Arctic Rivers Project Summary Report: Community Interviews and Modeling Results for Changing Climate in Aniak, Alaska

Cooperative Report: Study Funded by the National Science Foundation, the University of Colorado, Boulder, and the U.S. Geological Survey

Prepared by: Jenny Bacon[1] and Nicole Herman-Mercer[2]

[1] Oak Ridge Institute for Science and Education, Denver, Colorado
[2] United States Geological Survey, Denver, Colorado

Prepared for The University of Colorado, Boulder

Suggested Citation: Bacon, J. and Herman-Mercer, N.M., 2026. Arctic Rivers Project Summary Report: Community Interviews and Modeling Results for Aniak, Alaska. U.S. Geological Survey Cooperator Report prepared for the *University of Colorado Boulder*.

Acknowledgements: We would like to thank all workshop and interview participants for spending their time and sharing their knowledge with us. The Arctic Rivers Project is supported by the National Science Foundation under the Navigating the New Arctic program: Awards 1928189 & 1928078, "The climate impacts on Alaskan and Yukon rivers, fish, and communities as told through co-produced scenarios." Additional support was provided by the U.S. Geological Survey's Ecosystems Mission Area through the Alaska and Southwest Climate Adaptation Science Centers. We would also like to thank Agnes Macy for her assistance in creating the graphs used throughout this report.

Arctic Rivers Project Summary Report: Community Interviews and Modeling Results for Changing Climate

Executive Summary

The Arctic Rivers Project

This report shares climate modeling results produced by the Arctic Rivers Project and the results of interviews conducted by the project team. The project is an interdisciplinary effort funded by the National Science Foundation (NSF) and led by the University of Colorado, Boulder (CU) and the NSF National Center for Atmospheric Research (NCAR). Additional support was provided by the U.S. Geological Survey (USGS) Alaska and Southwest Climate Adaptation Science Centers. The project aims to better understand how climate change is affecting Arctic rivers, ice travel corridors, fish, and the communities that depend on them.

Summary of Findings

- Workshop and interview participants are observing warmer air and river temperatures than in the past. Our model projects that, on average, air and river temperatures will increase by mid-century.
- Workshop and interview participants described cascading effects of warming temperatures and changes in precipitation on people and the environment such as increasing wildfires, thinner river ice and more open water in the winter, and declines in the abundance of subsistence resources.
- Our model projects that wildfires may be more frequent in the future due to drier conditions and increases in lightning strikes.
- Workshop and interview participants discussed the declining salmon population in the Kuskokwim River and its effects on culture and subsistence. Chinook salmon are negatively impacted by warmer waters and changing habitat. According to our model, warming waters can also alter their abundance, growth, and timing of spawning and migration.
- The model projects, on average, an increase in rain occurring in the winter, a shorter snow season overall, and a decrease in snowpack. All of which may continue to impact winter travel.
- Workshop and interview participants in Aniak described actions the community has been taking to reduce the impacts of climate change, such as changing food sources, utilizing technology for weather prediction, and teaching younger generations cultural traditions in a classroom setting. Additional actions may be needed to mitigate future effects of a changing climate.

Contents

BACKGROUND

Climate Modeling

Recent changes in climate (i.e., climate change) have been caused by rising levels of greenhouse gases in the atmosphere that trap heat and make the planet warmer (see Figure 1). This is called the greenhouse effect. Human activities have substantially contributed to increases in atmospheric greenhouse gases over the past 150 years (IPCC, 2022). In both the United States and Canada, the primary source of greenhouse gas emissions is the combustion of fossil fuels for electricity generation, heating, and transportation (EPA, 2024). It is important to keep in mind that even though the impacts of climate change happen at the local level, climate change is a global problem, and greenhouse gases are created by countries around the world.

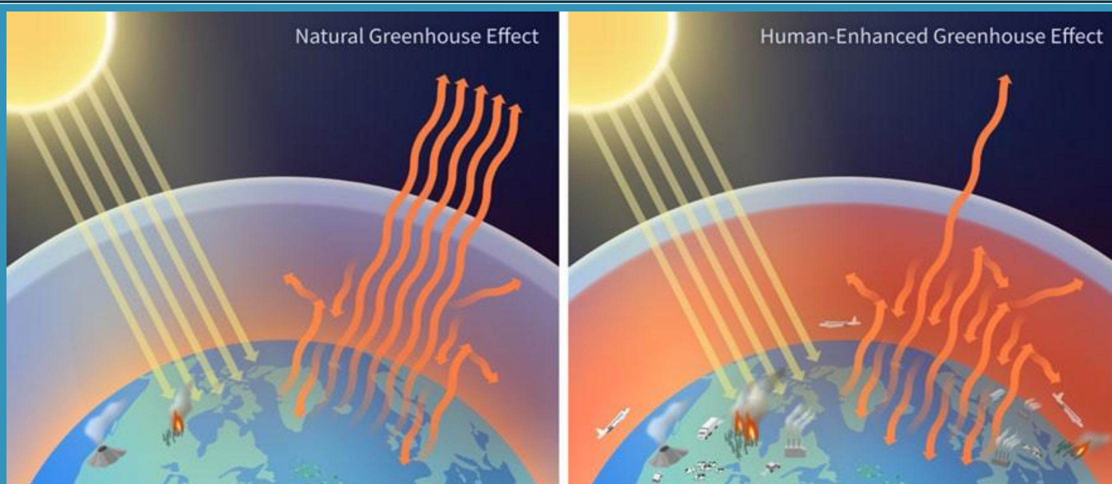


Figure 1: Human-produced greenhouse gases have intensified Earth's natural greenhouse effect by changing the balance between the amount of sunlight that reaches the surface and the amount of heat that escapes the atmosphere. CREDIT: National Oceanic and Atmospheric Administration Climate Program Office, Graphic by Anna Eshelman

Models that estimate the climate and environmental conditions under future warming scenarios can be a key tool to help inform community decisions in response to climate change. The Arctic Rivers Project has developed a regional climate model for the state of Alaska with feedback received from a survey of Indigenous leaders within the study area and an Indigenous Advisory Council (see Herman-Mercer, 2021 for more information about the survey and Cheng et al., 2025 for more information about model co-design). Climate models simulate the warming effects of greenhouse gas concentrations via a computer-based representation of Earth's systems using mathematical equations that represent real conditions, producing climate scenarios (see Figure 2). We provide regional climate information for the historical period of 1991-2020 and a mid-century future period of 2035-2064. Six climate scenarios with similar greenhouse gas concentrations were used to capture a range of possible futures. For simplicity, we present the average change from these six simulations. Modeled conditions include air temperature, precipitation, snowfall, snowpack, streamflow, and river temperature.

Differences between historical and future conditions are presented seasonally and annually. These are presented for the local rivers and the watershed upstream of Aniak, Alaska. Seasons are defined as Winter (December-February), Spring (March-May), Summer (June-August), and Fall (September-November). See Appendix A and Newman et al. (2026) for more specific information on modeling methods and Appendix B for all data included in the figures provided.

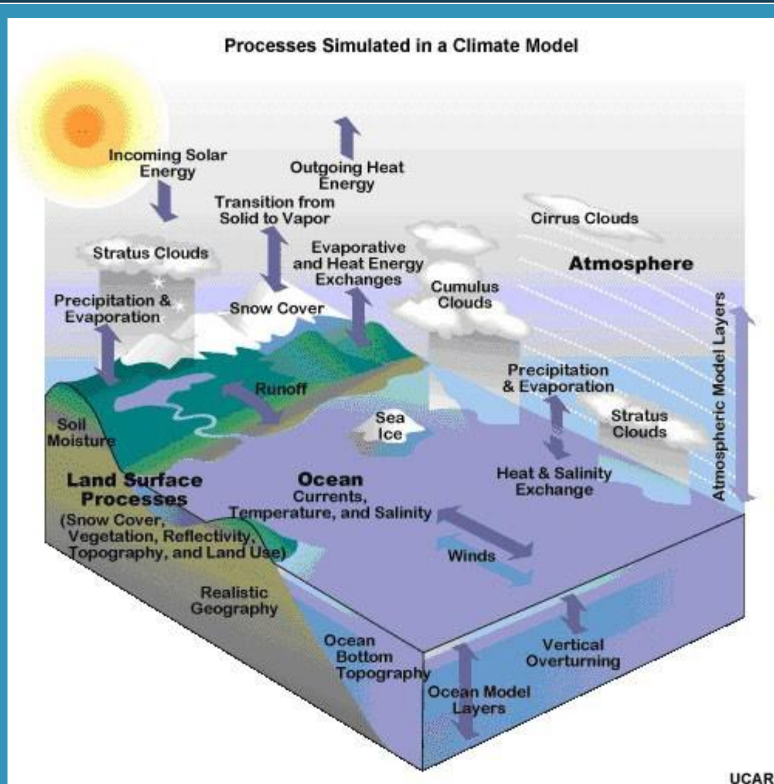


***Figure 2*:** This image shows the different processes that are simulated by computers to develop a climate model. Image courtesy of the University Corporation for Atmospheric Science (UCAR).

Community Workshops & Interviews

This project has two main objectives: 1) to understand how environmental changes are impacting individuals and communities and 2) to understand how communities have responded to changes in the past and might adapt in the future. To accomplish these objectives, we held workshops and conducted interviews in Aniak, Elim, and Saint Mary's, Alaska. Three workshops were held in each community in July and August of 2024 (Figure 3). A total of 82 community members participated in workshops. In January and February of 2025, we conducted follow-up interviews based on the topics raised in the workshops. Thirty-three interviews were conducted in total: 12 in Aniak, 10 in Saint Mary's, and 11 in Elim.

Quotes from the interviews were grouped into themes to analyze impacts and responses to specific events and long-term changes. Themes from the interviews were paired with relevant model outputs to create "Storylines of Change," which weave community experiences together with scientific data (see Appendix C). In April 2026, a follow-up workshop was conducted to discuss potential adaptation actions with local decision makers based on the previous results (See Figure 4 for difference between mitigation and adaptation).

***Figure 3**:* Community Workshop in Aniak August 2024 Photo credit: Keith Musselman

This report summarizes those storylines and highlights how projected changes may affect Aniak. Our goal is to provide information in a format that supports local decision-making and strengthens community resilience to climate change.

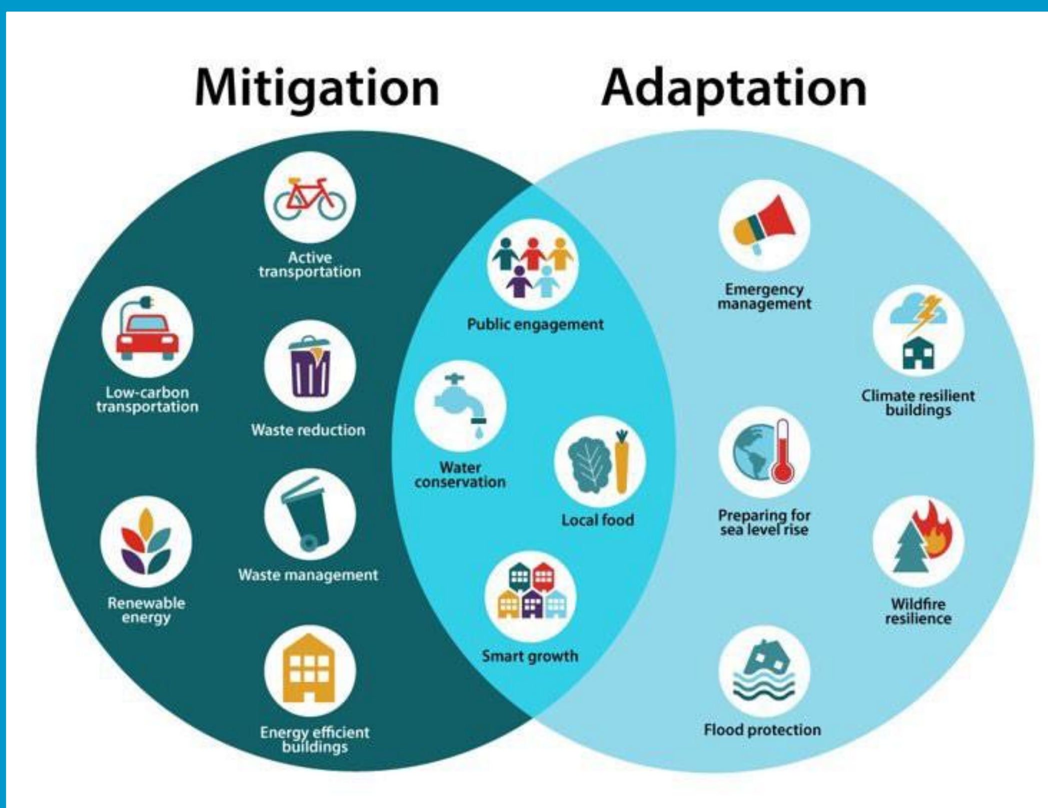


***Figure 4*:** Climate mitigation versus adaptation. Mitigation actions reduce greenhouse gases in an effort to limit future climate change. Adaptation actions can help communities respond to changes that are already occurring or predicted to occur in the future. Some actions can be considered both mitigation and adaptation as shown in the middle of the diagram.

Image Credit: tree-nation.com

REPORT STRUCTURE

This report is organized around primary exposures, secondary exposures, and adaptations (Figure 5). In climate science the term **exposure** is used to describe the environmental conditions that people experience. Primary exposures, such as air temperature and precipitation drive changes in other environmental systems, creating secondary exposures. Secondary exposures are one time or long-term events such as a wildfire, decline in subsistence resources, or thinner river ice. Secondary exposures can lead to specific community impacts on culture, economics, health, or safety.

We pair regional climate model results with quotes from interviews with community members in Aniak. Community impacts resulting from secondary exposures are organized by cultural, economic, and health and safety concerns. The report concludes with past and proposed future adaptation strategies discussed during interviews. All outside studies referenced in the report are in the Sources section (page 18) at the end of the document.

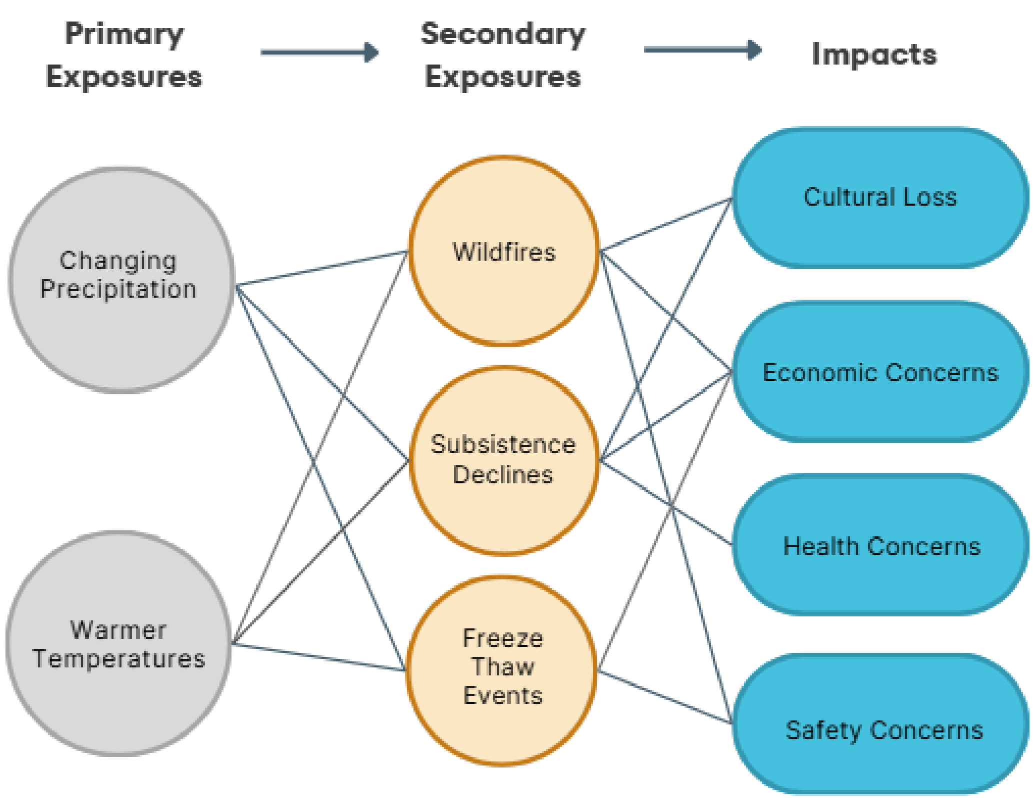


Figure 5: Diagram showing primary exposures leading to secondary exposures resulting in community impacts.

PRIMARY EXPOSURES

Climate-related shifts in air temperature and precipitation are altering environmental conditions in ways that affect daily life, travel, and subsistence practices. In the graphs below, the annual means are the average temperature over the entire historical (1991-2020) or mid-century (2035-2064) period. The seasonal means are the average temperature over the entire season for each time period. The maximum and minimum values are the average daily high and low averaged over the time period. While these are long-term changes observed and modeled over many years, workshop and interview participants also noted more rapid change in shorter periods of time, such as days or weeks.

Warming Temperatures

Air Temperature

Modeled future temperatures show warming in all seasons, with the largest changes happening in winter. During interviews, Aniak residents reported that winters are noticeably warmer and that cold periods no longer last as long. Winters and summers are predicted to be 4°F warmer on average during mid-century.

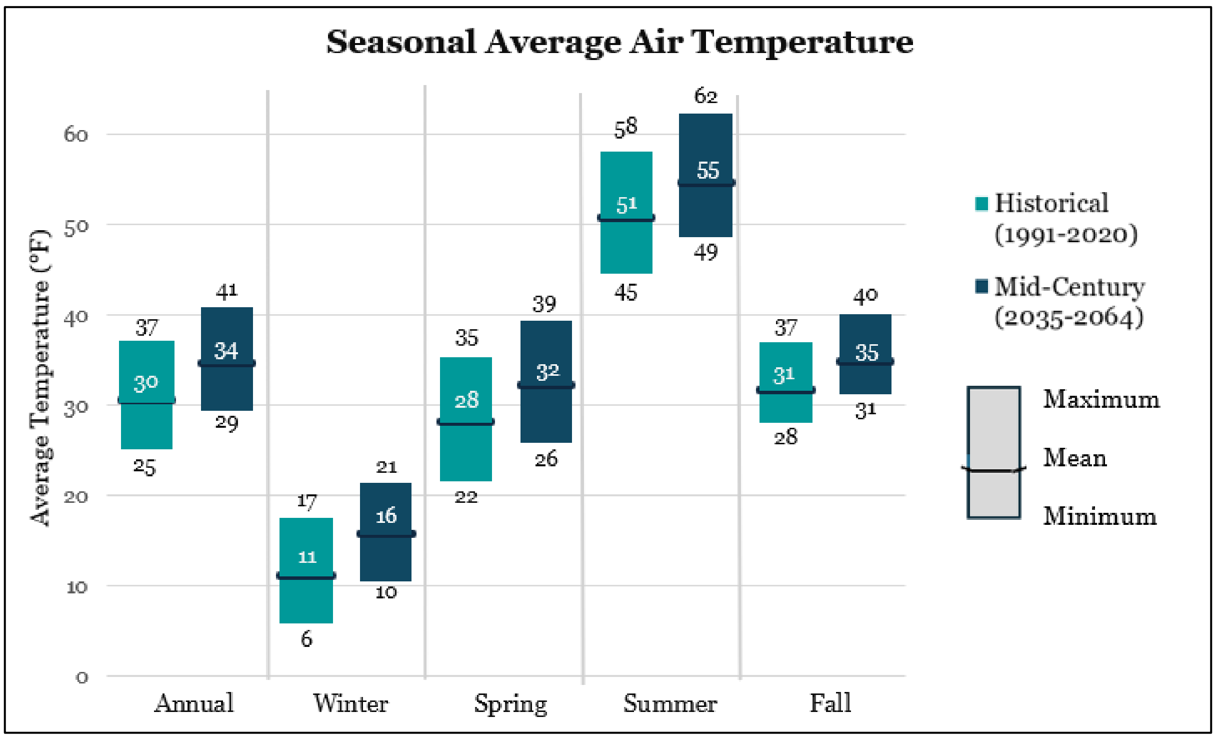
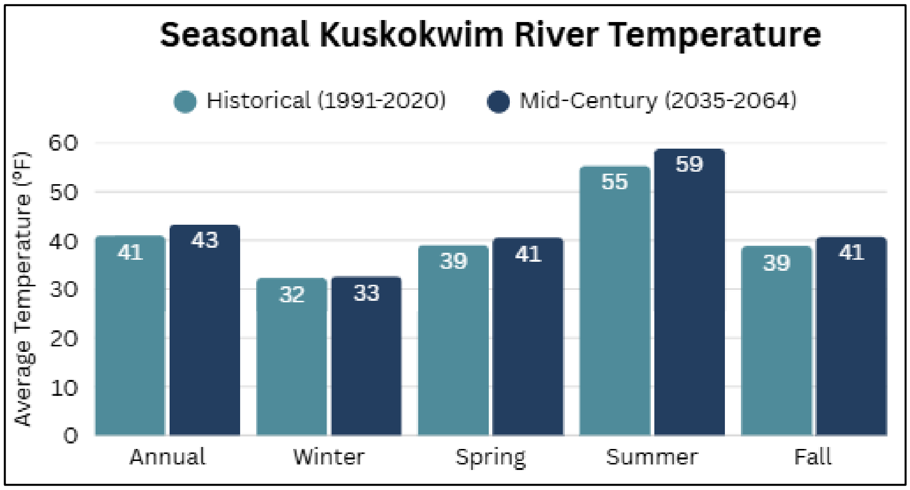


Figure 6: Average annual and seasonal air temperature means, daily average minimum temperature, and daily average maximum temperature, comparing modeled historical timeframe (1991-2020) to mid-century timeframe (2035-2064)

"Well, it's definitely gotten a **lot warmer for the winters** and **hotter during some of the summers.**" –Joe Kameroff Jr

River Temperature

With warming air temperatures, river water temperatures are also projected to rise annually. Aniak residents described increasingly unreliable ice thickness, more slush outs, and fewer periods of safe winter travel.



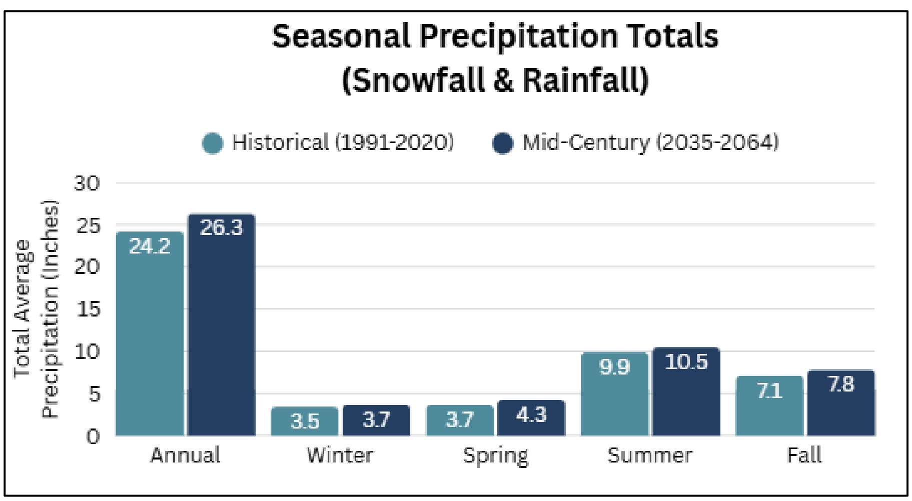
"There's sometimes we don't have the river open 'cause the ice is too thin for them to plow the road... **Weather was a lot warmer. There was too much water on the river—or the ice was too thin.**" -Aniak community member

Figure 7: Average annual and seasonal river temperature on the Kuskokwim River, comparing modeled historical timeframe (1991-2020) to mid-century timeframe (2035-2064)

Changing Precipitation

Total Precipitation

Annual precipitation (snow and rain combined) is projected to increase. Interview participants observed more winter rain and more variable spring, summer, and fall storms. Thus, the impact of these changes can be expected to continue.

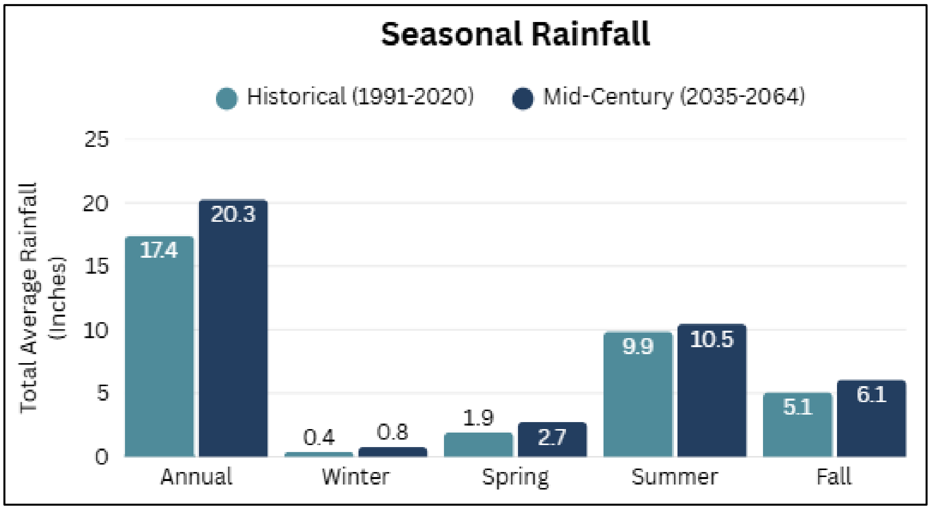


"I feel like this last storm wasn't our typical. We had, like, **pouring-down rain for days**, and it was icy, and **then dumped on with snow** and wind." –Richie Dahl

Figure 8: Average annual and seasonal precipitation in Aniak comparing modeled historical timeframe (1991-2020) to mid-century timeframe (2035-2064)

Rain

Rainfall is projected to increase in every season, though dry periods will still occur. These changes are already being reported by Aniak residents.



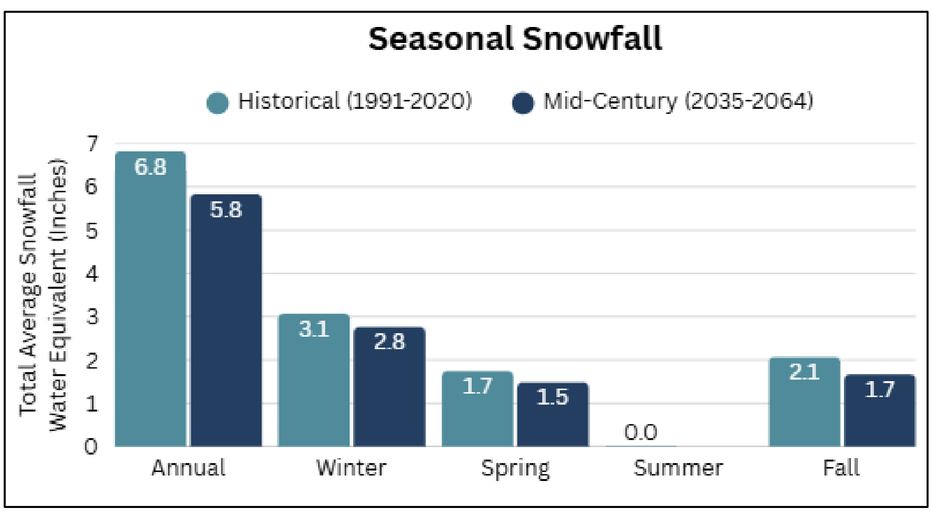
> "Well, **last summer, we got a lotta rain**—rain, rain, rain. And then **some years we get no rain**, and really hot, humid"
> -Lee Morgan

Figure 9: Average annual and seasonal rain in Aniak comparing modeled historical timeframe (1991-2020) to mid-century timeframe (2035-2064)

Snow

Snowfall is projected to decrease overall, with declines in snow water equivalent and a shorter snow season. This is due to the warming temperatures, especially in winter, shown in Figure 6, that lead to more precipitation falling as rain than snow. During interviews community members described dramatic reductions in snow depth over the years. Based on the modeling data, community members can expect these declines to continue over the following decades.

Note: Snow water equivalent is the total depth of water that would result when the snow melts.



> "When **I was younger there would just be snowstorms**. I mean, **now there's the rain**. We had quite a bit rain recently."
> -Tisha Folz

Figure 10: Average annual and seasonal snowfall in Aniak comparing modeled historical timeframe (1991-2020) to mid-century timeframe (2035-2064)

SECONDARY EXPOSURES

Increased frequency of wildfires, declines in subsistence resources, and increased frequency of freeze/thaw events during the winter are all concerns expressed during interviews which are exacerbated by climate change.

These secondary exposures can result in negative impacts on the community in the areas of culture, economics, and health and safety. Impacts on culture can include the disappearance of a culture's characteristics, traditions, beliefs, or social structures. Economic impacts can include strains on individual or family's livelihood or financial stability. Health and safety impacts have effects on the physical and mental health of individuals and the community. Concerns in each of these impact categories were expressed during interviews.

Wildfires

Warming air temperatures and drier conditions increase wildfire risk. Reduced snow cover in spring and increased lightning from warmer storms contribute to more frequent wildfires. A 26% increase in lightning strikes is projected for the Central Interior region (see Figure 19 in the Appendix for region map) during wildfire season. This has potential to increase the number of fires experienced in this region in the future.

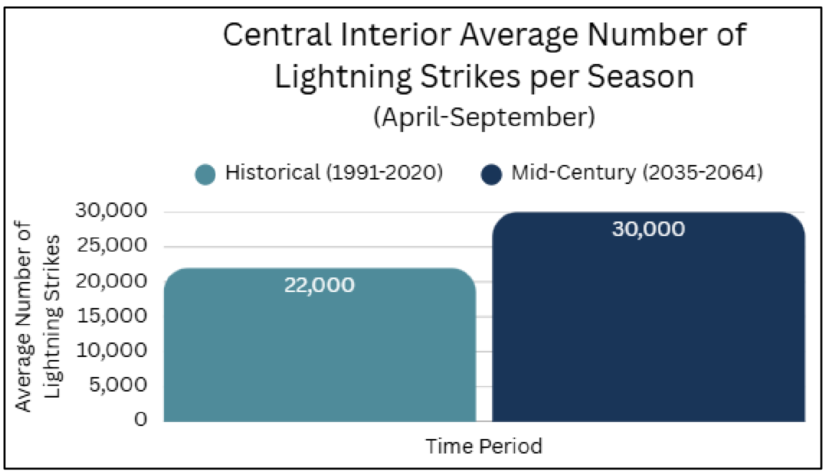


Figure 11: Average number of lightning strikes per season from April to September comparing modeled historical timeframe (1991-2020) to modeled mid-century (2035-2064) timeframe.

"With the summertime it's hotter than usual. **Then we have the thunder and lightning. And that's when the forest fires start**. And we've been looking more at trying to have Aniak prepared... maybe individuals clearing off [debris]"
-Clara Morgan

Impacts of Wildfire on Community

"Even though the fires aren't close the smoke will come this way. And **you had to stay in, or wear a mask, cause then if you wear a mask, you could still breathe that smoke**. The smoke through it. Talking, the smoke is affecting me. I get all foggy." – Clara Morgan

Wildfires can threaten subsistence areas, homes, and infrastructure. Subsistence areas are important for maintaining connections to the land and practicing important traditions. The burning of subsistence areas may create additional concerns for food security as community members may not be able to harvest certain foods.

Wildfires can also impose economic burdens through evacuation costs, damage, and lengthy recovery processes. During interviews community members expressed that smoke exposure, evacuation, and communication gaps were major safety concerns.

Salmon & Other Subsistence Declines

Warmer air and water, altered precipitation and snowpack, and habitat changes affect subsistence species (see paper by Green and others, 2021 in the Sources section). Interview participants shared that many families do not spend time at fish camp like they did in the past due to declines of subsistence species and new restrictions on harvesting. In interviews, community members expressed concerns that family bonding and traditional knowledge transmission was being reduced because of the decline in fish camp participation. Community-members also told us they rely more heavily on expensive store-bought foods. While not evaluated by this project, some subsistence species may not be negatively impacted by changes and instead may be expanding their ranges, such as moose (see paper by Tape and others, 2016) and pink salmon, which may be more adapted to warmer waters (see paper by Ruggerone and others, 2023).

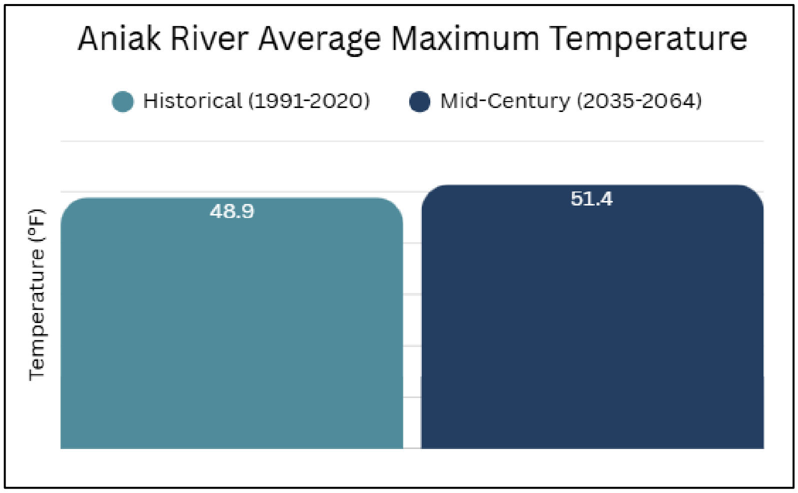
Salmon

Community members discussed significant declines in Chinook salmon in the past few years, coinciding with fisheries closures on the Kuskokwim River by resource managers. Many interview participants attributed these declines to overfishing by ocean trawlers. Salmon declines in the region have also been attributed to habitat loss, warming waters, and predation (see Fifth National Climate assessment, 2023 in the sources section of this document). Research is ongoing to understand the negative impacts on salmon.

Our model projects the Aniak River to have a 2.5°F warmer average daily maximum summer temperature by mid-century, creating ecological implications throughout the lifecycles of multiple species of fish. The optimal range for Chinook salmon spawning is 55.4-64.4°F. When water temperatures reach 68°F or above, Chinook cannot spawn and mortality increases (see Bergendorf, 2022 report on Chinook salmon in sources section at the end of document). Salmon size, health, and abundance have declined over time according to interview participants. Community members also reported an increased number of diseased fish. It is important to note that our model is averaging over a 29-year period, smoothing seasonal fluctuations in river temperature across the entire basin and does not portray extreme acute warm water events which could impact fish in the short-term.

Our fish simulations project the average number of spawning days for late-run Chinook salmon in the Aniak River will decline by 7 days (Figure 13), with the first spawning day projected to be 6 days later (see Fish Model Definitions in Appendix A). This could result in reduced spawning overall or shifts in the timing of spawning, as salmon wait until waters cool later in the summer season.

Warmer temperatures during migration periods can slow Chinook salmon migration due to physiological stress (see papers by von Biela and others, 2026 and Howard and von Biela, 2023). Based on our fish simulations, Chinook salmon in the Aniak River are projected to have 32 days longer migration periods, with the first migration day projected to be 6 days later (Figure 13). More migration days could mean that a longer portion of the summer remains suitable for migration or that the timing of migration shifts later. This may also indicate that adult Chinook must migrate over a longer period due to warming-related stress.



"Sometimes you get some big ones. The numbers aren't very good. Some years it's good for chums, but some years it'd be bad for Chinook. Some years it'd be good for silvers, and some years it'd be bad for red salmon returns**. Every year it's something else**." – Samuel Peterson

Figure 12: Daily maximum temperature of the Aniak River averaged over the summer months (June-August) modeled for the historical timeframe (1991-2020) and modeled mid-century timeframe (2035-2064).

Aniak River Chinook

	Historical (1991-2020)	Mid-Century (2035-2064)
Average Number of Migration Days	**20**	**52**
Average Number of Spawning Days	**59**	**52**

"**Salmon is getting pretty scarce**...They have closures and openings 'cause of the low number of fish. Yeah, they are getting smaller. The king salmon is smaller. **They're not really maturing like they used to**." -Aniak community member

Figure 13: Average number of migration and spawning days for Chinook salmon in the Aniak River comparing modeled historical timeframe (1991-2020) to modeled mid-century timeframe (2035-2064)

Berries

Berries are affected by snowpack loss, wildfires, storms, and warming temperatures. Salmon berries, cloudberries, blueberries, and blackberries were all mentioned as being key subsistence resources during interviews in Aniak. Interview participants discussed how a decline in winter snow has resulted in fewer berries. While **we did not model plants**, snowpack is projected to decline seasonally by 0.8 inches snow water equivalent on average (Figure 14).

These changes could impact the number of berries in the springtime. Other research has shown that warming temperatures, specifically in the months of January and July, are significant drivers for shifting berry plant habitat suitability (See paper by Hamilton and others, 2024 on berries). Berries can also be impacted if dry conditions lead to wildfires in berry harvesting areas. Severe storms have also been reported to impact berries by covering them in sand or other debris.

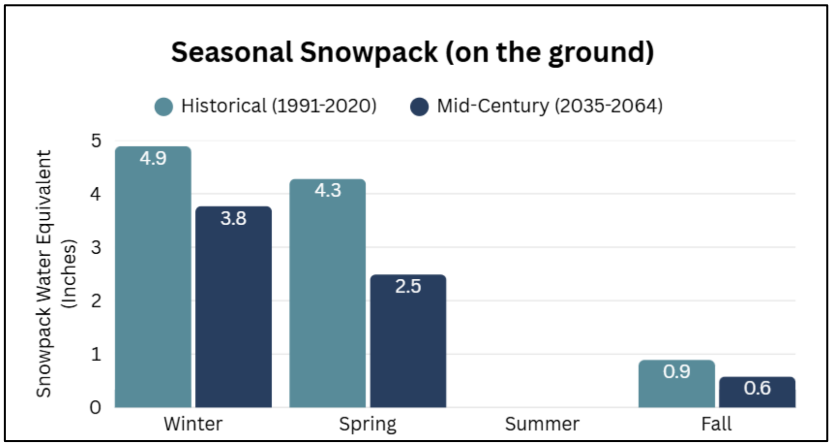


***Figure 14*:** Average annual and seasonal snowpack in Aniak comparing modeled historical timeframe (1991-2020) to mid-century timeframe (2035-2064)

"And we depend on the snows— for those kinds of things, different plants that grow. And berries that we collect in the summertime. 'Cause **if we don't have the snow or the rain then we don't have those berries**— or leaves that we collect." -Nora Kelila

Impacts of Subsistence Losses on Community

"I actually kind of worry about our kids when our generation gets— you know, spending time outdoors, you learn to do stuff... So, **I worry about them not knowing just the little basic things they need to know**." -Lee Morgan

Declines in harvest opportunities affect culture, food security, and health. Without fish camp during summer to bring people together, many people we spoke to in Aniak discussed feeling disconnected from family and friends. Fish camp was described as a time when families came together to share stories and pass on knowledge. Concerns about the loss of this time of knowledge sharing and connection building were described as particularly disruptive to sharing between youth and elders.

Physical health can be affected by the inability to harvest traditional foods and an increased reliance on store-bought foods, which can be less healthy than traditional foods. As Lee Morgan stated, *"It's gonna be tough—tough if we can't get salmon. That's one of our main resources, and people look forward to it for the summer. Great—really good nutritional values… we just have to get more moose meat and try to get [our] fish elsewhere, I guess."*

During interviews in Aniak there was discussion about an increase in buying expensive groceries from the store instead of subsisting. Hunting, fishing, and gathering require an investment in supplies, but because subsistence resources are unreliable, some interview participants talked about choosing the security of store-bought foods despite their desire to subsist.

Mental health concerns can also be exacerbated by the stress, uncertainty, and grief that comes from the loss of traditional activities. Emily stated, *"I miss seeing kids outside. There was lots of different activities for kids, and now, there's not very many."* Cultural loss may also come from some community members having to move out due to economic constraints in the villages. Some interview participants in Aniak told us they have considered moving out of the village. Outmigration can fracture families and make community connection even more difficult. Nora Kelila talked about feelings of a lack of community cohesion, saying, *"I think Aniak is weak right now… Aniak would benefit from that, like just to bring togetherness back, or the unity and community back."*

Seasonal Freeze-Thaw Cycle

Warmer winters mean more frequent freeze-thaw cycles, unpredictable ice, flooding and hazardous travel conditions. Recently, communities have experienced fatalities because of unsafe or unpredictable winter travel conditions. Inconsistently frozen river ice and subsequent open water are particularly limiting for safe travel. Ice roads are the primary routes of travel in the winter in Aniak, but timing for building them has been pushed later each year due to warming.

Figure 15: Modeled mid-century snow projections for the Central Interior region of Alaska which includes Aniak.

"During the winter, we used to always go dog teaming when we were kids. **The ice used to be good.** We never used to have to worry about open things, **not like right now**." -Lee Morgan

Changes in the cycle of freezing and thawing during the winter months can be caused by several factors. Increasing air and stream temperatures in the winter (Figures 6 and 7) can contribute to thinner river ice. Increasing winter streamflow (Figure 16) can also cause river ice to be thinner and create more open water. Our model projects increases in average streamflow annually on the Kuskokwim River as well as increases in the winter. Warmer air temperatures can also lead to precipitation falling as rain instead of snow in the winter and a shorter snow season overall. Our model projects an average increase in winter rain during the mid-century timeframe (Figure 9) and a shorter snow season with snow starting 5 days later and melting 8 days earlier on average (Figure 15).

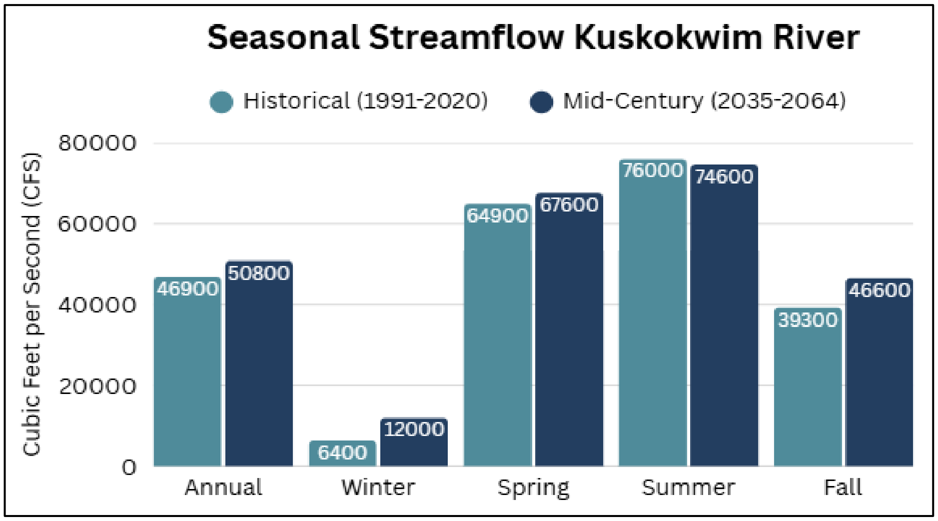


Figure 16: Average annual and seasonal streamflow on the Kuskokwim River comparing modeled historical timeframe (1991-2020) to mid-century timeframe (2035-2064)

Impacts of Seasonal Freeze-Thaw Shifts on Community

"Winter's been really warm—sometimes, and it makes the traveling difficult to go. The tundra is bare, and it's rough-rough going. **You can't travel. The rivers are dangerous.** The cricks or streams are dangerous." -Aniak community member

These conditions affect access to subsistence resources, recreation, travel.

Many participants discussed feeling a major loss in recreation due to changing weather conditions, primarily in the winter. People were nostalgic for times as children when they could play on giant snowbanks and ice skate on frozen water. They feel a loss for their own children or grandchildren who do not get to have these same experiences. Lee Morgan remembered,

"being a kid, jumping off this road, and the snow berms were taller than we were. And then we'd have little snowballs, and we'd chuck them over the snow berm to scare the drivers. There used to be tons of snow long ago compared to now."

Without safe routes of travel in the winter, community members are stuck at home and cannot go out to gather supplies, visit others in neighboring villages for family and social gatherings such as funerals, Potlatch, basketball games, or recreational activities. One person shared, *"To me, bein' out in the wilderness or outdoors is a good stress reliever. It's good for your health 'cause you get exercise.... And this year, it's like we've been in cabin fever, just can't go nowhere. You're just stuck."*

Safety under changing conditions is a major concern for interview participants. Unpredictable weather events, such as winter melting, create challenges for safe travel. It may be unclear how safe the trails or rivers are before going out, and there are few current mechanisms for sharing such information outside of word-of-mouth. Some participants commented on a desire for clearer communication on the safety of travelling by local leaders during the winter months.

ADAPTATION STRATEGIES

Adaptation strategies are actions or steps taken by individuals, households, or whole communities to respond to the changing environment. Effective adaptation means retaining features which are most important to people, like subsistence, while changing in other ways to meet new conditions.

Past Adaptations

In the interviews, we asked what people have done in the past when there have been changes outside of their control. These actions may not always feel like conscious adaptations, but instead just a necessary part of life. They may also feel like positive or negative changes. The following are examples of changes or adaptations described by interview participants in Aniak.

Using online weather forecasts

> "**We're big into looking at the forecast** and the charts and stuff" – Richie Dahl

Traditional methods of weather prediction were mentioned during interviews to be less reliable in recent years. Interview participants described accessing weather forecasts on their phones to determine if conditions are safe enough to go out.

Changing fish preparation methods

> "…the way they put away their foods, they dry some. **They vacuum-pack and freeze 'em. They jar them**." -Clara Morgan

Weather conditions can limit the ability to dry fish using traditional methods due to humidity that can make it difficult for the fish to dry or a lack of wind that allows flies to land on the fish. Interview participants told us that some community members have converted to freezing whole fish or smoking them instead in recent years.

Relying more on store-bought foods

> "If there was no resources, no fish, I don't know--- I don't know what we'd do. We'd have to make do. **We'd have to get all outside food** if you can afford 'em." – Aniak community member

Some interview participants described purchasing store-bought food more than in the past when they are unable to harvest subsistence resources either because of declines in availability or time constraints because of work or school commitments.

Harvesting alternative species

> "**I had to learn how to quench my taste with red salmon and the other fish, beef**. They do have different tastes. And learn how to cut that as much as I could and use that. And they're all textures are different and everything." -Aniak community member

When certain species, such as salmon, seal, or other important animals are no longer available to harvest, community members are harvesting more of other species who may be thriving under warmer conditions. Moose and some whitefish were described to be more available. However, there are concerns about the potential for mercury hyperaccumulation in the whitefish.

Teaching traditional activities in school

> "Then **they'll have these culture camps, and they'll pull us all in**, and we'll just teach something to someone. And it's so good to do that... But if you just take a minute to break down that barrier and say, "What do you wanna do?" "Let's do it. **Let's learn something**" And that's what those camps are good for. -Nora Kelila

In our interviews community members described school trips that teach wilderness preparedness and other traditional knowledge. If opportunities for youth to participate in traditional activities such as fish camp continue to be limited, schools could expand their teaching of these.

Proposed Actions

During interviews and a follow-up adaptation focused workshop, community members proposed a series of potential actions that could be taken to promote resilience.

Strengthening search and rescue training and preparation

> "When there's a 911 call- just **the search and rescue need to be more prepared** to go out and like have gas on hand and totes with survival gear." -Aniak community member

With conditions for travel becoming unpredictable and sometimes unsafe, interview participants proposed better preparing local search and rescue teams to respond to these new conditions. These participants felt that lives could be saved if search and rescue were able to respond more effectively and efficiently.

Working with friends and family to distribute costs

With rising costs, community members discussed the desire to split the expense of supplies to subsist and the gas to travel by going out in larger groups of family and friends.

Conducting Fire Mitigation Efforts

Past experiences with fire near the community have highlighted the need to be prepared for future wildfire in the area. In the adaptation workshop, participants discussed the possibility of taking preventative measures through maintaining vegetation and creating a fire break around the community. They also discussed continual environmental monitoring of important habitats which could be impacted by fire.

Promoting youth and elder connection & continuing Culture Camps

> "I wish more people could get involved **teaching the younger generations to do more activities and—culture, learning, hunting**. I would wish there was an elder house, housing up here, so the elders wouldn't have to move out of town. And they need an elder program too." -Aniak community member

One of the biggest losses resulting from declining participation in fish camp that was communicated during interviews is losing the space for inter-generational learning and bonding. Some interview participants spoke about a desire for a program that connects youth with their elders.

Improving risk communication

> "...everyone has a different idea of what's safe or what's dangerous. And so, unless you're out there and doing it, **it's kind of hard to know exactly what's safe and what's not**." -Richie Dahl

Experiences during extreme events left some interview participants wishing they had received better communication of risks during the event. There was an additional desire of some participants for better risk communication throughout the year on issues like travel conditions on the rivers as they feel there are currently too many unreliable sources sharing information.

CONCLUSION

The primary exposures modeled by the Arctic Rivers Project (temperature, precipitation, lightning, fish lifecycles), and secondary exposures (wildfires, subsistence declines, freeze thaw events) leading to community impacts were described by community members as negatively impacting many aspects of the traditional ways of life in rural Alaska. The primary impacts and concerns (cultural loss, economic concerns, health concerns, and safety concerns) could be the targets of adaptation planning efforts to promote climate change resilience in Aniak. In the coming decades, many of the changes currently being experienced in Aniak are projected to continue or increase. Responding to these changes may require individual, household, or community-wide strategies.

Please contact Jenny Bacon (jbacon@usgs.gov) or Nicole Herman-Mercer (nhmercer@usgs.gov) with any questions or comments on this report or the Arctic Rivers Project in general.

Sources

Bergendorf, D. (2022, November). The Influence of In-Stream Habitat Characteristics on Chinook Salmon (Oncorhynchus tshawytscha). *NOAA National Marine Fisheries Service*. https://www.webapps.nwfsc.noaa.gov/assets/11/7389_10232012_174142_Bergendorf2002.pdf

Cheng, Y., Herman-Mercer, N., Newman, A., Musselman, K., Woelfle-Hazard, C., Blaskey, D., et al. (2025). Toward co-designed Earth system models: Reflecting end-user priorities in local applications from a modeler's perspective. *AGU Advances*, 6, e2025AV001921. https://doi.org/10.1029/2025AV001921

Environmental Protection Agency (2024) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. U.S. Environmental Protection Agency, EPA 430-R-24-004. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022

Green, K. M., A. H. Beaudreau, M. K. Lukin, and L. B. Crowder. (2021). Climate change stressors and social-ecological factors mediating access to subsistence resources in Arctic Alaska. *Ecology and Society, 26*(4). https://doi.org/10.5751/ES-12783-260415

Hamilton, C. W., Smithwick, E. A. H., Spellman, K. V., Baltensperer, B. T., Chi, G. (2024) Predicting the suitable habitat distribution of berry plants under climate change. *Landscape Ecology*. *39*(2). https://doi.org/10.1007/s10980-024-01839-7

Herman-Mercer, N.M., 2021. Guiding the Arctic Rivers Project Climate Model Development: Results from the Climate Information Survey. Community Report. https://www.colorado.edu/research/arctic-rivers/media/4

Howard, K. G., & von Biela, V. (2023). Adult spawners: A critical period for subarctic Chinook salmon in a changing climate. *Global Change Biology*, 29, 1759-1773. https://doi.org/10.1111/gcb.16610

Intergovernmental Panel on Climate Change (2022). Climate Change 2021: Summary for All https://www.ipcc.ch/report/ar6/wg1/downloads/outreach/IPCC_AR6_WGI_SummaryForAll.pdf

Newman, A. J., Cheng, Y., Blaskey, D., Herman-Mercer, N. M., Craig, A. P., Koch, J., Toohey, R., Mutter, E., Carey, M. P., Gooseff, M. N., Swanson, H., Thomas, P., Brooks, C., & Musselman, K. N. (2026). Long-Term Regional Hydroclimate Modeling for Communities and Decision-Makers across Alaska and Northwestern Canada. *Bulletin of the American Meteorological Society*, *107*(5), E1071–E1091. https://doi.org/10.1175/BAMS-D-24-0131.1

Ristroph, E. B. (2019). Improving justice and avoiding colonization in managing climate change related disasters: case study of Alaska Native Villages. American Indian Law Journal, 7(2).

Ruggerone, G. T., Springer, A. M., van Vliet, G. B., Connors, B., Irvine, J. R., Shaul, L. D., Sloat, M. R., & Atlas, W. I. (2023). From diatoms to killer whales: impacts of pink salmon on *North Pacific ecosystems*. *Marine Ecology Progress Series, 719*, 1-40. https://doi.org/10.3354/meps14402

Tape, K. D., Gustine, D. D., Ruess, R. W., Adams, L. G., & Clark, J. A. (2016). Range Expansion of Moose in Arctic Alaska Linked to Warming and Increased Shrub Habitat. *PLOS ONE*, *11*(4), e0152636. https://doi.org/10.1371/journal.pone.0152636

USGCRP. (2023). *Fifth National Climate Assessment*. U.S. Global Change Research Program.

von Biela, V. R., Regish, A. M., McCormick, S. D., Spaeder, J., Whitworth, K., Leon, J., Gillikin, D., Liller, Z., Ivanoff, R., Bell, J., Larson, S. D., Carey, M. P., and Zimmerman, C. E. (2026). Migration water temperature and heat stress assessments in western Alaska Chinook salmon overlapping the 2019 heatwave. *Canadian Journal of Fisheries and Aquatic Sciences*. 83, 1-14. https://doi.org/10.1139/cjfas-2025-0109

Appendices

Appendix A: Climate Modeling

Climate models that estimate future climate and environmental conditions can be a tool to help inform decisions in response to climate change. Researchers from the National Science Foundation (NSF) National Center for Atmospheric Research (NCAR) and the University of Colorado (CU) Boulder have produced climate model simulations for the Arctic Rivers Project presented in this report.

What is a climate model?

A climate model is a computer-based representation of Earth's climate system that uses equations to represent the laws of physics and the known relationships that govern these Earth systems. The model replicates aspects of the climate, like global to regional-scale patterns of atmospheric circulation, temperature, and precipitation. Models simulate the warming effects of greenhouse gas concentrations and produce scenarios based on adjustments of the emissions of these gases by human activities.

Advanced regional climate models, like the one used in this project, provide detailed simulations at community scales and include elements like atmospheric chemistry, land and sea ice, biogeochemical cycles, and land surface interactions. The model was used by our researchers to develop different climate and river scenarios across Alaska and the Yukon River Basin, representing a range of possible future conditions, all informed by estimates of societal actions to reduce greenhouse gas emissions.

The regional climate information includes both historical (1991-2020) and future (2035-2064) air temperature, precipitation, snowfall, snowpack, streamflow, and river temperature. Regional climate models are developed from global models. Due to the uncertainty of future conditions, six global climate scenarios with similar greenhouse gas emissions were simulated. The shared socioeconomic pathways (SSP) 2-4.5 and 3-7.0 were selected as the greenhouse gas scenarios because they represent middle of the road scenarios where future greenhouse gas emissions are somewhat similar to current emissions, which was desired by our survey respondents. We developed two futures based on SSP2-4.5 and four based on SSP 3-7.0. This combination then includes future emission differences and atmospheric circulation changes. The number of future scenarios (six) was limited by the computational resources required for high-resolution modeling. These six scenarios were selected to be reasonably likely for planning purposes, yet as different as possible, maximizing the range of conditions represented. Results at the community scale were extracted from all six models and an average was computed. By comparing the historical and future conditions, an average change is reported. Impacts on the local river and the entire watershed upstream of the community are examined for monthly, seasonal, and annual changes. In this report, we define seasons as Winter (December-February), Spring (March-May), Summer (June-August), and Fall (September-November). For more information on model development see Newman et al., 2026 https://doi.org/10.1175/BAMS-D-24-0131.1

Community-specific data

In addition to producing climate and river data for Alaska and the Yukon, we extracted data for communities across Alaska at 158 locations. This community report examines future changes to the local rivers, as well as the weather and climate surrounding the community. Information in the report was obtained from the climate, land, and river models run by the Arctic Rivers Project Team.

Winter Conditions

Changes in winter conditions were a common theme in our workshops and interviews. These changes involve snow cover, air temperature, mid-winter rain and/or melting events. To examine possible future changes in winter conditions, we summarized model estimates both at the community level and the regional level. Regions across Alaska are defined by “climate divisions”, each characterized not only by distinct ecological features such as climate, topography, and vegetation but also by shared community and landscape conditions. The eco-regions provide a useful way to map and interpret snow dynamics across the state.

The winter conditions presented in this report include the following measures: 1) snow onset, 2) snow disappearance, 3) snow duration, 4) maximum snow water equivalent, and 5) the number of melt days. The data presented for this community draw on the eco-region it falls within.

Wildfire and Lightning Data

To investigate past and future changes in fire risk and lightning strikes across Alaska, we selected four climate divisions where the majority of fires occur: Central Interior, Northeast Interior, Southeast Interior, and West Coast (Figure 19).

We built a model that relates historical lightning activity with past atmospheric convection (a key atmospheric process that drives thunderstorm development) at different vertical heights in the atmosphere. We also included other atmospheric variables, such as vertical wind shear and relative humidity. The machine learning model selected the weather variables that were most strongly correlated with historical lightning strikes. Based on the daily average values of the variables within a climate division, the model was trained to predict how many lightning strikes would occur in that climate division on a given day. The resulting model can then be assessed in terms of its accuracy and uncertainty and then applied to future weather conditions to understand future fire risk.

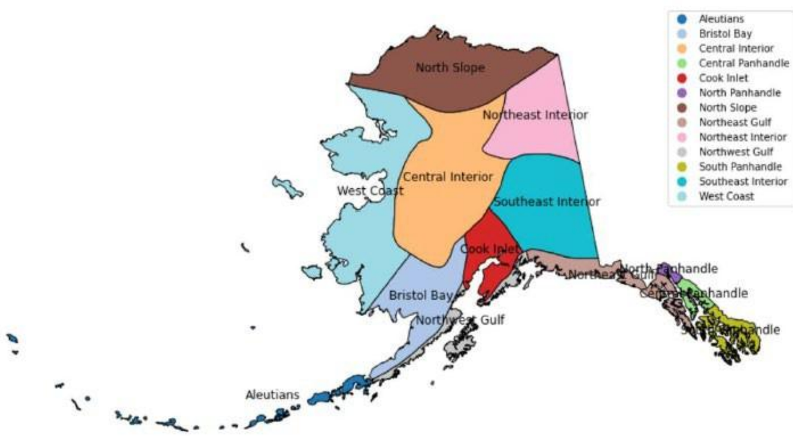


Figure 19: Climate divisions map

Fish Data

Derived temperature datasets were used for spawning and migration analyses where average summer river temperatures (May-September) across the specified river basin were modeled for historical (1991-2020) and mid-century (2035-2064) pseudo-global warming scenarios. Spawning and migration data were generated using established literature values for Chinook salmon (observed spawning temperature range, 3-13 °C, McCullough 1999; Beacham and Murray, 1985; Murray and McPhail, 1988; observed migration temperature range, 12-18 °C, Von Biela et al., 2023; Brett 1971; McCullough

1999) using maximum modeled temperatures in each watershed.

Fish Model Definitions

Number of spawning days: the theoretical number of days between May and September that fall within the temperature threshold for spawning for a fish species based on previously observed spawning behavior and thermal preferences.

First spawning day: The theoretical first available day of spawning in a given summer based on the literature-cited species' spawning temperature preference.

Number of migration days: The theoretical number of days between May and September that fall within the temperature threshold for migration of a fish species based on previously observed spawning behavior and thermal preferences.

First migration day: The theoretical first available day of migration in a given summer based on the literature-cited species migration temperature preference.

Fish Sources:

Beacham, T.D. and Murray. C.B. (1985). Effect of female size, egg size, and water temperature on developmental biology of Chum Salmon (Oncorhynchus keta) from the Nitinat River, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences, 42*, 1755–1765.

Brett, J.R. (1971). Energetic Responses of Salmon to Temperature. A Study of Some Thermal Relations in the Physiology and Freshwater Ecology of Sockeye Salmon (Oncorhynchus nerka), *American Zoologist*, *11*(1), 99–113, https://doi.org/10.1093/icb/11.1.99

Buchanan, D.V. and S.V. Gregory. (1997). Development of water temperature standards to protect and restore habitat for bull trout and other cold water species. *Oregon State University*.

McCullough, D.A. (1999). A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. *EPA Region 10*.

McPhail, J.D., and Murray, C.B. (1979). The early life history and ecology of Dolly Varden (Salvelinus malma) and bull trout (S. Confluentus).

Murray, C. B., and McPhail, J. D. (1988). Effect of incubation temperature on the development of five species of Pacific salmon (Oncorhynchus) embryos and alevins. *Canadian Journal of Zoology*, *66*(1), 266-273.

Thomas, P.A., Blaskey, D., Cheng, Y., Carey, M. P., Swanson, H. K., Newman, A. J., Brooks, C., Herman-Mercer, N., & Musselman, K. N. (2025). Warming Alaskan rivers affect first-year growth in critical northern food fishes. *Scientific Reports*, *15*. https://doi.org/10.1038/s41598-025-14711-8

von Biela, V. R., Bowen, L., McCormick, S. D., Carey, M. P., Donnelly, D. S., Waters, S., Regish, A. M., Laske, S. M., Brown, R. J., Larson, S., Zuray, S. and Zimmerman, C. E. (2020). Evidence of prevalent heat stress in Yukon River Chinook salmon. *Canadian Journal of Fisheries and Aquatic Sciences*. 77(12), 1878-1892. https://doi.org/10.1139/cjfas-2020-0209

Appendix B: Data Tables

Air Temperature

(°F, Fahrenheit)

	Historical	Mid-Century	Historical to Mid-Century
Season	Average Air Temperature (°F)	Average Air Temperature (°F)	Average Air Temperature Change (°F)
Annual	30.39	34.48	4.09
Winter	11.01	15.54	4.53
Spring	28.00	32.10	4.10
Summer	50.58	54.55	3.97
Fall	31.49	34.71	3.22

	Historical		Mid-Century		Historical to Mid-Century	
Season	Mean Daily Max. Air Temperature (°F)	Mean Daily Min. Air Temperature (°F)	Mean Daily Max. Air Temperature (°F)	Mean Daily Min. Air Temperature (°F)	Mean Daily Max. Air Temperature Change (°F)	Mean Daily Min. Air Temperature Change (°F)
Annual	36.94	25.03	40.82	29.31	3.88	4.28
Winter	17.44	5.80	21.30	10.39	3.86	4.58
Spring	35.22	21.53	39.30	25.73	4.08	4.20
Summer	58.12	44.54	62.27	48.51	4.15	3.97
Fall	36.82	28.03	40.04	31.25	3.21	3.21

Precipitation

(in, inches; %, percent change; SWE, snow water equivalent)

	Historical	Mid-Century	Historical to Mid-Century
Season	Total Annual Precipitation (in)	Total Annual Precipitation (in)	Total Annual Precipitation Change (%)
Annual	24.13	26.19	8.53
Winter	3.45	3.70	7.52
Spring	3.67	4.27	16.23
Summer	9.88	10.46	5.88
Fall	7.14	7.82	9.56

	Historical	Mid-Century	Historical to Mid-Century
Season	Snowfall (SWE, in)	Snowfall (SWE, in)	Snowfall Change (%)
Annual	6.86	5.87	-14.45
Winter	3.07	2.76	-9.84
Spring	1.74	1.48	-14.65
Summer	0.02	0.00	-90.07
Fall	2.07	1.67	-19.67

Precipitation, continued

(in, inches; %, percent change; SWE, snow water equivalent)

	Historical	Mid-Century	Historical to Mid-Century
Season	Rain (in)	Rain (in)	Rain Change (%)
Annual	17.27	20.13	16.57
Winter	0.38	0.77	102.26
Spring	1.93	2.74	41.52
Summer	9.86	10.46	6.02
Fall	5.07	6.06	19.63

	Historical	Mid-Century	Historical to Mid-Century
Season	Snowpack (SWE, in)	Snowpack (SWE, in)	Snowpack Change (%)
Annual	2.50	1.71	-31.78
Winter	4.89	3.77	-22.89
Spring	4.28	2.49	-41.87
Summer	0.00	0.00	-99.86
Fall	0.89	0.58	-35.11

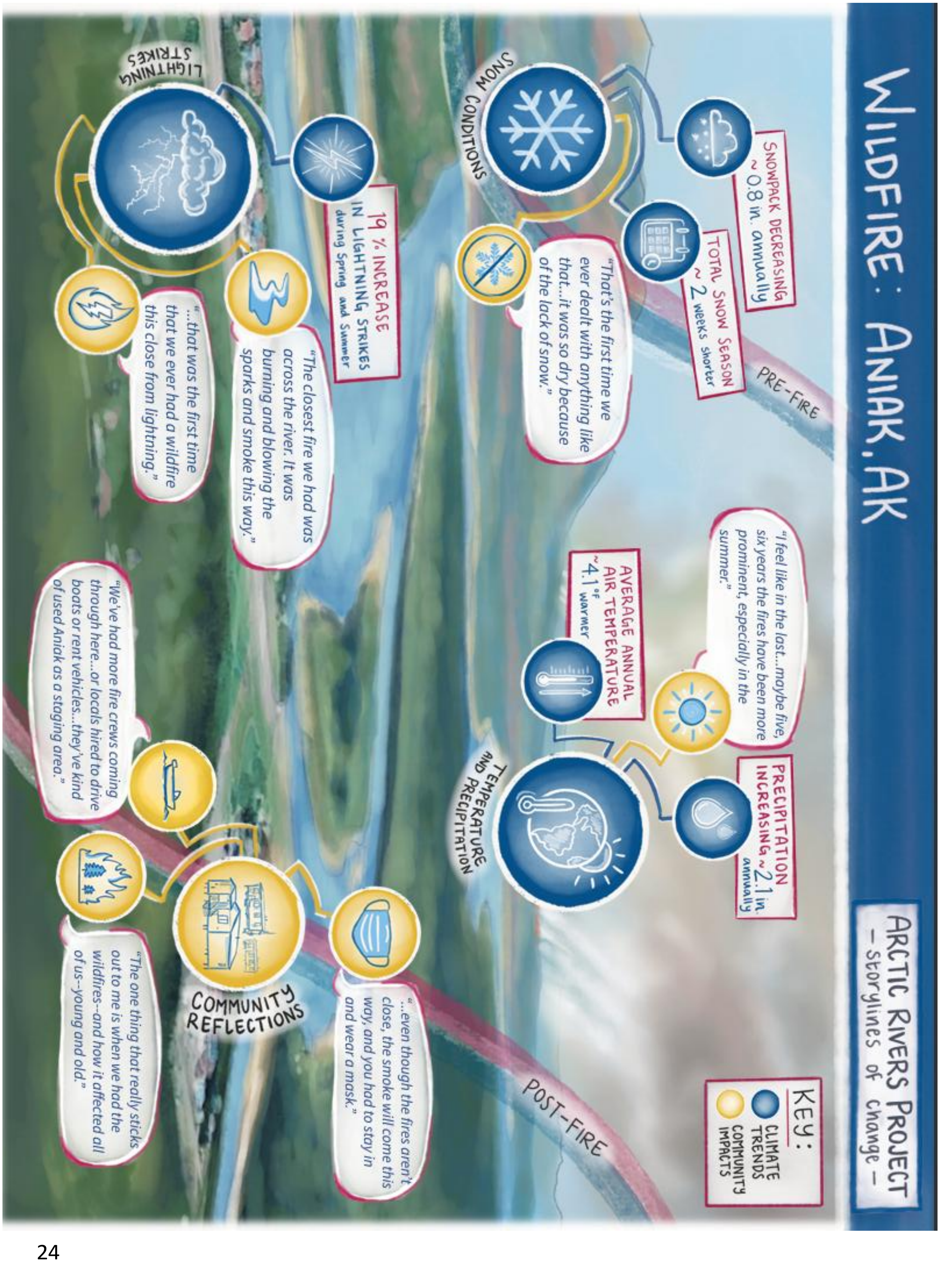
Aniak River Characteristics

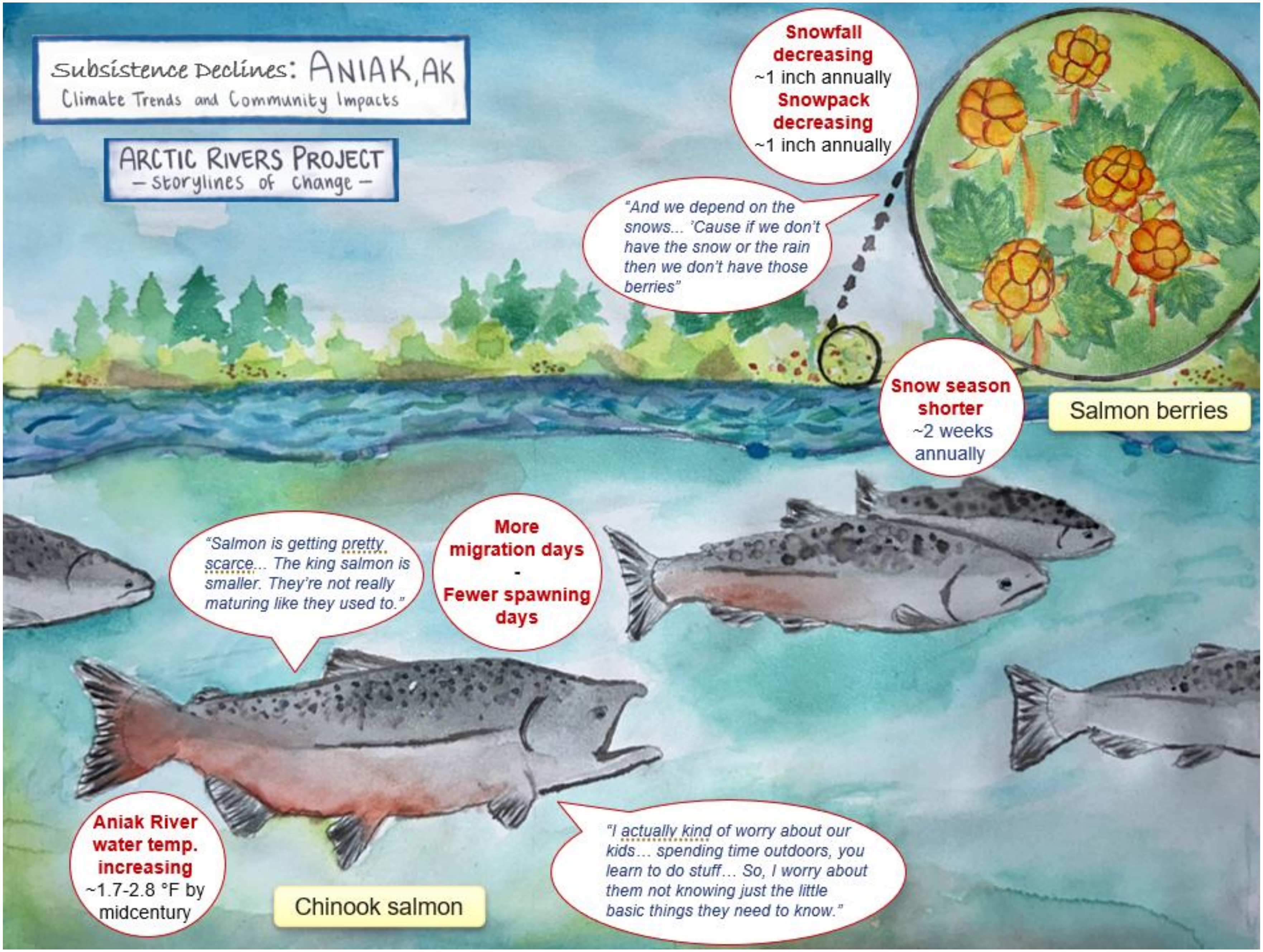
(cfs, cubic feet per second, %, percent change; °F, Fahrenheit)

	Historical	Mid-Century	Historical to Mid-Century
Season	Discharge (cfs)	Discharge (cfs)	Discharge Change (%)
Annual	46867.92	50775.81	8.34
Winter	6394.44	12042.83	88.33
Spring	64902.12	67561.69	4.10
Summer	75984.67	74569.86	-1.86
Fall	39342.54	46580.04	18.40

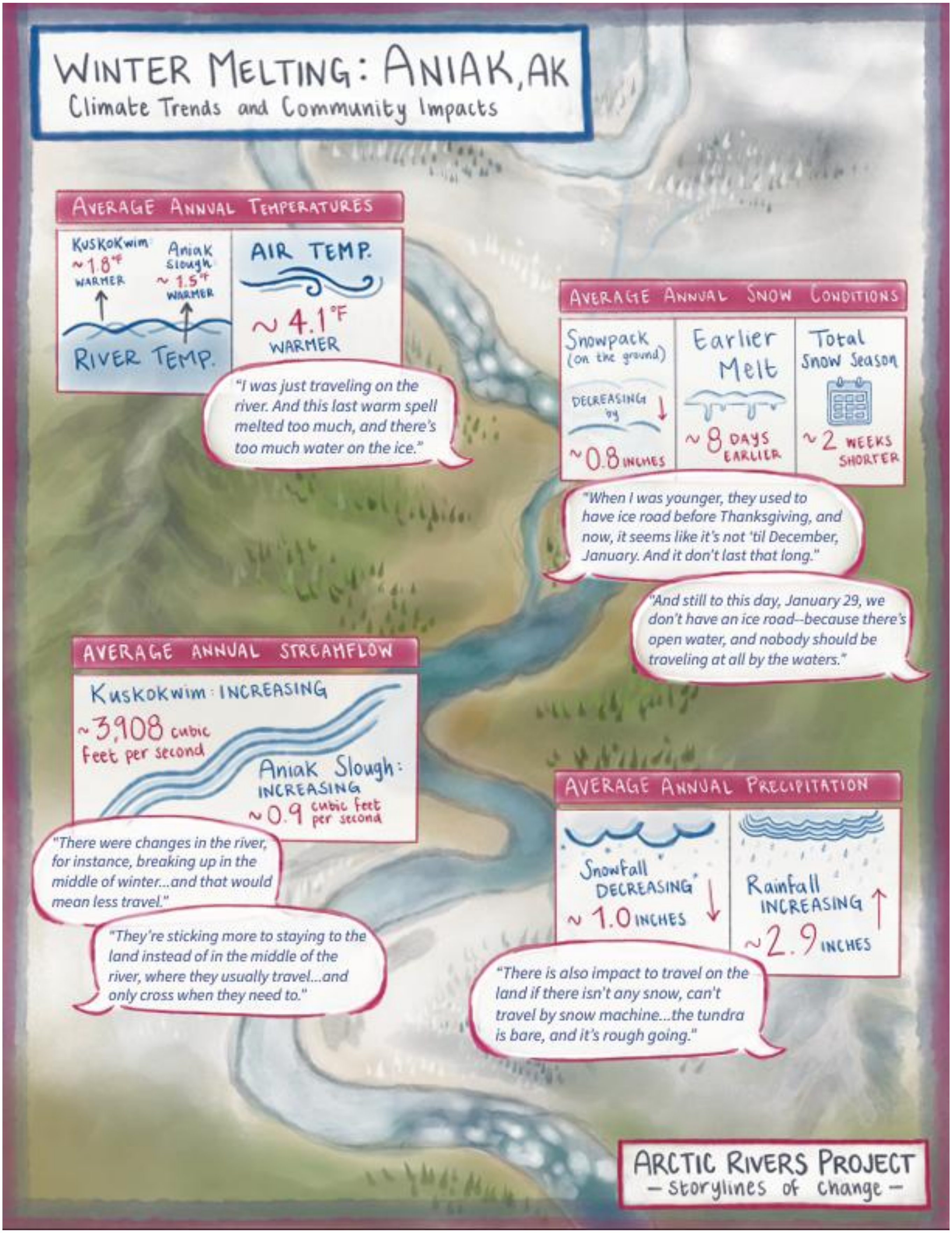
	Historical	Mid-Century	Historical to Mid-Century
Season	River Temperature (°F)	River Temperature (°F)	River Temperature Change (°F)
Annual	41.43	43.24	1.81
Winter	32.32	32.64	0.32
Spring	39.07	40.59	1.52
Summer	55.27	58.78	3.51
Fall	38.85	40.76	1.90

Appendix C: Storylines





Subsistence Declines: ANIAK, AK
Climate Trends and Community Impacts
ARCTIC RIVERS PROJECT
– Storylines of Change –
Snowfall decreasing ~1 inch annually Snowpack decreasing ~1 inch annually
"And we depend on the snows... 'Cause if we don't have the snow or the rain then we don't have those berries"
Snow season shorter ~2 weeks annually
Salmon berries
"Salmon is getting pretty scarce... The king salmon is smaller. They're not really maturing like they used to."
More migration days - Fewer spawning days
Aniak River water temp. increasing ~1.7-2.8 °F by midcentury
Chinook salmon
"I actually kind of worry about our kids… spending time outdoors, you learn to do stuff… So, I worry about them not knowing just the little basic things they need to know."



WINTER MELTING: ANIAK, AK
Climate Trends and Community Impacts
AVERAGE ANNUAL TEMPERATURES
Kuskokwim ~1.8°F WARMER
Aniak Slough ~1.5°F WARMER
RIVER TEMP.
AIR TEMP.
~4.1°F WARMER
"I was just traveling on the river. And this last warm spell melted too much, and there's too much water on the ice."
AVERAGE ANNUAL SNOW CONDITIONS
Snowpack (on the ground) DECREASING by ~0.8 INCHES
Earlier Melt ~8 DAYS EARLIER
Total Snow Season ~2 WEEKS SHORTER
"When I was younger, they used to have ice road before Thanksgiving, and now, it seems like it's not 'til December, January. And it don't last that long."
"And still to this day, January 29, we don't have an ice road--because there's open water, and nobody should be traveling at all by the waters."
AVERAGE ANNUAL STREAMFLOW
Kuskokwim: INCREASING ~3,908 cubic Feet per second
Aniak Slough: INCREASING ~0.9 cubic feet per second
"There were changes in the river, for instance, breaking up in the middle of winter...and that would mean less travel."
"They're sticking more to staying to the land instead of in the middle of the river, where they usually travel...and only cross when they need to."
AVERAGE ANNUAL PRECIPITATION
Snowfall DECREASING ~1.0 INCHES
Rainfall INCREASING ~2.9 INCHES
"There is also impact to travel on the land if there isn't any snow, can't travel by snow machine...the tundra is bare, and it's rough going."
ARCTIC RIVERS PROJECT
— Storylines of Change —