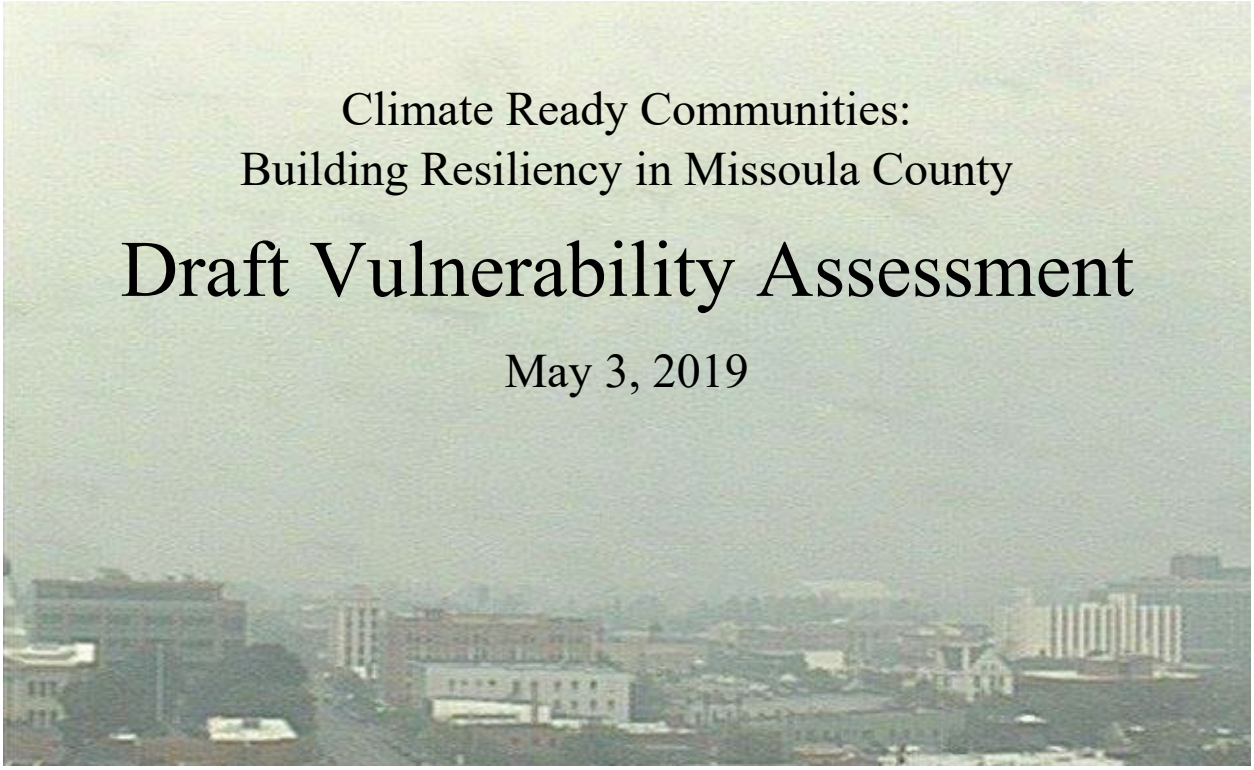


Climate Ready Communities:
Building Resiliency in Missoula County

Draft Vulnerability Assessment

May 3, 2019

Authors**:** Diana Maneta, Eliot Thompson, Amy Cilimburg, Nick Silverman

With huge thanks to the Climate Ready Communities Steering Committee and to the 100+ stakeholders who participated in the December 2018 Vulnerability Workshop

Table of Contents

Climate Ready Communities Project Leads

Diana Maneta, Energy Conservation and Sustainability Coordinator, Missoula County
Amy Cilimburg, Executive Director, Climate Smart Missoula
Chase Jones, Energy Conservation and Climate Action Coordinator, City of Missoula

Climate Ready Communities Steering Committee Members

Adriane Beck, Missoula County Office of Emergency Management
Bonnie Buckingham, Community Food and Agriculture Coalition
Bryce Christiaens, Missoula County Weed District
Donna Gaukler, City of Missoula Parks and Recreation
Heather Harp, Missoula City Council
Paul Herendeen, Missoula Federal Credit Union
Karen Hughes, Missoula County Community and Planning Services
Gwen Lankford Spencer, Sapphire Strategies, Inc.
Alex Leone, Clark Fork Coalition
Laval Means, City of Missoula Development Services
Eran Pehan, City of Missoula Housing and Community Development
Nick Silverman, Adaptive Hydrology LLC
Dave Strohmaier, Missoula County Commission
Shannon Therriault, Missoula City-County Health Department
Laurie Yung, University of Montana

Introduction

Climate change poses many threats to Missoula County's natural ecosystems, human health, economy, built environment, and cultural resources. This Vulnerability Assessment identifies and prioritizes these risks as a first step toward developing strategies to address the most problematic among them. The information it contains was generated by more than 100 local stakeholders involved in such sectors as public health, emergency services, agriculture, forestry, recreation, business, underrepresented communities, and local water, energy, and transportation systems, building from a foundation of climate change projections specific to Missoula County.

This Vulnerability Assessment completes the first phase of a project called ***Climate Ready Communities: Building Resiliency in Missoula County***. This initiative, which is led jointly by Missoula County, the City of Missoula, and Climate Smart Missoula, will continue with the development and implementation of a Climate Resiliency Plan for Missoula County. This planning process generally follows the Climate Ready Communities guidelines developed by the Geos Institute.

As the first step of the project, in the summer and fall of 2018 we assembled a ***Climate and Community Primer***, which brings together climate projections specific to Missoula County as well as information on the possible implications of these projections for the county's natural systems, economy, human health, and cultural resources. The primer also includes three Mid-Century Climate Scenarios for Missoula County which illustrate a range of plausible futures that Missoula County could face within the next 30 years. The primer is available to download at https://www.missoulaclimate.org/resiliency-planning.html.

The climate projections presented in the primer suggest that Missoula County is likely to experience hotter, drier summers; warmer, wetter springs; decreased low-elevation snowpack, and earlier spring runoff. We are already beginning to see the impacts of these changes. The conditions that led to our 2017 fire season and the 2018 flood season are likely to become increasingly common in the coming decades.

In December 2018, we held a stakeholder workshop at which participants were introduced to the climate projections and scenarios, and then broke into 11 sector groups to complete an exercise that involved identifying and prioritizing the climate change risks faced by that sector. The groups prioritized risks using two metrics: (1) how problematic the risk would be in the absence of any action to respond to it; and (2) how difficult it would be to respond to the risk. After the workshop, these two metrics were combined into a color-coded rating, from dark red (greatest concern) to light yellow (least concern).

This Vulnerability Assessment summarizes the information gathered at the workshop. It includes a prioritized list of Missoula County's vulnerabilities in the face of climate change by color-coded rating (pages 5-9), and a narrative description of the vulnerabilities included in the list, organized by climate impact (pages 10-30), followed by a discussion of the implications of these risks for our social and cultural systems and underrepresented groups (page 31). The Appendix includes a graphical depiction of the same vulnerabilities included in the prioritized list, but this time organized according to sector.

This Vulnerability Assessment completes the first phase of a two-phase process. A second stakeholder workshop, planned for late spring 2019, will focus on identifying strategies and solutions to address the highest-priority vulnerabilities identified in this Assessment. The findings from the two workshops will form the foundation of a draft Climate Resiliency Plan, which will be released for public input before being finalized in late 2019. We look forward to beginning implementation of the Climate Resiliency Plan in 2020.

Our Vulnerabilities in the Face of Climate Change

The following table summarizes the risks identified and prioritized by stakeholders at the December 2018 workshop. Each sector group prioritized climate change risks using two metrics: (1) how problematic the risk would be in the absence of any action to respond to it; and (2) how difficult it would be to respond. These two metrics were combined into the color-coded rating displayed here, from dark red (greatest concern) to light yellow (least concern). Within color category, risks are not ranked but rather listed alphabetically by sector. See the Appendix for more details on how the color-coded rating was determined.

Sector	Climate Impact	Vulnerability
Agriculture	Smoke	Health impacts on farmers
Buildings	Smoke	Buildings do not adequately keep smoke out
Buildings	Heat	Building stock is ill-prepared for extreme heat
Emergency Services	Wildfire	Increased draw on resources
Emergency Services	Wildfire	High potential for loss of life
Emergency Services	Various	Disruption of communication systems due to fire, extreme weather events
Energy	Wildfire	Damage to utility infrastructure
Health	Heat, Smoke	Increased mortality due to cardiovascular and respiratory stressors
Health	Various	Increased healthcare costs
Health	Smoke	Destabilization of people with existing mental health impacts
Water Infrastructure	Drought	Unreliable water supply
Water Infrastructure	Drought	Lack of dilution water for wastewater treatment
Agriculture	Smoke	Delay in crop development
Aquatic Systems	Heat	Increased evapotranspiration
Aquatic Systems	Various	Hydrologic disconnection
Aquatic Systems	Reduced streamflow	Increased competition among water users
Aquatic Systems	Reduced streamflow	Increased stress on aquatic species
Aquatic Systems	Flooding	Increased risk of contamination
Aquatic Systems	Various	Changes in hydrology/storage capacity

Aquatic Systems	Flooding	Reduction in aquatic species' adaptive capacities
Business, Recreation & Tourism	Variability	Climate variability makes business investment difficult
Business, Recreation & Tourism	Climate migration	Resource strain due to climate migrants
Business, Recreation & Tourism	Flooding	Reduced tourism/spending due to flooding
Business, Recreation & Tourism	Reduced snowpack	Reduced winter tourism/spending
Business, Recreation & Tourism	Reduced streamflow	Reduced tourism/spending due to reduced streamflow
Business, Recreation & Tourism	Wildfire, Smoke	Reduced tourism/spending due to fire and smoke
Business, Recreation & Tourism	Smoke	Reduced employee health and wellness
Emergency Services	Smoke	Impact of smoke on first responders
Emergency Services	Wildfire	Need for evacuations and places to shelter evacuees
Energy	Heat	Increased peak load
Energy	Climate migration	Increased demand for energy
Forests and Terrestrial Ecosystems	Various	Changes to ecosystem type (forest to grassland/shrubland)
Forests and Terrestrial Ecosystems	Various	Ecosystem effects of changes in amount/timing of water availability
Forests and Terrestrial Ecosystems	Various	Expansion of invasive species
Forests and Terrestrial Ecosystems	Various	Increases in tree mortality and reduction in regeneration
Health	Heat	Increased violence and substance abuse
Health	Smoke	Increased incidence of respiratory and cardiovascular problems
Health	Flooding	Waterborne illness
Health	Flooding	Vector-borne illness
Health	Various	Mental health impacts
Land Use Planning & Transportation	Wildfire	Community costs of development in the WUI
Urban Trees	Extreme weather	Damage to urban trees
Water Infrastructure	Drought	Availability of future water rights
Water Infrastructure	Flooding	Increased wastewater treatment plant flows
Water Infrastructure	Flooding	Acute and chronic physical infrastructure damage

Agriculture	Heat	Heat stress on crops and livestock
Agriculture	Drought	Decrease in non-irrigated production
Agriculture	Wetter springs	Delayed planting
Agriculture	Wetter springs	Increased pest/fungal pressures
Agriculture	Variability	Farmer mental health impacts
Agriculture	Wetter springs	Intense rain damages crops
Agriculture	Smoke	Lower attendance at farmers' markets
Agriculture	Variability	Mismatch between crops and local conditions
Agriculture	Variability	Early/late freezes
Aquatic Systems	Reduced streamflow	Increased water temperature
Aquatic Systems	Flooding	Increased invasive species
Buildings	Wildfire	Buildings vulnerability to wildfire
Buildings	Flooding	Buildings vulnerable to flooding
Buildings	Climate migration	Increased demand for buildings
Emergency Services	Smoke	Increased draw on resources
Forests and Terrestrial Ecosystems	Various	Altered productivity
Forests and Terrestrial Ecosystems	Various	Impacts to fauna of habitat loss and fragmentation
Forests and Terrestrial Ecosystems	Climate migration	Increased development and recreation pressure
Forests and Terrestrial Ecosystems	Various	More forest pathogens
Health	Various	Missed school/work days and lost wages
Health	Drought	Less available drinking water in rural areas
Health	Heat	Heat stress and increased cardiac health issues
Land Use Planning & Transportation	Drought	Inadequate water to support existing and future development
Land Use Planning & Transportation	Wildfire	Impact to transportation systems
Land Use Planning & Transportation	Drought	Tension between public and private interests
Water Infrastructure	Heat	Increased evaporation of stored water
Water infrastructure	Flooding	Stormwater system inundation

Water infrastructure	Flooding	Well contamination
Agriculture	Heat	Health impacts on farmers
Agriculture	Flooding	Increased soil pollutants
Aquatic Systems	Reduced streamflow	Decreased aquifer recharge
Aquatic Systems	Reduced streamflow	Decreased water quality
Aquatic Systems	Flooding	Changes and reductions to instream/habitat quality
Aquatic Systems	Heat	Increased stress on riparian vegetation
Buildings	Extreme weather	Building damage from extreme weather
Business, Recreation & Tourism	Various	Decline in timber products and tourism due to deforestation
Business, Recreation & Tourism	Smoke	Shifted consumer patterns
Emergency Services	Flooding	Increased draw on resources
Emergency Services	Smoke	Need for evacuations and places to shelter evacuees
Emergency Services	Wildfire	Impact of fire on first responders
Emergency Services	Heat	Increased draw on resources
Emergency Services	Extreme weather	Slower response time
Energy	Drought	Reduced hydropower production
Forests and Terrestrial Ecosystems	Various	Increase in wildlife disease
Forests and Terrestrial Ecosystems	Various	Impacts to flora of habitat loss and fragmentation
Forests and Terrestrial Ecosystems	Various	Changes to species composition, species richness, genetic diversity
Health	Various	More difficult to exercise
Health	Smoke	Inadequate capacity in healthcare system
Health	Heat	Social isolation
Health	Flooding	Trauma and drowning
Health	Wildfire	Trauma and burns
Health	Flooding	Wastewater treatment plant overload/septic system failures
Health	Wetter springs, drier summers	Asthma exacerbated by pollen, dust, mold

Land Use Planning & Transportation	Various	Impact to roads and bridges
Land Use Planning & Transportation	Flooding	Impact to homes and properties
Land Use Planning & Transportation	Wildfire, Flooding	Tension between private and public interests
Land Use Planning & Transportation	Heat	Heat island effect
Urban Trees	Heat	Urban tree mortality due to heat
Water Infrastructure	Wildfire	Reduction of surface water quality due to runoff sediment
Agriculture	Drought	Less irrigation water
Agriculture	Wildfire, Flooding	Crop loss
Agriculture	Milder winters	Pest/disease increases
Agriculture	Drought	Decreased nutrition of livestock feed
Agriculture	Flooding	Loss of topsoil
Aquatic Systems	Flooding	Increased erosion
Buildings	Heat	Decreased useful life of buildings
Health	Heat	Lost sleep
Water Infrastructure	Wildfire	Power outages affecting water infrastructure
Water Infrastructure	Climate migration	Increased system demand due to climate migrants
Agriculture	Drought	Increased cost for irrigation
Agriculture	Wetter springs	Soil compaction
Aquatic Systems	Heat	Increased water-based recreation
Energy	Flooding	Service disruptions due to flooding

Description of our Vulnerabilities

We have identified seven primary climate impacts for Missoula County:

1. Wildfires
2. Wildfire smoke
3. Higher temperatures
4. Wetter winters/springs and flooding
5. Drier summers and drought
6. Climate variability
7. Climate migration and population changes

In the following narrative sections, we briefly describe the implications of these impacts for key sectors of our county. This narrative is followed by an Appendix in which color-coded grids are organized by the sectors themselves. It is important to keep in mind that although we describe these risks one by one, in the coming decade, we may experience impacts concurrently (e.g., wildfire smoke and higher temperatures) and/or in quick succession (e.g., heavy precipitation and flooding in the spring followed by dry conditions and wildfires in the summer), which will be much more challenging than dealing with them in isolation.

Following the discussion of these seven climate impacts, we discuss the implications of these changes for our county's social and cultural systems and underrepresented groups (page 31). The impacts we face, in their entirety, have the potential to increase inequity, erode community ties and cultural identities, and divert local funding and resources. It will be essential that the strategies we develop consider and address these threats to our social fabric and the most vulnerable among us.

Wildfires

Wildfire is a naturally occurring phenomenon, and many ecosystems rely on fire at regular intervals to clear the forest floor, kill disease, and allow new plants to establish. In our region, the frequency and severity of fires vary over forest types and location. Over the last century, the policy of attempting to suppress wildfires has, in some areas, resulted in denser forests that, when they burn, do so much more intensely and destructively than they might have in the past. At the same time, expansion of the Wildland-Urban Interface (WUI) and increased development in the WUI put more people and structures at risk from wildfire.

Missoula County is ranked in the 89th percentile among all counties in the western U.S. for wildfire risk to *existing development* in the WUI. The county is ranked in the 98th percentile for wildfire risk to *potential development*, reflecting the large amount of undeveloped, forested private land bordering fire-prone public lands.

An increase in the frequency and severity of wildfires is expected in the coming decades as a result of both climate change and, in some areas, increased forest density due to the past century of fire suppression. Historically, fire frequency and acreage burned is directly associated with

increases in summer temperatures and decreases in summer precipitation. As Missoula County's climate warms and as summers become drier, wildfires are likely to increase in size and frequency and the fire season is likely to become longer. See the ***Climate and Community Primer*** for details and references.

This section describes vulnerabilities directly associated with wildfire. Vulnerabilities related to wildfire smoke are described in the following section.

Forests and Terrestrial Ecosystems

Over time the size and severity of wildfires will likely impact the ability of forests to recover after fires, leading to a transition from forests to grasslands or shrublands at low elevations. Terrestrial invasive species thrive in areas that have been recently disturbed by wildfires and will likely expand their range in the county. Increased erosion and soil loss will result from rain following wildfires.

Emergency Services

Addressing more frequent and intense wildfires—and the associated potential for loss of life—is likely to be the greatest climate-related challenge for Missoula City and County emergency services. Rural parts of the county that face the greatest wildfire threat are served by a combination of paid and volunteer firefighters, and volunteer fire departments throughout the county are understaffed and shrinking.

Larger fires and longer fire seasons, combined with continued development in the WUI, will increasingly strain these limited resources and increase the need for emergency planning and communication. More fires will also increase personal risk to firefighters. In addition to firefighting, there will be increased need to coordinate evacuations and shelter evacuees. Loss or disruption of communication systems, particularly cell phone service, has the potential to compound the difficulty of responding to wildfire by making it more difficult to notify affected residents.

Agriculture

Agricultural producers, in particular pasture lease-holders on forest lands, will be at increased risk of crop loss from fire.

Buildings

The vulnerability of a building to being destroyed by wildfire depends on where the building is located, the surrounding landscaping, and construction of the building itself. In terms of location, buildings in the WUI are at greatest risk. Clearing vegetation at least 100 feet from the building can help protect homes and small businesses in the WUI. The use of ignition resistant building materials and techniques reduces the vulnerability of a home to wildfire.

Business, Recreation and Tourism

Wildfires have direct economic impacts through property loss and firefighting costs. They also limit opportunities for outdoor recreation both directly – in areas affected by fire – as well as indirectly, by reducing air quality over a much larger geographic area (see Wildfire Smoke section).

Energy

Utility infrastructure has the potential to start wildfires, and also to be damaged by fire, causing service disruptions for utility customers. Residents of the WUI are most likely to be affected by these outages, though infrastructure damage could result in large scale outages affecting much of the city and county.

Human Health

In addition to the far-reaching health impacts of wildfire smoke (see that section), wildfires themselves are a direct threat to the health and safety of people in affected areas. People who live in the WUI are at greatest risk of burns and trauma, as are firefighters and other first responders. Survivors of traumatic events such as wildfires are at risk of mental health impacts such as anxiety and depression. In addition, fires can damage homes and property and cause people to miss school and work and to lose wages. These economic impacts can lead to health problems by further increasing anxiety and stress and/or by preventing people from meeting their basic needs. This is particularly likely for minimum wage workers and people already experiencing financial stress.

Land Use Planning and Transportation

Nearly all the development in Missoula County outside of the urban core is within the WUI and therefore particularly vulnerable to wildfire. As the county population expands and wildfire risk continues to increase, there will be increasing tension between private interests and the public good. For example, the rights of individuals to build their homes where they'd like may directly increase the cost to society of protecting those homes when they are threatened by wildfire.

Transportation systems are also impacted by wildfire, which is a particular problem for people in rural areas who are dependent on a single transportation route for evacuation, commerce, and emergency response.

Water Infrastructure

Wildfires lead to soil erosion by destroying vegetation that limits runoff and damaging the soil's ability to absorb water. Eroded soil and ash flow into streams and rivers, degrading surface water quality. This is an issue for parts of Missoula County, such as the Seeley Lake area, that rely on surface water for their drinking water. Loss of power from damaged power lines also poses a risk to water infrastructure (pumping) in rural communities and areas without power redundancy.

Wildfire Smoke

As Montana's climate warms and summers become drier, wildfires are likely to increase in frequency and intensity (see Wildfire section). More wildfires in Montana and the west, and a longer wildfire season, will mean more days of unhealthy air quality for Missoula County residents. Most Missoula County residents live in mountain valleys, and the nature of the topography increases residents' exposure to harmful pollution. In mountainous areas, cold air flows downhill and pools in valley floors every night, creating a temperature inversion that traps air pollutants near ground level in a layer of cold of air. The pollutants can't leave the area until the cold layer of air warms back up. This becomes particularly problematic when nearby fires send intense amounts of smoke into the mountain valleys—trapped smoke can quickly create unhealthy conditions that last for hours or days.

Human Health

Studies have found strong associations between exposure to wildfire smoke and worsening of respiratory diseases like asthma and chronic obstructive pulmonary disease (COPD), as well as increased incidence of respiratory infections like bronchitis and pneumonia. Some studies have also found associations between wildfire smoke and cardiovascular problems like heart attacks and strokes. Infants and children, older adults, people with existing respiratory or cardiovascular diseases, and outdoor workers are particularly vulnerable to wildfire smoke. Children are especially vulnerable because their lungs are still developing and because they breathe more air per pound of body weight than adults do. See the ***Climate and Community Primer*** for further details and references.

In addition to its immediate physical health impacts, smoke has the effect of exacerbating chronic health conditions, limiting outdoor activities, and increasing isolation. All of these factors can contribute to increased stress and anxiety, exacerbating mental health conditions and substance abuse.

Wildfire smoke makes exercising outdoors inadvisable, with worrying implications for physical health and obesity rates, particularly among people who lack the time and money to find indoor places to exercise. Even indoor exercise can be inadvisable during periods of thick wildfire smoke unless the indoor space has air filtration sufficient to remove fine particulate matter, which most buildings currently do not.

The health impacts of wildfire smoke in combination with the health impacts of other projected climate changes (discussed in other sections) will put increased pressure on the healthcare system, which is already capacity-limited and faces difficulty recruiting healthcare providers. These health impacts will also lead to increased healthcare costs for patients and employers.

Emergency Services

More frequent and longer periods of wildfire smoke will increase the demand on first responders and emergency medical services, which are already stretched thin. A study of more than 1

million emergency room visits in California found a spike in ER visits for heart attack and stroke, as well as breathing problems, during periods of dense wildfire smoke. For adults age 65 and older, the rate of ER visits for heart attack increased 42 percent during periods of dense smoke. In Missoula and Powell counties, the number of respiratory-related emergency room visits more than doubled between the unexceptional 2016 fire season and the record-setting 2017 season, from 163 to 378.

The Missoula City-County Health Department recommended evacuation of the entire town of Seeley Lake in 2017 due to wildfire smoke, and there may be an increased need for such evacuations in the future. Emergency services personnel will be needed to coordinate evacuations and shelter refugees.

In addition, firefighters and other first responders are particularly vulnerable to the health impacts of wildfire smoke described above, due to prolonged smoke exposure.

Agriculture

Wildfire smoke will have particularly severe impacts on farmers and ranchers due to the outdoor nature of their work. In addition, many small farmers rely on selling their produce at outdoor farmers' markets, and their revenues suffer when attendance at farmers' markets drops due to wildfire smoke. By obscuring sunlight, smoke also has the effect of delaying the development of fruiting crops, a particular problem in Montana due to our short growing season.

Buildings

While public health officials often recommend that people stay indoors during periods of thick wildfire smoke, most buildings do not do an adequate job of keeping smoke out. Even in new, state-of-the-art commercial buildings, standard air filters (classified as MERV 8) do not filter out the fine particulate matter that is the most harmful component of wildfire smoke, and few residents or commercial buildings have HEPA portable air cleaners. This is most problematic in the case of homes, schools, and public buildings that should be available as respite places during episodes of wildfire smoke.

Business, Recreation and Tourism

The businesses impacted most directly by wildfire smoke will be those involved in summer recreation and tourism. For example, a 2015 study of the impact of climate change on Montana's outdoor economy estimated that visitation to Montana's two national parks will decline by one-third as a result of increased wildfires and smoke, resulting in the loss of approximately 11,000 jobs in the recreation and tourism industry statewide. Businesses in the town of Seeley Lake suffered losses in the summer of 2017 when visitors canceled their plans due to thick wildfire smoke. These outcomes are not always straightforward, however; for example, Glacier National Park experienced record attendance in 2017 despite wildfires and smoke.

The economic impacts of wildfire smoke are not limited to the recreation and tourism industries. Smoke forces people indoors, reducing overall consumer spending and/or shifting consumer

spending patterns (for example, shifting from in-person to online purchases), affecting a wide variety of local business owners.

The need to cancel or reschedule summer and fall athletic events and festivals will also impact the local economy. Beginning in 2019, the Missoula Marathon was rescheduled from mid-July to late June due to concerns about wildfire smoke. Other events, both public and private (e.g. weddings) may follow suit, scheduling in early summer to avoid the risk of wildfire smoke and resulting in an overall contraction of the summer business season.

Local businesses will also be affected by declines in the health and wellness of their employees, and associated increased healthcare costs.

Higher Temperatures

By mid-century, Missoula County's average annual temperature is projected to increase by about 3-5°F, with the greatest temperature increases projected to occur in July, August, and September. As the average temperatures rise, the average number of hot days (> 90°F) per year is projected to increase 12-20 days by the middle of the century. See ***Climate and Community Primer*** for additional details.

Forests and Terrestrial Ecosystems

Increasing temperatures will likely increase the spread and impact of forest pathogens including fungi and insects. Warmer winter temperatures, in particular, are likely to allow mountain pine beetles and other bark beetle species to proliferate across Missoula County and expand their range to higher elevations. If continued large-scale bark beetle outbreaks occur, this, along with reduced regeneration due to climate change, is projected to lead to a substantial decline in the area covered by forest in Missoula County.

Warmer temperatures also have the potential to alter basic phenological processes that result in mismatches between species. For example, the timing of host plant flowering and pollinator activity may be out of sync, and changes in the timing of plant growth may affect foraging animals. Plant and animal species better adapted to warmer temperatures may outcompete local species, especially as other climate impacts continue to displace native flora and fauna.

Aquatic Systems

Higher air temperatures lead to higher water temperatures and increased evapotranspiration, exacerbating lower summer streamflows caused by earlier spring runoff (see Drought and Drier Summers section). Higher river temperatures will force temperature-sensitive species like bull trout and cutthroat trout to move upstream to cooler water, shrinking the size of their habitat.

Hotter summers and decreased streamflows will cause some smaller streams to dry up altogether for part of the year, increasing stress on riparian vegetation and aquatic species. With vegetation loss comes reduced shading of the stream, resulting in even higher water temperatures and

further reducing water levels. Loss of riparian vegetation can also lead to increased hillslope runoff and erosion.

Hotter summers will increase demand for water-based recreation, with the potential for increasing stress on aquatic plants and animals. For example, heavy use often results in the creation of unofficial river access trails, resulting in decreased vegetation and increased erosion. This is an ongoing problem on the Clark Fork River in Missoula and has the potential to worsen with increased river recreation.

Agriculture

Warmer weather will have some **positive impacts** on Missoula County's agricultural sector by increasing the length of the growing season (later fall freeze and earlier spring thaw), creating opportunities for new crops such as stone fruits, grapes, melons, and corn. The longer growing season may also increase revenues for alfalfa and hay producers by allowing for additional cuttings during the growing season. Missoula County agricultural producers report that there is already a shortage of farm labor during the growing season, and a longer season may make this challenge more acute by increasing labor needs.

However, hotter summers will make outdoor working conditions more difficult for farmers and ranchers, particularly in combination with increased wildfire smoke. Heat can also stress crops and reduce yields, particularly for cool weather crops such as spinach, lettuce, and peas. Heat stress in livestock affects animal growth and reproduction and can inflict heavy economic losses on ranchers. Milder winters can encourage the proliferation of pests and diseases that affect crops. Heat also exacerbates the impacts of drought and drier summers on agriculture by increasing evapotranspiration rates.

Human Health

Hotter summers increase the risk of heat stress and heat-related cardiac issues (heart attack and stroke), particularly among older adults, outdoor workers, people without access to cool indoor spaces, and people with chronic health conditions. These risks are exacerbated in the urban area since buildings and paved surfaces heat up faster than natural landscapes. This is known as the 'urban heat island' effect. The urban heat island effect can be exacerbated by increased use of air conditioners, since air conditioners release heat from inside buildings to the outdoors.

In addition to high temperatures during the day, those without air conditioning may suffer from sleep deprivation as average nighttime temperatures increase. Wildfire smoke combined with heat can be particularly problematic, since smoke discourages people from opening windows at night to cool their homes. Sleep loss can cause a range of health problems, including a weakened immune system.

High temperatures can discourage exercising, and in some cases make outdoor exercise inadvisable. This has worrying implications for physical health and obesity rates, particularly among people who lack the resources to find indoor places to exercise.

Extreme heat, especially for long periods of time, also negatively impacts mental health. An inability to escape the heat can lead to or exacerbate multiple mental health conditions, including anxiety, depression, and substance abuse. In addition, extreme heat can lead to social isolation, even for those with the ability to escape the heat. Rural residents, the elderly, those with existing mental health conditions, and mobility challenged individuals are particularly vulnerable to increased social isolation as a result of extreme heat. Aside from extreme heat, there is evidence to suggest that warmer weather across all seasons may increase rates of violent crime.

Emergency Services

As extreme heat contributes to and exacerbates health problems, emergency personnel will need to respond to more emergencies. This will require more emergency planning and communication and will further stress the limited resources of Missoula County's emergency services, especially when extreme heat coincides with other extreme events like wildfires. Emergency personnel who are active outdoors are also vulnerable to heat-related illnesses.

Land Use Planning and Transportation

Buildings and paved surfaces contribute to the urban heat island effect, making the Missoula urban area hotter than rural parts of the county. Missoula City and County zoning codes include requirements for off-street parking that have the potential to exacerbate the urban heat island effect by increasing impermeable paved area.

Land use planning and transportation also affect housing affordability and quality, and hence the building and health impacts of high temperature events.

Buildings and Urban Trees/Vegetation

Many homes, schools, and other public and commercial buildings in the county are ill-prepared for extreme heat (i.e. poorly insulated, lacking awnings, not air conditioned), so hotter temperatures will lead to diminished quality of life for building occupants. Heat also degrades building components and accelerates the growth of mold and insect infestations (e.g. termites and cockroaches), all of which decrease the useful life of the building.

Heat can kill urban trees, shrubs, and other plants, especially when combined with less summer precipitation and lack of adequate irrigation. Fewer trees and plants in the urban area decrease shading and exacerbates the urban heat island effect.

Building design and quality, particularly housing, can exacerbate the health effects of heat and smoke events. People living in poor-quality housing may experience increased heat stress, and the people living in the poorest quality housing often have the more limited resources to respond to these stresses.

Water Infrastructure

Higher temperatures will increase evapotranspiration rates across Missoula County, increasing the demand for irrigation. Covenants that require turf grass limit homeowners' flexibility to

convert to less water-intensive landscaping. Increased evaporation will also reduce surface water stored in reservoirs. While most of Missoula County relies on groundwater, this will impact the community of Seeley Lake and a small number of other county residents that relies on treated surface water.

Energy

Hotter summers will increase the demand for air conditioning, leading to increased energy bills for residents and businesses and to an increased overall demand for electricity during hot hours. This has the potential to increase utility costs to supply this increased 'peak load', ultimately leading to even higher costs for utility ratepayers.

Wetter Winters/Springs and Flooding

Climate projections indicate that Missoula County is likely to experience increased year-round precipitation. However, the change in precipitation is not expected to be uniform across all seasons. Winter and spring (and, to a lesser extent, fall) are expected to receive more precipitation, while summers are expected to be drier. Because year-round temperatures will be higher, more precipitation will fall as rain rather than snow, especially at low elevations.

Missoula County's rivers and streams experience regular flooding as a result of excess water from snowmelt and rainfall. Flooding can also be caused by ice jams, which are formed when pieces of floating ice accumulate and obstruct the stream, causing upstream flooding and the potential for flash flooding downstream when the ice jam gives way. Severe wildfires can increase the risk of flash flooding resulting from rainfall runoff over burned areas.

Throughout Montana's history, rain-on-snow events have caused the most severe and destructive floods. Some evidence suggests that warm and wet winter storms originating in the Pacific Ocean will become more severe in the future, likely bringing more rain-on-snow events to Missoula County. Extreme precipitation events (intense rain) are another common cause of flooding in Montana, and climate models project increases in the frequency and magnitude of the most intense precipitation events. See the ***Climate and Community Primer*** for details and references.

Human Health

In an immediate sense, flooding can lead to drowning and physical trauma. In addition, contact with floodwater increases the risk of waterborne illness. Flooding can also lead to wastewater treatment plant overload and septic system failure, further increasing the risk of waterborne illness. Standing water breeds mosquitoes, increasing the risk of vector-borne illnesses like West Nile virus. Mold is a major health concern in buildings that have been flooded, and can lead to respiratory problems and exacerbate existing conditions such as asthma. Wetter springs also

encourage mold growth as well as leading to more pollen, which can likewise exacerbate respiratory problems and allergies.

Flooding can damage homes and property and can cause people to miss school and work and to lose wages. These economic impacts can lead to health problems by increasing stress and anxiety and by preventing people from meeting their basic needs. This is particularly likely for minimum wage workers and people already experiencing financial stress.

Wetter springs make exercising outdoors more difficult, with potential long-term health impacts, especially for people without gym memberships or other opportunities to exercise indoors.

Emergency Services

Missoula County has had six federal disaster declarations for flooding since 1974, including in 2018. Property damage from flooding events in the county between 1969 and 2011 exceeded $14 million.

More flooding will require more emergency planning and communication and will increase the demand on emergency responders (e.g. evacuation and rescue), all of which will strain limited resources.

Flooding and extreme weather events (severe storms and associated winds) can disrupt transportation and communication systems such as roads, bridges, sidewalks, telephone lines, and cell towers, making emergency response more difficult and increasing response time.

Agriculture

Wetter springs can force farmers to delay planting, which can be particularly problematic for longer season crops such as potatoes, peppers, pumpkins, and corn. In addition, the combination of milder winters and cool, wet springs create a conducive environment for many plant pathogens. Producers will need to be more vigilant to avoid soil compaction, since too much traffic on wet soil can do long-term damage to soil structure. Intense rain events can damage annual crops and alfalfa.

Flooding can cause crop loss as well as topsoil loss, which is a particular problem for annual crops. In addition, pollutants in floodwater can be absorbed by crops, posing health risks to consumers and wildlife.

Aquatic Systems and Fisheries

More frequent and severe flooding will change the quality of instream habitats through increased erosion and sediment transport. While small and infrequent flooding is important for aquatic species by moving sediment and forming instream habitat features such as pools and riffles, intense and frequent flooding events can have negative impacts on aquatic ecosystems by not allowing for recovery and adaptation. Increased flooding also increases the risk of contamination for downstream communities. Furthermore, invasive aquatic species can thrive when floodplains and river systems are disturbed because they can outcompete native species in recovery.

When rivers flood more regularly than is natural they can move too much sediment along the river bed which scours the channel bottom and increases the distance from the bottom of the channel to the top of the stream bank. This disconnects the stream system from its floodplain, which reduces soil water storage, wetland and riparian function, and enhances velocity of flows within the river banks. This, in turn, further scours the channel bottom and disconnects the river.

Buildings and Urban Trees/Vegetation

Flooding can damage or destroy buildings in the floodplain, which are often lower-income neighborhoods including manufactured homes whose residents have limited resources to rebuild their lives.

Buildings and urban trees can all be damaged by snow load, wind, and stormwater associated with extreme weather events. Deciduous trees and shrubs are particularly susceptible to late season snowstorms, after leaf-out.

Business, Recreation and Tourism

Flooding directly affects the economy by damaging homes, businesses, infrastructure, and community resources in flooded areas. Flooding also impacts the tourism and recreation industries by limiting opportunities for river-based activities such fishing, rafting and kayaking.

Energy

Flooding can affect power lines and lead to electric service disruptions.

Land Use Planning and Transportation

Flooding and extreme precipitation events impact homes and property, as well as transportation systems (roads and bridges). Areas with single road access are particularly vulnerable.

Missoula City and County generally require development within the designated floodplain to have its lowest floors two feet above the 100-year flood elevation. According to FEMA floodplain maps adopted by Missoula City and County in 2015, 1.8 percent of county land area lies within the 100-year flood hazard area, including 362 residences, 35 commercial, industrial and agricultural buildings, and 3 critical facilities. However, FEMA floodplain boundaries and projected 100-year flood elevations are based on 50-year-old hydrologic and hydraulic analyses which do not account for climate change projections.

Increased flooding will lead to increased tension between the public and private good, as local government will need to make difficult decisions weighing the rights of individuals against the cost to society of development in areas that may be at risk of flood.

Water Infrastructure

Floods cause short term damage to water infrastructure, such as levees, as well as long term damage from repeated stress that affects water quality and availability. Low-lying areas and communities without adequate stormwater systems are particularly vulnerable. Private and

smaller well systems are at risk of contamination. Increased wastewater treatment plant peak flows from flooding can cause damage to the treatment plant itself and result in contaminated water.

Drier Summers and Drought

Missoula County's total annual precipitation is projected to increase slightly as a result of climate change. However, the change in precipitation is not expected to be uniform across seasons: winter and spring are expected to be wetter and summers are expected to be significantly drier.

Higher temperatures are projected to reduce low-elevation snowpack, early snowmelt, and an earlier peak in spring runoff. Over the past half-century spring runoff has shifted at least a week earlier in the northern Rockies, and this trend is likely to continue as the climate continues to warm. Earlier snowmelt and decreased summer precipitation are expected to reduce late-summer streamflows across the county.

Although there is uncertainty about the impacts of climate change on the frequency of long-term (multi-year) drought, there is widespread agreement that such droughts will be more severe when and where they do occur. See the ***Climate and Community Primer*** for additional details and references.

Forests and Terrestrial Ecosystems

Changes in the amount and timing of water availability, including drier summers and more intense droughts, may stress Missoula County's forests. Lack of water will leave trees weaker and less able to fight off forest pathogens. Native flora succumbing to drought and diseases and local fauna changing their habits to cope with decreased water availability will contribute to ecosystem change. For example, lower elevation forests may transition to grassland or shrubland. The decline of overall forest health may also lead to the further proliferation of invasive animal and plant species that are better suited to drier environments. Some snow-dependent animals will shift their range due to reduced low-elevation snowpack. There may be an increased incidence of some wildlife diseases. The timber industry may be affected by reduced productivity in forest growth.

Aquatic Systems

Reduced summer streamflows together with hotter summers will lead to increased water temperatures, which are detrimental to several aquatic species, including trout, and to the recreational fishing industry that depends on a healthy and robust fisheries. While native species such as westslope cutthroat trout, bull trout and Rocky Mountain sculpin are the most vulnerable, introduced game species such as rainbow trout and brown trout (which support the majority of the commercial fisheries) are also impacted.

Reduced streamflows can also lead to reduced water quality through increasing temperature and concentrations of pollutants. In turn, these conditions can enhance algae growth which diminishes the dissolved oxygen content that aquatic species rely on.

Ultimately, reduced streamflows will lead to increased competition for water resources from agriculture, recreation, and wildlife, as well as domestic use in those areas of the county that rely on surface water (see Water Infrastructure below). Low summer flows will also increase stress on some aquatic species by making them more vulnerable to terrestrial and aerial predators by reducing aquatic habitat diversity and protective instream features like deep pools and eddies.

Lower streamflow also means decreased groundwater recharge. While the Missoula Valley aquifer is fairly resilient compared to surface water resources (see p. 23), Missoula County residents outside the Missoula Valley rely on water resources that may be more vulnerable (see Water Infrastructure section below)

A healthy watershed requires the lateral and vertical connection of water resources across the landscape. When water levels in rivers, lakes, and wetlands become too low, many processes that support plants, wildlife, and healthy ecosystems are hindered. This phenomenon is known as "hydrologic disconnection." For example, when perennial streams become dewatered, fish become vulnerable to predation as a result of poor water quality and reduced habitat.

Changes to vegetation (see Forests and Terrestrial Ecosystems) will also impact the hydrologic cycle; for example, trees and grasses provide shade, slow runoff, and interact with snow cover. Conversely, the hydrologic cycle impacts vegetation, forming a dynamic and important relationship.

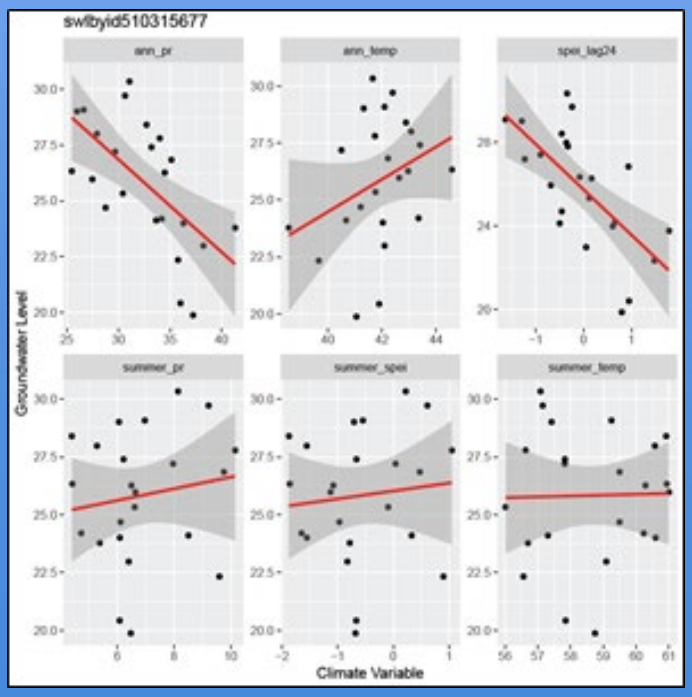
How Resilient is the Missoula Aquifer?

The Missoula Aquifer serves as the main water supply for the City of Missoula and surrounding areas. To this date there have been no known studies focused on evaluating the vulnerability of this water resource to climate change. To support the Climate Ready Communities process, Adaptive Hydrology, LLC completed a preliminary analysis of the resiliency of the Missoula Aquifer to climate change. The bottom line: **the Missoula Aquifer is likely to be more resilient to impacts from climate change than surface water resources**. The methods used to reach this conclusion are explained below.

As described in the Climate and Community Primer, climate change projections for Missoula County suggest that we are likely to experience increased temperatures throughout the year, with the largest increases in summer. While annual precipitation is projected to increase, most climate models suggest a decrease in summer precipitation. Here we attempt to answer the question: How will these projected changes impact our City's water supply?

We looked at eight groundwater wells around the Missoula area and evaluated how the annual minimum water levels can be explained by different climate variables (annual precipitation, annual temperature, 24-month drought metric, summer precipitation, summer drought metric, and summer temperature). The drought metric we used was the standardized precipitation evapotranspiration index (SPEI). We used a simple linear regression model to evaluate the explanatory power of the climate variables. Results are shown in the figure below.

In summary, we found that the variables at the annual (or larger) timescale had consistently higher explanatory power than the summer variables. The 24-month drought index consistently explained the variance in minimum aquifer levels the best while summer temperature consistently had the lowest explanatory power. Given that at the annual timescale we are expecting to see increases in precipitation and smaller temperature changes, these results suggest that the Missoula aquifer is likely to be fairly resilient to the projected decreases in summer precipitation and increases in summer temperature. The Missoula Aquifer is most vulnerable to long-term, multi-year droughts, just as it has always been historically. But the current climate projections do not project increases in the multi-annual drought in Missoula County.



Agriculture

Longer and more intense summer droughts will most directly impact non-irrigated producers, which are a minority in Missoula County. Irrigated producers may ultimately be affected if persistent drought reduces the availability and cost of irrigation water; however, irrigation water is not currently a limiting factor for agricultural production in Missoula County, and there is significant potential to improve irrigation efficiency. Drought will also impact ranchers by reducing the nutritional value of non-irrigated pasture used as feed for livestock.

Business, Recreation, and Tourism

The combination of reduced streamflows and higher air temperatures will lead to higher river temperatures, reducing populations of temperature-sensitive species such as bull trout and westslope cutthroat trout. Higher river temperatures will lead to more frequent fishing restrictions, with direct revenue impacts for fishing guides and outfitters and indirect impacts across the economy. Even when fishing is not restricted, warmer water impacts fishing businesses by stressing fish and therefore reducing catch rates. Multiple years of drought and warm water temperatures also increase trout mortality, reducing overall populations of catchable fish.

The transition of low-elevation forests to shrubland and grassland will affect the wood products industry since traditional sources of timber will no longer be as widely available. Opportunities for forest-based recreation such as hiking and camping will also be affected.

Reduced snowpack will directly impact winter recreation activities (nordic and alpine skiing, snowboarding, snowshoeing, snowmobiling), with revenue impacts for businesses such as Snowbowl ski area near Missoula and winter gear retailers. The most significant reduction in skiable days is likely to occur in the spring, with less significant impacts in the fall. However, warmer year-round temperatures and reduced snowpack will likely expand the season for other recreational activities such as hiking, biking and fishing.

It is worth noting that the impact of climate change on tourism in Missoula County will also be affected by the relative climate impacts on outdoor recreational opportunities elsewhere in the country.

Water Infrastructure

Decreased late summer water availability will result in less-reliable water supplies. Communities like Seeley Lake that rely on surface water are most vulnerable. Although the Missoula Valley aquifer is fairly resilient compared to surface water resources (p. 23), many Missoula County residents outside the Missoula Valley rely on wells that draw from smaller aquifers, and these may be more vulnerable.

Already, filed water rights in parts of Missoula County exceed the amount of surface water available. As a result, the state cannot approve new water rights, without proof of mitigation, in Grant Creek, Hayes Creek, the Clark Fork above the confluence of the Blackfoot River, and the

entire Bitterroot River. This prohibition affects both wells and surface water draws. Drought and drier summers may further reduce the availability of water rights in the county. However, since individual wells below established withdrawal thresholds are exempt from water right requirements, new development on individual wells may continue to occur in these areas.

Droughts also reduce available dilution water for wastewater treatment effluent, potentially degrading water quality.

Land Use Planning and Transportation

In rural parts of the county, existing development patterns tend to favor individual wells rather than community water systems. However, drier summers and the lack of available water rights (see Water Infrastructure section) will increasingly limit development in certain areas of the county. The more limited our water supplies become, the more tension there will be between private interests and the public good when it comes to water resources.

Energy

Drought has the potential to reduce hydropower production, which currently supplies more than half of the electricity used in Missoula County. Reduced hydropower production could result in increased use of higher-cost electricity sources, increasing costs for utilities and their ratepayers

Health

Longer summer droughts will lead to increasingly dry soils, increasing the likelihood of dust in the air which contributes to respiratory problems. Drought may also affect drinking water supplies in some parts of the county (see Water Infrastructure section).

Climate Variability

One plausible future scenario for Missoula County includes considerable year-to-year climate variability (see the Mid-Century Climate Scenarios in the ***Climate and Community Primer***). We may experience some very wet years and other intense drought years, with the concept of an "average" year simply no longer being meaningful. While variability and unpredictability will affect all sectors, agriculture, recreation and tourism will find it particularly difficult to adapt to these conditions.

Agriculture

The increasing unpredictability of the weather from month to month and year to year is likely to be one of the biggest challenges that climate change will pose to Missoula County farmers and ranchers. Less predictable weather and more variability in the timing of the first fall freeze and spring thaw will lead to more frequent crop loss due to the mismatch between crops and local conditions. There are also documented mental health impacts on farmers resulting from the challenges of climate change, in particular unpredictable weather and associated crop loss.

Business, Recreation and Tourism

Increasing yearly unpredictability will have significant impacts on recreational industries like skiing and fishing, since the seasons for these activities may vary greatly from year to year. This unpredictability will increase investment risk, making it very difficult for businesses to plan, make capital improvements, and invest in employees.

Climate Migration and Population Change

Missoula County's population is increasing. From 2010-2017 the county grew by 7.3%, and it is projected to grow an additional 21.8% by 2043, bringing the total population to more than 142,000 residents. These estimates are independent of the impacts of climate change on the flow of migrants to and from Missoula County.

In order to understand the true impacts of climate change in Missoula County, we need to know how it will affect the county's population. Will current residents move away, fed up with longer and longer periods of wildfire smoke? Or will people from other parts of the country that are experiencing even more disastrous climate impacts flock to Missoula County as a refuge?

To support the Climate Ready Communities process, Adaptive Hydrology, LLC performed a preliminary analysis of the impacts of climate change on Missoula County's population (see p. 27). The bottom line: **Missoula County will likely experience an increase in population due to climate change**. Without knowing the magnitude of this growth, or how it will be distributed throughout the county, it is impossible to assess its full implications; however, we are aware in a general sense of the challenges and opportunities presented by population growth, as described below.

How will Missoula County's population change due to climate change?

To support the Climate Ready Communities process, Adaptive Hydrology, LLC performed the following preliminary analysis of the impacts of climate change on Missoula County's population. The bottom line: **Missoula County will likely experience an increase in population due to climate change**. See below for the methods used to reach this conclusion.

Missoula County's population is increasing. From 2010-2017 the county grew by 7.3% and is projected to grow by an additional 21.8% by 2043, bringing the total population to 142,989 residents by around mid-century. These estimates are independent of the impacts of climate change on inflow and outflow of migrants to and from Missoula County. It is challenging to know exactly how climate change will affect the population of Missoula County, but there are some data available to allow us to at least estimate the **direction** of change, i.e., will population likely grow or shrink due to climate change? This analysis will not allow us to estimate the **magnitude** of projected population change.

We first use IRS data to investigate where people who move to Missoula County come from, and where people who leave Missoula County move to. The table below lists the top 10 "most connected" counties to Missoula County in the United States, outside the state of Montana, based on in-migration and out-migration. In this table, where "n1" is the estimated number of families and "n2" is the estimated number of individuals; "in" and "out" represent inflow and outflow to and from Missoula County, respectively.

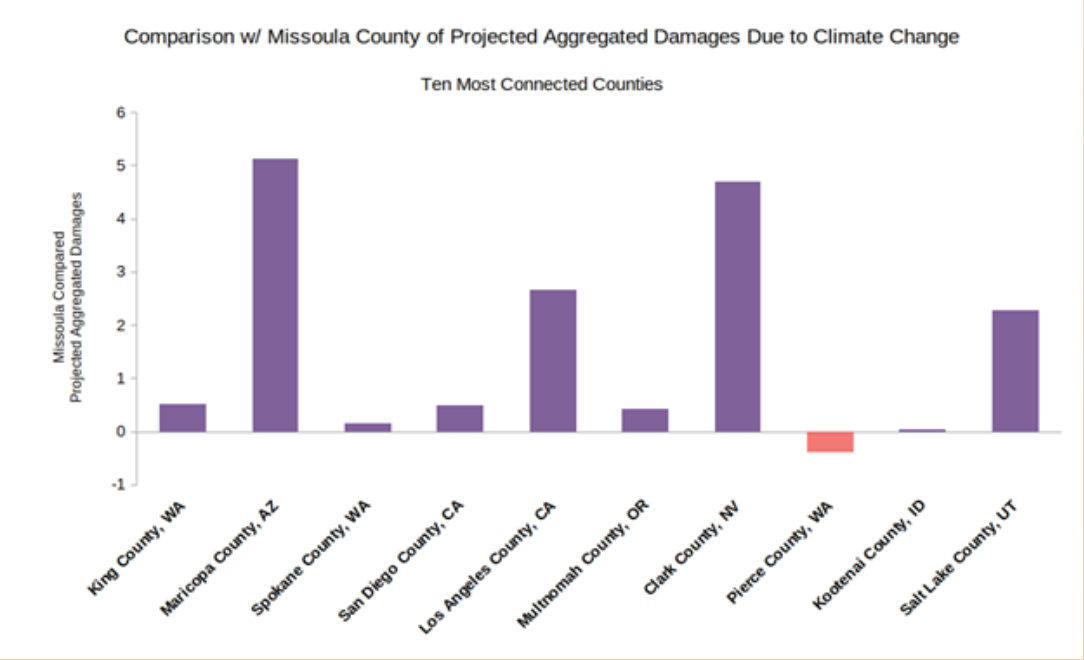
FIPS	Name	n1_in	n2_in	n1_out	n2_out
53033	King County, WA	339	529	490	654
4013	Maricopa County, AZ	203	345	272	445
53063	Spokane County, WA	201	339	316	540
6073	San Diego County, CA	161	275	81	113
6037	Los Angeles County, CA	160	236	118	166
41051	Multnomah County, OR	159	230	226	282
32003	Clark County, NV	122	222	137	235
53053	Pierce County, WA	117	209	88	164
16055	Kootenai County, ID	107	203	127	233
49035	Salt Lake County, UT	99	167	99	167

We then compare the projected impacts of climate change in those 10 counties versus Missoula County. The logic is that if climate change is projected to be worse in the counties where most Missoula citizens either migrate to or from, then climate change will likely have a positive (increasing) effect on population in Missoula. Conversely, if the projected climate change impacts in these counties are better than Missoula, then climate change will likely have a negative (decreasing) effect on population in Missoula.

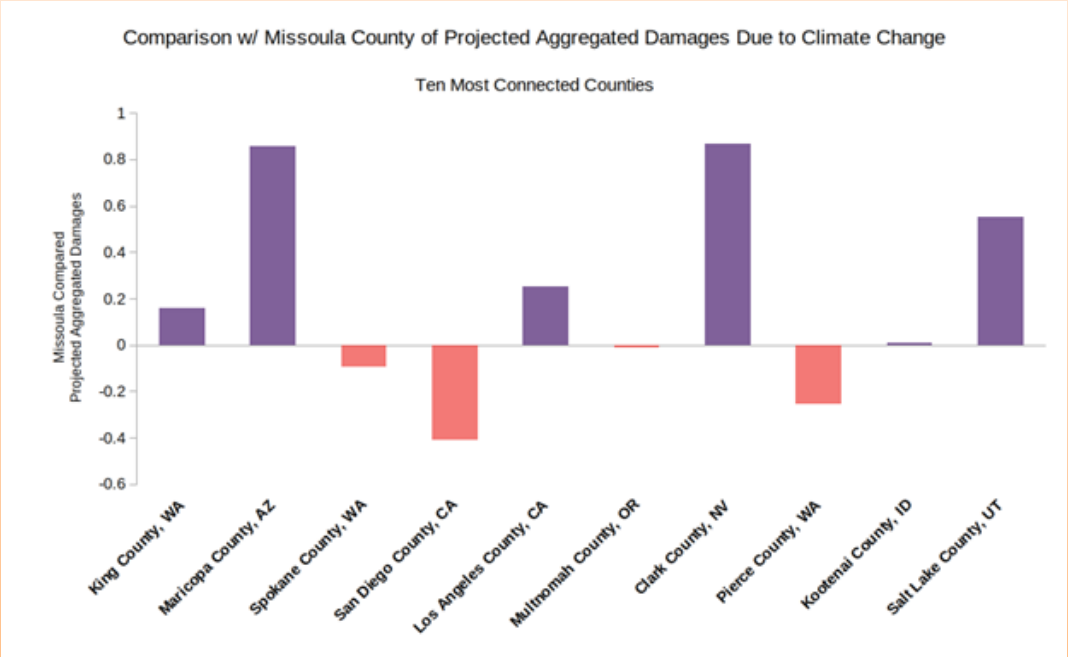
To evaluate the impact of climate change on each county we use two separate datasets: total economic damage estimated by Hsiang et al. (2017) and future wildfire smoke risk estimated by Liu et al. (2016). For documentation on their methods please see references in footnotes. We normalize these values and then add them together to create a climate change impact score. We then calculate the percent difference between each county's score and Missoula County's score to create a final relative climate change impact score. Values greater than zero represent counties where climate change is expected to be worse than Missoula County; values less than zero represent counties where climate change is expected to be better than Missoula. We weight the impact of fire as ⅛ the impact of total damages. This decision was made because total damages is an aggregation of 8 different metrics so we equally weight fire among them. We also show results for a fire weight of ½ to give an estimate of uncertainty (see below). The results are, unfortunately, sensitive to how much fire is weighted in comparison to total economic damage. If, for example, fire is equally weighted to total economic damage then there are only 3 counties with worse projected impacts than Missoula (not shown).

We recommend equally weighting the fire with the other factors (i.e. fire weight = ⅛) because there is no other evidence that people will be likely to move more due to fire than other factors. Based on this assumption, 9 out of the 10 most connected counties will have worse impacts from climate change than Missoula. And even with the emphasized fire scenario (i.e. fire weight = ½), 6 out of 10 counties are projected to have worse impacts from climate change than Missoula. This gives some confidence (although not a lot) that Missoula County will have an increase in population due to climate change.

Fire weight = 0.125



Fire weight = 0.50



Land Use Planning and Transportation

Missoula County's 2016 Growth Policy and the City of Missoula's 2015 'Our Missoula' Growth Policy are both based around official population growth projections, which do not consider the additional population growth likely as a result of climate change. In May 2019, the county adopted a land use map for the Missoula area which is intended to guide growth over the next 20 years. While population projections are always uncertain, climate change adds an additional layer of uncertainty and makes long-term planning more challenging.

Increased population growth interacts with land use planning and transportation to affect many of the other sectors described in this report. Population growth, in conjunction with planning decisions, can lead to development in the WUI and in flood zones, pressure on groundwater resources and emergency services, and increased impacts on local air quality and greenhouse gas emissions from transportation. Transportation infrastructure may contribute to the urban heat island effect. Poor-quality housing stock can contribute to adverse health effects during wildfire smoke and extreme temperature events.

Buildings

Population growth will increase the need for new housing and commercial buildings. City and County Growth Policies suggest a need for approximately 12,000 to 17,000 new housing units in county by 2035. Climate migration will increase this need by an unknown amount.

Housing affordability is an increasing concern in the county as the population grows and housing prices increase faster than incomes. As of 2016, about 25% of homeowners and 47% of renters in

Missoula County were "cost burdened," meaning that they pay more than 30% of their income for housing. The median home sale price in the Missoula urban area jumped 34% from 2010 to 2017, to $268,250. It would take an income of about $66,000 a year to afford the median-priced home, well above Missoula County's median household income of $46,371. See the ***Climate and Community Primer*** for details and references.

In recent years, construction costs have risen in the Missoula area due to increases in the price of materials and a shortage of skilled labor, exacerbating the challenge of housing affordability.

Issues of housing affordability can lead to increased development in areas where the cost of land is lower, which may be more vulnerable to climate impacts such as wildfires or flooding. The pressure to build homes quickly and to keep costs low also has the potential to conflict with the need to build high-quality, well-insulated homes that will better protect their occupants from the impacts of climate change such as heat and wildfire smoke.

Energy and Water Infrastructure

With increased population comes increased demand on water infrastructure, including water supply and wastewater treatment.

More people use more energy, increasing the demand for electricity and natural gas. Utilities will need to meet this additional demand by developing or purchasing additional energy resources, with costs ultimately passed through to consumers. Increase in extreme temperature events may increase peak loads on utility infrastructure, requiring additional, expensive, and typically non-renewable infrastructure to meet only occasional loads (e.g. peaking plants).

Business, Recreation and Tourism

When it comes to the county's economy, population growth will result in both benefits and challenges. More people means a more competitive labor market, more new businesses, and possibly diversification of the economy. It can also strain resources and increase crowding, with potential negative repercussions for tourism since access to uncrowded natural areas and recreational opportunities are among the area's key attractions for tourists. We are unable to weigh these pros and cons due to great uncertainty in the scale and speed of the growth we will experience due to climate change, and how it will interact with the population growth projected for our county independent of climate change.

Forests and Terrestrial Ecosystems

Increased population will lead to increased development pressure in the wildland-urban interface (WUI), which contributes to ecosystem fragmentation. It also means more people using the forest for recreation (e.g. hiking and camping), increasing the likely spread of invasives and diseases from other regions.

Implications for Social and Cultural Systems and Underrepresented Groups

Climate change poses a variety of challenges to Missoula County's social and cultural fabric, with the potential to increase inequity, erode community ties and cultural identities, and divert limited government resources.

Increased Inequity

Many of the impacts of climate change are likely to disproportionately impact disadvantaged groups. For example, people of lower socioeconomic status are more likely to live in homes that are not well-insulated and that lack shade trees, increasing their exposure to wildfire smoke and heat; and/or to live in low-lying areas, increasing their exposure to flooding. People of lower socioeconomic status also have fewer resources to cope with climate change impacts once they occur. For example, those without health insurance will be most burdened by the the increased healthcare costs associated with respiratory and cardiovascular disease related to wildfire smoke. Those with limited resources will be least likely to have the ability to rebuild their homes after a flood. For all of these reasons, climate change is likely to increase inequity by burdening disadvantaged populations the most.

Erosion of Community and Culture

If left unaddressed, several impacts of climate change are likely to increase social isolation and erode community ties. During periods of wildfire smoke or extreme heat, people are more likely to stay home, particularly the elderly and people with chronic health conditions. Studies have also found that higher temperatures are associated with increased crime rates, including domestic violence. Culturally significant local animal and plant species may migrate or disappear altogether in response to a changing climate, contributing to an erosion of tribal and rural cultural identities and traditions. Opportunities to engage in traditional activities such as hunting, fishing, and gathering may be more limited due to wildfire smoke, heat, and changing ecosystems.

Limited Government Resources

To the extent that government resources will be diverted to address more frequent emergency situations such as wildfires and floods, other priorities may suffer. There may be fewer resources for social programs addressing such basic needs as healthcare, food, housing and education. Underrepresented groups are less likely to be involved in these decisions and most likely to suffer the consequences of reduced funding for these programs.

Appendix: Vulnerability Grids by Sector

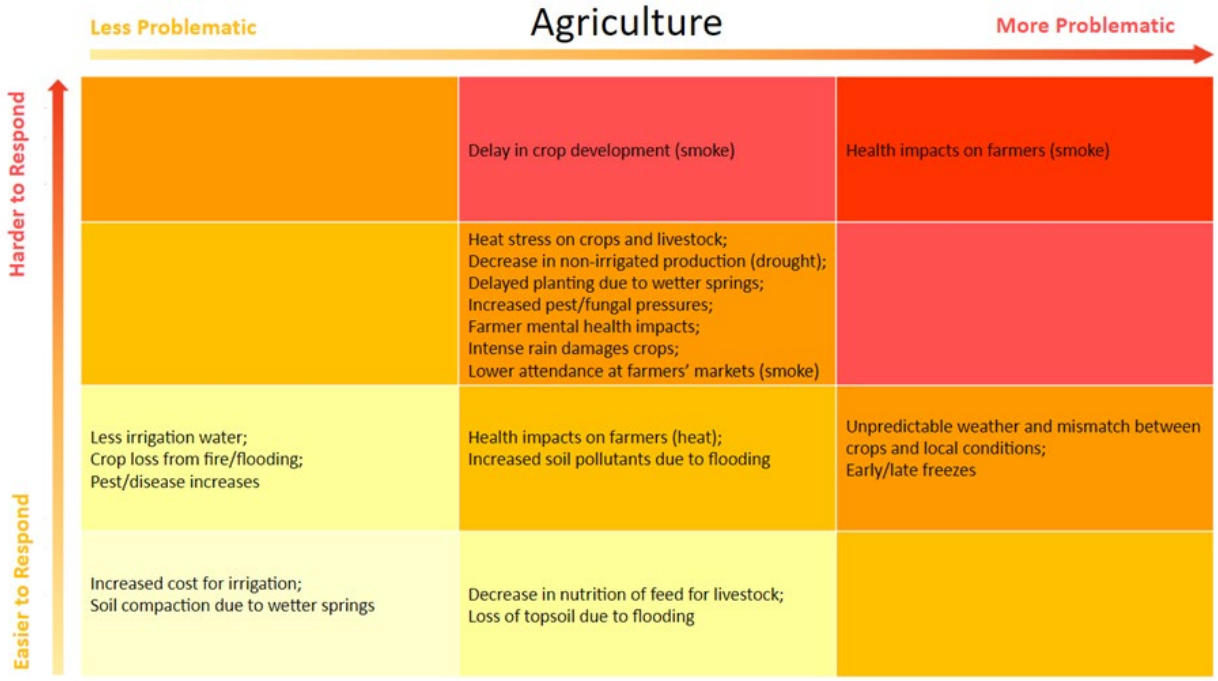
At the December 18 stakeholder workshop, each sector group identified climate change-related risks associated with their sector, and rated those risks using two metrics:

(1) How problematic the risk would be in the absence of any action to respond to it:
- Low (somewhat problematic)
- Medium (very problematic)
- High (extremely problematic)

(2) How difficult it will be to respond to the risk:
- Easy (we know what to do and have the capacity to do it)
- Moderate (we know what to do, but need resources/capacity/policy change to implement)
- Difficult (we do not even know how to respond to this change)

After the workshop, we discovered that a large majority of the risks were rated "moderate." In fact, some sector groups had chosen to split the "moderate" rating into two ("moderate plus" and "moderate minus") to differentiate among the many risks that received this rating. We worked with the Steering Committee to apply this differentiation to all sector groups to allow for more nuance in the prioritization of risks.

The Vulnerability Grids below are a visual representation of these ratings. The color of the box represents the overall priority of the risk; risks that appear in the red box on the top right were rated "High" and "Difficult" and are of the greatest overall concern. Risks that appear in the light yellow box on the bottom left were rated "Low" and "Easy" and are of the least overall concern. The risks shown in these grids are also listed at the beginning of this Vulnerability Assessment using the same color-based ratings.



Aquatic Systems and Fisheries

Less Problematic → More Problematic

Harder to Respond ↑ Easier to Respond

	Increased evapotranspiration; Impacts on aquatic species' adaptive capacities	
Decreased aquifer recharge		Hydrologic disconnection; Increased competition among water users; Increased stress on aquatic species; Increased risk of contamination; Changes in hydrology/storage capacity
	Decreased water quality; Changes and reductions to instream/habitat quality; Increased stress on riparian vegetation	Increased water temperature; Increased invasive species
Increased water-based recreation due to increased air temperature	Increased erosion	

Buildings and Urban Trees

Less Problematic → More Problematic

Harder to Respond ↑ Easier to Respond

		Buildings do not adequately keep smoke out; Building stock is ill-prepared for extreme heat
	Buildings vulnerability to wildfire; Buildings vulnerability to flooding	Damage to urban trees from extreme weather
Decreased useful life of buildings due to heat	Urban forest mortality due to heat; Building damage from storms and extreme weather	Increased demand for buildings due to climate migrants

Business, Recreation & Tourism

Less Problematic → More Problematic

Harder to Respond ↑ Easier to Respond

	Climate variability makes business investment difficult; Resource strain due to climate migrants; Reduced tourism/spending due to flooding; Reduced tourism/spending due to reduced snowpack	
		Reduced tourism/spending due to reduced streamflow; Reduced tourism/spending due to wildfires and smoke; Reduced employee health and wellness due to wildfire smoke
	Decline in timber products and tourism due to deforestation	
		Shifted consumer patterns due to wildfire smoke

Emergency Services

Less Problematic → More Problematic

Harder to Respond ↑ Easier to Respond

		Increased draw on resources due to fire; High potential for loss of life due to fire; Disruption of communication systems due to fire, extreme weather events
Increased draw on resources due to flooding	Increased draw on resources due to smoke	Impact of smoke on first responders; Need for evacuations and places to shelter evacuees (fire)
	Need for evacuations and places to shelter evacuees (smoke); Impact of fire on first responders; Increased draw on resources due to heat; Slower response time due to extreme weather events	
	Need for more emergency planning and communication due to heat, flooding	

Energy

Harder to Respond ↑ / Less Problematic →		More Problematic
		Damage to utility infrastructure from wildfires
		Increased peak load due to hotter summers; Increased demand for energy due to climate migrants
	Reduced hydropower production due to drought	
Service disruptions due to flooding		

Easier to Respond

Forests and Terrestrial Ecosystems

Harder to Respond ↑ / Less Problematic →		More Problematic
Altered productivity		
Increase in wildlife disease	Impacts to fauna of habitat loss and fragmentation; Increased development and recreation pressure due to climate migrants; More forest pathogens	Changes to ecosystem type (e.g. forests transitioning to grassland or shrubland); Ecosystem effects of changes in amount and timing of water availability; Expansion of invasive species; Increases in tree mortality and reduction in regeneration
	Impacts to flora due to habitat loss and fragmentation; Changes to species composition, species richness, genetic diversity	

Easier to Respond

Human Health

Less Problematic → More Problematic

Harder to Respond ↑ Easier to Respond

	Increased violence and substance abuse associated with heat	Increased healthcare costs; Destabilization of people with mental health issues associated with smoke
	Missed work days and lost wages; Less available drinking water due to drought (rural areas)	Increased incidence of respiratory and cardiovascular problems due to smoke; Waterborne illness due to flooding; Vector-borne illness due to flooding; Mental health impacts
Lost sleep due to heat	Difficult to exercise due to smoke, heat, wetter springs; Inadequate capacity in healthcare system; Social isolation due to heat; Trauma/drowning due to flooding; Wastewater treatment plant overload/septic system failures due to flooding; Asthma exacerbated by increased dust, pollen, mold	

Land Use Planning & Transportation

Less Problematic → More Problematic

Harder to Respond ↑ Easier to Respond

	Inadequate water to support existing and future development	Community costs of development in the wildland-urban interface (wildfires)
	Impacts to roads and bridges (floods and extreme weather); Impacts to homes and property (floods); Increased tension between private and public interests (wildfire, floods); Heat island effect exacerbated by increases in temperature	Impact of transportation systems (wildfire); Increased tension between private & public interests (drought)

Water Infrastructure

Harder to Respond ↑ / Less Problematic		More Problematic
Increased evaporation of stored water (heat); Decreased water quality due to population shifts (stagnation)	Availability of future water rights (drought)	Unreliable water supply (drought); Lack of dilution water for wastewater treatment (drought)
	Stormwater system inundation (flooding)	Increased wastewater treatment plant flows (flooding); Acute and chronic physical infrastructure damage (flooding)
Power outages that affect water infrastructure (wildfire)	Reduction of surface water quality due to runoff sediment (wildfire)	Well contamination (flooding)
	Increased system demand due to climate migrants	

Easier to Respond