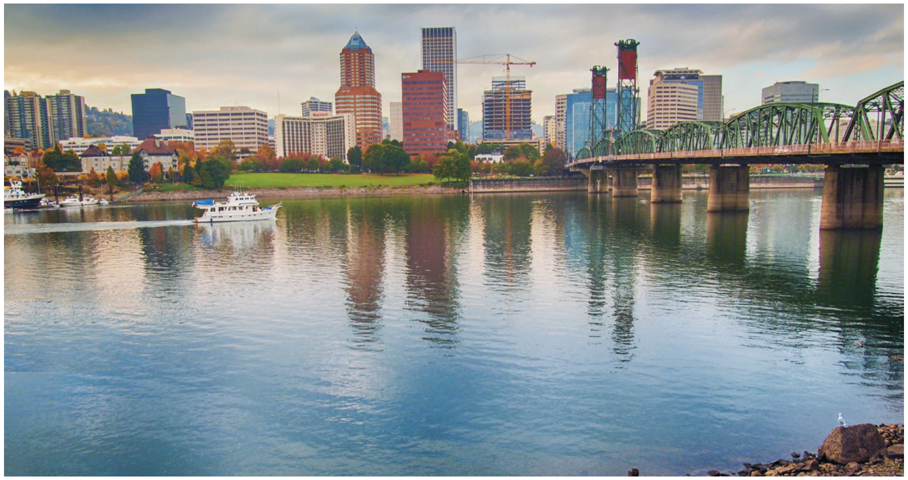
CHAPTER 1 — CLIMATE CHANGE PREPARATION

The City of Portland and Multnomah County have long understood the importance of addressing climate change. Portland has been addressing climate change for over two decades and in 1993 adopted the first local climate action plan in the United States. Our collective efforts have achieved notable results: As of 2012, local per-capita carbon emissions were 32 percent below 1990 levels, and total local carbon emissions had declined by 11 percent from 1990 levels. Portland's climate leadership is built on a tradition of excellence in land use planning and stewardship of natural resources. Despite worldwide efforts to reduce carbon emissions, climate change is already in evidence. The impacts on the Pacific Northwest region are expected to grow in scale and in scope over the years ahead, and the City and County's climate change preparation work will help the community prepare for and respond to these impacts.



Vision

This *Risk and Vulnerabilities Assessment* describes how climate affects the community today, identifies vulnerabilities and risks and outlines how those impacts are expected to change over the next century. The associated *Climate Change Preparation Strategy* (separate document) outlines key objectives and actions to build resilience into the City and County's operations, services and infrastructure.

Through implementing the *Climate Change Preparation Strategy*, the City and County seek to:

- Strengthen adaptive capacity based on the best available information on regional climate change projections and impacts.
- Outline priority risks, vulnerabilities and near-term actions.
- Lay the foundation for the development of implementation plans that consider available resources and prioritize the most effective actions from a cost and benefit perspective, while also taking into consideration carbon mitigation and other co-benefits, equity, urgency and window of opportunity.
- Prevent or reduce the risks to populations most vulnerable to the impacts of climate change.
- Develop a framework to monitor climate trends and projections, and assess local impacts.

As part of an adaptive management approach, the *Climate Change Preparation Strategy* will be revised as climate projections are refined, climate preparation practices become more defined and progress is assessed.

Content overview

This *Risk and Vulnerabilities Assessment* begins with an overview of climate change preparation, why we need to prepare, and the City and County's climate change preparation planning process (Chapter 1 — Climate Change Preparation, page 1). All populations are affected by the impacts of climate change, but some communities are more vulnerable than others. Chapter 2 — Climate Equity (page 7) outlines the challenges, opportunities and responsibilities to ensure that climate change preparation efforts serve all residents, and particularly populations most vulnerable to heat and flooding. Chapter 3 — Climate Projections (page 11) summarizes temperature and precipitation projections for the Pacific Northwest. Chapter 4 — Climate Risks reviews the expected risks and impacts associated with hotter, drier summers with more high-heat days, and warmer, winters with the potential for more intense rain events (page 15). Chapter 5 — Vulnerability Assessment by Sector (page 31) includes the findings of how climate change is expected to impact human systems (page 33), natural resource systems (page 41), and the built environment and infrastructure (page 53). Chapter 5 also contains an overview of potential impacts in other areas, including food systems, population shifts, energy systems and the economy (page 61).

The *Climate Change Preparation Strategy* (separate document) details the 2030 objectives and actions to ensure that Portland and Multnomah County are taking the steps necessary to prepare for and respond to the changing climate. The 2030 objectives and samples of associated actions are summarized on the following page.

Climate Change Preparation Strategy — At a Glance

HOTTER, DRIER SUMMERS WITH MORE HIGH-HEAT DAYS

2030 Objective 1: Decrease the urban heat island effect, especially in areas with populations most vulnerable to heat.

Design and implement programs that cool the urban environment, including revegetation and tree planting, pervious paving and green infrastructure like bioswales and ecoroofs. Utilize information and maps of Portland's urban heat islands and populations most vulnerable to heat to help inform decisions and priorities about such projects.

2030 Objective 2: Minimize health issues caused by extreme heat days, especially for populations most vulnerable to heat.

Improve the preparation for and response to extreme heat days by health, community service, public safety and emergency response staff and services. Coordinate operations of cooling environments and early warning and response systems.

2030 Objective 3: Increase the resilience of Portland's water supply to drier summers.

Expand the capacity of the groundwater system and ensure water is used efficiently by homes, businesses and in City and County facilities such as local parks. Continue to assess the potential impacts of climate change on the Bull Run watershed.

2030 Objective 4: Increase the resilience of natural systems to respond to increased temperatures and drier summers.

Seek to keep natural areas, especially urban streams, cooler including increasing the width of vegetation along streams and ensuring existing and new rules support wetlands and surface water temperature needs. Increase the ability of plantings (natural areas, restoration sites, greenstreets, ecoroofs, etc.) to withstand drought conditions. Address invasive species, connect habitats and support birds, amphibians and other species needing to alter their range.

2030 Objective 5: Manage the risk of wildfires as a result of drier summers.

Reduce wildfire risk in areas where homes and businesses are next to natural and forested areas (often called the "urban-wildland interface"). In a co-management role with partner agencies, respond to fires in and around the Bull Run watershed.

WARMER, WINTERS WITH THE POTENTIAL FOR MORE INTENSE RAIN EVENTS

2030 Objective 6: Increase the resilience of the natural and built environment to increased winter rainfall and associated flooding.

Work with local, state and federal partners to update floodplain data used in planning processes. Restore floodplains, reduce paved surfaces (to reduce stormwater runoff), and prepare to manage increased runoff amounts.

2030 Objective 7: Manage the increased risk of disease due to changes in vector populations.

Reduce health risks from vector populations. Strengthen education and outreach efforts to understand, prevent and respond to vector-borne diseases.

2030 Objective 8: Manage the increased risk of landslides due to changing precipitation patterns.

Identify, map and monitor landslide hazard areas and incorporate landslide hazard reduction techniques into infrastructure planning projects. Provide outreach and education on reducing landslide risks to private property owners.

BUILDING CAPACITY TO BETTER PREPARE FOR AND RESPOND TO CLIMATE CHANGE

2030 Objective 9: Strengthen emergency management capacity to respond to weather-related emergencies.

Strengthen the capacity of emergency management staff to prepare for and respond to weather-related emergencies, increase the capabilities of volunteer organizations, and develop response plans that minimize impacts on populations most vulnerable to heat and flooding.

2030 Objective 10: Institutionalize climate preparation planning and best practices.

Apply an equity lens to climate action efforts and where possible prioritize benefits to populations most vulnerable to the impacts of climate change. Improve the understanding of local climate change impacts. Recognize climate variables as a risk in how the City and County manage infrastructure.

2030 Objective 11: Improve community capacity, especially of populations most vulnerable to climate change risks, to understand, prepare for and respond to climate impacts.

Provide education, resources and services related to climate risks to the public including emergency preparedness, extreme heat and respiratory-related illness.

2030 Objective 12: Improve monitoring, evaluate effectiveness of climate change preparation and actions and advance new research to support climate preparation efforts.

Identify, compile and regularly update key data for climate change trend tracking (streamflows, temperature, natural resources, storms, condition of infrastructure, heat-related illness, air quality, etc.). Support monitoring programs and existing climate research, and advance new research on climate-related diseases, population shifts, food systems, etc.

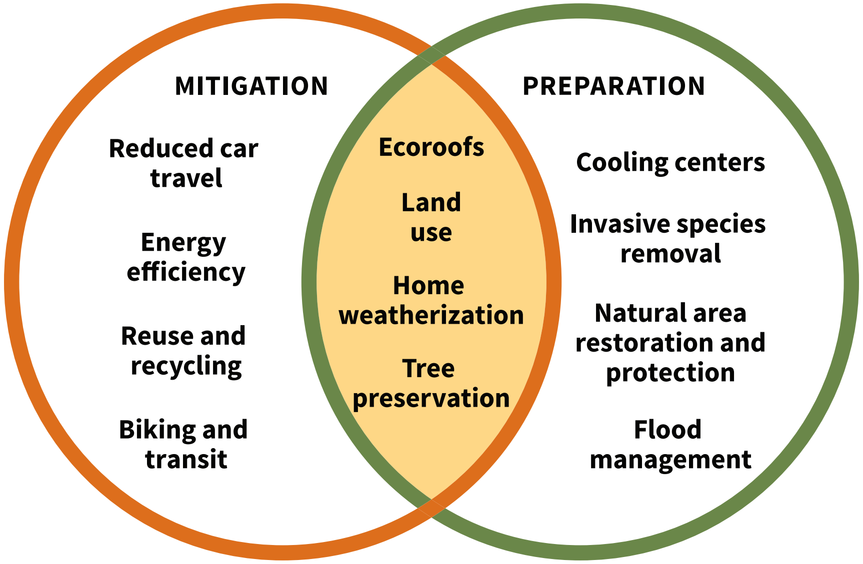
What is climate change preparation?

Climate preparation requires assessing risks and identifying deliberate action to protect residents and businesses from the most significant impacts of climate change. Many agencies have used the term “adaptation” to refer to similar efforts; in this document, the term “preparation” is used synonymously with “adaptation.”

In the context of climate change, the terms “preparation” (or “adaptation”) and “mitigation” represent two types of strategic goals with different purposes, though sometimes overlapping activities (see Figure 1). Mitigation deals with reducing carbon emissions, the primary driver of human-caused climate change. Throughout this document, the term “carbon emissions” refers to all greenhouse gas emissions. Preparation, by contrast, is primarily intended to respond to and minimize the impacts of a changing climate.

Some actions or strategies work toward both preparation and mitigation. For example, ecoroofs help better manage stormwater from winter storms (preparation), but they also provide an additional layer of insulation on a building, helping to reduce energy consumption and the associated carbon emissions (mitigation). Additional terms and definitions helpful in understanding climate change preparation can be found in the glossary, see Appendix A, page 65.

Figure 1. Relationship between climate change mitigation and preparation



Why do we need to prepare?

Scientists have a good understanding of how climate change impacts will manifest on a global scale. At the regional level, Oregon and Washington scientists are working to improve our understanding of climate projections. Based on currently available information, local communities need to anticipate a range of climate impacts. Portland's future climate will include hotter, drier summers with more high heat days; and warmer winters with the potential for more intense rain events (see Chapter 3, page 11, for more details on climate projections). Climate scientists have now established that climate change is moving climate conditions outside of what we have experienced in the recent past.

Portland's infrastructure was built based on the historic climatic record. Events outside of that record, as well as the cumulative effect of an increased number of damaging events, can significantly impact important infrastructure services such as water, sewer, electricity, transportation, stormwater and flooding control, communication and emergency response services. These impacts can result in infrastructure systems becoming more frequently stressed, overloaded, or at times partially or wholly unavailable.

Similarly, natural systems have evolved and adapted to historic climatic conditions. As a result, the function of natural systems, which provide critical services like pollinators for food, clean air and water, and natural cooling from trees, can become overwhelmed during atypical climatic events resulting in damage to habitat, fish, wildlife and people. In addition, human health services may be faced with new challenges associated with uncharacteristic events, impacting existing capacity and resources to manage the risks of heat-related illness, respiratory and vector-borne diseases.

How do we prepare?

Climate variability costs communities money and other resources. Therefore, considering the impacts of climate change, identifying vulnerabilities of public systems and risks of those impacts, and putting in place policies and strategies to make the community more resilient makes good public policy. This is especially true in urban areas that are vulnerable to climate impacts because of the density of people and assets within a relatively small geographic area.

Urban areas can also exacerbate climate impacts. For example, the greater density of large hard surfaces like pavement and roofs can increase runoff leading to flooding or prevent the city from cooling off at night during the summer. Reducing exposure to the impacts of extreme events can reduce the health and financial impacts of an event and speed up recovery.

Ongoing climate change preparation research

Regional trends in climate change variables are identifiable in current scientific research (see Chapter 3, page 11, for more details). Scientists and modelers from across the country are working to refine and expand the understanding of climate change projections and potential impacts.

Organizations like the Oregon Climate Change Research Institute (housed at Oregon State University) and the Climate Impacts Group (housed at the University of Washington) are leading such efforts for the Pacific Northwest. The National Oceanic and Atmospheric Administration-funded Regional Integrated Sciences and Assessments (RISA) program for climate change research in the Pacific Northwest is called the Pacific Northwest Climate Impacts Research Consortium (CIRC), and is housed in the Oregon Climate Change Research Institute (OCCRI). CIRC is focused on connecting decision makers such as the City and County with science to aid in preparing for climate impacts.

Regional climate change planning work also continues. One example of a collaborative effort of faculty from Oregon State University, the University of Oregon, Portland State University and local stakeholders is called "Willamette Water 2100." This is a project to evaluate how climate change, population growth and economic growth will alter the availability and use of water in the Willamette River Basin. Although Portland's water supply does not come from the Willamette basin, this effort is expected to provide more information about flooding and water availability for natural systems locally.

Similarly, the Northwest Biocarbon Initiative is a clearinghouse of non-governmental organizations, universities and agencies from around the Pacific Northwest to share best practices and research around carbon sequestration, and both natural and built green infrastructure.

Climate change preparation planning

Recognizing the need to evaluate climate projections and potential impacts systematically, the City of Portland and Multnomah County's 2009 *Climate Action Plan* called for the development of a City and County climate change preparation strategy to identify vulnerabilities and key climate change preparation strategies across several sectors. In reviewing the planning approaches of other jurisdictions, including New York City, Seattle, and the states of Oregon and Washington, two basic approaches emerged, "top down" and "bottom up." The "top down" approach is essentially an impact assessment — working from the identification of anticipated impacts. The "bottom up" approach is a vulnerability assessment — identifying when and where the community is sensitive to change. Both approaches can work well for climate change preparation planning and risk assessment; the City and County used a hybrid of the two approaches, with an emphasis on "bottom up" approach given the lack of finer-scale downscaled climate information.

The "top down" approach involves scaling down global climate models to the regional and local level. This method has been used in the Pacific Northwest, as well as by the Portland Water Bureau in evaluating the impacts of climate change on the Bull Run watershed. Scaling down global climate models is technically challenging and requires substantial resources and time to produce, evaluate and synthesize. The results of such work to date have produced a sizeable range of outcomes for climate variables, particularly precipitation. In this "top down" approach, the results are then processed by additional models (such as hydrology, land cover, integrated infrastructure or other decision support systems) to produce the actual climate impacts information.

The Climate Impacts Research Consortium (CIRC) at Oregon State University is working on producing downscaled climate information at smaller grid sizes using the latest global climate modeling efforts. Downscaled climate data was not available at grid sizes useful for the development of this assessment. However, in the future the City and County may be able to take advantage of more detailed information at the regional level.

The "bottom up" approach does not require downscaled climate change data or climate specific modeling tools. This method uses available information about climate change variables and trends, evaluates the impacts on those systems of interest (e.g., infrastructure, natural systems and public health), identifies vulnerabilities and risks, and then considers what climate change preparation strategies might best address the risks of highest concern over the timeframe of interest (e.g., near-, mid-, and long-term).

Along with many background resources, the City and County's approach draws on two climate change preparation planning processes:

1. *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* from the University of Washington (CIG/JISAO) and King County, Washington in association with ICLEI (2007).
2. The Center for Disease Control's *Building Resilience Against Climate Effects (BRACE)* — a framework developed by the Climate Health Program and piloted in partnership with the Oregon Health Authority.

Three City and County staff working groups were created to look at health and human services, built infrastructure and natural systems. These three groups followed a similar process (see Figure 2) that included:

- Identifying specific climate variables that impact City or County services (e.g., temperature, precipitation), and observed and expected trends using the best available scientific research. The teams also identified secondary impacts due to climate trends (e.g., flooding, drought, heat-related illnesses, pests).
- Assessing vulnerabilities of various systems (infrastructure, natural systems, and health and human services) that could be impacted by climate conditions outside of the historic past. This included looking at expected impacts, probability of change and projected impact of change by 2030. The teams also assessed risks by evaluating the likelihood and consequences of the change or impact by 2030.
- Identifying existing and proposed strategies to address those impacts that have higher likelihood of occurrence and consequences of higher concern.
- Identifying strategies that meet multiple objectives and maximize co-benefits and equity outcomes; and build on existing cross-jurisdictional strategies of monitoring, education, implementation and sharing results.

Figure 2. Climate change preparation planning and implementation process

CHAPTER 2 — CLIMATE EQUITY

All populations are affected by climate change, but not all communities have the same ability to respond. As a result, some are more vulnerable than others. In Portland, communities of color and low-income communities experience disparities that will be exacerbated by the impacts of climate change. These disparities include greater risk of poor health, reduced access to housing, un- and under-employment, limited access to transportation options and parks, higher mortality rates and the legacy of inequitable public policy.

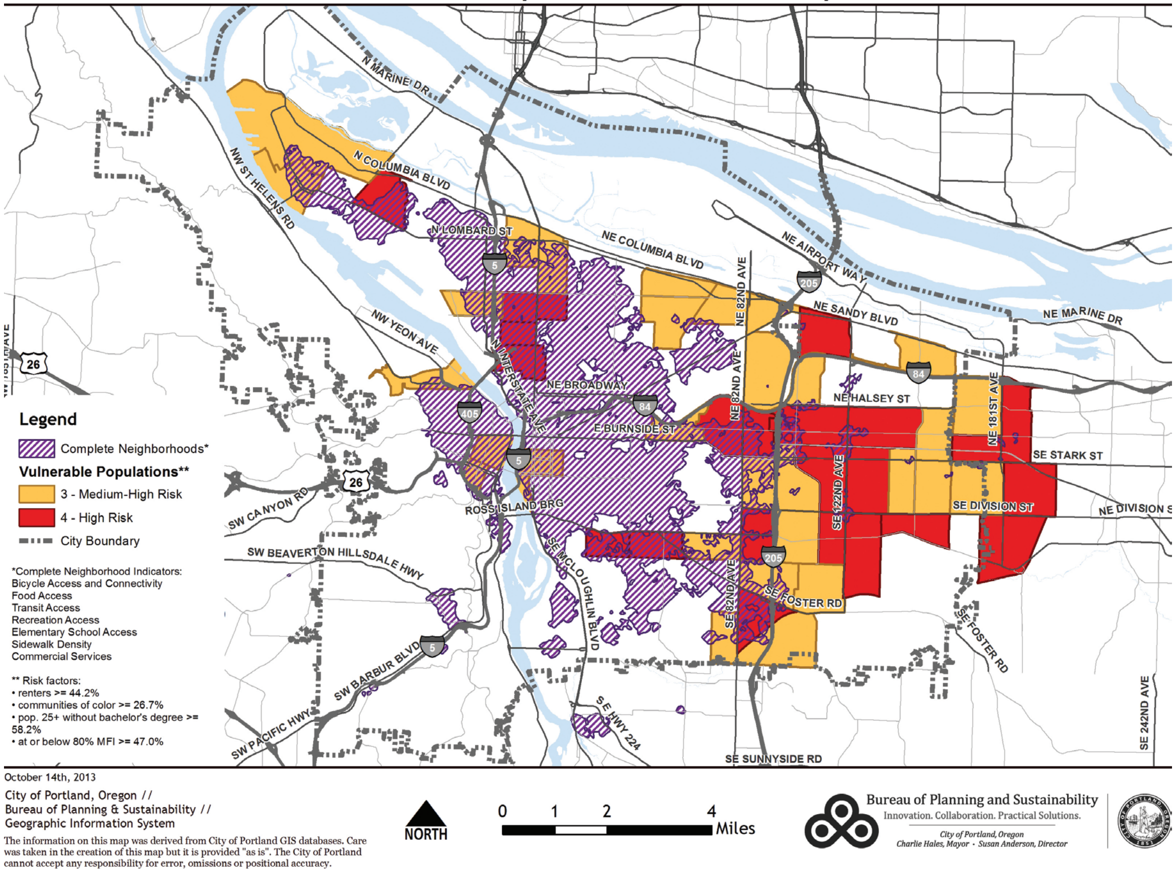
Intentional and focused efforts to identify and to repair inadequate program and project designs for these communities must be a priority. In addition, concerted efforts must be made to understand existing aspects of the community that support resilience, such as social-cultural networks or indigenous knowledge. Partnering with these communities to understand challenges experienced and opportunities available will enable the implementation of effective preparation strategies that deliver more equitable outcomes.

The *Climate Change Preparation Strategy* (separate document) and this *Risk and Vulnerabilities Assessment* seek to create a more climate-resilient community (as described by the Interagency Climate Change Adaptation Task Force, 2011) that has the capability to anticipate, prepare for and recover from climate impacts on public health and safety, the built environment, the local economy, and natural resources. In doing so, the City and County seek to ensure that the benefits of taking actions to prepare for climate change are shared by the whole community and across multiple generations.

Portland broadly defines communities that may be more vulnerable to a variety of socio-economic and environmental justice risks as those that have concentrations (above the City average) of at least three of the following factors: renters, lower educational attainment, reduced household income and people of color (see Figure 3). A 2013 gentrification and displacement study worked to define these indicators (Bates, 2013). While individuals may be more or less vulnerable to a given climate change impact (e.g., heat, flooding, landslides), this general identification of at risk communities is a starting place to begin a deeper assessment of populations that may be hit hardest by climate change. Figure 3 maps vulnerable communities and relative access to “complete community” services that are likely to help improve resilience, including transit, sidewalks, food, schools and businesses.

Figure 3

Urban Resilience: Vulnerable Populations and Complete Communities



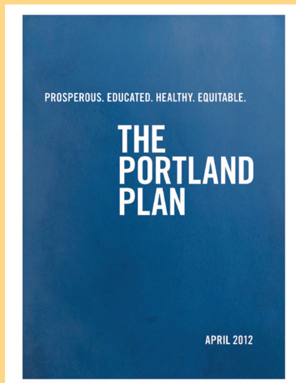
Integrating climate equity into the City and County's climate preparation efforts can result in the following long-term benefits:

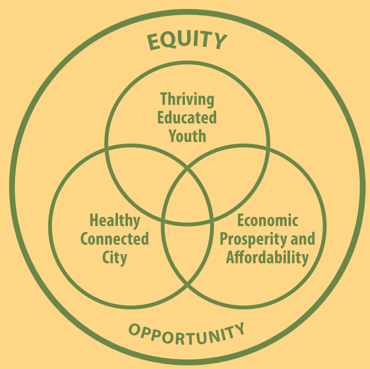
- Improved data collection, including a broad set of sources and research methods, to better understand the conditions and challenges facing marginalized communities.
- Increased awareness and understanding to identify critical disparities in an inclusive manner.
- Improved service delivery, particularly for communities facing disparities, while improving the reliability, quality and safety of the entire system.
- Improved transparency and accountability through effective public engagement.
- Improved and expanded community partnerships that leverage the skills and expertise of others to research and develop innovative approaches to climate change preparation.
- Tailored outreach and service delivery that is relevant to the primary needs of each at-risk community.

Putting equity into practice requires looking at relevant questions, data and priority setting needed to advance equity in decision-making. To ensure the most equitable outcomes possible, these or similar questions will be explored at different phases of a climate change preparation project, policy or program:

1. What are the desired results or outcomes of the action?
2. What are the current and historical racial disparities related to the action (or similar actions in the past)?
3. Does the action involve land or space? If yes, how is any historical connection to the land and the populations who hold such connections considered in decision-making?
4. Who primarily benefits from the action?
5. Are racial, ethnic, low-income populations, older adults or disabled people positively affected by the action? Is there a missed opportunity to reduce existing disparities these communities experience?
6. Are there unintended consequences or negative impacts of this action for racial, ethnic, low-income communities, older adults or disabled people? If so, what are the strategies to mitigate negative impacts?
7. How does the proposed action promote 1) meaningful engagement of those most impacted, and 2) transparent, inclusive and empowering collaboration?

THE PORTLAND PLAN — A FRAMEWORK FOR EQUITY





The City and County will use the Portland Plan's "Framework for Equity" as a guide when implementing actions outlined in this strategy.

The Portland Plan defines equity as "when everyone has access to the opportunities necessary to satisfy their essential needs, advance their well-being and achieve their full potential. We have a shared fate as individuals within a community and communities within society. All communities need the ability to shape their own present and future. Equity is both the means to healthy communities and an end that benefits us all."

The Portland Plan also states that without healthy, thriving, prepared people we cannot achieve our highest goals, implement our best plans for dealing with climate change or secure Portland's position in the global economy. Without a city that is physically designed to last, future generations will not benefit. We want a city where we are better on a good day so we can bounce back from a bad day. It requires that everyone thrive and everyone participate.

CHAPTER 3 — CLIMATE PROJECTIONS

An existing climate of variability

The climate of the Portland metropolitan area is historically variable, both seasonally and annually. The cool season is affected by variations over the Pacific Ocean, particularly the El Niño Southern Oscillation (ENSO) (Mote et al., 2013). Several other factors also influence Pacific Northwest climate including proximity to the ocean, topography, and latitude (K. Dello, personal communication, January 9, 2014). These factors dictate the major aspects of weather such as temperature, wind, precipitation (type and amount) and humidity. This complexity extends to defining the global climate type for the area that includes characteristics of both the marine West Coast and the Mediterranean climate classifications.

Portland experiences a temperate climate that is usually described as mild, with wet winters and most precipitation falling in October through March. Summers are warm and dry (Oregon Climate Service, 2013). According to the Koppen climate classification system the Portland area, like much of the Pacific Northwest, falls within the cool, dry-summer subtropical zone (Csb), also referred to as cool-summer Mediterranean. While extremes of temperature and precipitation are infrequent, they do occur.

Recent climate trends

The factors that influence climate in Portland present complexities in understanding Portland's future climate. The Pacific Northwest has already experienced some climatic shifts in the past century. While these changes in the climate are significant, Portland is unlikely to suffer the severity of impacts related to hurricanes, intense drought and sea level rise as many cities around the world will face.

An increase in average annual temperature is the most consistent trend identified in the last century. For the Pacific Northwest, average annual temperatures increased by about 1.3 °F in the 20th century (Dalton et al., 2013). Trends in extreme precipitation are ambiguous and often depend on the period of record and method used. Extreme 1-hour precipitation increased in Portland, but there was a slight decrease in the 24-hour period. (IPCC, 2007a; Rosenberg et al., 2010; OCCRI, 2010; Kunkel et al., 2012; Mote et al., 2013).

In addition, several research papers document shifts in the amount of regional snowpack (or snow water equivalent) as of April 1 each year. Snowpack is an important indicator for Portland because the Willamette and Columbia Rivers are fed by snowpack, and subsequent snowmelt, in the late spring and summer that may cause flooding or affect hydro-electricity generation. While there have been a few monitoring sites that have shown increases, the majority of sites, particularly in elevations below 4,000 feet, show significant declines in average snowpack. The Pacific Northwest has experienced the largest declines in average snowpacks in the western United States, a change that can be primarily attributed to an increase in winter temperatures (OCCRI, 2010).

Unlike increasing average annual temperatures and decreasing snowpack, historical trends in annual precipitation are neither increasing nor decreasing. Additionally, there does not appear to be a statistically significant trend in extreme precipitation events in the Pacific Northwest (OCCRI, 2010; Rosenberg et al., 2010; Kunkel et al., 2012).

PORTLAND TEMPERATURES AND PRECIPITATION

Historic average monthly temperatures in Portland range from lows of around 36 °F (December) to highs around 80 °F (August) (see Figure 4). Days with maximum temperatures above 90 °F occur 11 times per year, and temperatures above 100 occur once per year on average. The all-time record high temperature is 107 °F, temperatures below zero have only occurred once every 25 years (Oregon Climate Service, 2013; Western Regional Climate Center, 2013; National Weather Service, 2013). The average length of a heat wave is three days (Bumbaco et al., 2013).

The average annual precipitation amount in Portland is approximately 36 inches, and localized precipitation amounts can vary due to elevation changes of a few hundred feet across the metropolitan region. Snow does occasionally occur, typically in the higher elevations (e.g., West Hills and East County buttes). However it usually melts within days, if not hours. Extreme precipitation events are often associated with a phenomenon typically referred to as a "Pineapple Express" which is a large-scale atmospheric river carrying high amounts of water from the equatorial Pacific Ocean, resulting in high amounts of rainfall over a few days (e.g., over 2.5 inches of rain in a 24-hour period). Figure 4 shows the average temperature and precipitation patterns for the Portland area for the period 1981–2010.

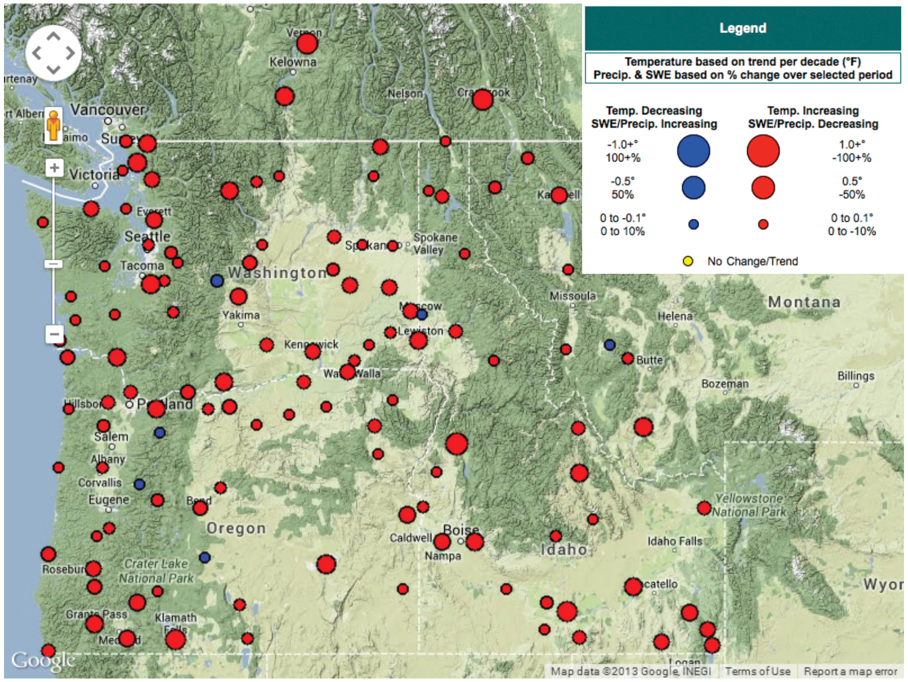
Figure 4. Portland climate data

CLIMATE DATA FOR PORTLAND, OREGON (PDX), 1981–2010 NORMALS

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	66 (19)	71 (22)	79 (26)	88 (31)	103 (39)	101 (38)	104 (40)	107 (42)	103 (39)	92 (33)	71 (22)	67 (19)	107 (42)
Average high °F (°C)	46.0 (7.8)	50.0 (10.0)	56.0 (13.3)	61.4 (16.3)	67.9 (19.9)	73.5 (23.1)	79.5 (26.4)	80.1 (26.7)	75.0 (23.9)	63.8 (17.7)	52.7 (11.5)	45.5 (7.5)	62.62 (17.01)
Average low °F (°C)	38.8 (3.8)	38.3 (3.5)	41.7 (5.4)	44.2 (6.8)	49.7 (9.8)	53.7 (12.1)	57.9 (14.4)	58.0 (14.4)	54.2 (12.3)	48.1 (8.9)	41.5 (5.3)	36.2 (2.3)	46.86 (8.25)
Record low °F (°C)	−2 (−19)	−3 (−19)	19 (−7)	29 (−2)	29 (−2)	39 (4)	43 (6)	44 (7)	34 (1)	26 (−3)	13 (−11)	6 (−14)	−3 (−19)
Precipitation inches (mm)	4.88 (124)	3.66 (93)	3.68 (93.5)	2.73 (69.3)	2.47 (62.7)	1.70 (43.2)	.64 (16.3)	.66 (16.8)	1.47 (37.3)	3.00 (76.2)	5.64 (143.3)	5.49 (139.4)	36.01 (914.7)
Snowfall inches (cm)	0.3 (0.8)	1.2 (3)	0.1 (0.3)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.2 (0.5)	0.7 (1.8)	2.4 (6.1)
Avg. precipitation days (≥ 0.01 in)	18.0	14.9	17.6	16.4	13.6	9.2	4.1	3.9	6.7	12.5	19.0	18.6	154.5
Avg. snowy days (≥ 0.1 in)	0.4	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.8	2.5
Mean monthly sunshine hours	86.8	118.7	192.2	222.0	275.9	291.0	331.7	297.6	237.0	151.9	78.0	65.1	2,347.9

NOAA Weather Station Data — Portland Airport

Figure 5. Mean temperature trend analysis (1920 to 2010)



Source: Office of Washington State Climatologist, University of Washington

Portland's climate future

Climate models suggest that future shifts in climate factors, such as temperature and precipitation, will occur. Projections for the Pacific Northwest indicate an annual average temperature increase of 2.0 °F to 8.5 °F by mid-century (2041–2070) (Dalton et al., 2013). The lower end of this range is only possible with significant global carbon emission reductions.

Snowpacks in the Pacific Northwest are expected to be particularly sensitive to warming. Climate models project continued winter warming and Cascade snowpacks are projected to be less than half of what they are today by 2050 (OCCRI, 2010). Although these projections will impact the Willamette and Columbia Rivers, Portland might be buffered but not insulated by these changes because of the extensive network of hydropower and flood storage dams on those two river systems (Dalton et al., 2013). Managers for those systems are updating the models to incorporate effects of climate change and will be reviewing their operational plans accordingly (NWPCC, 2013). Additionally, projected increases in annual precipitation, averaged over all models, are small (an increase of one to two percent). However, some models project an enhanced seasonal cycle with changes toward wetter autumns and winters and drier summers (CIG, 2009a).

Work conducted by Dr. Alan Hamlet for the Oregon Water Resources Department generated hydrographs (measures of river flow over time at a specific river location) for several locations on rivers in the Portland area (The Resource Innovation Group (TRIG), 2011). Higher river flows in the winter could catalyze operational changes for up-river dams on the Columbia and Willamette Rivers. In addition, the dam system in the Willamette River basin provides a significant proportion of summer flows in the lower river.

Limited information is currently available about projected impacts of sea level change on river levels in the Portland area. A study of sea level rise is being conducted in the Puget Sound area that may shed further light on the magnitude of potential sea level rise that could impact the Portland metropolitan area. A recent study published by the National Academy of Science (National Academy Sciences (NAS), 2012) on sea level rise for the West Coast found that sea level is projected to change between –2 inches to +9 inches by 2030, –1 inches to +19 inches by 2050, and +4 inches to +56 inches by 2100. Oregon's coast is currently experiencing tectonic uplift which could mitigate the impacts of sea-level rise in some coastal areas (OCCRI, 2010). Since tidal influence reaches as far inland as Willamette Falls and Bonneville Dam, changes in sea level may raise local river levels. In turn, this could increase river-flooding levels by a small factor in the mid-term and by a more significant factor in the longer-term depending on dam operations and the operation and maintenance of the local levee system.

The projected climate changes for Oregon and the Pacific Northwest, compiled from a variety of sources, are summarized in Table 1 (page 14). This table formed the basis for the City and County's climate change preparation planning efforts. This table will be updated as information and data become available

Table 1. Summary of projected climate changes for Oregon and the Pacific Northwest

Climate variable	Seasonal patterns of projected change	Expected trend	Size of projected change	Confidence of projected change	Context	Sources
Increased temperature	Overall warming with more warming in the summer; higher highs and higher lows.	Increasing	+2.0 to +8.5 °F by mid-century (2041–2070). Lower end only possible with significant global carbon emission reductions.	High	High confidence that the Pacific Northwest will warm (all models project warming in all seasons).	NWCAR
Changing precipitation patterns	Annual precipitation	Near-zero	Mean change of 3% with a range from –4.7% to +13.5% by mid-century (2041–2070)	Moderate	Annual mean changes for all models are small relative to inter-annual variability such as El Niño Southern Oscillation (ENSO).	NWCAR
	Winter Precipitation (December–February)	Increasing	Mean change of 6.3%, but large range –5.6% to +19.8%	Low	Projected changes in models split between increases and decreases.	NWCAR
	Summer Precipitation (June–August)	Decreasing	Mean change of –6.5% by mid-century	Moderate	Majority of models project decreases in summer precipitation.	NWCAR
Extreme weather events	Intense rainfall, heat events	Increasing	Extreme events may increase in frequency, magnitude, and duration.	Moderate	Models point to an increase in extreme precipitation and heat events, but the projections depends on the metric used for "extreme."	OCCRI, NWCAR
Sea level rise	(not applicable)	Increasing	Sea level is projected to change between –2 inches to +9 inches by 2030, –1 inches to +19 inches by 2050, and +4 inches to +56 inches by 2100 with significant local variations.	Moderate to High	In the Portland area, the Columbia and Willamette Rivers may see changes in basic elevations due to tidal influence.	NWCAR, NAS

NWCAR = Dalton et al., 2013

NAS = National Academy of Sciences, 2012

OCCRI = OCCRI, 2010

CHAPTER 4 — PRIMARY CLIMATE RISKS

Hotter, drier summers with more high-heat days

Risk 1: Increased temperatures (both day and night) and frequency of high-heat days PAGE 17

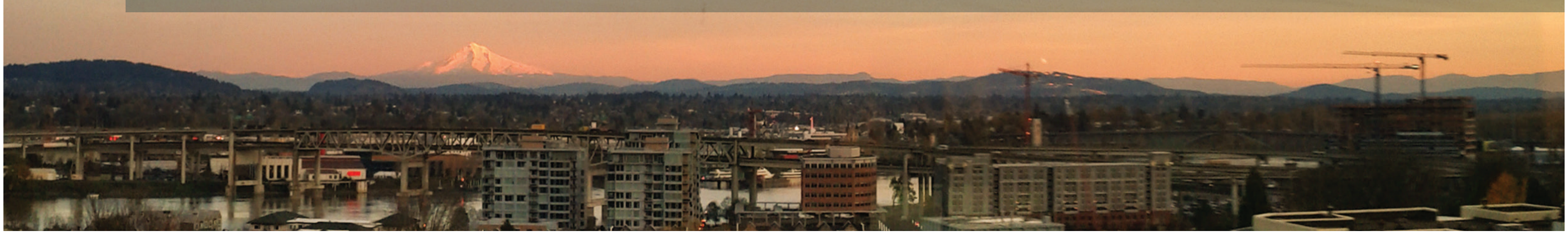
Risk 2: Increased incidence of drought PAGE 21

Risk 3: Increased wildfire frequency and intensity PAGE 23

Warmer winters with the potential for more intense rain events

Risk 4: Increased incidence and magnitude of damaging floods PAGE 25

Risk 5: Increased incidence of landslides PAGE 29



Oregon's climate risks

The overall climate change risks that apply to Oregon are summarized in Table 2 (State of Oregon, 2010). All of the risks identified in Table 2 pose a significant threat to Oregon, but each one varies in the likelihood of its occurrence. The likelihood of a risk impacting Oregon through 2050 was based on the state's assessment of literature and the scientific confidence about that risk.

- **Very likely** means that change is almost certain to occur in Oregon (90 percent probability of occurrence).
- **Likely** means a very high level of probability the risk will occur in Oregon (66 percent probability of occurrence).
- **More likely than not** means there is a range of possible future outcomes, or there is a lack of research available for Oregon or the Pacific NW to confidently quantify the risk as almost certain (50 percent probability of occurrence).

Several of the identified risks in Table 2, while important for Oregon, pose less of a direct risk to the Portland region. These include the risks identified related to ocean temperatures and acidification, coastal erosion and inundation, and increasing wave heights and storm surges. Therefore, the City of Portland and Multnomah County did not focus on those risks in the development of this assessment.

The primary climate changes Portland is projected to face in the future can be generally characterized as hotter, drier summers with an increased frequency of high-heat days; and warmer winters with the potential for more intense rain events. These changes to the region's climate present several secondary risks, as outlined on page 15 and further explored in this chapter.

Table 2. Likelihood of climate risks for Oregon

Oregon climate risk	Likelihood in Oregon	Potential issue for Portland area?
Increase in average annual air temperature and likelihood of extreme heat events	**Very likely**	**Yes**
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**	**Yes**
Increase in wildfire frequency and intensity	**Likely**	**Yes**
Increase in ocean temperatures with potential for changes in ocean chemistry and increased ocean acidification	**Likely**	**No**
Increased incidence of drought	**Likely**	**Yes**
Increased coastal erosion and risk of inundation from increasing sea levels and increasing wave heights and storm surges	**Likely**	**No**
Changes in abundance and geographical distributions of plant species and habitats for aquatic and terrestrial wildlife	**Likely**	**Yes**
Increase in diseases, invasive species and insect, animal and plant pests	**Likely**	**Yes**
Loss of wetland ecosystems and services	**Likely**	**Yes**
Increase incidence and magnitude of damaging floods and frequency of extreme precipitation events	**More likely than not**	**Yes**
Increased incidence of landslides	**More likely than not**	**Yes**

(State of Oregon, 2010)

HOTTER, DRIER SUMMERS WITH MORE HIGH-HEAT DAYS

RISK 1: Increased temperatures (both day and night) and frequency of high-heat days

HISTORIC TEMPERATURE PATTERNS

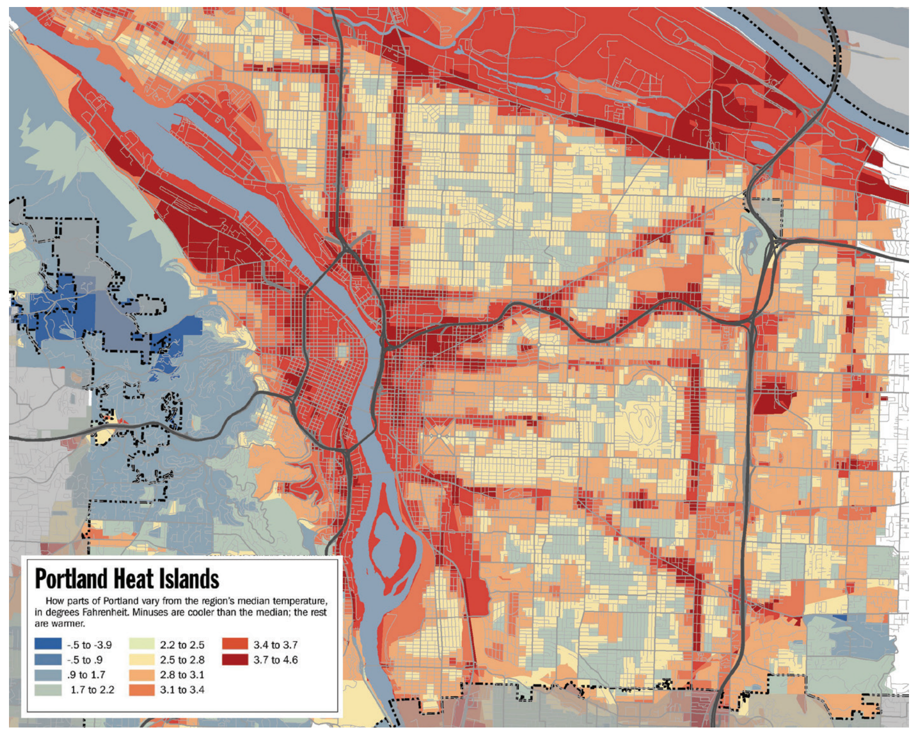
Average monthly temperatures in Portland range from lows of around 36 °F to highs around 80 °F (see Figure 4, page 13), and days with maximum temperatures above 90 °F occur 11 times per year. The record high (since 1981) is 107 °F, and Portland rarely exceeds five days in a row of high temperatures (e.g., above 95 °F). In July 2009, a historic heat wave occurred in Portland and broke several heat records for the area. The event included the top two hottest three-day periods in Portland and made July 2009 the hottest month on record for Portland.

In measuring the frequency of heat waves over time, it is important to note that what constitutes as an unusually hot day in one part of the country is not the same as what constitutes a hot day elsewhere. This is primarily due to the acclimation of the public to the typical climate of that region. For example, residents of Phoenix are unlikely to experience widespread heat stress from 95 °F afternoons; many Portlanders, however, are likely to experience heat-related illnesses and injuries because they are less accustomed to and prepared for managing such heat with air conditioning, for example. This is particularly true for populations most vulnerable to heat such as low-income populations, older adults and people with disabilities, (see the Multnomah County Heat Vulnerability Index Map, Chapter 5, page 36) and those working outside. While there is no single agreed upon definition of an extreme heat event, most definitions refer to an extended period of time (several days or more) with unusually hot weather conditions that can potentially harm human health. Multnomah County considers three consecutive days with an average maximum temperature above 95 °F to be an extreme heat event triggering heat advisory protocols.

In addition, metropolitan areas experience a phenomenon known as the urban heat island effect, in which the urban area is significantly warmer than surrounding rural areas. Densely concentrated roads, sidewalks and buildings in an urban environment are made of materials that retain and re-radiate heat. Waste heat, like that radiating off a vehicle's engine or from a building's air conditioning system, also contributes to the urban heat island. Compared to 15 other metropolitan areas around the country, Portland is ranked among the middle of the pack (along with Minneapolis, Denver and Orlando) in terms of satellite-derived measures of urban heat islands. Communities like Phoenix, Houston and Atlanta top the list (Law, 2012).

Portland's urban heat island map (see Figure 6) shows the parts of the city that tend to be the coolest and the parts of the city that tend to be the warmest. Forest Park and neighborhoods with a high concentration of trees and less development tend to be cooler than the surrounding region by as much as 4 to 8 degrees. Conversely, busy roads and parking lots, higher concentrations of commercial and industrial development, and relatively few trees characterize the warmest areas of the city. These areas include downtown, along freeways and busy roads (e.g., 82nd Ave., Sandy Blvd, Foster Road, Martin Luther King Jr. Blvd), and in the industrial areas (e.g., central east side, northwest, the Columbia Corridor).

Figure 6. Urban heat islands in Portland



(Source: PSU's Sustaining Urban Places Research Lab, SUPR Lab; and David Sailor and Melissa Hart)

INCREASED TEMPERATURE PROJECTIONS

Oregon has already experienced warming average temperatures, including a 1.3 °F increase over the past century (Dalton et al., 2013). Climate projections clearly indicate average air temperatures in Oregon will very likely continue to increase by as much as 1 °F per decade over the next century, although the magnitude of the increase depends on the amount of global carbon emissions (OCCRI, 2010).

Seasonal increases in average temperatures will be more pronounced and are often more important than annual temperature. Portland will experience hotter summers and warmer winters. Maximum temperatures will increase and minimum temperatures will also be higher (OCCRI, 2010 , Dalton et al., 2013). In addition, the Pacific Northwest could see an increase in heat wave intensity in the coming century (State of Oregon, 2010).

A FEW DEGREES OF WARMING WILL REALLY MAKE A BIG DIFFERENCE

An average temperature increase of 1 °F per decade might not seem dramatic. However, such a shift in temperature will have significant impacts in Oregon.

For example, pinot noir grapes grow best at an average temperature of 57.2–60.8 °F, which is the temperature in the Willamette Valley during peak grape-growing season. Based on climate modeling, temperatures are predicted to increase 3.7 °F by year 2049 (Jones, White, Cooper & Storchmann, 2005). This change would mean that the Willamette Valley climate would shift to the current California wine region climate (61.7–67.1 °F), which is the optimal temperature range for cabernet sauvignon grapes rather than pinot noir.

Pacific Northwest ski areas are also at risk for negative impacts due to precipitation falling as rain rather than snow and earlier snowmelt. Data collected from 1948 to 2000 shows an average 9- to 11-day earlier snowmelt in the Pacific Northwest. Scientists project a 3.6 °F increase in winter temperatures in the Cascade and Olympic ranges. This warming could have a profound impact on local winter recreational activities (Nolin & Daly, 2006).

Source: Tinsley Hunsdorfer/Audubon Society of Portland

Increased temperatures, along with associated dry spells, can result in dramatic impacts on the ecology of the region. In the fall of 2012, Smith and Bybee Lakes experienced an outbreak of avian botulism that resulted in the death of more than 4,000 birds. The Audubon Society of Portland treated over 150 birds from a variety of species. Coupled with impacts to the natural flushing mechanisms of the hydrologic system from surrounding development and invasive species — dry, hot weather created the ideal conditions for the outbreak of botulism. Hotter, drier summers could result in more of these types of events in the future.

INCREASED TEMPERATURE IMPACTS

Increasing air temperatures (annual, seasonal and heat waves) may contribute significantly to many other risks including changes as outlined in table 3.

HEALTH IMPACTS FROM HEAT WAVES

Extreme heat is the leading cause of weather-related death in the United States (Luber et al., 2008).

Several recent heat waves across the country have resulted in significant loss of life, including over 700 deaths in Chicago in 1995 and 600 deaths in California in 2006. Tens of thousands of people died from extreme heat across Europe in 2003 and Russia in 2010.

Western Oregon has a fairly mild climate and, since heat waves are relatively uncommon, most homes in Portland lack air conditioning or passive cooling designs. Portlanders are generally inexperienced in dealing with extreme heat, are not well prepared and often do not take the necessary precautions to protect their health.

Between 2000 and 2009, Oregon had approximately 33 heat-related hospitalizations and two heat-related deaths per summer. In 2008, Multnomah County saw approximately 12 days over 90 °F. Several consecutive days of temperatures of this nature can lead to heat illness for populations in Portland without access to well insulated homes, cooling centers or air conditioning.

Evidence associated with extreme hot weather conditions and heat events show that particular population groups are at increased risk of mortality during heat waves, including adults over 65 years of age, people who live alone, people of color, people below the poverty line, people with low educational attainment, homeless people and people without access to air conditioning (Reid et al., 2009).

Table 3. Summary of potential increased temperature impacts

Human systems	Increased air pollution and pollen counts, contributing to respiratory illnesses and allergies.	Increased heat-related illnesses and death, particularly among vulnerable populations, during heat waves.	Changes in patterns of infectious disease, including waterborne and vector-borne diseases from ticks, mosquitoes and rodents.
Natural systems	Increased surface water temperatures, changes in current plant community composition, and negative impacts on habitats and the fish and wildlife they support.	Increased frequency of blue-green algae blooms, and increased risk of infestations by insect and plant pests.	Changes to the growing season, including the timing of blossoms, and plant and animal communities shift north and to higher elevations.
Infrastructure and the built environment	Impacts to transportation infrastructure during heat waves, such as bridge expansion joints and pavement integrity and warping of train tracks.	Increased biological activity, and associated odors, in sewer pipes and at the wastewater treatment plant.	Increased use of energy to run air conditioning and reduced efficiency of electricity transmission lines.

INCREASED TEMPERATURE — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to increased temperatures and frequency of extreme heat events include:

2030 Objective 1: Decrease the urban heat island effect, especially in areas with populations most vulnerable to heat.

Design and implement programs that cool the urban environment, including revegetation and tree planting, pervious paving and green infrastructure like bioswales and ecoroofs. Utilize information and maps of Portland's urban heat islands to help inform decisions and priorities about such projects.

2030 Objective 2: Minimize health issues caused by extreme heat days, especially for populations most vulnerable to heat.

Improve the preparation for and response to extreme heat days by health, community service, public safety and emergency response staff and services. Coordinate operations of cooling centers and early warning and response systems.

2030 Objective 4: Increase the resilience of natural systems to respond to increased temperatures and drier summers.

Seek to keep natural areas, especially urban streams, cooler, including increasing the width of vegetation along streams and ensuring existing and new rules support wetlands and surface water temperature needs. Increase the ability of plantings (natural areas, restoration sites, greenstreets, ecoroofs, etc.) to withstand drought conditions. Address invasive species, connect habitats and support birds and other species needing to alter their range.

HOTTER, DRIER SUMMERS WITH MORE HIGH-HEAT DAYS

RISK 2: Increased incidence of drier summers and drought

HISTORY OF DROUGHT

In Oregon, most of the precipitation for the year falls in the autumn, winter and spring, typically October through March. Native vegetation and animal species have adapted to the region's naturally low rainfall amounts in the summer months.

Drought in the Pacific Northwest can be caused by low winter precipitation, low summer precipitation and lack of snowpack due to a warm winter (State of Oregon, 2010). Drought has historically been an issue in much of Oregon, particularly agricultural areas. However, in Portland, hot dry summers primarily cause short-term impacts. For a variety of reasons, including proximity to the Willamette and Columbia River systems (and associated micro-climates) and winter precipitation patterns, Portland rarely sees drought-related issues that persist from one year to the next.

Portland's water supply comes from reservoirs on the Bull Run River, as well as a supplemental and emergency back-up system of groundwater wells known as the Columbia South Shore Well Field. These two water sources provide more than sufficient water to meet Portland's current water demands.

The most significant drought year for Portland's water supply was in 1987, a year with lower than average precipitation and streamflows in the Bull Run watershed, and higher than average temperatures in Portland. As a result, the Portland Water Bureau had to rely on the groundwater system for 88 days to augment the City's water supply.

DROUGHT PROJECTIONS

Precipitation is one of the most difficult variables for climate models to project, particularly for the Pacific Northwest. In general, climate model projections indicate an increase in 3–6 month droughts in the Willamette Valley and the Western Cascades through 2100 (OCCRI, 2010).

DROUGHT IMPACTS

In Portland, many short-term impacts on water supply from increased incidence of year-long drought will be less noticeable than in other parts of the state due to the nature of Portland's drinking water system, including large storage reservoirs fed by rain instead of snow, and a large secondary groundwater well system (see Chapter 5, page 55 for more details on Portland's drinking water infrastructure).

Many natural systems in Portland may experience impacts from increased incidence of seasonal droughts, particularly to wetlands, stream systems and aquatic habitats. Reduced stream flows contribute to fish and wildlife mortality. Drought may affect the condition and composition of vegetation and habitat types, in turn affecting wildlife species viability. Drought-related insects and diseases may cause impacts on tree health, which can in turn increase risks associated with urban-wildland interface fires (see additional discussion in this chapter beginning on page 23).

Table 4. Summary of potential drier summers and drought impacts

Human systems	Changes in breeding season and habitat of vector populations and the diseases they transmit.	Greater respiratory irritation and illness due to increased dust.
Natural systems	Lower summer stream flows, reduction or rapid drying of wetlands and higher water temperatures.	Shifts in plant-animal relationships, and possible mortality for vegetation and trees.
Infrastructure and the built environment	Higher water demand for outdoor uses such as watering of lawns and other landscaping.	Greater demand for hot weather-related programming and recreation opportunities in park facilities.

INCREASED INCIDENCE OF DRIER SUMMERS AND DROUGHT — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to drought include:

2030 Objective 3: Increase the resilience of Portland's water supply to drier summers.

Expand the capacity of the groundwater system and ensure water is used efficiently by homes, businesses and in City and County facilities such as local parks. Continue to assess the potential impacts of climate change on the Bull Run watershed. Continue to implement water conservation education and outreach programs and activities.

2030 Objective 4: Increase the resilience of natural systems to respond to increased temperatures and drier summers.

Seek to keep natural areas, especially urban streams, cooler, including increasing the width of vegetation along streams and ensuring existing and new rules support wetlands and surface water temperature needs. Increase the ability of plantings (natural areas, restoration sites, greenstreets, ecoroofs, etc.) to withstand drought conditions. Address invasive species, connect habitats and support birds, amphibians and other species needing to alter their range.

HOTTER, DRIER SUMMERS WITH MORE HIGH-HEAT DAYS

RISK 3: Increased wildfire frequency and intensity

HISTORY OF WILDFIRE

Wildfires in Oregon typically occur between July and October, although they can and do occur during any month of the year. Several factors contribute to wildfire behavior, including vegetation type, density and characteristics (e.g., fuel moisture, size), topography and weather. Wildfires can burn in the large natural areas located throughout Portland's urban area.

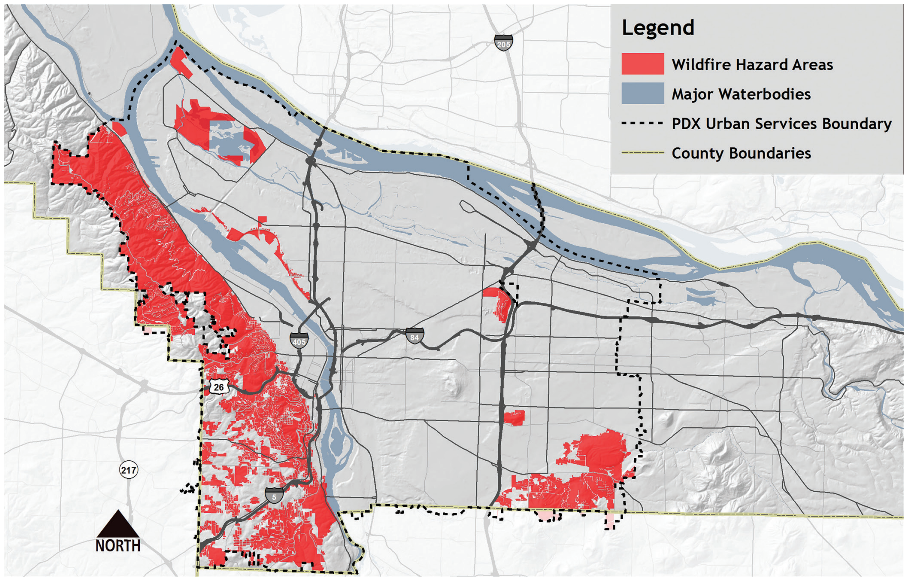
Portland's considerable urban forest, natural parks and open space areas contribute to the potential for wildfires within the urban area. Portland's largest urban fires have occurred in and around Forest Park. The most recent broke out in 1951 and burned 2,400 acres of the more than 5,000-acre park. At a smaller scale, the vast majority of wildfires in Portland involve grasses and brush (over 1,000 fires between 1998 and 2004), with far fewer involving forests or woodlands.

1951 Forest Park wildfire

(Source: City of Portland Archives, Oregon, A2000-025.2278)

Wildfire hazard areas in Portland include Forest Park, Powell Butte, the Willamette Bluffs or Escarpment (Oaks Bottom and Mocks Crest), Marquam Nature Park, Terwilliger Wildlands, Kelly Butte, Rocky Butte and Mt. Tabor (see Figure 7). These areas have been identified as high risk because of the high-density commercial and residential development that is immediately surrounded by natural area parks and open spaces.

Figure 7. Portland wildfire hazard map



WILDFIRE PROJECTIONS

Several climate-related factors in the western United States make wildfires more likely, including earlier snowpack melt resulting in longer fire seasons, drier conditions, increased fuels (e.g., dead and highly combustible trees from beetle infestations), and increased frequency of lightning. In Oregon, the likelihood of increased frequency and intensity of wildfire is very high under the climatic changes expected in the coming decades (State of Oregon, 2010). In addition, an increasing pattern of hot, dry summers and earlier springs increases the likelihood of more and prolonged wildfires.

The forested nature of the Bull Run watershed is important for maintaining a reliable supply of clean drinking water for the Portland metropolitan area. Climate change has the potential to affect forest health, the type of vegetation present, and the frequency and intensity of weather patterns that can, in turn, increase the risk of catastrophic wildfire. While uncertainty remains around the timing and magnitude of these fire-related changes, especially at local scales, the probability of a very large fire year in the Northwest region is projected to increase significantly before 2100 (Littell et al., 2010).

WILDFIRE IMPACTS

Wildfires are part of the life cycles of wildlands. They create new habitat, regenerate fire-dependent species such as Oregon White Oak and reduce potential for large catastrophic fires by reducing fuel loads. Portland's ecosystems, however, have been highly modified due to development. As a result, wildfires often have significant detrimental impacts on human health, the environment, and public and private property. Historically, minor wildfires in the city have damaged relatively few homes, structures and natural resources. A major wildfire has the potential to impact homes, businesses, roads, power lines and other critical infrastructure, in addition to the potential for human health impacts including injury, reduced air quality and loss of life.

Table 5. Summary of potential wildfire impacts

Human systems	Decreased air quality, endangering those with compromised respiratory systems.	Injuries and illness associated with damaged homes, buildings, infrastructure (e.g., power lines, roads), and natural areas.	Increased demand for emergency services to respond to fires and evacuations.
Natural systems	Damage and mortality of vegetation, habitat and wildlife in fire areas.	Increased landslides, erosion, and sediment in rivers and streams due to loss of stabilizing vegetation in burned areas.	Benefits for some species of grasses and trees that depend on fire for propagation, as well as some species like woodpeckers that prefer dead or downed wood.
Infrastructure and the built environment	Vulnerability of infrastructure facilities in or near natural areas (buildings, playground equipment, etc.).	Higher water demand for fighting fires.	Reduced effectiveness of natural infrastructure.

A City and County Wildfire Technical Committee was formed in 2009 and created a Community Wildfire Protection Plan (CWPP) for Multnomah County. The CWPP effort includes fuel-reduction projects to reduce hazardous fuels around homes and transportation corridors in forested areas, reduce flammable biomass, manage invasive species, and integrate information about fire-resistant plants and building materials for homeowners.

The City monitors and prepares for fire and fire-prone conditions in the Bull Run watershed. The City works closely with the USDA Forest Service, the region's primary wildland fire responder.

REDUCING WILDFIRE RISKS

The City's Portland Parks and Recreation, Bureau of Environmental Services, and Portland Fire and Rescue work to reduce wildfire fuels by removing non-native and invasive vegetation in the most threatened natural areas and adjacent open space areas.

In 2006 the City of Portland began a three-year project to reduce the risk of significant wildfires at the interface between Portland's natural and developed areas. This project was funded by the Federal Emergency Management Agency (FEMA) and Oregon's Office of Emergency Management. The four target areas for this effort were Oaks Bottom, the Willamette Bluffs, Powell Butte and Forest Park. The work consisted of controlled grass fires (which burned thatch and weeds to make way for native grasses and perennials) as well as the removal of flammable vegetation. Climbing vines (English ivy and clematis), shrub layers (Himalayan blackberry and Scotch broom), tall non-native grasses, and non-native trees (English Hawthorne) were removed.

Vegetation management is an ongoing effort for the City and County.

INCREASED WILDFIRE FREQUENCY AND INTENSITY — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to wildfire frequency and intensity in the urban environment, as well as the Bull Run watershed, include:

2030 Objective 5: Manage the risk of wildfires as a result of drier summers.
Reduce wildfire risk in areas where development (e.g., homes and businesses) is next to natural and forested areas (often called the "urban-wildland interface"). In a co-management role with partner agencies, respond to fires in and around the Bull Run watershed.

WARMER WINTERS WITH THE POTENTIAL FOR MORE INTENSE RAIN EVENTS

RISK 4: Increased incidence of floods

Climate models suggest that Portland's total annual precipitation will not change dramatically and will continue to be dominated by natural variability and El Niño conditions. However, seasonal shifts in precipitation patterns are expected, leading to drier summers and the potential for more intense rain events in the other seasons (OCCRI, 2010; Dalton et al., 2013). Some global and Pacific Northwest regional climate models suggest that extreme daily precipitation amounts could increase (Dalton et al., 2013).

HISTORY OF FLOODING

Two types of floods primarily affect Portland: urban flooding and river flooding. The Portland region is subject to flooding from local stormwater drainage as well as overflow from the Willamette, Columbia, Sandy and Tualatin Rivers, and Johnson Creek.

Urban flooding occurs when rains fall on buildings, concrete and pavement because these surfaces are unable to absorb and then slowly release rainfall like forests and fields can. As such, the risk of urban floods increases as development increases. During heavy rainstorms, runoff from buildings, streets and other hard surfaces can exceed the capabilities of the existing drainage infrastructure and result in flooded streets and basements. In addition, flash floods can occur soon after a heavy rain, presenting significant risks to people and property.

River flooding occurs when river or stream water levels rise and spill over the banks. This type of flooding often results from prolonged rainfall over a large geographic area. River flooding is an important natural process that adds sediment and nutrients to fertile floodplain areas. Rivers can also change course over time, called channel migration, which can change where rivers crest in their banks. Because the Willamette and Columbia Rivers are also influenced by tides and melting snowpack, significant coastal storms, or early snowmelt and rain on snow events at higher elevations can exacerbate flooding in downtown Portland.

The Portland region has a long history of flooding, with significant floods recorded as far back as 1861. Some of the most notable flood events in Portland's past include:

- **1948:** Constructed in 1943, Vanport was Oregon's second largest city and was located in what is now the site of North Portland's Delta Park and the Portland International Raceway. In May 1948 a dike system was breached resulting in a catastrophic flood that covered the city of Vanport with 10 to 20 feet of water, killing fifteen people and leaving nearly 20,000 residents homeless — many of whom were African American.

Steel Bridge during 1964 "Christmas Flood"

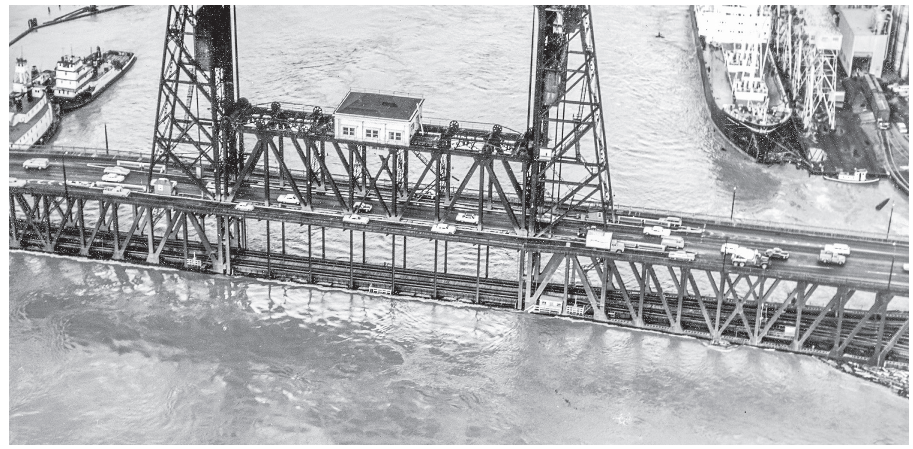


Photo source: Oregon Department of Transportation

- **1964:** Record-breaking precipitation on top of snow in the Cascades caused the December 1964 flood event, known as the "Christmas Flood." Flooding and debris flows resulted in bridge failures and the closure of roads and train tracks. The lower deck of the Steel Bridge was underwater, and logs and debris severely damaged the Hawthorne Bridge.
- **1996:** Flooding was caused by a combination of heavy snowfall followed by warm temperatures and four days of heavy rain on areas of Oregon that had already received higher than average rainfall. Rivers and creeks throughout the watershed rose, with the Willamette River nearly cresting Portland's downtown seawall. Many of Portland's roads were closed due to high water and landslides. At the peak of the flood all major highways were closed revealing limitations of the FEMA floodplain maps. Statewide, power outages occurred, hundreds of homes were destroyed, thousands of people were evacuated and five people died. The February 1996 flood resulted in a Presidential Disaster Declaration.

- **2009:** Johnson Creek flooded in 2009 due to a higher than average amount of winter snow accumulation followed by sudden warming and 24 hours of rainfall. The Johnson Creek water level measured 3-½ feet above the flood stage and covered nearly 500 acres. This flood was ranked as the second highest recorded Johnson Creek stream level and the third largest stream flow.

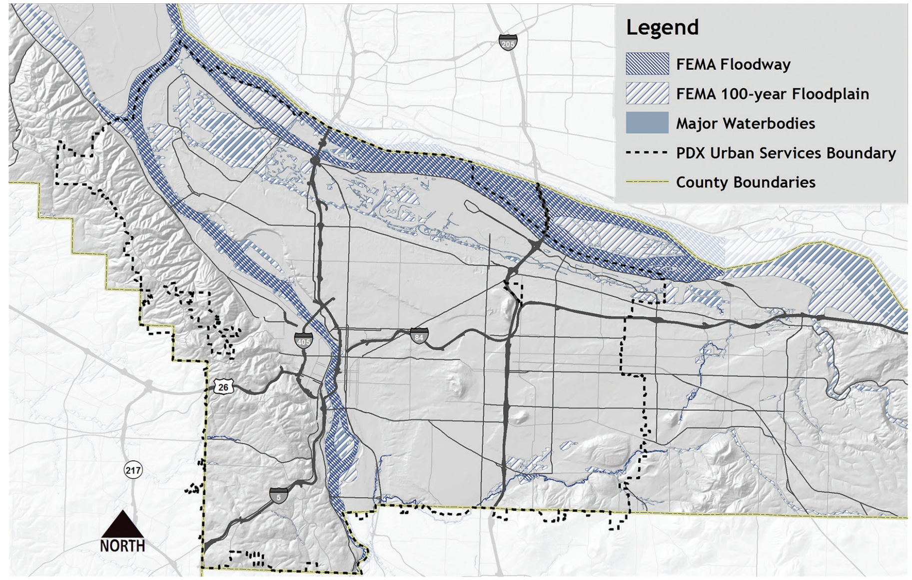
Currently, the Portland area is at risk of winter rain flooding between October and April, and spring snowmelt in the Cascades can cause flooding from May to July. Typically, Portland experiences flooding after more than three days of rain or when heavy rain falls on already saturated soil in a short period of time. Severe and prolonged storms can raise rivers and streams to their flood stages and keep them there for several days.

Areas vulnerable to flooding in Portland are at low elevations along streams and rivers, including the floodplain of the Columbia River, the Lower Columbia Slough and Johnson Creek (see Figure 8). For example, Johnson Creek has flooded nearly 40 times since 1942, and nearby residents have experienced at least seven floods causing major property damage in the last 35 years. Urban floods and the resulting impacts are exacerbated by residential growth, infill and other development.

Approximately 60 miles of drainage ways, the Columbia Slough and a series of smaller sloughs help protect the city from flood damage. The drainage ways are remnants of natural sloughs and streams that were historically in Portland. Today, water must be moved into the main Columbia Slough channel and downstream into the Lower Slough by pumps and levees to manage flooding. In addition, the Columbia River Treaty between the United States and Canada provides flood protection for downstream communities such as Portland and Multnomah County.

The levees are constructed for what is considered a 100-year event by historic standards. The 100-year event estimates are currently based on historical trends that do not take into account future climate change projections. The Multnomah County Drainage District's system of dikes helps protect properties such as the Portland Expo Center, Portland International Airport and the Portland International Raceway, as well as the Columbia South Shore Well Field. This area is home to numerous residents, and 8,000 to 10,000 jobs in transportation and warehousing. However, constructing and maintaining the levee system has had significant impacts on the surrounding natural system by cutting off connections to the natural floodplain, removing and in some places prohibiting vegetation including mature trees, and degrading surface water quality, among other impacts.

Figure 8. Portland flood hazard map



Floodplain-restoration projects and the City's long-standing willing-seller program to move people out of the Johnson Creek floodplain have helped to reduce damages and impacts from flooding. For example, the Foster Floodplain Natural Area Project (see next page) reduces the frequency of flooding on Foster Road and area homes and businesses, while also improving habitat for fish, birds and other wildlife.

For more information about flooding in Portland, see Chapter 5, page 48 of this assessment.

RESTORING THE FLOODPLAIN

Prior to floodplain restoration — flooding of Foster Road

Foster floodplain natural area — restoration project

Heavy rains in January of 2012 pushed Johnson Creek to more than two feet above flood stage. In years past, an event such as this would have flooded SE Foster Road and the surrounding area. The restored floodplain at Foster Floodplain Natural Area was able to effectively store and manage the floodwaters. SE Foster Road remained open and flood damages to area homes and businesses were prevented.

FLOODING PROJECTIONS

Flooding has been an issue in the Portland region for many decades. This trend will continue, even if annual precipitation patterns tend to be dominated by natural variability. Today, Portland's most severe floods are winter rainfall floods from December to February. Historically, models based on stream flow gage readings have been used to determine the probability of occurrence for floods of different magnitudes. However, climate change may affect the frequency and duration of precipitation events and risk of riverine flooding. A seasonal shift in precipitation patterns means historical records may no longer provide a reliable guide to future flooding. In addition, the Willamette and Columbia Rivers are tidally influenced so sea level rise may affect flooding as well. However, as mentioned previously, in the near-term tectonic uplift could mitigate the impacts of sea-level rise (OCCRI, 2010).

Flood risks are likely to increase, particularly in Portland's urbanized environment with the potential for more intense rain events in mid-winter. Such floods may often take the form of nuisance floods, causing public inconvenience but little to no property damage. At other times, they may be smaller and more localized in nature (e.g., Johnson Creek).

FLOODING IMPACTS

Flooding can cause significant economic, social and environmental impacts. In the past 30 years, Portland has experienced over $200 million in flood-related damage to both private and public property. A single large flooding event such as the 1996 flood can result in hundreds of millions of dollars in damages. Portland has laws regulating development in the floodplain to minimize impacts and damage from these floods. Channel migration (where a river or stream moves, or migrates, laterally across the floodplain) can occur abruptly during a single flood event and can cause significant impacts to homes, businesses and infrastructure through increased erosion, flood extent and debris movement. Portland participates in the Federal Emergency Management Agency's Community Rating System that reduces insurance rates for landowners living in a floodplain if the community meets certain criteria. The more criteria that are met, the lower the flood insurance rates for that community.

Table 6. Summary of potential flooding impacts

Human systems	Increased risk of injuries, death and displacement.	Release of toxic or hazardous materials from the inundation of industrial and wastewater treatment facilities, or damage to storage tanks and pipelines.	Additional costs due to emergency response expenses, business closures, lost productivity and cleanup costs.
Natural systems	Loss of fish and wildlife washed into urbanized areas during flooding, called "stranding."	Release of toxic or hazardous materials from increased street runoff and flooded businesses and homes, degrading water quality.	Loss of habitat through scour, erosion and vegetation removal that also increases water temperatures.
Infrastructure and the built environment	Water and structural damage to homes and businesses, as well as railroads, roads, bridges and culverts, and other infrastructure facilities located within, over or under floodplain locations.	Increased sediment in stormwater that can clog pipes and makes greenstreet facilities less effective.	Disruptions to utility (e.g., electricity, water, sewer) and transportation services.

Increased incidence and magnitude of flood events as a result of seasonal shifts in precipitation patterns will exacerbate the impacts outlined above. Areas that are already experiencing repeated flooding will become even more vulnerable, and areas outside of the historical floodplain may begin to experience flooding.

INCREASED INCIDENCE OF FLOODING — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to flooding include:

2030 Objective 6: Increase the resilience of the natural and built environment to more intense rain events and associated flooding.

Work with local, state and federal partners to update floodplain data used in planning processes. Restore floodplains, reduce paved surfaces (to reduce stormwater runoff), and prepare to manage increased runoff amounts in streams.

WARMER WINTERS WITH THE POTENTIAL FOR MORE INTENSE RAIN EVENTS

RISK 5: Increased incidence of landslides

HISTORY OF LANDSLIDES

Landslides can occur in just a few seconds or over the course of years. Factors that contribute to landslides in the Portland region include steep slopes, weak soil deposits, precipitation, development and tree removal.

The Portland Bureau of Transportation Landslide Management System has recorded over 1,300 landslide incidents since 1968. Many of these landslides happened in the West Hills and the slopes on the east bank of the Willamette River. There are two active (and very slow moving) landslides in Portland. The largest active landslide (8 million square feet) includes parts of Washington Park, and is located just north of Highway 26 and the Vista Ridge Tunnel.

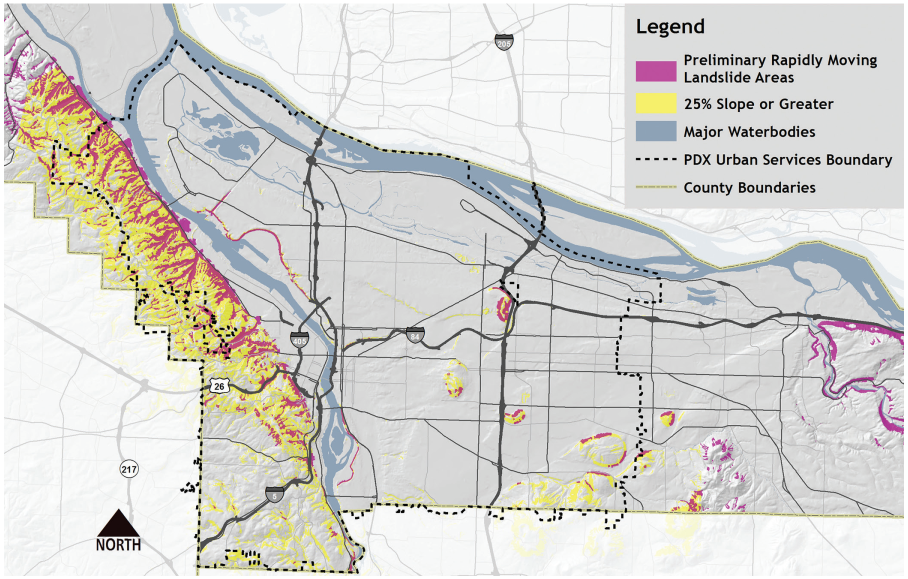
In 1995, a landslide occurred in Portland's Bull Run watershed that damaged two conduits used to transfer Bull Run water to Portland's reservoirs. Groundwater was used to provide potable water to Portland for 27 days until the conduits were repaired. In the winter of 1996, approximately 705 individual landslides, mostly in the West Hills area, occurred throughout the Portland region as a result of rainstorms (Burns, et al., 1998).

Oregonians lose over $10 million per year due to landslides; however, high rainfall years can be exponentially more expensive. For example, landslide-related losses in 1999, a moderate storm year, were estimated to be approximately $20 million, while 1996, a heavy storm year, cost over $100 million in direct losses (OR DOGAMI, 2002). These figures do not include indirect losses (such as the cost of landslide related transportation delays, etc.), which are more difficult to quantify.

The precipitation and flooding events in 1996 highlighted several areas of concern for landslides including the West Hills and the steep slopes along the Willamette (e.g., Oaks Bottom, Swan Island) and Columbia Rivers (see Figure 9). Thirteen percent of major Portland roadways (70 miles) and railways (50 miles) have been identified as being vulnerable to landslides. The majority of roads that are at risk are located in the West Hills (Walker, et al., 2011).

Landslides in Portland are a particular problem for roads and houses in the West Hills

Figure 9. Portland landslide hazard map



LANDSLIDE PROJECTIONS

The primary driver for landslides in the Portland region is intense precipitation, either from single events like a storm with heavy downpours, or longer events such as several days of precipitation. The incidences of landslides increase when intense precipitation events happen when the soil is already saturated with water.

An increased incidence of landslides due to climate change as a result of shifting seasonal precipitation patterns is likely. Increased potential for more intense rain events in winter precipitation creates greater risks associated with erosion and landslides, particularly in the West Hills due to topography and impacts from construction and development. Shifts in precipitation may also re-activate large, deep slides. Increased winter precipitation will also generally decrease slope stability, increasing the risk of failure if residents are doing normal grading activities or if a roof downspout fails and water is discharged onto a slope that is more unstable than it was before.

LANDSLIDE IMPACTS

Landslides have created many problems in and around Portland's hills including public and private property damage, damage to city infrastructure, and disruptions to key transportation routes.

Table 7. Summary of potential landslide impacts

Human systems	Injuries and fatalities	Temporary or permanent displacement of homeowners and families	Increased demand for emergency services
Natural systems	Depositing of sediment in stream channels	Loss of trees and vegetation and reduced access to parks and trails	Turbidity in the Bull Run reservoirs
Infrastructure and the built environment	Public and private property damage	Roadblocks, damage to transportation routes and associated economic impacts	Damage to power lines and other key utility services, including conduits, water pump stations, in-town reservoirs and pipelines

INCREASED INCIDENCE OF LANDSLIDES — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to landslides include:

2030 Objective 8: Manage the increased risk of landslides due to due to changing precipitation patterns.

Identify and monitor landslide hazard areas, and incorporate landslide hazard reduction techniques into infrastructure planning projects. Provide outreach and education on reducing landslide risks to private property owners.

CHAPTER 5 — VULNERABILITY ASSESSMENTS BY SECTOR

HUMAN SYSTEMS **PAGE 33**

NATURAL SYSTEMS **PAGE 41**

INFRASTRUCTURE AND BUILT ENVIRONMENT **PAGE 53**

FOOD, CLIMATE MIGRANTS, ENERGY, ECONOMY **PAGE 61**

Portland and Multnomah County rely on many "systems" to support a healthy and functional community:

- Natural systems that include trees, rivers and streams, wetlands and green spaces that help manage stormwater and cool the built environment.
- Infrastructure systems that provide essential services for daily life like transportation, drinking water, sewer and parks.
- Human systems, which encompass the people living and working in Multnomah County as well as the services these people depend upon.

To develop this risk and vulnerabilities assessment, three inter-departmental staff teams were created to focus on health and human services, natural resources and built infrastructure. Each team conducted a vulnerability assessment and developed recommended actions to address the greatest vulnerabilities to climate change facing the Portland region (see Chapter 1, page 5, for a general outline of the planning process used). The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change.

This section of the assessment outlines the vulnerabilities, expected impacts and recommended climate change preparation actions for human systems (see page 33), natural resources (see page 41) and infrastructure (see page 53). The City and County also explored potential impacts in other areas, including food systems, climate migrants, energy and the economy (see page 61).

VULNERABILITY ASSESSMENT OF HUMAN SYSTEMS

HUMAN SYSTEMS

Community organizations, healthcare agencies, businesses, neighborhood associations and individuals play a key role in helping to create a resilient community. A resilient community has the capability to anticipate, prepare for and recover from climate impacts on public health and safety, and the local economy and environment. This section of the assessment focuses on how community members will be impacted by changes in the region's climate and, in particular, what government programs can do to prepare for climate change and ensure the community is served in the best way possible.

Multnomah County includes six cities and approximately 750,000 people. Local governments provide a wide range of social services and many of those programs are already running beyond maximum capacity. Climate change impacts may expand gaps in services and potentially exacerbate longstanding social inequities.

Many important local government programs support the health and well being of the community:

- Social services assist families in poverty, the homeless, survivors of domestic violence, older adults, the recently incarcerated, adults and children with physical and developmental disabilities, veterans, and people recovering from mental illness and addiction.
- School-based services support children and families, as well as services that assure, promote and protect the health of community members through health and clinical services.
- Both the City and County have emergency management departments focused on preparing for and coordinating the response to emergencies and working collaboratively with regional, state and federal partners to optimize resources to protect life and property.
- The City and County have several departments focused on public safety, including police, sheriff, fire, medical response and justice.

All of these programs respond to the community's needs on a routine basis, as well as during emergencies.

VULNERABLE POPULATIONS

All populations are at risk from climate change in some way, but some communities are more vulnerable than others. This climate gap is one in which "the poor and people of color will be hit the worst" (TRIG, 2011). In Multnomah County, communities of color experience many environmental and socioeconomic risk factor at higher rates than the white population due to historical disparities in resource distribution, infrastructure investment and access to decision making processes (Curry-Stevens et al., 2000; Urban League of Portland, 2009).

The communities impacted by the climate gap already experience poorer health and disparities related to the factors that influence our health. These factors such as access to safe and stable housing, un- and under-employment, access to healthful food and educational attainment are often referred to as the "social determinants of health." According to the World Health Organization, these determinants account for the circumstances in which people are born, grow up, live, work, and age (WHO, 2008). These circumstances are in turn shaped by a wider set of forces: economics, social policies, and politics. Table 10 is a snapshot of the social determinants of health in Multnomah County.

Table 10. Social determinants of health in Multnomah County

Social determinant	Percent of Multnomah County residents
No high school diploma	10.5%
Living in poverty	17.1%, 33%*
People of color	28.1%
Language other than English used at home	19.6%

Source: U.S. Census Bureau

**Poverty rates have traditionally been derived from those living under the Federal Poverty Level, an indicator based on income and family size. In 2014 Multnomah County commissioned a report on poverty using the self-sufficiency standard. This standard determines the amount needed for a family to meet all basic needs, without government supplements. The report found approximately ⅓ of all County residents cannot meet their basic needs (Multnomah County, 2014).*

The same factors that influence our health, the social determinants, also influence our ability to be resilient to the effects of climate change (ICCG, 2014). Some examples of this relationship include:

- Access to quality housing protects people against weather events such as extreme heat.
- English proficiency increases the ability to receive and understand information about climate-related health risks such as a mosquito-borne disease outbreak or an air-quality advisory.
- Stable and adequate income gives people access to counter-measures such as an air-conditioner, or the ability to repair damage caused by extreme weather.

Inequities related to the social determinants of health results in some communities being more vulnerable to the effects of climate change than others. In addition to those previously mentioned, the following vulnerable populations are at particular risk:

- Those are un- or underinsured
- Lack of transportation
- Lack adequate air-conditioning or cooling systems
- Those who are houseless
- Those who live in areas experiencing poor air-quality
- Those who live in urban heat islands
- Those who primarily work outdoors
- Those with physical or mental health disabilities
- The very young and the elderly

Examples of how weather-related events may affect vulnerable populations in Multnomah County include:

- People with physical disabilities generally lack the mobility required to evacuate their place of residence under emergency conditions such as extreme heat or flooding (TRIG, 2011). There are 40,500 people (5.5 percent of the population) with physical disabilities in Multnomah County.
- People with pre-existing mental illness tend to suffer more than the general population during weather extremes, and may have additional health risks from heat due to the effects of psychiatric medications (U.S. EPA, 2008). Extreme heat and flooding events can also cause psychological problems (e.g., grief, depression, aggression and anxiety) for the general population for reasons such as displacement, loss, housing and employment instability, physical injury, or general disruption of daily life (Doherty & Clayton, 2011). In Multnomah County, the adult population with diagnosable mental illness (including anxiety and depression) is 26 percent, while 6 percent suffer from severe mental illness (TRIG, 2011).
- People who are homeless are among the most vulnerable, as they include people suffering from high rates of untreated chronic disease, substance abuse, extreme poverty, smoking, respiratory conditions and mental illness (TRIG, 2011). Approximately 4,650 people (0.6 percent of the population) are homeless in Multnomah County.
- People living in assisted living nursing facilities, adult foster care, residential facility and in-home care, and adult foster homes are limited in their ability to take emergency action on their own during weather-related emergencies. In Multnomah County this includes over 6,470 people (TRIG, 2011).
- Individuals who live in areas with urban heat island effect — areas in urban communities that retain heat due to a higher quantity of buildings and paved surfaces versus vegetation — may experience warmer temperatures. This means they are more vulnerable to heat-related illnesses. For more information about Portland's urban heat islands, see Chapter 4, page 17.

HUMAN SYSTEMS — CLIMATE CHANGE PREPARATION PLANNING PROCESS

The Multnomah County Health Department (MCHD), with funding from the Oregon Health Authority, piloted a five-step process to help assess climate-related health impacts. The process was developed by Centers for Disease Control and Prevention's Climate Health Program and is called Building Resilience against Climate Effects (BRACE). Key steps included 1) data collection and analysis, 2) stakeholder engagement and 3) determining interventions to prevent an increase in health disparities. This assessment served as the keystone for many of the human system-related climate preparation objectives and actions contained in the *Climate Change Preparation Strategy* (separate document). The actions were also informed by a vulnerable population study supported by an Urban Areas Security Initiative grant.

MCHD reviewed literature about the public health impacts of climate change regionally and coordinated a variety of work sessions with stakeholders to identify public health issues and populations that may be disproportionately impacted by changes in temperature, precipitation, decreased snowpack and degraded air quality. Participants brought expertise in heat-related morbidity and mortality trends, knowledge of asthma rates, awareness of emergency preparedness plans and capacity to respond to weather-related emergencies, knowledge of surveillance and monitoring of vectors, and overall understanding of health disparities and impacts to vulnerable populations. MCHD prioritized heat-related illness, vector-borne diseases, and allergic and respiratory disease based on the following criteria:

- Likelihood of changes in the future climate.
- The subject matter expertise of its Stakeholder Advisory Committee.
- A preliminary literature review.
- Accessibility and quality of data related to heat, asthma, air quality and vectors.
- Impacts to populations that are likely to be most vulnerable to climate change impacts and potential for increasing health disparities.
- Gaps in response and risk communication plans related to weather-related emergencies.
- Alignment with the MCHD's current surveillance and monitoring scope of work.

MCHD reviewed a combination of data to develop a baseline view of the three priority health issues to be impacted (heat-related illness, vector-borne diseases, and allergic and respiratory disease). One focus of this review was to gain a better understanding of the geographical areas that might be vulnerable to increases in high-heat events and worsening air quality, and the populations that live in those areas. Examples of data collected include hospital discharge, death certificate, and hospitalization data (specifically looking at cases with a diagnosis for excessive heat due to weather condition).

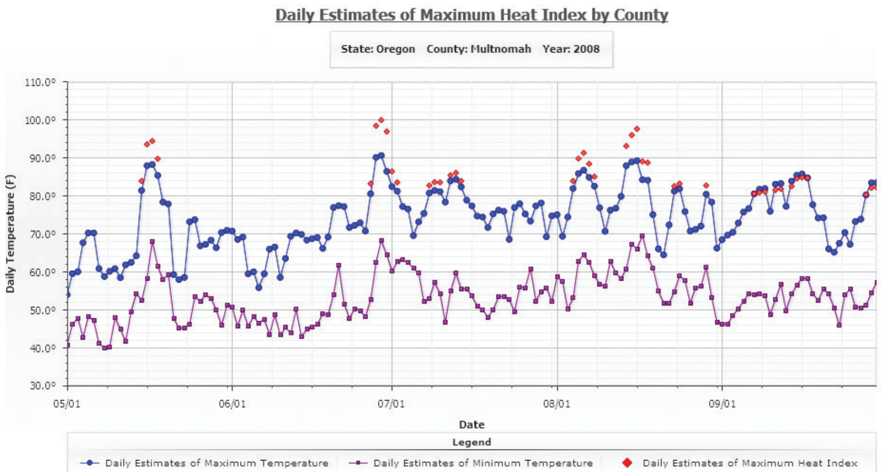
HUMAN SYSTEMS — VULNERABILITIES AND IMPACTS

Increased temperatures, especially a higher incidence of extreme heat days (see Figure 10), as well as the potential for more intense rain events in the winter, will impact people directly, as well as the programs and services that support the community as a whole. An increase in hot days can cause heat-related illness in populations most vulnerable to heat and require services like the Health Department to increase education and outreach to prevent heat strokes. Several of the potential impacts are outlined below.

Hotter, drier summers with more high-heat days:

- Increased heat-related illness including heat stroke, heat exhaustion and exacerbation of existing medical conditions such as cardiovascular and respiratory disease, diabetes, nervous system disorders, emphysema and epilepsy. This impact is particularly challenging for those who are elderly, low income, homeless or pregnant, and those with outdoor occupations.
- Increased demand for wellbeing checks and cooling centers for populations most vulnerable to heat, requiring the use of limited fiscal resources to perform checks and keep cooling shelters open longer, and to provide transportation to shelters if needed.
- Increased need for river-related public safety services (e.g., Sheriff Office's River Patrol Unit) due to increased river recreation during high temperatures, including law enforcement and boat safety inspections, emergency medical and boater assistance, boating and water safety and education.
- Changes in the breeding season and habitat of vector populations like mosquitoes and ticks, and the diseases they transmit.
- Increased wildfires decreasing air quality, endangering those with compromised respiratory systems.
- Increased stress on vulnerable populations including those suffering from mental illness.
- Earlier and extended allergy seasons affecting those with asthma and respiratory disease.

Figure 10. 2008 Daily estimates of days with higher temperatures in Multnomah County



(Source: Centers for Disease Control and Prevention. Environmental Health Tracking Program. North American Land Data Assimilation System (NLDAS) data.)

Warmer winters with the potential for more intense rain events:

- Increased psychological stress, exacerbation of pre-existing chronic conditions and an increase in occurrence of infectious disease due to flooding.
- Increased risk of property damage, physical injury and stress-related incidents due to flooding or landslides.
- Potential displacement of communities living in or near floodplains potentially creating an economic burden on individuals already struggling to remain independent.
- Potential increase in mold spores triggering asthma and other chronic health conditions.
- Delayed emergency response from compromised access (wires down, landslides, sinkholes, etc.).
- Potential interruption of routine duties (grocery shopping, doctor appointments, accessing mass transit, etc.), creating additional vulnerable populations out of normally independent individuals.
- Increased economic pressure as households, businesses and local government bear the costs of flood-related events that do not elevate to disaster declaration level — translating into budget cuts for other valuable services.
- Increased demand for law enforcement to respond to increased emergency-related calls, establish roadblocks, reroute traffic, respond to accidents and facilitate evacuations.
- Increased mosquito populations creating a seasonal burden on the Health Department's Vector Control Department and potentially requiring increased surveillance efforts and suppression activities.

HEAT VULNERABILITY

MCHD did a more detailed analysis for heat by developing a heat vulnerability index (HVI), which identifies the areas where community members are most vulnerable to impacts from extreme heat, which is defined as three days or more over 95 °F (see Figure 11). This analysis provides valuable information for allocating resources to the areas in greatest need during extreme heat events. MCHD used the methodology of a national HVI to locate populations vulnerable to heat at the sub metropolitan level (Reid et al., 2012).

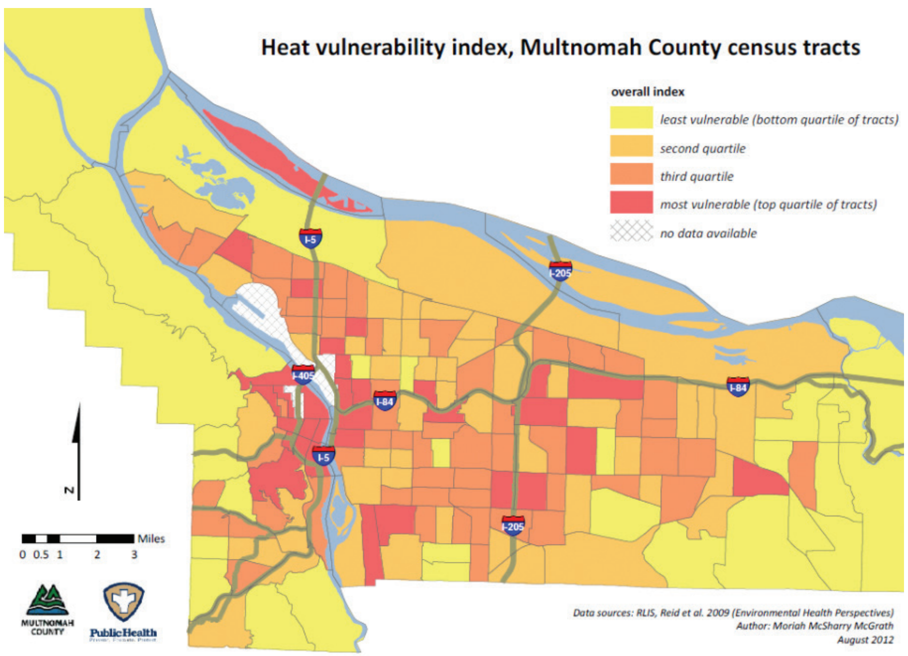
Heat vulnerability is determined based on the following factors:

- **Factor 1 —** Social and Environmental Determinants: This factor is a combination of data that describe social characteristics and environmental features including poverty, race, educational attainment and green space.
- **Factor 2 —** Social Isolation: This factor describes social isolation using data that assess the percentage of the population that live alone and those over age 65 that live alone.
- **Factor 3 —** Air Conditioning: This factor assesses the prevalence of air conditioning in homes including the percent of homes with central air conditioning, and the percent of homes with no air conditioning of any kind.
- **Factor 4 —** Pre-Existing Health Conditions: The final factor summarizes pre-existing health effects by assessing age and diabetes diagnoses.

The Heat Vulnerability Index tallied these indicator scores on a census tract level and created a rating system. Although the Heat Vulnerability Index is not an exact predictor it does help generally describe areas of the county where residents are likely to be more impacted during extreme heat events. In many cases, areas with higher concentrations of people most vulnerable to heat line up with areas most impacted by Portland's urban heat islands (see Portland's Urban Heat Island map, page 17).

Local governments provide a variety of programs and services to support populations most vulnerable to heat in dealing with increased temperatures. For example, the Weatherization Assistance Program provides energy-efficiency retrofits of single family and multifamily housing for low- and fixed-income citizens including seniors and persons with disabilities. This program provides residents with some protection against the health effects of extreme heat, as well as mold growth due to household temperatures below 68 °F. The City and County also provide air-conditioned sites, cooling centers and transportation for aging and disabled populations during periods of extreme heat.

Figure 11. Multnomah County heat vulnerability index



REDUCED AIR QUALITY

Hotter summers will lead to reduced air quality, especially ground level ozone, which can become particularly problematic during high-heat days. In addition, air quality may worsen with hotter, drier summers contributing to increased pollens and dust, which exacerbate respiratory health issues.

Ground-level ozone, a local air pollutant that is created when sunlight interacts with oxides of nitrogen (NOx) and volatile organic compounds (VOCs), increases during high-heat days. Elevated levels of ozone and other air pollutants like fine particulate matter (PM2.5) have well documented human health effects. Short-term effects of exposure to air pollution include irritation to eyes, nose, and throat, as well as increased incidence of upper respiratory inflammation. Air pollution is associated with chronic obstructive pulmonary disease hospitalizations, respiratory and cardiovascular morbidity and mortality, acute asthma care events, diabetes mellitus prevalence, lung cancer risk, birth defects, lung impairment, fatigue, headaches, respiratory infections, and eye irritation (Centers for Disease Control and Prevention, 2013). Children, the elderly, and those with respiratory illnesses or compromised immune systems are generally most vulnerable to degraded air quality.

Since 2011, Oregon has ranked among the top 6 states with the highest percentage of adults with asthma in the nation (OHA, 2013). Asthma has indirect and direct costs on the public. Emergency department visits and hospitalizations for asthma have significant direct costs: the average emergency department visit is $1,070 and the average hospitalization is $11,540 (Hoppin et al., 2007). Asthma and other respiratory and cardiovascular illnesses result in societal impacts that are much harder to monetize. Chronic illness keeps children from school, adults from work and prevents communities' from realizing their full health potential.

Nearly 10 percent of the children in Multnomah County have asthma, and the majority of those children are of color, live in low-income households, or both (OHA, 2013). Similarly, compared to mid- to high-income primarily white communities, disproportionate impacts from air pollution occur for minority and low-income populations in the Portland region (Oregon DEQ, 2012).

These existing air quality-related health disparities mean the burdens of worsening air quality will not fall equally. Low-income families are more likely to have asthma impact their quality of life, routinely seek asthma care at emergency departments, and be hospitalized due to asthma. Without intentional and targeted preparation and strategies designed to promote community resilience, climate change stands to amplify these disparities.

REDUCING ENVIRONMENTALLY CAUSED HEALTH CONDITIONS

Multnomah County Environmental Health Services has three community-based programs that work with families whose children have environmentally caused health conditions by providing nurse case management and education. The programs also help families in rental housing who are dealing with extreme mold and mildew, which will likely increase with warmer, wetter winters.

These programs include Healthy Homes, which is a free program for low-income families where a nurse asthma educator and community health worker make home visits to provide education, medication management, an asthma action plan, an environmental home inspection, and community resources. Additionally, through the Asthma Inspection Referral program, a healthcare provider refers an environmental healthcare specialist for a free home inspection if a child has asthma.

VECTOR-BORNE DISEASE

As the climate changes, conditions may become more favorable for invasive mosquito species to become established in the region. Multnomah County Vector Control currently monitors approximately 18 mosquito species that are considered native to Northwest Oregon, six of which have known vector capacity. Non-native species have been detected in the area, but only three have considerable vector capacity for West Nile Virus and other viral causes of encephalitis. One of these non-native species, *Ochlertatus japonicus*, has become established. There are two additional mosquito species that when introduced, could become a greater concern in the region, *Aedes albopictus* and *Aedes aegypti*, both of which can transmit Chikungunya and Dengue.

Invasive mosquito species that are transported here are likely to establish themselves due to the hotter summers that mimic the habitat of their current distribution, warmer winters that allow some species to survive, and the potential for increased pools of standing water left from heavier winter and spring rains. These conditions provide ideal environments for eggs to hatch, especially if the water has low turbidity and/or high nitrogen content, which is typically associated with increased fertilizer runoff from homes, parks and golf courses during the rainy season (Service, 1997). Additionally, eggs can withstand dry conditions for up to five years and the larvae emerge after rainfall raises the water level in the containers or habitat in which they live (Moore et al., 1988). This means that as the summers become hotter and drier in the region, these mosquito species will continue to thrive and could become an important vector species.

Multnomah County's Vector Control program is responsible for mosquito surveillance and control using an integrated pest management approach. This holistic approach utilizes multiple complementary methods: identification of insect or animal species of concern, prevention, surveillance, treatment, and education. Adult and immature mosquitoes are collected, identified, and counted to determine the level and distribution of local populations. Some species of adult mosquitoes are tested for the presence of mosquito-borne diseases such as West Nile virus, St. Louis encephalitis (SLE), and Western Equine encephalitis (WEE).

West Nile virus was first found in Multnomah County in 2005, which presented an opportunity for the program to develop policies, procedures, and relationships to respond quickly to increased demands on services. This included developing template risk communication materials and memorandums of understanding with property owners of large ideal mosquito habitats, as well as coordination with local jurisdictions to avoid conflicts with natural and built green infrastructure. These practices have provided Multnomah County Vector Control with the ability to address emerging vector populations and the diseases they spread.

EMERGENCY MANAGEMENT

Both the County Office of Emergency Management (MCEM) and the Portland Bureau of Emergency Management (PBEM) have developed Natural Hazard Mitigation Plans to protect life, health, infrastructure, property and the environment. These plans identify many strategies and action items to reduce the impacts of significant precipitation events, landslides and floods. In most instances, actions taken to mitigate natural hazard risks (e.g., protecting tree canopy, planting native plants with deep root systems) also reduce the risks associated with climate change. PBEM and MCEM also work with other City and County departments to develop emergency preparedness, response and operations plans and to collaborate with private sector, government and community organizations in preparedness activities. For example, MCEM has a Community Wildfire Protection Plan (2011) prepared in coordination with the City of Portland. PBEM and MCEM are working together to develop a process for community volunteers to perform wellbeing checks during extreme weather events, and both jurisdictions continue to collaborate on flood planning and preparedness.

Both the Sheriff's Office and the Department of Community Justice have established plans and identified resources to ensure the health and safety of detainees in the event of emergencies including extreme heat and flooding. Emergency Preparedness and Response Plans are current, redundant electrical systems are in place and evacuation, transportation and contingency facilities are identified.

The Health Department's Public Health Emergency Preparedness team works to improve its capacity to respond to public health emergencies by enhancing its agency response, as well as its ability to work with partner agencies and elected officials. For example, they maintain a Volunteer Emergency Registry, which is a list of persons who need help evacuating their homes during an emergency, or who would be unable to evacuate without special notification from emergency response personnel. The registry also includes people who would be unable to remain at home without assistance following a disaster. Information in this list will be provided to the Bureau of Emergency Communications (911) and other emergency response personnel from the City of Portland, the City of Gresham and Multnomah County.

HUMAN SYSTEMS — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to improving the resilience of human systems include:

2030 Objective 1: Decrease the urban heat island effect, especially in areas with populations most vulnerable to heat.

Design and implement programs that cool the urban environment, including revegetation and tree planting, pervious paving and green infrastructure like bioswales and ecoroofs. Utilize information and maps of Portland's urban heat islands to help inform decisions and priorities about such projects.

2030 Objective 2: Minimize health issues caused by extreme heat days, especially for populations most vulnerable to heat.

Improve the preparation for and response to extreme heat days by health, community service, public safety and emergency response staff and services. Coordinate operations of cooling centers and early warning and response systems.

2030 Objective 7: Manage the increased risk of disease due to changes in vector populations.

Reduce health risks from vector populations. Strengthen education and outreach efforts to understand, prevent and respond to vector-borne diseases.

2030 Objective 9: Strengthen emergency management capacity to respond to weather-related emergencies.

Strengthen the capacity of emergency management staff to prepare for and respond to weather-related emergencies, increase the capabilities of volunteer organizations, and develop response plans that minimize impacts on vulnerable populations.

2030 Objective 10: Institutionalize climate preparation planning and best practices.

Apply an equity lens to climate action efforts and where possible prioritize benefits to vulnerable populations. Improve the understanding of local climate change impacts. Recognize climate variables as a risk in how the City and County manage infrastructure.

2030 Objective 11: Improve community capacity, especially of populations most vulnerable to climate change impacts, to understand, prepare for and respond to climate impacts.

Provide education, resources and services related to climate risks to the public, especially vulnerable populations, including emergency preparedness, extreme heat and respiratory-related illness.

2030 Objective 12: Improve monitoring, evaluate effectiveness of climate change preparation actions and advance new research to support climate preparation efforts.

Identify, compile and regularly update key data for climate change trend tracking (streamflows, temperature, natural resources, storms, condition of infrastructure, heat-related illness, air quality, etc.). Support monitoring programs and existing climate research, and advance new research related to climate-related diseases, population shifts, food systems, etc.

HUMAN SYSTEMS — CLIMATE CHANGE PREPARATION CHALLENGES

Low-income communities, communities of color, immigrants and refugees in Portland experience disproportionately high rates of the negative health outcomes that are likely to be exacerbated by climate change impacts. Many of these communities will bear the brunt of climate change-related ill health because of their present demographic, social, or geographic situation and their experiences of historical inequities.

Grounding Portland and Multnomah County's climate change discussion in the principles of environmental justice and equity is a key opportunity to deepen the understanding of the intersection between race, class and power dynamics in the community. In turn, this can improve collaboration efforts. By integrating a scientific, data-driven approach to climate change with an understanding of who benefits and who is burdened by climate impacts and preparation response, the City and County can achieve more balanced and meaningful participation, perspectives and outcomes (see Chapter 3, page 7 for more about the City and County's approach for integrating equity into climate change preparation efforts).

VULNERABILITY ASSESSMENT OF NATURAL RESOURCE SYSTEMS

NATURAL RESOURCE SYSTEMS

Portland's unique natural systems consists of many facets: trees, forests, meadows, open spaces, rain, rivers, floodplains and wetlands, fish, wildlife, insects, air and the soil, among others. These elements collectively provide a vast range of functions known as ecosystem services. Ecosystem services help to improve air quality, reduce heating and cooling costs, control flooding, manage stormwater, regulate air temperature, produce food, and provide recreation and mental health benefits. Beyond the human systems, local natural systems serve critical roles in the regional ecosystem.

THE REGIONAL NATURAL SYSTEM

In 2011, the Intertwine Alliance launched an effort to identify the region's natural resources and the historic context. The Biodiversity Guide for the Greater Portland-Vancouver Region describes 14 sub-watersheds covering 1.8 million acres in 10 counties and two states (The Intertwine Alliance, 2012). The Biodiversity Guide amplifies how the Portland area's natural system is a keystone to a much larger West Coast Pacific ecosystem. The region is located at the confluence of the Columbia River and the Willamette River, the two largest rivers in Oregon and among the largest in the US, resulting in rich and diverse aquatic resources. There are over 290 miles of rivers and streams (nearly 200 miles of which are unnamed creeks) in the City of Portland.

These resources include federal protected salmon, steelhead, eulachon, bull trout and species in decline such as lamprey and sturgeon that use the area as important migratory and rearing grounds at various stages in their lifecycle. Located along the Pacific flyway, the Portland area is an important stopover area for migratory birds between the Arctic and Canada to Southern California, Mexico and South America. It lies in a broad valley between two mountain ranges, the Coast Range and the Cascades. The mosaic of these different habitat types and species concentrated in the small Portland area creates an ecological richness.

THE LOCAL NATURAL SYSTEM

To gauge the extent of risk and vulnerability to local natural systems, City staff inventoried elements of the natural system that are owned, managed, regulated, relied upon or invested in by any City of Portland bureau (see Table 9). The inventory includes rivers, streams, drainages and waterways, as well as forests and woodlands, vegetation in stormwater facilities, wetlands, seeps and springs, and fish and wildlife. The inventory also reflects Portland's unique approach to managing stormwater naturally, as a resource. Impacts to the more traditional piped stormwater solutions are included in the infrastructure team analysis (see the next section of this chapter, page 56).

Table 9 draws on data from the City's Natural Resources Inventory as well as other data collected by bureaus. The inventory did not limit the analysis based on ownership (public or private) but did distinguish between protected and unprotected (i.e., resources that are within an environmental zone and resources that have no environmental zoning).

While not all elements of the natural system are captured in this inventory (notably missing are elements such as groundwater, soil and air), this inventory provides a strong starting point to evaluate the natural system's vulnerabilities to climate change and to help prioritize preparation actions.

Additional activities will be needed to build a resilient natural system within the region, and will depend on the actions of other federal, state and local partners, stakeholders and private landowners. Several actions identified in the *Climate Change Preparation Strategy* (separate document) are focused on building partnerships because the City and County cannot fully prepare for climate impacts alone.

TABLE 9. Natural Resource System Inventory

Major rivers, streams, drainages and waterways	
Columbia River and floodplains	Total miles: 10.68
	Protected miles: 7.34 Unprotected miles: 3.34
Willamette River and floodplains	Total miles: 20.13
	Protected miles: 6.0 Unprotected miles: 14.13
Willamette tributaries and floodplains	Total miles: 13.10
	Protected miles: 9.66 Unprotected miles: 3.43
Johnson Creek, tributaries and floodplains	Total miles: 16.60
	Protected miles: 15.64 Unprotected miles: 0.95
Fanno Creek, tributaries and floodplains	Total miles: 9.81
	Protected miles: 8.78 Unprotected miles: 1.03
Tryon Creek, tributaries and floodplains	Total miles: 5.01
	Protected miles: 4.20 Unprotected miles: 0.81
Tualatin tributaries and floodplains	Total miles: 1.84
	Protected miles: 11.34 Unprotected miles: 0.5
Columbia Slough	Total miles: 18.22
	Protected miles: 18.08 Unprotected miles: 0.14
Unnamed streams	Total miles: 298.11
	Protected miles: 246.53 Unprotected miles: 51.59
Urban Service Boundary Streams	Total miles: 3.49
	Protected miles: 2.91 Unprotected miles: 0.59

Stormwater	
Runoff	Total 17.3 billion gallons (BG)/year for average rainfall of 37 inches/year
	8.9 BG/year in combined sewer area (2011) 8.4 BG/year in separated sewer area (2011)
Infiltration / Vegetated / Natural Systems	Managed discharge: 8.4 BG/year
	3.3 BG/year in combined sewer area 5.1 BG/year in separated sewer area
Unmanaged runoff from streets, buildings, parking, public and private property	Unmanaged discharge: 3.6 BG/year
	0.3 BG/year from combined sewer area 3.3 BG/year from separated sewer area
Impervious surface (2013)	Properties: 11,777 acres
	Streets: 9,406 acres
	Parking lots: 8,146 acres
Forests, woodlands, shrub or herbaceous (public and private)	
Riparian area	29,701 acres
Forests, woodlands, shrublands	25,744 acres
Islands (Ross, Elk, Hayden)	1,394 acres
Special habitat types	Willamette Bluffs: ~100 acres
	Publicly owned: 70 acres Privately owned: 30 acres
Urban vegetation resources	
Greenstreets, planters, and swales	~1,200 facilities in public right-of-way
Ecoroofs, roofgardens	Ecoroofs: 343 facilities
	Roofgardens: 138 facilities
Street trees	250,967 trees
Yard trees (estimated)	508,000 trees
Stormwater facilities	Total facilities: 5,080
	Private property: 2,540 facilities City of Portland property: 62 facilities All other: 2,478 facilities

Wetlands, seeps and springs	
Publicly owned	Total acres: 1,965 acres
	Protected zone: 1,849 acres Unprotected zone: 116 acres
Privately owned	Total acres: 552 acres
	Protected zone: 505 acres Unprotected zone: 47 acres
Fish and wildlife	
Endangered Species Act (ESA) listed	Fish: 15 District Population Segments (DPS)
	Salmon, Steelhead, Bull Trout, Eulachon, Green Sturgeon
	Birds: 1 species
	Streaked Horned Lark
City designated sensitive species	Wildlife: 76 special status species

NATURAL RESOURCES — CLIMATE CHANGE PREPARATION PLANNING PROCESS

The City of Portland Natural Resources Team (NRT), an existing internal, cross-bureau team, evaluated the potential impacts of climate change to the natural systems and proposed citywide responses. For this project, the NRT included representatives from the City of Portland Environmental Services, Parks, Portland Development Commission, Planning and Sustainability, and Water Bureaus, and the former Office of Healthy Working Rivers.

NATURAL RESOURCES — VULNERABILITIES AND IMPACTS

Natural features such as rivers, trees, fish and wildlife, and the ecosystems that connect them, are as dynamic as the climate. However, even dynamic natural systems will be degraded by large changes in temperature and changes in hydrology related to climate change. Depending on the nature and extent of the climatic changes, rivers, streams, vegetation, fish and wildlife and the habitats they depend on will be affected by climate change. For systems that are already stressed, small climatic changes may be enough to cause extinctions, loss of biodiversity, and shifts in species composition, complexity, and stability. Many of Portland's natural resources fall into this category.

Portland has more endangered and threatened species within the city boundary than any other city in the United States, and this tally is increasing at an average of one new Endangered Species Act listing per year. The forest biodiversity has been simplified from oak-prairie and fir to one dominated by Douglas-Fir. Streams have been buried, channelized, simplified and stripped bare of any wood. Only 13 percent of streams sampled meet targets for large wood, and only 2.5 percent of sampled streams have macro-invertebrate populations that are considered healthy. Finally, none of the streams in Portland meet water quality benchmarks mainly due to mercury, total suspended solids and temperature. For healthy systems — such as Forest Park, which has the most intact forest, rich biodiversity, and the healthiest streams in the city — the climate would likely have to change dramatically before an effect is seen in the natural environment.

The two major climatic changes that will affect the region's natural systems are increased temperatures and shifts in the timing and amounts of precipitation (see Chapter 3, page 11, for more details). The potential climate change risks and impacts to natural systems are outlined in Table 10.

TABLE 10. Risks and potential impacts to the natural system derived from scientific literature (Houck and Lovell, 2012; OCCRI, 2010; TRIG, 2011; CIG, 2009a)

Climate variable	Risks to the natural system	Potential impacts
Increased temperature	Higher air temperature and extreme heat, and increased water temperature	Increased fire risk in summer
		Increased tree stress and mortality
		Increased threat of forest pests and pathogens
		Vegetation, habitat and wildlife shifts and fragmentation
		Longer growing season
		Higher mortality in vegetation
		Habitat fragmentation
		Increased pollen
		Shifts in plant-animal relationships
		Loss of biodiversity
		Increase in species listed as threatened and endangered
		Increase in invasive species
		Greater heat island effect
		Reduced water quality
		More short-term drought
	Reduced air quality	Increased air stagnation
Changing precipitation patterns (less in summer, potential for more intense rain events in the winter)	Changes in hydrology, water supply and stream flows	Flooding (frequency and extent)
		Groundwater fluctuations
		Increased landslide risk
		Increased tree stress and mortality
		Increased threat of forest pests and pathogens
		Increased fire risk in summer
		Higher/Lower river elevations
		Lower summer stream flows
		Shifts in plant-animal relationships
		Vegetation, habitat and wildlife shifts and fragmentation
		Increase in threatened and endangered species listings
		Seasonal summer drought
		Increased fire risk

Climate variable	Risks to the natural system	Potential impacts
	Reduced water quality	Higher water temperatures
		Increased erosion
	Changes in wetland ecosystems	Vegetation, habitat and wildlife shifts
		Potential for increase in water borne diseases
		Increase in threatened and endangered species
		General loss of wetland habitat especially seasonal loss of smaller and/or ephemeral wetlands
Extreme weather events	Increased frequency, duration and magnitude of storms *(Postulated but not statistically demonstrated for the Portland metropolitan area.)*	Flooding (frequency and duration)
		Increased tree failures and emergencies (street blockage, property damage, public safety impacts)
		Increased landslide risk
		Increased flood plain
		Increased erosion and channel migration
		Changed water quality
		Vegetation damage*
Sea level rise	Changes in river elevations due to tidal influence	Flooding (frequency and duration)
		Groundwater level rise
		Higher river elevations
		Increased floodplain

**No literature available. Best professional judgment of the City's Natural Resource Team.*

Hotter, drier summers with more high-heat days

In addition to the effects on the human population, higher air temperature also impacts natural systems. The climate impacts depend both on the intensity of the heat, and the length of time the heat persists.

VEGETATION IMPACTS

Increased air temperatures stress and can kill trees and vegetation. For example, trees scorch, lose foliage and eventually die when exposed to excessive and prolonged heat. Stressed vegetation is also more susceptible to diseases and pests. For example, forest pests such as the Asian long-horned beetle and emerald ash borer have decimated urban forests elsewhere in the United States (Haack, 2010; Poland et al., 2006). A slow but consistent increase in air temperature may cause some species to migrate to higher elevations or latitudes. The biodiversity of vegetation in the Portland area may shift, bringing more southern species (i.e., southern Oregon, northern California) and drought-tolerant species to the area in greater quantities. In an urban environment, however, natural introduction of new and climate-adapted species can be limited. To succeed, tree species and other vegetation planted in parks, along streets, in yards and in development projects will need to be selected to account for the changing climate.

Depending on the intensity of the heat, massive die-offs of some types of vegetation are possible. This pattern is intensified by droughts but can occur in the absence of a declared drought. Loss of vegetation can exacerbate urban heat island effect impacts because the natural cooling mechanisms provided by trees are reduced or eliminated. Increased tree mortality due to climate change will result in more hazard trees, tree emergencies and expensive removals, and increased risks to public safety and property. Loss of trees will also reduce carbon sequestration and air quality mitigation.

For plant species that are specialists and require microclimates, like madrones, a small shift in temperatures may lead to localized extinctions. Some species may not be able to migrate with the shifting climate. Conversely, higher temperatures earlier in the spring and later in the fall can lead to longer growing seasons, which may increase the productivity of some vegetation and increase pollen counts.

INVASIVE SPECIES

Invasive species are plants and animals that can displace native species and have long-lasting negative effects on habitats and the organisms that depend on them. Next to land conversion, invasive species are the most serious threats to biodiversity. Invasive species alter landscapes and fundamental ecosystem processes. They decrease biodiversity and ecosystem resilience and can damage infrastructure. In an urbanized and fragmented area, invasive species threaten remaining habitats, human health, infrastructure and livability.

Increases in the mean annual temperature, and alterations to precipitation patterns, will likely result in shifts to higher elevations and latitudes. This, coupled with the stress imparted to native organisms discussed above, will be significant and impair the ability of native habitats to successfully compete with invasives and will also decrease their ability to resist human-induced introductions. The results of these factors will be significant with respect to landscape composition: after an initial increase in biodiversity with the arrival of new, invasive plant species, the landscape is at risk to become more homogeneous as a relatively small number of species outcompete other species for available resources.

The Willamette Valley ecoregion has already experienced negative effects from invasive plant species: damage to human health and property, decreases and local extinctions of native plant and animal populations, and increased risks associated with fire severity and return intervals, hazard trees and toxic plants are among other noted impacts. While recent climatic changes have not been conclusively implicated as the cause for the establishment of specific invasive species, a number of invasive species are currently proliferating in the region, including species whose populations were relatively static and confined to the south in the California Floristic Provence. This dynamic of more southerly species rapidly migrating north has been predicted in the scientific literature for some time. Species such as yellow and purple starthistle, pampas and jubata grasses, many thistle species, many broom species and others have rapidly expanded their ranges north in just the last few decades. Species already in Portland — such as goatsrue, pampas grass, Italian and milk thistles — will likely become much more abundant and typically result in an increased use of herbicides, decreases in property values in some cases and decreases in habitat functionality.

In 2009, the City of Portland completed an invasive animal assessment (see Table 11) that identified invasive species present or likely to be present in Portland (Oregon Invasive Species Council, 2009). The level of invasiveness and the impact that these species will have is currently unknown but is likely to increase with climate change.

Species that are considered native and common may become rare. Rare species may shift ranges north and become more common but are still considered native. For example, analyses of data from Audubon's Christmas Bird Count identified that 177 species of the 305 "common" species in North America (140 of which are found in Oregon) had shifted their range north, in some cases by hundreds of miles.

Table 11. Portland invasive animal assessment

Present in the Portland area	Present, but not yet established in Portland	Likely to invade habitats in Portland in the next 5–10 years
Brown Garden Snail	Banded European Woodsnail	Wrinkled Dune Snail
Bullfrog	Asian Gypsy Moth	Rosy Gypsy Moth
Red-eared Slider	European Gypsy Moth	Nun Moth
Common Snapping Turtle	Japanese Beetle	Asian Longhorned Beetle
European Starling	Mute Swan	Light Brown Apple Moth
House Sparrow		Oak Splendour Beetle
Rock Pigeon		Oak Ambrosia Beetle
Domestic Duck and Goose Species		Woodwasps
Nutria		Emerald Ash Borer
Eastern Gray Squirrel		Apple Snails
Eastern Fox Squirrel		Chinese Mystery Snails
Virginia Opossum		Rusty Crayfish
Eastern Cottontail		Virile Crayfish
Black Rat		Ringed Crayfish
Norway Rat		New Zealand Mudsnails
Domestic Cats and Dogs		Mitten Crab
		Spiny Waterflea
		Fishhook Waterflea
		Zebra Mussel
		Western Quagga Mussel
		Eurasian Collared-dove*

**Table 11 is based on the 2009 invasive animal assessment report. The Eurasian Collard-dove is now present in Oregon.*

STREAM AND AQUATIC SPECIES IMPACTS

The Pacific Northwest is known for its relatively cold, clean rivers and streams, even in urbanized areas such as Portland. Hundreds of species of plants and animals such as the iconic salmon and beavers depend on the cold water for survival. Increased air temperature can lead to increase water temperatures in smaller streams. Larger waterways, such as the Willamette River, are less influenced by air temperatures but still may be affected at critical microhabitats along the margins, off channel areas and at tributary confluence areas.

Increased water temperature creates a cascade of impacts. Water quality, including levels of dissolved oxygen, declines with increased temperature. Species change migration and spawning behaviors, sometimes avoiding streams completely. Extreme temperatures can result in mass die-offs.

Macro-invertebrates and aquatic plants, the base of the food web, are already changing emergence and growth times, possibly disrupting the food cycle. Some migration and breeding patterns are timed specifically around macro-invertebrate emergence. For example, steelhead migrate when certain food sources, such as the salmonfly, hatch from rivers. Those steelhead in turn become food for osprey and newly hatched chicks in the early summer. If the food source shift, migration patterns may shift where possible. Some patterns, such as incubation times, cannot change as quickly and some species within the food web may decline. Other species, such as western painted and Pacific pond turtles, depend on temperature for gender determination. Too hot or too cold may result in a gender imbalance.

For salmon, changes to the precise temperature requirements are measureable. When stream temperatures exceed 59.9 °F, salmon become susceptible to disease, above 60.8 °F they stop spawning, above 65 °F juvenile salmon (smolts) will die, and above 69.8 °F adult salmon will stop migrating and streams effectively become dams (McCullough, 1999; McCullough et al., 2001). In 2012, Portland biologists recorded stream temperatures exceeding 82 °F in Johnson Creek, a salmon bearing stream. This indicates that increasing temperatures are preventing salmon from using some parts of our urban streams, even if the habitat is otherwise suitable for them.

Even for species that do not show as dramatic physiological changes as turtles or salmon, the change in temperature may still leave the animals susceptible to disease. This was the case in the Klamath River in September 2002, where increased river temperatures led to a proliferation of disease at the height of the fall Chinook salmon run, resulting in between 36,000 and 70,000 salmon killed (CDFG, 2004). Ten years later, in September 2012, increased temperatures led anaerobic conditions in Smith and Bybee Lakes in northeast Portland creating anaerobic conditions (decreased dissolved oxygen). This allowed maggots carrying the avian botulism toxin to proliferate. September is the start of migration season and a botulism outbreak killed over 4,500 waterfowl and birds at Smith and Bybee Lakes (Audubon Society, n.d.).

DROUGHTS

Droughts are a function of both temperature and precipitation. Short-term extreme heat events last a few days or weeks, and short-term droughts are between three and six months in length. Long-term droughts last 12 months or longer. The region is likely to see an increase in the extreme heat events and the short-term droughts, but the long-term droughts are not expected to change significantly in the Willamette Valley (OCCRI, 2010).

Droughts likely will have a significant impact on aquatic resources. Stream flows in Portland may be reduced and some tributaries may dry earlier or dry up altogether in the face of seasonal medium-term droughts. Of Portland's 290 miles of streams and rivers, approximately 162 miles are intermittent streams (streams that exist seasonally) and 128 miles are perennial streams (streams that flow year round). Loss of spring and summer rains will cause intermittent streams to dry earlier, persistent droughts may convert perennial streams into intermittent streams, and other perennial streams are likely to experience reduced summer flows. If there is a decrease in summer rainfall, all of the aquatic species that depend on these streams will be impacted. Perennial streams will have higher summer temperatures, exacerbating the effects of increased heat.

Wetlands are hit particularly hard by droughts. Groundwater and shallow aquifers are drawn down faster during droughts, which can exacerbate low flows in the summer and desiccate normally wet soils. Depending on winter precipitation patterns, aquifers may be recharged during the wetter winter, which may alleviate some of the summer droughts and protect those wetlands that depend on groundwater. Wetlands rely on precipitation and groundwater to maintain standing water and wetted soils. Increased summer temperatures and decreases in summer precipitation cause many wetlands to shrink and dry up. Many species of amphibians depend on wetlands for spring breeding, and waterfowl depend on wetlands into the early summer to rear and fledge their young. These species frequently require wetland vegetation for food and cover, which may shift or die altogether with frequent or prolonged droughts.

WILDFIRE

The lack of precipitation associated with droughts exacerbates the impact of temperature on vegetation, wildfires and invasive species, with few exceptions. Some species can recover and even depend on wildfires for survival, such as Oregon White oak and Ponderosa pine. However, if the wildfires are too intense

as a result of lack of precipitation, even the fire-dependent species may perish. The lack of precipitation will mean that more drought-tolerant species are likely to flourish, potentially making portions of the Portland region hospitable to more southern species that include deciduous trees and grasses.

Increased air temperature resulting in drier vegetation may increase the intensity and frequency of wildfires. Increases in wildfires may benefit some species and habitats, such as grasslands and oaks. These unique species of grasses and trees depend on fire for propagation and currently are considered “special habitat types” in Portland due to their decline. Habitat managers are using prescribed burns and logging to restore these fire-dependent habitats, and the City of Portland also participates in a fuels-reduction group with the Oregon Department of Forestry. Some species, such as woodpeckers, prefer dead or downed wood and will likely benefit from these changes.

WARMER WINTERS WITH THE POTENTIAL FOR MORE INTENSE RAIN EVENTS

The Pacific Northwest is characterized by both seasonal wet and dry periods. Natural systems in the area have evolved to this pattern with familiar beauty: abundant evergreen forests and a historically common prairie and oak savanna in the Willamette Valley. Wetland species with unusual lifecycles such as the red-legged frog that lives in wetlands but breeds in forests depend on these weather patterns and habitat diversity. With respect to the natural system, changes in temperature can rarely be isolated from changes in precipitation. The scientific literature is inconclusive about whether Portland will see more or less total annual precipitation, but modeling is predicting warmer winters with the potential for more intense rain events (OCCRI, 2010; Dalton et al., 2013). As a result, Portland may expect to experience greater and more frequent flooding in the next 100 years.

RIVER FLOODING

In the Portland metro region most streams are rain driven (as opposed to snow or transitional streams). Climate change is likely to lead to increased flooding in these systems, but it will not be as dramatic a change as other parts of the state that are snow driven (e.g., McKenzie River) or transitional (e.g., Sandy River). Nonetheless, the frequency of flooding is expected to increase. Because of the legacy of development along the river’s edge, even a slight increase in flooding can put people, property, businesses and natural resources at risk.

Portland streams flood when there is an intense, long duration storm event. However, the Columbia and Willamette Rivers can flood separately due to upstream events or tidal events, as was the case in June 2011 when the Columbia approached flood stage but none of the other streams in Portland flooded. Table 12 outlines the flood stages for Portland’s major rivers.

Table 12. Portland area floodstages

Gage location	Floodstage (elevation datum)	Times exceeding floodstage since 1990
Columbia River at Vancouver	16 feet (NGVD29)	7
Willamette River at Portland	18 feet (NGVD29)	1
Johnson Creek near Sycamore	11 feet (NGVD29)	16
Tryon Creek	(not established)	(not established)
Clackamas River near Estacada	20 feet (NGVD29)	20
Sandy River near Bull Run	19.3 feet (NGVD29)	6
Tualatin River at West Linn	13.5 feet (NGVD29)	3

(NGVD29 = National Geodetic Vertical Datum of 1929)

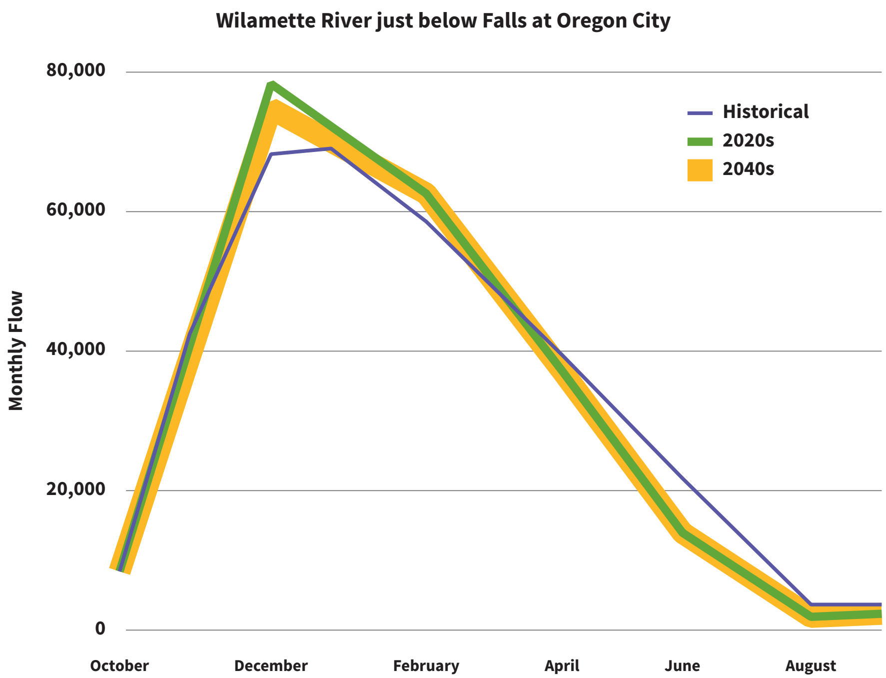
While detailed studies on the potential change in flooding in Portland have not been conducted, many nearby and gross level analyses indicate increased flooding is likely. The Northwest Power and Conservation Council’s Independent Science Advisory Board reviewed the issue in 2007 (Merrill, 2007). The report projected that winter precipitation will increasingly fall as rain and not snow, which will increase water levels in streams, rivers and reservoirs in the winter. Depending on winter precipitation, hydropower system operators may have to release more water in the winter, which could increase river levels around Portland. Similarly, the Willamette River contains 13 federally operated dams used for flood protection and hydropower operations. A recent report analyzing the effect of climate change on the Willamette projected increased peak flows in the winter but a decrease of flows in the summer (Climate Leadership Initiative, 2009).

Portland is also protected by a network of levees, the most extensive of which is along the Columbia River and managed by the Multnomah County Drainage District (MCDD). The levee system was built prior to the construction of the Columbia River dams in a time when flooding was much more varied and extensive. The effectiveness of the levees in the future depends on many factors

including maintenance, structural encroachments and vegetation. MCDD is commissioning a study by Oregon State University to look at the structural effects of trees growing on levees.

Modeling of the Willamette River under different climate change scenarios projected a significant increase in peak flows in December and a lower river flow in the summer (see Figure 12) (Climate Leadership Initiative, 2009). These higher flows represent a change in the baseline condition. Lower flows in the summer will mean higher temperatures and decreased water quality in the Willamette River, which will have impacts for resident and migrating fish.

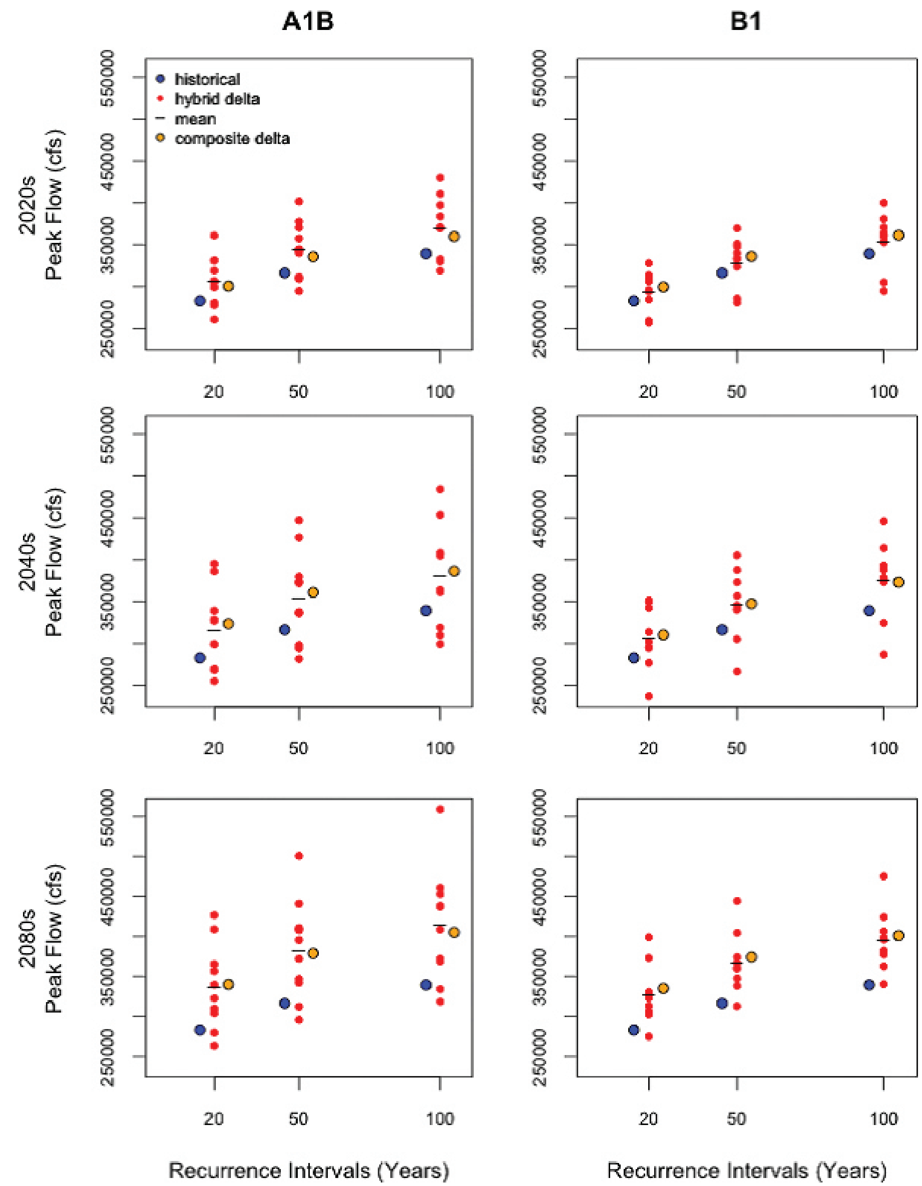
Figure 12. Sample stream flow change for the Willamette River



(University of Oregon, Climate Leadership Initiative, 2009)

Significantly more flooding in Portland could result if rainstorms occur during the higher base flows in December. Figure 13 shows an increase in flooding risk in the Willamette River in the near- and long-term future under two different climate scenarios (Tohver et al.). The blue dots represent the historical floods at the 20-, 50- and 100-year event (the 5 percent, 2 percent and 1 percent flows) at the Willamette River in Portland. The yellow dots represent the modeled increases under two climate change scenarios, A1B and B1. The graphs project that under both climate scenarios and in all future years and all future flood events, average flooding increases.

Figure 13: Willamette River flooding risk



(Tohver et al.)

New data are emerging about the potential impact of sea level rise that indicate sea level has already risen and could rise up to 4 feet on the Oregon Coast by the year 2100 (NRC, 2012). Portland is located in the Columbia River Estuary and is affected by ocean levels and tides. As such, any changes in sea level rise due to climate change may affect the river levels. However, the overall flow and elevation of the river is expected to be more influenced by the hydropower system, especially closer towards Bonneville Dam. Additional factors such as El Niño and a change in earthquake patterns could increase the effects of sea level rise even more. Scientists from Portland State University recently documented an increase in the amplitude of tides on the Oregon Coast (Jay, 2009).

The Portland region has already shown it can implement climate change preparation actions. TriMet completed a climate change analysis for the Portland-Milwaukie Light Rail Bridge over the Willamette River to determine the optimal bridge height. The river is projected to rise 3.9 feet due to climate change (Metro et al., 2010). In response to climate projections and various safety considerations, TriMet increased the elevation of the bridge by 3.4 feet.

NATURAL SYSTEM IMPACTS FROM FLOODING

Portland's long history of river development has compromised or eliminated most of the area's floodplains. More than 48 miles of shoreline along the Willamette and Columbia Rivers are hardened, reinforced or levied, leaving little natural shoreline and floodplain accessible during floods (see Figure 14). In the 1930s, the Works Progress Administration straightened and rock lined Johnson Creek to alleviate the flooding. Though well intentioned, the stream alterations exacerbated flooding in Johnson Creek. Johnson Creek homeowners receive more flood-damage payments than any other area of Portland. As a result of development in the floodplain, many of the flood benefits and floodplain-dependent species and wildlife are lost or severely degraded.

Increased flooding will impact people, property, and infrastructure. How it will impact natural resources is less certain. Natural flooding processes have been compromised by the hardening of shorelines limiting river-floodplain connectivity. Floodwaters on developed property will wash back into the stream or into storm drains rather than infiltrate into the ground. Increased flooding onto developed lands is likely to result in increased sediment and other pollutants entering streams, reducing water quality. The lack of infiltration is also likely to increase peak flows in the streams and prevent the recharge of groundwater and aquifers.

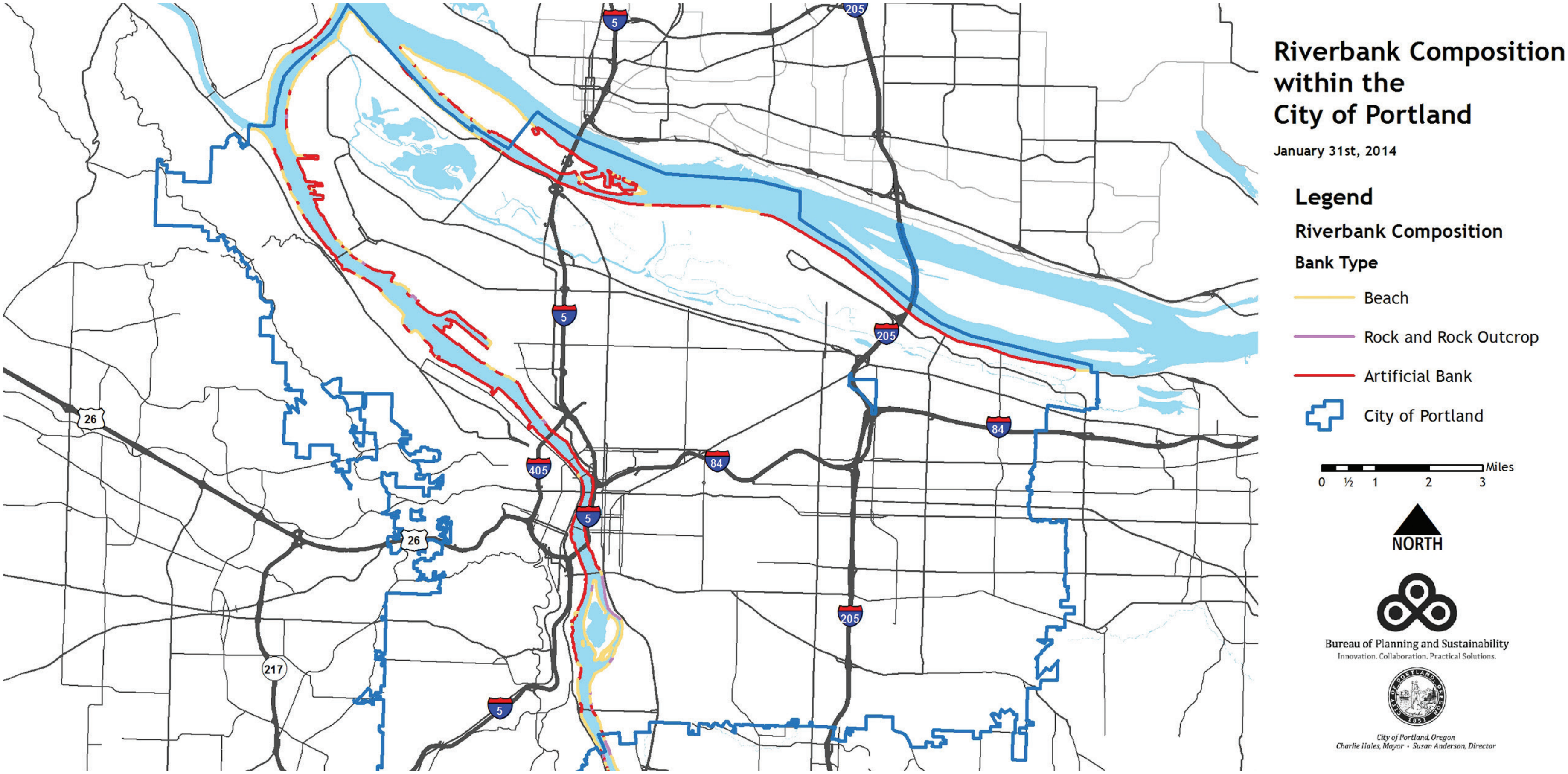
BENEFITS FROM FLOODING

Flooding is a natural and necessary function of rivers. It produces tremendous benefits that increase channel complexity, including the movement of sediment, wood and nutrients. Floodplains — lands that are irregularly inundated with flooding — support a rich diversity of plant and animal species. Species such as cottonwood, ash, cedar, dogwoods, willows and grasses thrive in floodplains. Floodplains create and provide habitat for rare, endangered, threatened, sensitive and declining species (i.e., "at-risk" species) in Portland such as:

- 19 Endangered Species Act-listed salmon and trout, eulachon and sturgeon.
- One Endangered Species Act-listed marine mammal.
- Five at-risk bats.
- 13 at-risk birds.
- One at-risk amphibian.

Floodplains also provide extensive social benefits such as flood storage that protects people and property from harm. Floodplains attenuate peak flows, reducing erosion and scour of infrastructure including roads and pipes. Even when not underwater, floodplains continue to capture, clean and infiltrate rainwater and stormwater. Floodplains sequester carbon, important for reducing carbon emissions, and moderate temperatures that can offset the urban heat island effects.

Figure 14. Shoreline lengths within the City of Portland



Increased peak flows will increase erosion and scour, and may wash out salmon eggs (called redds), flush juvenile salmon into the estuary before they have smolted, and flush other fish into the Willamette and Columbia where they are more susceptible to predation. Fish and wildlife typically seek out inundated natural floodplains for refuge because the water is slow and food is plentiful. However, fish, invertebrates and other animals that are washed on developed land by floods are likely to be stranded and injured by buildings and infrastructure. Standing water may also increase the risk of water-borne diseases spread by insects.

Increased rainfall and flooding may also impact vegetation. Vegetated floodplains may become inundated more frequently, changing the ability of certain species of trees to grow and survive, however the impact could be lessened if the floods occur during the vegetation's dormancy. Vegetation is likely to shift to ephemeral and tolerant plants.

Landslides are likely to increase as well. Vegetated hillsides are generally more stable than developed hillsides. While landslides pose a risk for infrastructure, they also have the effect of shedding all the trees and vegetation on the hillside and can leave large patches of bare ground that may not be stable enough for replanting and may be susceptible to invasion by exotics. This may increase patchiness and reduce the overall quantity and quality of vegetation.

NATURAL RESOURCES — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to improving the resilience of natural systems include:

2030 Objective 4: Increase the resilience of natural systems to respond to increased temperatures and drier summers.

Seek to keep natural areas, especially urban streams, cooler, including increasing the width of vegetation along streams and ensuring existing and new rules support wetlands and surface water temperature needs. Increase the ability of plantings (natural areas, restoration sites, greenstreets, ecoroofs, etc.) to withstand drought conditions. Address invasive species, connect habitats and support birds and other species needing to alter their ranges.

2030 Objective 5: Manage the risk of wildfires as a result of drier summers.

Reduce wildfire risk in areas where development (e.g., homes and businesses) is next to natural and forested areas (often called the "urban-wildland interface"). In a co-management role with partner agencies, respond to fires in and around the Bull Run watershed.

2030 Objective 6: Increase the resilience of the natural and built environment to more intense rain events and associated flooding.

Work with local, state and federal partners to update floodplain data used in planning processes. Restore floodplains, reduce paved surfaces (to reduce stormwater runoff), and prepare to manage increased runoff amounts in streams.

2030 Objective 10: Institutionalize climate preparation planning and best practices.

Apply an equity lens to climate action efforts and where possible prioritize benefits to vulnerable populations. Improve the understanding of local climate change impacts. Recognize climate variables as a risk in how the City and County manage infrastructure.

2030 Objective 12: Improve monitoring, evaluate the effectiveness of climate change preparation actions and advance new research to support climate preparation efforts.

Identify, compile and regularly update key data for climate change trend tracking (streamflows, temperature, natural resources, storms, condition of infrastructure, heat-related illness, air quality, etc.). Support monitoring programs and existing climate research, and advance new research related to climate-related diseases, population shifts, food systems, etc.

NATURAL RESOURCES — CLIMATE CHANGE PREPARATION CHALLENGES

The consequences of failing to minimize the risks of climate change to the natural system could be significant, and include:

- Failure to meet water quality regulatory and permit requirements.
- New or increasingly restrictive regulations and requirements on the City, and/or that the City may need to impose on private property.
- Reduced effectiveness of restoration projects, condition of parks and stormwater facilities, and increased expense for more highly engineered solutions and reliance on existing infrastructure including pipes, levees and sea walls.
- Increased maintenance, and associated costs, of existing resources including vegetated facilities, parks, floodplains, restoration sites and vector control.

These consequences have substantial financial and health impacts for residents and business. Therefore continued coordination across jurisdictions and with other regional partners on recommended responses is critical to minimizing the impacts and maximizing the effectiveness of preparation actions.

VULNERABILITY ASSESSMENT OF INFRASTRUCTURE AND THE BUILT ENVIRONMENT

BUILT ENVIRONMENT

The built environment includes built or engineered systems in the urban area, including buildings and urban spaces, infrastructure systems, industrial structures, energy systems (see page 62 of this chapter for more details on energy systems) and other products of human design and construction that are intended to deliver services in support of human quality of life (US DOE, 2012). These systems are interwoven with the human and social systems (see page 33 of this chapter for more details on human systems) and have significant impacts on and interactions with natural systems (see page 41 of this chapter for more details on natural systems).

Metropolitan areas like Portland and Multnomah County are characterized by large populations with significant economic and social activity in a concentrated geographic area. Much of Portland's economic activity is located in industrial areas along rivers, and housing and other development have partly or wholly replaced natural areas along creeks, rivers and steep hillsides, often impeding important natural processes such as seasonal flooding.

Multnomah County is expected to grow by nearly 290,000 people and 180,000 jobs by 2035 (compared to 2010, based on the MetroScope 2035 Gamma Forecast). Redevelopment and expansion of the built environment, at least to some degree, will be needed to accommodate this growth. Planning for this growth creates an opportunity to ensure climate change variables and impacts are considered in future development of the built environment. The revision to the City of Portland's Comprehensive Plan, scheduled for completion in 2014, is one key effort that plans for growth and the changing climate, as well as the need to reduce the carbon emissions that are the primary cause of climate change.

BUILT INFRASTRUCTURE

Infrastructure consists of both natural and built assets that serve whole communities and are necessary municipal or public services. Built infrastructure is generally provided by the government or regulated utilities, and defined as durable capital assets that normally are stationary in nature and can be preserved for a many years. Examples are railroads, streets, bridges, tunnels, drainage systems, parks and park facilities, water and sewer lines, pump stations and treatment plants, dams, electricity poles and wires, natural gas pipes and lighting systems. Portland includes buildings, green infrastructure, and communications and information technology as necessary infrastructure investments that serve the community.

This section of the plan addresses only the infrastructure that meets all three of the following criteria:

- Owned or managed by the City of Portland or Multnomah County.
- Built infrastructure (e.g., engineered systems made of metal, concrete, asphalt).
- Water supply, transportation, parks, or stormwater, sanitary or combined sewage collection, treatment and disposal infrastructure.

What is built infrastructure? There is a continuum between built infrastructure and natural systems, and green infrastructure can span the two. In this assessment, the term "built" refers to the engineered, non-natural facilities and equipment. Green infrastructure is included only in reference to its built aspects. For example, the size and placement of green street facilities are considered to be part of the built infrastructure, but the survival and health of the vegetation planted in the greenstreet facility is addressed in the Natural Resources section of this assessment (see page 41). Similarly, this section addresses built park facilities (e.g., buildings, recreational facilities, sports fields), but not trees and natural areas. Additional infrastructure systems, including liquid fuel distribution and storage facilities, communications infrastructure and public buildings, may be assessed for climate vulnerabilities in subsequent updates.

The City's infrastructure bureaus implement asset management programs. The goal of infrastructure asset management is to meet required levels of service in the most cost-effective manner for present and future customers (NAMS & IPWEA, 2011). In practical terms, one of the steps in this process involves systematically assessing all the risks of infrastructure failure. Assets can fail due to poor condition, failure to provide the intended service, failure to meet regulatory goals or failure to be cost effective. Climate change could influence all of these and will need to be factored into the risks of failure of City and County assets so that these assets can be appropriately maintained and replaced. As asset management programs are updated, climate change will need to be considered in risk analysis and the examination of impacts of failure.

BUILT ENVIRONMENT AND INFRASTRUCTURE — CLIMATE CHANGE PREPARATION PLANNING PROCESS

The infrastructure team included participants from the Portland Water Bureau, Bureau of Environmental Services, Bureau of Transportation, Parks & Recreation and Multnomah County Department of Community Services. The team adapted the steps outlined in “Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments” from the University of Washington and King County, Washington (Snover et al., 2007). The steps included:

1. Identification of specific climate variables (e.g., temperature, precipitation) and their observed and expected trends using the best available scientific research.
2. Identification of secondary climate impacts due to trends in climate variables (e.g., flooding, drought, heat-related illnesses, pests).
3. Assessment of vulnerabilities of various systems (water supply, stormwater, wastewater and transportation infrastructure, and parks facilities) that could be impacted by climate change variables outside of the historic past. This included looking at expected impacts, probability of change and projected impact of change by 2030.
4. Assessment of risk by evaluating the likelihood and consequences of the change or impact by 2030.
5. Identification of existing and proposed climate change preparation strategies.
6. Selection of the most important remaining vulnerabilities that are not adequately addressed by existing actions (a gap analysis).
7. Identification of climate change preparation strategies that meet multiple objectives and maximize co-benefits and equity, as well as development of cross-jurisdictional strategies that build on the framework of monitoring, education, implementation and sharing results.

The planning staff conducted a preliminary review of the potential risks related to the built environment, building on existing work as part of the Portland Plan and the Comprehensive Plan Update. The resulting recommendations are included in the *Climate Change Preparation Strategy* (separate document).

BUILT ENVIRONMENT AND INFRASTRUCTURE — VULNERABILITIES AND IMPACTS

Climate change presents challenging issues for urban environments like the Portland metro area. Many of the built systems and structures in the urban environment are complex, interdependent, and some are deteriorating and already at risk of failure due to age and deferred maintenance.

Understanding climate change impacts in the built environment includes recognizing the impact on and interaction with the people living in that environment. The two are inexorably linked. In particular, policy making needs to consider the disproportionate impacts to vulnerable populations, including communities of color and low-income communities. Addressing inequalities that currently exist in Portland and Multnomah County’s built environment is critical to ensuring that all members of the community are able to prepare for and respond to a changing climate in the future.

The systems and structures that make up the built environment are especially important because they provide key services that residents and businesses rely on daily. When these services are disrupted, the impacts can in turn affect other sectors, including infrastructure, human and natural systems. For example, floods or landslides can disrupt transportation services, impacting commuting patterns and timely access to jobs or school, as well as the movement of commercial traffic and freight; loss of water or power can result in the closure of businesses and other important services; extreme heat events can result in reduced activities in construction or other outdoor employment opportunities. As a result, the full costs of impacts to the built environment extend beyond the direct costs associated with the actual damage to the built structures or systems.

The concentration of concrete, cars and impervious surfaces in the built environment magnifies temperature increases through urban heat islands (see Chapter 4, page 17, for more details on Portland’s urban heat islands), making extreme heat days particularly problematic for vulnerable populations living in the city. In addition, the interface of natural areas and the built environment can often exacerbate climate change impacts for one or both systems, particularly as it relates to flooding, wildfires and landslides.

Land use planning can help manage and mitigate future vulnerabilities to climate change impacts through zoning and land use regulations that reduce damage from climate risks like floods and landslides, as well as through increasing trees and vegetation to reduce urban heat island effects. By incorporating climate change impacts and projections, other decision-making and planning frameworks can also be used to improve the resilience of the built environment, including Portland’s Comprehensive Plan and smaller-scale area/district/corridor plans, infrastructure asset management, natural hazard mitigation, emergency management, and natural area preservation and restoration.

Built infrastructure is impacted by weather and climate in a variety of ways. In the preparation of this assessment, a literature review was conducted to compile a list of all the ways built infrastructure could be impacted by climate change:

Warmer winters with the potential for more intense rain events:

- Increased erosion and turbidity in water.
- Increased chance of small, shallow, rapid landslides as well as re-activation of large, deep slides.
- Overwhelmed stormwater facilities (underground injection control structures, swales, greenstreets, pipes).
- Increased wind, flooding, and other storm damage to facilities.
- Increased bridge scour.
- Increased need for bridge lifts.
- Retaining wall damage.
- Shifting demand for different types of indoor and outdoor recreation activities.
- Increased damage to docks, boat ramps and floats.
- Increased flooding of roads and bike paths, and potential flood-protection breach.
- Rising groundwater levels, causing problems with constructability and damage to underground facilities.
- Increased pumping of treated wastewater.

Hotter, drier summers with more high-heat days:

- Algae and bacterial growth in water.
- Increased soil temperatures causing more soil corrosion and shallow groundwater quality changes.
- Increased water temperatures causing water quality changes, wastewater treatment process changes, and increased odor in wastewater.
- Pavement buckling, rail warping, increased stress on bridge expansion joints, shortened pavement life.
- Increased use of air conditioning.
- Increased outdoor summer water demand.
- Increased danger of fire in the urban environment.
- Shifting demand for different types of indoor and outdoor recreation activities.

Many of the impacts listed above are not expected to be significant in the Portland area for many years to come. For each infrastructure function, the primary impacts of concern are detailed below.

DRINKING WATER SUPPLY

A Portland Water Bureau analysis of the range of potential climate change impacts on the drinking water system indicated that significant adaptation strategies are already in place. In 2002, the Water Bureau conducted a study of the potential impacts of climate change on the Bull Run water source (Palmer & Hahn, 2002). The information and results from that study have informed the Water Bureau's actions and programs for the past 10 years. The Water Bureau is committed to prepare for and monitor climate change impact snow and into the future.

The long-term potential impacts of climate change on the Bull Run watershed need to be considered in the context of variability in historical climate patterns. Significant concerns are climate patterns that are outside of the past record, include more rainfall in mid-winter months, or cause an increase in the average number of days of the reservoir drawdown period. Longer duration drawdown would increase Portland's reliance on its secondary groundwater source to supplement water stored in Bull Run reservoirs.

The other potential impacts of concern include increases in the number of rainfall events; damage from wind storms; and higher temperatures in the summer, which may increase fire risk because of dry vegetation. Many of these potential impacts could increase erosion which, in turn, could cause elevated turbidity levels in the unfiltered Bull Run water supply. In addition, potentially higher summer temperatures could increase the demand for water for outdoor use over the peak season.

The Water Bureau has been improving the resilience of the water system over time, such as by having adequate in-town storage to meet peak-event demands, and by hardening important infrastructure facilities such as pump stations, pipelines and river crossings.

The Water Bureau's secondary groundwater supply enables water to be provided when Bull Run is not sufficient to meet demands. The groundwater supply currently supplements the Bull Run for summer peak-season needs and is a backup supply when the Bull Run is partially or totally unavailable due to elevated turbidity levels or other emergency conditions. The Water Bureau has ensured that water rights in the Columbia South Shore Well Field are available to meet existing and future needs through state-approved extensions and an approved Water Management and Conservation Plan. This strategy significantly protects Portland water customers from the potential impacts of climate change on the surface water supply portion of the municipal water system. Between the two sources of supply the Water Bureau's planning indicates that, in combination with factors mentioned above, adequate water supplies are available for many decades to come.

In addition, the Water Bureau and water providers in the region have implemented conservation programs which, along with factors such as building and plumbing code changes, land use changes and significantly more efficient water appliances, have resulted in dramatic reductions in per capita water demands. For example, water consumption has dropped by 4 gallons per person per day (per year, on average, between 1993 and 2012, in the Portland retail service area). This decades-long decrease in system wide per person water demands, and a likely downward trend in future demands from wholesale water customers outside of the City, combine to provide an added buffer to any impacts on supply that might result from climate change.

Lastly, the Water Bureau, as a member of the Water Utility Climate Alliance (WUCA), is committed to enhancing its ability to study, analyze and understand potential climate change impacts on the Portland drinking water system and building collaborative relationships with the scientific community.

STORMWATER

The climate variable with the most potential to cause problems for the stormwater system is the potential for more intense rain events in the winter. Most of the stormwater pipes and underground injection control structures in Portland have been in place for decades and were sized with assumptions about climate and land use that were appropriate at the time they were built. Some of these systems are already having problems handling the increased runoff caused by development and additional impervious area; more intense rain events during the winter months would exacerbate this problem if nothing were done. In addition, increased rainfall causes increased erosion and sediment in stormwater. Sediment can clogs pipes and make greenstreet facilities less effective.

Since 1992, Portland has been taking steps to capture, treat and infiltrate water close to where it falls. This is outlined in the City's Watershed Management Plan, which spells out an integrated approach to watershed health. By design, the approach is not focused on solving any one specific issue, such as climate change impacts, but rather using science to guide decision making with a goal of overall watershed health. One of the six strategies in the plan calls for better management of stormwater by reducing impervious area, increasing infiltration and removing pollutants. This must be done carefully, however, in landslide risk areas. Increasing the overall resilience of Portland's watersheds and stormwater facilities also increases resilience to changes in the climate.

Actions already undertaken that help make the stormwater system more resilient include:

- Adoption of the 2008 revision of the Stormwater Management Manual that emphasizes the use of vegetated surface facilities to treat and infiltrate stormwater on the property where the stormwater runoff is created.
- Portland's Sustainable Stormwater Management Program supports greenroofs, greenstreets, downspout disconnections, and porous pavement on both public and private property.
- Watershed monitoring and restoration, including the recently completed Johnson Creek restoration project that has reduced flooding in the area.

SANITARY AND COMBINED SEWER SYSTEMS

Older Portland neighborhoods have a sewer system that mixes untreated sewage and stormwater runoff in a single pipe. These combined sewers have the same issue with increased winter rainfall as the stormwater system, with the added concern of the potential for additional combined sewer overflows (CSOs). During very heavy rain storms, runoff from buildings, streets and other hard surfaces can fill the combined sewers to capacity and cause them to overflow. The City of Portland completed its 20-year CSO Control Program in December 2011, reducing CSOs to the Columbia Slough by more than 99 percent and to the Willamette River by 94 percent. Instead of an average of 50 Willamette River CSO events each year, there are now an average of two to four CSO events each winter and one event in three summers during very heavy rainstorms. Implementation of the stormwater recommendations of the Watershed Management Plan will continue to help address these issues as well.

Another concern is higher summer air temperatures that increase water temperatures. When wastewater temperatures increase, the dissolved oxygen content decreases and the biological activity of wastewater treatment processes tend to increase. The Bureau of Environmental Services has an ongoing odor control program for both the Treatment Plants and the wastewater collection system. Higher temperatures projected for the future could result in increased odor production potential in the collection system and increased oxygen requirements for some biological treatment processes. These changes are expected to be gradual, making monitoring of climate trends and water temperatures the most appropriate climate change preparation actions to take at this time.

TRANSPORTATION INFRASTRUCTURE

Changes in temperature, precipitation and freeze/thaw cycles may require the revision of maintenance levels for transportation infrastructure. Extreme heat increases the risk of fires in brush along roadways, stress on bridge expansion joints, and increased risk of pavement buckling and decreased pavement life. Increased winter precipitation can increase the occurrence of erosion and landslides, increased scour and put additional pressure on retaining walls. All of these may increase the need for maintenance and replacement. However, a reduction in freezing winter temperatures could have a positive impact on ice-related maintenance operations. Careful tracking of maintenance schedules and asset conditions will allow the City and County to adjust as appropriate in the future.

Floods caused by more intense rain events in the winter have two primary impacts on transportation infrastructure:

- An increased need for bridge lifts and the accompanying delays in street traffic near the river surface, such as the Eastbank Esplanade bike/pedestrian path. Increased bridge lifts will require additional transportation system planning and coordination with river users to schedule lifts to minimize disruptions.
- The potential for increased flooding could require alternative paths to ensure residents and commercial traffic can get where they need to go.

In the time frame covered by this assessment, the City and County will monitor river levels and bridge lift frequencies to determine if any change in planning or operations will become necessary.

PARKS FACILITIES

The combination of changing temperature and precipitation patterns may impact maintenance and resource needs for park facilities. For example, as temperatures rise, demand for water-related recreation and air-conditioned indoor recreation may increase. Changes in rainfall could impact asset lifespan, increasing maintenance requirements for structures, trails, docks, trees and landscaping, and other facilities.

Portland Parks & Recreation (PP&R) is currently taking actions to address issues related to climate change. In particular, several existing efforts are building resilience of parks facilities to hotter, drier summers. For example, PP&R has made significant progress to reduce water usage at parks, including a formal Water Conservation policy and actions that have been in place since 1993. PP&R has installed wells at a dozen park sites to reduce water demand on the municipal water supply and uses computer controlled irrigation systems that water at night or in the early morning to reduce evaporation loss and allow greater infiltration. A centrally controlled irrigation system manages water use at PP&R's largest parks, as well as many smaller parks. PP&R uses low-flow toilet fixtures and low-flow nozzles on fountains. In addition, PP&R selects grasses that are moisture-, drought-, disease- and wear-tolerant, and uses plants and trees that are well adapted to place, adjacent uses, water regime and soil conditions.

Portlanders seeking to escape from the heat often use Park facilities, including community centers. An increased incidence of high-heat days means these parks facilities will see increased demands. Energy efficiency is a key strategy to ensure the efficient use of resources and comfort of guests, especially during heat waves. PP&R has taken several steps to improve energy efficiency of parks facilities including lighting upgrades, high-efficiency appliances, liquid pool covers and centrally controlled HVAC systems. PP&R also employs a variety of technologies to monitor and manage energy consumption.

Reducing wildfire risk is also an important aspect of building resilience to hotter, drier summers. The City and County are actively working to reduce hazardous wildfire fuels, especially highly flammable invasive weeds at the edges of parks and natural areas, or Wildland Urban Interface (WUI) areas.

Bio-swales and other stormwater pre-treatment and infiltration facilities are common in parks. For example, the University Park Community Center (UPCC) has a rainwater harvesting system with a meter to track the actual harvested water going through the system. These and similar systems increase the resilience of parks and stormwater systems to better manage increased winter precipitation.

Future design and locating of park facilities will need to take into account trends in river levels, temperatures and rainfall. Parks will continue to monitor maintenance activities and look for trends in maintenance needs. Resource efficiency will also be a priority; the less water and energy a facility uses, the more resilient it will be to changes in the climate. Parks will work to increase energy efficiency, water conservation, maintenance efficiency and the use of resilient materials. Parks will look at adding tree and shrub cover where appropriate to help mitigate heat and air quality impacts, and design plantings and select species that are resilient and water-efficient.

BUILT ENVIRONMENT AND INFRASTRUCTURE — CLIMATE CHANGE PREPARATION OBJECTIVES AND ACTIONS

The *Climate Change Preparation Strategy* (separate document) contains the full set of objectives and actions that have been identified to prepare for and respond to climate change. Objectives specific to improving the resilience of infrastructure and the built environment include:

2030 Objective 1: Decrease the urban heat island effect, especially in areas with populations most vulnerable to heat.
Design and implement programs that cool the urban environment, including revegetation and tree planting, pervious paving and green infrastructure like bioswales and ecoroofs. Utilize information and maps of Portland's urban heat islands to help inform decisions and priorities about such projects.

2030 Objective 3: Increase the resilience of Portland's water supply to drier summers.
Expand the capacity of the groundwater system and ensure water is used efficiently by homes, businesses and in City and County facilities such as local parks. Continue to assess the potential impacts of climate change on the Bull Run watershed.

2030 Objective 5: Manage the risk of wildfires as a result of drier summers.
Reduce wildfire risk in areas where development (e.g., homes and businesses) is next to natural and forested areas (often called the "urban-wildland interface"). In a co-management role with partner agencies, respond to fires in and around the Bull Run watershed.

2030 Objective 6: Increase the resilience of the natural and built environment to more intense rain events and associated flooding.
Work with local, state and federal partners to update floodplain data used in planning processes. Restore floodplains, reduce paved surfaces (to reduce stormwater runoff), and prepare to manage increased runoff amounts in streams.

2030 Objective 8: Manage the increased risk of landslides due to changing precipitation patterns.
Identify and monitor landslide hazard areas, and incorporate landslide hazard reduction techniques into infrastructure planning projects. Provide outreach and education on reducing landslide risks to private property owners.

2030 Objective 10: Institutionalize climate preparation planning and best practices.
Apply an equity lens to climate action efforts and where possible prioritize benefits to vulnerable populations. Improve the understanding of local climate change impacts. Recognize climate variables as a risk in how the City and County manage infrastructure.

2030 Objective 12: Improve monitoring, evaluate the effectiveness of climate change preparation actions and advance new research to support climate preparation efforts.
Identify, compile and regularly update key data for climate change trend tracking (streamflows, temperature, natural resources, storms, condition of infrastructure, heat-related illness, air quality, etc.). Support monitoring programs and existing climate research, and advance new research related to climate-related diseases, population shifts, food systems, etc.

BUILT ENVIRONMENT AND INFRASTRUCTURE — CLIMATE CHANGE PREPARATION CHALLENGES

Climate change preparation options available in the built environment are constrained significantly due to:

- Lack of funding to make many needed infrastructure improvements (particularly for transportation and parks) and to strengthen social safety nets.
- Historic development patterns that have placed whole areas of the community in harm's way with respect to floods and wildfires.
- Limited financial resources of populations most vulnerable to climate impacts to prepare for (e.g., air conditioning) and recover from (e.g., flooded basement) the effects of climate change.

Humans are an impressively adaptable species, but the factors identified above significantly constrain adaptation options in urban built environments. Under any scenario they present major economic and social costs to local governments, residents, and businesses.

Preparing for built environment impacts from climate change remains challenging due to:

- The long timeframe for the projected changes.
- The range of possible futures in terms of how those changes will manifest.
- The natural tendency to focus on near-term needs and issues.

However, much can be learned from climate change preparation actions focused on the built environment that are already underway in other urban areas, including Boston, New York City, Syracuse, Seattle, Philadelphia, the San Francisco Bay Area, as well as London and Hamburg.

While the science on global climate change is well developed, localized modeling of future conditions is still taking shape. The largest risk in starting climate change preparation actions relates to the uncertainty of future carbon emission scenarios and how those scenarios will effect local conditions and impact the built infrastructure. Because of this, many of the recommended actions involve improving climate knowledge and monitoring for trends. However, there are some adaptation strategies that mitigate multiple identified vulnerabilities (for example regulatory requirements, catastrophic risks such as earthquakes, service and maintenance deficiencies, or open space/biodiversity needs), which present opportunities to address climate change impacts at the same time. Emergency preparedness has a similar role in implementing risk management strategies that may present significant future opportunities for addressing climate vulnerabilities.

Funding is another significant barrier to implementation of climate change preparation recommendations. Besides the costs of building new facilities, research and tracking also take significant staff resources. Current economic conditions have meant that infrastructure bureaus have had cuts in operational (non-construction) funding which reduces the ability to address maintenance and operations needs and manage risk — which includes many preparation and resilience activities. Budget pressures are not limited to operations, for example, it has been difficult in recent years to acquire sufficient funds to identify appropriate properties, purchase, develop and maintain new parks, community centers, or natural areas in underserved areas; even when those areas may be home to populations most vulnerable to climate change impacts who will have a greater need for facilities as climate changes occur. The use of green infrastructure, and the acquisition and restoration of the natural system has the potential to reduce capital costs and generate jobs through maintenance of green systems.

VULNERABILITY ASSESSMENT OF OTHER SYSTEMS

Local residents and businesses depend on systems that are larger than the City and County's sphere of influence. Portland and Multnomah County can only be resilient if other local, regional, state and federal jurisdictions and partners also take steps to become more resilient.

Several other systems and sectors could be impacted by climate change and may warrant a more detailed vulnerability assessment in the future. This section of the assessment includes an initial look at several of these areas, including food systems, climate migrants, energy systems and the economy.

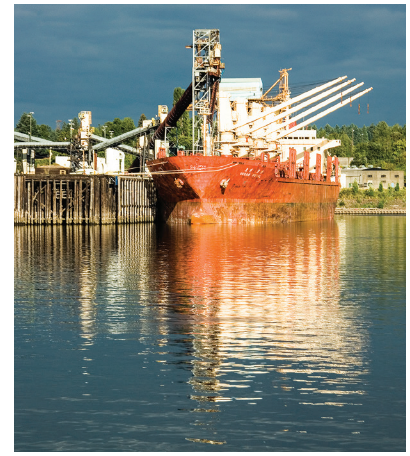
FOOD SYSTEMS

"Food systems" refers to the production, processing, distribution, consumption and disposal of food products, as well as the ability of people to access food for their health and cultural nourishment. Due to the complex and global nature of the food system, it is difficult to measure the future impacts of climate change on food. Existing challenges such as the cost and availability of food may be further stressed at the regional, national and international level, but it is difficult to assess the potential local impacts with accuracy.

Agriculture and fisheries are highly dependent on specific climate conditions (U.S. EPA, 2013), and food distribution systems may be affected by climate change impacts to built infrastructure. Human health may also be impacted by the unavailability or unaffordability of foods due to changes in production and distribution. In addition, food is closely interwoven with culture. For example, in the Pacific Northwest, climate change may impact the availability and abundance of culturally significant foods like salmon for the region's Native American communities.

Fluctuations in climate — globally, nationally, locally — and the increasing frequency of weather extremes pose a significant risk to agricultural production (Austin, 2011). Agriculture in general is highly sensitive to changes in climate, as animals and crops are often optimized to local climate and resource availability. Food price is more volatile with extreme shifts in weather norms (IPCC, 2007b). For example, global droughts between 2006 and 2008 were responsible for a three-fold rise in the cost for rice and more than doubled the cost of wheat, corn, and soybeans (Mazhirov, 2011).

Water availability, quality, and cost are anticipated to present the biggest challenge to regional agricultural production (OCCRI, 2011). Nationally, strategies likely exist to manage much of the climate disruption the agricultural sector will face over the next 25 years. By mid-century however, "yields of major U.S. crops and farm profits are expected to decline" (IPCC, 2007c; Ortiz et al., 2008; Schlenker et al., 2005). Globally, there is an unclear relationship between climate change and overall food production/availability, but cost increases may make food unavailable to many who are "priced out."



Food security is the "ability to provide future physical and economic access to sufficient, safe, and nutritious food that fulfills the dietary needs and food preferences for living an active and healthy lifestyle" (FAO Agricultural and Development Economics Division, 2006). Based on USDA guidelines, over 16 percent of Multnomah County residents are considered food insecure (Feeding America, 2013). Multnomah County residents served by the Oregon Food Bank grew from 370,000 in FY 2007/2008 to over 627,000 in FY 2012/2013. The number of Multnomah County SNAP recipients rose almost 100 percent over the past five years, from 108,701 residents in 2008 to 216,094 in 2013.

Any change to global, national, or local food production that increases cost and decreases variability would likely further stress the ability of people to adequately feed themselves. Additional research is required to understand the global, national and regional impacts to the food system. Under all realistic scenarios, however, addressing existing issues around hunger and food insecurity are likely effective strategies for building additional climate resilience within Multnomah County.

CLIMATE MIGRANTS

The Portland Metropolitan region is projected to grow by nearly 1 million people by 2030, challenging planners and resource managers to guide development in a way that will meet the needs of existing residents and new entrants (Oregon Metro, 2009). The region currently faces many challenges, including elevated unemployment, poor health outcomes, inadequate supply of affordable housing and food insecurity. An increased population may exacerbate these existing challenges.

In addition to immigration to the region because of traditional rationales (social, economic, etc.), planners are beginning to consider the possibility of “climate migrants” or “climate refugees.” These are individuals who are moving either by force or by choice in response to changing climates in their places of origin, both domestic and international. Impacts of climate change will be felt more severely in certain parts of the country and the globe, making less-affected areas relatively attractive locations for immigration. Multnomah County could potentially become a magnet for displaced people from the Pacific Rim, southwestern United States and other places with existing migration links to the Portland metro region (Portland State University, 2011). However, at this time there is no indication that the addition of climate migrants to the area would exceed the planned-for population growth.

While it is impossible to predict how many people would move here because of climate change, local planners and policymakers should analyze long-term climate trends and migration data to begin to predict who might come here and why, as well as assess potential climate migrants’ needs and values. Understanding the economic circumstances and demographic characteristics of those likely to migrate helps planners understand the mix of jobs, housing and culturally appropriate social support necessary for successful inclusion of immigrant communities. Such work will help ensure that climate change preparation efforts are compatible with shared, place-based values.

ENERGY SYSTEMS

The energy system, which distributes electricity, natural gas and other fuels, is likely to be impacted by a changing climate. The utilities serving Multnomah County produce 27 percent of their electricity from hydroelectric power produced by flows of the Columbia River and its tributaries, which will be impacted by changing precipitation patterns and warmer temperatures that impact snow pack retention. One study estimates a ~3 percent decrease in overall energy production from Columbia River Basin hydroelectric production, varying from a ~7 percent increase in winter months, to an 18 percent decrease in the summer (CIG, 2009b).

Impacts to the availability of other primary energy sources in Multnomah County (coal, natural gas, gasoline, and diesel) are not immediately anticipated but not well understood. Policy responses to climate change, including cap and trade or a carbon tax, may increase the cost of fossil fuel energy sources such as natural gas and coal. Coal-fired plants also require significant water inputs, which could be impacted by changes in cost or availability of water with changing precipitation patterns. Climate change impacts to renewable energy sources such as wind and solar are difficult to determine and merit additional research.

Rising average temperatures are likely to increase the summer demand for electricity, the primary energy input for air conditioning. Similarly, the demand for heating is likely to decrease with average increases in temperature resulting in warmer winters. As the region’s climate is relatively temperate, heating represents a significantly higher percentage of the overall regional energy demand. Even with significant increases in demand for cooling, in the near-term this is likely to represent a relatively small increase in overall energy demand. It is important to note, however, that any decreases in hydroelectric production due to climate change are likely to occur in the summer, when cooling demand is at its peak.

Weather can impact energy distribution system in many ways, including downed electrical power lines from wind, and extreme heat. Increased average temperatures and flooding events could result in increased impacts to the distribution systems, including liquid fuel storage and distribution systems.

While the potential impacts from climate change are important to identify and incorporate into planning activities, increased energy demand from regional population increases will likely far outweigh climate-related impacts to the energy system. Utilities in the State of Oregon are required to complete Integrated Resource Plans (IRPs) to demonstrate how the utility will meet future additional energy demand for generation and distribution. To date, utilities serving Multnomah County do not anticipate any inability to meet future projected energy demand.

Moreover, two key planning documents anticipate meeting all additional demand through investments in energy conservation: Oregon’s 10 Year Energy Plan and the Northwest Power and Planning Council 6th Northwest Conservation and Electric Power Plan. Finally, the Portland Local Energy Assurance Plan (LEAP) brought together key regional partners to identify vulnerabilities to energy supply and strategies to address them. Implementation of recommendations in LEAP will build additional regional resilience in the energy system against impacts from climate change and other natural disasters.

ECONOMY

When it comes to assessing the regional economic impacts of climate change, significant questions remain. Because the impacts will vary across different physical and geographic scales, and across different sectors and industries, projecting the direct and indirect economic costs, or benefits, is challenging and considerably more research and study is needed.

A limited number of studies about the economic impact of climate change in Oregon have been conducted and suggest that the impact of climate change on the economy is unknown. However, it is reasonable to anticipate the following areas could be impacted: energy, forest and range production, fish and wildlife, recreation, flood and storm damage, public health, and food production (Resource Innovations, Institute for a Sustainable Environment, University of Oregon, 2005); Climate Leadership Initiative, 2006; EcoNorthwest, 2009).

For example, a change in climate inevitably affects food production. Reductions in beef, wheat, wine and other crops can be expected. The incidence of pests and plant diseases will likely rise, and increased temperatures will lead to a decreased amount of fresh water available for agriculture. All of these effects increase costs for farmers, increase the cost of local food and may decrease employment opportunities in the agricultural sector.

An important consideration is the increased cost of energy. Water flows will change, affecting the Northwest's substantial hydropower resources. This poses challenges to all businesses as well as households. Energy is an important input for nearly all industries. An increase in energy costs will force many organizations and companies to make tough financial decisions. As Portland summers become increasingly warm, the use of energy to cool homes and businesses is also expected to increase and could cause additional financial impacts.

It is important to acknowledge and prepare for the wide-reaching effects of this type of economic transition. Climate change related economic transitions will deeply affected households and communities. Lower income households often feel environmental harm the most acutely. For example, potential climate change induced increases to the cost of food and healthcare as well as reduced access to employment, is likely to disproportionately impact lower income people.

Some industries will be negatively impacted by climate change while others may be positively impacted. For example, the solar industry may thrive in a warmer climate with higher energy costs, while companies that sell products that are disproportionately reliant on fuel or energy are likely to feel the impacts.

APPENDICES

APPENDIX A: Glossary of terms

1. **Adapt or adaptation:** Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. In this document, the term adaptation is used synonymously with climate change preparation.
2. **Adaptive capacity:** The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
3. **Adaptive management:** A dynamic planning and implementation process that applies scientific principles, methods, and tools to improve management activities incrementally as decision makers learn from experience and better information, and as analytical tools become available. Involves frequent modification of planning and management strategies, goals, objectives and benchmarks. Requires frequent monitoring and analysis of the results of past actions and application of those results to current decisions.
4. **Asset management:** The continuous cycle of asset inventory, condition, and performance assessment that has as its goal the cost-effective provision of a desired level of service for physical assets. Investment decisions consider planning, design, construction, maintenance, operations, rehabilitation, and replacing assets on a sustainable basis that considers social, economic and environmental impacts.
5. **Atmospheric river:** A narrow band of concentrated low-level water vapor that, when encountering mountain ranges such as the Cascade Range, produces large amounts of precipitation.
6. **Best practice:** An activity that has proven its effectiveness in multiple situations and may have applicability in another situation.
7. **Channel migration:** Lateral movement of rivers in response to normal sedimentation (gradual) or flooding events (abrupt).
8. **Climate change risk:** A combination of the magnitude of the potential consequence(s) of climate change impact(s) (e.g., injury, damage, loss of habitat) and the likelihood that the consequences will occur.
9. **Community:** A group of people that may or may not be geographically based.
10. **Green infrastructure:** Public or private assets — either natural resources or engineered green facilities — that protect, support or mimic natural systems to provide stormwater management, water quality, public health and safety, open space, or other complementary ecosystem services. Examples include trees, ecoroofs, green street facilities, wetlands, natural areas, and natural waterways.
11. **Hydrologic or hydrologic cycles:** The movement of water on, in and above the earth.
12. **Infrastructure:** Consists of assets that serve whole communities. These are necessary municipal or public services, provided by the government or by private companies and defined as long-lived capital assets that normally are stationary in nature and can be preserved for a significant number of years. Examples are streets, bridges, tunnels, drainage systems, parks and park facilities, water and sewer lines, pump stations and treatment plants, dams, and lighting systems. Portland includes buildings, green infrastructure, communications and information technology as necessary infrastructure investments that serve the community.
13. **Mitigate or mitigation:** To moderate a quality or condition in force or intensity. “Climate Mitigation” typically references efforts to reduce carbon emissions in order to slow climate change.
14. **Preparation:** Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. In this document, the term adaptation is used synonymously with climate change adaptation.
15. **Resilience:** A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.
16. **Risk assessment:** The process to prioritize climate change risks focusing on the potential consequences of an impact.
17. **Urban Heat Island:** The urban heat island effect is a measurable increase in ambient urban air temperatures resulting primarily from the replacement of vegetation with buildings, roads, and other heat-absorbing infrastructure. The heat island effect can result in significant temperature differences between rural and urban areas.
18. **Vulnerability:** The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.
19. **Vulnerability assessment:** The process to prioritize climate change risks focusing on where a community or system is most susceptible.

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