

Native Village of Georgetown

Climate Change Vulnerability Assessment



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Our vision is to have a community and environment where land, water, and subsistence resources are preserved and respected.

Our mission is to monitor and preserve the traditional tribal lands in and around the Native Village of Georgetown by being proactive in environmental issues, working together, and utilizing traditional and contemporary data and knowledge to accomplish goals set forth by the Tribe.

Georgetown Tribal Council Environmental Committee

Native Village of Georgetown

Climate Change Vulnerability Assessment

2017

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Executive Summary

Change is a part of existence for the Native villages along the Kuskokwim River and throughout Alaska. Natural resources, landscapes, community structure and resources have changed significantly over hundreds of years. Climate change is a natural phenomenon that has been occurring for millennia. Recent change, however, has been greatly accelerated by burning of fossil fuels and deforestation around the world.

Alaska is experiencing a wide range of impacts at a much faster rate than the rest of the globe. Thus, changes are being felt and seen over decades, rather than centuries. Residents of the Middle Kuskokwim report changes to weather, seasons, ice and snow, plants, animals, and people's health and safety. Tracking such changes and preparing for the changes ahead are vital for maintaining sustainable subsistence lifestyles and communities. The first step in planning for the future is developing a sound understanding of current vulnerabilities and how future conditions are expected to continue to change.

This climate change vulnerability assessment documents climate change impacts and trends that have been observed along the Kuskokwim River. It was commissioned by the Georgetown Tribal Council to help inform their efforts to re-settle the Native Village of Georgetown, and to provide a starting place for working with neighboring communities to plan for climate change. Information was collected through a variety of methods, including interviews with elders and the collection of Traditional Knowledge, mapping and graphing of environmental data, review of published literature, and interviews with local scientists and natural resource managers.

The climate change vulnerability assessment revealed that subsistence resources are highly vulnerable to the impacts of climate change



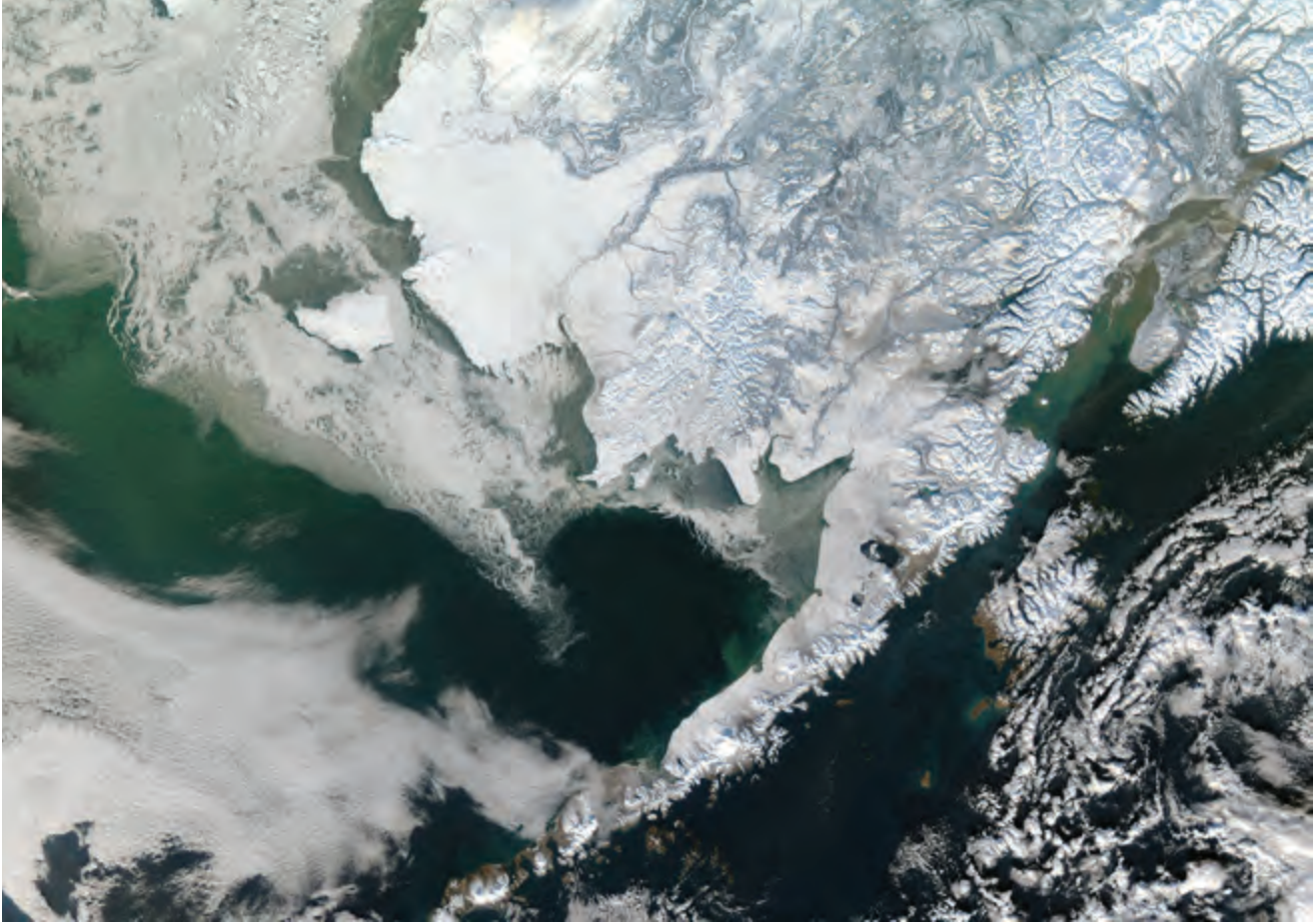


Photo: Jeff Schmaltz, NASA Earth Observatory

(Figure 1). Some of the most vulnerable resources included berries, salmon, moose, and other game animals. Populations of these vital resources could become less reliable over time, but in addition, issues related to food storage, access, health, economics, and spiritual well-being are also at risk.

Some of the issues identified in this assessment related to the re-settlement of Georgetown in terms of infrastructure and community planning include the potential for increased contamination of water resources, increased risk of wildfire to structures, and increased risk of flooding. The Native Village of Georgetown has an opportunity to develop their village using approaches to building and siting that reduce their risks over time.

This climate change vulnerability assessment was created to inform future development of the Native Village of Georgetown. Much of the information contained in this report, as well as the companion *Climate Science Primer*¹ specific to the area, can be used to inform efforts to prepare for climate impacts in neighboring villages and throughout the region.

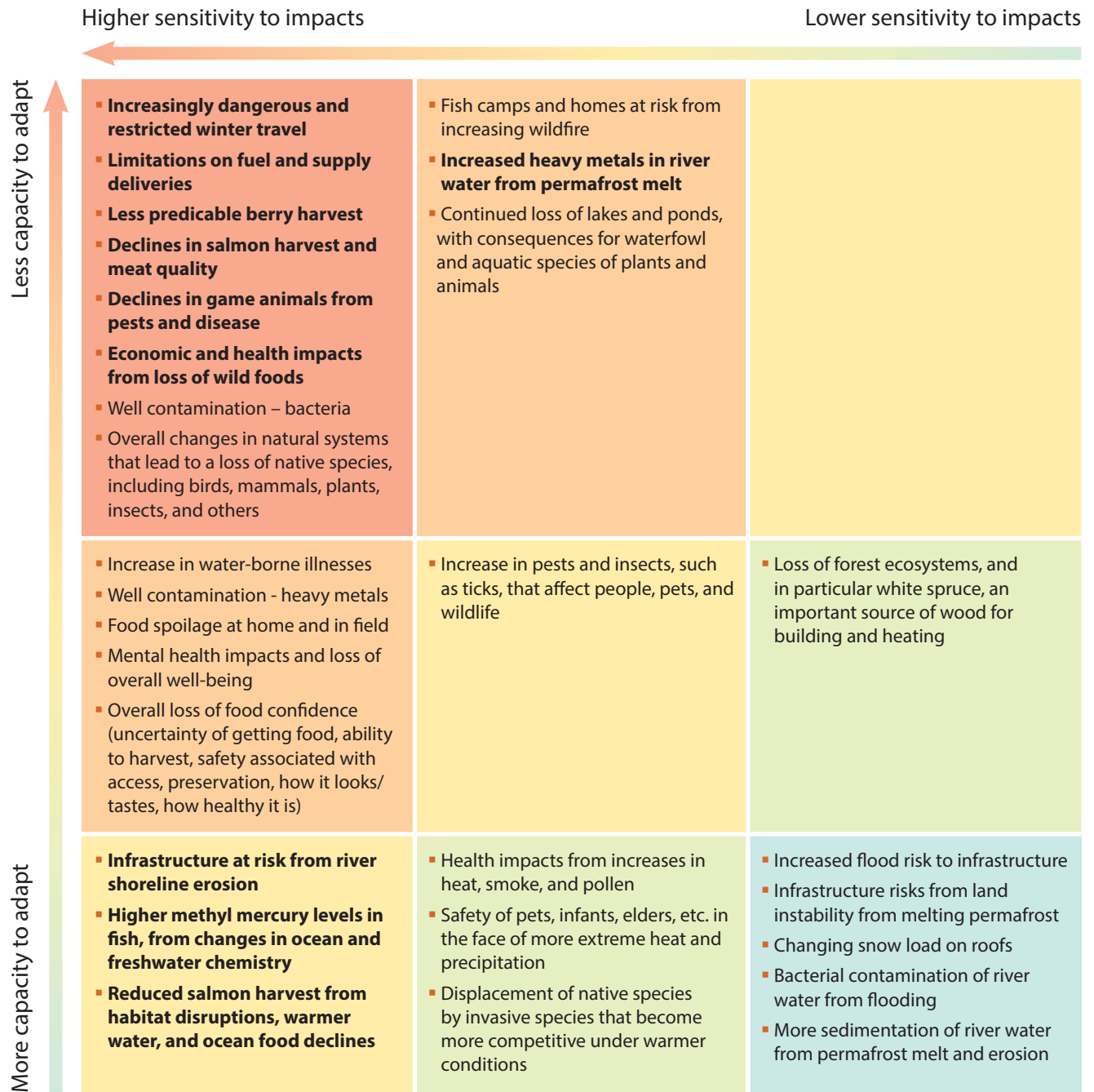


Figure 1 All vulnerabilities, ranked based on how much the Native Village of Georgetown would be impacted (Sensitivity) and whether there are already behaviors or resources in place to reduce the potential impact (Adaptive Capacity). Highest priority vulnerabilities, as identified by workshop participants, are shown in bold type.



History and Future

The Native Village of Georgetown is located along the banks of the Kuskokwim River, approximately 220 river miles northwest of Bethel, a central hub located near the mouth of the Kuskokwim River and 16 river miles from the nearest village of Red Devil. While the focus of this report is the Native Village of Georgetown, much of the region is experiencing similar climate impacts and trends. In this report, we define the Middle Kuskokwim as the area represented in Figure 2. The climate change trends, impacts, and projections for the region can be used to inform similar vulnerability assessment and preparedness planning in other communities as well.²

Previously known as Keledzhichagat, the Native Village of Georgetown was originally a summer village for the peoples of nearby Kwigiumpai-nukamuit. When gold was found in the nearby George River, a mining settlement was built. Three traders named George Fredericks, George Hoffman, and George Morgan were some of the early founders, and the town and river were named after them. By 1910, Georgetown had about 300 residents and 200 structures. A fire that swept through the village in 1911, however, destroyed almost all the buildings.³

A second settlement was developed on the east side of the George River, and a school opened in 1965. A decline in mining, however, led to a loss of residents and the school closed just 5 years later. In 1971, the Alaska Native Claims Settlement Act allowed the town's descendants to take ownership of ancestral lands.

Tribal members have worked for half a century to fight for federal recognition, and secure their native land claims. The claims and re-conveyance of lands to date have provided opportunities for Tribal members to live within the community, and to return home for traditional



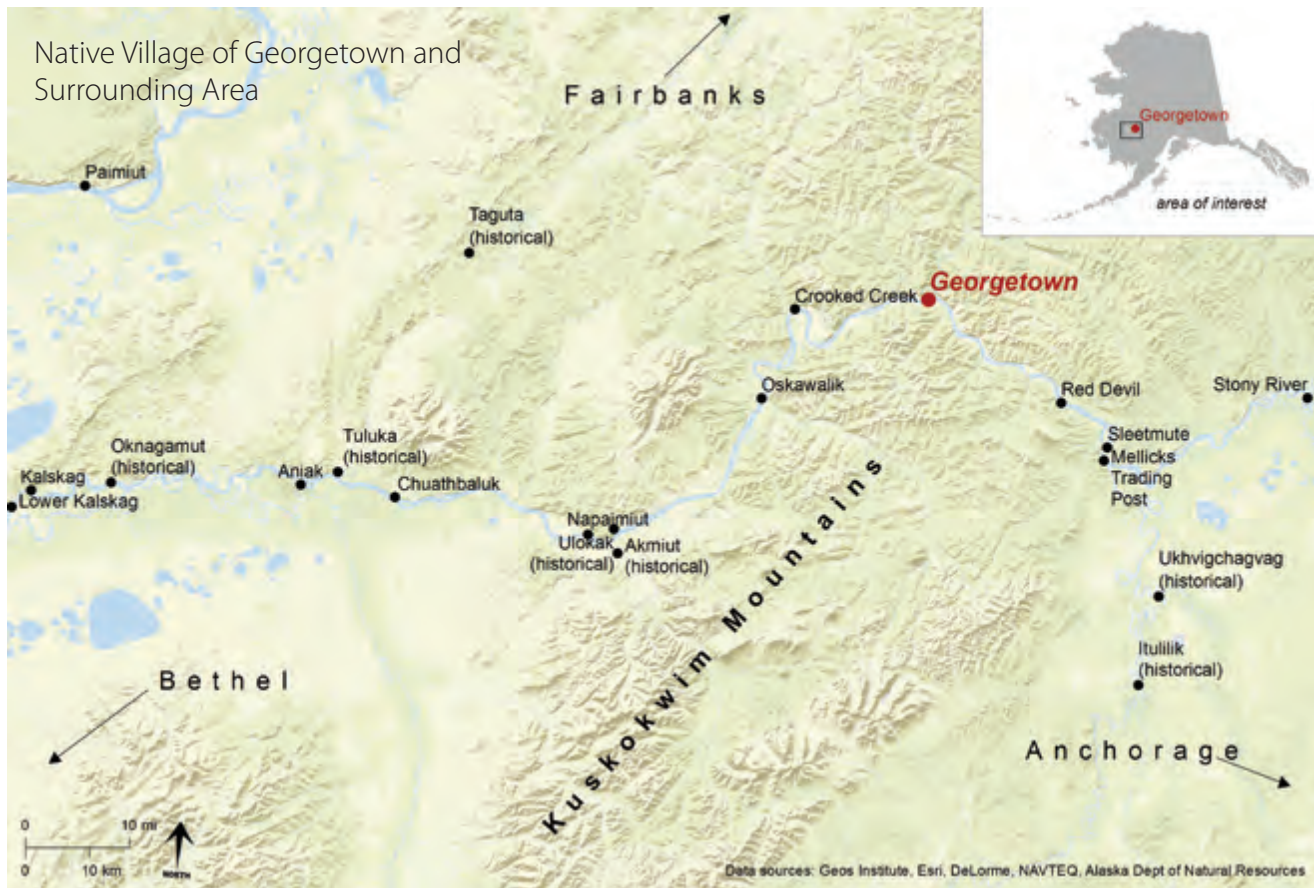


Figure 2 Map of Middle Kuskokwim



subsistence use, goals which are identified in their Community Master Plan. By re-establishing its traditional village at Georgetown, the Tribal Council hopes to perpetuate the cultural identity, survival, and well-being of its citizens.

Returning to Georgetown is, for the original members, a return to their birthplace, to the place that is fundamentally home. For younger members, it is the place that provides them with a shared identity and continuity with future generations. The place, the resources, and the culture provide Georgetown's members with pride and a sense of who they are as a people.

The new community is planned for the south side of the Kuskokwim River, across from previous settlement locations. The south side is less prone to flooding and erosion. The new community plan includes full time residences, seasonal cabins, a community center, traditional and subsistence activities, as well as economic development for a sawmill and tourism.

Vulnerability Assessment

PURPOSE

Georgetown has a unique opportunity to be proactive in their planning for the village, in a way that mitigates the impacts of climate change as best they can. The purpose of this project was to identify which populations and resources, relevant to the Native Village of Georgetown, are most vulnerable to impacts associated with climate change, which will be imperative in this planning process. The Native Village of Georgetown recognizes the benefit of working in collaboration with neighboring communities on climate change issues, and plans to use the information from this report to inform future work.

METHODS

Climate change is progressing twice as quickly in Alaska as compared to the contiguous United States, and the impacts are already being felt. The Geos Institute worked with Native Village of Georgetown staff and Environmental Committee to identify which specific resources and/or issues to focus on for the assessment. Those included ecosystems, subsistence, infrastructure, water, and health.

In order to assess how vulnerable specific resources are to climate change, three primary variables were considered. These include Exposure, Sensitivity, and Adaptive Capacity (Figure 3). Each of the three components was assessed based on a combination of local knowledge, expert input, and best available science.



Photo: Rebecca Wilmarth

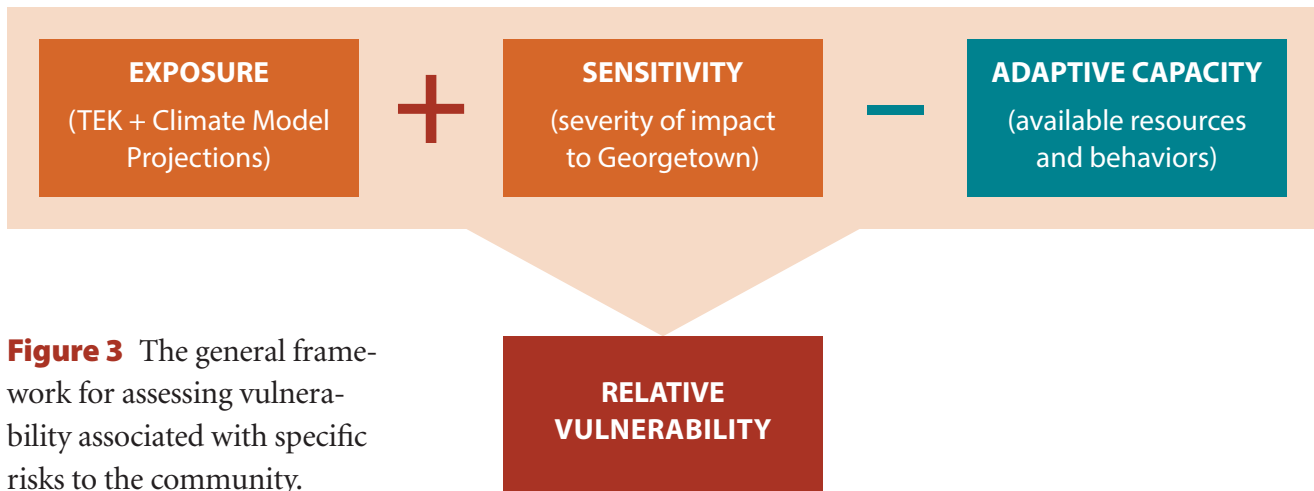


Figure 3 The general framework for assessing vulnerability associated with specific risks to the community.

Three Components of Vulnerability

Exposure – Climate change trends and impacts are locally specific. Some areas will be hit harder by heat waves while others will experience more flooding.

Sensitivity – Some populations or resources experience greater impacts than others, even with the same level of change. For example, people with respiratory illnesses are more sensitive to smoke from wildfires than the general population.

Adaptive Capacity – Many resources or behaviors are already in place, allowing people to respond to the changes ahead. For example, if alternative subsistence foods are available and/or affordable, then people are less vulnerable when primary foods become unavailable.

Traditional knowledge provided invaluable information on how resources have responded to changing conditions and variability in the past, as well as how native Alaskans have adapted to change over time and remained resilient. Traditional knowledge and scientific information are equally weighted and complementary throughout this report.

Exposure – Exposure was assessed based on three complementary approaches to gather information: traditional knowledge gathering, a workshop with local residents, and climate change data and model projections. First, in order to assess historic climate-related impacts to the Native Village of Georgetown and surrounding area, Traditional Ecological Knowledge (TEK) was provided from a series of interviews held this summer with elders who are intimately familiar with life on the Kuskokwim River.

A combination of several different types of methods were used in this process, including key respondent interviews, semi-directed group interviews, and participant observation.⁴ A total of 18 elders participated in this project, and were interviewed by two Georgetown Tribal Members. Interviews were audio recorded, and analyzed by GTC staff members, who provided climate-related excerpts for this project.

The interviewers had a list of topics and questions developed by the GTC Environmental Committee, but the person being interviewed was given the opportunity to guide the conversation, allowing them to bring up topics they felt were related. The topic that provided the most information for the Vulnerability Assessment was “Observing Nature,” which included questions related to seasonal moves, predicting weather, patterns in nature, changes in the river(s), and changes in weather.



Information about exposure was also collected during a workshop, which was held in Sept. 2017. The workshop included Georgetown Tribal members and individuals from neighboring villages. During the workshop participants were asked to assess a list of risks to Georgetown and provide their knowledge and expertise on each of the risks.

Traditional and local knowledge was complemented with climate change data and model projections, in order to look at past and future potential trends across numerous variables. A short synopsis of the historical and future projected trends is included in the section on climate. More in-depth climate change trends and projections for the Middle Kuskokwim watershed are available in the companion *Climate Science Primer* that was developed for this project.⁵ Exposure included relevant climate trends, associated ecological trends, and consideration of the level of uncertainty associated with future potential trajectories of change.

Sensitivity – In order to assess sensitivity, a thorough review of the scientific literature was conducted, pertinent TEK was considered, regional experts were consulted (see Appendix 1), and Georgetown staff and members provided input. In addition, all information on the specific impacts, as well as their potential severity in relation to the focal resources and issues, was collected into a database and reviewed during a workshop with Georgetown members and members from nearby communities. Workshop participants ranked the sensitivity of the native village to each of the risks that were identified, using a rank of High, Medium, and Low. High severity meant that the impact to Georgetown’s people and/or resources would be severe. Medium severity meant that the impact would be moderate. Low severity meant that the impact would be relatively inconsequential to the Tribe.

Adaptive Capacity – Information on adaptive capacity was largely collected through expert interviews and through consultation with Georgetown staff and members. Some published reports also had relevant information. Workshop participants were asked to rank their Tribe’s ability to respond to the identified risks based on existing resources and/or changes in behavior.

Prioritization – Workshop participants were asked to rank the importance of each of the risks to the Native Village of Georgetown. In many cases, a specific resource may be identified as particularly vulnerable, yet not important enough to warrant investment of resources to reduce the vulnerability. In other cases, a particularly important resource could warrant great investment, even if the risk is highly uncertain.

FINDINGS

CLIMATE

“Nowadays when you get 20 below holy cow so cold out, used to be 60 below sometime ... you can’t even go outdoors very long, you gotta dress up when you go out always.”

The climate of the Middle Kuskokwim is characterized by long cold, snowy winters and warm summers. Georgetown’s continental climate ranges from -59° to 94° F. Precipitation averages 17 in. annually. The area receives about 80 in. of snowfall per year with the greatest snowfall in January. The growing season is approximately 120 days long. The Kuskokwim River is generally ice-free from mid-June through October. Fall and winter are frequently characterized by high winds, which can delay local flights for days at a time.⁶

Climate change is a global issue with locally-specific consequences. Due to increased emissions of greenhouse gases into the atmosphere, the global temperature has increased by about 1.7° F above the 20th century average. Alaska, however, is warming at about twice this rate because of the high latitude. Average temperature in Alaska has warmed about 3° F in the last 60 years, and winters have warmed by 6° F. Precipitation has increased by about 10%.

Global climate models (GCMs) can provide us with information on future warming as well as changes in precipitation, heat waves, extreme storms, and other variables. These models have been “down-scaled” to local levels to provide information that is relevant for smaller areas, such as the Middle Kuskokwim. There is quite a lot of uncertainty associated with the model output, but most of the



Photo: Kate Schaberg

uncertainty is due the fact that we are unable to predict the quantity of greenhouse gases that people will continue to emit into the atmosphere. This report provides projections for future conditions, assuming that the global community continues on a “business-as-usual” path for greenhouse gas emissions.

Much of the data on future trends in this report are compiled from an “ensemble” or average across 15 GCMs. A full suite of projections can be found in the companion report *Climate Science Primer: Projections for the Middle Kuskokwim Region*.⁷ When ensembles are used, it is important to understand the range of variation among the different models in the ensemble, as it can be quite great.⁸ In general, precipitation projections are associated with higher uncertainty (i.e. more variation among models) while temperature projections are associated with lower uncertainty. Also, short to mid-term projections have lower uncertainty than long-term projections.

“ [It was] Cold all the way to February. Lots of snow? Yeah. Snow and everything. March is so windy, so windy. It isn’t like now, it wasn’t like that. ”

Table 1 Climate trends and projections for the Middle Kuskokwim region.

Historical Trends (1949–2016)

- Temp. ↑ 4° F on average
- Temp. ↑ 2° F in summer
- Temp. ↑ 8° F in winter

By mid-century (2050s)*

- Average temp. ↑ 9° F
- Summer temp. ↑ 6° F
- Winter temp. ↑ 12° F
- Precipitation ↑ 20%
- Snowfall ↓ 5%
- Moisture deficit ↑ 16%
- Frost-free days ↑ 34 days/yr.
- Change in dominant vegetation potentially with an increase in forest cover
- Increase in wildfire
- Thawing permafrost throughout much of the region

By late-century (2080s)*

- Average temp. ↑ 13° F
- Summer temp. ↑ 9° F
- Winter temp. ↑ 19° F
- Precipitation ↑ 32%
- Snowfall ↓ 19%
- Moisture deficit ↑ 17%
- Frost-free days ↑ 57 days/yr.
- Change in dominant vegetation potentially with an increase in grasslands and prairie
- Increase in wildfire
- Little permafrost left in the region

* Compared to the historical period 1961–1990

Future Projections for the Middle Kuskokwim

Temperature – Average annual temperatures in the Native Village of Georgetown and surrounding area are expected to rise an additional 9° F by mid-century and 13° F by late-century, as compared to the historical period (1961–1990), based on assumptions of continued high global greenhouse gas emissions. Winters are expected to continue to warm more than summers.

By mid-century, winters are expected to be 12° F warmer and summers 6° F warmer. By late-century, winters are projected to be 19° F warmer and summers 9° F warmer.

Precipitation and Drought Stress – Precipitation is projected to increase 19% by mid-century and 30% by late-century, assuming continued high greenhouse gas emissions. Even with higher precipitation, however, water availability and soil moisture could decline due to increased evaporation from longer growing seasons and higher temperatures, as well as the soil desiccation as permafrost melts. Climatic moisture deficit, a measure of drought stress from both temperature and precipitation change, is expected to increase over time by 16–17% (ranging as much as 49%). Climatic moisture deficit has a strong link to wildfire.⁹ Precipitation as snow is expected to decline by 5% by mid-century and 19% by late-century.

“It’s more warmer now
than it used to be”

ECOSYSTEMS

The Kuskokwim River, located in southwestern Alaska, runs 702 miles from its headwaters to the Kuskokwim Bay on the Bering Sea. It is the longest free flowing river in the United States and is the ninth largest by average discharge. The Native Village of Georgetown is located in the Middle Kuskokwim region. This region includes mountains generally with elevations below 4,000 feet, steep valleys with swift flowing rivers and streams, and large expanses of mostly flat lowlands with the meandering Kuskokwim and its tributaries. The Middle Kuskokwim is a region with a complex mosaic of boreal forest, wetlands, lakes, meadows, and a diverse complement of wildlife. These dynamic natural ecosystems are shaped by long winters, permafrost that holds water close to the surface, and forest fires that periodically reshape ecosystems.

The site on which the Native Village of Georgetown is planned for development is largely dominated by black spruce woodlands, which include black spruce, white birch, tamarack, alder, and willow. Trees are generally 80–100 years old, with evidence of previous wildfires. Cranberry, blueberry, and snowberry make up some of the lower vegetation, with sphagnum moss and crowberry as ground cover. White spruce, an important resource for building and firewood, is located along the Kuskokwim River corridor and also upriver.

Wildlife is abundant throughout the area, including hawks, eagles, ptarmigan, numerous songbirds, ducks, blackbirds, and owls. Furbearers include marten, mink, weasels, beaver, and lynx. Bear, moose, and wolves are all abundant in the area.

Aquatic species include five species of salmon, sheefish, whitefish, Dolly Varden, northern pike, arctic grayling, and lake trout. The fish and wildlife species of the region provide critical subsistence resources for local residents.

Residents of the Middle Kuskokwim region have noticed changes to the natural systems that dominate the Georgetown site and other nearby communities. Winters were much colder than they are now, with deep snow that is no longer common. Ptarmigan, cranberries, and caribou, once plentiful, are all extremely rare now. Shrub cover has increased, making it harder to find and access berries, while providing more cover for predators. Water levels are lower than they were, and many lakes and ponds have dried up completely.



Photo: Kate Schaberg



Photo: Kate Schaberg

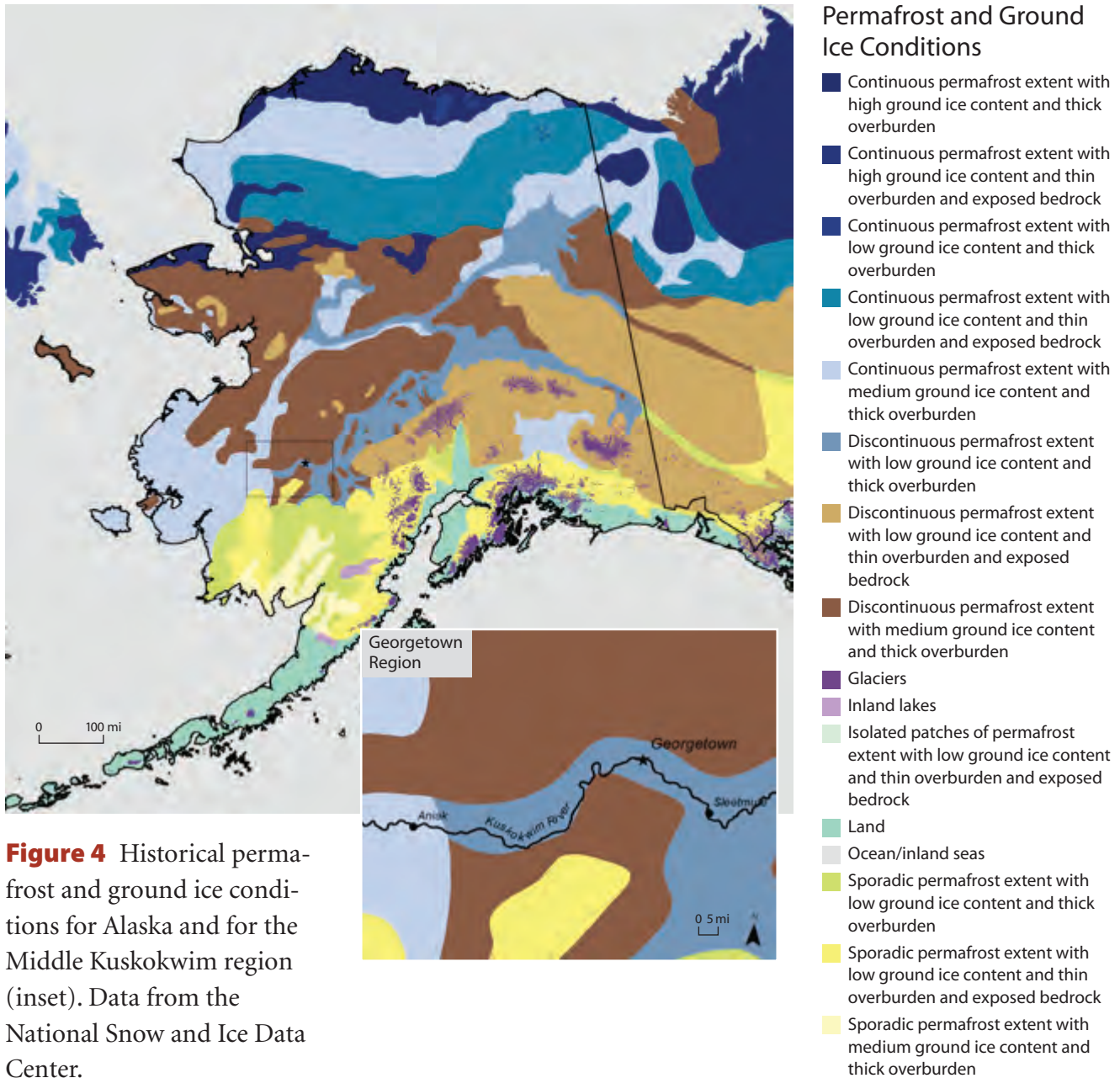


Figure 4 Historical permafrost and ground ice conditions for Alaska and for the Middle Kuskokwim region (inset). Data from the National Snow and Ice Data Center.

Lakes, ponds, and wetlands – Most of the Middle Kuskokwim region is underlain by permafrost, but varies in thickness from thin to moderate (Figure 4). Permanently frozen ground acts as a barrier to water, keeping lakes, ponds, and rivers in place. This region is one of the most vulnerable regions to permafrost melt, because the permafrost is already thin and close to the thawing point.¹⁰ Much thaw has already taken place, and little to no permafrost is expected to persist by the end of the century. As permafrost has thawed, many ponds and lakes have already disappeared, and more are expected to do so. The loss of permafrost is expected to result in significant change to dominant types of vegetation and wildlife, as soils dry and wildfire becomes more common.

Vegetation and Wildfire – Model projections from the Scenarios Network for Alaska and Arctic Planning (SNAP), at the University of Alaska at Fairbanks, indicate that natural ecosystems are expected to experience substantial amounts of change over the coming years. SNAP used computer models to assess current and future “cliomes,” or representations of temperature, precipitation, and dominant vegetation types.¹¹ These models indicate landscape level change from the current cliome of “Dry boreal wooded grasslands” and “More densely forested closed-canopy boreal” to boreal forest types more common in the southern parts of the state, by mid-century. By late century, the models project the area to be dominated by the “prairie and grassland” cliome, which does not currently occur in Alaska.

SNAP models also project increases in wildfire as the cliomes change. Vegetation flammability in the area is expected to increase by 25–37% by the end of the century, if global greenhouse gas emissions continue on the current trajectory.¹²

Alaska’s forests are already being affected by climate change, with large scale forest die-off from spruce beetle outbreaks, which are closely linked to increasing temperatures and drought stress on the landscape.¹³ As temperatures continue to rise throughout the region, and growing seasons lengthen, long-lived trees are expected to become increasingly stressed by conditions that are very different than they were during initial establishment. White spruce (*Picea glauca*) has shown decreased growth in response to recent higher temperatures and drought stress in Alaska.¹⁴

Invasive Species – Historically, Alaska’s cold climate prevented non-native plants from becoming established. As temperatures, ecosystems and fire regimes change, native species are expected to be increasingly displaced by non-native and invasive species. Warmer winters, longer growing seasons, and greater human activity may contribute to current rapid expansion of invasive species across the state. Recently burned forest forms a major component of the vegetation of Interior Alaska, and this habitat is particularly vulnerable to invasion by early-successional non-native species. Sweetclover was introduced to Alaska in 1913 as potential forage and has expanded rapidly along roadsides and more recently along flood plains and into burns. Narrowleaf hawksbeard, pictured on the bottom right in Aniak, Splitlip hempneedle, and Yellow toadflax are some of the invasive species currently established in the region.¹⁵ Canada thistle, oxeye daisy, spotted knapweed, and meadow hawkweed all have established populations in



Photo: Kate Schaberg



Photo: Dave Cannon

“ [there was] lots more snow, there was lots more water, way back then. There was permafrost and we’d have lots of water and now, we used to have a little pond up there, but now we get it right from where the water’s coming out on the creek. There used to be lots of moss up there, but now it’s turning all into brush here. ”

Alaska as well, and could move into the Kuskokwim region. Elodia and reed canarygrass are of particular concern due to impacts to waterways and the potential to affect salmon spawning areas.

Identified Vulnerabilities

The Vulnerability Assessment identified the following primary vulnerabilities to the Native Village of Georgetown, related to Ecosystems:

HIGH – Overall changes in natural systems that lead to a loss of native species, including birds, mammals, plants, insects, and others

MEDIUM-HIGH – Continued loss of lakes and ponds as permafrost melts, with associated declines in waterfowl and other aquatic plants and animals

MEDIUM-LOW – Loss of forested ecosystems as temperature and precipitation patterns change, and in particular white spruce, which is important for construction

MEDIUM-LOW – Displacement of native species by invasive or non-native species that become more competitive under warmer conditions



Photo: Kate Schaberg

“ There was all kinds of birds, I don't know swans and cranes, geese, spruce chicken and ptarmigan but we don't see any more ptarmigan. They come and go, you know, like we have spruce chicken but no more little grouse. I don't know, they change, you know, every so many years they disappear and come back. ”



Photo: Dawn Encino CC BY SA2.0

“ Used to pick a lot of cranberries, gram and I, where the dump is we used to walk up this edge, and there was always cranberries right there. ”

SUBSISTENCE

Residents of the Kuskokwim River drainage rely substantially on subsistence hunting, fishing, and gathering. Georgetown members value these traditions not only for the food they supply, but also for the cultural and spiritual connection to the land, each other, and their ancestors. Resources harvested and hunted have changed over time, as availability, economic considerations, transportation options, regulations, and other variables change.

Historical and archeological sources show that until the early 20th century, subsistence resources in the Georgetown area focused more on caribou, moose, and beaver with fish as secondary sources of food.¹⁶ In the early 20th century, because of the development of highly efficient fishing technologies, salmon became the greater portion of the subsistence harvest rather than large game.

Many Georgetown Tribal members set up at fish camp annually for the harvest and processing of salmon, primarily sockeye salmon. A study from 2013 on subsistence foods in the Lower and Central Kuskokwim River Drainage reported that Georgetown Tribal members harvested an average of 173 lbs. of food per year.¹⁷ By weight, 44% of the subsistence harvest was salmon, 40% moose, 8% other fish, 3% blueberries, and 2% caribou.

Salmon and other fish – Salmon harvest in the Kuskokwim has become less reliable in recent years, likely because they are affected by a range of impacts across a diversity of habitats. Salmon are affected by changes in both freshwater systems and the ocean, and during many different life phases.

Ocean acidity, which has already increased by 30%, can affect important salmon prey in the oceans. Arctic waters are especially prone to acidification, and even small changes in pH can dramatically reduce the ability of marine organisms to grow shells. Pteropods, or swimming sea snails, are a vital food source for salmon and other important fish populations and are already impacted.¹⁸

Kuskokwim River flows have already declined, on average, by 25%.¹⁹ Warmer waters and lower flows in the Kuskokwim lead to new and more prevalent diseases and parasites, as well as lower oxygen levels from nutrient-related algae blooms. Larger storms, more sedimentation, and lower low flows are expected to negatively impact spawning habitat and reproduction for many species. While 2017 was a



Photo: W Hartman

“ We ate a lot of ptarmigan. We ate a lot of moose. Moose and beaver, ptarmigan and spruce chicken, and rabbits; we used to eat those. In the winter, we’d have moose meat and ptarmigan. ”



Photo: W Hartman

“ Everything was so darn cold it never spoiled. They didn’t do moose in summer time. They’re too busy eating fish. ”

good year for Chinook salmon harvest relative to recent years, overall declines in productivity, abundance, and inshore harvest appear widespread and persistent.²⁰

Moose and other terrestrial wildlife – Moose, the most important subsistence food item by weight, appear to be increasing in abundance due to changes in vegetation. Moose have extended their range in Alaska in response to warmer temperatures and increasing shrub cover, such as willow and alder.²¹ Because Alaska is warming quickly, however, and large-scale ecosystem change can be expected, the future for moose in the area is somewhat uncertain. Moose in other parts of the U.S. are experiencing severe population declines from climate change due to parasites and disease.²²

Local residents have reported changes in the terrestrial wildlife of the region. Many Georgetown Tribal members have reported that ptarmigan are increasingly scarce, whereas they used to be quite abundant. Declines in salmon numbers are a concern, but they are not the only concern in relation to subsistence harvest. Diseases like *Ich* (caused by the parasite *Ichthyophonus hoferi*) can cause salmon meat to be unappealing for consumption or difficult to dry or store. Bioaccumulation of mercury is another problem, especially in fish species such as Northern pike and Burbot, as dissolved organic carbon from melting permafrost increases the rate of methylization of mercury, which causes mercury to bioaccumulate at higher rates. Georgetown already has some of the highest mercury concentrations in fish along the Kuskokwim due to



Photo: Denali National Park and Preserve CC BY NA2.0

“ They never used to go moose hunting until frost. Frost outdoors, then they go moose hunting. Nowadays, way before it even frost they go moose hunting.. they’re noisy after frost ”



abandoned mines and naturally high mineralization levels. Mercury can become toxic for young children and developing fetuses.

Berries – Many types of berries, including blueberries, cloudberry (or salmon berries), crowberries (or blackberries), and cranberries are important subsistence resources for local residents of the Kuskokwim region. Years with low berry productivity can mean a significant loss of subsistence food for native Alaskans. Berries can also be important forage for species such as moose, caribou, snowshoe hare, ptarmigan, and grouse. Berry distribution, abundance, productivity, and variability are all expected to be impacted by climate change, but specific impacts are not well understood at this time. Ongoing research includes the coupling of standard modeling approaches with local observer data to determine how berries are impacted over time (R. Loehman, personal communication).



Photo: Dawn Encino CC BY SA2.0

“ They used to pick berries on this hill over there, used to pick back here but there’s too much brush ”

“ They don’t get as much snow up there as they do around here. Black creek is the cutting off point the snow gets deeper down here, but yeah if there’s lot of snow and it’s a good spring there should be berries. I don’t know what happened this year something, it froze or something, with the blueberries.”

“ There’s no more cranberries up here. I think they start to get blossoms on tundra but the trouble is no sunshine, that’s why they didn’t grow too much rain. After the rain, you gotta have lots of sunshine for the cranberries to grow; they never grow anymore.”

Food Storage – Long term high temperatures can negatively impact the ability to dry fish, causing inadequate preservation and food spoilage.²³ During the hunting season, warm temperatures can cause meat to spoil before it can be processed and preserved. Many area residents have reported having to use more refrigeration for food storage where they used to use root cellars or permafrost for storage.

Access – One of the largest obstacles to harvest of wild foods, at this time, is safe access. Winter travel by snow machine can be dangerous when there is less snow and warmer temperatures. Increased growth of shrub cover hampers access to berry picking grounds. Warming soils and increasing erosion can cause riverbanks to become unstable as well. Unfamiliar and unpredictable changes in the environment have meant that traditional knowledge, which had previously provided reliable cues to aid safe travel to hunting grounds across dangerous landscapes, may be less dependable now.²⁴

Food Confidence – Successful harvest, processing, and consumption of subsistence foods rely on numerous components all coming together, to form food confidence (M. Brubaker, personal communication). Food confidence depends on safe travel routes to access wild foods; abundant populations of important food items like berries, fish, or moose; predictable harvest seasons and locations; ability to store and/or preserve food on-site during harvest as well as at home; quality of the meat, berries, or plants; how healthy the food is and how it looks and tastes. Food confidence is important not only for health, but also for spiritual and cultural well-being.

“ In the spring-time they’d put the meat in, you know when it used to have permafrost and cold in those little lakes, they’d just put it in the water where it was really cold and that’s how they’d keep meat for awhile. Down on the flats, there in the bogs. ”



Photo: W Hartman

Identified Vulnerabilities

The Vulnerability Assessment identified the following primary vulnerabilities to Subsistence:

HIGH – Less predictable berry harvest, affecting Georgetown’s food security and economic situation

HIGH – Reduced salmon harvests due to increased pests and disease, affecting populations numbers as well as quality of the meat

HIGH – Declines in moose and other terrestrial game animals, due to increased pests and disease and/or loss of habitat

HIGH – Economic burden from purchasing food to replace subsistence, or increased travel costs to harvest food

MEDIUM-HIGH - Food spoilage due to higher temperatures, especially during hunting trips but also at home

MEDIUM-HIGH - Overall loss of food confidence (includes uncertainty of getting food, ability to harvest, safety associated with access, preservation, how it looks/tastes (perception), how healthy it is)

MEDIUM – Higher methyl mercury levels in fish, from changes in water chemistry

MEDIUM – Reduced salmon harvest from habitat disruptions, warmer water, and ocean food declines



Photo: Kate Schaberg

INFRASTRUCTURE

The Georgetown Community Master Plan provides an overview of future development of the native village.²⁵ Because the village is in the planning phases, however, many of the risks that were identified were based on the experiences and trends in nearby communities, including, Napaimute, Crooked Creek, Red Devil, and Sleetmute. As Georgetown develops, members of the native village have many opportunities to avoid the risks that are present in other communities, providing Tribal members with increased adaptive capacity and resilience in the face of climate change. This section outlines where traditional approaches to infrastructure in the region may be most vulnerable to climate impacts.

“The road
ate away at Red
Devil...that’s why
we’re living here
now, too much
flooding in Red
Devil.”

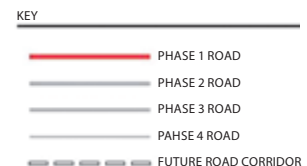
Bethel is the main port on the Kuskokwim River and serves as the main administrative and transportation hub for the region’s 56 villages, including those in the middle stretch of the river. Transportation of goods and people between Bethel and the many villages along the river consists of river boat and barge during the summer and small plane year-round. A series of ice roads for light trucks and passenger vehicles as well as snow machine trails connect Bethel to many of the regional villages in the wintertime, but no roads exist to connect them during other seasons.

The risks associated with climate change likely to affect infrastructure are numerous. Some of the more common risks include increased risk of flooding from larger storms and more frequent ice jams; loss of land stability due to melting permafrost; increased erosion and sedimentation of waterways; and increased leaching of minerals into ground and surface water, from melting permafrost.

Shoreline Erosion – Many villages along the Kuskokwim are experiencing unprecedented rates of shoreline erosion, which have serious consequences for infrastructure, including homes, piers, airstrips, roads, and other development. Erosion occurs for a variety of reasons, but primarily because the soils are frozen for a shorter amount of time during the year, increasing the length of time that they are susceptible to erosion. River banks, for example, used to freeze in the fall and stay frozen until spring thaw. This protected them from the impacts of ice and water during break-up. As snow shifts to rain, and soils remain above freezing, however, these soft banks can quickly wash away. At least 3 villages along the Kuskokwim have been listed by the Army Corps of Engineers as “Imminently threatened” from erosion



Figure 5 Land use diagram for the resettlement of the Native Village of Georgetown, from the Community Master Plan.



and flooding, including McGrath, Napakiak, and Akiak.²⁶ Many others have reported ongoing battles with quickly retreating shorelines.

Flooding – As precipitation increases overall, and snow shifts to rain, flooding in the Middle Kuskokwim region is expected to increase. Climate change is expected to lead to larger storms that produce more precipitation in a short period of time. In addition, projections for the Middle Kuskokwim include a 20–32% increase in annual average precipitation during this century. Warmer winters could lead to more freeze/thaw events on the Kuskokwim River, which can lead to more frequent ice jams that cause flooding as well.²⁷

Flooding has caused serious damage to nearby villages in recent years. In spring 2011, for example, Crooked Creek experienced historic floods, and 70% of buildings were affected. Only the buildings on highest ground were spared. The flooding, caused by an ice jam during break up, was unlike anything the elders had ever observed, with river height 30 feet above normal.

The site chosen for Georgetown's resettlement is located on the south side of the Kuskokwim River, opposite the mouth of the George River (Figure 5). This site is located in the interior of the River's curve,

“(The) river bank has changed a lot...if the ground is froze down good, like in a long fall with no snow...when the river goes out it has to fight frozen ground; when the ground is thawed and lots of snow, you get a high water event and the banks are soft and the water really attacks it.”



Photo: Rebecca Wilmarth

reducing the risk of erosion. The river bank is growing by accretion from deposition of river silt and gravel. Furthermore, the selected site sits on a terrace of land 60 feet above the normal river level making it a prime location that is less likely to flood.²⁸

Permafrost Melt – 80% of the state of Alaska is underlain by permafrost. Much of the middle Kuskokwim region’s permafrost is already thawing or is close to thawing. No permafrost in this region is expected to persist by the end of the century, so very substantial changes can be expected. Depending on the ice content and local topography, permafrost thaw can result in dramatic changes to land stability and the overall landscape. *Thermokarst* is the resulting disfigurement of the landscape that occurs when permafrost with large quantities of ice begins to thaw and the lands begin to slump. Thermokarst activity has resulted in depressions in the region that are over 100 feet deep.²⁹

SNAP has mapped out the vulnerability of the area to thermokarst and shows the area nearest to the river to be classified as “discontinuous permafrost extent with low ground ice content and thick overburden” (Figure 4). This bodes well for the chosen site for the future village of Georgetown, but SNAP’s model of thermokarst vulnerability identified the Georgetown development site between 3-50% vulnerable to the development of thermokarst (Figure 6). On-the-ground sampling for permafrost at varying depths is the only way to obtain the site specific information that is needed on this topic.

Permafrost melt poses additional risks to the Native Village of Georgetown. When permafrost melts, and especially in conjunction with larger storms and rain instead of snow, water flows more freely through the

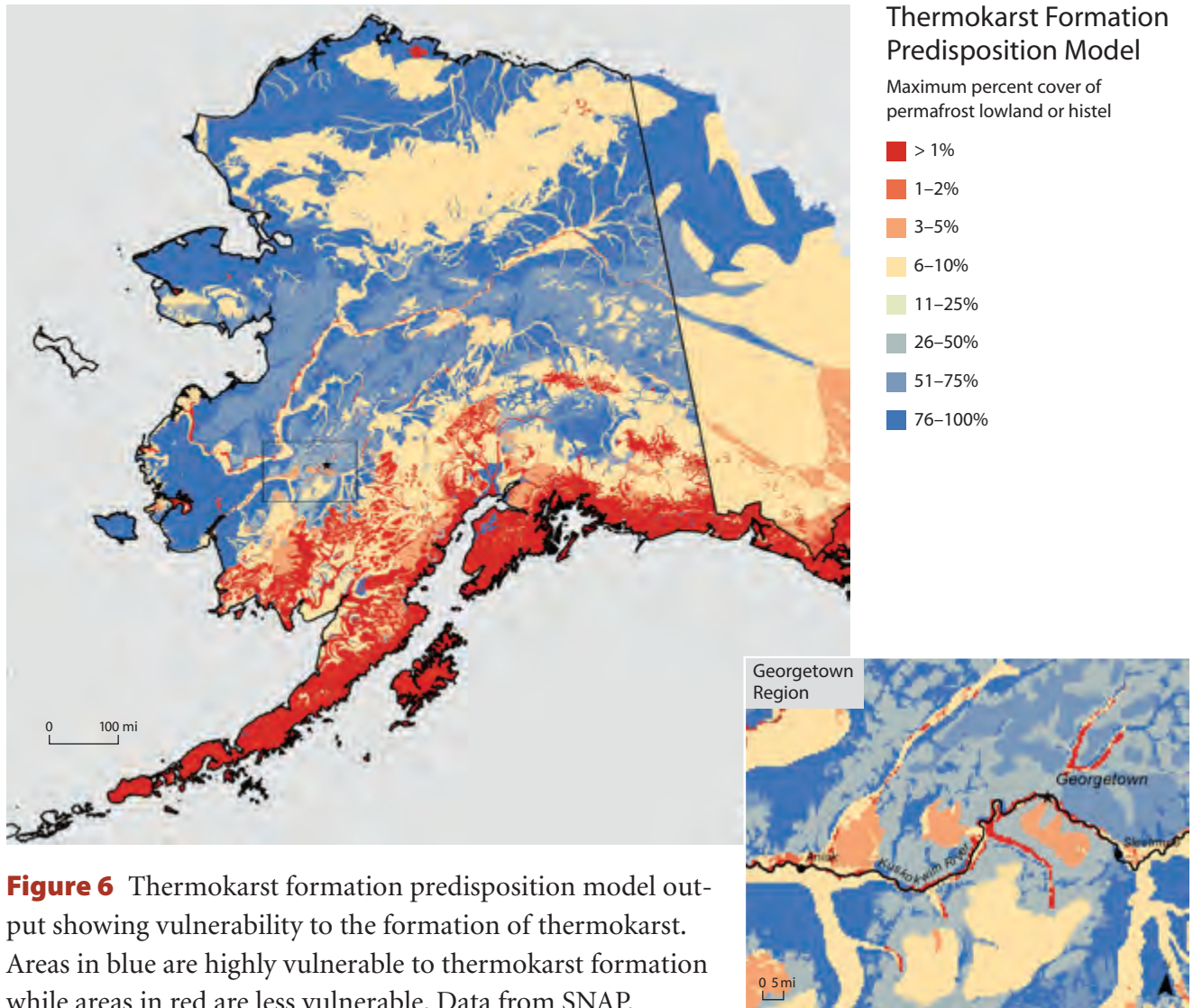


Figure 6 Thermokarst formation predisposition model output showing vulnerability to the formation of thermokarst. Areas in blue are highly vulnerable to thermokarst formation while areas in red are less vulnerable. Data from SNAP.

substrate, leaching minerals into rivers and streams, including calcium, sodium, phosphorus, magnesium, and sulfates. These minerals can dramatically change water chemistry and affect aquatic organisms. Newly and more frequently thawed soils are also susceptible to erosion, causing sedimentation of streams and rivers. Well water and river water are both expected to be affected by permafrost melt, and need to be monitored carefully for changes in water quality.

Wildfire – As outlined previously in the Ecosystems section, wildfire is already increasing across the region and is expected to continue to increase. The future site for development of the Native Village of Georgetown has evidence of past wildfire.³⁰ The heavily wooded areas surrounding the site indicate that wildfire risk should be managed and planned for in the design phase of the new community.

“Lots of snow back then, not like nowadays. Used to be deep, deep snow that used to go over us”

“ I remember going trick or treating in red devil and it was cold and that ice, you could hear that ice... I was walking and you could just hear the ice it was cold. Dad said one time the ice it was running he set a net over there and three days later it turned around and got so cold it freeze up in like 3 days. It just turned around and got cold and froze. ”

Transportation – Winter travel in the Middle Kuskokwim relies heavily on snow machine trails and ice roads for subsistence hunting, travel between villages, and obtaining necessary provisions and supplies. Travel by snow machine has already become limited in duration due to lower snowpack and unstable river ice causing dangerous conditions along the river. Ice roads are maintained in many areas throughout the winter, and can be placed and managed to maximize the amount of time they remain intact. As temperatures continue to warm, however, ice roads will become limited in their availability causing travel by light trucks and snow machine to become even more dangerous and limited.

During the summer, many residents rely on barge deliveries for fuel and other supplies. Warmer summers and drier conditions are expected, which are likely to continue to result in lower river levels in summer months. These factors could limit barge access to Georgetown and other villages along the river.



Photo: Kate Schaberg



Identified Vulnerabilities

The Vulnerability Assessment identified the following primary vulnerabilities to Infrastructure:

HIGH – Winter travel on ice roads and trails along the Kuskokwim river, its tributaries, lakes and streams increasingly dangerous, and shorter winter travel season from melting ice and erosion

HIGH – Limitations on barge travel during low flows, limiting fuel and other supply deliveries

MEDIUM-HIGH – Fish camps and homes at risk from increasing wildfire

MEDIUM – Infrastructure at risk from river shoreline erosion

LOW – Homes and other structures at risk from increased flooding

LOW – Homes, pipes, airstrips, roads, and other infrastructure at risk from land instability from melting permafrost

LOW – Changing snow load on roofs, as the potential for larger storms in winter increases, as well as wetter snow

“ Seemed like it used to be around September cause my mom’s birthday August 31st. Still used to be nice and warm. But maybe used to be maybe September getting toward end of September it start getting colder. And we haven’t had snow round here for sooo long. ”



Photo: Will Hartman

“ Yeah, it was different. I never see this kind of break up long ago. You know how it went this last year, never saw that long time growing up. ”

WATER

Life on the Kuskokwim revolves around the water. The Kuskokwim is the 9th largest river in the U.S., by volume. The river provides important habitat for aquatic wildlife, transportation for the numerous villages along its banks, cultural traditions that provide connection among native peoples, and a source of income for many.

Water quantity – Some of the most profound changes associated with climate change are likely to be those affecting water. Peak stream flow has declined in the Kuskokwim, by about 25% since 1952,³¹ even as precipitation has increased. As climate change progresses, a shift from snow to rain is expected, which will lead to earlier peak flows. As temperatures continue to warm, increased evaporation will continue to reduce water availability, but precipitation is also expected to increase by 19% by mid-century and 30% by late-century, especially in winter.³² Larger storms and more precipitation could lead to larger peak flows in some years, and greater year-to-year variability, with lower low flows as well.



Photo: Kate Schaberg



Photo: Kattie Wilmarth

“Seemed like there was more water back then. When it froze up it used to be bank to bank and last year it was kind of in the middle of the river. I’ve never seen it like that before.”

Another important variable on the Kuskokwim is ice break up. Based on data from the National Weather Service, ice break up occurs, on average, 6 days earlier than it used to.³³ Many of the elders from the area report that ice break up has not just changed in timing, but also in character. When they were younger, ice break up was sudden and loud, whereas now it happens more gradually and quietly.

Ice jams during break up are another feature of the hydrology of the Kuskokwim that can have major ramifications for local communities. River ice jams can produce major flooding events, such as those in 2011 in Crooked Creek and Red Devil. Increased incidence of mid-winter breakup could increase the likelihood of ice jams and associated flood events.³⁴

Water quality – Water quality is of great concern on the Kuskokwim River, as it is affected by a wide variety of trends and activities throughout the region. Many Alaskan Native tribes and organizations are collecting baseline data to monitor the overall health of the Kuskokwim River. The baseline dataset, being collected by villages throughout the watershed, will serve three main purposes: 1) as a water-quality reference against which to measure any future changes in the river, 2) to identify trends to help predict future changes, and 3) as a baseline database to measure against and to locate point source pollutions. The measures that are collected include temperature, pH, dissolved oxygen, turbidity, and total solids (dissolved and suspended).

Climate change is expected to affect water quality in numerous ways. The Middle Kuskokwim runs through an area that is highly mineralized, and the concentrations of metals such as mercury, arsenic, and antimony are already high and concentrate in fish and aquatic insects.³⁵ As permafrost melts and riverbanks thaw for longer periods, this mineralization is expected to increase. More precipitation and larger storms could exacerbate this leaching, and also lead to more turbidity and suspended solids.

Water temperatures have warmed in recent decades, and are expected to continue to warm with climate change, due to warmer air temperature, loss of snowpack, and lower low flows. Warmer water holds less oxygen, and can exacerbate disease and parasite issues for fish and other aquatic organisms.

Water quality can also be affected by the influx of bacteria and other contaminants from people, pets, and industrial activities. With larger storms expected, and warmer waters that breed bacteria, potential for contamination of surface water and ground water are expected to



Photo: Will Hartman

increase. Even if Georgetown develops the village to reduce the likelihood of flooding, contaminants can come from villages and camps further upstream, and leaching of heavy metals will continue.

Finally, water-borne diseases such as giardia and cryptosporidium can be affected by climate change in different ways. Warmer temperatures are expected to increase giardia in waterways, while increases in flooding may affect cryptosporidium. All of these changes to water resources in the Middle Kuskokwim indicate increased need for water treatment and filtration, along with the greater expense required for such procedures.

Identified Vulnerabilities

The Vulnerability Assessment identified the following primary vulnerabilities to Water:

HIGH – Contaminated well water from flooding impacts to septic systems

MEDIUM-HIGH – River water increasingly mineralized from permafrost melt

MEDIUM-HIGH – Increase in pathogens in streams and rivers, causing more water-borne illnesses

MEDIUM-HIGH – Well water increasingly contaminated with heavy metals

LOW – River water bacterial contamination from flooding

LOW – More sedimentation of river water from permafrost melt and erosion

HEALTH



Photo: Kate Schaberg

Climate change is expected to affect human health in the Middle Kuskokwim in numerous ways, many of which were covered in previous sections, especially risks to health and safety from the loss of healthy wild foods and food confidence, and increasing risks associated with winter travel.

Individual risks to human health are important to consider and address. While the region does not get very warm compared to other parts of the U.S., many residents of the Middle Kuskokwim are not used to higher temperatures, and could be at risk. Infants and elders are most at risk from heat, and temperatures are expected to rise substantially in coming decades.

Of equal importance is the overall collective impact that climate change is likely to have on mental health and well-being among Georgetown members and others in the Middle Kuskokwim. Mental health impacts are common in response to natural disasters such as floods and wildfires, which can take a significant toll on the economic and social well-being of the community. Mental health impacts could also arise from the loss of important subsistence, cultural and spiritual traditions due to climate change.

Warmer temperatures and new plants, including many invasive species, can lead to more pollen, allergies, and asthma. Pests and parasites affecting people, pets and wildlife may also become more abundant with a rise in temperature. Water and food-borne illnesses and the increased need for refrigeration could also become more prevalent.

While warmer temperatures can disrupt many of the traditional ways of life in the Middle Kuskokwim, they also can provide many benefits to the community. Increased opportunities for gardening and growing food could help to offset some of the lost opportunities for harvesting wild foods. Also, longer summers, less snow, and warmer temperatures provide more opportunities for people to spend outdoors, with potential benefits to physical and mental health.



Photo: Kate Schaberg

Identified Vulnerabilities

The Vulnerability Assessment identified the following primary vulnerabilities to Health:

MEDIUM-HIGH – Impacts to mental health and overall well-being from the loss of cultural, spiritual, subsistence, and economic opportunities

MEDIUM – Increase in pests and insects, such as ticks, that affect people, pets, and wildlife

MEDIUM-LOW – Health impacts from increases in heat, smoke, and pollen

MEDIUM-LOW – Safety of pets, infants, elders, etc. in the face of more extreme heat and precipitation

BENEFIT – More opportunities for outdoor activities increasing physical health

BENEFIT – More opportunities for gardens and agriculture

Summary of Georgetown's Vulnerabilities

Table 2 Native Village of Georgetown vulnerabilities and their relative rankings based on sensitivity and adaptive capacity. Certainty rankings reflect the level of certainty in climate change projections, as well as the potential response to the projected changes. Temperature and snowpack projections, for example, have higher certainty than streamflow projections. The issues most important to Georgetown, regardless of vulnerability, are prioritized in the far right column.

Sector	Risk	Exposure	Certainty	Time Frame	Sensitivity	Rank	Adaptive Capacity	Rank	Priority
Ecosystems	Overall changes in natural systems that lead to a loss of native species, including birds, mammals, plants, insects, and others	Overall changes in temperature and precipitation; changes in extreme conditions; shifts in species ranges	M	Already an issue; increasing severity over time	Individual species are expected to respond differently, causing ecological relationships to collapse	H	Some species will be more adaptable than others; studies show it will be difficult for species to adapt fast enough to match the rate of change	L	M
Infrastructure	Disruption to winter travel from unsafe ice conditions	Warmer temperatures and permafrost thaw	H	Already an issue; increasing severity over time	Travel on ice roads becoming less predictable and seasons shorter. Hunters and subsistence, goods, services, travel affected.	H	More awareness. More flights during shoulder seasons. Siting ice roads to last longer. Monitor conditions and safety, outreach to communities in winter season	L	H
Subsistence	Less predictable or reliable berry harvest	Overall changes in temperature and precipitation; loss of snowpack; lower soil moisture; shifts in species ranges	M	Already an issue; increasing severity over time	Spiritual connection to traditions will be lost, impacting wellness. Bears, birds, and other wildlife will be affected. People preserve berries to use year round. They will have to replace with other foods, which are more expensive. Loss of income for those who pick and sell berries.	H	Alternative berries are an option, unless all berries fail at the same time. Cranberries are gone, but blueberries are doing better. The problem could worsen over the longer term. Spiritual, cultural traditions can't be replaced.	L	H
Subsistence	Diseases affecting salmon – both quantity (harvest) and quality of the meat	Warmer water temperatures; lower streamflow	M	Already an issue; increasing severity over time	Salmon, bears, and people will be affected. Cascading effects on ecosystems that rely on nitrogen and phosphorus from salmon. Coho already diseased. No monitoring on the Kuskokwim	H	Some species more prone to disease than others, so substitutions available. Identification, monitoring, and outreach.	L	H

Sector	Risk	Exposure	Certainty	Time Frame	Sensitivity	Rank	Adaptive Capacity	Rank	Priority
Subsistence	Increased cost of purchasing food, travel costs for getting to subsistence foods, etc.	Overall changes in temperature and precipitation; shifts in species ranges	M	Already an issue; increasing severity over time	Lower income families, large families, and unemployed are most at risk.	H	More opportunities for farming, gardening, and agriculture. Free high tunnels (greenhouses) available from NRCS.	L	H
Subsistence	Increased pests and disease among moose and other game animals	Warmer temperatures	L	Near- to mid-term; Has been seen in other areas	Half of protein source for many families comes from moose. Caribou already moved out of the area. Trappers of wolves and other furbearers could lose money if pelts are of lower value.	H	Cultural traditions hard to replace but could hunt other animals. Better manage populations through conservation, protection, sustainable harvest.	L	H
Water	Contaminated well water from flooding impacts to septic system	Increase in large storms and flooding; permafrost melt	L	Mid- to long-term	Residents on well water are most at risk.	H	Water treatment/ filtration	L	M
Infrastructure	Limitations on barge travel during low flows, limiting fuel and supply deliveries	Increasing overall drought stress, lower low flows due to loss of snowpack	L	Mid- to long-term	Significant economic impacts on the community if supplies cannot be delivered	H	More flights to replace barge, but already they are seeing fewer flight options	L	H
Water	Increased mineralization and contamination of river water with heavy metals	Permafrost melt, increased precipitation, increase in large storms and flooding, lower low flows	H	Already an issue; increasing severity over time	Fish camps, animals and fish are impacted. People still use surface water when hunting, fishing, etc. Also for cleaning equipment and at fish camps.	M	Behavior change	L	H
Ecosystems	Continued loss of lakes and ponds, which provide important habitat for waterfowl and aquatic plants and animals	Permafrost melt	H	Already an issue; increasing severity over time	Waterfowl, aquatic species at risk	M	None identified	L	M
Infrastructure	Fish camps and homes at risk from wildfire	Increase in vegetation flammability	M	Mid- to long-term	Lots of spruce at the site, with no natural barrier, plus past evidence of wildfire. Fish camps and homes are least protected. There is no fire service.	M	Reduce fuels. Homes can be built to have lower risk, but local lumber is used and it is difficult to get other materials out to the site.	L	M
Water	Wells increasingly mineralized and contaminated with heavy metals, including mercury and arsenic	Melting permafrost, increasing precipitation	M	Near- to mid-term	Everyone affected. Georgetown already has high arsenic	H	Behavior change	M	M
Water	Streams and springs increasingly contaminated with pathogens, such as giardia, cryptosporidium, causing water borne illnesses	Increase in water temperatures	M	Already an issue; increasing severity over time	Hunters, fishers, people doing outdoor activities (pretty much everyone)	H	Boiling water or filtration; Education	M	M
Subsistence	Food spoilage due to higher temperatures, leading to loss of food	Increased temperatures	M	Already an issue; increasing severity over time	Moose hunting used to be after the first frost. Now its warmer, so the meat can spoil before they are able to get it back.	H	Regulate timing of the hunt for moose. Georgetown could get involved in management.	M	M

Sector	Risk	Exposure	Certainty	Time Frame	Sensitivity	Rank	Adaptive Capacity	Rank	Priority
Health	Impacts to mental health and overall well-being from loss of ability to harvest traditional food sources	Increased temperatures, overall change in conditions, increasing variability and uncertainty,	M	Mid- to long-term	Those who hunt, fish and gather	H	Close families, close communities, sharing of harvest, all provide support	M	H
Subsistence	Overall loss of food confidence (uncertainty of getting food, availability, access, preservation, look/taste (perception), how healthy it is	Increased temperatures, snow-pack declines, warmer waters, lower flows	M	Near-term	Pregnant women, young people, elders, everyone	H	Education, outreach on food safety, participation in LEO to compare to others and learn about issues	M	M
Subsistence	Changes in water chemistry, increased dissolved organic carbon creating anoxic conditions and higher methyl mercury uptake in fish	Melting permafrost, warmer temperatures	M	Already an issue; increasing severity over time	Subsistence hunters, fishers, everyone, especially pregnant women and children. Georgetown especially at risk - already has the "hottest" pike on the river.	H	Education, outreach, change behavior, eat smaller fish or different species	H	H
Subsistence	Reduced salmon harvest from habitat disruptions, warmer water, and ocean food declines	Ocean acidification, warmer water, increase in large storms and flooding, increased erosion and sedimentation	M	Already an issue; increasing severity over time	Subsistence and commercial both impacted. Chinook most at risk due to the time they spend in the Bering Sea.	H	Could harvest other species like Sockeye, lower risk species. Change regulations, participate in the Intertribal Fish Commission.	H	H
Infrastructure	River shoreline developments at risk from erosion	Increase in large storms and flooding, increase in ice jams, changing hydrograph, melting permafrost	L	Mid-term	Fish camps, shoreline developments	H	Not seeing much erosion in Georgetown. New developments not in flood zone.	H	H
Health	Increases in pests and insects that affect people, pets, and wildlife	Increased temperatures	H	Near- to mid-term		M	Pest deterrents for people and pets	M	M
Ecosystems	Loss of forest ecosystems, firewood, and in particular white spruce, an important species for construction	Overall changes in temperature and precipitation, shifts in species ranges; long term shifts from forest to grasslands and shrublands	M	Already an issue; increasing severity over time	Those who are looking to build homes in Georgetown	L	Investigate other building materials	M	M
Health	Air quality impacts from increases in heat, smoke, and pollen	Increased temperatures; increased flammability of vegetation; increased drought stress	M	Mid-term	People with chronic respiratory problems, elders, infants	M	New construction provides an opportunity to increase air filtration, insulating and passive cooling properties of structures	H	M
Health	Safety of pets, infants, elders, etc. in the face of more extreme heat and precipitation	Increased temperatures; increase in extreme precipitation	M	Near-term	People unused to higher temps.	M	Education and behavior change	H	M
Ecosystems	Displacement of native species by invasive species that become more competitive under warmer conditions	Increased temperatures; species range shifts	M	Already an issue; increasing severity over time	Reduced biodiversity and natural systems resilience, can affect subsistence foods	M	Education and outreach	H	M

Sector	Risk	Exposure	Certainty	Time Frame	Sensitivity	Rank	Adaptive Capacity	Rank	Priority
Water	More sedimentation of river water from permafrost melt and erosion	Permafrost melt; increase in large storms and flooding; increased sedimentation and erosion	H	Already an issue; increasing severity over time	Fish affected, spawning tributaries	L	More filtration needed if surface water will be used, but Georgetown plans to have well water	H	L
Water	Increased contamination of river water with bacteria and pathogens	Increase in extreme precipitation, increase in ice jams, warmer water and lower low flows	M	Already an issue; increasing severity over time	Regional risk is high, but specific to Georgetown it is low. Flooding can bring sewage and animal feces into the water.	L	Georgetown can develop lower risk systems, but is still affected by villages upstream	H	L
Infrastructure	Homes and other structures at risk from increased flooding	Increase in large storms and flooding	M	Mid-term	Fish camps and structures near shoreline most at risk; most of Georgetown's planned community more than 60ft. above the river	L	New construction can be placed in areas of low risk, higher above the river	H	M
Infrastructure	Homes, pipes, airstrip, and other infrastructure at risk from land instability from melting permafrost	Increase in large storms and flooding; melting permafrost	M	Mid-term	Homes, roads, sewage infrastructure, water infrastructure; already roads are sinking in other areas (Napaimute). New construction will need deeper/taller supports, could cost more.	L	Historic floodplain has less permafrost; mostly the permafrost is not near the river; balance flood risk with permafrost risk	H	M
Infrastructure	Changing snow load on roofs, as the potential for larger storms in winter increases, as well as wetter snow	Increase in large storms during winter	L	Mid-term	Fish camps, older construction	L	New construction	H	L

Conclusions

The Native Village of Georgetown has many features that make it resilient in the face of change, even as temperatures continue to rise and conditions change dramatically. Because the village has not yet been re-established, opportunities for reducing risks and creating resilience are plentiful. This vulnerability assessment is one step in the process needed to develop a sustainable and vibrant community. It raises awareness of many of the issues that could affect the success of Georgetown's re-establishment.

The vulnerability assessment identified numerous ways in which climate change could affect Georgetown and surrounding villages



Photo: Will Hartman



Photo: Kate Schaberg

within the sub-region, from impacts to ecosystems, subsistence, infrastructure, water, and health. As this vulnerability assessment was being developed, strategies for addressing the risks were often recommended, and have been compiled and included at the end of this report. The next steps would be to use these strategies as a starter list, and build upon them to develop a full suite of strategies that will make the Native Village of Georgetown resilient to the identified vulnerabilities. Because of the uncertainty associated with climate change, as well as the fact that many of the impacts will be surprising and unpredictable, it will be especially important to build a highly resilient community that can withstand a range of future conditions.

Climate change poses a significant threat to Georgetown and the other communities dispersed throughout Alaska. Reliance on subsistence foods, limited transportation options, and lack of economic opportunities in the area present real challenges for the people of Georgetown. And yet, Native people are strong, resilient and highly adaptable, with close ties to the land and to one another. In fact, the wisdom of Georgetown Elders is needed now more than ever, in order to face today's challenges with the same strength with which they met the many challenges of the past.



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APPENDIX

Vulnerability Assessment Workshop Participants

A workshop was held September 9th, 2017 at Alaska Pacific University in Anchorage. Georgetown Tribal Council (GTC) staff (W. Hartman and K. Schaberg) and Geos Institute staff (M. Koopman and T. Graham) helped to facilitate the workshop. Workshop participants reviewed both the Traditional Knowledge and the climate change science relevant to the Middle Kuskokwim region. Participants contributed information and knowledge on the current and future potential impacts to people and resources of the region, as well as ongoing stressors, current capacity, and potential adaptation strategies. Thank you to all who participated! Your input was vital to this project.

Barbara Askoak, Village of Lower Kalskag

Valerie Dudley, Native Village of Georgetown, GTC Environmental Committee

Renee Fredericks, Native Village of Georgetown, GTC Environmental Committee

Dan Gillikin, Native Village of Napaimute

Debby Hartman, Native Village of Georgetown, GTC Environmental Committee

Will Hartman, GTC Tribal Administrator

Traci Maczynski, Native Village of Georgetown, GTC Chairperson

Jonathan Samuelson, GTC Traditional Ecological Knowledge Project Assistant

Kate Schaberg, GTC Environmental Coordinator

Steve Street, Association of Village Council Presidents, Bethel

Subject Area Experts

Numerous subject area experts were consulted for this project. Information on ongoing and future potential impacts of climate change to the people and resources of the Middle Kuskokwim region was solicited from the following individuals. Thank you for your contributions!

Dr. Todd Brinkman, University of Alaska, Fairbanks

Michael Brubaker, Director, Alaska Native Tribal Health Consortium

Jeff Currey, Materials Engineer, Alaska Department of Transportation

Ann Gravier, US Dept. Housing and Human Services

Dr. Jeremy Littell, Lead Scientist, USGS Alaska Climate Science Center

Dr. Rachel Loehman, Climate Change Analyst, USGS Alaska Science Center

Dr. Elizabeth Powers, Western Alaska Landscape Conservation Cooperative

Sally Russell-Cox, Alaska Department of Commerce, Community, and Economic Development, Division of Community and Regional Affairs

Deanne Stevens, Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys

Dr. Ryan Toohey, Lead Scientist, USGS Alaska Climate Science Center

Additional Resources

Numerous resources are available to provide additional information and support for the Native Village of Georgetown.

ADAPT (Arctic Development and Adaptation to Permafrost in Transition) – <http://www.cen.ulaval.ca/adapt/>

Alaska Native Tribal Health Consortium – <https://anthc.org/>

Association of Village Council presidents (AVCP) Regional Housing Authority (RHA) has Georgetown in their jurisdiction as a tribally designated housing entity (TDHE) – <https://www.avcphousing.org/>

Cold Climate Housing Research Center – <http://www.cchrc.org>

First Foods and Climate change – http://tribalclimate.uoregon.edu/files/2010/11/firstfoods_climatechange_12-14-11_final1.pdf

GAO Report from 2009 (extensive lists of resources, but slightly out-of-date) – <http://www.gao.gov/products/GAO-09-551>

State of Alaska Division of Community and Regional affairs (DCRA) – <https://www.commerce.alaska.gov/web/dcra/CommunityAidAccountability.aspx>

State of Alaska Division of Geological and Geophysical Surveys (DGGS) – <http://dggs.alaska.gov/sections/engineering/profiles/climatehazards.html>

US Department of Housing and Urban Development – https://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/ih/codetalk/onap/akonap

USDA RD and BIA – <https://www.rd.usda.gov/ak>

Institute for Tribal Environmental Professionals – <http://www7.nau.edu/itep/main/tcc/Home>

Climate change adaptation

is the response to climate change that seeks to reduce the vulnerability of social and ecological systems to ongoing impacts and change.

Adaptation strategies can be implemented to protect both people and nature from the impacts associated with climate change.

Climate change mitigation

is the reduction in greenhouse gas emissions related to fossil fuels combustion, deforestation, and other activities, in order to reduce the overall magnitude of climate change.

Climate change adaptation

will help to protect people and nature, but **climate change mitigation**, at the global scale, is needed in order to reduce the overall magnitude of impacts. Otherwise, many impacts will be too severe to “adapt” to.

Potential Adaptation Strategies for the Native Village of Georgetown

This project was focused on identifying and ranking the relevant vulnerabilities associated with a changing climate in the Middle Kuskokwim region, with specific focus on the Native Village of Georgetown. A rigorous process to identify vulnerabilities in a focused and structured manner was applied. Although they were not the focus of this effort, many strategy recommendations were made in an opportunistic manner. Thus, the strategies listed below are not comprehensive, nor have they been vetted for efficacy, cost, or potential alternatives. These strategies can provide an initial starter list, however, for a more robust adaptation strategy development process.

Because the Native Village of Georgetown will be new construction, there are many options for developing the village in a more sustainable and resilient manner. Yet cost is always an important consideration, and some types of construction may require more investment upfront, but save money over time due to higher efficiency and greater resistance to extreme events.

Some of the potential adaptation strategies that were suggested included:

River shoreline erosion risk – New construction should be built in lower risk areas. Transportation infrastructure (such as runways) should be built away from the river to reduce flood and erosion risk. Riparian vegetation can be restored and protected to further support the shoreline, especially from wood cutting. Ordinances and codes should be updated to also protect shoreline vegetation and reduce development in risky areas.

Wildfire risk – Camp owners can work to reduce fuels near camps and homes should be built to have lower risk, through the materials used and fuels management to maintain a buffer between forests and buildings.

Increasingly unsafe ice conditions for winter travel – Not many options are available for maintaining safe ice roads and conditions as temperatures warm and become more variable. Local residents will need to become more aware of safety issues and seasonal limitations. Ice roads can be installed to last longer by siting them correctly. Ice conditions will need to be monitored so people know about conditions and safety. Ice penetrating radar can be used to map ice conditions as well.

Water contamination due to increase in severe storm and flooding that can overwhelm septic systems and leach metals and minerals from soils – Local residents will need to monitor well water, create baselines (this is already being done), increase water filtration, and boil water when contaminated with bacteria.

Declining fish populations due to loss of marine food and freshwater habitat, and increased disease – Identification, monitoring, and outreach are needed. Some potential options are to change regulations, participate in the Intertribal Fish Commission, and work on co-management. Manage for biological diversity. Encouraging harvest of lower risk species. Changing timing of fishing so that they can dry the fish - preservation techniques could be changed to accommodate different things.

Increase in wildlife disease – Changes in how food is prepared may be needed if diseases make wild meat less safe, especially for people with compromised immune systems. LEO (through ANTHC) is one way to track wildlife disease and

food safety. Samples can be sent in to wildlife toxicology lab to be tested for contaminants, trichinosis, other pathogens.

Increase in mercury and other toxins in food, especially fish – Pregnant women should be cautious and should eat smaller fish. Children as well. More education and outreach are needed to make sure that people are aware of the risks and understand behavioral changes that can reduce the risk. Hair samples can help to detect high mercury exposure (ANTHC).

Loss of subsistence foods – Subsistence foods could potentially be farmed or enhanced through management. Longer summers and warmer temperatures could lead to more opportunity for gardens, farming, and agriculture.

Food spoilage due to warmer temperatures – Moose season timing could be regulated to occur during cooler weather. Georgetown members could get involved in game management to influence policy.

Air quality impacts from heat, smoke, and pollen – As the Native Village of Georgetown is developed, insulation, passive cooling, and air filtration can be incorporated into building design.

Loss of forest ecosystems, especially white spruce – Assisted migration (seed dispersal or planting) could be needed using different species of vegetation, or even stocks of the same species, from further south, to replace those that might die off.



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