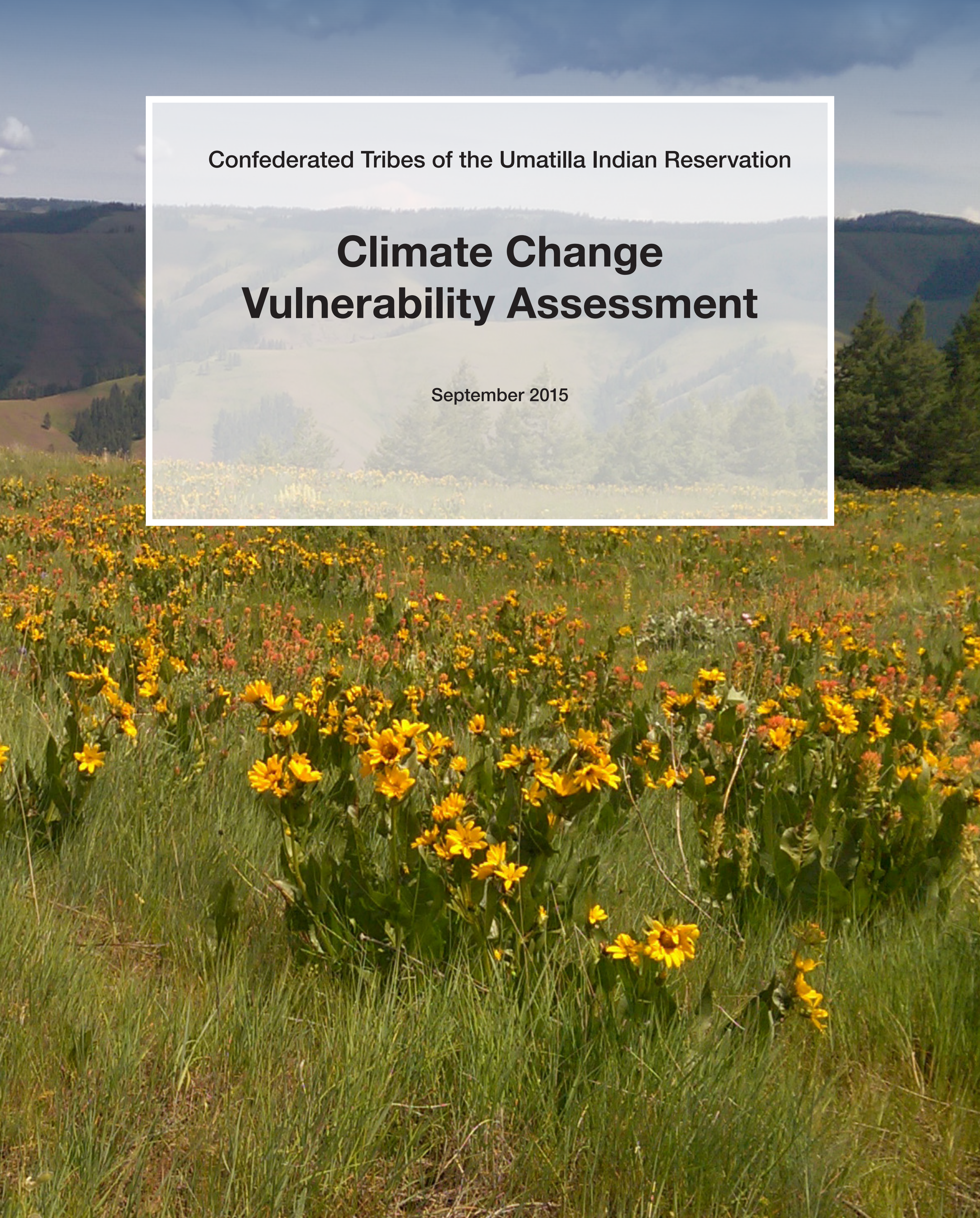

Confederated Tribes of the Umatilla Indian Reservation

Climate Change Vulnerability Assessment

September 2015

This report is a collaboration between the CTUIR, Adaptation International, and the Oregon Climate Change Research Institute (OCCRI).

For information about the CTUIR and its Vulnerability Assessment work, contact CTUIR Department of Science and Engineering at:

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Cover Image Caption
Gibbon Ridge wildflowers in June, Rattlesnake and Stumbough Ridges in the distance.

Cover Image Credit
Scott Peckham, CTUIR Department of Natural Resources

Funding
Project funding was provided by a grant from the Bureau of Indian Affairs for the November 2013 Category 2 (adaptation planning) grant proposal titled Climate Adaptation: CTUIR Vulnerability and Resiliency Assessment and in-kind assistance by the Confederated Tribes of the Umatilla Indian Reservation.

Recommended Citation
Confederated Tribes of the Umatilla Indian Reservation, 2015. Climate Change Vulnerability Assessment. Nasser, E., Petersen, S., Mills, P. (eds). Available online: www.ctuir.org

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Acknowledgements

The success of this project is the result of contributions from dedicated, long-term members of staff, Committees, and Commissions at the Confederated Tribes of the Umatilla Reservation (CTUIR). Without their willingness to provide detailed input, bring in years of knowledge and expertise, and share their concerns about how changing climate conditions and extreme weather will affect all people living and working on the reservation, this report would not have been possible. This report and the process that went into creating it lays the foundation for continued work on this issue. The solid foundation established by the vulnerability assessment will help guide future action to make the CTUIR more resilient in the face of a changing climate.

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We extend our gratitude to the CTUIR GIS program for developing maps and to individuals at the National Oceanic and Atmospheric Administration and the Oregon Health Authority for reviewing the report and assisting with its development.

Funding

Project funding was provided by a grant from the Bureau of Indian Affairs for the November 2013 Category 2 (adaptation planning) grant proposal titled *Climate Adaptation: CTUIR Vulnerability and Resiliency Assessment* and in-kind assistance by the Confederated Tribes of the Umatilla Indian Reservation.

Recommended Citation

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Definitions and Acronyms

BIA: Bureau of Indian Affairs.

B.P.: *Before Present* is a time scale used mainly in geology and other scientific disciplines to specify when events in the past occurred. Because the "present" time changes, standard practice is to use January 1, 1950 as the start of the age scale, reflecting the fact that radiocarbon dating became practicable in the 1950s[1].

CH_4: *Methane* is the second most prevalent greenhouse gas (after CO_2) and is quite potent with an average of 25 times the heat trapping capability of carbon dioxide[2].

CIRC: *Climate Impacts Research Consortium* is a research organization funded by the National Oceanic and Atmospheric Administration to provide policy makers, resource managers, and fellow researchers with the best available science covering the changing climate of Oregon, Washington, Idaho, and western Montana.

CMIPS: Coupled Model lntercomparison Project v5.

CO: *Carbon Monoxide* is an odorless, colorless, toxic gas resulting from combustion, which can cause health effects and is usually associated with indoor exposure[3].

CO_2: *Carbon Dioxide* is the primary greenhouse gas emitted from human activities; in 2013, it accounted for about 82% of all U.S. greenhouse gas emissions[4].

CSC: *Climate Science Center* serves as a resource for Department of the Interior agencies and other partners in providing necessary science in advising policy decisions. The regional CSC for the Pacific Northwest is located at Oregon State University.

CRITFC: Columbia River Inter-Tribal Fish Commission.

CTUIR: Confederated Tribes of the Umatilla Indian Reservation.

DOI: Department of the Interior.

ENSO: El Niño Southern Oscillation.

GCM: Global Climate Models.

GHG: *Greenhouse gas* is the name for a group of gasses that trap heat in the atmosphere. They act like a blanket around the Earth and keep it warm.

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[1] Wikipedia, 2015. *Retrieved from:* https://en.wikipedia.org/wiki/Before_Present
[2] United States Environmental Protection Agency, 2015. Overview of Greenhouse Gases: Methane. *Retrieved from:* http://epa.gov/climatechange/ghgemissions/gases/ch4.html
[3] United States Environmental Protection Agency. An Introduction to Indoor Air Quality: Carbon Monoxide. *Retrieved from:* http://www.epa.gov/iaq/co.html
[4] United States Environmental Protection Agency, 2015. Overview of Greenhouse Gases: Carbon Dioxide. *Retrieved from:* http://epa.gov/climatechange/ghgemissions/gases/co2.html

IPCC: Intergovernmental Panel on Climate Change, established in 1988, is the leading international body for the assessment of climate change to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts[5].

KICs: Key Items of Concern.

MACA: Multivariate Adaptive Constructed Analogs is a statistical downscaling method, which utilizes a training dataset (i.e. a meteorological observation dataset) to remove historical biases and match spatial patterns in climate model output[6].

NOAA: National Oceanic and Atmospheric Administration.

N_2O: *Nitrous Oxide* is a significant greenhouse gas with 298 times the global warming potential of CO_2. It accounts for about 5% of all greenhouse gas emissions from human activity in the U.S.[7].

NWS: National Weather Service.

OCCRI: *Oregon Climate Change Research Institute* was created by the Oregon state legislature in 2007 to foster climate change research among faculty of the Oregon University System, serve as a clearinghouse for climate information, and to provide climate change information to the public.

PDO: Pacific Decadal Oscillation.

PM: *Particulate Matter,* also known as particle pollution is a toxic mix of extremely small particles which form as a result of combustion, the size of which is directly linked to its toxicity (e.g. the smaller the particle, the more toxic it is). The U.S. EPA regulates it.

PNW: Pacific Northwest.

RCP 4.5 and RCP 8.5: RCP stands for Representative Concentration Pathway. In the projections contained herein, RCP 4.5 is considered the "low emissions" scenario, while RCP 8.5 is considered the "high emissions" scenario. RCP 4.5 is generally considered to be a "best case" scenario (representing concerted efforts to reduce emissions), while RCP 8.5 is generally considered "worst case" or "business as usual."

TEK: Traditional Ecological Knowledge.

U.S. EPA: United States Environmental Protection Agency.

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[5] Intergovernmental Panel on Climate Change, 2015. Organization. *Retrieved from:* http://www.ipcc.ch/organization/organization.shtml

[6] University of Idaho, 2015. Multivariate Adaptive Constructive Analogs (MACA) Statistical Downscaling Method. *Retrieved from:* http://maca.northwestknowledge.net

[7] United States Environmental Protection Agency, 2015. Overview of Greenhouse Gases: Nitrous Oxide. *Retrieved from:* http://www.epa.gov/climatechange/ghgemissions/gases/n2o.html

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Executive Summary

Introduction

The people of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) have a long history of living in the southern portion of the Columbia Plateau. The area has a diverse array of natural resources and the Tribes' connection with those resources can be seen through their on-going connection with their First Foods. Water, salmon, game (deer and elk), roots (cous), and berries (huckleberry) are not just food sources, but are integral to the cultural, spiritual, and community identity of the Tribes. These foods depend on healthy and vibrant landscapes to thrive and those landscapes are changing as the climate of the region shifts.

CTUIR is already experiencing some of those changes. In order to respond to and better plan for the future, the CTUIR took action to assess the climate related vulnerability of key resources and assets that are important to tribal life. The results of this work are summarized in this report.

Collaborative Project Process

A Climate Change Project Team composed of CTUIR staff plus Committee and Commission members came together over the course of the 6-month project to collaborate on this vulnerability assessment. Through a series of events and outreach activities they developed a comprehensive Key Items of Concern (KIC) list summarizing the important aspects of tribal life potentially vulnerable to climate change. The prioritized list of concerns is shown in the table below.

Availability and Access to First Foods
Water
Chinook Salmon
Elk
Cous
Huckleberry
Agriculture
Non-irrigated crops (winter wheat, dry land peas, canola)
Irrigated crops (hay, alfalfa)
Human Health
Wildfires
Heat waves
Vector borne diseases
Increases in crime
Population Dynamics
Forest Health and Welfare

By integrating the cultural and spiritual, economic, and health significance of these items with new projections of future climate conditions the project team worked together to understand how these KICs could be affected by a changing climate. The project team assessed the *sensitivity* and *adaptive capacity* of each of the KICs to determine their vulnerability. These results were used to categorize the KICs based on their vulnerability and priority for taking action will ultimately help the Tribes to prioritize action in the next phase of planning.

Projections of a Changing Climate

The Oregon Climate Change Research Institute (OCCRI) was a key partner in generating new climate projections to guide the assessment process. Working collaboratively, the project team selected a geographic region, or "domain", for analysis, based around the Aboriginal Title Lands for the CTUIR. They selected two climate scenarios for this analysis—Representative Concentration Pathway (RCP) 4.5 and RCP 8.5. RCP 4.5 is considered the "low emissions" or "best case" scenario, representing a future wherein concerted efforts are made globally to reduce greenhouse gas emissions. RCP 8.5 is considered the "high emissions" scenario wherein business proceeds normally without concerted efforts to decrease greenhouse gas emissions. The climate projections summarized in this report show both scenarios out to the end of the century. The key results are summarized below.

Summary of Key Climate Results for the Aboriginal Title Lands of the CTUIR
For the CTUIR region, the seasonal average maximum monthly temperatures will likely increase steadily throughout the 21st century. This trend will culminate with an increase of around 5 to 12 °F by the end of the century (i.e. 2070-2099). The largest increase is projected to be during the summer.
Increases in average maximum ***summer*** temperatures alone are projected to increase by between +2 °F and +10 °F by mid century while ***winter*** temperatures are projected to increase by between +1 °F and +8 °F depending on the scenario used (RCP 4.5 or RCP 8.5).
There will likely be a large increase in the number of days that exceed 90° F in the summer by the end of the century. Projections show a doubling of the number of days that exceed 90° F in the ***summer*** from 13 to 26 days by mid-century and a tripling to 39 days by the end of the century. Spring and fall may see a few more days over 90° F.
The temperature projections for the two emissions scenarios are approximately the same until the middle of the century. After this point, RCP 8.5 temperatures are steadily higher than those for RCP 4.5.
Changes in precipitation patterns are less clear-cut than for temperature. The analysis suggests little overall change in total annual precipitation, but summers will be potentially drier while the other seasons are slightly wetter.
Uncertainties in the precipitation projections are much larger than uncertainties in the temperature projections. There are especially large uncertainties for projections of the number of days with no precipitation.
The analysis suggests that precipitation is less sensitive to the emissions scenario than temperature.

Results
By combining the new climate projections with background literature and their professional expertise, the project team worked to assess the vulnerability of each of the KICs on the prioritized list. This process created clear distinctions between those areas of tribal life that are more and less vulnerable to climate. The results are outlined below:

High Vulnerability, High Priority
Chinook Salmon

Medium Vulnerability, Medium Priority
Cous
Elk
Flooding
Agricultural Crops (Non-Irrigation)

Medium Vulnerability, Low Priority
Agricultural Crops (Irrigation)
Water (Long-term)

Medium-Low Vulnerability, Medium Priority
Huckleberry
Wildfires

Low Vulnerability, Medium Priority
Heat Waves

Low Vulnerability, Low Priority
Increases in crime
Water (Short-term)
Vector Borne Diseases
Population Dynamics

The results of this assessment can help guide the CTUIR's future efforts to reduce vulnerability and build climate resilience. In addition, this assessment has identified specific knowledge and research gaps that can help guide investments and the development of new research projects to help fill those gaps.

This current effort and those of the future, build on the long legacy of the Tribes in the region. They have adapted to many changes in the past and will continue to adapt into the future. Being proactive to identify, evaluate, and respond to the impacts of climate change will help ensure that the CTUIR continues to maintain its culture while strengthening the health, economic vitality, and climate resilience of the Tribes.

1.0 Climate and the CTUIR

The peoples of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR)[8] have lived on the Columbia Plateau (what is present-day northeastern Oregon and southeastern Washington) for thousands of years and have been concerned about climate change for more than 70 years. The Tribes of the region consider themselves part of, and not separate from, the natural world and the resources that they have depended on and lived with for all of history[9].

Primarily because of the Columbia River, the area has a diverse array of natural resources and the Tribes' connection with those resources can be seen through their on-going connection with their First Foods. Water, salmon, game (deer and elk), roots (cous), and berries (huckleberry) are not just food sources, but are integral to the cultural, spiritual, and community identity of the Tribes. These foods depend on healthy and vibrant landscapes to thrive and those landscapes are changing as the climate of the region shifts.

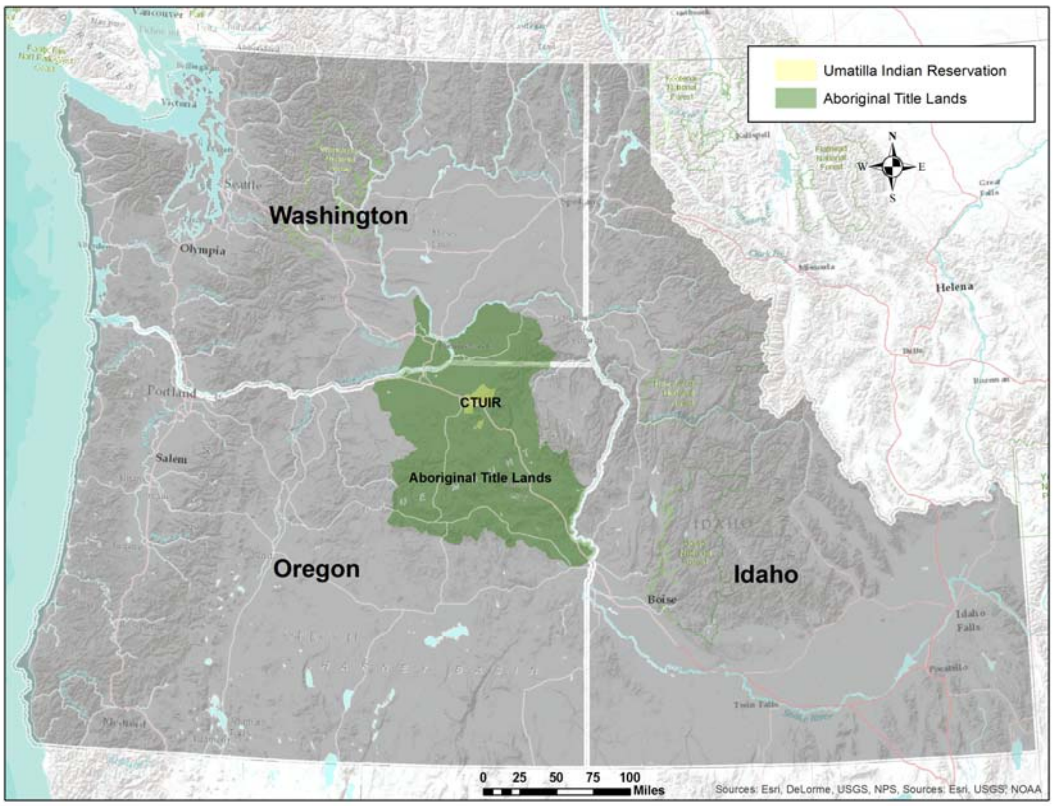

Figure 1: The Aboriginal Title Lands of the peoples of the Cayuse, Umatilla and Walla Walla Tribes. Green area is the aboriginal tribal lands and the yellow area in the center is the Umatilla Indian Reservation.

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[8] The CTUIR is composed of peoples from the Umatilla, Cayuse, and Walla Walla tribes.

[9] Confederated Tribes of the Umatilla Indian Reservation, 2015. History of the CTUIR. *Retrieved from:* http://ctuir.org/history-culture/history-ctuir

The Pacific Northwest is defined in large part by its landscape and abundant natural resources, including timber, fisheries, productive soils, and plentiful water[10]. Eastern Oregon is generally warmer and drier than areas west of the Cascade mountain range, with average annual precipitation on the Columbia Plateau of less than eight inches (compared to more than 16 feet on the western slopes of the Olympic Mountains in Washington)[11]. The Plateau is a significant agricultural region, producing the majority of Oregon's wheat through dry land cropping[12]. The climate conditions on the Plateau and in the Blue Mountains along with the Columbia and Umatilla rivers influence the abundance and availability of the Tribes' First Foods. The Chinook salmon runs of the Columbia River bring culturally and nutritionally important food from the ocean to the Plateau region. The water available from rain and snowpack in the Blue Mountains provides drinking water and supports the First Foods that are important to the Tribes.

Although the climate in the region has been relatively stable since the end of the last ice age, it has not been static. The people have adapted to and survived wet years (or decades) and dry years (or decades), droughts, and floods. They have also managed to maintain their culture and community through a myriad social and economic changes in the last two hundred years and will be able to adapt to the changing climate conditions in the future. Because the Tribes are unable to move the reservation lands, they have no other choice than to adapt to the future projected climate changes. This project, and others the Tribes are undertaking, will help them identify more specifically how changing climate conditions will affect the things they value and what they can do to prepare for those changes.

1.1 Paleoclimate Data

The current landscape of the region reflects its ancient history. The Umatilla drainage basin (and surrounding area) is part of the Blue Mountain and Walla Walla Plateau sections of the Columbia Plateau Province, a physiographic region in Intermontane Plateaus[13] and the land we see today was shaped by the geological events of the past. To provide insight into the current climate and future climate of the region it can be useful to look at the paleoclimate of the region.

This section reviews the literature and summarized the paleoclimate for the region starting from the Miocene Epoch (23-25 million years ago [m.y.]). The paleoecology of this time is recognized by other climate researchers as similar to the

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[10] Dalton, M.M., P.W. Mote, and A.K. Snover [Eds.]. 2013. Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Washington, DC: Island Press.
[11] Ibid.
[12] Western Regional Climate Center, Climate of Oregon Narrative, 2015. *Retrieved from:* http://www.wrcc.dri.edu/narratives/OREGON.htm.
[13] United States Geological Survey, 2015. Physiographic Divisions of the Conterminous U.S. *Retrieved from:* http://water.usgs.gov/GIS/metadata/usgswrd/XML/physio.xml.

environments of modern times[14]. The climatic swings of Miocene time can give us important clues as to future climate swings.

The derived paleoclimate suggests that about 12 m.y. ago, northeast Oregon had a temperature range of 45.9 °F to 63.9 °F, and annual precipitation of 23.78 to 43.23 inches[15]. This data compares well with the modern climate records from the National Weather Service[16] of an average minimum of 37.4 °F to an average maximum of 63.9 °F and 16.57 inches of average annual precipitation[17].

1.1.1 Paleoclimate Indicators

Paleoclimate indicators include: paleosols (fossil soils), fossilized plants and animals, carbon and oxygen isotopic ratios and patterns, petrographic thin-slices of rocks (which determine rock and mineral origin, and hence the type of environment during the time deposition), plus geochemical analysis of paleosols and rocks. These samples were time-bracketed by age-dated regional volcanic ash deposits and magnetic-stratigraphy (i.e., similar paleo-magnetic signals that have been previously age-dated). The paleoclimate indicators suggest that the environments of northeast Oregon at that time were wooded grasslands, savannahs, swamps, and alluvial valleys but warmer and moister as compared to modern times. The warm-wet (mid-Miocene) peak was followed by a moderate cooling/dry trend, partly driven by the rising Cascade volcanoes (which created a rain-shadow effect for east-side basins) that preceded the Pleistocene Ice Age (2.6 m.y. to 11,700 years ago).

Another useful proxy tool is oxygen isotope analysis. Oxygen isotopes are sensitive to the temperature of water samples contained within rocks and sediments[18]. The variation in the oxygen isotope ratio in sediment or rock as a time-series can indicate the amount of relative change and absolute change (if the sample water incorporated in the rock/sediment is analyzed for its Deuterium content) in temperature[19]. That isotopic variation, when combined with the Uranium Thorium age dating of thin slices of continual cave calcite deposits, can offer a relatively high

[14] Retallack, G.J., 2004. Late Miocene climate and life on land in Oregon within a context of Neogene global change. Palaeogeography Palaeclimatology Palaeoecology 214, 97-123.
[15] Ibid.
[16] Records are from the Western Regional Climate Center, a part of the climate program of the National Oceanic and Atmospheric Administration National Weather Service (NOAA/NWS), and the NOAA/NWS Cooperative Observer site at the Pendleton Branch Experimental Station (Climate Station ID #356540, 454 meters moisture sensitive level, at the lower edge of the Umatilla Basin).
[17] Western Regional Climate Center (NOAA/NWS), 2015. *Retrieved from:* http://www.wrcc.dri.edu/coopmap/#
[18] Penn State University, 2015. Maya Socioeconomic Dynamics: Cave and Speleothem Work. *Retrieved from:* http://php.scripts.psu.edu/dept/liberalarts/sites/kennett/index.php?id=spwork
[19] Sasowsky, I. and J. Mylorie 2004. Studies of Cave Sediments: Physical and Chemical Records of Paleoclimate. Springer Publishing, New York.

temporal (i.e., centuries to millennia) time scale of past climate change[20]. In general, the temperature of the cave drip water and the deeper interior of a cave is an excellent proxy to the mean annual surface temperature [21,22]. Unfortunately, given the few limestone caves in the Pacific Northwest, few studies have been conducted. The closest limestone cave system to the Umatilla Basin where an oxygen isotope study was conducted is located in northeast Washington at Gardner Cave[23]. This study sought to document the paleoclimate of the late Pleistocene Ice Age using cave calcite deposits. Gardner Cave is located at 2,779 feet elevation (comparable to the headwaters of the Umatilla Basin) with a mean annual temperature of 47.7 °F. Another study showed that the cave drip water temperatures (reflecting surface conditions) changed as follows: 64.2 °F (9,700 years before present [B.P.]), 48.2 °F (15,100 years B.P.), 53.2 °F (17,400 years B.P.), and 61.5 °F (22,100 years B.P.). The data suggests that the coldest temperatures corresponded to the last push of glacial ice occurred about 15,100-year ago[24].

1.1.2 Paleoclimate from Ice Age to the Modern Holocene Epoch

In a review of a published summary of several paleoclimate studies that document the climate in the Pacific Northwest (PNW) at the end of the Pleistocene Ice Age, transitioning into the modern Holocene Epoch[25], glacial features, pollen, fauna, and stratigraphy/geomorphology are the four paleoclimate proxy types used in the study. Calibrated radiocarbon dates are used.

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[20] NASA (Earth Observatory), 2015. Paleoclimatology: Written in the Earth. *Retrieved from:* http://earthobservatory.nasa.gov/Features/Paleoclimatology_Speleothems http://earthobservatory.nasa.gov/Features/Paleoclimatology_Speleothems

[21] Gunn, J. 2004. Encyclopedia of Caves and Karst Science.

[22] National Park Service, 2015. Carlsbad Cavern...Weather. *Retrieved from:* http://www.nps.gov/cave/learn/nature/weather.htm

[23] Martin, K., 1988. Oxygen-isotope analyses, U/Th dating, and Paleomagnetism of Speleothems in Gardner Cave, Washington: Paleoclimatic Implications. Master's Thesis, Department of Geology, Eastern Washington University, 101 p.

[24] Ibid.

[25] Fulkerson, T.J., 2012. Climate change at the Pleistocene-Holocene boundary in the Pacific Northwest: a comparison of proxy datasets and the archaeological record. EWU Masters Thesis Collection, Paper 64.

Paleoclimate Temperature in the Pacific Northwest

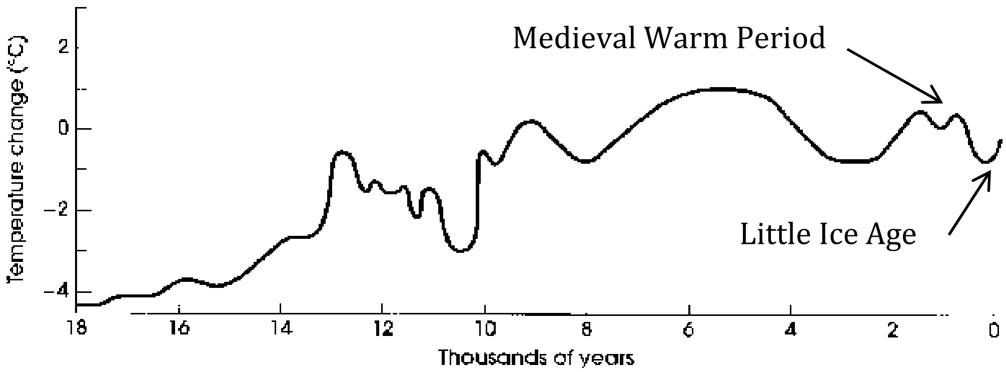

Figure 2: Holocene-to-present temperature departure curve. Temperature change relative to present day is shown on the y-axis and the x-axis shows the time in number of 1,000 years before today[26].

The boundary of the Pleistocene-Holocene (12,600 to 10,200 years B.P.) is significant in that the rapidly changing climate, transitioning to a warmer, drier climate, placed great environmental stressors on the flora and fauna, and ancient peoples that depended upon such resources. Abrupt climate change episodes are documented by high-temporal resolution paleoclimate proxy records, suggesting a rapid time window—years to decades instead of centuries to millennia as previously thought.

The Bølling-Allerød warming period (17,600 to 13,200 B.P.) was the last interglacial (warm) period at the end of the Pleistocene Ice Age before the climate destabilized at the Pleistocene-Holocene boundary. It was this warming episode that triggered the Lake Missoula Ice Age floods. These floods were the last major geologic activity to impact and shape the landscapes of the Columbia Basin, including the lower part of the Umatilla drainage, during 15,000 to 13,000 B.P.

The Pleistocene-Holocene transition began during the Younger Dryas (a well-documented global abrupt climate change event), which occurred at 13,200-11,400 B.P. The Younger Dryas cooling is shown by a rapid return to glacial conditions in the Northern Hemisphere, big increases in global ice volume, and a shift in the track of the jet stream over the PNW. This last point is important because the jet stream and its seasonally moving track define the climate for a region. Hence, we can infer that the modern climate of the PNW settled in during this 13,200-11,400 year period.

[26] Ibid.

During the Early Holocene (11,400 to 9,000 B.P.), warmer-drier conditions prevailed, base levels of rivers and lakes lowered, land desiccation occurred, precipitation may have been up to 40 percent less than today, and the frequency of forest fires increased. Forests of pine, fir, and spruce quickly gave way to grassland and/or shrub-land.

An abrupt climate change event in the PNW occurred around 9,000 to 8,000 B.P. This event correlates with a well-documented Heinrich Event abrupt climate change event (i.e., a major disruption of the North Atlantic thermohaline circulation caused by Greenland glacier freshwater inputs associated with the decay of the Laurentide Ice Sheet) of the Greenland Ice Sheet at 8,200 B.P.

It is worth noting that the Holocene is well documented for climate change and variability with a major suite of paleoclimate, archaeological, and historical data[27]. The significant changes in climate are much more pronounced at the start of the Holocene, which is what the Earth is experiencing currently. From approximately 8,000 B.P., the Earth's climate has been relatively stable up until the present with notable exceptions such as the Medieval Warm Period (900 to 1300 A.D.) and the Little Ice Age (1550 to 1850 A.D.).

In recent years, studies of paleoclimate reconstructions using high-resolution proxy data on a centennial time-scale have increased our understanding of the drivers of natural variability drivers such as the Pacific Decadal Oscillation (PDO), El Niño Southern Oscillation (ENSO). We are finding that regional and local data can have general correspondence with major global trends but have departures due to local conditions based on geography, micro-climate, etc. Steinman et al. shows that PNW hydroclimate was more prone to shifts in long-term ENSO-like dynamics in the last 1,000 years[28].

1.2 Historical Regional Climate Context

The Umatilla Indian Reservation is located in Northeastern Oregon where conditions are generally warmer and drier than many parts of the Pacific Northwest. Temperatures vary seasonally and average daily maximum temperatures range from the mid to high 30 degrees Fahrenheit (°F) in the winter to the high 80s °F during the summer[10]. Precipitation also varies seasonally from a high of around seven inches in the winter to a low of just under three inches in the summer.

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[27] University of Arizona, 2015. ATM 336, Weather, Climate, and Society lecture. Climate of the Holocene. *Retrieved from:* http://www.atmo.arizona.edu/students/courselinks/fall12/atmo336/lectures/sec5/holocene.html

[28] Steinman, B. A., M. B. Abbott, M. E. Mann, J. D. Ortiz, S. Feng, D. P. Pompeani, N. D. Stansell, L. Anderson, B. P. Finney, and B. W. Bird, 2014. Ocean-atmosphere forcing of centennial hydroclimate variability in the Pacific Northwest. Geophys. Res. Lett., 41, doi:10.1002/2014GL059499.

Averages, of course, do not tell the whole story. The CTUIR Aboriginal Title Lands area is subject to extremes with an average of 30 days during the summer with no precipitation and an average of 10 to 15 days over 90 °F every summer.

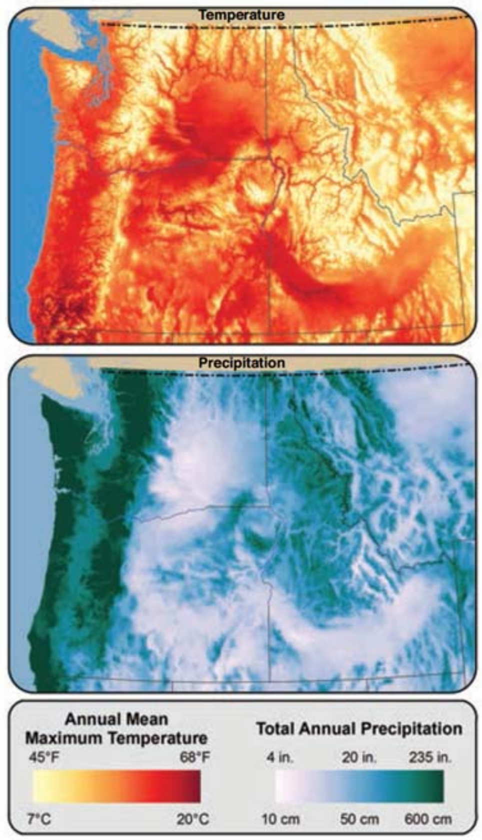

Figure 3: Average annual mean maximum temperature and precipitation (1981-2010) for the region taken from the PRISM data[29]. Temperatures and precipitation vary over the CTUIR abriginal title lands based on elevation and other factors but are generally warmer and drier than many other parts of the Paficic Northwest.

Water, in particular the Columbia River, plays a significant role in shaping the ecological, economic, and cultural character of the region. From 1895 to 2011, the PNW regional annual average temperature increased by about 1.3 °F. Seasonally, the highest increase (about 2.0 °F) has occurred during the winter. Precipitation trends have been small compared to natural variability, such that no statistically significant trends (either annually or seasonally) have been observed[30].

[29] Ibid, page 27.
[30] Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K. T. Redmond, and J. G. Dobson, 2013: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 6. Climate of the Northwest U.S. NOAA Technical Report NESDIS 142-6. 83 pp., National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington, D.C.

1.3 Climate Science, Human Influence, and Global Climate Change

Climate Change, once considered an issue for a distant future, has moved firmly into the present – U.S. National Climate Assessment, 2014 [31].

The Pacific Northwest is already experiencing drier summers, reductions in snowpack and glacial mass, higher spring and lower summer river flows, and a more acidic ocean. These are not isolated incidents, but part of a larger regional and global trend of changing climate conditions that is driven primarily by human activity [10].

> *Evidence for climate change abounds, from the top of the atmosphere to the depths of the oceans. Scientists and engineers from around the world have meticulously collected this evidence, using satellites and networks of weather balloons, thermometers, buoys, and other observing systems. Evidence of climate change is also visible in the observed and measured changes in location and behavior of species and functioning of ecosystems. Taken together, this evidence tells an unambiguous story: the planet is warming, and over the last half century, this warming has been driven primarily by human activity (U.S. National Climate Assessment 2014)* [27].

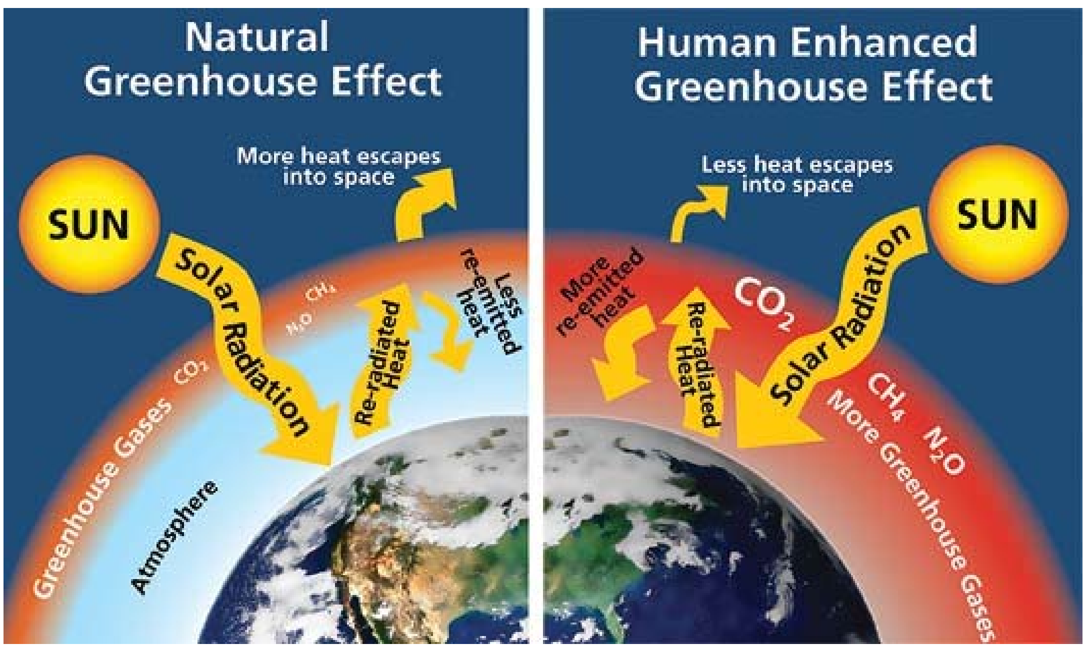

Figure 4: An illustration of the greenhouse effect showing radiation flux to and from the earth for the Natural Greenhouse Effect and the Human Enhanced Greenhouse Effect [32].

Greenhouse gasses in the atmosphere act like a heat-trapping blanket around the earth, warming the atmosphere, land, and oceans [33] (Figure 4). The natural

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[31] United States Global Change Research Program. National Climate Assessment 2014. Overview. *Retrieved from:* http://nca2014.globalchange.gov/highlights/overview/overview

[32] Livescience, 2015. *Retrieved from:* http://i.livescience.com/images/i/000/053/475/original/Greenhouse-effect.jpg?1370382117

greenhouse gas effect is responsible for keeping the planet warm and habitable. Human activity (such as burning fossil fuels for energy) releases greenhouse gases that act like an additional blanket around the Earth, trapping more heat and raising the temperatures of the land, air, and oceans. Carbon dioxide (CO_2) is the primary greenhouse gas emission from human activity and other gasses such as methane (CH_4) nitrous oxide (N_2O), and water (H_2O), also trap heat in the atmosphere. Figure 5 shows the percentage contributions from each of the greenhouse gases for the United States.

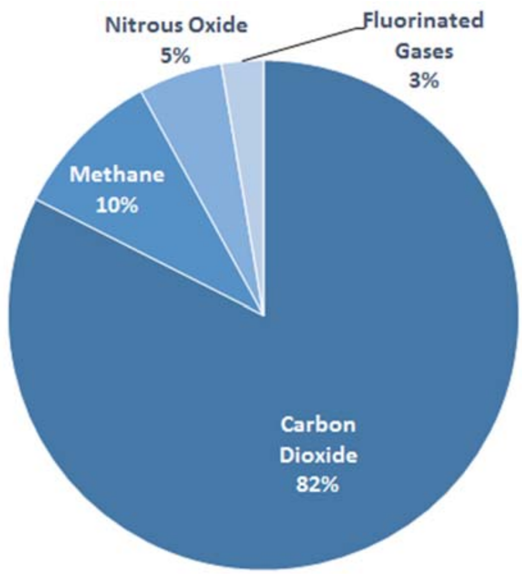

Figure 5: United States Greenhouse Gas Emissions in 2013.

While CO_2 is the most common greenhouse gas from fossil fuels, both CH_4 and N_2O are more potent. The impact of CH_4 on climate change (almost 60% of which comes from human activity), pound for pound, is 25 times greater than that of CO_2 over a 100-year period [34]. N_2O (about 40% of emissions come from human activity) on the other hand is almost 300 times more impactful pound for pound than CO_2 [7]. In addition, water vapor is the most powerful greenhouse gas, although not a direct result of human activity. As temperatures increase so does evaporation from the ocean and soil, which increases concentrations of water vapor in the atmosphere. This increase in turn captures more heat and helps warm the atmosphere, thus creating a positive feedback cycle.

Global emissions of greenhouse gases have increased dramatically since the industrial revolution. These emissions increase the concentration of CO_2 in the atmosphere and create a correlated increase in global temperatures. The global average increase in atmospheric concentration of CO_2 is shown in Figure 6 below

[33] United States Environmental Protection Agency, 2015. Global Greenhouse Gas Emissions Data. *Retrieved from:* http://www3.epa.gov/climatechange/ghgemissions/gases.html
[34] Ibid.

(black line) along with the temperatures above (red bars) and below (blue bars) the long-term global average.

Based on the current concentrations of these gases in the atmosphere, the planet is already committed to a certain amount of atmospheric warming and the associated impacts related to that warming.

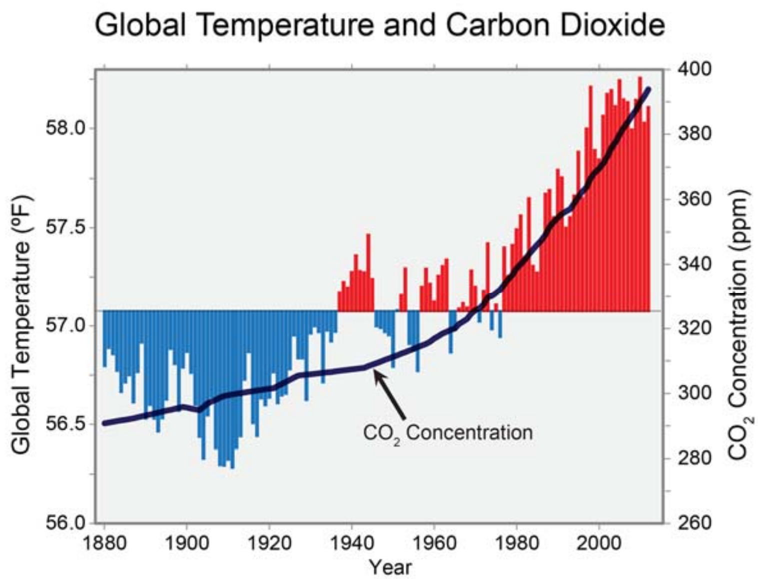

Figure 6: Global annual average temperature (as measured over both land and oceans) has increased by more than 1.5 °F since 1880 (through 2012). Red bars show temperatures above the long-term average, and blue bars indicate temperatures below the long-term average. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm) [35].

[35] University of Washington, Climate Impacts Group, 2013. Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers. *Retrieved from:* http://cses.washington.edu/cig/reports.shtml

2.0 Climate Change Vulnerability Assessment Overview

Not all climate-related impacts are created equal; rather there are those that are more or less urgent. A vulnerability assessment process is designed to illuminate those differences and help a community prioritize the use of their limited time, budget, and other resources to address the most vulnerable and/or most important systems first. In addition, data or knowledge gaps can emerge from the process, which assists a community in their ability to focus further research and respond accordingly to potential impacts.

This report describes the CTUIR's efforts to identify, evaluate, and prioritize key vulnerabilities and lays the foundation for future planning and the development of strategies to decrease the vulnerabilities identified in this report through a series of planned adaptation actions and implementation strategies. The process of actually developing these adaptation actions and implementation strategies is outside the scope of this vulnerability assessment project. However, this report will support subsequent identification of adaptation actions based on prioritized vulnerabilities. In addition, this report highlights Key Items of Concern (KICs), their individual sensitivity and adaptive capacity, and outlines the prioritization of the KICs to focus future efforts. Finally, this project builds on past climate and hazard mitigation planning work including:

- Regional workshop: Adaptive Governance in Climate Change (August 2008)
- CTUIR Hazard Mitigation Planning process (2008)
- Regional workshop: Roundtable on Private, Public, and Tribal Collaboration on workforce and supply chain opportunities in Energy (September 2011)

From this initial work, the need for an in-depth vulnerability assessment emerged as a critical next step for the CTUIR, culminating in the submission of a funding application to the Bureau of Indian Affairs (BIA) in November 2013 for Climate Change Adaptation Planning (Category 2) funding. Upon receipt of funding, the CTUIR organized and held a Water, Weather, Human Health, and Food workshop in January 2015. During the workshop, key subject matter experts presented on climate-related impacts relevant to local weather, water, food and human health (Table 1). The workshop presented attendees with relevant climate change information, solicited their input on the topics presented, and laid the foundation for the vulnerability assessment. A total of 52 people attended the workshop, including CTUIR staff, Bureau of Indian Affairs staff, tribal members, Umatilla County officials, and members of the general public. Of those, 11 tribal and 16 non-tribal members completed post-workshop surveys sharing their concerns about potential climate-related impacts to weather, water, human health, food and other concerns. See Appendix 1 for an example of the participant worksheet distributed at the January meeting.

Table 1: Water, Weather, Human Health, and Food Workshop Agenda

Session	*Topics of Discussion*
10:00 AM • **Introductions** • **Presentation on climate change impacts to weather by Stephen Bieda III, Ph.D., NOAA** 11:00 AM • **Presentation on climate change impacts to water by Kyle Dittmer, CRITFC** Noon • **Catered lunch** 12:30 PM • **Presentation on climate change impacts to human health by Emily York, Oregon Health Authority** 1:00 PM • **Presentation on climate change impacts to food by Darrin Sharp, OSU/OCCRI** 2:00 • **Event closing**	• Climate change impacts to water, weather, human health and food • CTUIR climate change vulnerability assessment • Key Items of Concern

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability to climate change is, "*the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change*"[36]. Figure 7 highlights that vulnerability is determined by understanding where the intersection of current and projected climate exposures interact with the degree of susceptibility of a system to climate impacts, its *sensitivity*, and that system's ability to adjust or respond to impacts, its *adaptive capacity*. Given the same amount of climate exposure, the systems, assets, or resources that are highly sensitive and have limited adaptive capacity, are the most vulnerable. Those that are less sensitive or have higher adaptive capacity are less vulnerable.

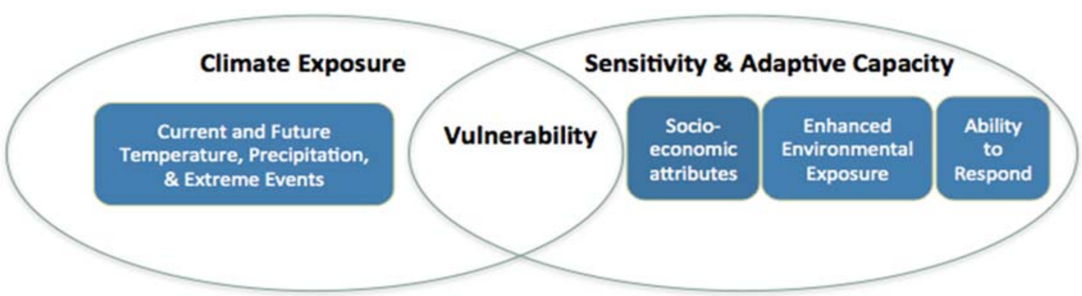

Figure 7: Climate change vulnerability of a system, asset, or resource depends on the climate exposure, sensitivity, and adaptive capacity of that system.

[36] Adger, WN et al. Assessment of Adaptation Practices, Options, Constraints and Capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press* 717-743.

2.1 The CTUIR Key Items of Concern

The CTUIR developed a comprehensive list of KICs to lay the foundation for the vulnerability assessment process by combining elements from the *Tamánwit* (Natural Law) model, Homeland Security, and the EPA's Three Pillars of Sustainability. The initial list was refined by participant input and discussions during the January workshop and was circulated to all department staff for review and additional input. The *Tamánwit* model is a collection of tribally significant lifestyle attributes (referred to as *Tamánwit* Elements). Figure 8 depicts the *Tamánwit* Model for the CTUIR.

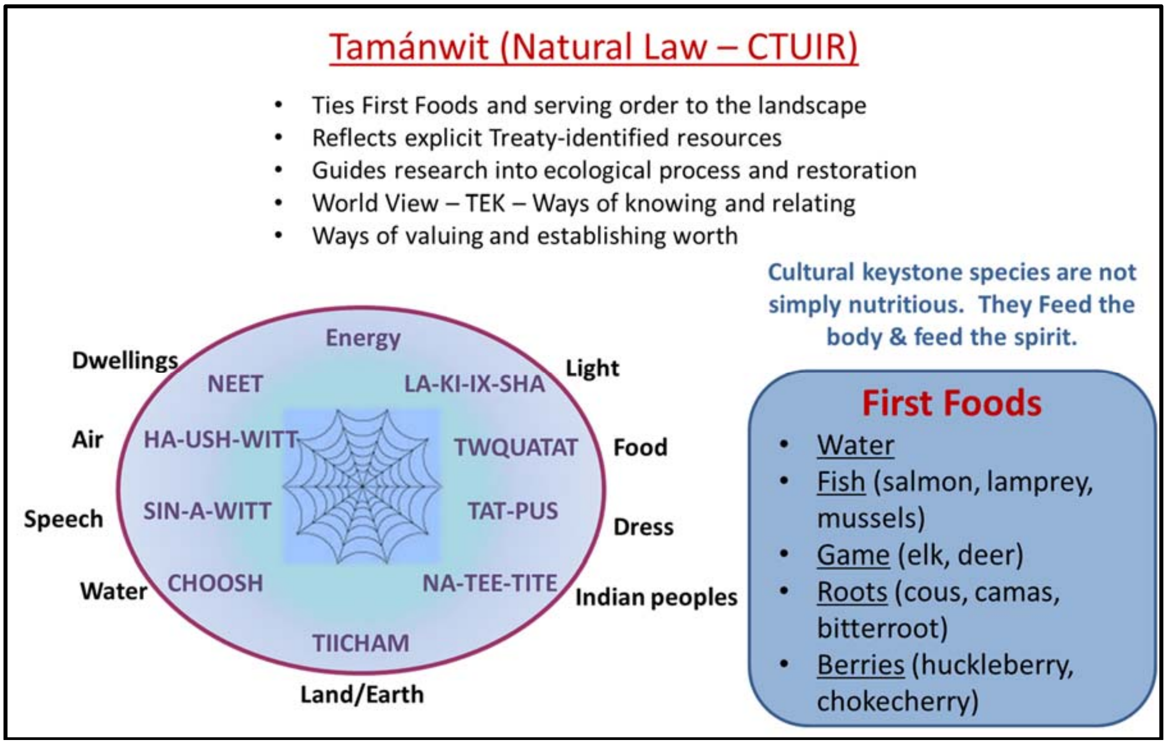

Figure 8: The Tamánwit (Natural Law) Model for the CTUIR, which depicts the relationship between tribally significant lifestyle attributes.

In addition to inclusion of *Tamánwit*, the CTUIR recognizes the connection of their concerns (as a full-service government) with those of homeland security and climate vulnerability and resilience. Thus, these principles were also incorporated (see Appendix 2 for the detailed table of homeland-security climate principles. Further, the U.S. Environmental Protection Agency's (U.S. EPA) *Three Pillars of Sustainability* focus on the social, environmental, and economic well-being and advancement of a community were integral in the manner in which the CTUIR defined KICs. As defined by the U.S. EPA,

> *Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations*[37].

The comprehensive list of KICs is categorized under water, weather, food, people, built environment, and economy. Further, slight additions were made to the comprehensive KICs list during Participatory workshop 1 (described below) and are reflected in the version shown in Appendix 3.

2.2 Participatory Workshop 1: Prioritizing the Key Items of Concern List and Framing the Climate Scenarios and Domain

The project team for the CTUIR Climate Change Vulnerability Assessment included a group of the CTUIR's departmental chairs and staff members, *Adaptation International,* and the *Oregon Climate Change Research Institute (OCCRI*). The technical aspects of the project commenced with a meeting on April 27, 2015 at the CTUIR's Nixyaawii Governance Center with twelve members of the working group. The goals of the meeting were to:

1) Develop an understanding of the local geography and the assets and resources potentially impacted by climate change;
2) Bring together and engage with the knowledgeable team members;
3) Finalize the comprehensive KICs list; and
4) Move towards the development of a prioritized list of concerns for use in the next phase of the assessment.

The meeting included an overview of the global climate change scenarios given by Darrin Sharp from OCCRI, which provided background and context for the final selection of the two scenarios chosen for this analysis—Representative Concentration Pathway (RCP) 4.5 and RCP 8.5. For more background information about the scenarios see *Section 3.0: Observed and Projected Climate Trends for the CTUIR Aboriginal Title Lands.*

The critical accomplishment of this one-day meeting occurred during the afternoon breakout sessions when the team members worked from the Comprehensive KICs list to prioritize those items, using their experience and long tenures in their diverse committee and department positions to identify the items of critical importance for the Tribes. This prioritized set of concerns is the foundation for the remainder of the vulnerability assessment (shown below in Table 2). The species listed under First Foods are considered representative species to understand potential climate impacts and not designed to exclude other important species.

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[37] United States Environmental Protection Agency, 2015. Sustainability Home Page. *Retrieved from:* http://www.epa.gov/sustainability/basicinfo.htm#sustainability

Table 2: Prioritized List of Key Items of Concern for the vulnerability assessment

Availability and Access to First Foods
Water
Chinook Salmon
Elk
Cous
Huckleberry
Agriculture
Non-irrigated crops (winter wheat, dry land peas, canola)
Irrigated crops (hay, alfalfa)
Human Health
Wildfires
Heat waves
Vector borne diseases
Increases in crime
Population Dynamics
Forest Health and Welfare

Forest Health and Welfare emerged at the end of the entire process as an area of critical importance to the Tribes. Due to the timing of the addition of the additional item, it was added to the prioritized list, however, the project team did not assess its vulnerability.

Further, mental and spiritual health impacts of climate change did emerge in the group discussions. The project team decided to integrate this information into the vulnerability assessment process discussions for the other items of concern. It is important to note that data from the State of Equity Report demonstrate that Native Americans are adversely affected by a disproportionate burden of disease across nearly every measure of health and well-being[38]. Such disparities could increase due to climate change through multiple pathways affecting access to resources, culture, and ways of life. These risks are compounded by existing inequities in income and by a history of exclusion. The loss of culture and connection to the land, in addition to the stress of food and economic insecurity can create mental and emotional distress. Tribes are at greater risk for mental illness, substance abuse and suicide in connection to climate change and its impacts. The rate of suicide among American Indians is already the highest in the country[39]. For more detailed information about the process to prioritize the KICs see Appendix 3.

[38] Oregon Health Authority and Department of Human Services, 2013. State of Equity Report Phase 2. *Retrieved from:* http://www.oregon.gov/oha/oei/Documents/soe-report-ph2-2013.pdf
[39] Haggerty B, York E, Early-Alberts J, Cude C. Oregon Climate and Health Profile Report. Oregon Health Authority. September 2014: Portland, OR

2.3 Key Stakeholder Interviews: Domain and Thresholds for Modeling

The next step for the project was to analyze downscaled climate projections for the region to provide the CTUIR with as detailed an assessment of climate exposure as possible. This modeling is described in more detail in *Section 3.0.* Following on the success of the initial workshop, the project team worked together to ensure that local traditional ecological knowledge (TEK) was used to select the appropriate domain boundaries for analysis and ensure that the KICs were included in the geographic region selected.

Further, through a series of six key stakeholder interviews the working group members shared their perspective on specific temperature, precipitation, and other extreme events to guide the analysis of the climate projections for the project. According to the IPCC, an "extreme weather event" is defined as:

> *[An] event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile.* ***By definition, the characteristics of what is called extreme weather may vary from place to place.*** *[Emphasis added][40].*

Because of the regional differences for extreme weather events, integrating the local knowledge about climate and weather thresholds provided opportunity to hone in on the weather-related events that are the most important for the CTUIR region. The prevailing concerns were the temperature extremes of both hot and cold days.

2.4 Participatory workshop 2: Determining Key Item of Concern vulnerability by assessing sensitivity and adaptive capacity.

The project team came together again on June 5, 2015. The morning session of this workshop focused on summarizing the analysis of the downscaled climate projections for precipitation, temperature, and the critical thresholds identified for the CTUIR Aboriginal Title Lands Territory. This new analysis provided localized climate exposure information relevant to the KICs. Following the climate data presentation, a detailed review of the literature for the potential climate-related impacts for each of the KICs was also presented for discussion. These two pieces provided the context necessary for the working group to identify the *sensitivity* and *adaptive capacity* of each of the KICs (Table 3). The use of *sensitivity* (how susceptible a potential vulnerability is to changing climate conditions) and *adaptive capacity* (ability of a system or asset to respond to changing climate conditions) is

[40] Intergovernmental Panel on Climate Change. Working Group I: The Scientific Basis, Appendix I: Glossary. *Retrieved from:* http://www.ipcc.ch/ipccreports/tar/wg1/518.htm

an internationally recognized means for assessing climate change related vulnerabilities[41]. More detail is available in Appendix 4.

Table 3: Sensitivity and Adaptive Capacity Levels. The relative vulnerability of the KICs depends on the combination of the sensitivity and adaptive capacity scores. Those KICs with the highest sensitivity and lowest adaptive capacity (e.g. Chinook salmon) are the *most* vulnerable, while those KICs with the lowest sensitivity and highest adaptive capacity have *lower* vulnerability (e.g. Availability of drinking water in the short-term). See the vulnerability rankings in **Figure 9** below.

Sensitivity Levels	
S0	System will not be affected by the impact
S1	System will be minimally affected by the impact
S2	System will be somewhat affected by the impact
S3	System will be largely affected by the impact
S4	System will be greatly affected by the impact

Adaptive Capacity Levels	
AC0	System is not able to accommodate or adjust to impact
AC1	System is minimally able to accommodate or adjust to impact
AC2	System is somewhat able to accommodate or adjust to impact
AC3	System is mostly able to accommodate or adjust to impact
AC4	System is able to accommodate or adjust to impact in a beneficial way

[41] Intergovernmental Panel on Climate Change, 2015. Working Group II: Impacts, Adaptation and Vulnerability. *Retrieved from:* http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=650

	S0	S1	S2	S3	S4
AC0					
AC1					• Chinook Salmon
AC2				• Cous • Elk • Agriculture (Non-irrigated crops)	
AC3				• Huckleberry • Wildfires	• Agriculture (Irrigated crops) • Water (long-term) • Flooding
AC4	• Water (short-term)	• Vector-borne diseases • Population dynamics	• Increases in crime • Heat waves		

Figure 9: The relative vulnerability ranking of each of the Key Items of Concern based on their sensitivity and adaptive capacity rankings. Items shown in red and orange are more vulnerable and those items in green are less vulnerable.

These vulnerability rankings help identify the areas that will need immediate attention and those that can simply be monitored for future changes. Based on the results of the vulnerability assessment, there are clearly three groups of KICs – those with high vulnerability (*Chinook salmon*), those with medium or medium high vulnerability (items in yellow and orange), and those with low vulnerability (items in green). The top two groups rise to the top as a KICs that will require immediate attention, while those at the last group (such as *increases in crime)* are not as pressing a need for the community at this time.

2.5 Prioritizing Key Items of Concern

To prioritize the vulnerabilities, the working group ranked each of the KICs on a set of criteria. These criteria (explained in detail below) use a 1-5 scale for ranking where 1 correlates to low magnitude, 3 to moderate magnitude, and 5 to large magnitude of impact, with the exception of *Potential for Adaptation,* which uses a reverse ranking process (1= high potential, 3= moderate potential and 5 = low potential). See Appendix 5 for the detailed worksheet instructions used for the prioritization process. The criteria are as follows:

- **Magnitude of Impact:** determined by its scale (e.g., the area or number of people affected) and its intensity (e.g., the degree of damage caused).
- **Timing of Impact:** when in time the impact is likely to occur as well as the rate at which impacts are likely to happen.
- **Persistence and Reversibility of Impact:** whether or not an impact is a one-time occurrence or is likely to happen more often and/or be irreversible.
- **Likelihood of Impacts and Vulnerabilities:** probably of an impact or vulnerability having occurred or occurring in the future.
- **Importance of the System at Risk:** This measure evaluates the importance of the system that is impacted. While subjective, this is an important chance to acknowledge the non-monetary values that different systems contribute.
- **Distributional Nature of Impacts and Vulnerabilities:** The distributional nature of impacts is an assessment of how wide spread and equitably distributed impacts are across the community. Those exposures that disproportionately affect one segment of the population receive a higher ranking than those that are spread across the community.
- **Potential for Adaptation:** the ability to reduce or eliminate the adverse impacts (including the financial, technical, and human capacity).

The group prioritized all of the KICs, either during or after the workshop. The results of the prioritization process are summarized below. See Appendix 6 for the detailed results and scores of the prioritization for each of the KICs.

It is not always the case that vulnerability rankings lead to priority rankings of similar importance. It could be that KICs of low vulnerability may be high priority. For example, *heat waves* is a low vulnerability concern but scored in the "high priority" category. Although the vulnerability is low, the working group decided that there is still a need to address this issue, and the actions to address it could be feasible and simple, thus giving it a higher priority. In most cases, however, the highest priority items are also those most vulnerable to climate-related impacts. The list below delineates the KICs by priority:

High Vulnerability, High Priority
Chinook Salmon

Medium Vulnerability, Medium Priority
Cous
Elk
Flooding
Agricultural Crops (Non-Irrigation)

Medium Vulnerability, Low Priority
Agricultural Crops (Irrigation)
Water (Long-term)

Medium-Low Vulnerability, Medium Priority
Huckleberry
Wildfires

Low Vulnerability, Medium Priority
Heat Waves

Low Vulnerability, Low Priority
Increases in crime
Water (Short-term)
Vector Borne Diseases
Population Dynamics

The **high-priority KIC**s – Chinook salmon, is in a class all to itself at the top due to its critical cultural importance as a First Food, and the magnitude and timing of impacts of climate change. The CTUIR has already observed impacts to the existing salmon population and there are thresholds beyond which the species is unlikely to adapt (critical stream temperature and flow thresholds).

The **medium-priority KICs** – All of the other First Foods fall into this category, as do agriculture (non-irrigated crops), heat waves, and wildfires. Also of medium priority are the potential impacts of increased flooding.

The **low-priority KICs** – Items related to water availability for agricultural crops and residential use as well as the potential for climate refugees and public health impacts from vector borne diseases and increased crime are included in this group.

Despite the delineation of prioritized groupings, all of the KICs shown are important to the CTUIR. This process simply provides the opportunity to identify the ones that should be addressed first given limited time, resources, and budget. Each of the KICs and their vulnerability and prioritization results are summarized in *Section 4.0: Results and Discussion*.

3.0 Observed and Projected Climate Trends for the CTUIR Aboriginal Title Lands

3.1 Overview of Modeling Methods

The Oregon Climate Change Research Institute (OCCRI) at Oregon State University led the climate analysis work done specifically for this project. OCCRI is the anchor institution for the National Oceanic and Atmospheric Administration's Pacific Northwest Climate Impacts Research Consortium (CIRC), as well as the Department of the Interior's (DOI) Pacific Northwest Climate Science Center (CSC). OCCRI focuses on making climate science information useful and usable by decision makers in the Pacific Northwest.

For this project, OCCRI used downscaled monthly Coupled Model lntercomparison Project v5 (CMIP5) climate data to generate the projections for changes in temperature and precipitation in the CTUIR Aboriginal Title Lands. Downscaling was performed using the Multivariate Adaptive Constructed Analogs (MACA) method for downscaling the climate projections[42]. This is a statistical downscaling method, which utilizes a training dataset (a meteorological observation dataset) to remove historical biases and match spatial patterns in climate model output. For this analysis, the MACAv2-LIVNEH training data was used (i.e. version 2 of the MACA dataset, using the Livneh training data[43]). This data is at 1/16 degree or about 6 kilometers resolution[44].

MACA data covers the period 1950-2099. The years from 1950-2005 are considered the "historical" period, while those from 2006 on are considered the "future" period. "Historical modeled" data is used instead of actual observations for comparison to future data for several reasons. Chief among these is that it is important to use bias corrected and gridded historical data when comparing to future projections to eliminate any errors due to statistical artifacts in the "raw" observational data. Without the bias correction and grid generation step, comparing historic observations to future MACA is not a true "'apples-to-apples" comparison. While the historical modeled data is not expected to match historical observations day for day, the overall mean climate should be captured accurately. More detail on the modeling is available in Appendix 7.

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[42] Abatzoglou JT and Brown TJ. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology* (2012). DOI: 10.1002/joc.2312.
[43] Livneh B, Rosenberg EA, Lin C, Mishra V, Andreadis K, Maurer EP, and Lettenmaier DP. A long-term hydrologically based data set of land surface fluxes and states for the conterminous United States: Updates and extensions. *Journal of Climate* (2013, in press).
[44] To obtain more information visit here: http://maca.northwestknowledge.net/

When considering projections of future climate change it is important to take into account human activities. Depending on these activities, the amount of greenhouse gases (GHGs) in the atmosphere (and thus the amount of warming caused by them) by 2100 could vary greatly, leading to very different future climates.

For this project, the project team chose two emissions scenarios to represent possible emissions futures: Representative Concentration Pathway 4.5 (RCP 4.5) and RCP 8.5. RCP 4.5 is considered the "'low emissions" scenario, while RCP 8.5 is considered the "high emissions" scenario. In this nomenclature, "4.5" and "8.5" refer to the amount of additional radiative forcing (relative to pre-industrial values) applied to the climate system (in watts/m^2) by 2100. RCP 4.5 is generally considered to be a "'best case" scenario (representing concerted efforts to reduce emissions), while RCP 8.5 is generally considered the "'business as usual" scenario.

The downscaled data from 20 source CMIP5 global climate models (GCMs) was analyzed for the area of interest, which is essentially equivalent to the Aboriginal Title Lands shown in Figure 1 but the project boundaries also referred to as the "domain" is shown in Figure 10 as the rectangular black box.

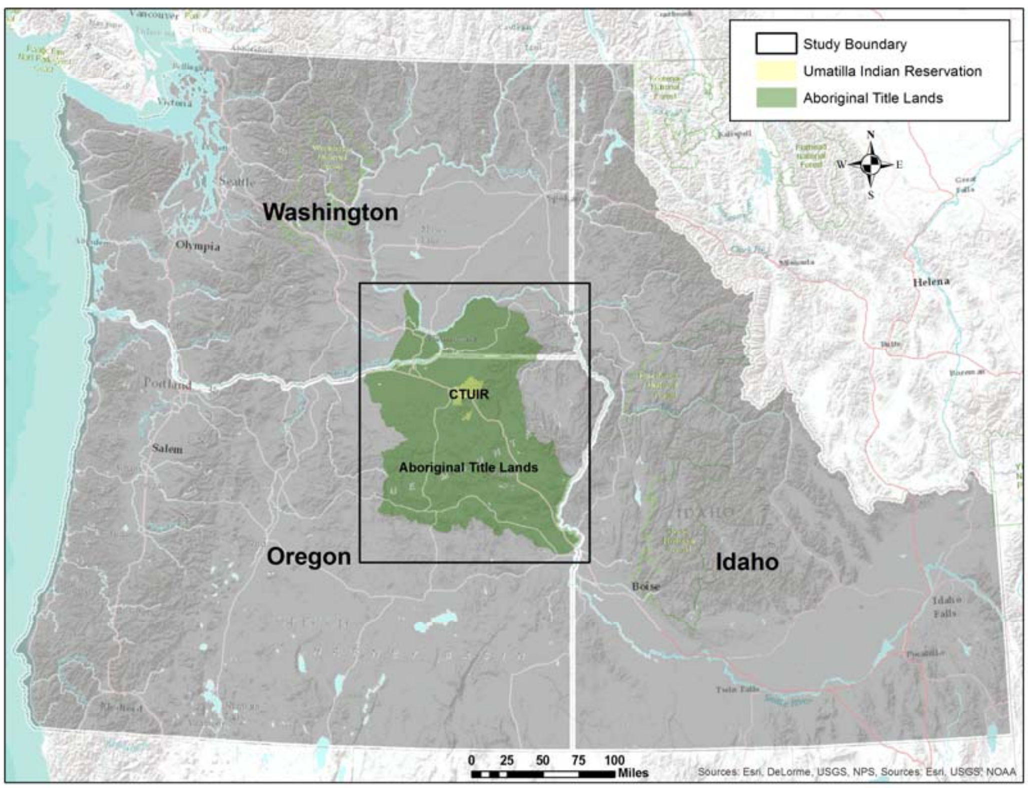


Figure 10: The domain for the downscaled modeling. The black rectangle represents the area analyzed for the project, which encompasses the Aboriginal Title Lands of the CTUIR. All the data points in the domain were aggregated to give an area average for the particular climate parameter being evaluated. This domain is defined by the following latitudinal and longitudinal points: LL corner = 43.99N/120.05W, UR corner 46.66N/116.89W.

3.2 Temperature and Precipitation Projections: Trends and Extremes

While projections of future climate always carry with them some level of uncertainty, some conclusions can be drawn from the results of this analysis (shown in Figure 11 thru 14 below) and are summarized in Table 4 below. Additional results from the downscaled climate modeling are shown in Appendix 8.

Table 4: Summary of the Key Climate Results for the Aboriginal Title Lands of the CTUIR

Summary of Key Climate Results for the Aboriginal Title Lands of the CTUIR
For the CTUIR region, the seasonal average maximum monthly temperatures will likely increase steadily throughout the 21st century. This trend will culminate with an increase of around 5 to 12 °F by the end of the century (i.e. 2070-2099). The largest increase is projected to be during the summer.
Increases in average maximum ***summer*** temperatures alone are projected to increase by between +2 °F and +10 °F by mid century while ***winter*** temperatures are projected to increase by between +1 °F and +8 °F depending on the scenario used (RCP 4.5 or RCP 8.5).
There will likely be a large increase in the number of days that exceed 90° F in the summer by the end of the century. Projections show a doubling of the number of days that exceed 90° F in the ***summer*** from 13 to 26 days by mid-century and a tripling to 39 days by the end of the century. Spring and fall may see a few more days over 90° F.
The temperature projections for the two emissions scenarios are approximately the same until the middle of the century. After this point, RCP 8.5 temperatures are steadily higher than those for RCP 4.5.
Changes in precipitation patterns are less clear-cut than for temperature. The analysis suggests little overall change in total annual precipitation, but summers will be potentially drier while the other seasons are slightly wetter.
Uncertainties in the precipitation projections are much larger than uncertainties in the temperature projections. There are especially large uncertainties for projections of the number of days with no precipitation.
The analysis suggests that precipitation is less sensitive to the emissions scenario than temperature.

Total Modeled Average Maximum Temperature by Season for the years 1950-2099: Projections call for an increase in average maximum temperature for all seasons under both the lower emissions RCP 4.5 scenario and higher emissions RCP 8.5 scenario.

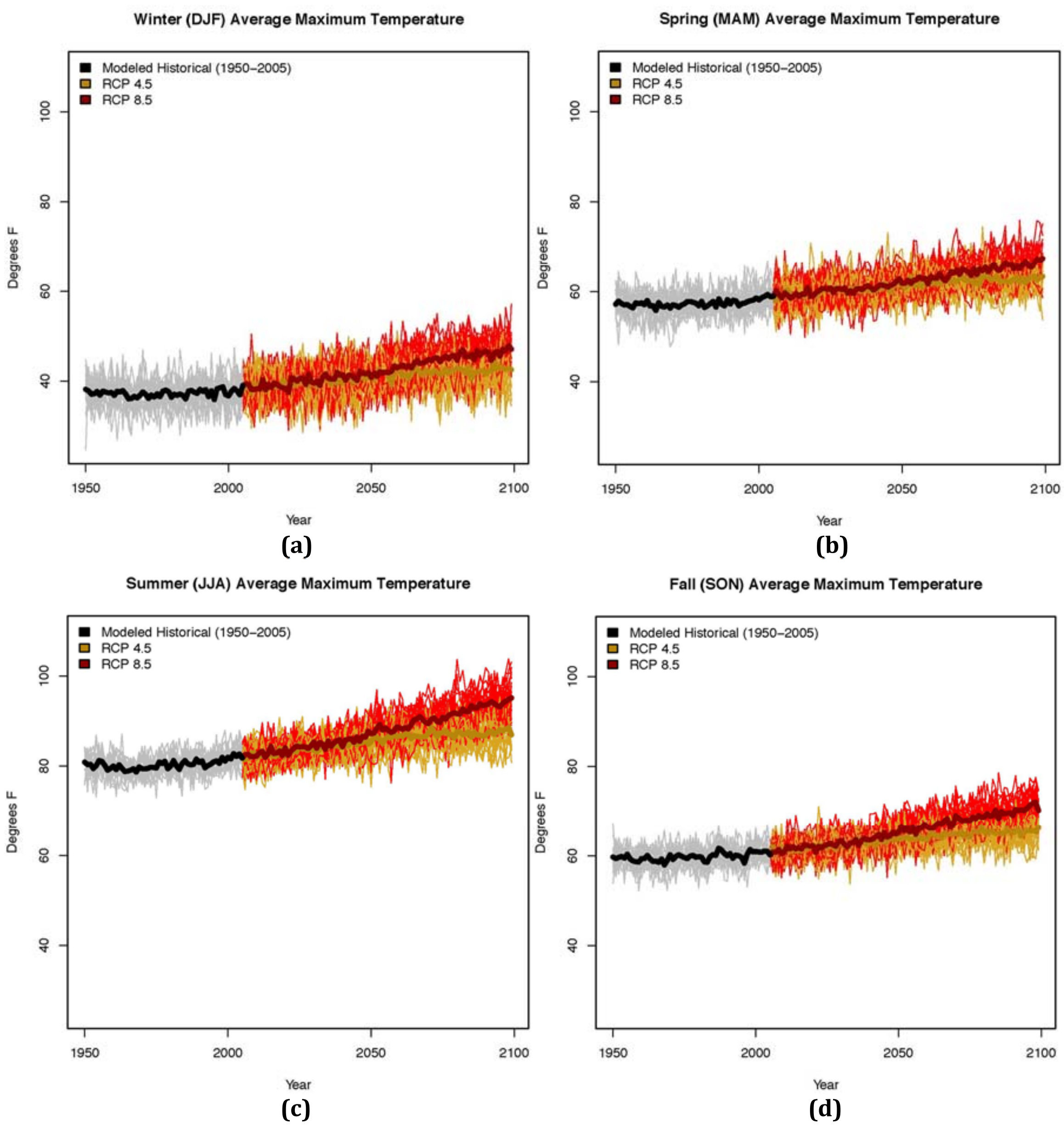
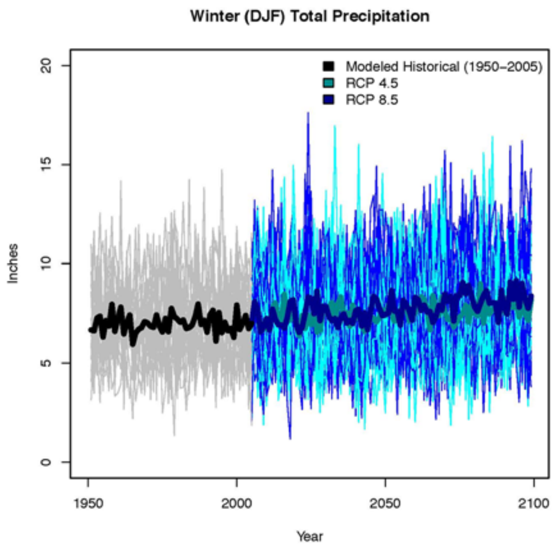
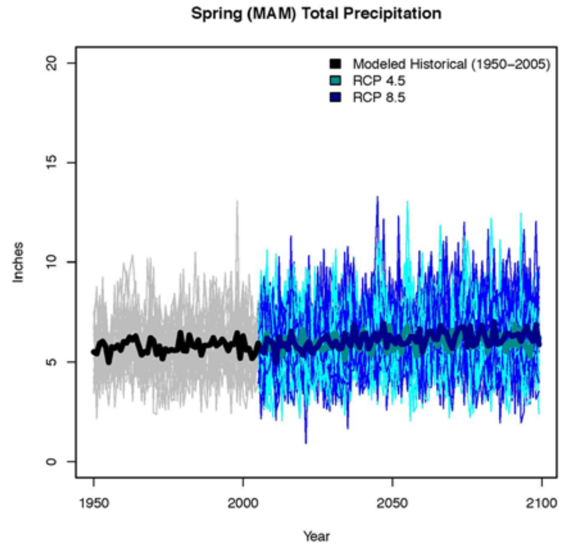


Figure 11: (a) Winter , **(b)** Spring, **(c)** Summer and **(d)** Fall average maximum temperatures by year from 1950-2099. Each line represents the results of 1 of the 20 models. The heavy line is the ensemble mean. The grey lines with the black heavy line is the modeled historical for the years 1950-2005. The yellow lines are the projections under RCP 4.5 "lower emissions" while the red lines are the projections under RCP 8.5 "higher emissions".

Total Modeled Precipitation by Season for the years 1950-2099: For both scenarios, the projections suggest a slight increase in total seasonal precipitation for winter and spring; a slight decrease for summer; and little change in the fall.



(a)



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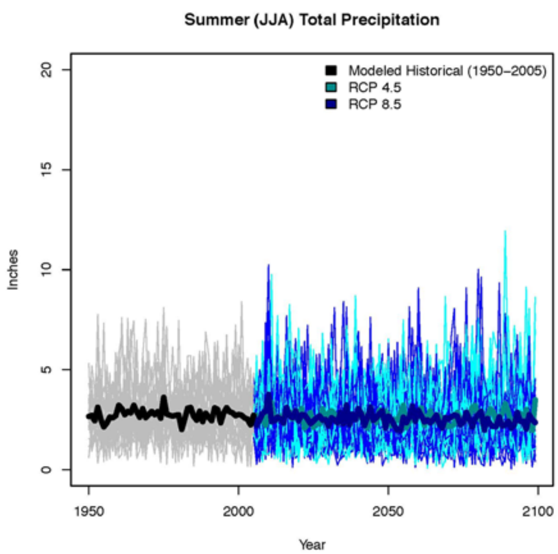

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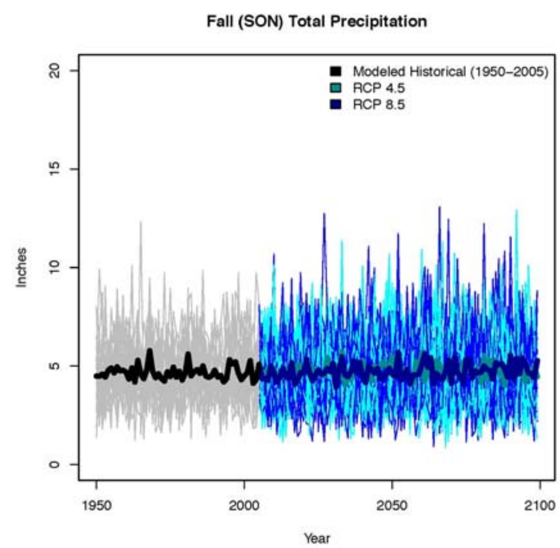
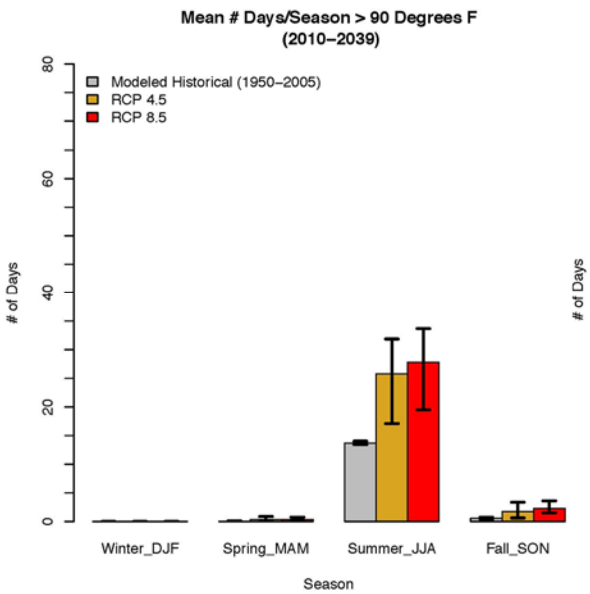


(d)

Figure 12: (a) Winter , **(b)** Spring, **(c)** Summer and **(d)** Fall total modeled precipitation by year from 1950-2099. Each line represents the results of 1 of the 20 models. The heavy line is the ensemble mean. The grey lines (all values) with the black heavy line (average) is the modeled historical precipitation for the years 1950-2005. The light blue lines are the projections under RCP 4.5 "lower emissions" while the dark blue lines are the projections for the RCP 8.5 "higher emissions" scenario.

Mean Number of Days per Season where the Average Temperature Exceeds 90° F Throughout the Entire Domain: Historically the region experiences about 13 days over 90 °F over the course of the summer. That number is expected to double by the middle of the century under both the RCP 4.5 and RCP 8.5 scenarios (b) and triple by the end of the century (c) even with the lower emissions scenario (RCP 4.5).



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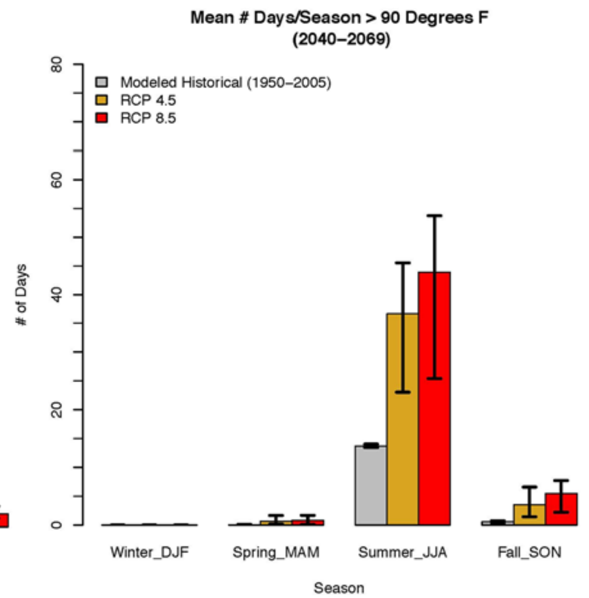

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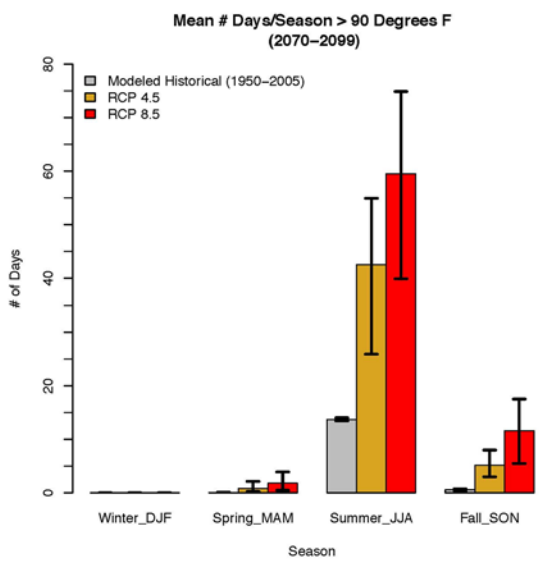
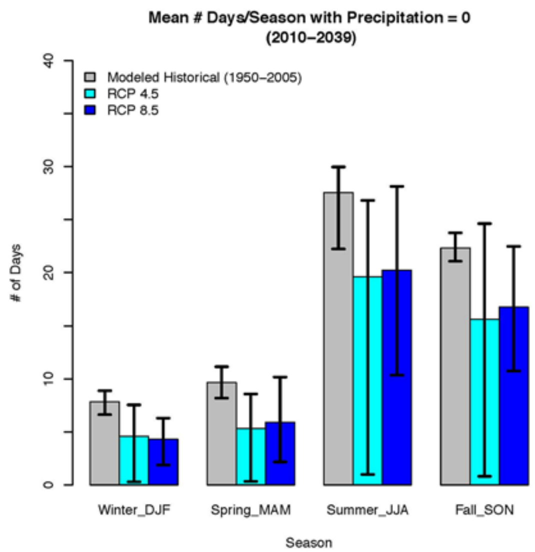


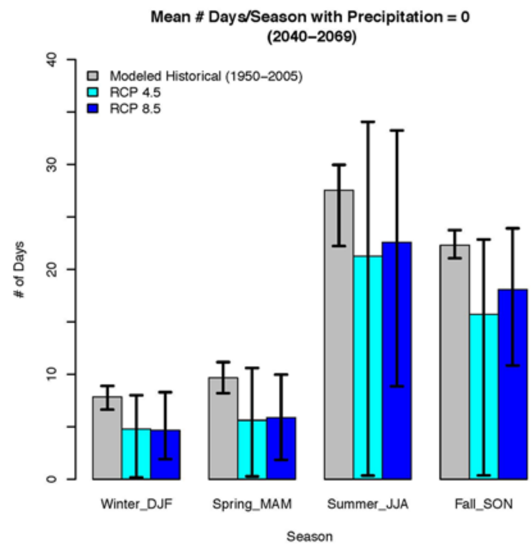
(c)

Figure 13: Mean number of days for each season for which the average temperature over the entire domain exceeded 90 °F for the years **(a)** 2010-2039, **(b)** 2040-2069, and **(c)** 2070-2099. The bars shown in grey are the modeled historical results for the years 1950-2005 as a comparison for reference. The bars in yellow show the results for RCP 4.5 “lower emissions”, while the red bars are the results for RCP 8.5 “higher emissions”. For each of the bars shown, the bar itself represents the 20-model mean, while the error bars (black whiskers) extend to the most extreme model projections.

Mean Number of Days per Season with no Precipitation Throughout the Entire Domain: Historically the region has experienced between 8 and 10 days without precipitation during both the winter and spring seasons. That number is expected to decrease by approximately half for both seasons by the middle of the century and remain at that level. This implies a wetter winter and spring. However, given the extent of the error bars on these projections, they should be interpreted with caution.



(a)



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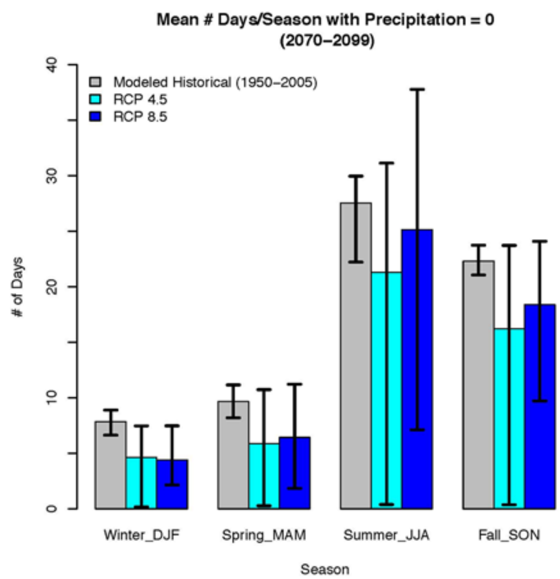


(c)

Figure 14: Mean number of days for each season for which there was no precipitation over the entire domain for the years **(a)** 2010-2039, **(b)** 2040-2069, and **(c)** 2070-2099. The bars shown in grey are the modeled historical results for the years 1950-2005 as a comparison for reference. The bars in light blue show the results for the RCP 4.5 "lower emissions" scenarios, while the dark blue bars are the results for the RCP 8.5 "higher emissions". For each of the bars shown, the bar itself represents the 20-model mean, while the error bars (black whiskers) extend to the most extreme model projections.

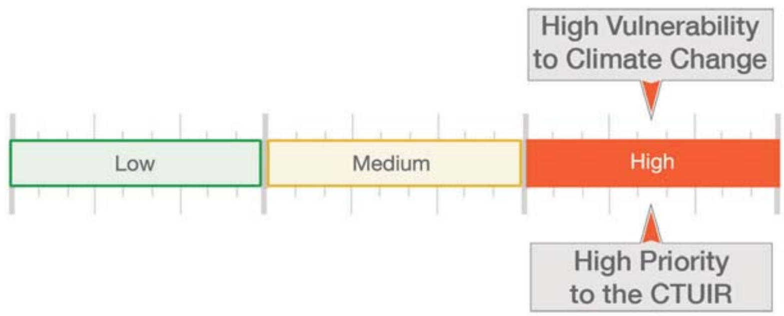
4.0 Results and Discussion

4.1 Climate Change and Prioritized List of Key Items of Concern

The results of the vulnerability assessment are summarized below with the most vulnerable and highest priority items first.

4.1.1 High Vulnerability Key Items of Concern

Chinook Salmon



For centuries, the CTUIR Tribes have relied on a diverse diet of locally available native foods known traditionally as the First Foods that have contributed to the physical, mental, and spiritual health of the Tribes. Many First Foods ceremonies include a serving ritual commencing with water, followed by salmon, deer and elk meat and roots, and ending with huckleberries or other berries[45]. The serving order of the First Foods replicates the order in which the foods are ready for annual harvest from the landscape.

The Walla Walla and Umatilla Tribes are primarily river people and much of their dietary intake has been salmon, although they would also gather uplands foods or trade for these foods. For the Cayuse Tribe, despite being primarily upland people whose winter village sites lined the western flank of the Blue Mountains, salmon still plays a critical role in the diet and, more importantly, the spiritual and cultural identity of the Tribes (Figure 15).

[45] Cockle, R. Umatilla Tribe Bases Land Management Strategy on Preserving Food. *The Oregonian,* March 1, 2009. *Retrieved from:* http://www.oregonlive.com/news/index.ssf/2009/02/confederated_tribes_of_the_uma_1.html

Photo credit: CTUIR Fisheries.

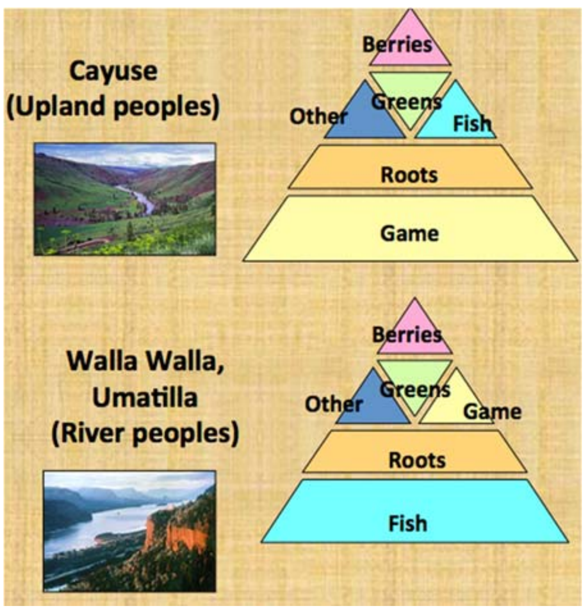


Figure 15: Representation of the CTUIR tribal diets and the importance of the different First Foods by tribe[46]..

Cultural and Spiritual Identity

Activities associated with the First Foods include: accessing, teaching, learning, harvesting, preparing or processing, consuming, celebrating, preserving, and sharing these foods, all of which are central to the tribal community cultural traditions of caring for the First Foods[47].

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[46] Harris S.G. and Harper B.L. A Native American Exposure Scenario. *Risk Analysis* 17(6), 1997.

[47] Confederated Tribes of the Umatilla Indian Reservation, Comprehensive Plan, 2010, page 81.

According to a tribal belief,

> *[W]hen the Creator was preparing to bring forth people onto the earth, he called a grand council of all the animals and plants. He asked each for a gift for these new creatures – a gift to help the new humans survive, since they would be quite helpless and require much assistance. The very first to come forward was Salmon, who offered his body to feed the people [48].*

Each April, a thanksgiving feast, *ká'uyit,* meaning, "first feast," is held to celebrate the return of the salmon. There are three additional significant feasts—the celery, root, and huckleberry feast and other traditional ceremonies such as namings, memorials and funerals which take place annually. Salmon is served for each one and plays a unique role in tribal life.

Economy

Salmon has, until recent history, always been an abundant, seemingly infinite resource[49]. Salmon fishing provides both an exchange of cultural and traditional values between tribal members and a livelihood. In the past, salmon, and salmon-based trade, were the primary sources of revenue for the Tribes[50]. The CTUIR has anecdotally seen diminishing populations of salmon in years past due to the damming of the Columbia River, making preservation of salmon for use by the Tribes critically important[51].

Although the literature exploring the potential climate-related impacts on salmon is burgeoning, understanding the exact ways in which climate change will affect salmon is challenging due to complexity of the environmental and biologic systems involved in the life cycle of the salmon[52]. The species has some degree of adaptive capacity through the genetic diversity within the population and some populations within the species are more sensitive to changes in certain environmental conditions, while others are less affected[53]. Despite this capacity, based on the literature reviewed for this report there is a trend towards more negative impacts of climate change rather than positive.

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[48] Columbia River Inter-tribal Fish Commission, First Salmon Feast. *Retrieved from:* http://www.critfc.org/salmon-culture/tribal-salmon-culture/first-salmon-feast/#sthash.q2vndhGo.dpuf

[49] Confederated Tribes of the Umatilla Indian Reservation, Comprehensive Plan, 2010, pages 20-24.

[50] Ibid.

[51] Ibid.

[52] Hardiman J and Mesa M. The effects of increased stream temperatures on juvenile steelhead growth in the Yakima River Basin based on projected climate change scenarios. *Climatic Change* (2014) 124:413–426 DOI 10.1007.

[53] Mote P., Parson E., Hamlet A., Keeton W., Lettenmaeir D., et al. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. *Climatic Change* 61: 45–88, 2003.

Changing climate conditions

Changing climate conditions in the region will affect salmon populations. For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. *Winter* temperatures are projected to increase nearly as much (between +3 °F and +8 °F). The projected increases in winter temperatures are likely to reduce the snowpack in turn changing the timing of spring run-off, decreasing the availability of cold water during the summer, and reducing river flow rates. Increases in summer temperatures will likely increase stream temperatures.

Understanding how climate affects salmon requires an understanding of their life cycle. This complex life cycle that includes hatching in a freshwater river environment, migration to the ocean, spending multiple years in the ocean, and then returning to the same river to spawn means that climate, weather, river, and ocean conditions all have the potential to affect the salmon. In Figure 16, the blue line on the graph shows the average Chinook salmon population counts at the Bonneville Dam from 1995-2004. The first increase in counts during the springtime is due to the fry traveling past the dam and downriver to the ocean. The counts drop off during the summer months. Then, in the fall, there is a large increase in salmon counts as the adult salmon from previous years return to the river to spawn. Ultimately, survival depends on the conditions in each of these different environments and different salmon species are more or less susceptible to changes in those conditions.

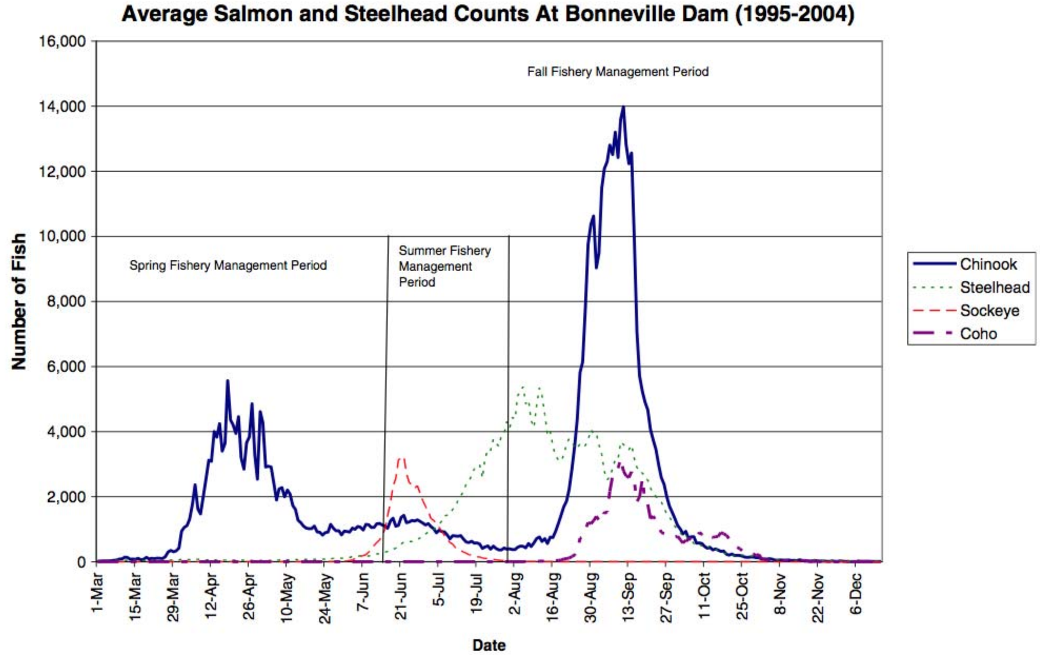

Figure 16: Historical average (1995-2004) number of salmon at the Bonneville Dam by date during the summer. Different colored lines represent different species. Dark blue line is chinook, light green dashed line is steelhead, orange dashed line is sockeye, and red dashed line is coho [54].

Increases in overall temperatures will shift the spring runoff earlier, resulting in decreased stream flow and increased stream temperatures during the summertime. This has already been observed in dry or warm years such as 2015 where the peak stream flow occurred much earlier than historic averages. The 2015 peak flow of the Umatilla River at Gibbon occurred on February 10th, 70 days earlier than expected (Figure 17 below). Stream flow condition can vary widely from year-to-year, depending on ENSO driven ocean-conditions and the resultant hydro-meteorological changes over land[55], the longer-term climate projections suggest that snow dominated basins like the Umatilla will become transient (mixed snow-rain) and eventually rain-dominated with warmer wetter autumn and winters and drier summers[56]. 2015 provided a dramatic example of future conditions that are consistent with the climate projections and a preview of how these mid-to-lower elevation basins across the Columbia Basin will likely change in the next 100 years.

[54] Dittmer, K. *Climatic Change* (2013) 120:627–641 DOI 10.1007

[55] Climate Impacts Group, 2015. About ENSO. JISAO, UW, Seattle. *Retrieved from:* http://cses.washington.edu/cig/pnwc/aboutenso.shtml

[56] Climate Impacts Group, 2015. Climate Impacts on Pacific Northwest Water Resources. JISAO, UW, Seattle. *Retrieved from*: http://cses.washington.edu/cig/pnwc/pnwwater.shtml

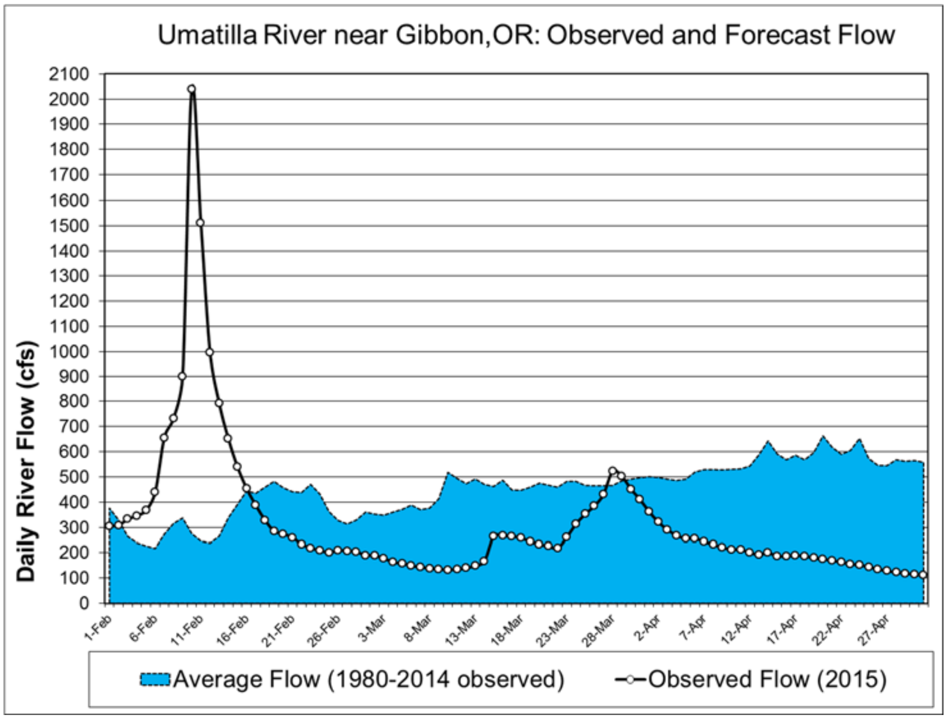

Figure 17: Hydrograph of the 2015 flow conditions in the Umatilla River at Gibbon near the headwaters of the river.

In his paper, *Changing stream flow on Columbia basin tribal lands—climate change and salmon*, Dittmer found that the Columbia basin's spring flow onset date (i.e., start of the annual snowmelt cycle) over the last 100-years has moved earlier by 5.7 days (17 to 31 days earlier for the Umatilla basin), indicating a shift towards an earlier spring runoff date. Weather variability, as measured in the stream flow standard deviation, increased by +5% for the Columbia basin as a whole and +6% to +21% for the Umatilla basin. The average Columbia basin 100-year November flood has increased in frequency by 49%. For the Umatilla basin, an increase of +25% to +42% has been observed. Further, he found that the average April to July (summer) flow volume for the Columbia basin declined by 16% (-22% to -28% for the Umatilla basin)[57]. In addition, Parson et al. found:

> *On snowmelt-dominated rivers like the Columbia, the very likely effect of these linked changes in temperature, precipitation and snowpack will be to increase winter flow and decrease summer flow. Winter flow increases both because there is more winter precipitation and because more of it falls as rain; summer flow decreases both because there is less snowpack and because it melts earlier in the spring. Both precipitation and temperature matter. When changes in temperature and precipitation are considered separately,* ***temperature…has the larger effect on crucial summer stream flows***[58]*.*

[57] Ibid.

[58] Parson E., Mote, P., Hamlet A., Keeton W., Lettenmaeir D., et al. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. *Climatic Change* 61: 45–88, 2003.

Stream flow is important to salmon survival. Increased winter stream flows have the potential to wash out the habitat for redds (salmon nests). During lower summer flows, there is the potential for diminished habitat, food, less predator protection for juvenile salmon, less dilution of pollutants in the water, and lower stream flows resulting in increased stream temperatures[59].

Stream temperature is important because high temperatures hinder development, slow growth rates, and inhibit salmon's innate behavior to avoid predators[60,61]. In fact, one study found that, "*prolonged exposure to stream temperatures at and above 21 °C (69.8 °F) is lethal for most adult salmon (pg. 227)"[62].* Warmer water also impacts the presence of pollutants by accelerating the accumulation of chemical nutrients (algae, bacterial) thus decreasing oxygen availability and reducing water quality[63].

As mentioned earlier, ocean conditions, although outside the boundaries of this assessment, also play a critical role in the lifecycle of salmon. Two primary changes in the ocean are worth mentioning. First, warming ocean temperatures have the potential to create trophic mismatches between predators (like salmon) and their prey (like plankton). The success of migrating juvenile salmon depends on pulses of plankton production to provide nutrients to the salmon in this narrow window of their life cycle[64]. Second, oceans have absorbed about one quarter of human-produced CO_2 emissions in the last two centuries[65], a process that drives ocean acidification. There is a direct correlation between increasing atmospheric CO_2 since 1958 and decreasing pH (increasing acidity) of ocean waters[31]. This acidification has a variety of chemical consequences that lead ultimately to a reduced availability of carbonate ions (CO_3^-) in seawater, one of the structural building blocks for organisms that utilize calcium carbonate ($CaCO_3$) to build and maintain their shells.

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[59] United States Environmental Protection Agency, 2015. Climate Impacts in the Northwest. *Retrieved from:* http://www.epa.gov/climatechange/impacts-adaptation/northwest.html

[60] Crozier LG, Zabel RW, Hamlet AF (2008) Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. *Glob Change Biol* 14:236–249

[61] United States Environmental Protection Agency, May 2001. Salmonoid Behavior and Water Temperature. *Retrieved from:* http://yosemite.epa.gov/R10/water.nsf/6cb1a1df2c49e4968825688200712cb7/5eb9e547ee9e111f88256a03005bd665/$FILE/Paper%201-Behavioral-5-9.pdf

[62] McCullough, D. A.: 1999, *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*, Region 10 Water Resources Assessment Report No. 910-R-99-010, United States EPA, Seattle.

[63] Institute for Tribal Environmental Professionals, Climate Change and Fisheries Factsheet, April 2013.

[64] Olympic National Forest and Olympic National Park. Gen. Tech. Rep. PNW-GTR-844. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 130 p. http://www.fs.fed.us/pnw/pubs/pnw_gtr844.pdf

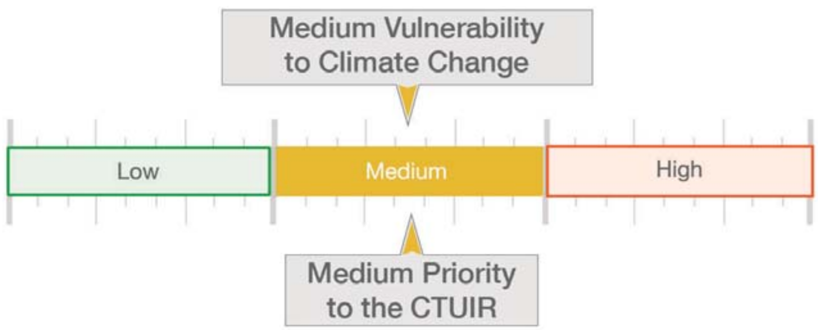
[65] Feely, R.A., Klinger, T., Newton, J.A., Chadsey, M., 2012. Scientific Summary of Ocean Acidification in Washington State Marine Waters. Washington State Blue Ribbon Panel on Ocean Acidification. *Retrieved from:* https://fortress.wa.gov/ecy/publications/SummaryPages/1201016.html

Carbonate is one of the structural building blocks for the shells of small marine organisms such as phytoplankton and zooplankton that form the foundation of the marine food chain that supports salmon and other marine species[66].

Not surprisingly, Chinook salmon are critical to tribal life for a variety of reasons and rose to the top of the Key Items of Concern. Despite recognition that existing land use protections, abundant reservoirs, floodplain restoration efforts, and interagency cooperation all help address the challenges facing salmon, they ranked as a high vulnerability and high priority. The project team also recognized that changes and/or updates to floodplain zoning laws to support in-stream flows, managing dam systems for ecosystem restoration, and the expansion of river sinuosity are needed to begin addressing the challenges facing Chinook salmon.

4.1.2 Medium Vulnerability Key Items of Concern

Cous



Cous was the species selected to represent the roots significant to the Tribes for food and for ceremonial purposes. χáwš (cous) was one of the earliest root crops harvested, sometimes at large communal fields and in conjunction with other Plateau groups. According to the CTUIR:

> *The cous root (Kowsh, also known as biscuitroot) with its bright flowers turned the late spring and early summer hillsides of Eastern Oregon yellow. Women dug the roots with diggers made of hardwood or antlers. The roots were boiled and mashed together and shaped into small biscuits and dried in the sun. The biscuits were stored away for later use[9].*

[66] Ibid.

Photo credit: "Lomatium cous (3531695611)" by Matt Lavin from Bozeman, Montana, USA Licensed under CC BY-SA 2.0 via Wikimedia Commons.

Increasing summer temperatures and trends of diminishing summer precipitation create critical climate concerns for cous. For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. *Winter* temperatures are projected to increase nearly as much (between +3 °F and +8 °F). The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century (both RCP 4.5 and 8.5 scenarios).

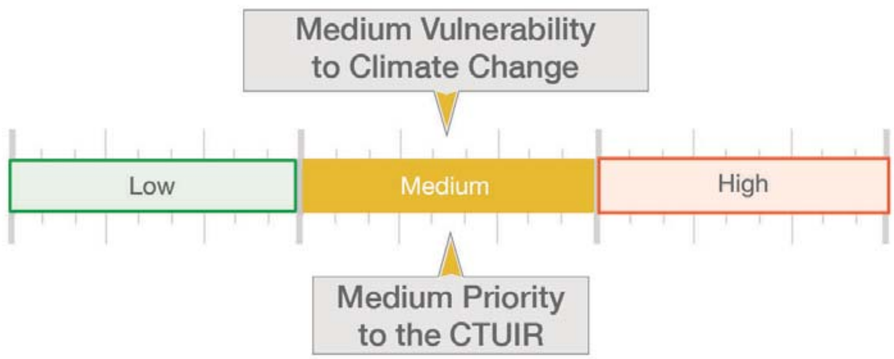
The warmer temperatures will likely result in plant migration towards cooler temperatures (i.e. higher elevations), making plants more difficult to harvest as they may leave traditional harvesting sites and the species may even move beyond the currently negotiated treaty boundaries over time[67]. This plant migration impacts tribal members' ability to maintain intergenerational connections being shared specific to the location and timing of when to harvest roots. As cous plants move to new habitats they become vulnerable to non-native plants as they must compete for limited habitat and resources, such as water [68]. Climate change brings the likely increase of invasive species. Increased invasions by non-species may occur as conditions become less well suited for native species. The most recent comprehensive plan for the CTUIR found that "*Modern day energy generation facilities on lands surrounding the Reservation and infrastructure components passing*

[67] Graves, D. (2009) Climate Change and Ecological Restoration: A GIS Analysis of Climate Change and Snowpack on Columbia Basin Tribal Lands. *Ecological Restoration* 27:3, 256-57.
[68] Swinomish Adaption Action Plan. 2010. *Retrieved from:* www.swinomish.org/climate_change/Docs/SITC_CC_AdaptationActionPlan_complete.pdf

through the Reservation have had negative impacts to the Reservation environment and Treaty reserved rights (page 125)" [69].

When cous was discussed during the group vulnerability assessment process it was clear that the Tribes are already seeing changes matching what the literature projects could occur. Tribal gatherers have noticed advanced flowering of the cous plants [70]. Replanting activities (assisted migration), better land management practices and policies, and working to create better habitat continuity could enhance the resilience of these plants to these changing climate conditions. In addition, the project team felt that although the root itself is vulnerable to climate effects, the Tribes have an element of adaptability by changing the timing and location for harvest. This ability to adapt led to medium vulnerability and medium priority ratings.

Elk



Elk was selected as the representative game species for the Tribes. Also a First Food, Elk have been abundant and available to the Tribes for centuries. By summer, Plateau bands were fishing, hunting, and gathering while living in camps in the mountains. Again, the CTUIR's First Foods description shares that,

> *In the late summer, the Cayuse, Umatilla and Walla Walla people would move to the upper mountains to pick huckleberries and hunt for game. The berries and meat were also dried. Chokecherries were pounded with dried meat or salmon to make pemmican [a mixture of pounded meat and melted fat]* [9].

[69] Confederated Tribes of the Umatilla Indian Reservation, Comprehensive Plan, 2010, page 83
[70] Lessica P, Kittelson P.M. Precipitation and temperature are associated with advanced flowering phenology in a semi-arid grassland. *Journal of Arid Environments* 74 (2010) 1013-1017.

Photo credit: MONGO (Own work) [Public domain], via Wikimedia Commons

For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century (both RCP 4.5 and 8.5 scenarios). Summer precipitation projections have a large range of variability and are projected to vary between -40% and +23% (RCP 8.5) in the 2050s.

Critical climate changes affect how the region can sustain populations of elk. Projected trends of diminishing summer precipitation and higher summer temperatures can create drought-like conditions. A research study conducted in Rocky Mountain National Park, Colorado found elk populations increased with increased precipitation. As a result it was found that during times of drought elk populations decreased[71].

Projecting exactly how changing temperatures and precipitation patterns will affect elk is difficult. They may migrate towards cooler temperatures (higher elevations) and these areas could lack the necessary habitat for elk to survive, resulting in a decrease in the rate of population growth[68]. The cascading ecological impacts of this migration towards higher elevations could drastically change the habitats and ecosystems in those areas. For example, songbirds have been found to be in danger due to elk's presence and winter grazing in regions where they are not typically present[72].

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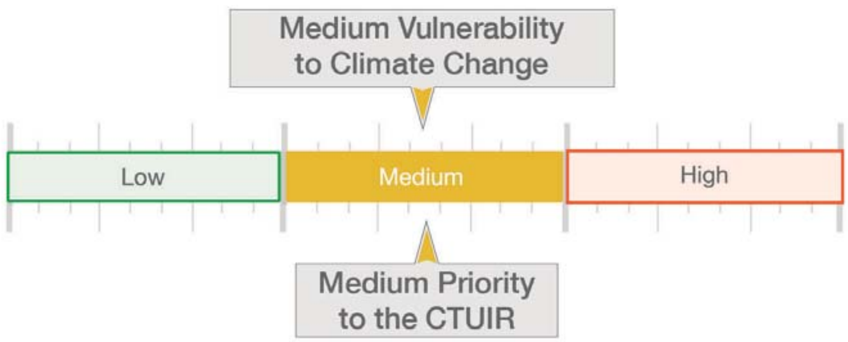
[71] Wang G, Hobbs NT, Singer F, Ojima D and Lubow B. Impacts of Climate Changes on Elk Population Dynamics in Rocky Mountain National Park, Colorado, U.S.A. *Climatic Change* 54: 205-223, 2002.
[72] United States Geological Survey, January 9, 2012. Dramatic Links Found Between Climate Change, Elk, Plants, and Birds. *Retrieved from:*
http://www.usgs.gov/newsroom/article.asp?ID=3069#.VaKytJ0o7IV

During discussions about climate impacts to availability and access to elk for the CTUIR, there was agreement within the group that the species was vulnerable but that realistic and meaningful strategies exist to address the potential impacts. For example, working with the U.S. Forest Service to increase connectivity of land for elk so as to ensure that herds are intact and available for hunting (i.e. do not migrate off the Aboriginal Title Lands) was one strategy discussed that is both workable, and realistic. Changing policies to protect rangeland, limit human development in certain areas, and enhance existing land preserves could also help. The group rated availability and access to elk a medium vulnerability and medium priority.

Flooding



Flooding within the CTUIR of areas closest to the Umatilla River has blocked transportation routes, compromised power and communication systems, created bridge and other road failures, isolated parts of the community, and challenged emergency response. Further, flooding causes damage to infrastructure such as roads, water and sewer lines, agricultural lands, and residential areas on reservation[73]. According to the 2008 Hazard Mitigation plan for the area, flooding has impacted a number of specific areas on reservation. To view the full list see Appendix 9.

Flooding can have devastating financial, social, and emotional impacts. One extreme event that damages property, critical infrastructure, and other public facilities can have high costs for repair or replacement of those facilities.

> *There are approximately 49 addressed buildings located within the Umatilla River floodway and approximately 74 addressed buildings within the 100-year floodplain. These homes have an estimated average assessed valuation of $130,000. There are 49 homes located within the Umatilla River "floodway." If a major flood occurred, and these 49 homes were "substantially damaged," the estimated loss would be approximately $6,370,000. If the 74 homes, located within the Umatilla River floodplain but outside the Umatilla River floodway,*

[73] The Umatilla Indian Reservation Hazard Mitigation Plan, November 2008, Section 4.

were damaged but less than 50% of their value, the estimated losses could reach as high as $4,800,000 (page 17, Section 4)[74].

Beyond the potential financial impacts of flooding, displacement (temporary or permanent) of tribal members from their homes, the potential damage areas where First Foods grow (such as certain roots and berries) as well as the potential injury or death of tribal members have a value that cannot be assessed. While flooding will not impact everyone in the community, the substantial impacts it would have on one subset of the community warrants a medium priority ranking (this was highlighted by the working group as it was the only item of concern that received a score of 4 for the distributed nature of impact criteria, indicating a narrowly focused set of impacts that should not be overlooked).

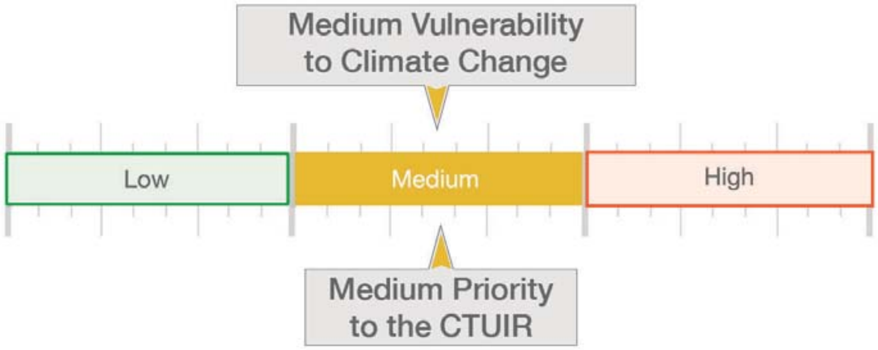
The key climate concern relative to flooding is increasing temperatures and its effect on snowpack and the timing of spring runoff. By the 2050s average maximum *winter* temperatures are projected to by between +3 °F and +8 °F (RCP 8.5). These projected increases in winter temperatures will mean that more precipitation will fall as rain (versus snow), reduce the snowpack, and increase the potential for flooding. Projected changes to precipitation patterns by mid-century (-3% to +20% change in winter and -2% to +25% change in spring precipitation (RCP 8.5)) could also result with increases in flooding.

Flooding is a particular concern in areas near the streams and rivers in the 100-year floodplain. These impacts are already being seen in the CTUIR landscape. There are some existing facilities that are already vulnerable to flooding, thus planning to protect that infrastructure, accommodate the new potential flood risk, or move buildings out of harm's way should be considered. The working group rated flooding a medium vulnerability because, despite the vulnerability of the CTUIR to flooding, adaptation strategies do exist. For example, the CTUIR could develop land use regulations that limit or have special standards for new development within the flood prone areas.

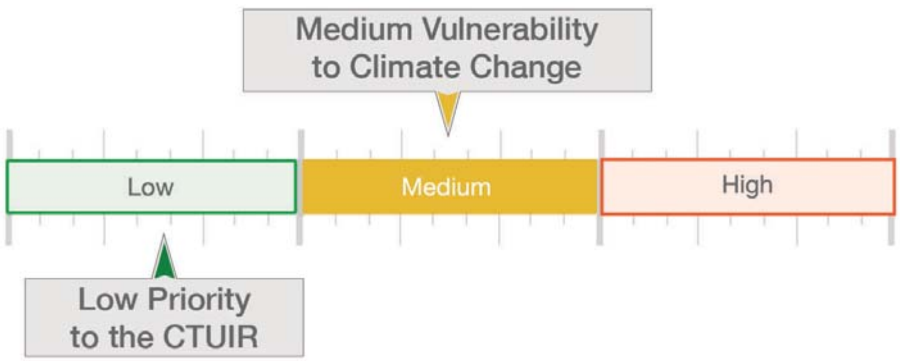
[74] Ibid.

Agriculture

Non-Irrigated Agricultural Crops



Irrigated Agricultural Crops



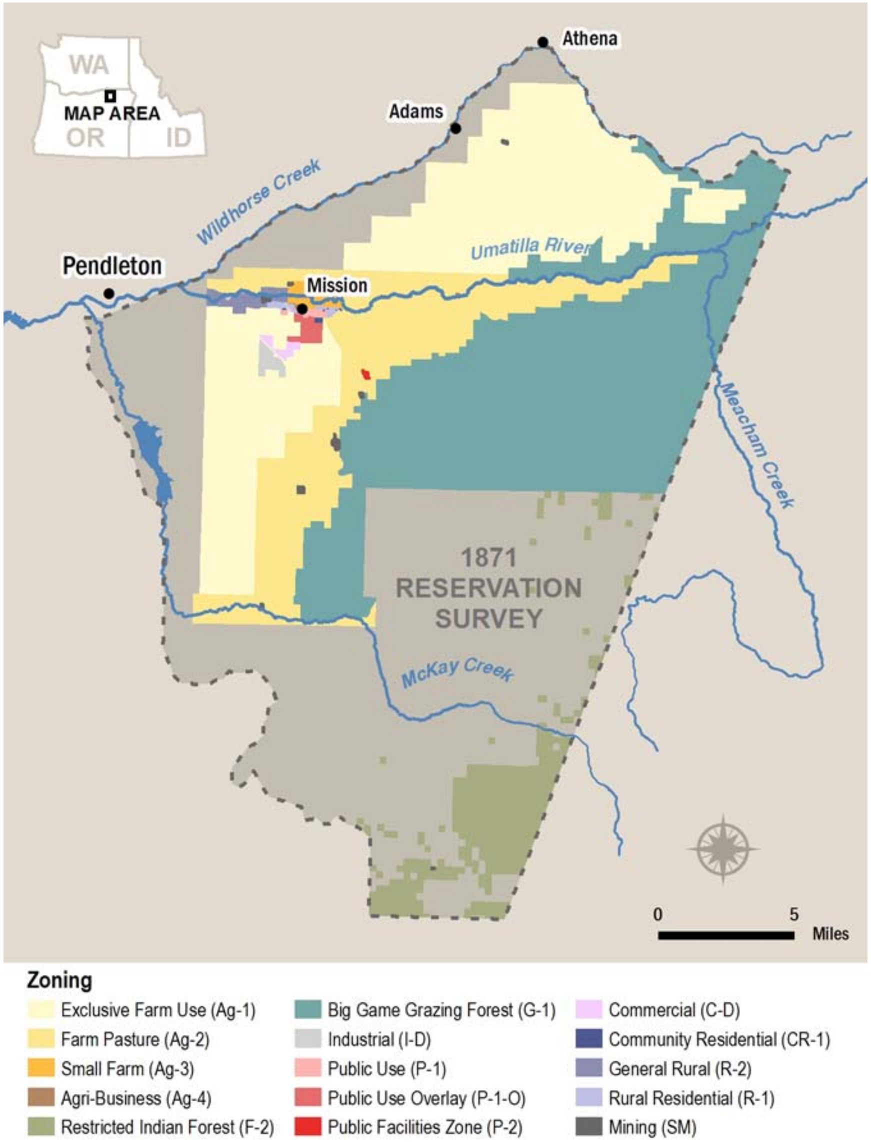


Figure 18: Land Development Zones for the CTUIR.[75]

Figure 18 outlines CTUIR agricultural land use areas (the light yellow, light orange, orange and brown portions of the map). Agricultural crops on the Reservation are grown by either individual Indian landowners on land they own, non-Indian landowners on land they own or lease, or by CTUIR Farming Enterprises on lands owned or leased by the CTUIR. Crop-related information for the CTUIR-owned land for the year 2015 is shown in Table 5. These crops generate funds for the Tribes but the amount of revenue depends on that year's price and yields.

[75] Confederated Tribes of the Umatilla Indian Reservation, Comprehensive Plan, 2010, Page 68.

Table 5: 2015 Crop Information for the CTUIR

	Acres in 2015
Tribally owned wheat	1,287.90
Leased from others	275.66
BIA leased wheat	1,440.62
Tribally owned spring barley	111.00
Canola	0.00
Austrian Dry Peas	35.70
Dry Hay	348.00
Fallow	2,272.50
CRP*	4,351.48
Total Acres	**10,122.86**
*The Conservation Reserve Program (CRP) pays a yearly rental payment in exchange for farmers removing environmentally sensitive land from agricultural production and planting species that will improve environmental quality.	

The effect of climate on agriculture in the Pacific Northwest is complex because the systems themselves are multifaceted. This makes predicting exactly how crops will respond difficult[76]. For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century (both RCP 4.5 and 8.5 scenarios). Further, although projected changes in precipitation patterns are less clear-cut than for temperature, the analysis suggests summers will be potentially drier (-40% to +25% change in summer precipitation by the 2050s (RCP 8.5)).

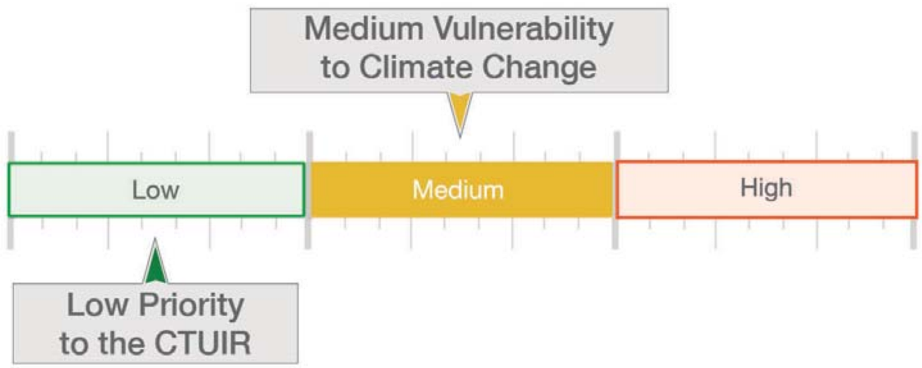
Without making adjustments to planting times or other adaptations, these changes have the potential to decrease crop yields, especially for dry land crops, decrease seed germination, and increase vulnerability from pests and diseases due to enhanced heat and water related stress on the crops[54]. For the northwest region, increasing temperatures,

> *…will bring increases in the probability of heat-related stress and water shortages to field crops and tree fruit, but will also be associated with longer growing seasons and, perhaps, shifts in precipitation that can benefit some crops…increasing atmospheric CO_2 concentrations are expected to be beneficial for most NW [northwest] commodities due to CO_2 fertilization at least until mid-21st century (pg. 153)[10].*

[76] Center for Sustaining Agriculture and Natural Resources. Climate Impacts and Adaptation. *Retrieved from:* http://csanr.wsu.edu/climate-impacts-adaptation/

The CTUIR grows both irrigated and non-irrigated crops on tribal lands. Because of the current availability of water and the potential ability for the Tribes to shift their agricultural crops to more water-resilient crops, there was a general recognition that these crops (both irrigated and non-irrigated) have a medium vulnerability to changing climate conditions. In fact, according to the 1998 CTUIR Mission Community Plan the CTUIR, "*Discourage[s] returning non-productive agricultural lands to production when they may have other land use and management benefits*[77] *(pg. 17).*" However, the non-irrigated dry land crops were given a higher priority than irrigated, again, because there is less flexibility in providing water to those crops during dry years, without a substantial investment in infrastructure.

Long-term Availability of Drinking Water



According to the 2010 CTUIR Comprehensive Plan, "*clean, cold and fast flowing water*" is a critical aspect of the economic and environmental security for the Tribes, and are a foundation for wealth[78]. The natural storage process for drinking water in the region is intricately linked to climate. For the Northwest region, during the winter months water is stored in the mountains as snowpack and during the spring this snowpack melts slowly, filling the rivers, streams, and aquifers with much needed water to carry the system through the summer months when water availability (as precipitation) is much lower[54]. The Pacific Northwest region is especially vulnerable from a drinking water perspective in a future climate with less snow. As Mote et al. state,

> *Despite the large number of dams in the Northwest, the regional infrastructure relies heavily on snowpack to transfer water from the wet winters to the dry summers, making the region especially vulnerable to a warming climate with less snow. Furthermore, water supply, availability, and quality are already stressed by many growing demands (pg. 54)*[54]*.*

According to the 2008 Umatilla Hazard Mitigation Plan, "*Umatilla County submitted emergency declarations due to low water conditions and drought in 2002 and 2005*"

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[77] Confederated Tribes of the Umatilla Indian Reservation, Mission Community Plan, 1998, page 17.
[78] Confederated Tribes of the Umatilla Indian Reservation, Comprehensive Plan, 2010, page 58.

demonstrating a precedence for challenges related to providing municipal water (Section 3, page 30).

For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. *Winter* temperatures are projected to increase nearly as much (between +3 °F and +8 °F). The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century (both RCP 4.5 and 8.5 scenarios). Further, although projected changes in precipitation patterns are less clear-cut than for temperature, the analysis suggests summers will be potentially drier (-40% to +25% change in summer precipitation by the 2050s (RCP 8.5)). The projected increases in winter temperatures are likely to reduce the snowpack in turn changing the timing of spring run-off, decreasing the availability of cold water during the summer, and reducing river flow rates. The resulting low stream flows make the availability and timing for providing water challenging for municipal as well as other uses (agricultural, fisheries, etc.)[79].

Drinking water for the Tribes comes from underground aquifers. In the short-term the aquifers that provide the drinking water for the Tribes naturally buffers the annual variability in precipitation. During wet-years the aquifer refills and during dry years, the Tribes are able to draw on the aquifer to meet the needs of the community. In the long-term (2050 and beyond), the working group felt there was a higher vulnerability but for both, short and long-term supplies were given a low priority ranking. However, there is a need in the long-term to respond and protect this reservoir through investments, engineering solutions, conservation efforts, and continued monitoring.

[79] Blue Mountains Adaptation Partnership. Hydrology, Water Use and Infrastructure. *Retrieved from:* http://www.adaptationpartners.org/bmap/docs/BMAP_VAP_Water.pdf

4.1.3 Medium-Low Vulnerability Key Items of Concern

Huckleberry

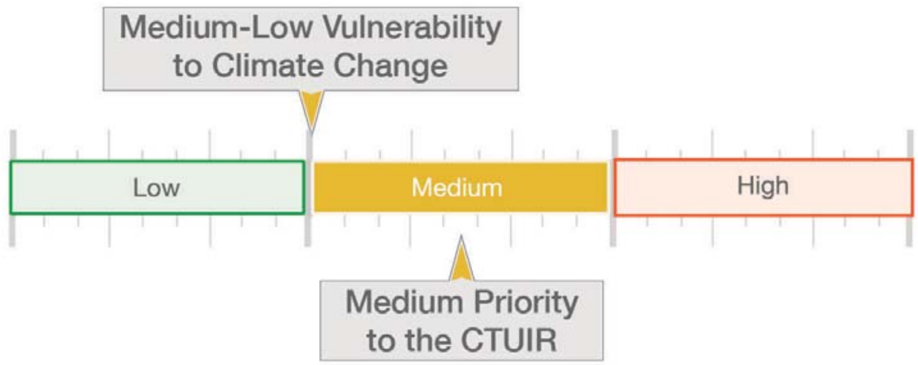

Photo credit: "Vaccinium membranaceum Fruit and leaves" by Julie from Idaho, United States. Licensed under CC BY 2.0 via Wikimedia Commons.

As previously discussed, First Foods are central to the CTUIR way of life. Huckleberry is one of those First Foods and was selected as the representative berry species for this assessment. Gathering of berries has similar cultural and dietary significance as the gathering of roots and the changing climate conditions can negatively impact traditional picking locations and timing of collection.

Similar to cous, increasing summer temperatures and trends of diminishing summer precipitation create critical climate concerns for huckleberries. For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. *Winter* temperatures are projected to increase nearly as much (between +3 °F and +8 °F). The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century (both RCP 4.5 and 8.5 scenarios). Further, although projected changes in precipitation patterns are less clear-cut than for temperature, the analysis suggests summers will be potentially drier (-40% to +25% change in summer precipitation by the 2050s (RCP 8.5)).

When combined, these changes are likely to increase drought-like conditions in the summer. Further analysis and modeling is needed to understand how huckleberry yields may be impacted, however, one study found that early flowering with a combination of high spring temperatures and late spring frost could cause low berry yields. Although the reasoning for early flowing affecting yields is not well understood it is thought to be due to a mix of temperature and atmospheric conditions[80]. Researchers also found a strong correlation with high temperatures bringing an early spring and decreased berry production[81]. Huckleberry seed germination is extremely intolerant to drought conditions thus limiting its ability propagate during drought[82]. Finally, plant migration northward or to higher elevations towards cooler climate is probable, increasing plant interaction with non-native species and making gathering challenging as traditional harvesting areas may be inaccessible for tribal communities[68].

For a food so significant and central to the tribal way of life, consistency and predictability of harvest yields and harvest locations is essential, and changing climate conditions threaten this consistency. Of note, there is a data gap relative to the climate impacts on huckleberry plants. It would be valuable for the CTUIR to develop a monitoring program to evaluate how changing precipitation and temperature are affecting huckleberry plants in the region. Huckleberry plants have the capacity to continue to survive with existing land management practices, tribal members can shift their harvesting times and locations to accommodate the plant's movement, and it is a relatively easy habitat to restore. Despite the medium-low vulnerability ranking, it is a medium priority because of its cultural importance to the Tribes, falling only below Chinook salmon as a priority.

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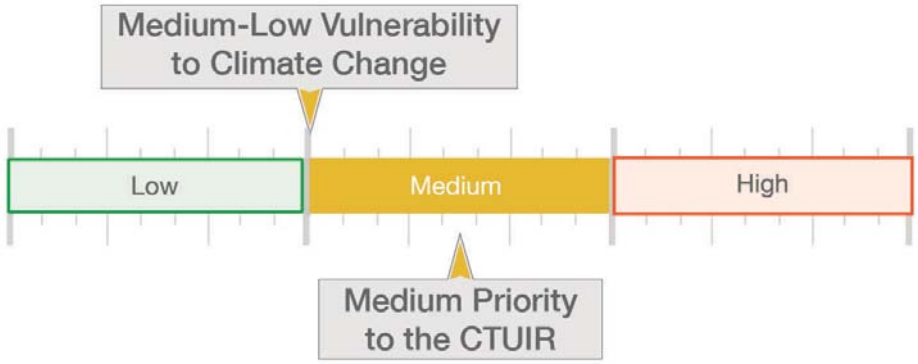
[80] Holden et al. Sensitivity of Berry Productivity to Climatic Variation in the Cabinet–Yaak Grizzly Bear Recovery Zone, Northwest United States, 1989–2010. Wildlife Society Bulletin 9999:1–6; 2012; DOI: 10.1002/wsb.128

[81] Ibid.

[82] Erickson, H. Biology, ecology and management of PNW huckleberries. March 2012. *Retrieved from:* http://ecoshare.info/wp-content/uploads/2012/03/Erickson.pdf

Wildfires



The CTUIR has some vulnerability to wildfires, which have the potential to be devastating if left uncontrolled. These impacts could include burning homes and businesses, loss of trees, temporary changes to the watershed habitat, decreased water quality through increased sediment loading and run-off, human health impacts from exposure to smoke and air pollutants, and loss of critical habitat for First Foods which are vital to the tribal community[74, 83]. According to the 2008 Umatilla Hazard Mitigation Plan,

> *From 1970 to 2004 there were 4,592 fires reported in the Umatilla National Forest. Lightening was the cause of 66% of those fires and burned 149,034 acres. Human-caused fires accounted for 1,503 fires involving 45,843 acres (Section 3, pg. 12)[74].*

For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. *Winter* temperatures are projected to increase nearly as much (between +3 °F and +8 °F). The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century (both RCP 4.5 and 8.5 scenarios). Further, although projected changes in precipitation patterns are less clear-cut than for temperature, the analysis suggests summers will be potentially drier (-40% to +25% change in summer precipitation by the 2050s (RCP 8.5)). With these changes there will be an increasing risk of more intense wildfires, higher rates of lightning ignition, and larger areas burned[84]. According to a landmark *National Research Council Report* conducted in 2011, for every 1.8-3.2 °F of warming, there was a 200-400% increase in area burned in the Western U.S.[85] .

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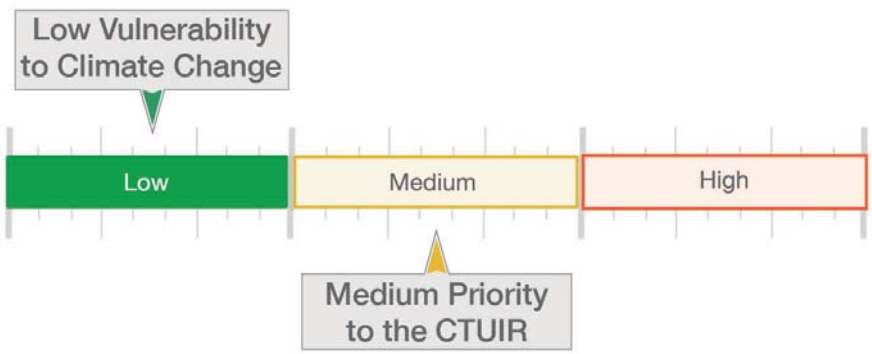
83 Yellowhawk Tribal Health Center Emergency Preparedness Plan, August 2013.
84 Stavros E.N., Abatzoglou J.T., McKenzie D., and Larkin N. Regional projections of the likelihood of very large wildland fires under a changing climate in the contiguous Western United States. *Climatic Change* (2014) 126:455–468 DOI 10.1007
85 National Academies Press. Climate Stabilization Targets: Emissions, Concentrations and Impacts Over Decades to Millennia, 2011. *Retrieved from:* http://www.nap.edu/openbook.php?record_id=12877

In addition, smoke from wildfires (particulate matter [PM], carbon monoxide [CO] and nitrous oxides [NOx]) downwind has impacts on health. Exposure can increase respiratory, cardiovascular, and asthma related hospitalizations, cause more emergency department visits, and increase lung-related illnesses[60, 86]. There are also likely to be losses of habitat (and thus availability) of First Foods as wildfires increase in severity and regularity. This loss in availability of First Foods could have secondary impacts on tribal community health as chronic disease rates, such a diabetes and heart disease, increase as tribal communities move away from eating a traditional diet [87].

There are plans in place to manage and continue to manage wildfires. Despite this, wildfires were rated a medium priority given that a coordinated response on all levels is required to adequately address this vulnerability.

4.1.4 Low Vulnerability Key Items of Concern

Heat Waves



For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century and triple by the 2080s (both RCP 4.5 and 8.5 scenarios). While 90 °F is not necessarily extreme it does have the potential to negatively impact potentially vulnerable populations (like tribal elders) and the trend in increasing days over 90 °F serves as an indicator that the CTUIR can expect more frequent high temperatures in the summer.

Increasing summer temperatures, and a doubling or tripling of days over 90 °F by mid and late century respectively, increases heat-related morbidity (cramps, rash, exhaustion, fainting, stroke) and mortality (cardio vascular disease, renal failure,

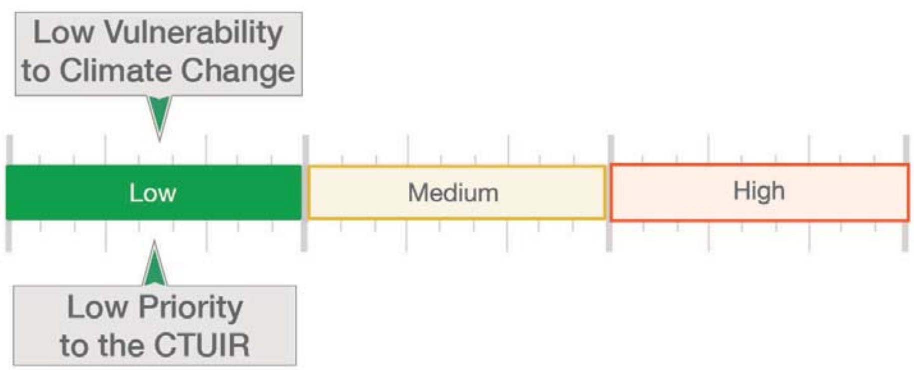
[86] Institute for Tribal Environmental Professionals, Climate Change and Human Health Factsheet, April 2013.
[87] Lynn K., Daigle J., Hoffman J., Lake F., Michelle N., et al. The impacts of climate change on tribal traditional foods. *Climatic Change.* 4 March 2013 DOI 10.1007

respiratory deaths, strokes), particularly among vulnerable populations (elderly, children, pregnant, chronically ill, low-income, socially isolated, or outdoor workers)[88, 89, 90]. Tribal residents may be vulnerable simply because they live in more rural areas making them more isolated. Many tribal members may not have access to air conditioning or cooling stations (formal or informal, i.e. the casino, libraries, community centers, etc.).

According to the Umatilla Hazard Mitigation Plan, extreme heat events are not very common in Oregon. However, there are days every year above 100 °F. Many of the highest single-day temperatures for the CTUIR-area were recorded at Umatilla, on the Columbia River, not far from Pendleton. Before the Umatilla weather station closed in 1965, it had recorded temperatures of 117 °F, 115 °F (three times) and 114 °F (four times). However, the fact that these temperatures occurred does not necessary translate into disasters for two reasons. First, these conditions occurred without accompanying high humidity and second, they were not prolonged. Most heat waves in Oregon are short-lived[74].

There was recognition during the assessment process that actions need to be taken to ensure that cooling stations are available and increase access to air conditioning. However, it was clear that the group felt that the Tribes were adequately prepared to handle any forthcoming heat waves.

Increases in Crime



There is a growing body of literature that demonstrates a connection between increasing rates of crime during heat waves. The critical climate concern is increases

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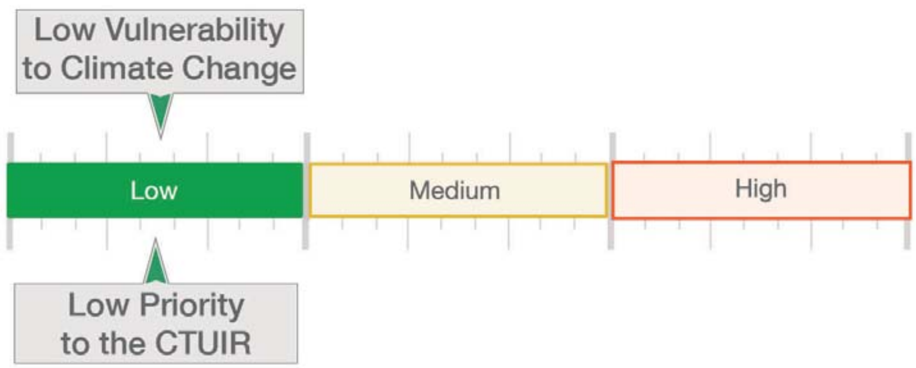
[88] Oregon Climate and Health Profile Report, 2014. *Retrieved from:* http://public.health.oregon.gov/HealthyEnvironments/climatechange/Documents/oregon-climate-and-health-profile-report.pdf

[89] Centers for Disease Control and Prevention, 2015. Climate Change and Extreme Heat Events. Retrieved from: http://www.cdc.gov/climateandhealth/pubs/ClimateChangeandExtremeHeatEvents.pdf

[90] United States Environmental Protection Agency, 2015. Human Health Impacts and Adaptation from Climate Change. *Retrieved from:* http://www.epa.gov/climatechange/impacts-adaptation/health.html#impactsheat

in summer temperatures (heat waves). The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century and triple by the 2080s (both RCP 4.5 and 8.5 scenarios). Higher temperatures have been shown to increase metabolic "fight or flight" symptoms and increase violence and resulting crime. Studies have shown an increase of 9 murders or assaults per 100,000 people with every 2 °F increase in temperature[89]. A 2013 landmark meta-analysis of 60 of the most rigorous studies on the issue (worldwide) found that for every standard deviation change in climate toward warmer temperatures, the frequency of interpersonal violence increases 4% and the frequency of intergroup conflict rises 14%[91]. Despite research documenting increases in crime with increasing temperatures, the project team felt that existing emergency response and public safety efforts were well run and able to prepare for and respond to these incidents. That said, there was recognition that should crime increase, these efforts would have to be enhanced with more police protection and enhanced emergency response.

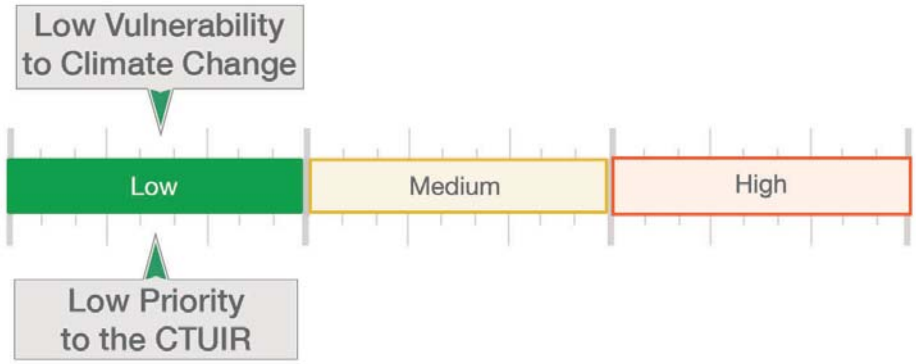
Availability of Water (Short-term)



The background detail and climate concerns regarding availability of drinking water have been discussed previously in this report. During the vulnerability assessment exercises, the project team determined that there were differing challenges related to short- and long-term provision of drinking water. In the short-term, the Tribes are adequately prepared to meet their municipal water needs. Municipal water supplies are buffered from short-term droughts and fluctuations in precipitation since they are primarily drawn from aquifers that are more influenced by long term recharge rates than seasonal or annual changes in precipitation.

[91] Hsiang S., Burke M. and Miguel E. Quantifying the Influence of Climate on Human Conflict. *Retrieved from:* *http://users.clas.ufl.edu/prwaylen/geo3280articles/Climate Change and Conflict.pdf* 1 August 2013. Page 1-12.

Vector Borne Diseases



Vector borne diseases are often cited as an emerging or imminent climate-related health effect. The vector borne diseases typically influenced by changing climate conditions are mosquito-related (e.g., West Nile) and tick-related (Lyme disease)[89].

The key climate concerns affecting the spread of these diseases are increasing *winter* temperatures, which are projected to increase by between +3 °F and +8 °F by the 2050s (RCP 8.5), and the resulting diminished die off mosquitos, ticks or other vectors during the cold winter months, increasing exposure and overall numbers of ticks and mosquitos.

Although it is frequently assumed that mosquito-related illnesses increase during flooding (more water = more mosquitos), it is actually during declines in summer precipitation (drought) when increases in vector-borne illnesses occur. For the "business as usual" emission scenario (RCP 8.5), average maximum *summer* temperatures are projected to increase by between +3 °F and +10 °F by the 2050s. The number of days that exceed 90 °F in the *summer is expected to double* from 13 to 26 days by mid-century. Summer precipitation is more varied (-40% to +24% during the 2050s) but may decrease create drought-like conditions. These changes will create conditions favorable for increases in the incidence of vector borne diseases.

When natural water sources dry up, two species critical to carrying out the transmission of these vector borne illnesses—birds and mosquitos—concentrate in more urban areas where humans provide water and food during drought times. As these conditions occur, birds may flock to more urban areas due to the fact that humans store more water and food scraps and waste can be a food source for birds. Because of this, there is increased interaction between birds and mosquitos which breed in these water storage areas. It is this increased interaction that enhances the ability for vector-borne diseases to thrive[92].

[92] Palermo, E. An Unexpected Health Consequence Of The California Drought, 7/23/15. *Retrieved from:* http://www.huffingtonpost.com/entry/an-unexpected-health-consequence-of-the-california-drought_55b11203e4b08f57d5d3d480?kvcommref=mostpopular

According to a Umatilla County Health bulletin from August of 2014, "*West Nile has yet to be detected but remains a threat,*" providing some context about the existing potential vulnerability for the Tribes[93]. Similarly, recent assessment of the incidence of Lyme disease in the state of Oregon (Figure 19) shows a minimal threat as ticks that cause Lyme disease were not found (2008 data), and the rate for Umatilla County is the same as the Willamette Valley: 0.23 per 100,000 people.

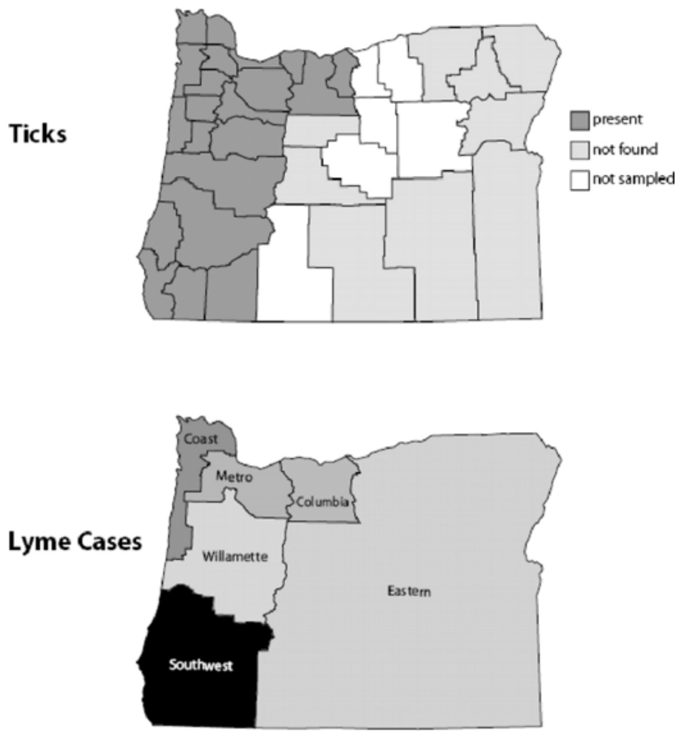


Figure 19: Presence of Ticks and Incidence of Lyme disease by region in Oregon, 2008. The top map displays the known distribution of ticks. The bottom map summarizes the Oregon adjusted annual case rate. The highest rate of 1.28/100,000 population is found in the southwestern portion of the state (in black). The lowest rate of 0.23/100,000 runs north to south through the Willamette Valley (light gray)[94].

The project team rated vector borne diseases a low vulnerability and low priority due to limited exposure to these diseases and the existing disease monitoring and communication systems that are in place and functioning well. Continued education and communication about outbreaks will be needed.

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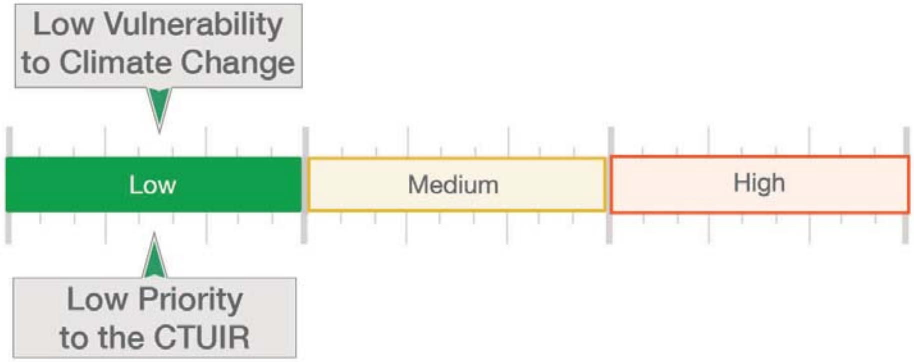
[93] Umatilla County Health Department, West Umatilla Mosquito Control District Media Release, August 20, 2014. *Retrieved from:* http://www.co.umatilla.or.us/News/releases/Press%20Release%20WNV%208-20-14.pdf

[94] Doggett J.S., Kohlhepp S., Gresbrink R., Metz P., Gleasves C., and Gilber D. Lyme Disease in Oregon. *Journal of Clinical Microbiology*, 2008: 46 (6), 2115-2118. *Retrieved from:* http://jcm.asm.org/content/46/6/2115.full

Population Dynamics



Movement of populations because of changing climate conditions is anticipated as some areas of the country will be less habitable or desirable over time. This notion has gained increasing attention in the media and the literature[89,95]. Population movement or climate driven migration could increase strain on natural resources due to climate refugees moving to one area. There is no literature on this subject for Eastern Oregon, but some expectation can potentially be extrapolated from work completed in other parts of the region. According to a 2011 report, the baseline expected growth of population for the Willamette Valley of the United States between 2011-2040 is 2.7 million to 3.9 million without climate-related migration. This baseline population growth condition creates challenges for land use and planning, which must be addressed[96]. What is difficult to say is whether or not the migration and population-related strains on resources and public safety have a direct, causal relationship with a changing climate. According to a recent paper focusing on climate related migration in Puget Sound, the issue is complex and depends on the climate element being considered (e.g. increased drought or floods).

Further,

> *A synthesis of this information suggests that a sudden and dramatic population increase is unlikely to occur, given the nature of anticipated climate impacts in Puget Sound's migration system and the fact that migration into Puget Sound is driven primarily by economic factors. However, climate change could have some effect on population flows, both directly and indirectly through its economic impacts, and population forecasting currently does not fully account for these possible consequences (pg. 2)*[97].

[95] Lang, J. Look Out Oregon for a Global Warming Land Rush. *The Oregonian,* October 5, 2008. *Retrieved from:* http://www.oregonlive.com/environment/index.ssf/2008/10/look_out_oregon_for_a_global_w.html
[96] USP 594: Planning in the Pacific Northwest, Fall 2011. *Environmental Migrants and the Future of the Willamette Valley. Retrieved from:* https://www.pdx.edu/usp/sites/www.pdx.edu.usp/files/Environmental_Migrants.pdf
[97] Saperstein, A. 2015. Climate Change, Migration, and The Puget Sound Region: What we Know and How We Could Learn More. Report prepared for the University of Washington Climate Impacts Group. The Daniel J. Evans School of Public Policy and Governance, University of Washington, Seattle.

Climate migrants and their strain on the public infrastructure for the CTUIR could be considered, but the impacts appear to be much smaller than the known strain from a growing population currently living in the area.

Forest Health & Welfare

Photo credit: CTUIR DNR-Range Ag & Forestry staff, undated.

Near the end of the working group meetings, it became apparent that a critical Key Item of Concern had not been evaluated: forest health and welfare. Forest health and welfare in many ways is integrated throughout many of the KICs (described above) and directly and indirectly influences the health and vitality of Chinook salmon, cous, huckleberry, and elk, as well as the prevalence and intensity of wildfires. It also indirectly affects water quality, storm water run-off, and flooding. In many ways it underlies the ultimate vulnerability rankings of the other KICs. However, this Key Item of Concern was considered critical enough that it should receive its own discussion section, even if was not evaluated as part of the vulnerability assessment. Given this, a summary of the potential climate-related impacts for the surrounding forests is provided to highlight the importance of this resource to the CTUIR.

Vegetation and forest models of the Pacific Northwest offer differing projections of how climate change will affect forests. Increasing concentrations of CO_2 in the atmosphere have the potential to increase tree growth rates, but it is unknown whether trees will flourish under those conditions or die off due to projected changes in other conditions (such as higher temperatures and lower summer precipitation leading to drought). According to the U.S. Department of Fish and Wildlife, Pacific Region,

> *The likeliest scenario seems to be that increased forest growth could occur during the next few decades, but that at some point temperature increases would overwhelm the ability of trees to make use of higher winter precipitation and higher CO_2*[98].

Despite the varying projections of what will occur, there will be large ecological disturbances as various species adapt to the warming climate with less snowpack. According to the Blue Mountains Adaptation Partnership,

> *Tree growth in energy-limited portions of the landscape (high elevations, north aspects) may increase as the climate warms and snowpack decreases, whereas tree growth in water-limited portions of the landscape (low elevations, south aspects) will probably decrease (pg. 1)*[99].

Secondary climate-related impacts, such as infestation from mountain pine beetles, are likely to be more prevalent and able to move to higher elevations with warmer temperatures, making pine trees more vulnerable to attack[100]. Further, as was previously mentioned under the wildfire impacts, increases in summer drought conditions (caused by increasing temperatures and decreasing precipitation), are likely to result in more frequent and/or intense wildfires. According to one report, "the area burned by fire regionally is projected to double by the 2040s and triple by the 2080s" for the Pacific Northwest[101]. Figure 20 also shows this increase in both projected burn area and probability in mountain pine beetle survival for the Umatilla region.

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[98] United States Fish and Wildlife Service, 2015. Climate Change in the Pacific Northwest. *Retrieved from:* http://www.fws.gov/pacific/Climatechange/changepnw.html
[99] Blue Mountains Adaptation Partnership: Vegetation. *Retrieved from:* http://www.adaptationpartners.org/bmap/docs/BMAP_VAP_Vegetation.pdf
[100] The Climate Impacts Group, University of Washington. The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, June 2009. *Retrieved from:* http://www.cses.washington.edu/db/pdf/wacciaexecsummary638.pdf
[101] Ibid.

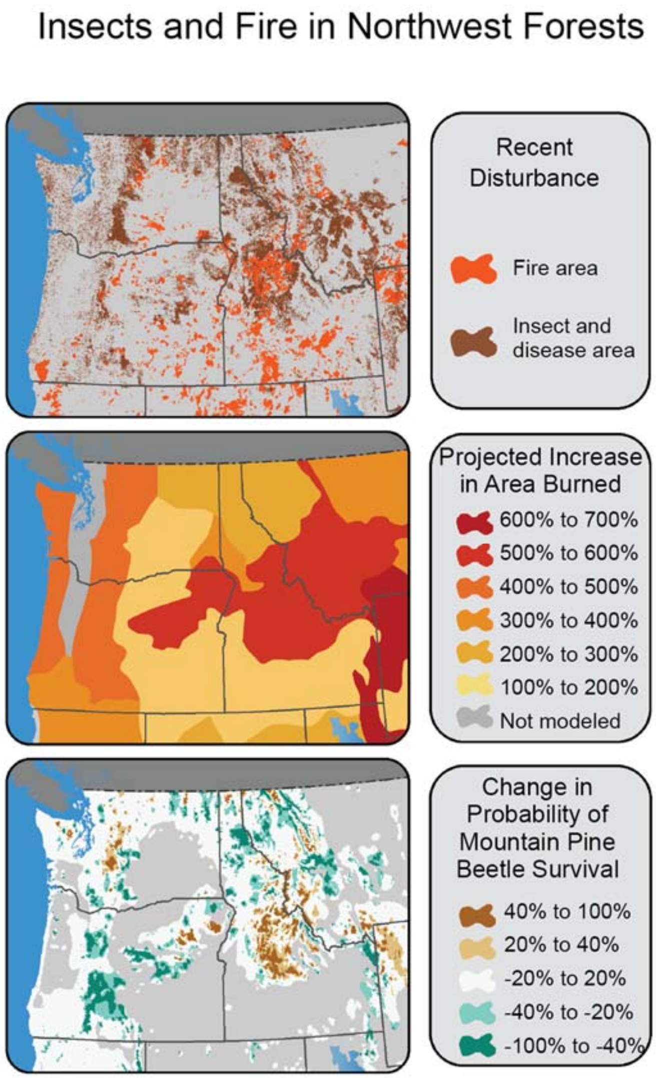

Figure 20: Insects and Fire in Northwest Forests[31].

The potential increased vulnerability or degradation of the forests in the Blue Mountains, which serve as both a cultural and natural resource to the CTUIR, due to projected climate impacts is an area worth considering as the CTUIR moves forward in its climate change work.

4.2 Additional Potential Climate Change Impacts

The impacts of climate change are not limited to the key concerns identified and evaluated in this report. The following potential impacts of climate change are the perspective of the CTUIR Tribes and lie outside the Climate Change Vulnerability Assessment process outlined in this report. They reflect concerns raised by the community and internal conversations about climate change within the CTUIR. They are important to include in this first climate-specific publication from the Tribes.

4.2.1 Traditional Ecological Knowledge

Traditional Ecological Knowledge may be impacted by climate change as landscapes, habitats, and species respond to changing temperature and precipitation patterns. Traditional use areas are likely to migrate along with the affected plant or animal species as described in this report. In more extreme cases, sacred sites could be at risk for damage or deterioration due to erosion from unusually large volumes of moving water. To this end, CTUIR Tribal Members may one day be hunting and gathering in areas not previously used. As such, no historically valid TEK may exist for these new areas of use.

4.2.2 Local Economy

The local economy will also likely be impacted by climate change. The following topics are speculative, based on current climate change induced trends across the United States. Although these are only potential impacts for which limited references are provided, they were included in this report to provide readers with awareness of these issues.

Energy Prices

Energy prices will likely be affected by climate change. Increasing temperatures could increase demand for power and cooling during longer periods of the year[102]. Less water for hydropower and reductions in thermoelectric power generation efficiencies with increasing temperatures can increase energy costs[103]. The cost for transportation could also increase in response to climate change with the imposition of carbon taxes on fossil fuels (See section 4.2.3) in the United States.

Wildhorse Resort and Casino

The Wildhorse Resort and Casino is a pillar of the local economy that relies on tourism. The profitability of the Resort and Casino depends not only its revenue but also its expenses. If energy prices rise and all other factors remain the same, profitability would decrease. Higher energy prices could also decrease tourism for those tourists that can not afford the increased transportation costs.

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[102] Deschenes and Greenstone, 2006. *Retrieved from:* *http://www.econstor.eu/bitstream/10419/74160/1/NDL2006-006.pdf*
[103] Ibid.

Agriculture

Farming

Potential economic impacts to the local agricultural industry may occur as crop yields are impacted by a changing climate. According to Deschenes and Greenstone, model estimates indicate a general increase in national profits with increasing temperatures and precipitation, however, state-by-state variation is predicted with some states having substantial gains and others, such as California, experiencing diminished profits[104]. There has already been a clear reduction in California agricultural profits with the current drought. As previously discussed in this report, these impacts are primarily attributed to increasing CO_2 concentration, changing temperatures and growing seasons, and more sporadic weather. Higher energy prices would also increase the costs of agricultural operations [105].

Forest Resources

Biomass collected from the local forest could become increasingly useful as technologies for generating energy from cellulosic debris and forest residues advance. Heat and electricity are potential products for a local market. Further, because biomass has a carbon neutral footprint, these technologies would not encounter the same restrictions and regulations that conventional fossil fuels could face in coming years. Another advantage is that forest management plans that call for thinning will have a valuable added outlet for forest debris that is typically wasted.

4.2.3 Policy

Changes to policy are eventually expected to take place in order to reduce human caused CO_2 emissions. Legislative proposals for taxing carbon emissions are a type of policy change already under consideration in Oregon. These changes include the "Polluters Pay, People Prosper" program sponsored by Oregon Climate[106], which is being proposed on the state level, and the "Carbon Tax"[107] at the federal and international levels. Impacts from passage of these measures would ultimately mean that the price of all goods and services that rely on the use of fossil fuels would rise. In response, these costs will likely be passed along to consumers as prices for everything from power to transportation and shipment of goods increases. Some programs such as "Polluters Pay, People Prosper" will balance the end cost-increase to consumers by offering a dividend (see Appendix 10 for more information).

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104 Ibid.

105 CCSP, 2007. Retrieved from: http://www.fws.gov/southeast/climate/policy/Climate%20USCCSP%20Effects%20on%20Energy%20sap4-5-final-all.pdf

106 Oregon Climate, 2015. *Retrieved from:* http://www.oregonclimate.org/

107 Carbon Tax Center, 2015. *Retrieved from:* http://www.carbontax.org/whats-a-carbon-tax/

Additionally, EPAs Clean Power Plan[108] calls for states to reduce carbon emissions in response to climate change. This too will affect the economy.

[108] United States Environmental Protection Agency, 2015. Clean Power Plan Final Rule. *Retrieved from:* http://www2.epa.gov/cleanpowerplan/clean-power-plan-final-rule

5.0 Recommendations and Next Steps

This project is the first phase of an important three-step climate adaptation planning process that has been developed by the CTUIR.

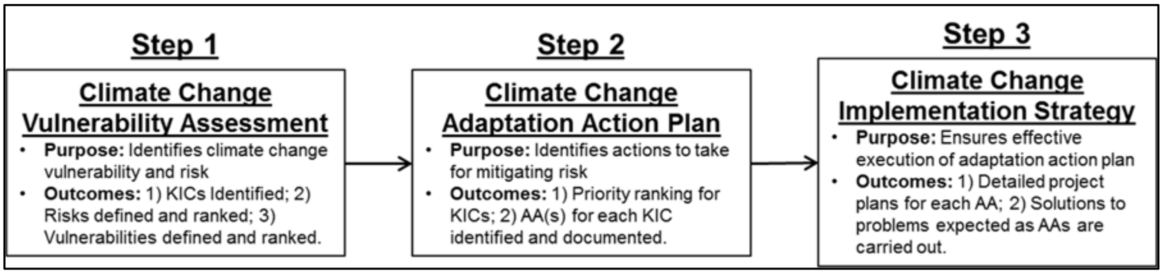

Figure 21: Three-step climate adaptation planning process being implemented by the CTUIR. Step 1 is the climate change vulnerability assessment process described in this report.

By completing this project (Step 1 in Figure 21), the CTUIR has assessed the climate-related vulnerabilities for the Aboriginal Title Lands and prioritized the focus areas for future efforts to reduce vulnerability and build climate resilience. In addition, this assessment has identified specific knowledge and research gaps that can help guide investments and the development of new research projects to help fill those gaps. Based on the results of this assessment, the recommended next steps are:

1) Build on the momentum generated by the project by formally establishing a climate change working group for the CTUIR that includes the members of the project team. Have the team meet quarterly to share information on the work that they are doing related to climate change and continue to build cross departmental collaboration within the CTUIR.

2) Incorporate the results of this assessment into the next iteration of the Hazard Mitigation Plan (currently fall 2015) so that the plan includes not only consideration of historic hazards, but also potential future hazards created by changing climate conditions.

3) Once both the vulnerability assessment and adaptation planning efforts are complete, integrate the plans for reducing these vulnerabilities into the Hazard Mitigation Plan (likely fall 2019) as well as other appropriate planning documents.

4) Seek funding for, or collaborate within existing staffing budgets, the following research efforts:
   - An assessment of stream flow projections which incorporate the projected changes in precipitation: this would involve the development or update of a hydrological model for the area using the daily or ideally hourly

precipitation values for the climate projections (hourly values would require hourly precipitation value in climate model projections) to understand potential changes to stream flows. Of primary concern are: 1) identifying low flow conditions in the summer/fall; 2) characterizing seasonal high flows and potential flooding; and 3) quantifying stream flows and temperatures for salmon.

- Develop and run a forest model to understand and analyze the forest dynamics and potential wildfire risk based on projected changes in temperature and precipitation.
- Develop a monitoring program to evaluate how projected changes in temperature and precipitation are affecting (and could affect) cous & huckleberry plants in traditional gathering sites.
- Develop a CTUIR-specific monitoring program to assess the spread of vectors for public health impacts (vector borne diseases).
- Strengthen extreme heat response procedures through collaboration with community stakeholders and the populations most vulnerable to heat.
- Conduct a detailed groundwater modeling study to look for the specific threshold where the aquifer is not able to replenish itself and identify how changing temperature and precipitation will affect the availability and supply of water.
- Complete additional analysis of the existing downscaled data modeling from this project to include assessment in the change in the number of consecutive days greater than 90 °F, or other thresholds of concern.
- Conduct predictive modeling assessments of First Food resources.

The next phase of the CTUIR's climate work is to develop strategies that will reduce the vulnerabilities identified in this project and help the Tribes prepare for the climate-related impacts as outlined in this report. In some cases, the ideal actions will be things that the CTUIR can do independently. In other cases, the impacts of a changing climate will be felt regionally on the assets, resources, and species that are important to the Tribes. Action to address these changes will require partnerships and collaboration with other tribal and non-tribal communities, local, state, or federal entities and even non-profit or private sector organizations.

Fortunately, the CTUIR has already secured funding for this next phase of its climate preparedness efforts. This funding helps ensure that the CTUIR can build on the foundation created by this project and continues to take a leadership role in helping the region prepare for the impacts of climate change. This current effort and those of the future, build on the long legacy of the Tribes in the region. They have adapted to many changes and will continue to adapt into the future. Being proactive to identify, evaluate, and respond to the impacts of climate change will help ensure that the CTUIR continues to maintain its culture while strengthening the health, economic vitality, and climate resilience of the Tribes.

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