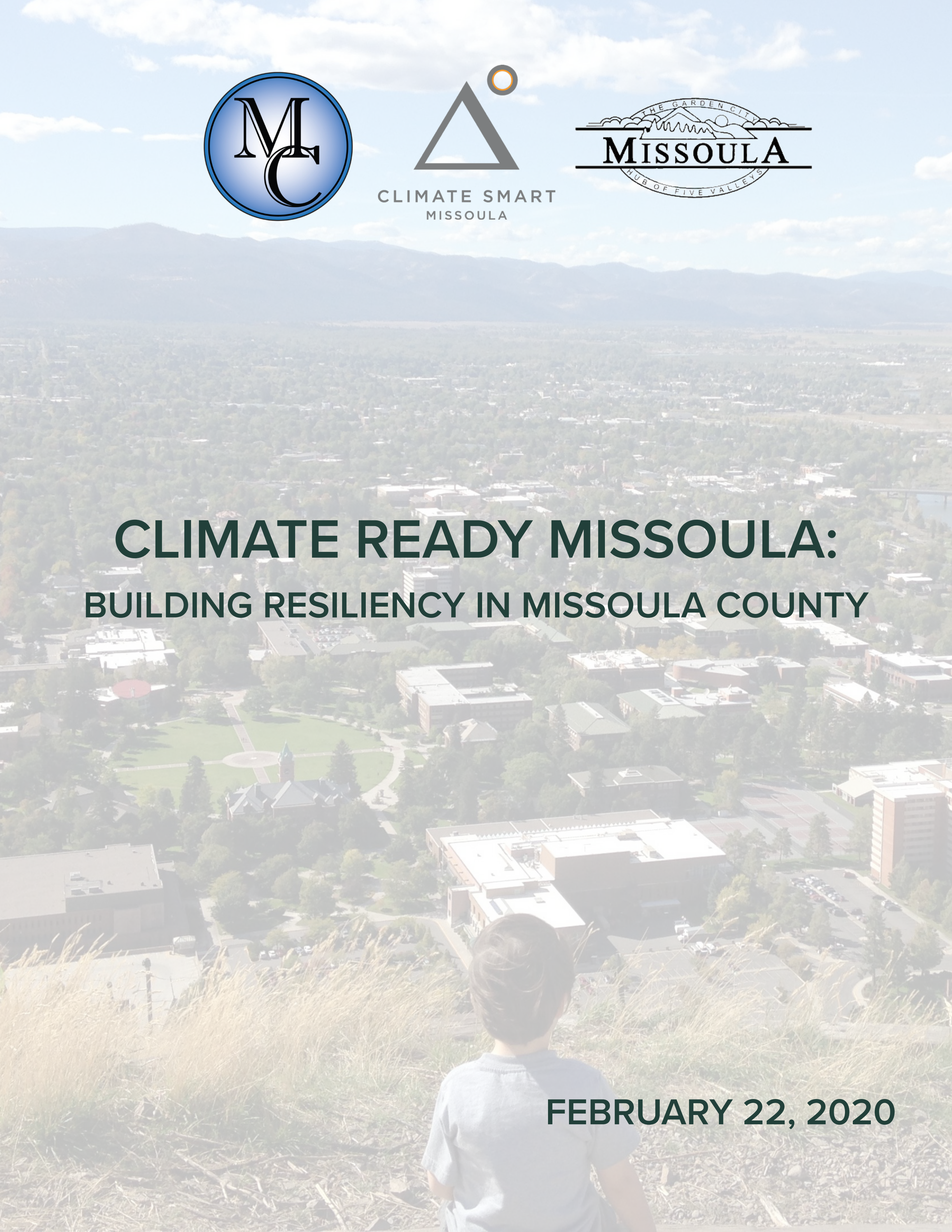

CLIMATE SMART
MISSOULA

CLIMATE READY MISSOULA:

BUILDING RESILIENCY IN MISSOULA COUNTY

FEBRUARY 22, 2020

CLIMATE CHANGE IMPACTS US DAILY.

LET'S GET CLIMATE READY, MISSOULA.

CLIMATE READY MISSOULA:
BUILDING RESILIENCY IN MISSOULA COUNTY

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Executive Summary

Executive Summary

There is overwhelming scientific consensus that our climate is changing, and that urgent action is required to avert a potentially catastrophic outcome. We are already experiencing the impacts of climate change in Missoula County, including hotter, drier summers; warmer, wetter springs; more frequent and intense wildfires and floods; and more wildfire smoke. These changes are projected to intensify in the coming decades and will have far-reaching impacts on public health and safety, our economy, and our natural environment. The purpose of the Climate Ready Missoula planning effort has been to identify the greatest risks that Missoula County faces as a result of climate change, and to develop strategies to address those risks.

Efforts to address climate change fall into two main categories: **mitigation**, which involves reducing the carbon pollution that is changing our climate; and **adaptation**, which involves addressing the impacts of climate change that we are already experiencing and preparing for the projected changes to come. Given that our climate is already changing, both mitigation and adaptation are essential and urgent.

The focus of Climate Ready Missoula is adaptation, not mitigation. Missoula County, the City of Missoula, Climate Smart Missoula, and numerous other local organizations also have mitigation efforts underway, and commitments to carbon reduction are strong. Those efforts are not the focus of this plan, though some of the adaptation strategies identified in this plan also support our mitigation efforts, and that alignment is noted where it occurs.

The Plan and Process. The planning process began in the summer of 2018 and has been developed with the participation of hundreds of local organizations and individuals via two large stakeholder workshops, online surveys, and numerous public meetings. Climate Ready Missoula was inspired by the Climate Ready Communities program developed by the Geos Institute.

This Executive Summary includes an abbreviated version of the main components of the full plan, including climate projections and scenarios, the vulnerability assessment, climate adaptation goals and strategies, and next steps. The full Climate Ready Missoula plan includes a more comprehensive discussion of all of these topics, including a more detailed table of adaptation goals and strategies.

Guiding Principles

These 12 principles were developed to guide the process of prioritizing and implementing the climate adaptation goals and actions that are presented in this plan. While all of these principles should be considered with respect to each adaptation goal or action, there will be some cases of tradeoffs among the principles.

1. Collaborate and think holistically. Climate change touches all aspects of our lives, requiring us to collaborate in new ways, to work across sectors and silos, and to think beyond our geographic boundaries.

2. Prioritize equity. Adaptation actions should not increase inequity. Prioritize actions that build resilience while focusing on underrepresented and vulnerable groups and increasing equity.

3. Act with, not for. Maximize transparency and inclusivity in planning and implementation. Empower people with knowledge and tools to participate and take ownership of climate resiliency actions.

4. Draw on tradition and culture. Honor cultural values and draw on traditional ecological knowledge through collaborative partnerships. The Confederated Salish and Kootenai Tribes are key partners, especially given that Missoula County falls within the ancestral homelands of these tribes.

5. Use science. Make decisions based on the best available science while explicitly considering uncertainty.

6. Value natural processes. Learn from nature and protect and restore naturally resilient ecological processes.

7. Don't exacerbate the problem. Adaptation actions should avoid increasing our contribution to climate change or undermining the ability of other sectors or regions to adapt. Prioritize actions that reduce our contribution to climate change while building resilience.

8. Build on past work. Recognize, value, and integrate prior and ongoing work. Don't reinvent the wheel.

9. Balance immediate and long-term needs. When prioritizing actions, select a combination of easy, quick wins and critical but challenging longer-term initiatives.

10. Consider costs and benefits. Adaptation actions should be evaluated by considering their long-term costs and benefits alongside the costs of not taking action.

11. Focus on prevention. When possible, prioritize actions aimed at avoiding problems rather than addressing them after they occur.

12. Innovate and adapt. Monitor and evaluate actions to learn what's actually working. Experiment with emerging solutions, be creative, maintain flexibility as conditions change, and build capacity to respond to the unexpected.

Climate Projections and Scenarios

The Climate Ready Missoula project started by gathering and summarizing climate change projections specific to Missoula County. Data sources included the Montana Climate Assessment and the U.S. Climate Resilience Toolkit developed by the National Oceanic and Atmospheric Administration in partnership with twelve other federal agencies.

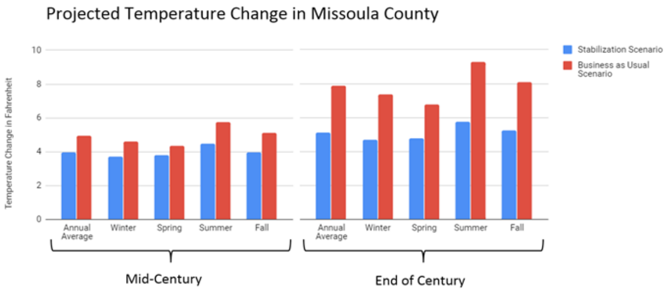
Any effort to predict the future is accompanied by uncertainty. In climate modeling, this uncertainty stems from the fact that the models themselves are by necessity simplifications of reality, as well as uncertainty about whether and how quickly greenhouse gas emissions will be reduced worldwide. The Climate Ready Missoula projections are based on the results of twenty different climate models in order to account for the uncertainty that accompanies any one model. We also present results for two greenhouse gas emissions trajectories, one in which emissions are reduced substantially in the coming decades (“stabilization scenario”), and another in which they continue to increase (“business-as-usual scenario”).

Temperature

Missoula County’s average annual temperature is projected to increase 4-5°F by midcentury and 5-8°F by the end of the century (Figure ES-1). The greatest temperature increases are projected in July, August, and September.

As 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 and 18-39 days by the end of the century. In contrast, the average number of frost days per year is projected to decrease 36-46 days by the middle of the century and 45-73 days by the end of the century.

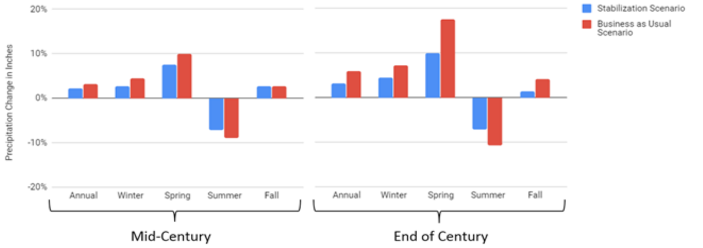
Figure ES-1 Projected change in annual and seasonal average temperature for Missoula County by mid- and end of the century.



Precipitation

Average and annual precipitation for Missoula County is projected to increase by 2-3% by mid-century and by 3-6% by the end of the century. 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 (Figure ES-2). Warmer temperatures are likely to result in more precipitation falling as rain rather than snow in western Montana, especially at low elevations.

Figure ES-2 Projected change in annual and seasonal average precipitation for Missoula County by mid-century and the end of the century.



Mid-Century Climate Scenarios

The following three scenarios describe plausible futures for Missoula County in the next 30 years based on current trends, recent events, scientific research, and the climate projections presented above. Scenarios enable us to envision the range of futures that climate change might bring to Missoula County.

Scenario 1 | Turn Up the Heat

In this scenario, the annual average temperature increases by approximately 6°F by mid-century, with the greatest temperature increase in the summer. Average summer temperatures will be hotter than the summer of 2017, when we experienced a prolonged heat wave. We’ll experience 2-3 additional weeks per year with daily high temperatures above 90°F. Average annual precipitation will remain about the same, but the timing of precipitation will change: summers will be drier and the rest of the year slightly wetter.

With higher temperatures and less precipitation in the summer and early fall, fire seasons will last an average of 12 days longer than they do today, and the total land area burned each year will increase about 50% on average. Over time, increases in the size and severity of fires will reduce the extent of low elevation forests, converting forested areas to shrublands or grasslands.

Longer and more intense fire seasons in Missoula County and throughout the region will mean longer periods of unhealthy air quality due to wildfire smoke, increasing the incidence and severity of respiratory and cardiovascular disease among county residents. Outdoor recreation and tourism will decline during periods of wildfire smoke and thousands of jobs will be lost in the tourism industry statewide.

Warmer winters will lead to a decline in mountain snowpack, and that snowpack will melt earlier due to warmer spring temperatures. Late summer streamflows will be much lower than they are now, and stream temperatures will be higher, stressing fish and riparian vegetation.

Due to a later fall freeze and earlier spring thaw, the growing season will increase in length by about 2 months. However, less summer precipitation and lower August streamflows will mean that less water is available for agriculture during the growing season.

Reduced snowpack and earlier snowmelt will impact winter recreation. Ski hills will face shorter seasons and more frequent closures of low-elevation terrain, and opportunities for low-elevation nordic skiing and backyard ice skating will be reduced or eliminated. Seasons for other recreational sports such as mountain biking may be extended due to warmer springs and falls, but will also be affected by wildfire smoke.

Scenario 1 Snapshot:

- Average annual temperature increases by ~ 6°F by 2050, more in the summer
- 2 - 3 additional weeks/year with daily highs above 90°F
- Average annual precipitation will remain the same, but summer rainfall will decrease by about 30%
- Longer fire seasons, more wildfire smoke

Scenario 2 | Here Comes the Rain Again

In this scenario, average annual temperatures increase by about 3°F by mid-century, and average annual precipitation increases by 15%. This additional precipitation falls in the winter, spring, and fall; summer precipitation does not change. We also experience several more days per year of intense rainfall. There will be an increase in the number and intensity of droughts and wildfires in this scenario, but not as pronounced as the increase as in Scenario 1. On the other hand, flooding will be a much bigger issue in this scenario than in Scenario 1.

While summer precipitation does not change in this scenario, hotter summers increase evaporation rates, reducing water available for plant growth in the summer and resulting in a greater contrast between wet and dry seasons. Early but short spring rains promote rapid green-ups, followed by prolonged dry summers and brown landscapes. The growing season increases in length by 2-3 weeks due to increased fall and spring temperatures.

Elk and other wildlife will benefit from the availability of ample forage in early spring, but may be forced to change their normal winter ranges due to warmer winters and deeper mountain snowpack.

Warmer temperatures and wetter winters and springs will lead to more frequent and severe flooding. By mid-century, the average winter and spring will be even warmer and wetter than 2018, when severe flooding damaged houses and tipped power poles. In the urban area, more severe rain events will challenge our stormwater system, and greater volumes of stormwater runoff that flow to the aquifer will increase the potential for contamination of our drinking water supply. Flooding will impact populations of fall spawning fishes, such as bull trout, whose eggs and young are vulnerable to spring floods.

Scenario 2 Snapshot:

- Average annual temperature increases by ~ 3°F by 2050, more in the summer
- ~ 1 additional week/year with daily highs above 90°F
- Average annual precipitation increases by 15%, falling in winter, spring, and fall - summer precipitation does not change
- More flooding

Scenario 3 | Feast or Famine

In this scenario, average temperatures will increase 4-5°F by mid-century. Average annual precipitation will not change, but there will be much greater variability in precipitation from year to year, with some very wet years and some intense drought years. A “normal” year will be a thing of the past.

Increased year-to-year variability in precipitation will result in increased variability in fire season length and area burned. The timing of season-ending events, in particular, will be highly variable among years.

In dry years, we will experience low late-summer streamflows and reduced water available for plant growth, with impacts on aquatic ecosystems, river recreation, and agriculture similar to Scenario 1. In wet years we will experience flood events similar to those described in Scenario 2. Flooding will be exacerbated by the increase in wildfires in dry years, since rainfall runoff over burned areas can cause flash flooding. Burned hillsides are also vulnerable to landslides when it rains, resulting in soil loss which degrades land, slows regrowth, and leads to excessive sedimentation in streams and rivers.

From year to year, the season and conditions for outdoor activities like skiing and fishing will vary dramatically. Businesses involved in outdoor recreation and those that cater to tourists will be particularly challenged to prepare for this unpredictability. Increased variability will also be difficult for farmers and ranchers, as the strategies for drought years may be very different from wet years.

Scenario 3 Snapshot:

- Average annual temperature increases by 4 - 5°F by 2050, more in the summer
- 2 additional weeks/year with daily highs above 90°F
- Average annual precipitation will remain the same, but there will be much greater variability in precipitation from year to year
- An “average” year will be a thing of the past

Vulnerability Assessment

These climate projections and scenarios served as the foundation for our first stakeholder workshop, at which more than 100 participants worked in 11 sector groups to complete an exercise that involved identifying and prioritizing climate change risks based on the seven climate impacts described below.

The Vulnerability Assessment summarizes the information gathered at the workshop, as well as public input that was gathered through a subsequent online survey and public meetings. Altogether, the sector groups identified more than 100 specific risks that are described on pages 12 - 40 of this plan. Figure ES-3 depicts the sectors in which risks were identified related to each of the seven climate impacts.

Wildfires

In Missoula County, wildfire is a naturally occurring phenomenon that is important to forest ecosystems. 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. 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 relative to what we are accustomed to today.

Wildfire Smoke

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, where trapped smoke can create unhealthy conditions that last for hours or days. Exposure to wildfire smoke is associated with a range of negative health consequences including increased respiratory and cardiovascular problems.

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 summer. The average number of hot days (> 90°F) per year is projected to increase 12-20 days by the middle of the century.

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.

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. Intense rain is another common cause of flooding in Montana, and climate models project increases in the frequency and magnitude of the most intense precipitation events.

Drier Summers and Drought

Climate projections suggest that while winters and springs in Missoula County are likely to see an increase in precipitation, summers will become drier. In addition, higher temperatures are projected to lead to reduced low-elevation snowpack, early snowmelt, and an earlier peak in spring runoff. 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.

Climate Variability

One plausible future scenario for Missoula County includes a significant increase in year-to-year climate variability. We may experience some very wet years and other intense drought years, with the concept of a "typical" 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.

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. These estimates are independent of the impacts of climate change on the flow of migrants to and from Missoula County. To support the Climate Ready Missoula process, Adaptive Hydrology, LLC performed a 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.


Climate Smart Missoula Photo

Climate + Equity

The impacts we face have the potential to increase inequity, erode community ties and cultural identities, and divert local funding and resources. It will be essential that we address these threats to our social fabric and the most vulnerable among us during implementation, frequently referencing the guiding principles for this effort (page ES-1), which emphasize equity, inclusiveness, and cultural values.

Figure ES-3 Sectors Affected by Climate Impacts

	Wildfire	Wildfire smoke	Higher temperatures	Wetter winters and springs (flooding)	Drier summers and drought	Climate variability	Climate migration and population changes
Agriculture	X	X	X	X	X	X	
Buildings, Land Use, + Transportation	X	X	X	X			X
Business, Recreation + Tourism	X	X		X	X	X	X
Ecosystems + Wildfire	X		X	X	X		X
Emergency Response	X	X	X	X			
Energy	X		X	X	X		X
Water	X		X	X	X		X
Wildfire Smoke, Heat, + Health	X	X	X	X	X		

Climate Smart Missoula Photo

Climate Adaptation Goals and Strategies

At the second stakeholder workshop, participants worked in cross-sector groups to develop strategies to address the risks identified in the Vulnerability Assessment. Following the workshop, these strategies were refined into the following list of adaptation goals and actions, which forms the heart of this plan. The list is organized by sector. Each sector contains one or more adaptation goals (in green) and strategies to forward each goal (in black).

	ID	Goal + Strategy
wildfire smoke, heat, and health	A	Improve indoor air quality in homes during wildfire smoke events.
	1	Educate homeowners about options to create safe indoor air (MERV 13 air filters, portable air cleaners).
	2	Make portable air cleaners more accessible.
	B	Improve indoor air quality in (and access to) public and commercial buildings during wildfire smoke and heat events.
	3	Develop voluntary measures and incentives, such as a certification program for clean air buildings, to encourage safe indoor air in public buildings, schools, and businesses.
	4	Find, develop and promote indoor recreation, exercise and creative activity spaces that are available to individuals and recreational programs (youth and adult) that are accessible to all income levels.
	C	Improve health and safety of outdoor workers during heat and smoke events.
	5	Encourage employers to change workplace environment to reduce wildfire smoke and heat exposure, for example by adapting work hours, following Cal/OSHA guidance and/or providing pop-up clean air shelters and/or appropriate safety equipment (e.g. Personal Protective Equipment - PPE) for employees.
	D	Increase awareness of physical health impacts of wildfire smoke, heat, and their intersection.
	6	Conduct an educational campaign about air quality data, health risks of wildfire smoke, connection between smoke and heat, and activity guidelines.
	7	Collaborate with healthcare providers to develop and promote wildfire smoke exposure checklist; educate providers who are unaware.
	8	Encourage healthcare providers to work with sensitive subgroups to reduce controllable exposures (smoking, radon) and have a plan in place before wildfire smoke arrives.
	9	Coordinate education efforts to consider best health practices during concurrent heat and smoke events.
	10	Conduct an educational campaign about the prevention of and signs of heat related illness for the most vulnerable populations.
	11	Conduct an educational campaign for healthcare, public safety, and emergency response communities about the connection between heat and aggression.
	E	Increase awareness of mental health impacts of climate change.
	12	Educate the public and healthcare providers about the mental health impacts of wildfire smoke and other climate vulnerabilities, including those specific to agricultural community.
	F	Increase healthcare system capacity to respond to wildfire smoke events, wildfires, floods, and other climate impacts.
	13	Assess existing mental health resources and increase as needed, such as network of providers, integration with general practitioners and emergency responders, screenings, and capacity of inpatient and outpatient care, scalable to smoke events.
buildings, land use, + trans.	G	Balance competing land use needs in the context of population growth.
	14	Consider, and ultimately incorporate, climate migration in population growth projections in growth policy and other planning efforts.
	15	Ensure that city and county land use plans adequately protect habitat, open space, and agricultural land.

	ID	Goal + Strategy
buildings, land use, + transportation	16	Encourage urban gardens and small-scale agriculture to preserve the ability to grow food in Missoula County.
	17	Protect strategically important private lands with conservation easements and acquisition.
	H	Reduce development in the floodplain.
	18	Prevent or restrict new development in the floodplain.
	19	Work with federal partners on education and buy-out programs in floodplain areas where there is a history of repetitive loss.
	20	Enhance FEMA floodplain maps with climate change projections to be used for local regulatory and educational purposes.
	I	Reduce cooling costs by increasing efficiency of building stock.
	21	Develop programs to implement and incentivize more energy efficient building practices (new and retrofits) that are accessible to all socio-economic groups, including weatherization and cool roofs.
	22	Develop an educational campaign to increase consumers' energy efficiency, with a focus on cooling.
	J	Reduce vulnerability of buildings to wildfire.
	23	Adopt regulations and programs to address the home ignition zone (structure and surroundings), such as neighborhood ambassadors, Wildland Urban Interface (WUI) building codes, WUI zoning codes, and WUI standards in building, zoning, and subdivision codes.
	24	Restrict and regulate new development in high wildfire hazard areas.
	25	Levy impact fees and/or use other funding sources to fund fire protection related infrastructure (fire trucks, hydrants, responders, etc.)
	K	Address urban heat island effect and maintain and grow healthy, diverse urban forests that account for social equity considerations.
	26	Create incentives and programs to decrease urban heat island effect for example through building siting, shade and vegetation.
	27	Develop and promote an educational campaign to build shared understanding of value of urban forests and encourage planting appropriate species, watering, and care.
	28	Develop and promote an educational campaign to build shared understanding of the importance of xeriscaping.
	L	Ensure sustainable transportation options are part of land use planning and development.
	29	Support land use regulations and incentives that encourage densities and mixes of uses that allow for and support a wide range of sustainable transportation options.
	30	Pursue policies and prioritize funding to achieve transportation mode split goals in the Long Range Transportation Plan, considering population growth projections.
	31	Strengthen public transit system to provide safe travel during heat and/or smoke events.
	32	Pursue complete street policies and programming that incorporates urban forestry and stormwater management.
water	M	Conserve water through water conservation plans, practices, regulations and strategic/guided growth.
	33	Implement Missoula Water's plan to reduce infrastructure water loss (leaks, losses, theft, aging meters).
	34	Take water availability into account in county growth policy and zoning.
	35	Develop educational materials and incentives to increase water use efficiency during drought and flood conditions.
	36	Articulate water use best practices in real time, across user groups (agricultural producers, outfitters), based on drought conditions.
	37	Create community-wide water (rather than individual wells) in developed or developing areas.

	ID	Goal + Strategy
water	N	Enhance water storage opportunities and infrastructure to reduce incidence and impact of flooding and low-streamflow events.
	38	Expand storage (natural and human created, e.g. reservoirs, wetlands, beavers, and beaver mimicry).
	O	Preserve water quality through improved stormwater management, prioritizing green infrastructure over traditional methods.
	39	Develop a funding mechanism to support green infrastructure.
	40	Implement low-impact development standards to encourage fewer impervious surfaces.
	41	Improve and expand stormwater facilities, via new land use regulations or other methods.
	P	Preserve water quality through efficient wastewater treatment, water delivery systems, education and regulation.
	42	Create and support community-wide wastewater systems (rather than septic) in developed or developing areas.
	43	Create, fund, and implement a well contamination response plan (identify at-risk wells, potential contaminants, places to restrict new well construction).
	Q	Balance competing water needs in the context of population growth.
	44	Enhance/incentivize more effective, multi-stakeholder (recreation and agriculture) approach to drought response planning.
	45	Advocate for state water policies that provide innovation and flexibility in encouraging water conservation and resiliency.
ecosystems (aquatic + terrestrial) + wildfire	R	Build understanding of forest, terrestrial and aquatic ecosystems and appropriate, site/landscape-specific management options that account for climate change.
	46	Analyze current, departure from historical conditions, and projected climate conditions to identify and prioritize where to resist, accept, or facilitate site or ecosystem change, considering cultural values.
	47	Create and implement watershed management plans based on climate projections that prioritizes habitats to protect (include restoration strategies, human access considerations, and agricultural best management practices).
	48	Maintain and enhance connected habitat corridors.
	S	Reduce high severity wildfires and their impact in high risk areas/landscapes.
	49	Increase prescribed fire and/or thinning when and where appropriate.
	50	Implement best practices such as prescribed fire, streamside buffers, and support of beavers to increase watershed resilience to fire.
	T	Build a shared understanding of the realities of wildfire and our expectations of wildfire response.
	51	Grow educational and outreach efforts within and between agencies, community partners, and public to build support for forest management options (including allowing natural fires to burn), considering divergent values (for example, Wildfire Adapted Missoula).
	U	Ensure ecological integrity during and after fire, and/or fire suppression activities.
	52	Create a watershed reinvestment fund to support restoration after wildfire.
agriculture	V	Increase adoption of ecologically sound and climate smart practices for Missoula County agriculture.
	53	Identify and promote ecologically sound agricultural best practices in a 1-stop shop, considering pests, pathogens, heat, drought, smoke.
	54	Promote regenerative soil building to revitalize soil quality.
	55	Develop and communicate water-use best practices for agricultural producers in real time to inform plant and animal water needs, improve efficiency, and reduce water loss.
	W	Increase economic resilience of Missoula County agriculture given climate change.
	56	Promote diversification of farm income sources (e.g. carbon offsets, value added products, and eco-tourism).

	ID	Goal + Strategy
agriculture	57	Increase access to locally sourced food through aggregation, storage and distribution of agricultural products.
	58	Increase support for locally sourced food through education and outreach, economic incentives, and other programs.
	X	Strengthen social connectivity between farmers, ranchers, and community members.
	59	Create a farmer and rancher support network at regional or sub-regional level, considering economic and mental health needs of agricultural community.
emergency preparation + response	Y	Ensure “hard” infrastructure (roads, bridges, power lines, telecommunications, etc.) is resilient to climate change.
	60	Assess infrastructure needs and vulnerabilities to inform infrastructure strategic plan (protect, enhance, develop redundancies).
	Z	Ensure “soft” infrastructure (systems, people, partnerships, communication, plans, etc.) is resilient to climate change.
	61	Enhance emergency communication capabilities and evacuation strategies, routes, and safety zones.
	62	Connect with and support Invest Health, Missoula College, Missoula Emergency Services Inc., Missoula City-County Health Dept. and partners regarding preventative health measures (upstream health response).
	63	Ensure public safety and emergency response communities have the necessary tools to provide care, outreach and/or referrals.
	64	Ensure sufficient emergency response personnel within rural areas of Missoula County.
business, recreation, + tourism	AA	Prepare tourism and recreational industries for changing climate.
	65	Increase agility of existing tourism and recreational businesses to adapt to changing conditions (timing and location of activities).
	66	Diversify tourism and recreational industries by identifying, investing in, and promoting new, sustainable-oriented opportunities.
	67	Develop and market flexible indoor recreation and tourism opportunities.
	68	Develop recreational resource plan, including a comprehensive map of resources, to adapt uses and types of recreation, as well as protect assets and promote access.
	BB	Strengthen and diversify local economy (aside from tourism and recreation) in a changing climate.
	69	Partner with economic development organizations and universities to develop a certification program and knowledge sharing for existing businesses that are climate resilient.
	70	Create economic innovation hub to identify new business opportunities given climate change.
	71	Enhance energy efficiency and weatherization workforce and business opportunities.
	72	Expand and diversify value-added timber market, for example small diameter mass timber.
energy	CC	Ensure a clean, reliable, affordable energy system in the context of increased heat, drought, extreme weather, wildfire, and population growth.
	73	Collaborate statewide to facilitate and advocate for legislative, regulatory, and utility program change that accelerates development of renewable energy, energy storage, energy efficiency, and load flexibility, and reduces our reliance on fossil fuels.
	74	Develop local energy savings programs to reduce energy cost burden and exposure to energy price volatility.
	75	Accelerate adoption of distributed renewable energy systems, electrification and microgrids.
	76	Manage vegetation near utility infrastructure to reduce the risk of igniting fires in very hot/dry periods.
	77	Bury overhead power lines.

Next Steps

The strategies presented in this plan are intentionally high-level; they identify *what* needs to be done to prepare for and adapt to climate change. All the details for each strategy—*who* should be involved in implementing it, *how* it can best be accomplished, timeline, costs and benefits, funding sources—will need to be determined in the implementation phase.

An Implementation Task Force and dedicated staff capacity will be necessary to prioritize adaptation strategies, coordinate and monitor implementation of this plan as a whole, report on progress, redirect actions that are not achieving the desired results, update the plan as needed, and continue engaging the community. Smaller working groups will also be necessary to make progress on specific goals and strategies within each sector, and the Implementation Task Force will need to ensure that the working groups coordinate with one another, leveraging the connections among sectors.

It will be important for the Implementation Task Force to refer frequently to the guiding principles of this effort as strategies are prioritized and implemented. For example, equity and inclusiveness should be key considerations in all steps of implementation. Adaptiveness and flexibility will be critical as strategies are implemented and evaluated and as climate conditions continue to change.

Implementation of many of these strategies will not be easy. We will confront numerous barriers—policy, economic, technological, and social—that will need to be overcome. Identifying these barriers and addressing them strategically will be essential to allow for the successful implementation of the plan.

We must coordinate with efforts to address other critical challenges facing Missoula County, such as affordable housing, homelessness, health care costs and availability, and income inequality. Given tight budgets and the urgency of addressing all of these issues, we can expect tensions to arise. Our challenge will be to consider these issues holistically rather than in isolation. We will need to revisit our guiding principles at every step, craft innovative solutions, and learn from the successes of other communities.

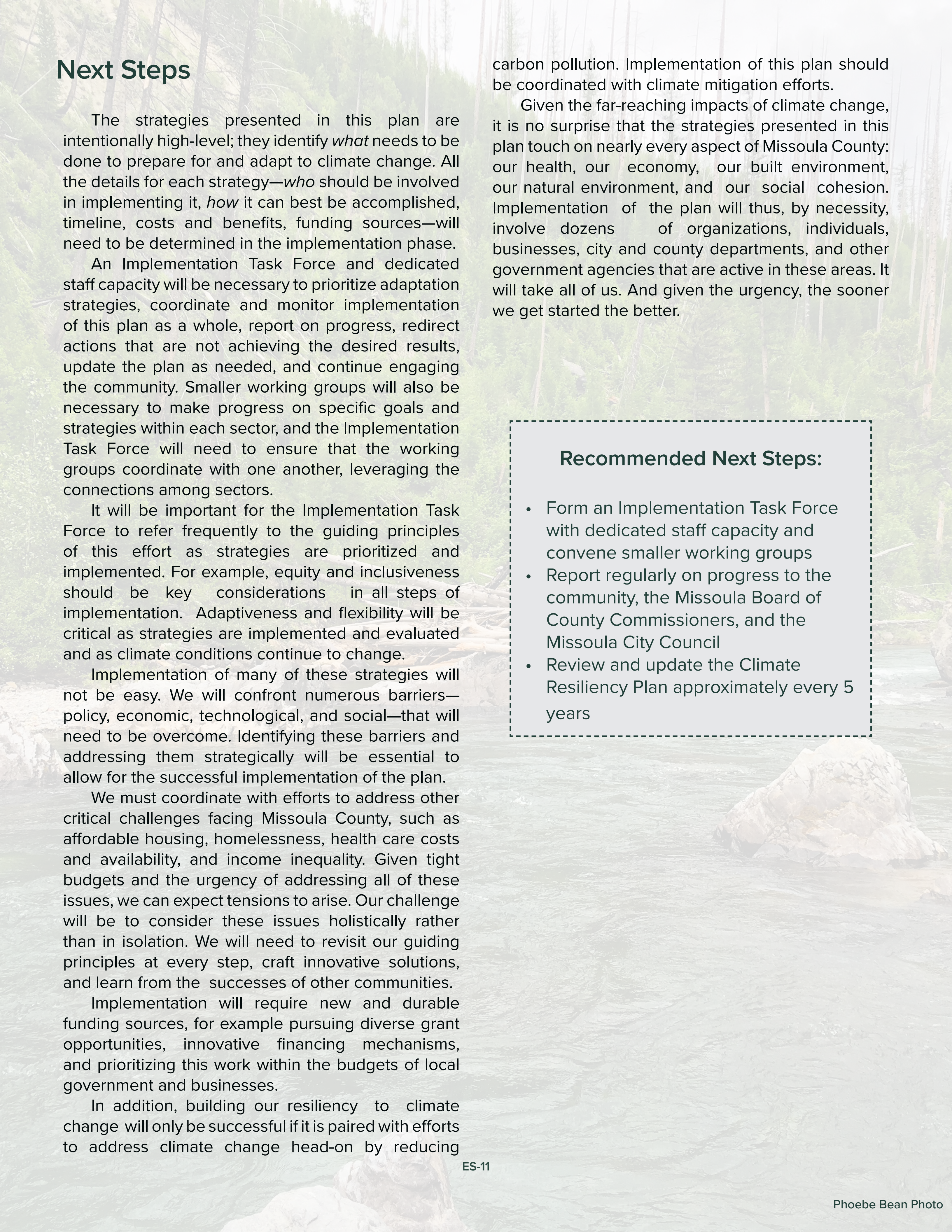
Implementation will require new and durable funding sources, for example pursuing diverse grant opportunities, innovative financing mechanisms, and prioritizing this work within the budgets of local government and businesses.

In addition, building our resiliency to climate change will only be successful if it is paired with efforts to address climate change head-on by reducing carbon pollution. Implementation of this plan should be coordinated with climate mitigation efforts.

Given the far-reaching impacts of climate change, it is no surprise that the strategies presented in this plan touch on nearly every aspect of Missoula County: our health, our economy, our built environment, our natural environment, and our social cohesion. Implementation of the plan will thus, by necessity, involve dozens of organizations, individuals, businesses, city and county departments, and other government agencies that are active in these areas. It will take all of us. And given the urgency, the sooner we get started the better.

Recommended Next Steps:

- Form an Implementation Task Force with dedicated staff capacity and convene smaller working groups
- Report regularly on progress to the community, the Missoula Board of County Commissioners, and the Missoula City Council
- Review and update the Climate Resiliency Plan approximately every 5 years



Phoebe Bean Photo

Introduction

Introduction

There is overwhelming scientific consensus that our climate is changing, and that urgent action is required to avert a potentially catastrophic outcome. In a 2018 report, the Intergovernmental Panel on Climate Change concluded that human activities have already caused the Earth to warm by 1°C, and that allowing warming to exceed 1.5°C will result in massive impacts to ecosystems, human health, and economic and social wellbeing. The IPCC further concluded that limiting warming to 1.5°C will require unprecedented global action, including reducing carbon emissions 45% by 2030 and phasing them out entirely by 2050.[1]

We are already experiencing the impacts of climate change in Missoula County, and those impacts are projected to intensify over the coming decades and to touch every sector of our county. Changes are likely to include reduced low elevation snowpack, earlier spring snowmelt, and more frequent and intense wildfires, droughts, and floods. The severity of the impacts we experience will depend on how quickly global carbon emissions are reduced.

How We Address Climate Change: Mitigation and Adaptation

Efforts to address climate change fall into two main categories: **mitigation,** which involves reducing the carbon pollution that is changing our climate; and **adaptation,** which involves addressing the impacts of climate change that we are already experiencing and preparing for the projected changes to come. Mitigation addresses the problem at its root, while adaptation addresses its effects. Given that our climate is already changing, both mitigation and adaptation are essential and urgent. Neither is sufficient on its own.

The focus of Climate Ready Missoula is adaptation, not mitigation. In addition to building our resilience in the face of climate change, adaptation makes good economic sense. Indeed, studies have shown that every $1 spent on climate adaptation will save between $2 and $10 in the future.[2]

However, the fact that Climate Ready Missoula is focused on adaptation should not be interpreted to mean that we have given up on mitigation, or that adaptation is more important. Both are essential. As the locally-specific climate projections presented in this plan make clear, the more quickly we reduce global carbon emissions, the less severe the changes we will experience here, and the more manageable the task of adaptation will be. We cannot adapt our way out of this. We must also do our part to address the root of the problem by reducing carbon emissions.

Indeed, Missoula City, County, and community are committed to numerous climate mitigation efforts. These include working toward a goal of 100% clean electricity for the Missoula urban area by 2030 (adopted jointly and unanimously by the Missoula City Council and the Missoula Board of County Commissioners in 2019)[3]; goals of carbon neutrality in city and county government operations[4]; and a goal of carbon neutrality for the community as a whole.[5]

A number of other community efforts are also essential to climate mitigation. For example, Missoula's ZERO by FIFTY plan[6], which includes a goal of 90% waste reduction by 2050, is key to climate mitigation given that a large fraction of global carbon emissions are associated with resource extraction, manufacturing, and distribution of goods and food. Land use and transportation planning are also essential, given that transportation is the largest contributor to local carbon emissions.[7] The City's "Our Missoula" Growth Policy[8], the County Growth Policy[9], and the Missoula Long-Range Transportation Plan[10] include climate mitigation strategies in the form of a focus on density, mixed-use development, transit-oriented development, and reducing vehicle miles traveled by expanding sustainable transportation options. Energy efficiency, water conservation, and terrestrial carbon sequestration are other examples of local climate mitigation efforts.

Given that Climate Ready Missoula is focused on adaptation rather than mitigation, most of the efforts mentioned in the previous two paragraphs are not detailed in this plan. However, several adaptation strategies that are identified in this plan also support our mitigation goals. Those strategies are identified in the table of strategies on page 39 with a thumbs-up in the far-right column labeled "Mitigation Benefit."

The Climate Ready Missoula Process

While climate change is a global challenge, its impacts are experienced at the local level, and it falls to local communities to address them. Beginning in the summer of 2018, Missoula County, Climate Smart Missoula, and the City of Missoula led a county-wide process, Climate Ready Missoula, to better understand our greatest vulnerabilities in the face of climate change, and to develop a coordinated plan to prepare our county for the changes we are facing. This is the plan that has emerged from that process.

Climate change will touch all aspects of our community, and the focus of this plan is therefore extremely broad. The reason for undertaking this plan holistically—rather than completing separate, sector-specific climate resiliency plans—is that climate impacts cross sector boundaries, and an adaptation strategy developed for one sector in isolation could easily have unintended consequences on other sectors.

Climate Ready Missoula was inspired by, and generally followed the guidelines of, the Climate Ready Communities program developed by the Geos Institute.[11] Climate Ready Communities is a flexible process that allowed us to incorporate a number of Missoula-specific elements to fit our local circumstances and take advantage of local expertise available at the University of Montana. It has been a stakeholder-driven process and has benefited from the participation of hundreds of community members.

The process started in the summer and fall of 2018 with development of a Climate and Community Primer that included climate change projections specific to Missoula County and a discussion of the implications of those projections for the county's natural systems, economy, human health, and cultural resources. The primer also included 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 (page 8). Much of the material presented in the primer is incorporated into this plan.

The primer was the foundation for the first stakeholder workshop, held in December 2018. At the workshop, over 100 community members were introduced to the climate projections and scenarios, and then divided 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.

The information developed at the workshop was summarized in a draft Vulnerability Assessment. Public input - gathered through public meetings, open houses, and an online survey - was incorporated into the final Vulnerability Assessment, which was the foundation for the second stakeholder workshop, held in late May 2019.

At the May workshop, stakeholders worked in cross-sector groups. Each group was assigned a subset of the risks from the Vulnerability Assessment (excluding risks identified as "less problematic") and completed an activity focused on developing strategies to respond to those risks. The workshop was highly productive; altogether, more than 300 strategies were identified to address more than 100 risks. Due to overlap in many of the strategies, it was possible to distill them into a shorter list of 77 actions that address 29 goals. The list of these goals and actions forms the heart of this plan and can be found on page 39.

Guiding Principles

These 12 principles were developed to guide the process of prioritizing and implementing the climate adaptation goals and actions that are presented in this plan. While all of these principles should be considered with respect to each adaptation goal or action, there will be some cases of tradeoffs among the principles.

1. Collaborate and think holistically. Climate change touches all aspects of our lives, requiring us to collaborate in new ways, to work across sectors and silos, and to think beyond our geographic boundaries.

2. Prioritize equity. Adaptation actions should not increase inequity. Prioritize actions that build resilience while focusing on underrepresented and vulnerable groups and increasing equity.

3. Act with, not for. Maximize transparency and inclusivity in planning and implementation. Empower people with knowledge and tools to participate and take ownership of climate resiliency actions.

4. Draw on tradition and culture. Honor cultural values and draw on traditional ecological knowledge through collaborative partnerships. The Confederated Salish and Kootenai Tribes are key partners, especially given that Missoula County falls within the ancestral homelands of these tribes.

5. Use science. Make decisions based on the best available science while explicitly considering uncertainty.

6. Value natural processes. Learn from nature and protect and restore naturally resilient ecological processes.

7. Don't exacerbate the problem. Adaptation actions should avoid increasing our contribution to climate change or undermining the ability of other sectors or regions to adapt. Prioritize actions that reduce our contribution to climate change while building resilience.

8. Build on past work. Recognize, value, and integrate prior and ongoing work. Don't reinvent the wheel.

9. Balance immediate and long-term needs. When prioritizing actions, select a combination of easy, quick wins and critical but challenging longer-term initiatives.

10. Consider costs and benefits. Adaptation actions should be evaluated by considering their long-term costs and benefits alongside the costs of not taking action.

11. Focus on prevention. When possible, prioritize actions aimed at avoiding problems rather than addressing them after they occur.

12. Innovate and adapt. Monitor and evaluate actions to learn what's actually working. Experiment with emerging solutions, be creative, maintain flexibility as conditions change, and build capacity to respond to the unexpected.

Climate Change

Projections + Scenarios

Climate Change Projections and Scenarios

Climate change will affect all parts of the globe, but not all will be affected in the same way. Some areas will be most impacted by sea level rise, others by extreme heat, others by drought or flooding or wildfire. Our discussion of climate resiliency begins with an in-depth understanding of historical climate conditions and projected climate trends in Missoula County. This chapter aims to provide that understanding, given what we know today.

In brief: Missoula County's summers are expected to become hotter and drier. Winters and springs are expected to become warmer and wetter. More precipitation will fall as rain instead of snow, especially at low elevations. These changes will directly impact our quality of life and the local economy. For example, warmer, drier summers increase the risk of wildfires and wildfire smoke that damages pulmonary and respiratory health and deters tourists. Prolonged periods of high temperatures increase the risk of heat-related illnesses. Changes in temperature and precipitation patterns affect Missoula County's water resources and the wildlife, agriculture, and recreation economies that depend on them.

While there is much that we can say with confidence about how our climate is changing, any effort to predict the future is accompanied by uncertainty. In climate modeling, this uncertainty stems from the fact that the models themselves are by necessity simplifications of reality, as well as uncertainty about whether and how quickly greenhouse gas emissions will be reduced worldwide. The projections presented in this section are based on the results of twenty different climate models in order to account for the uncertainty that accompanies any one model. We also present results for two greenhouse gas emissions trajectories, one in which emissions are reduced substantially in the coming decades, and another in which they continue to increase (see Climate Models section on page <?>). In addition, we address the uncertainty in climate projections by presenting three plausible mid-century climate scenarios (page 8), which illustrate a variety of possible futures for Missoula County based on the climate projections presented in this chapter.

This chapter begins with a discussion of climate basics and the data sources used in this project. It then describes historical trends and future projections for temperature and precipitation in Missoula County, followed by the three mid-century climate scenarios.

Climate Basics

What's the difference between weather and climate? Weather refers to the condition of the atmosphere at a given time and place, usually a short period of time lasting from minutes to months. Climate, on the other hand, refers to average weather conditions of a region over a longer period of time. The World Meteorological Organization describes climate using a minimum period of 30 year averages, but climate can also be broadly described over hundreds to millions of years.[12] Climate may also be described by the magnitude and frequency of extreme weather events like flooding or droughts. Climate change, therefore, refers to long-term changes in average weather conditions.

Earth's climate and weather systems are powered by the radiant energy of the sun. Most of that energy is either reflected back out to space or absorbed by the Earth's surface, but about 20% of it is absorbed by gases in the Earth's atmosphere. Some of the energy absorbed in the atmosphere is radiated back toward the Earth's surface, further heating the land and oceans. This process by which the atmosphere absorbs and radiates solar energy is known as the "greenhouse effect." The gases that contribute to the greenhouse effect, known as greenhouse gases, include carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), and ozone (O3).

The Earth's climate is inherently dynamic and has been changing throughout the planet's history. Past climate changes have been associated with natural causes such as changes in the Earth's orbit, volcanic activity, and gradual, periodic shifts in the atmosphere's greenhouse gas concentrations. However, the recent change in Earth's climate has been largely, if not entirely, caused by human activity, in particular greenhouse gases emitted by the combustion of fossil fuels (coal, oil, and natural gas) that we use to fuel our cars and trucks, heat our buildings, and produce electricity. Since 1750, atmospheric concentrations of CO2, N2O, and CH4 have increased by 40%, 20%, and 150%, respectively, to levels that are unprecedented in at least the past 800,000 years.[13] For comparison, an equivalent natural increase in greenhouse gases during the end of the past ice age took over 5,000 years.

Data Sources

The Montana Climate Assessment, a project of the Montana Institute on Ecosystems, was completed in 2017 following two years of work by a team of researchers at the University of Montana and

Montana State University.[14] The Montana Climate Assessment includes climate projections for seven climate divisions across the state (Missoula County falls within the northwestern climate division), as well as chapters addressing the impacts of climate change on Montana's water, forests, and agriculture.

The climate projections presented in this plan draw heavily from the Montana Climate Assessment. In addition, for climate projections specific to Missoula County, we made use of the Climate Explorer, a web application built to accompany the U.S. Climate Resilience Toolkit developed by the National Oceanic and Atmospheric Administration in partnership with twelve other federal agencies.[15] For current and historical conditions, we used the Climate Explorer's observational data along with NOAA's Climate at a Glance web application, which is gathered from local weather stations for the years 1950-2013. For future projections, we used the Climate Explorer's modeled projected data.

Climate Models

Climate scientists use complex computer models, called general circulation models, to make climate change projections by simulating interactions in the atmosphere, land, and oceans. Data sources for this project, including both the Montana Climate Assessment and the Climate Explorer, use data from an ensemble of general circulation models known as the Coupled Model Intercomparison Project Phase 5 (CMIP5). The climate models in the CMIP5 rely on standard socioeconomic trajectories, known as Representative Concentration Pathways (RCPs), that describe different potential future greenhouse gas emission scenarios. RCPs are not forecasts or predictions but are plausible climate scenarios based on future energy sources, population growth, economic activities, and technological advancements over the course of the century. There are four RCP scenarios in the CMIP5: RCP2.6, RCP4.5, RCP6.0, and RCP8.5.

Following the Montana Climate Assessment, this projections presented here include information from the RCP4.5 and RCP8.5 scenarios. RCP4.5 is a stabilization scenario that assumes a peak in greenhouse gas emissions around 2040 followed by a decline, and expresses confidence that the global community will take action in the near future to reduce emissions. RCP8.5 is a business-as-usual scenario that assumes greenhouse gas emissions will steadily increase throughout the 21st century and expresses low confidence in the global community's ability to reduce emissions. In this plan, RCP4.5 and RCP8.5 will be referred to as the "stabilization scenario" and the "business-as-usual scenario", respectively.

Current and Historical Conditions

Missoula County is located west of the Continental Divide, and as such its climate is heavily influenced by the weather patterns of the Pacific Northwest, with cooler summers, milder winters, and more year-round precipitation than central and eastern Montana. Figure 1 and Figure 5 compare seasonal average temperature and precipitation in Missoula County and Montana as a whole. Note that while the City of Missoula receives an average of about 14 inches of precipitation per year, higher-elevation regions in the county receive much more, resulting in a county-wide average of nearly 30 inches per year. Since 1950, Montana's annual and seasonal average temperatures have been steadily increasing.

From 1950-2015 northwestern Montana's average annual temperature increased by about 2.5°F, with the highest rate of warming occurring in the spring.[16] During the same period, average annual precipitation in northwestern Montana decreased by about 3.8 inches, with most of that decline occurring during the winter season. This decreasing trend likely comes from an increased number of El Niño events, which are associated with warmer and drier winters, during this time period. The El Niño Southern Oscillation (ENSO) is a natural phenomenon and therefore it is likely that this declining precipitation trend is a part of the natural climate variability of the Pacific Northwest. For more information on ENSO and its relationship to Montana's climate, see Chapter 1 of the Montana Climate Assessment.[17]

Rising average temperatures have been accompanied by changes in Montana's climate extremes. An analysis of climate extremes performed by the Montana Climate Assessment found a significant decrease in the number of days per year with intense cool temperatures and a significant increase in the number of days per year with intense warm temperatures. During the period 1951-2010, monthly minimum and maximum temperatures have increased by 5°F and 1.1°F, respectively. Throughout the state, the number of frost days (days with minimum temperatures below 32°F) has decreased by 12 days from 1951-2010, while the number of hot days (days with maximum temperatures exceeding 90°F) has increased by 11 days. These trends have contributed to an increase in the length of the growing season by 12 days since 1951.[18]

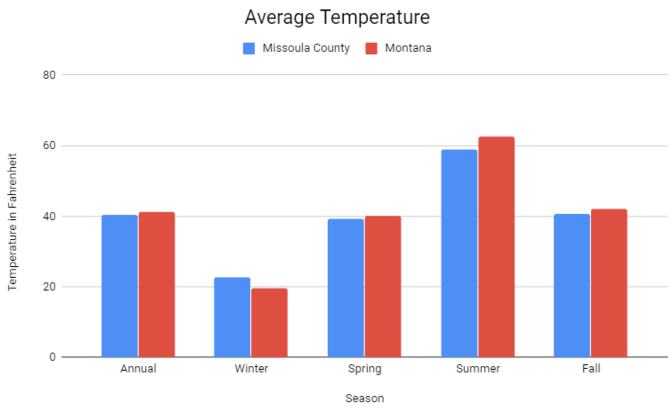


Figure 1 Comparison of Missoula County's and Montana's annual and seasonal average temperature. Data from NOAA Climate at a Glance tool for years 1901-2000. Averages include both daytime and nighttime temperatures.

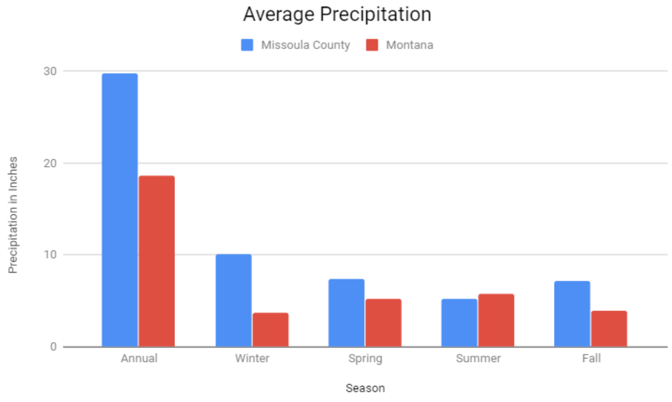


Figure 2 Comparison of Missoula County's and Montana's annual and seasonal average precipitation. Data from NOAA Climate at a Glance tool for years 1901-2000.

Future Climate Projections

Temperature

In both the stabilization and business-as-usual emission scenarios, temperatures are projected to continue increasing. By mid-century, Missoula County's average annual temperature is projected to increase by about 4°F in the stabilization scenario and 5°F in the business-as-usual scenario. By the end of the century, Missoula County's average annual temperature is projected to increase by about 5°F in the stabilization scenario and 8°F in the business-as-usual scenario. The greatest temperature increases are projected in July, August, and September. Figure 3 shows the projected change in average annual and seasonal temperature by mid-century and the end of the century.

As 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 and 18-39 days by the end of the century. In contrast, the average number of frost days per year is projected to decrease 36-46 days by the middle of the century and 45-73 days by the end of the century.

Precipitation

Average annual precipitation for Missoula County is projected to increase by 2-3% by mid-century and by 3-6% by the end of the century. 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 (Figure 4). This projection differs from the decrease in precipitation (especially winter precipitation) observed in Missoula County in recent decades. This difference is likely due to natural variability from the El Niño Southern Oscillation, as discussed above, and a time lag in the effect of anthropogenic warming on precipitation. While it takes many years to establish climate trends, recent changes in precipitation appear to align more closely with projections. Warmer temperatures are likely to result in more precipitation falling as rain rather than snow in the western Montana, especially at low elevations.[19]

Bryce Christiaens Photo

Figure 3 Projected change in annual and seasonal average temperature for Missoula County by mid-century and the end of the century. Data from Climate Explorer.

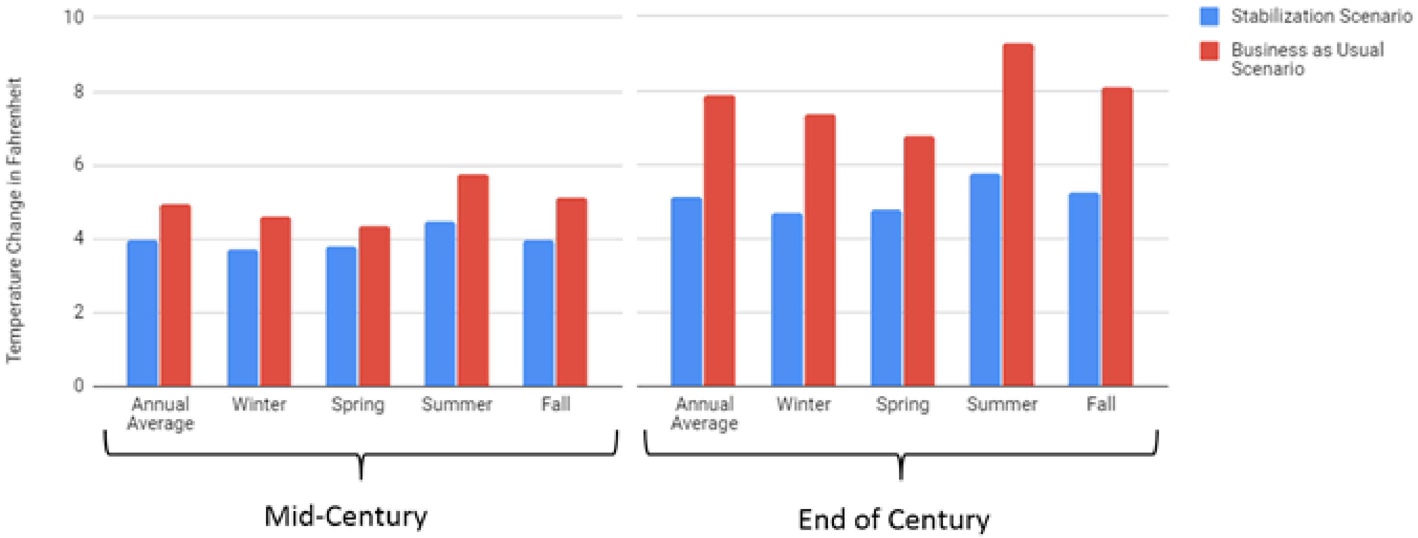
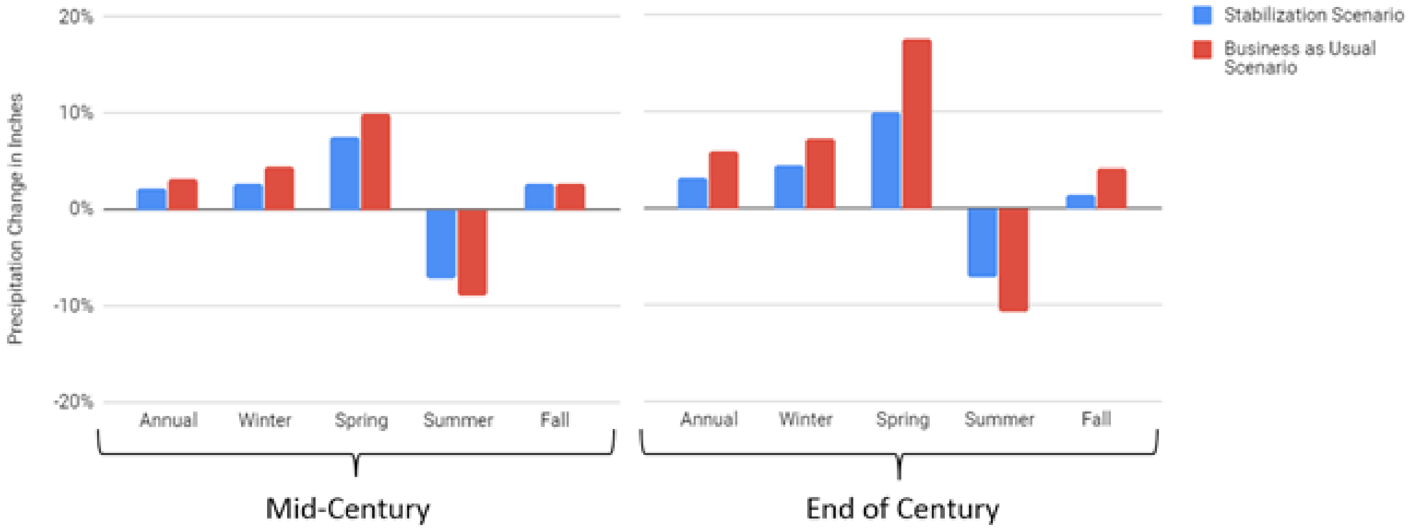
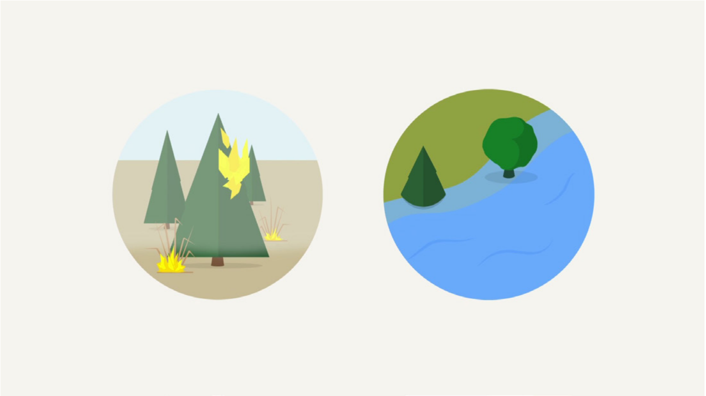


Figure 4 Projected changes in average seasonal precipitation for Missoula County by mid-century and the end of the century. Data from Climate Explorer.



Concluding Thoughts on Climate Projections

It's hard for statistics to paint a complete picture of what it will be like to live in Missoula County in 2050 or 2100. Luckily, we can draw on recent experience to help paint that picture. The summer of 2017 was significantly warmer and drier than the historical average; in northwest Montana, summer temperatures were 4.1°F higher than the average of the past 30 years, and summer precipitation was 2.4 inches less than the 30-year average. These conditions are similar to what projections suggest will be the new average in Missoula County by mid-century. It is likely no coincidence that 2017 was also one of the worst fire seasons ever recorded for Missoula County.



Mid-Century Climate Scenarios for Missoula County

This section presents additional illustrations of what climate change could mean for Missoula County in the coming decades.

The following three scenarios describe plausible futures that Missoula County could face in the next 30 years. They were developed based on current trends, recent events, scientific research, and the climate projections presented above. Scenarios are used in planning for climate adaptation as a way to tangibly represent key uncertainties related to a) projected changes in temperature and precipitation at the local scale, and b) the implications of those changes for ecosystems and human communities. The goal is to provide detailed descriptions of what the future could look like to help people identify specific challenges and opportunities within different sectors and communities across the county. Scenarios also enable us to prepare for the range of futures that climate change might bring to Missoula County.

The scenarios below were reviewed by seven subject matter experts to ensure that they reflect the latest science on current and projected climate impacts.

Scenario 1 | Turn Up the Heat

In this scenario, the annual average temperature increases by approximately 6°F by mid-century, with the greatest temperature increase in the summer (about 7°F, versus 5°F the rest of the year). This is similar to the present day average annual temperature in Denver, Colorado, 500 miles south of Missoula. Average summer temperatures will be hotter than the summer of 2017, when we experienced a prolonged heat wave. We'll experience 2-3 additional weeks per year with daily high temperatures above 90°F. Average annual precipitation will remain about the same, but the timing of precipitation will change: summers will be drier and the rest of the year slightly wetter. On average, summer rainfall will decrease by about 30%.

Fire and Smoke Impacts

With higher temperatures and less precipitation in the summer and early fall, fire seasons will last an average of 12 days longer than they do today, and the total land area burned each year will increase about 50% on average. While we will not see extensive, region-wide burning every year, fire seasons like 2012 and 2017, which saw widespread burning across the northern Rockies, will become more frequent.

Wildfires will pose an increasing threat to the lives and properties of Missoula County residents, in particular those who reside in the wildland-urban interface (which encompasses nearly all inhabited areas of Missoula County, with the exception of the Missoula urban core).

Over time, increases in the size and severity of fires will reduce the extent of low elevation forests, converting forested areas to shrublands or grasslands. Invasive species such as leafy spurge and spotted knapweed thrive in areas that have been recently disturbed and will increase their range as a result of more area burned. Warmer winters will also promote larger pine beetle populations.

Longer and more intense fire seasons in Missoula County and throughout the region will mean longer periods of unhealthy air quality due to wildfire smoke, increasing the incidence and severity of respiratory and cardiovascular disease among county residents. Emergency room visits for breathing problems, heart attacks, and strokes will spike during periods of dense wildfire smoke. Children, the elderly, people with heart and lung disease, and outdoor workers will be among the most impacted. The smoke season will last well into September, and possibly October, with increasing impacts on schools and fall athletic programs. Outdoor recreation and tourism will decline during periods of wildfire smoke. Portions of Yellowstone and Glacier National Parks will close more frequently due to wildfires; and even when the parks are open, wildfire smoke will obscure vistas and deter tourists, many of whom would otherwise visit Missoula County en route to the national parks. Thousands of jobs will be lost in the tourism industry statewide.

Water Impacts

Warmer winters will lead to a decline in mountain snowpack. That snowpack will melt earlier due to warmer spring temperatures, leading to peak streamflows 2-3 weeks earlier in the year. Late summer streamflows will be much lower than they are now, reducing the amount of water available for fish and riparian vegetation. In addition, lower flows combined with hotter summers will mean higher river temperatures, reducing populations of temperature-sensitive species such as bull trout. Higher river temperatures will lead to more frequent and longer-lasting "hoot owl" fishing restrictions, which prohibit fishing during certain hours of the day in order to minimize stress on trout when water temperatures are high. Warming water temperatures may also result in the proliferation of parasites, viruses, fungal infections, and algae blooms, impairing water quality, affecting aquatic plants, and killing fish.

Due to a later fall freeze and earlier spring thaw, the growing season will increase in length by about 2 months. While annual precipitation does not change in this scenario, warmer temperatures will result in increased evaporation, reducing the water available for plant growth by 4-8%. In addition, less summer precipitation and lower August streamflows will mean that less water is available for agriculture during the growing season. The longer growing season could be beneficial to irrigated agricultural producers in the county, as long as they have adequate access to water for irrigation. Warmer temperatures might also benefit the nascent viticulture industry in Missoula County. However, some crops may be damaged by heat stress due to hotter summer temperatures, and ranchers will experience decreased forage production and an increase in invasive species on rangelands.

Reduced snowpack and earlier snowmelt will impact winter recreation. For example, ski resorts will face shorter ski seasons and more frequent closures of low-elevation terrain, and opportunities for low-elevation nordic skiing and backyard ice skating will be reduced or eliminated. Seasons for other recreational sports such as mountain biking may be extended due to warmer springs and falls, but will also be affected by wildfire smoke.

Scenario 1 Snapshot:

- Average annual temperature increases by ~ 6°F by 2050, more in the summer
- 2 - 3 additional weeks/year with daily highs above 90°F
- Average annual precipitation will remain the same, but summer rainfall will decrease by about 30%
- Longer fire seasons, more wildfire smoke

Scenario 2 | Here Comes the Rain Again

In this scenario, average annual temperatures increase by about 3°F by mid-century (about half as much as in Scenario 1), and we experience roughly one additional week per year with daily high temperatures above 90°F. Average annual precipitation increases by 15%. This additional precipitation falls in the winter, spring, and fall; summer precipitation does not change. We also experience several more days per year of intense rainfall.

There will be an increase in the number and intensity of droughts and wildfires in this scenario, but not as pronounced as the increase in Scenario 1 Turn up the Heat. On the other hand, flooding will be a much bigger issue in this scenario than in Scenario 1.

Changing Seasons Impacts

While summer precipitation does not change in this scenario, hotter summers increase evaporation rates, reducing water available for plant growth in the summer and resulting in a greater contrast between wet and dry seasons. Early but short spring rains promote rapid green-ups, followed by prolonged dry summers and brown landscapes.

The growing season increases in length by 2-3 weeks due to increased fall and spring temperatures. These conditions will expand not only the growing season, but also the types of crops we can grow in Missoula County, as well as affecting the timing of planting, fertilizer application, and harvest.

Elk and other wildlife will benefit from the availability of ample forage in early spring, but may be forced to change their normal winter ranges due to warmer winters and deeper mountain snowpack.

Flooding Impacts

Throughout Montana’s history, “rain on snow” events have caused the most severe and destructive floods. In this scenario, warmer temperatures and wetter winters and springs will cause more rain on snow events and faster snowmelt, leading to more frequent and severe flooding. By mid-century, the average winter and spring will be even warmer and wetter than 2018, when the Clark Fork River crested at its second highest level in 100 years and severe flooding damaged houses and tipped power poles.

More frequent and severe flooding will lead to extensive property damage and pose a risk to the health and safety of the hundreds of Missoula County residents who live or work in the floodplain. Flooding will also increase the incidence of waterborne illness such as giardia.

In the urban area, more severe rain events will challenge our stormwater system, and greater volumes of stormwater runoff that flow to the aquifer will increase the potential for contamination of our drinking water supply.

Flooding will impact populations of fall spawning fishes, such as bull trout, whose eggs and young are vulnerable to spring floods.

Missoula Marathon
Amy Cilimburg Photo

Scenario 2 Snapshot:

- Average annual temperature increases by ~ 3 degrees (F) by 2050, more in the summer
- ~ 1 additional week/year with daily highs above 90
- Average annual precipitation increases by 15%, falling in winter, spring, and fall - summer precipitation does not change
- More flooding

Scenario 3 | Feast or Famine

In this scenario, average temperatures will increase 4-5°F by mid-century and we'll experience about two more weeks each summer with daily temperatures above 90°F. Average annual precipitation will not change, but there will be much greater variability in precipitation from year to year, with some very wet years and some intense drought years. An "average" year will be a thing of the past.

Variability Impacts

On average, the total area burned by wildfires each year will be larger than it is today but smaller than in Scenario 1 Turn Up the Heat. Increased year-to-year variability in precipitation will result in increased variability in fire season length and area burned. Intense rainfall will reduce total area burned in some years, depending on the timing within the fire season. The timing of season-ending events, in particular, will be highly variable among years.

In dry years, we will experience low late-summer streamflows and reduced water available for plant growth, with impacts on aquatic ecosystems, river recreation, and agriculture similar to Scenario 1.

In wet years we will experience flood events similar to those described in Scenario 2. Flooding will be exacerbated by the increase in wildfires in dry years, since rainfall runoff over burned areas can cause flash flooding. Burned hillsides are also vulnerable to landslides when it rains, resulting in soil loss which degrades land, slows regrowth, and leads to excessive sedimentation in streams and rivers.

From year to year, the season and conditions for outdoor activities like skiing and fishing will vary dramatically. Businesses involved in outdoor recreation and those that cater to tourists will be particularly challenged to prepare for this unpredictability. Increased variability will also be difficult for farmers and ranchers in the county, as the strategies for drought years may be very different from wet years. Indeed, not being able to plan for an "average year" can be difficult for many, from athletes (youth to adult) to construction firms. Being forced to alter schedules and expectations each season can be stressful and economically costly.

Ecosystems Impacts

Extreme conditions such as long winters with heavy snowfall and summer drought are hard on fish and wildlife. For example, elk distributions will change due to long winters in some years and dry summers in other years. Fish that spawn in the fall are vulnerable to spring flooding; and all fish species are stressed by low summer flows and warmer river temperatures.

Scenario 3 Snapshot:

- Average annual temperature increases by 4 - 5°F by 2050, more in the summer
- 2 additional weeks/year with daily highs above 90°F
- Average annual precipitation will remain the same, but there will be much greater variability in precipitation from year to year
- A normal year will be a thing of the past

Vulnerability Assessment

Vulnerability Assessment

As described in the previous section, climate projections for Missoula County suggest that we are likely to experience hotter, drier summers and warmer, wetter springs, and the implications of these changes will include more frequent and intense wildfires and floods. These climate projections served as the foundation for the first stakeholder workshop, held in December 2018, at which more than 100 participants worked in 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.

This Vulnerability Assessment summarizes the information gathered at the workshop, as well as public input that was gathered through an online survey and public meetings held in the spring of 2019. It is organized according to seven climate impacts, shown in Figure 5.

These impacts are interrelated; for example, higher temperatures exacerbate drought by increasing evapotranspiration, and the combination of heat and drought increases the risk of wildfire, which results in wildfire smoke. We consider them separately in the following sections because in addition to the connections among them, they each pose their own risks to Missoula County.

However, by considering these impacts separately, we run the risk of obscuring the fact that some of the risks identified may be caused by a complex combination of impacts that occur on various spatial and temporal scales. For example, shifts in forest system types and the species that reside therein may result from a combination of warmer, drier summers, extreme weather events, and disturbances such as wildfire.

It is also 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.

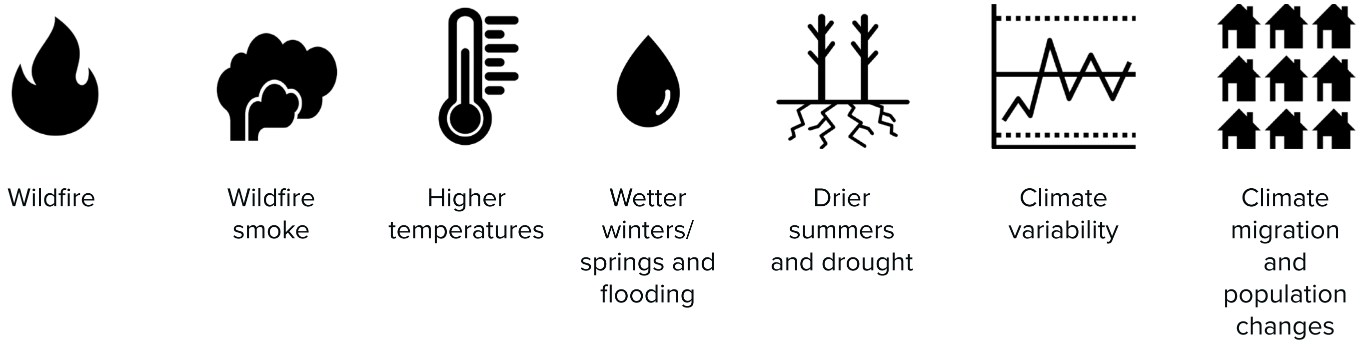
In the following sections, we briefly describe the risks stemming from each of the seven climate impacts for key sectors of our county. The risks described here are also presented graphically in color-coded grids, organized by sector (page 33).

CLIMATE AND EQUITY

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. As we implement adaptation actions, it will be essential that we consider and address these threats to our social fabric and the most vulnerable among us.

Read more on page 32.

Figure 5 Seven Climate Impacts in Missoula County



Wildfires

Wildfire
Wildfire smoke
Higher temperatures
Wetter winters/ springs and flooding
Drier summers and drought
Climate variability
Climate migration and population changes

> “As Missoula County’s climate warms and as summers become drier, wildfires are likely to increase in size and frequency. The fire season is likely to become longer.”

In Missoula County, wildfire is a naturally occurring phenomenon that is important to forest ecosystems. From 1998-2017, there were more than 3,000 recorded fires in Missoula County that burned 23% of county land area.[20] 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.

The 2018 Community Wildfire Protection Plan for Missoula County defines the WUI as “Any area where the combination of human development and vegetation have a potential to result in negative impacts from wildfire on the community.”[21] With the exception of the Missoula urban core, all inhabited areas of the county are in the WUI (Figure 7).

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.[22]

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.[23] Historically, fire frequency and acreage burned is directly associated with increases in summer temperatures and decreases in summer precipitation.[24]

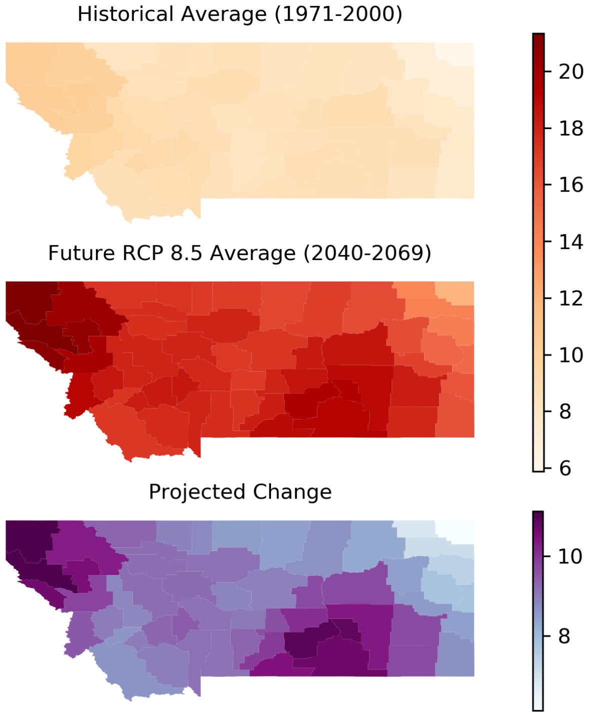


Figure 6 Historical average from simulations and projected change in “extreme” fire danger days

Figure 6 shows the projected change in “extreme” fire danger days (100 hour fuel moisture below 3rd percentile) for summer (June, July, and August). Future projected changes are based on the RCP 8.5 emission scenario for 2040 - 2069 and subtracted from historical simulations for 1971 - 2000. Estimates are the multi-model ensemble mean from 18 downscaled CMIP5 models.[25]

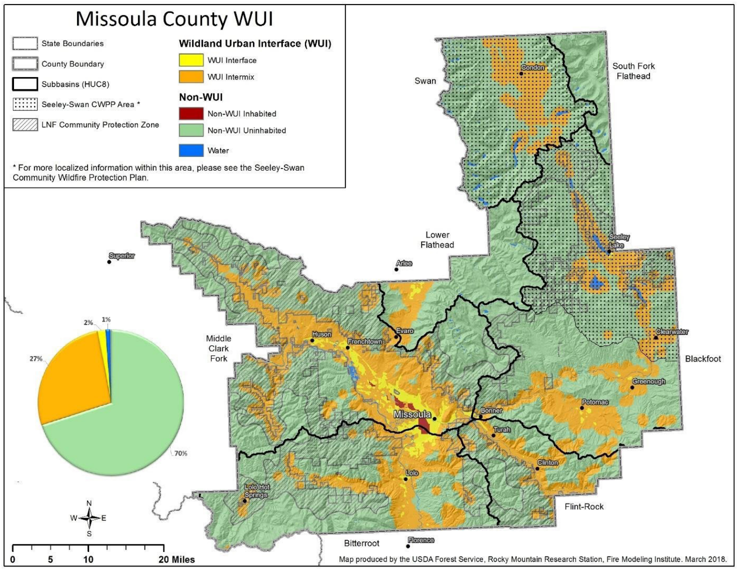


Figure 7 Wildland Urban Interface in Missoula County. Figure from Community Wildfire Protection Plan

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 or to a change in dominant tree species composition. 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. Fighting large fires requires support from firefighting crews based elsewhere in the country, which may be unavailable during extreme fire seasons when fires are widespread across the region and country.

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. Cell phone service is already limited in some rural parts of the county.

Agriculture

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

Buildings and Land Use

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, outbuildings, 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, or by the heat from 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 hardship.

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.

Land Use Planning and Transportation

Nearly all the development in Missoula County outside of the urban core of the City of Missoula is within the WUI and therefore particularly vulnerable to the impacts of wildfire, particularly from ember showers and/or creeping groundfire igniting surface debris near homes. 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 and how they like may directly increase the cost to society of protecting those homes when they are threatened by wildfire.

High temperature and wildfire smoke also affect transportation and land use. When development is spread far out and far away from basic services, people walking or biking may be less likely to connect with those services during heat waves or wildfire smoke events. Additionally, wildfire may limit transportation routes and affect people's ability to access services or evacuate the area safely.

Wildfire Smoke

Wildfire
Wildfire smoke
Higher temperatures
Wetter winters/ springs and flooding
Drier summers and drought
Climate variability
Climate migration and population changes

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 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.

Researchers have created a metric called "Fire Smoke Risk Index" based on a combination of the number, intensity, and length of smoky periods per year.[26] Figure 8 shows the Fire Smoke Risk Index by county in the western US in the recent past (panel a) and projected for mid-century (panel b). Fire Smoke

Risk Index in Missoula County is projected to increase from Level 4 to Level 5 (the highest risk) during that time period, meaning more frequent and longer periods of poor air quality.

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.[27] 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. Growing evidence also suggests that the fine particulates in wildfire smoke are harmful to pregnant women and fetal development in certain stages of pregnancy.

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 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.[28] 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.[29]

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.[30] 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 due to their prolonged smoke exposure and high rates of physical activity.

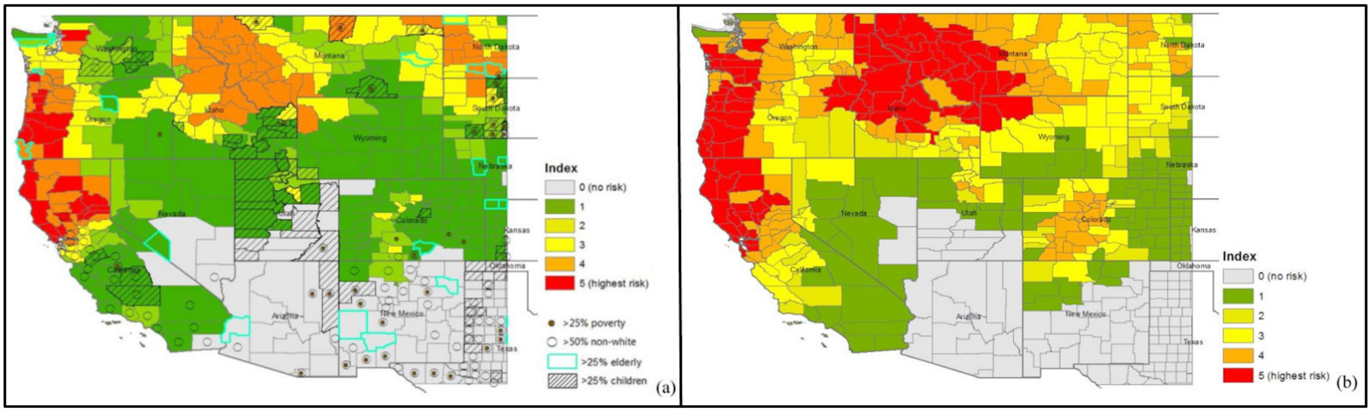


Figure 8 Fire Smoke Risk Index during fire seasons (May-October). Panel (a) is for present day (2004-2009) and panel (b) is for future (2046-2051) under climate change. Figure from Liu et al. (2016).

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.

> **"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."**

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.[31] 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; 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

Wildfire
Wildfire smoke
Higher temperatures
Wetter winters/ springs and flooding
Drier summers and drought
Climate variability
Climate migration and population changes

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 page 6 for 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. Beetle increases are directly tied to warming temperatures and increasing stress on trees.[32] It is projected that increases in winter temperatures will lead to more frequent and severe outbreaks of mountain pine beetle and other bark beetle species.[33] 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 and Montana as a whole.[34]

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 on 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.

On the other hand, warmer springs, summers and falls may result in Missoula County residents spending more time outdoors, resulting in increased rates of skin cancer. Montana already has higher than the national average rate of skin cancers.

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.[35]

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.

Paul Willet Photo

Buildings and Landscaping

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 decreases 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 may have 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 rely 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. Additionally, extreme heat can decrease the effectiveness of power lines and other electrical equipment, potentially leading to blackouts during very hot conditions.

Wetter Winters/Springs and Flooding

Wildfire

Wildfire smoke

Higher temperatures

Wetter winters/ springs and flooding

Drier summers and drought

Climate variability

Climate migration and population changes

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.

There is considerable uncertainty regarding future flood risk due to climate change, since flood risk depends in part on specific storm characteristics that are difficult to accurately model. 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.[36]

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. This is especially problematic in remote rural areas. For example, some portions of Missoula County have limited cell service, only one major access road, and limited electrical infrastructure, which could all be disrupted simultaneously, leaving residents stranded and without power or means of communication.

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. Many ranchers calve or lamb in late winter/early spring, and wetter conditions are also conducive to livestock diseases, particularly those transmitted through water or by waterfowl.

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. Spring flooding can also cause ranchers to have to move their livestock out of valley bottoms and onto summer pastures in the uplands sooner, which can decrease grass/forage production if animals are released onto pastures too soon.

Missoula County Emergency Management

Buildings and Landscaping

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.

Missoula County Emergency Management

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.

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.

“Invasive aquatic species can thrive when floodplains and river systems are disturbed because they can outcompete native species in recovery.”

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.[37] 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 flooding.

“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 flooding.”

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 decreased treatment, contaminating surface waters like the Clark Fork River.

Phoebe Bean Photo

Drier Summers and Drought

Wildfire
Wildfire smoke
Higher temperatures
Wetter winters/ springs and flooding
Drier summers and drought
Climate variability
Climate migration and population changes

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 lead to reduced low-elevation snowpack, early snowmelt, and an earlier peak in spring runoff. Studies suggest a 30-40% decrease in snowpack by mid-century and a higher elevation snowline. Some studies suggest that we could see an increase in snowpack at high elevations (above 6,500 ft); however, since a small fraction of Missoula County is so high, this potential increase is unlikely to offset the expected decrease in snowpack at lower elevations. By the end of the century, increasing temperatures will likely reduce snowpack significantly across the county, even at high elevations.

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.[38]

Earlier snowmelt and decreased summer precipitation are expected to reduce late-summer streamflows across the county. A study of August flows in the Clark Fork River at St. Regis from 1929-2015 found that higher spring and summer temperatures and lower summer precipitation were associated with lower August streamflows.[39]

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.[40]

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.

> **"Lack of water will leave trees weaker and less able to fight off forest pathogens."**

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 section). 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 (p. 25), Missoula County residents outside the Missoula Valley rely on water resources that may be more vulnerable (see Water Infrastructure section).

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.


Phoebe Bean Photo

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.

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.

Human Health

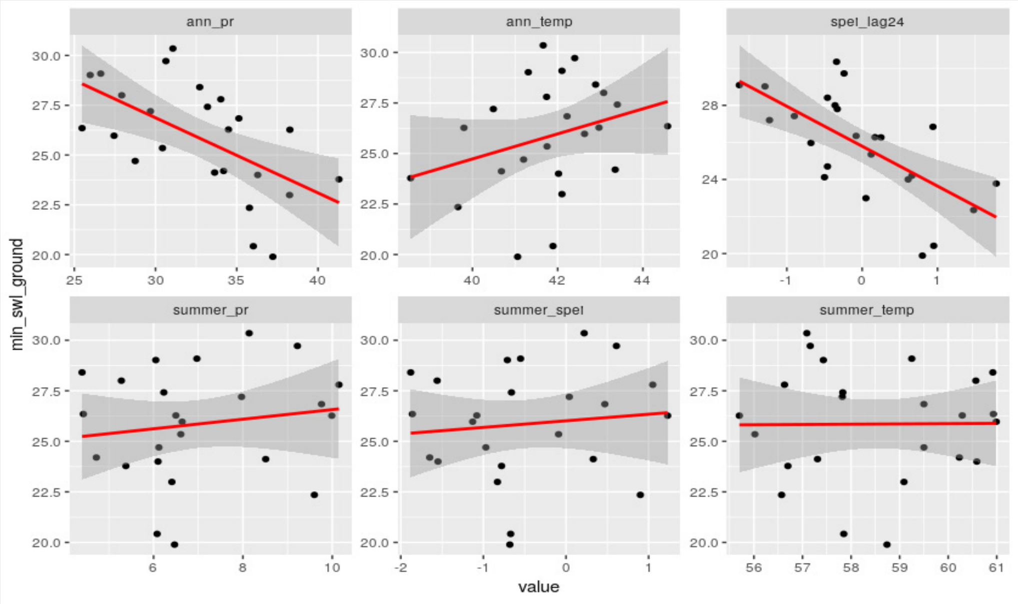
Longer summer droughts will lead to increasingly dry soils, increasing the likelihood of dust in the air which contributes to respiratory problems. Drought may also affect drinking water supplies in some parts of the county (see Water Infrastructure section).

How Resilient is Missoula's Aquifer?

The Missoula Aquifer serves as the main water supply for the City of Missoula and surrounding areas. To date there have been no known studies focused on evaluating the vulnerability of this water resource to climate change. To support the Climate Ready Missoula 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.

Figure 9 Missoula Aquifer's Resiliency Analysis, Adaptive Hydrology, LLC



As described on page 6, 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 Figure 9.

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 multi-annual drought in Missoula County.

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 (page 25), 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.

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.

Agriculture

Longer and more intense summer droughts will most directly impact non-irrigated producers, which are a minority in Missoula County. Irrigated producers will be less impacted since irrigation water is not currently a limiting factor for agricultural production in Missoula County, and there is significant potential to improve irrigation efficiency. However, irrigated producers may ultimately be affected if persistent drought reduces the availability and cost of irrigation water. In addition, some irrigated producers will face higher electricity costs due to the need to run irrigation equipment more frequently.

Most ranchers in Missoula County are both livestock producers and crop (e.g. alfalfa/hay) producers. They typically use irrigated crops to feed their stock in the winter months, and in some cases sell the excess. Summer feed comes from mostly non-irrigated grasslands and grazing areas. Drier summers will reduce productivity of these non-irrigated grasslands, forcing ranchers to shift to irrigated croplands for summer grazing, thereby decreasing the number of animals the operation can support and/or reducing revenues from the sale of excess hay. Drought will also impact ranchers by reducing the nutritional value of non-irrigated pasture used as feed for livestock.

Garden City Harvest Photo

Climate Variability

Wildfire
Wildfire smoke
Higher temperatures
Wetter winters/ springs and flooding
Drier summers and drought
Climate variability
Climate migration and population changes

One plausible future scenario for Missoula County includes a significant increase in year-to-year climate variability (see the Mid-Century Climate Scenarios on page 27). We may experience some very wet years and other intense drought years, with the concept of a "typical" 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.

> **"Unpredictability will increase investment risk, making it very difficult for businesses to plan, make capital improvements, and invest in employees."**

Amy Cilimburg Photo

Caroline Lauer Photo

Climate Migration and Population Changes

Wildfire
Wildfire smoke
Higher temperatures
Wetter winters/ springs and flooding
Drier summers and drought
Climate variability
Climate migration and population changes

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 (page 29). 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.

Climate migration is one example of how Missoula County will ultimately be affected not only by our own changing climate, but by the impacts of climate change elsewhere in the country and world. As another example, disruption of energy systems (such as damage to oil refineries due to hurricanes and sea level rise) could affect energy prices and, by extension, the price of food and consumer products due to increased transportation costs. Disruption of food systems in other parts of the country could also affect food prices and food availability for Missoula County residents, and could increase our reliance on locally grown food. While critical, these 'reverberation' effects are for the most part beyond the scope of this assessment.

What is a climate migrant?

There has been much debate over the terms "climate migrant" and "climate refugee". The United Nations discourages the use of the term "climate refugee" because the word "refugee" has a very specific meaning in international law, i.e., a person who has crossed an international border "owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion." Some publications use the term "forced climate migrant" as an alternative to "climate refugee." The discussion here is intended to encompass both forced and unforced climate migrants; in other words, people who come to Missoula County after being forced to leave their homes due to the impacts of climate change as well as people who choose to come here in search of a higher quality of life (though we recognize that there is not always a clear distinction between forced and unforced migration). Use of the term "climate migrant" rather than "climate refugee" is not in any way intended to minimize the plight of people forced to leave their homes as a result of climate change.

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

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. 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.

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. and future wildfire smoke risk estimated by Liu et al.[41] 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

Figure 10 Missoula County Population Change Analysis, Adaptive Hydrology, LLC

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

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.

Figure 11 Missoula County Population Change Analysis, Fire Weight = .125, Adaptive Hydrology, LLC

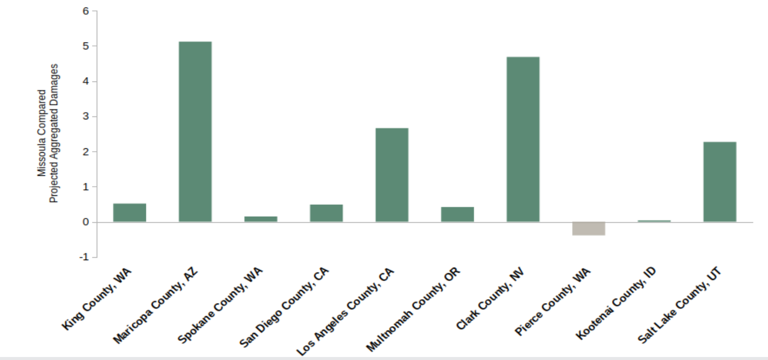
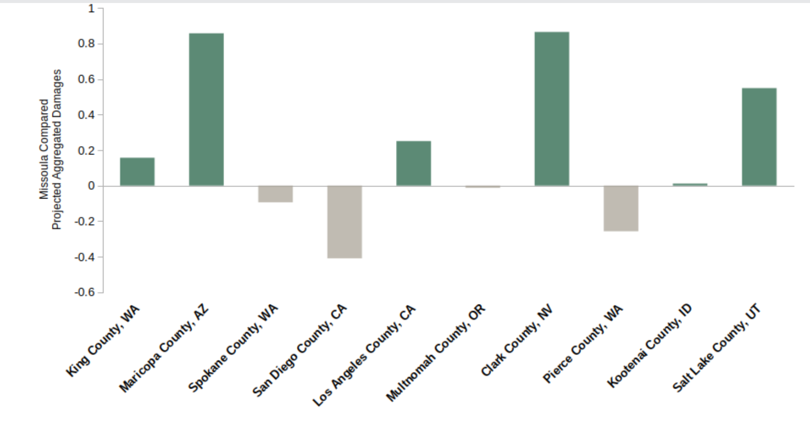


Figure 12 Missoula County Population Change Analysis, Fire Weight = .50, Adaptive Hydrology, LLC



The bottom line: Missoula County will likely experience an increase in population due to climate change.

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.

The City and County growth policies along with the associated Long Range Transportation Plan provide supportive climate change policies like the need for compact development in appropriate areas and encouraging multi-mode transportation. Accounting for additional population means growth projections and associated issues need to be addressed sooner then expected.

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 2017, about 22% of homeowners and 49% of renters in Missoula County were "cost burdened," meaning that they pay more than 30% of their income for housing.[42] Housing prices have increased faster than incomes over the last decade, resulting in an increased number of cost burdened households. The median home sale price in the Missoula urban area jumped 39% from 2009 to 2018, to $290,000. It would take an income of at least $75,000 a year to afford the median-priced home, well above Missoula County's median household income of $54,311.

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 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 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, unless intentional steps are taken to address this.

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.[43] 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.

Amy Cilimburg Photo

Vulnerability Grids by Sector

At the December 2018 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:

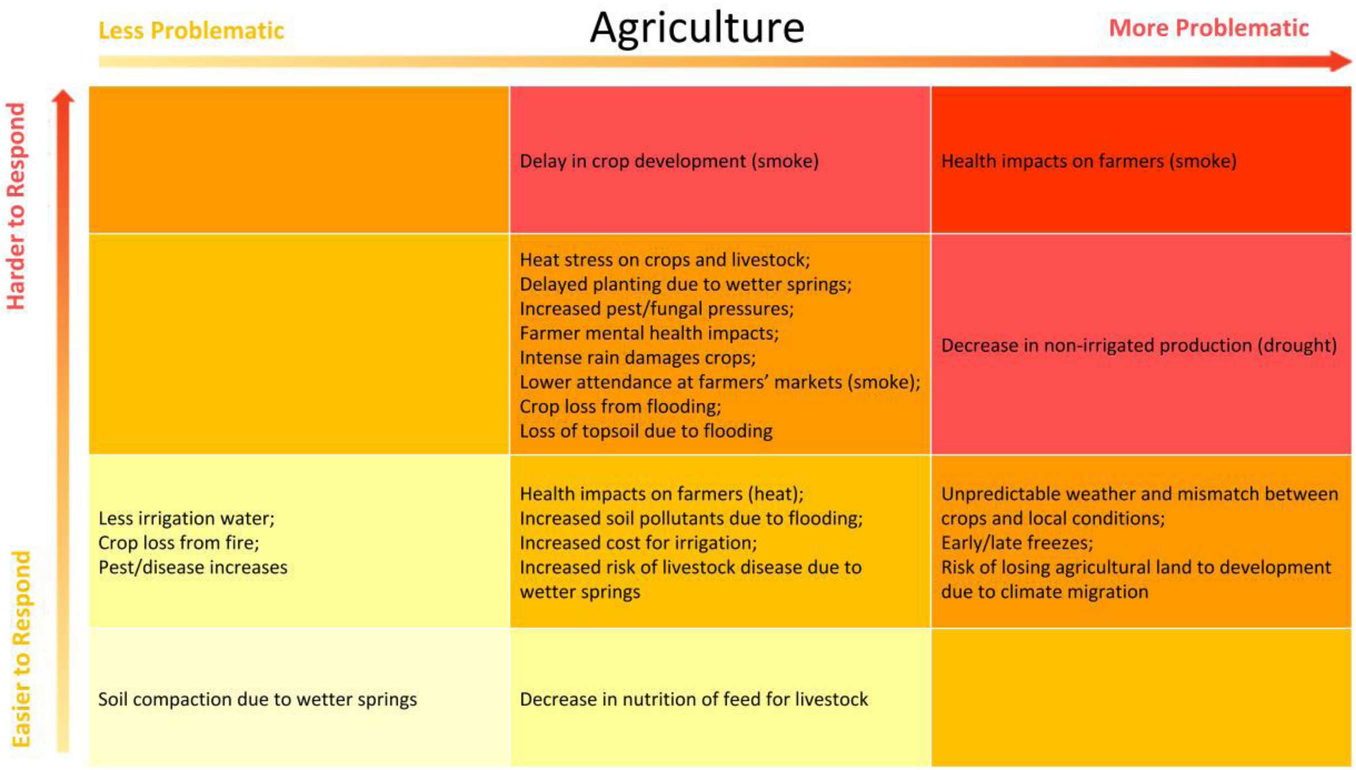
Low (*somewhat problematic)*
Medium (*very problematic)*
High (*extremely problematic)*

2. How difficult it will be to respond to the risk:

Easy (*have knowledge + capacity to do it)*
Moderate (*have knowledge but need resources or policy change to do it)*
Difficult (*we do not even know how to respond to this change)*

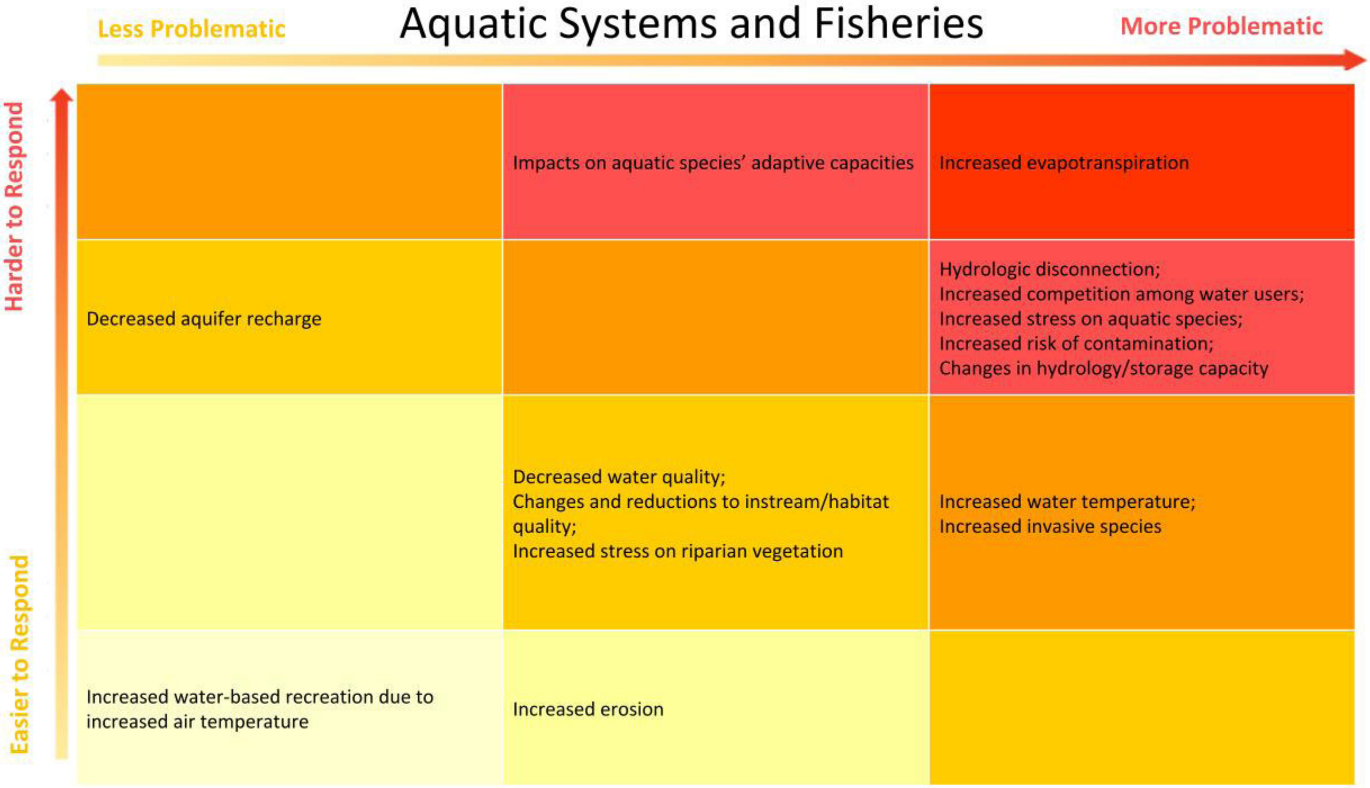
It turned out that a large majority of the risks were rated "moderate." In fact, some sector groups chose to split the "moderate" rating into two ("moderate plus" and "moderate minus") to differentiate among the many risks that received this rating. After the workshop, this differentiation was applied to all sector groups to allow for more nuance in the prioritization of risks.

The following Vulnerability Grids are a visual representation of these ratings, as revised based on public input. 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.



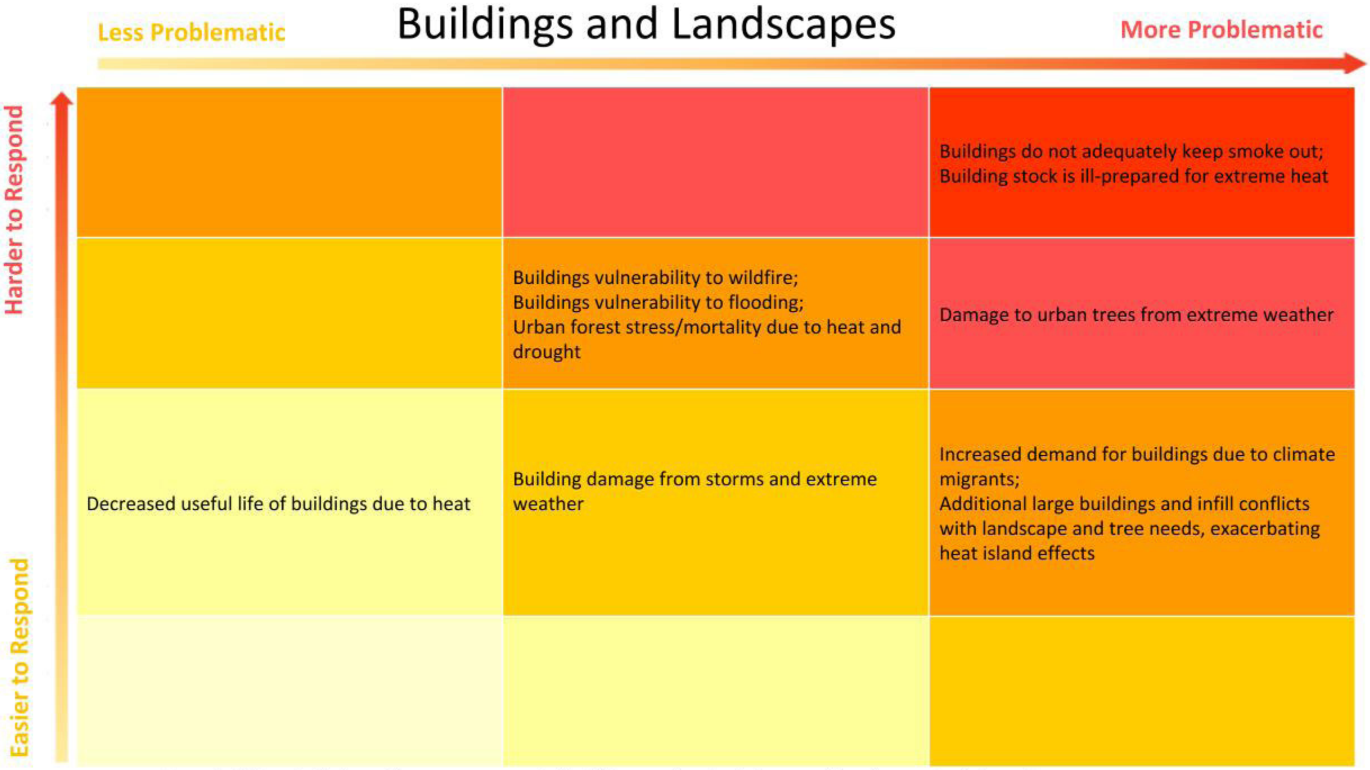
	Delay in crop development (smoke)	Health impacts on farmers (smoke)
	Heat stress on crops and livestock; Delayed planting due to wetter springs; Increased pest/fungal pressures; Farmer mental health impacts; Intense rain damages crops; Lower attendance at farmers' markets (smoke); Crop loss from flooding; Loss of topsoil due to flooding	Decrease in non-irrigated production (drought)
Less irrigation water; Crop loss from fire; Pest/disease increases	Health impacts on farmers (heat); Increased soil pollutants due to flooding; Increased cost for irrigation; Increased risk of livestock disease due to wetter springs	Unpredictable weather and mismatch between crops and local conditions; Early/late freezes; Risk of losing agricultural land to development due to climate migration
Soil compaction due to wetter springs	Decrease in nutrition of feed for livestock	

Aquatic Systems and Fisheries



	Impacts on aquatic species' adaptive capacities	Increased evapotranspiration
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	

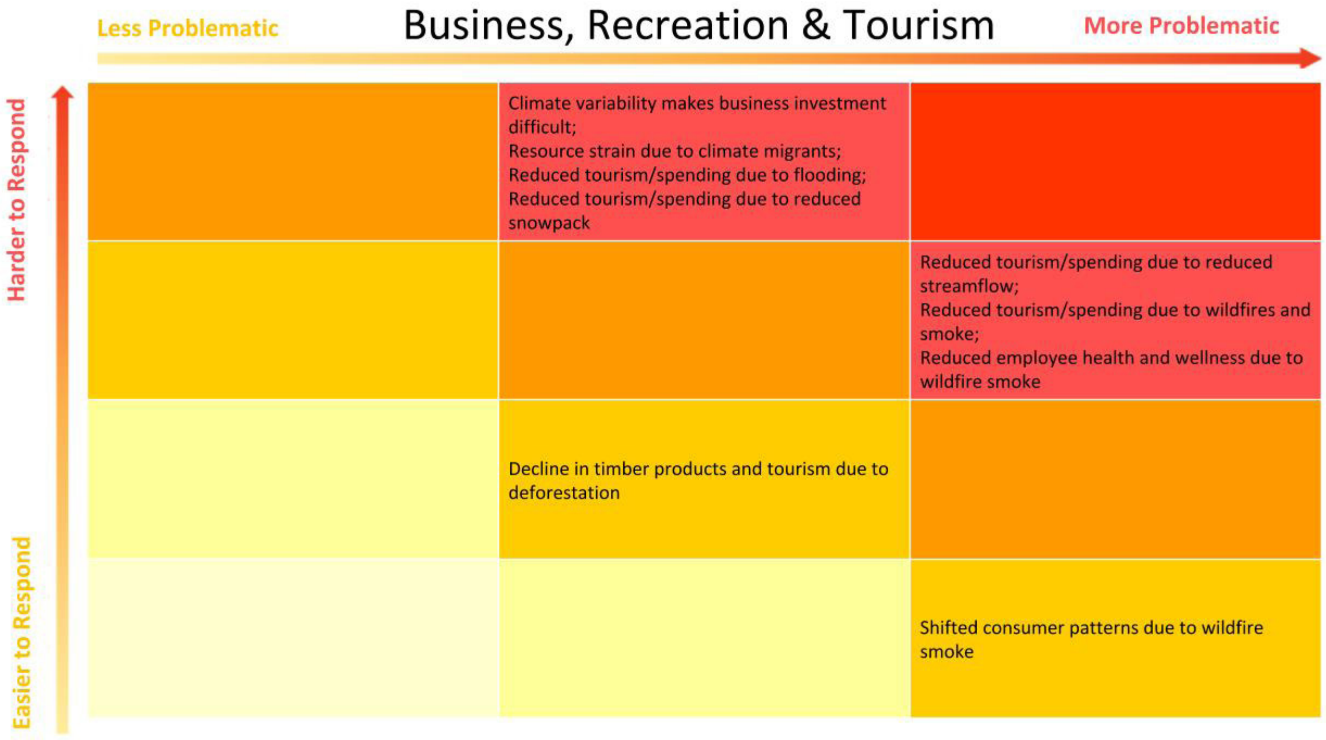
Buildings and Landscapes



		Buildings do not adequately keep smoke out; Building stock is ill-prepared for extreme heat
	Buildings vulnerability to wildfire; Buildings vulnerability to flooding; Urban forest stress/mortality due to heat and drought	Damage to urban trees from extreme weather
Decreased useful life of buildings due to heat	Building damage from storms and extreme weather	Increased demand for buildings due to climate migrants; Additional large buildings and infill conflicts with landscape and tree needs, exacerbating heat island effects

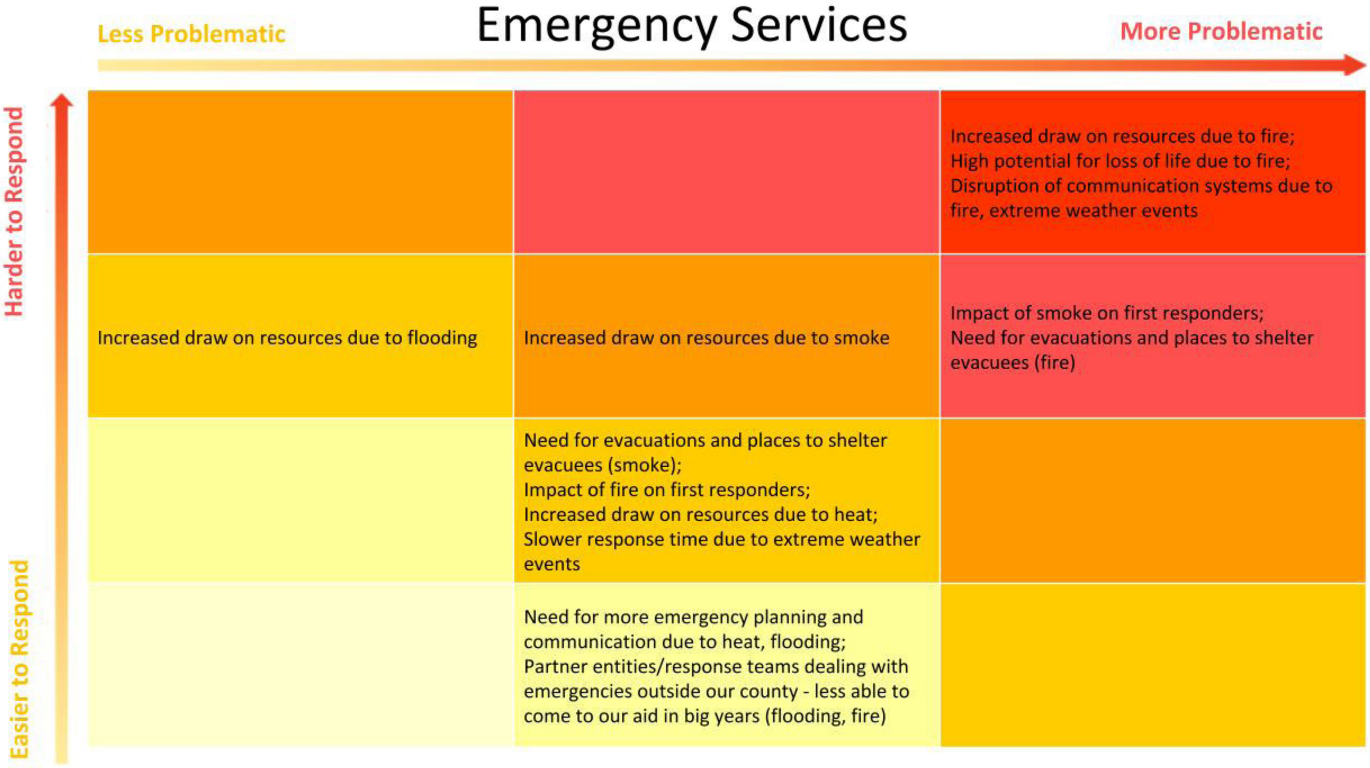
Note: buildings include residences, commercial buildings and outbuildings, and landscapes includes urban trees

Business, Recreation & Tourism



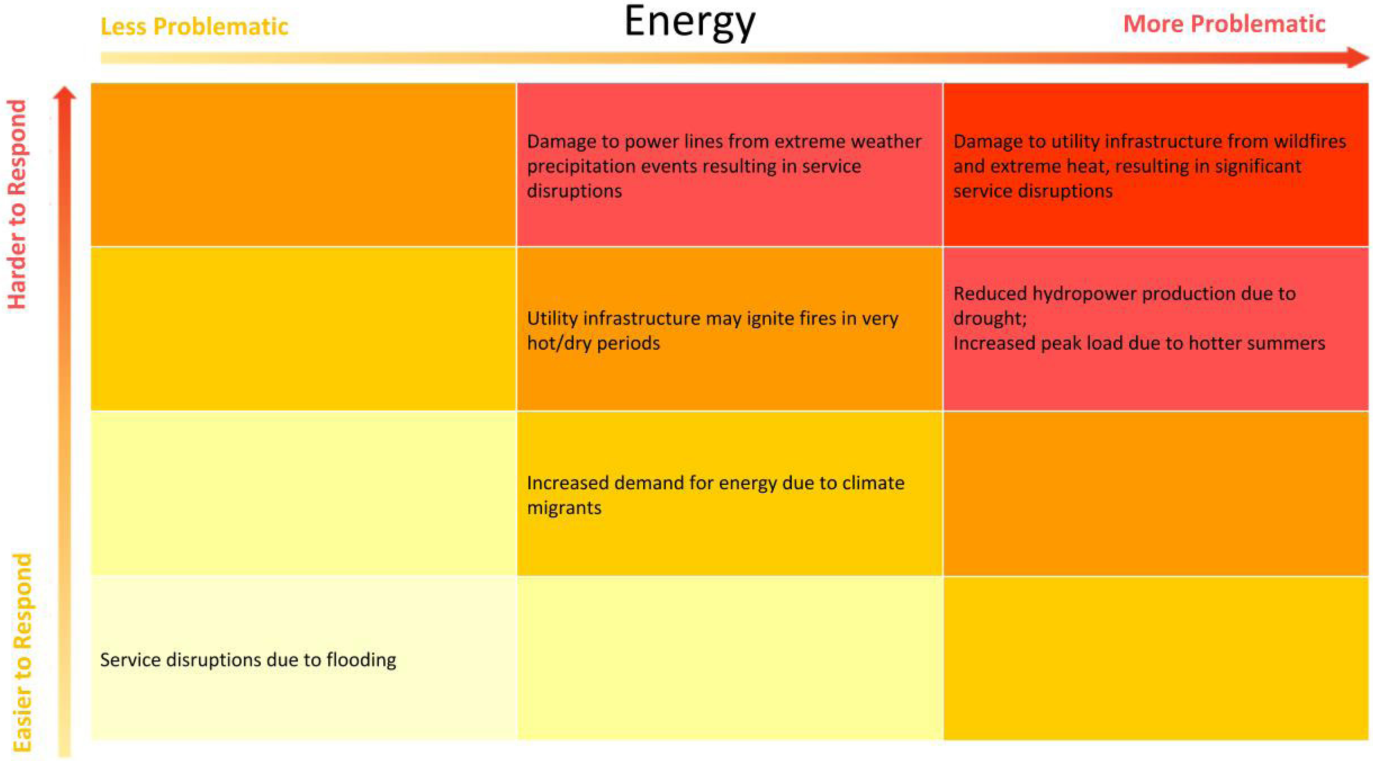
	Climate variability makes business investment difficult; Resource strain due to climate migrants; Reduced tourism/spending due to flooding; Reduced tourism/spending due to reduced snowpack	
		Reduced tourism/spending due to reduced streamflow; Reduced tourism/spending due to wildfires and smoke; Reduced 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



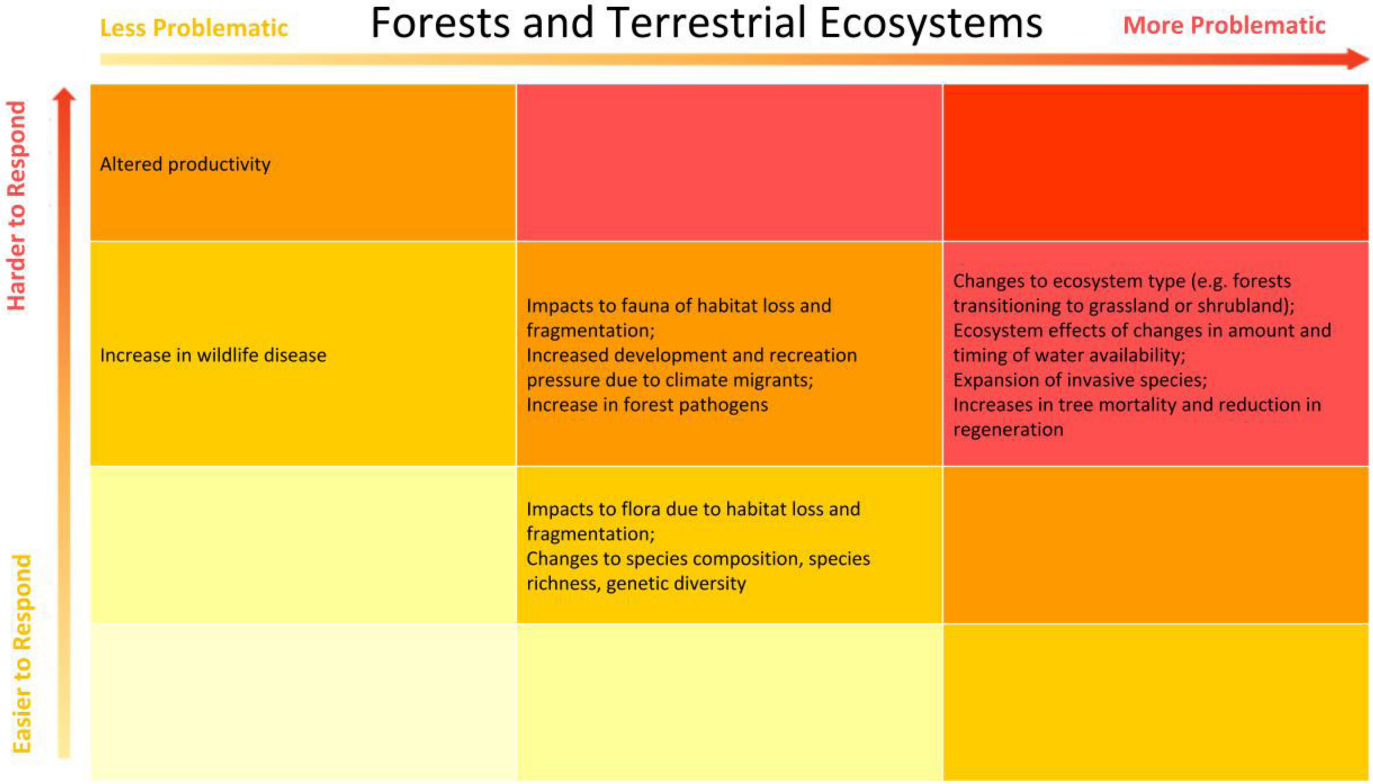
		Increased draw on resources due to fire; High potential for loss of life due to fire; Disruption of communication systems due to fire, extreme weather events
Increased draw on resources due to flooding	Increased draw on resources due to smoke	Impact of smoke on first responders; Need for evacuations 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; Partner entities/response teams dealing with emergencies outside our county - less able to come to our aid in big years (flooding, fire)	

Energy



	Damage to power lines from extreme weather precipitation events resulting in service disruptions	Damage to utility infrastructure from wildfires and extreme heat, resulting in significant service disruptions
	Utility infrastructure may ignite fires in very hot/dry periods	Reduced hydropower production due to drought; Increased peak load due to hotter summers
	Increased demand for energy due to climate migrants	
Service disruptions due to flooding		

Forests and Terrestrial Ecosystems



Altered productivity		
Increase in wildlife disease	Impacts to fauna of habitat loss and fragmentation; Increased development and recreation pressure due to climate migrants; Increase in 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	

Human Health

Less Problematic → More Problematic

Easier to Respond → Harder to Respond

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

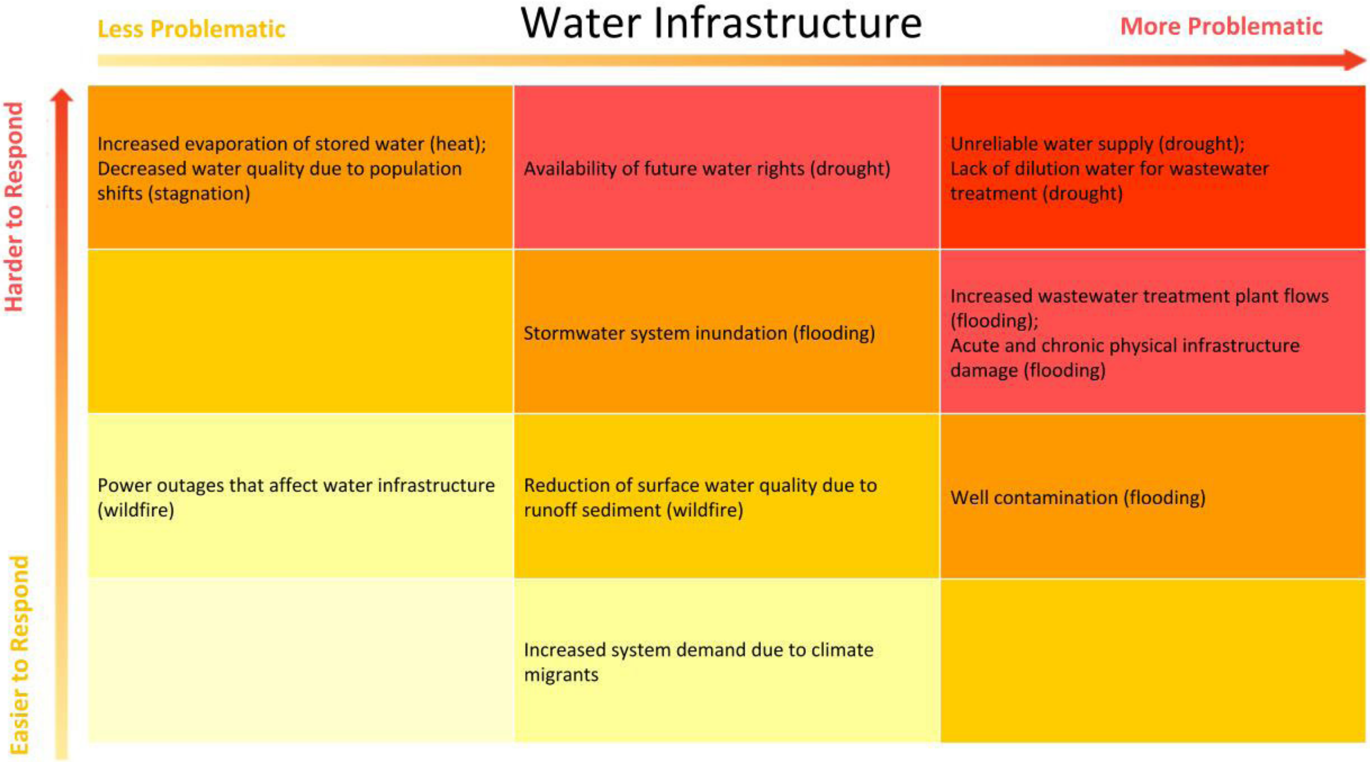
Transportation

Less Problematic → More Problematic

Easier to Respond → Harder 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 and loss of urban forest	Impact of transportation systems (wildfire); Increased tension between private & public interests (drought)

Water Infrastructure



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	

Climate Adaptation

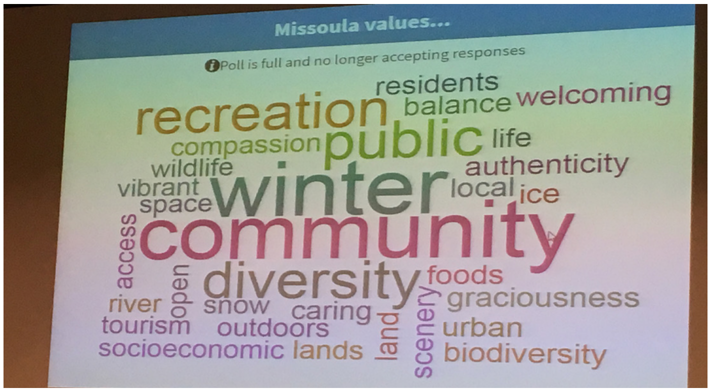
Goals + Strategies

Climate Adaptation Goals + Strategies

At the second stakeholder workshop, participants worked in cross-sector groups to develop strategies to address the risks identified in the Vulnerability Assessment, resulting in 304 total actions. Following the workshop and through a series of expert surveys and extensive discussions with the steering committee, these strategies were refined into the following list of adaptation goals and actions. After refining the goal and action statements, each goal was cross-referenced with the vulnerability assessment to identify and fully articulate all of the vulnerabilities that the goal aimed to address. Finally, the relationships between each action and the seven climate hazards (wildfire, wildfire smoke, hotter temperatures, wetter winters/springs and flooding, drier summers and drought, climate variability, and climate migration) were identified. All of this information is displayed in the following table.

The list is organized by sector in the following order:

- Wildfire Smoke, Heat, and Health
- Buildings, Land Use, and Transportation
- Water
- Ecosystems (Terrestrial and Aquatic) and Wildfire
- Agriculture
- Emergency Preparedness and Response
- Business, Recreation, and Tourism
- Energy



Missoula values...

Poll is full and no longer accepting responses

Each sector contains multiple adaptation goals (in green), one or more strategies to forward each goal (in black), the vulnerability codes that the goal corresponds to (see Appendix 2 for list of vulnerability codes), and the climate hazard that each action is related to (as identified by a highlighted icon). Lastly, if an action reduces carbon emissions, the table notes that it has a climate mitigation benefit as shown with a green "thumbs up."

ADAPTATION + MITIGATION INTERSECTIONS

The adaptation strategies outlined here intersect both with one another and with climate mitigation strategies in important ways. For example, weatherizing homes (e.g., increasing insulation and reducing unwanted air leaks) can help to create cool, clean indoor air during hot, smoky summers, while also cutting carbon emissions by reducing the amount of electricity needed to heat or cool the home.

Here's another slightly less obvious example:

As we move forward with carefully planned, environmentally appropriate forest thinning, we can utilize the harvested trees for new wood products, ultimately sequestering carbon. For example small diameter timber can be used in structural wood products like cross laminated timber or wood-fiber based insulation products, growing new regional markets for these products. Because buildings are designed to last many decades, the tree's carbon is locked up - sequestered - an oft cited mitigation effort. Wood fiber not incorporated into building materials could also be sent to Missoula's Garden City Compost where it can be used to improve soil, keeping it out of the waste stream and ultimately helping to grow local food or urban trees.

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W							
Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mitigation Benefit
wildfire smoke, heat, + health	A	Improve indoor air quality in homes during wildfire smoke events.	B10, T9, R3, R7, H14, H15, H18, H19, H20, H21							
	1	Educate homeowners about options to create safe indoor air (MERV 13 air filters, portable air cleaners).		✓	✓				✓	
	2	Make portable air cleaners more accessible.		✓	✓				✓	
	B	Improve indoor air quality in (and access to) public and commercial buildings during wildfire smoke and heat events.	B10, T9, R3, R7, H2, H14, H15, H18, H19, H20, H21							
	3	Develop voluntary measures and incentives, such as a certification program for clean air buildings, to encourage safe indoor air in public buildings, schools, and businesses.		✓	✓				✓	
	4	Find, develop and promote indoor recreation, exercise and creative activity spaces that are available to individuals and recreational programs (youth and adult) that are accessible to all income levels.		✓	✓				✓	
	C	Improve health and safety of outdoor workers during heat and smoke events.	B10, T9, R3, R7, H2, H14, H15, H18, H19, H20, H21							
	5	Encourage employers to change workplace environment to reduce wildfire smoke and heat exposure, for example by adapting work hours, following Cal/OSHA guidance and/or providing pop-up clean air shelters and/or appropriate safety equipment (Personal Protective Equipment - PPE) for employees.		✓	✓				✓	
	D	Increase awareness of physical health impacts of wildfire smoke, heat, and their intersection.	T9, H2, H3, H14, H15, H19, H20							
	6	Conduct an educational campaign about air quality data, health risks of wildfire smoke, connection between smoke and heat, and activity guidelines.		✓	✓				✓	
	7	Collaborate with healthcare providers to develop and promote wildfire smoke exposure checklist; educate providers who are unaware.		✓					✓	
	8	Encourage healthcare providers to work with sensitive subgroups to reduce controllable exposures (smoking, radon) and have a plan in place before wildfire smoke arrives.		✓					✓	

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W							
Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mit. Benefit
wildfire smoke, heat, + health	9	Coordinate education efforts to consider best health practices during concurrent heat and smoke events.		●	●				●	
	10	Conduct an educational campaign about the prevention of and signs of heat related illness for the most vulnerable populations.			●					
	11	Conduct an educational campaign for healthcare, public safety, and emergency response communities about the connection between heat and aggression.			●					
	E	Increase awareness of mental health impacts of climate change.	A13, T9, H18, H20, H21							
	12	Educate the public and healthcare providers about the mental health impacts of wildfire smoke and other climate vulnerabilities, including those specific to agricultural community.	●	●	●	●	●	●	●	
	F	Increase healthcare system capacity to respond to wildfire smoke events, wildfires, floods, and other climate impacts.	H3, H20							
	13	Assess existing mental health resources and increase as needed, such as network of providers, integration with general practitioners and emergency responders, screenings, and capacity of inpatient and outpatient care, scalable to smoke events.	●	●	●	●	●	●	●	
buildings, land use, + transportation	G	Balance competing land use needs in the context of population growth.	A21, B7, T3, E21							
	14	Consider, and ultimately incorporate, climate migration in population growth projections in growth policy and other planning efforts.							●	
	15	Ensure that city and county land use plans adequately protect habitat, open space, and agricultural land.							●	
	16	Encourage urban gardens and small-scale agriculture to preserve the ability to grow food in Missoula County.							●	
	17	Protect strategically important private lands with conservation easements and acquisition.							●	

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W	🔥	☁	🌡	⋔	💧	📈	🏘
Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mit. Benefit
buildings, land use, + transportation	H	Reduce development in the floodplain.	B5, R2, H5, H16, H17, P1, P2, W8, W9, W10							
	18	Prevent or restrict new development in the floodplain.					💧			
	19	Work with federal partners on education and buy-out programs in floodplain areas where there is a history of repetitive loss.					💧			
	20	Enhance FEMA floodplain maps with climate change projections to be used for local regulatory and educational purposes.					💧			
	I	Reduce cooling costs by increasing efficiency of building stock.	B11, N6, H9, H11, H12							
	21	Develop programs to implement and incentivize more energy efficient building practices (new and retrofits) that are accessible to all socio-economic groups, including weatherization and cool roofs.			🌡				🏘	👍
	22	Develop an educational campaign to increase consumers' energy efficiency, with a focus on cooling.			🌡				🏘	👍
	J	Reduce vulnerability of buildings to wildfire.	B4, R9, R10, R11, P8							
	23	Adopt regulations and programs to address the home ignition zone (structure and surroundings), such as neighborhood ambassadors, WUI building codes, WUI zoning codes, and WUI standards in building, zoning, and subdivision codes.	🔥							
	24	Restrict and regulate new development in high wildfire hazard areas.	🔥							
	25	Levy impact fees and/or use other funding sources to fund fire protection related infrastructure (fire trucks, hydrants, responders, etc.)	🔥							
	K	Address urban heat island effect and maintain and grow healthy, diverse urban forests that account for social equity considerations.	B6, B8, B9, H9, H11, H12, H18, P5							
	26	Create incentives and programs to decrease urban heat island effect for example through building siting, shade and vegetation.			🌡				🏘	👍

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W	🔥	☁	🌡	⫛	💧	📈	🏠
Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mitigation Benefit
buildings, land use, + transportation	27	Develop and promote an educational campaign to build a shared understanding of the value of urban forests and encourage planting appropriate species, watering, and care.				✓			✓	✓
	28	Develop and promote an educational campaign to build a shared understanding of the importance of xeriscaping.				✓			✓	✓
	L	Ensure sustainable transportation options are part of land use planning and development.	B11, N6, H9, H11, H12							
	29	Support land use regulations and incentives that encourage densities and mixes of uses that allow for and support a wide range of sustainable transportation options.							✓	✓
	30	Pursue policies and prioritize funding to achieve transportation mode split goals in the Long Range Transportation Plan, considering population growth projections.							✓	✓
	31	Strengthen public transit system to provide safe travel during heat and/or smoke events.		✓	✓				✓	✓
	32	Pursue complete street policies and programming that incorporates urban forestry and stormwater management.					✓		✓	✓
water	M	Conserve water through water conservation plans, practices, regulations and strategic/ guided growth.	A8, A22, H8, P5, P7, W4, W7, W8, W9, W11, W12							
	33	Implement Missoula Water's plan to reduce infrastructure water loss (leaks, losses, theft, aging meters).				✓	✓		✓	✓
	34	Take water availability into account in county growth policy and zoning.				✓	✓		✓	
	35	Develop educational materials and incentives to increase water use efficiency during drought and flood conditions.				✓	✓		✓	✓

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W	🔥	☁	🌡	🌾	💧	📈	🏠
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	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mitigation Benefit
water	36	Articulate water use best practices in real time, across user groups (agricultural producers, outfitters), based on drought conditions.				🟩			🟩	
	37	Create community-wide water (rather than individual wells) in developed or developing areas.							🟩	
	N	Enhance water storage opportunities and infrastructure to reduce incidence and impact of flooding and low-streamflow events.	B5, T4, H16, H17, P1, P2, W6, W8, W10							
	38	Expand storage (natural and human created, e.g. reservoirs, wetlands, beavers, and beaver mimicry).				🟩	🟩		🟩	
	O	Preserve water quality through improved stormwater management, prioritizing green infrastructure over traditional methods.	B5, T4, H16, H17, P1, P2, W6, W8, W10							
	39	Develop a funding mechanism to support green infrastructure.				🟩	🟩		🟩	
	40	Implement low-impact development standards to encourage fewer impervious surfaces.					🟩		🟩	
	41	Improve and expand stormwater facilities, via new land use regulations or other methods.					🟩		🟩	👍
	P	Preserve water quality through efficient wastewater treatment, water delivery systems, education and regulation.	H7, H16, W4, W8, W9, W12							
	42	Create and support community-wide wastewater systems (rather than septic) in developed or developing areas.					🟩		🟩	
	43	Create, fund, and implement a well contamination response plan (identify at-risk wells, potential contaminants, places to restrict new well construction).					🟩		🟩	
	Q	Balance competing water needs in the context of population growth.	A8, A22, T7, P5, P7, W4, W7, W11, W12							
	44	Enhance/incentivize more effective, multi-stakeholder (recreation and agriculture) approach to drought response planning.				🟩			🟩	👍

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W	🔥	☁	🌡	🌱	💧	📈	🏠
Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mit. Benefit
water	45	Advocate for state water policies that provide innovation and flexibility in encouraging water conservation and resiliency.	○	○	○	●	●	○	●	
ecosystems (terrestrial + aquatic) + wildfire	R	Build understanding of forest, terrestrial and aquatic ecosystems and appropriate, site/ landscape-specific management options that account for climate change.	E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E15, E18, E19, E20, E21, E22, E23, E24, E25, E26							
	46	Analyze current, historical, and projected conditions to identify and prioritize where to resist, accept, or facilitate site or ecosystem change, considering cultural values.	●	○	●	●	○	●	○	
	47	Create and implement watershed management plans based on climate projections that prioritizes habitats to protect (include restoration strategies, human access considerations, and agricultural best management practices).	●	○	○	●	●	○	●	
	48	Maintain and enhance connected habitat corridors.	○	○	○	○	○	○	●	
	S	Reduce high severity wildfires and their impact in high risk areas/landscapes.	B4, T8, E23, E26, R4, R9, R10, R11, R12, N7, H6, P3, P6, P8, W5							
	49	Increase prescribed fire and/or thinning, when and where appropriate.	●	○	○	○	○	○	○	
	50	Implement best practices such as prescribed fire, streamside buffers, and support of beavers to increase watershed resilience to fire.	●	○	○	○	○	○	○	
	T	Build a shared understanding of the realities of wildfire and our expectations of wildfire response.	P3, P8							
	51	Grow educational and outreach efforts within and between agencies, community partners, and public to build support for forest management options (including allowing natural fires to burn), considering divergent values (for example, Wildfire Adapted Missoula).	●	●	○	○	○	○	○	

Vulnerability Code Key									Climate Hazard Key						
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Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mit. Benefit
eco.	U	Ensure ecological integrity during and after fire, and/or fire suppression activities.	E3, E4, E18, E20, E23, E25, E26							
	52	Create watershed reinvestment fund to support restoration after wildfire.	✓							
agriculture	V	Increase adoption of ecologically sound and climate smart practices for Missoula County agriculture.	A7, A8, A10, A11, A12, A14, A16, A17, A18, A19, A20, A22							
	53	Identify and promote ecologically sound agricultural best practices in a 1-stop shop, considering pests, pathogens, heat, drought, smoke.			✓	✓		✓		👍
	54	Promote regenerative soil building to revitalize soil quality.				✓		✓		
	55	Develop and communicate water-use best practices for agricultural producers in real time to inform plant and animal water needs, improve efficiency, and reduce water loss.				✓				👍
	W	Increase economic resilience of Missoula County agriculture given climate change.	A8, A9, A10, A11, A12, A14, A15, A16, A17, A18, A19, A20, A22							
	56	Promote diversification of farm income sources (e.g., carbon capture offsets, value added products, and eco-tourism).		✓	✓	✓		✓		
	57	Increase access to locally sourced food through aggregation, storage and distribution of agricultural products.			✓	✓		✓		
	58	Increase support for locally sourced food through education and outreach, economic incentives, and other programs.			✓	✓		✓		
	X	Strengthen social connectivity between farmers, ranchers, and community members.	A13							
	59	Create a farmer and rancher support network at regional or sub-regional level, considering economic and mental health needs of agricultural community.	✓	✓	✓	✓	✓	✓	✓	

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W							
Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mit. Benefit
emergency preparedness + response	Y	Ensure “hard” infrastructure (roads, bridges, power lines, telecommunications, etc.) is resilient to climate change.	R12, N3, N4, N7, P1, P6							
	60	Assess infrastructure needs and vulnerabilities to inform infrastructure strategic plan (protect, enhance, develop redundancies).	●	○	●	○	●	○	●	
	Z	Ensure “soft” infrastructure (systems, people, partnerships, communication, plans, etc.) is resilient to climate change.	R2, R5, R6, R7, R10, R12							
	61	Enhance emergency communication capabilities and evacuation strategies, routes, and safety zones.	●	●	●	○	●	○	●	
	62	Connect with and support Invest Health, Missoula College, Missoula Emergency Services Inc., Missoula City-County Health Dept. and partners regarding preventative health measures (upstream health response).	○	●	●	○	●	○	●	
	63	Ensure public safety and emergency response communities have the necessary tools to provide care, outreach and/or referrals.	●	●	●	○	○	○	●	
	64	Ensure sufficient emergency response personnel within rural areas of Missoula County.	●	●	●	○	○	○	●	
business, recreation, + tourism	AA	Prepare tourism and recreational industries for changing climate.	T1, T2, T4, T5, T6, T7, T8							
	65	Increase agility of existing tourism and recreational businesses to adapt to changing conditions (timing and location of activities).	●	●	○	●	●	●	●	
	66	Diversify tourism and recreational industries by identifying, investing in, and promoting new, sustainable-oriented opportunities.	●	●	○	●	●	●	●	
	67	Develop and market flexible indoor recreation and tourism opportunities.	●	●	●	●	●	●	●	
	68	Develop recreational resource plan, including a comprehensive map of resources, to adapt uses and types of recreation, as well as protect assets and promote access.	●	●	●	●	●	●	●	

Vulnerability Code Key									Climate Hazard Key						
A	B	T	E	R	N	H	L	W	🔥	🌫	🌡	🌾	💧	📈	🏘
Agriculture	Buildings and Landscape	Business, Recreation, Tourism	Ecosystems	Emergency Prep. and Response	Energy	Health	Land Use Planning	Water	Wildfire	Wildfire Smoke	Higher temperatures	Drier summers and drought	Wetter winters/ springs + flooding	Climate variability	Population increase and climate migration

	ID	Goal + Strategy	Vulnerability Code + Climate Hazard							Mit. Benefit
business, recreation, + tourism	BB	Strengthen and diversify local economy (aside from tourism and recreation) in a changing climate.	A15, B3, T1, T2, T6							
	69	Partner with economic development organizations and universities to develop a certification program and knowledge sharing for existing businesses that are climate resilient.		🌫	🌡	🌾		📈	🏘	👍
	70	Create economic innovation hub to identify new business opportunities given climate change.	🔥	🌫	🌡	🌾	💧	📈	🏘	
	72	Enhance energy efficiency and weatherization workforce and business opportunities.			🌡				🏘	👍
	73	Expand and diversify value-added timber market, for example small diameter mass timber.	🔥	🌫					🏘	👍
energy	CC	Ensure a clean, reliable, affordable energy system in the context of increased heat, drought, extreme weather, wildfire, and population growth.	N2, N3, N4, N5, N6, N7							
	74	Collaborate statewide to facilitate and advocate for legislative, regulatory, and utility program change that accelerates development of renewable energy, energy storage, energy efficiency, and load flexibility, and reduces our reliance on fossil fuels.			🌡				🏘	👍
	75	Develop local energy savings programs to reduce energy cost burden and exposure to energy price volatility.			🌡				🏘	👍
	76	Accelerate adoption of distributed renewable energy systems, electrification and microgrids.	🔥		🌡		💧		🏘	👍
	77	Manage vegetation near utility infrastructure to reduce the risk of igniting fires in very hot/dry periods.	🔥		🌡				🏘	
	78	Bury overhead power lines.	🔥			🌾			🏘	

Next Steps

The strategies presented in this plan are intentionally high-level; they identify what needs to be done to prepare for and adapt to climate change. All the details for each strategy—who should be involved in implementing it, how it can best be accomplished, timeline, costs and benefits, funding sources—will need to be determined in the implementation phase.

An Implementation Task Force and dedicated staff capacity will be necessary to prioritize adaptation strategies, coordinate and monitor implementation of this plan as a whole, report on progress, redirect actions that are not achieving the desired results, update the plan as needed, and continue engaging the community. Smaller working groups will also be necessary to make progress on specific goals and strategies within each sector. However, the risks we face will require a collaborative, cross-sector approach that leverages the connections among sectors, and the Implementation Task Force will need to ensure that the small groups coordinate with one another rather than working in isolation.

It will be important for the Implementation Task Force to refer frequently to the guiding principles of this effort (page ES-1) as strategies are prioritized and implemented. For example, equity and inclusiveness should be key considerations in all steps of implementation. Adaptiveness and flexibility will be critical as strategies are implemented and evaluated and as climate conditions continue to change and scientific knowledge grows.

In some cases, implementation will take the form of incorporating strategies identified in this plan into ongoing or upcoming planning efforts, programs, and regulations. Examples include updates to city and county growth policies, zoning codes, the Long-Range Transportation Plan, the Pre-Disaster Mitigation Plan, and the Community Health Improvement Plan. In all cases, implementation should be undertaken collaboratively and should build on the work already underway in our county. Moreover, given that many of the risks we face (and the strategies to address them) cross jurisdictional boundaries, we will be most effectively if we collaborate with resilience efforts in other communities and at the state level (for example, the plan currently being developed by the Montana Climate Solutions Council).

Implementation of many of these strategies will not be easy. We will confront numerous barriers—policy, economic, technological, and social—that will need to be overcome. Identifying these barriers and addressing them strategically will be essential to allow for the successful implementation of the plan.

In particular, implementation of this plan must be coordinated with efforts to address other

Recommended Next Steps:

- Form an Implementation Task Force with dedicated staff capacity and convene smaller working groups
- Report regularly on progress to the community, the Missoula Board of County Commissioners, and the Missoula City Council
- Review and update the Climate Resiliency Plan approximately every 5 years


Ronni Flannery Photo

critical challenges facing Missoula County, such as affordable housing, homelessness, health care costs and availability, and income inequality. Given tight budgets and the urgency of addressing all of these issues, we can expect tensions to arise. Our challenge will be to consider these issues holistically rather than in isolation. For example, how can we accelerate the development of affordable housing, while ensuring that we are not strapping occupants with homes that will be difficult or expensive to keep cool and smoke-free? We will need to revisit our guiding principles at every step, craft innovative solutions, and learn from the successes of other communities.

Successful implementation will require new and durable funding sources, for example advocating for a local options sales tax that can be allocated in part for adaptation strategies, pursuing grant opportunities, and prioritizing this work within the budgets of local government and businesses.

In addition, building our resiliency to climate change will only be successful if it is paired with efforts to address climate change head-on by reducing carbon pollution. Implementation of this plan should be coordinated with climate mitigation efforts, for example the implementation of Missoula City and County's joint goal of 100% clean electricity by 2030. Many adaptation strategies identified in this plan are also mitigation strategies, and pursuing them will have the dual benefit of preparing our county for the changes we're facing while also reducing the carbon pollution that drives climate change.

How will we know if we are succeeding?

The Implementation Task Force will report regularly on progress to the community, the Missoula Board of County Commissioners, the Missoula City Council, and key government departments.

Approximately every 5 years, the entire Climate Resiliency Plan should be reviewed and updated based on new conditions and data (including updated climate projections), the effectiveness of implemented strategies, and new ideas and best practices.

Finally, implementation of the strategies in this Climate Resiliency Plan should be coordinated with climate resiliency efforts at the state level and in other Montana communities as they develop in the coming years. We look forward to working across jurisdictions and in alignment with recommendations forthcoming from the 2020 Governor's Climate Solutions Council. Many of the challenges we're facing are bigger than our county, and we can build resiliency most effectively by collaborating with other communities and with statewide and regional efforts.

Given the far-reaching impacts of climate change, it is no surprise that the strategies presented in this plan touch on nearly every aspect of Missoula County: our health, our economy, our built environment, our natural environment, and our social cohesion. Implementation of the plan will, by necessity, involve dozens of organizations, individuals, businesses, city and county departments, and other government agencies. It will take all of us. And given the urgency, the sooner we get started the better.

Climate Ready Missoula Video

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Appendices

Appendix 1 | Overview of Missoula County

Physical Setting

Missoula County is located in western Montana and is the second most populous county in the state. The county has a population of 117,441 (2017 U.S. Census estimate) and an area of 2,593 square miles. The City of Missoula is the only incorporated city and serves as the county seat. More than 60% of Missoula County residents live in the City of Missoula, and more than 80% of county residents live in the Missoula urban area. Unincorporated communities in Missoula County include Bonner-West Riverside, Clinton, Condon, East Missoula, Evaro, Frenchtown, Greenough, Huson, Lolo, Milltown, Orchard Homes, Potomac, Seeley Lake, and Turah. The north-central portion of the county is part of the Flathead Reservation which is home to the Confederated Salish and Kootenai Tribes (CSKT).

The forested mountains that frame the valleys and the open spaces that extend across the valley floors are iconic of Missoula County. Over 1,975 miles of rivers, streams and named tributaries crisscross the valleys. The City of Missoula is located at the base of Mount Sentinel at the hub of five valleys and three rivers (the Blackfoot, the Bitterroot, and the Clark Fork).

Missoula County falls predominantly within the Clark Fork River Basin. The Clark Fork, which is the largest river in Montana by volume, is a snowmelt-dominated river that sees most of its annual streamflow delivered during a relatively brief period (April-July). The majority of snowpack in the Clark Fork River Basin occurs at relatively low elevations, below 8,000 ft. The Clark Fork River and its tributaries are central to Missoula County's identity and to its economy. The river recharges the aquifer that supplies drinking water to the Missoula Valley, agricultural operations rely on water from the Clark Fork and other rivers and streams, and rivers are key to the county's recreation and tourism industries.

The Seeley Lake area is located in the Clearwater River watershed, with a chain of lakes running through the valley and forested mountain ranges on either side. The northernmost portion of the county, which includes Condon, is in the Swan River Valley.

Almost 63 percent of the land in Missoula County is managed by state, federal and local governments, with tribal lands accounting for an additional 6 percent. The U.S. Forest Service is the largest landowner, with 51 percent of county land area, followed by the State of Montana at 9 percent. Figure 13 shows the distribution of these lands across the county.

Figure 14 shows land cover distributions across Missoula County. Selected land cover classifications are described below. Complete descriptions of the various ecological systems in Missoula County are available from the Montana Natural Heritage Program's Map Viewer at http://mtnhp.org/MapViewer/.

- Forest and Woodland Systems (49.5%): Depending on the environmental conditions of the area, forests in Missoula County range from conifer dominated systems comprised of Douglas-fir, ponderosa pine and western larch, to ecosystems that are primarily comprised of Engelmann spruce and subalpine fir.[44] These forest systems provide a home to countless species of wildlife including several species of concern such as the Canada lynx and the grizzly bear. Embedded within the forests are riverine and riparian systems, home to fisheries and rich aquatic life.

- Recently Disturbed or Modified (23.5%): This classification includes recently burned or logged areas.

- Grasslands Systems (8.9%): Grassland ecosystems border the City of Missoula and line the highways in and out of the town. Rough fescue, Idaho fescue, and bluebunch wheatgrass are by far the most dominant plant species of these ecosystems (Montana Natural Heritage Program 2017c). Grassland ecosystems are particularly vulnerable to invasive species. In some areas, invasives such as leafy spurge and spotted knapweed have completely taken over and forced out these native grasses (Montana Natural Heritage Program 2017c).

- Open Water/Wetland and Riparian Systems (7.6%): Riparian and wetland areas provide habitat for a diverse array of flora and fauna and are particularly important for Montana's native birds. These natural areas can be extremely valuable within heavily modified landscapes like city centers (e.g., Clark Fork River and the City of Missoula).

- Alpine System (1.0%): Although accounting for

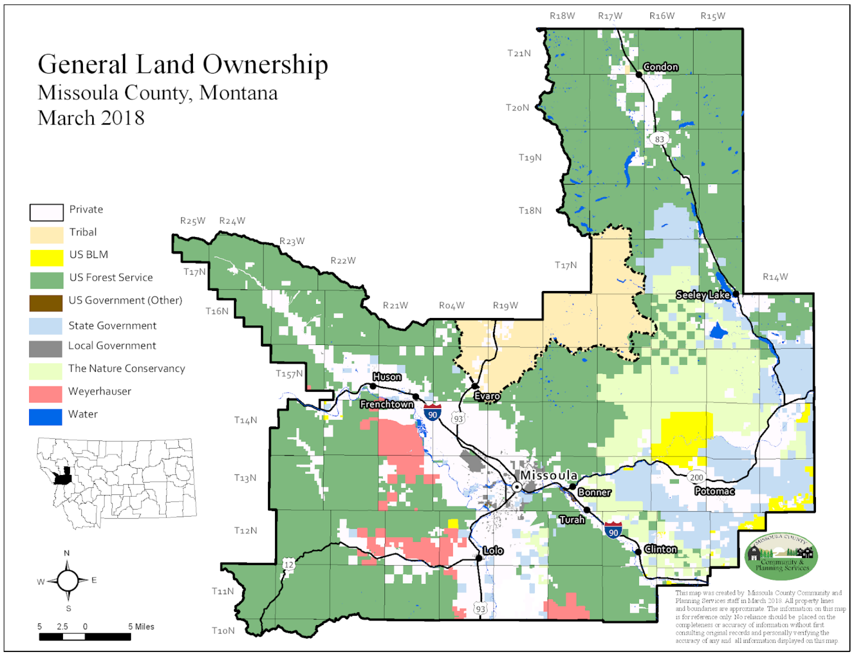

Figure 13 Land Ownership in Missoula County, Montana

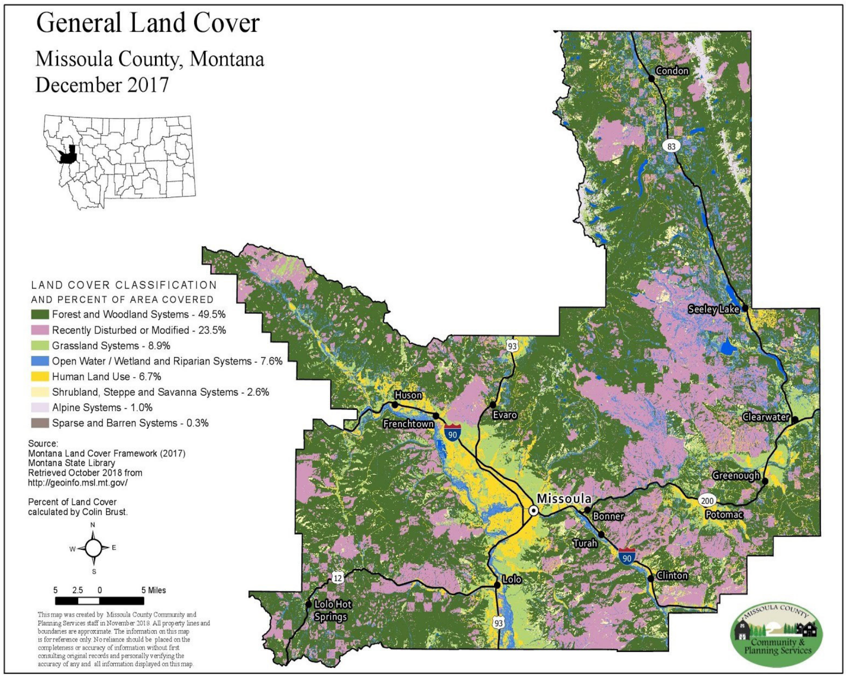

Figure 14 Land Cover in Missoula County, Montana

- just 1% of the land cover of Missoula County, alpine systems, including high elevation meadows and barren lands, are important environments. This area is above the “treeline” -- the elevation at which cold temperatures and long-lasting snowpack stop trees from growing -- and it provides habitat for unique species of plants and animals such as bighorn sheep and pika.

Important Lands

Missoula County contains parts of the Mission Mountain Wilderness, Bob Marshall Wilderness, and Selway-Bitterroot Wilderness and the entire Rattlesnake Wilderness. In addition to these wilderness areas, there are many other locations within Missoula County that wildlife and natural systems depend on. Some areas are key corridors that link large protected areas crucial for species movement. In the 2015 Montana Wildlife Action Plan, three areas within Missoula County were cited as key habitats for wildlife.

- Seeley-Gold Creek Area: The Seeley-Gold Creek area in the northwestern corner of Missoula County is a critical habitat for several species of concern including the Canada lynx, grizzly bear, and the great blue heron. Because of its location between the Mission Mountain, Bob Marshall, and Rattlesnake Wilderness areas, this area also provides connectivity for these species of concern to travel between wilderness areas.
- Bitterroot-Clark Fork Riparian Corridor: The Bitterroot-Clark Fork Riparian Corridor is another critical area for Missoula County’s wildlife. The corridor is a key breeding habitat for a number of Montana’s bird species including some species of concern such as the Great Blue Heron. Additionally, the corridor serves as a migration path for migrant species of birds. A portion of this area west of Missoula is an Audubon designated “Important Bird Area” considered for both the riparian and surrounding grassland habitats.[45]
- Fish Creek Area: In addition to these crucial bird and mammal habitats, riparian areas also play an important role for the wildlife of Missoula County. Although riparian areas only comprise 7.6% of the County’s total land cover, 95% of the wildlife in Missoula County depend on these riparian habitats.[46] One such habitat is the Fish Creek area in the western portion of the county. The Fish Creek area is a key habitat for
- bull trout, a threatened species, and westslope cutthroat trout, a species of concern.[47]

Demographics

The county is expected to grow from its current population of 117,441 to 137,055 by 2035. The highest rate of growth is expected in the 65+ age group.[48]

Growth rate is not uniform across the county; among the smaller communities, Lolo is growing the fastest, while Seeley Lake is losing population. Age distributions also vary across the county. The populations of Seeley Lake and Condon are older than the county as a whole, while the populations of Frenchtown, Lolo, Turah, Clinton, and Bonner are younger.[49]

Missoula County has a largely white population, with 92.1% of residents identifying as white. The second largest racial category in the county is Native American, accounting for 2.5% of residents. These percentages are relatively uniform across the county, with the exception of Evaro, where 38.1% of residents identify as Native American.[50] Evaro is located on the Flathead Indian Reservation.

Economy

The City of Missoula serves as the economic hub not only of the county, but of the entire region. Of the more than 76,000 jobs in Missoula County in 2013, less than 6,000 jobs were located outside of the city. The local economy was historically fueled by timber production and agriculture, and while these industries are still important, the economy has been changing rapidly. Today, health care, education, retail and wholesale trade, tourism, government, professional, technical and business services, and construction are the largest income generating industries in the county.[51]

The unemployment rate in the county was 2.8% as of October 2019, below the national rate of 3.6%.[52] Missoula County residents are well educated, with 41.8% holding Bachelor’s degrees or higher, compared to 30.3% nationwide.[53] However, the median household income in the county is $46,371, significantly lower than the US average of $55,322. The median household income in the City of Missoula is even lower, at $42,389. Poverty rates are higher than nationwide, with 16.1% of county residents (and 19.3% of city residents) living below the poverty line, versus 15.1% nationwide. Poverty rates in the county are higher among Native Americans (32.1%) than whites (15.5%).[54]

Recreation and Tourism

Missoula County's natural beauty and recreational opportunities are important to the county's economy. Outdoor activities such as hiking, mountain biking, fishing, and snow sports contribute much more to the county's economy than expenditures on gear and lift tickets; they are major factors in the high quality of life that draws residents and businesses to the area. More than 20% of Missoula County jobs are related to travel and tourism, much of it driven by these recreational opportunities.[55]

Agriculture

Agriculture plays a modest but important role in Missoula County's economy, and makes a major contribution to the county's culture and quality of life. Large and small farms, ranches, teaching farms, urban community gardens, and personal garden plots dot the county's landscape. In addition to agricultural production, such lands provide open space, scenic vistas and in some cases, bird and wildlife habitat. Missoula has a thriving local food scene and there is growing interest in localizing the food system and shortening the distance from farm to plate in order to reduce our food footprint, support the local economy, and feed our residents from within our foodshed. Both the City and County Growth Policies include the preservation of agricultural land and local food production among their goals and objectives.

Despite the value that the community places on local agriculture, there is significant development pressure on agricultural land in and near the Missoula urban area. The Community Food and Agriculture Coalition reports that nearly 29,000 acres of farm and ranchland was converted from agricultural to non-agricultural use between 1986 and 2010, and that roughly 80% of the lands containing the best agricultural soils have been subdivided into parcels less than 40 acres.[56]

Between 1974 and 2012 the total number of acres in agricultural production in the county decreased about 6%. While the number of farms in the county more than doubled during that period, from 310 to 637, the size of the average farm decreased from 845 to 388 acres. Today nearly half of farms in the county sell less than $1,000 worth of agricultural products per year. This suggests that an increasing number of "farms" in the county are rural residences with agriculture playing a secondary role on the property.[57]

In total, farm employment accounts for less than 1% of total jobs in Missoula County. The largest agricultural sales in the county are cattle and calves ($8.1 million), nursery and greenhouse sales ($1.9 million), and crops and hay ($1.5 million).[58] Alfalfa is the largest crop in the county by acreage planted (about 12,000 acres in 2017) followed by non-alfalfa hay (4,400 acres), wheat (900 acres) and barley (300 acres).[59] The majority of Missoula County crop production is irrigated, including about 90% of alfalfa production. Profit margins for Missoula County farmers are slim; overall net farm income (receipts minus expenses) has been negative nearly every year for the past several decades.[60]

Housing

Housing affordability is an increasing concern in Missoula County. As the county population grows and household size (number of people per household) shrinks, there is increasing pressure on the county's housing stock, particularly in the urban area. As of 2017, about 22% of homeowners and 49% of renters in Missoula County were "cost burdened," meaning that they pay more than 30% of their income for housing.[61] Housing prices have increased faster than incomes over the last decade, resulting in an increased number of cost burdened households.

The median home sale price in the Missoula urban area jumped 39% from 2009 to 2018, to $290,000. In the first half of 2019, the median home sale price exceeded $300,000 for the first time ever. It would take an income of at least $75,000 a year to afford the median-priced home, well above Missoula County's median household income of $54,311.[62]

Over the past several years both the city and county have had rental vacancy rates below 5%, indicating the need for additional rental housing stock.[63] However, the construction of several large multifamily housing projects in the Missoula urban area in 2018 appears to have eased pressure on the rental market.

More than 5,000 people, or about 8% of the Missoula County workforce, commute from neighboring counties (mostly Ravalli County), due in part to lower housing prices in these areas.

Homelessness is an ongoing concern in Missoula County, and in 2011 the city and county jointly developed "Reaching Home: Missoula's 10 Year Plan to End Homelessness." A point-in-time survey in January 2018 identified 319 homeless individuals in Missoula, and an estimated 500 children were homeless or in unstable housing during the 2017-18 school year.[64]

Infrastructure

Water

The City of Missoula water system, acquired from the private Mountain Water Company in 2017, is the largest public water supply in Missoula County. It serves over 56,000 residents, pulling water from the Missoula aquifer via 37 wells. The next largest water systems are the Lolo Water District, which serves about 2,600 residents in the community of Lolo, and the Seeley Lake Water District, which provides treated surface water to almost 1,400 residents.[65] Another 12,000 residents get their drinking water from 82 smaller community public water systems. The rest of Missoula County residents are served by private water supplies, typically from individual wells.

The Missoula aquifer provides water for 80 percent of Missoula County residents; the rest are served by smaller aquifers, rock and clay groundwater systems, springs, surface water or, for a small percentage of the population, water hauled to the site and stored in cisterns. In the valleys, alluvial aquifers (those with sand and gravel base) tend to be prolific and productive, but in some areas of the County, wells drilled into bedrock or clay groundwater systems are less productive.

Filed water rights in parts of Missoula County exceed the amount of surface water available. As a result, the Montana Department of Natural Resources 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. Because DNRC recognizes that groundwater and surface water are connected, this prohibition affects both wells and surface water draws. However, since individual wells below established withdrawal thresholds are exempt from water right requirements, new development on individual wells continues to occur in most of these areas.

Stormwater

When rain and melting snow run across hard surfaces such as rooftops, roads and parking lots, they pick up pollutants which they then carry into the county's rivers, streams, lakes, and aquifers. Common pollutants in stormwater runoff include fertilizers, pesticides, oil, grease, detergents, and metals, all of which harm water quality and aquatic plants and animals. The Montana Department of Environmental Quality identifies the Bitterroot River as the only surface water in Missoula County with specific impairments caused by stormwater. However, non-point source contamination is the leading cause of the remaining water quality impairments throughout the county and the state.

The Missoula Water Quality Ordinance (Missoula Municipal Code Chapter 13.26) is intended to protect water quality within the city limits and 5 miles beyond city limits. The Missoula Valley Water Quality District responds to reports of illicit discharges to storm drains, soil, and water bodies.

Rain that falls on natural, undeveloped areas is primarily absorbed by the soil. "Green infrastructure" refers to the use of vegetation, soils, and other natural elements to reduce stormwater runoff, while also providing habitat, flood protection, and cleaner water for the community. Outside the Missoula urban area, most stormwater runoff from roads in the county is managed through swales: shallow grassy channels that run alongside roads and absorb stormwater. In addition, stormwater injection wells, or sumps, are used to infiltrate water into the ground rather than direct it to surface water.

Wastewater

The City of Missoula operates the Missoula Wastewater Treatment Facility, which services most of the urban area, East Missoula, and west along the interstate as far as the Wye. The Missoula County Public Works Department runs the Lolo Wastewater Treatment Plant. Together these public sewer systems serve about 66% of the households in the County. The rest of the households in the county use onsite wastewater systems, although plans for a public sewer system in Seeley Lake are under development.

Transportation

There are about 350 miles of public roadway in the City of Missoula and an additional 1,500 miles of roadway in the county outside city limits, as well as 2,400 miles of US Forest Service roads. The Missoula International Airport is served by four airlines and provides nonstop flights to 12 destinations. There are small airports in Seeley Lake and Rock Creek.

Montana Rail Link and Burlington Northern-Santa Fe move freight through Missoula County. According to Montana Rail Link, about 16 to 20 freight trains pass through Missoula daily.[66] Passenger rail service is not available in the county.

More than 70% of Missoula County residents commute to work alone, driving their own vehicle.[67] However, there are a number of alternative transportation methods available, especially for residents of the urban area. The Mountain Line bus system offers 13 fixed routes, primarily within in the urban area, and has provided fare-free service since 2015. In 2017 Mountain Line provided over 1.5 million rides. Mountain Line also operates ADA Comparable Paratransit service and Senior Van service for eligible passengers within a ¾ mile radius of existing fixed routes. The University of Montana's UDASH bus system is also fare-free and serves mostly university students. The Missoula Ravalli Transportation Management Association offers fee-for-service van pooling connecting Missoula with Ravalli and Lake Counties.

There is extensive bicycle infrastructure in the urban area, including bike lanes, protected bike lanes, and shared use paths. The League of American Bicyclists has designated Missoula a Gold-Level Bicycle Friendly Community. Missoula's Long-Range Transportation Plan, titled "Activate Missoula 2045," sets a goal of reducing drive-alone trips by one-third through tripling the number of trips taken by bike, walking, and transit.[68] The City's Missoula in Motion program works with non-profits, businesses and residents to make progress toward that goal.

Energy

Three electric service providers operate in Missoula County: investor-owned utility NorthWestern Energy serves the Missoula urban area, Missoula Electric Cooperative serves much of the rural area of the county, and Mission Valley Power, which is a federal utility operated by the Confederated Salish and Kootenai Tribes, serves the Flathead Indian Reservation. These providers supply electricity from a variety of sources including hydroelectric dams, coal-fired power plants, natural gas-fired power plants, and wind farms. With the exception of a small amount of solar energy (see Renewable Energy section, below), none of these generation sources are located within Missoula County.

NorthWestern Energy supplies natural gas to the majority of households in the county. Residents of rural areas that are not served by natural gas lines utilize electricity, propane, and/or wood for heating. Overall, 7 percent of Missoula County households use propane as their primary heat source, and 6 percent use wood as their primary heat source.[69]

Historically, woodstoves and fireplaces have been the primary cause of poor winter air quality in Missoula County, since winter temperature inversions trap air pollution on the valley floors. Today the Missoula City-County Health Department regulates the installation and use of woodstoves and fireplaces throughout the county, with the most stringent regulations in the "Missoula Air Stagnation Zone," which encompasses the city of Missoula and about four miles outside city limits in every direction. Today, the Missoula valley meets the federal ambient air quality standards for fine particulates, but the small community of Seeley Lake experiences exceedances of the standards almost every winter because of woodstove smoke.

Renewable Energy

Renewable energy development is accelerating worldwide due to climate change policies as well as the dropping costs of many renewable energy technologies.

As of 2016 there were about 250 small customer-owned solar energy systems on homes and businesses in Missoula County, and that number continues to grow.[70] In addition, Missoula Electric Cooperative operates three 50 kilowatt "community solar" projects, the output of which it sells to participating co-op members. Google's Project Sunroof estimates that 83 percent of buildings in Missoula County are viable for solar panels based on roof orientation, size, and shading.[71] If solar were installed on all those rooftops, it would provide enough electricity for about 34,000 households, or 72 percent of households in the county.

The state of Montana is ranked in the top five among all U.S. states for wind energy potential. However, that potential is located in central and eastern Montana. Wind speeds in Western Montana, including Missoula County, are not suitable for wind energy development.

Much of Missoula County is forested, and over the years there has been interest in expanding the use of biomass as an energy source. An effort to develop a biomass boiler at the University of Montana in 2011 ultimately failed as a result of the high cost of sourcing and transporting appropriate biomass material in comparison to the low price of natural gas, as well as concerns about its impact on air quality.

Emergency Preparedness

The Missoula County Office of Emergency Management's mission is to protect lives, property, and the environment through preparedness, response, recovery, and mitigation planning and activities. They emphasize preparedness in addressing potential natural threats. Their 2017 update to the Pre-Disaster Mitigation Plan provides a review of critical facilities in Missoula County and the current state of services.[74]

Cultural Resources

Missoula County is home to current and aboriginal lands of the Confederated Salish and Kootenai Tribes (CSKT). Before European settlement, the Salish, Kootenai, and Pend d'Oreille peoples seasonally resided in the Missoula and Bitterroot valleys for the collection of camas and bitterroot plants, fishing, and big game hunting. Non-native settlers arrived in the region in the early 19th century and began changing land use from resource collection and agroforestry to farm and ranch lands.[72] Today, 5.6% of Missoula County falls within the Flathead Indian Reservation. Because of their current and historical connection to the lands of Missoula County, the CSKT are an important stakeholder for climate change preparedness and adaptation planning.

As a sovereign nation, the Tribes have taken the noteworthy step of creating their own climate readiness plan. Their findings, priorities, and future plans can be found in the CSKT Climate Change Strategic Plan.[73] The CSKT plan uniquely combines scientific research on the effects of climate change with traditional ecological knowledge of the region through the use of elder interviews. For example, elders understood the decreasing intensity of winter cold by noting changes in natural systems like snowpack and beetle infestations, and also its effect on cultural traditions like the timing of various hunting and gathering subsistence practices. In his forward to the strategic plan, former Council Chairman Joe Durglo writes, "Our survival is woven together with the land." Changes in climate, which the Tribes are already experiencing, threaten a way of life that has existed since time immemorial. The Tribes are committed to mitigating and adapting to these changes in order to preserve their natural resources, livelihoods, health, and cultural practices.

Appendix 2 | Vulnerability Codes

	Code	Vulnerability
agriculture (A)	A5	Decrease in nutrition of feed for livestock
	A6	Health impacts on farmers (heat)
	A7	Increased soil pollutants due to flooding
	A8	Increased cost for irrigation
	A9	Increased risk of livestock disease due to wetter springs
	A10	Heat stress on crops and livestock
	A11	Delayed planting due to wetter springs
	A12	Increased pest/fungal pressures
	A13	Farmer mental health impacts
	A14	Intense rain damages crops
	A15	Lower attendance at farmers' markets (smoke)
	A16	Crop loss from flooding
	A17	Loss of topsoil due to flooding
	A18	Delay in crop development (smoke)
	A19	Unpredictable weather and mismatch between crops and local conditions
	A20	Early/late freezes
	A21	Risk of losing agricultural land to development due to climate migration
	A22	Decrease in non-irrigated production (drought)
	A23	Health impacts on farmers (smoke)
buildings + landscaping (B)	B2	Building damage from storms and extreme weather
	B3	Economic impact/expense of building retrofits to withstand heat, storms, etc.
	B4	Buildings vulnerability to wildfire
	B5	Buildings vulnerability to flooding

	Code	Vulnerability
buildings + landscaping (B)	B6	Urban forest stress/mortality due to heat and drought
	B7	Increased demands for buildings due to climate migrants
	B8	Additional large buildings and infill conflicts with landscape and tree needs, exacerbating heat island effects
	B9	Damage to urban trees from extreme weather
	B10	Buildings do not adequately keep smoke out
	B11	Building stock is ill-prepared for extreme heat.
business, recreation, + tourism (R)	T1	Decline in timber products and tourism due to deforestation
	T2	Climate variability makes business investment difficult
	T3	Resource strain due to climate migrants
	T4	Reduced tourism/spending due to flooding
	T5	Reduced tourism/spending due to reduced snowpack
	T6	Shifted consumer patterns due to wildfire smoke
	T7	Reduced tourism/spending due to reduced streamflow
	T8	Reduced tourism/spending due to wildfires and smoke
	T9	Reduced employee health and wellness due to wildfire smoke
ecosystems (E)	E3	Increased erosion
	E4	Decreased water quality
	E5	Changes and reductions to instream/habitat quality
	E6	Increased stress on riparian vegetation
	E7	Impacts on aquatic species' adaptive capacities
	E8	Increased water temperature
	E9	Increased invasive species (aquatic)
	E10	Hydrologic disconnections
	E11	Increased competition among water users

	Code	Vulnerability
ecosystems (E)	E12	Increased stress on aquatic species
	E13	Increased risk of contamination
	E14	Changes in hydrology/storage capacity
	E15	Increased evapotranspiration
	E18	Impacts to flora due to habitat loss and fragmentation
	E19	Changes to species composition, species richness, genetic diversity
	E20	Impacts to fauna of habitat loss and fragmentation
	E21	Increased development and recreation pressure due to climate migrants
	E22	More forest pathogens
	E23	Changes to ecosystem type (e.g. forests transitioning to grassland or shrubland)
	E24	Ecosystem effects of changes in amount and timing of water availability
	E25	Expansion of invasive species (terrestrial)
	E26	Increases in tree mortality and reduction in regeneration
emergency preparedness + response (R)	R2	Need for more emergency planning and communication due to heat, flooding
	R3	Need for evacuations and places to shelter evacuees (smoke)
	R4	Impact of fire on first responders
	R5	Increased draw on resources due to heat
	R6	Slower response time due to extreme weather events
	R7	Increased draw on resources due to smoke
	R8	Impact of smoke on first responders
	R9	Need for evacuations and places to shelter evacuees (fire)
	R10	Increased draw on resources due to fire
	R11	High potential for loss of life due to fire
	R12	Disruption of communication systems due to fire, extreme weather events

	Code	Vulnerability
energy (N)	N2	Increased demand for energy stemming from climate migrants
	N3	Utility infrastructure may ignite fires in very hot/dry periods
	N4	Damage to power lines from extreme weather precipitation events resulting in service disruptions
	N5	Reduced hydropower production due to drought
	N6	Increased peak load due to hotter summers
	N7	Damage to utility infrastructure from wildfires and extreme heat, resulting in significant service disruptions
health (H)	H1	Increased incidence of skin cancer due to increased sun exposure
	H2	Difficult to exercise due to smoke, heat, wetter springs
	H3	Inadequate capacity in healthcare system
	H4	Social isolation due to heat
	H5	Trauma/drowning due to flooding
	H6	Trauma/burns due to wildfire
	H7	Wastewater treatment plant overload/septic system failures due to flooding
	H8	Less available drinking water due to drought (rural areas)
	H9	Lost sleep due to heat
	H10	Missed school/work days and lost wages
	H11	Increased violence and substance abuse associated with heat and extreme conditions
	H12	Heat stress and increased cardiac health issues due to heat
	H13	Asthma exacerbated by increased dust, pollen, mold
	H14	Increased incidence of respiratory and cardiovascular problems due to smoke
	H15	Declining health for chronically ill
	H16	Waterborne illness due to flooding
	H17	Vector borne illness due to flooding
	H18	Mental health impacts

	Code	Vulnerability
health (H)	H19	Increased mortality due to cardiovascular and respiratory stressors
	H20	Increased healthcare costs
	H21	Destabilization of people with mental health issues associated with smoke
land use planning + transportation (P)	P1	Impacts to roads and bridges (floods and extreme weather)
	P2	Impacts to homes and property (floods)
	P3	Increased tension between private and public interests (wildfire, floods)
	P4	Heat island effect exacerbated by increases in temperature and loss of urban forest
	P5	Inadequate water to support existing and future development
	P6	Impact on transportation systems (wildfire)
	P7	Increased tension between private and public interests (drought)
	P8	Community costs of development in the wildland-urban interface (wildfires)
water infrastructure (W)	W4	Increased system demand due to climate migrants
	W5	Reduction of surface water quality due to runoff sediment (wildfire)
	W6	Stormwater system inundation (flooding)
	W7	Availability of future water rights (drought)
	W8	Well contamination (flooding)
	W9	Increased wastewater treatment plant flows (flooding)
	W10	Acute and chronic physical infrastructure damage (flooding)
	W11	Unreliable water supply (drought)
	W12	Lack of dilution water for wastewater treatment (drought)

Phoebe Bean Photo