Climate Change in **Kiana**, Alaska

Strategies for Community Health

ANTHC Center for Climate and Health

Funded by

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Through adaptation, negative health effects can be prevented.

Cover Art:
Whale Bone Mask
by Larry Adams

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SUMMARY

Rural Arctic communities are vulnerable to climate change

and residents seek adaptive strategies that will protect health and health infrastructure. In the Inupiat community of Kiana, climate change is impacting the weather, land, river, wildlife, plants, and the lives of the people who live there. Identified health concerns include food insecurity, damage to water and sanitation infrastructure, and increased risk of injury related to unpredictable weather conditions.

This report documents climate change impacts as described by the local people and interpreted through the lens of public health. It is the fourth report in a series describing climate change in Northwestern Alaska. The first two reports focused on the coastal whaling communities of Point Hope and Kivalina. This is the second report to look at an upriver community; the first was Noatak located on the Noatak River, and now Kiana located on the Kobuk River. These reports were prepared by the Alaska Native Tribal Health Consortium, Center for Climate and Health in partnership with the Maniilaq Association, the Northwest Arctic Borough, Kiana Tribal Council and the City of Kiana. Funding was provided by the United States Indian Health Service and Environmental Protection Agency.

Leaning utility poles are a safety concern.
Mike Brubaker, 2011.

This Climate Change Health Assessment was performed based on requests from tribal health representatives and from local and regional leadership. Information about local climate, environment, and health conditions was gathered with the help of local and regional government, universities, industry, and state and federal agencies.

Information sources for this report include the observations of local residents, reports from government agencies, and scientific evidence gathered from published sources. Kiana has experienced climate change for at least the past 50 years, as evidenced by rising temperatures in every month and increased precipitation in every month except July (SNAP 2011). Residents also report increasingly variable seasonal weather, more frequent storms, and extreme temperature swings, especially in winter. Climate change is resulting in new challenges that need to be addressed. It is hoped that this report will facilitate informed decision making, and help Kiana and other communities in the Northwest Arctic region pursue appropriate responses and a healthy future. A summary of the finding are as follows.

1. Permafrost thaw is making the landscape increasingly fragile. Seasonal warming is increasing the thaw zone, resulting in land erosion and subsidence, river bank erosion, and drying of nearby lakes. In areas where the permafrost has been disturbed or exposed, thawing during summer months is accelerated and constant. Tundra located north of the sewage lagoon was disturbed by effluent discharge in 2004; this area has since developed into a 200' long, 50' wide, by 15' deep ravine. Best practices for permafrost protection are critical to prevent future environmental damage and infrastructure failure. *Points of contact: ANTHC, Maniilaq, NWAB, NANA, DOT.*

2. The river bank in some areas of Kiana is rapidly eroding. Over four feet of river bank has eroded in the past year. At the current rate, houses and infrastructure located on the bluffs will be vulnerable to damage and landslide over the next decade. Annual monitoring of erosion and river bank protection is needed. *Points of contact: NWAB, U.S. Army Corps, NWAHB.*

3. Permafrost thaw is damaging local utilities. Within the last decade, water and sewer main breaks have been attributed to ground movement caused by thawing permafrost.

Exposed river bank at Kiana.
Mike Brubaker, 2011.

Anecdotal data was collected on the observations and experience from local experts in health, wildlife, Inupiat culture, weather, subsistence, education, sanitation, local governance, law enforcement and emergency services.

Predictions and projections on future conditions such as warming, flooding, and erosion are based on available information and limited by the quality of current scientific data and the uncertainties inherent in climate models.

Thaw driven erosion is visible all along the Kobuk River.
P. Chavan, 2011.

Over a one year period between site visits in 2010 and 2011, a marked increase in permafrost degradation was observed. Electric utility poles and power lines in one area leaned and sagged. Clean outs on the community's sewage force main settled in several locations and the broke in one location. More frequent monitoring and maintenance may be necessary to prevent line breaks and repair them before they can develop into service interruption. *Points of contact: ANTHC, Maniilaq, AVEC.*

4. River change is decreasing the ice season and increasing travel hazards. The primary transportation route for Kiana is the Kobuk River, by snow machine in winter and by boat in summer. Warming is making the season for ice travel shorter and more hazardous. Finding ways to reduce

Where once the land was characterized by resilience, today it is increasingly fragile and vulnerable to erosion.

travel hazards is a priority. Residents are also concerned that low water could impact barge access and the shipment of fuel and freight. Information about current conditions and projections for the future are a priority. *Points of Contact: NWAB, DCCED, NANA, NWS, USACE.*

5. Smoke, dust, and allergens are impacting air quality. Kiana has experienced increased wildfires related to hot summer temperatures, increased lightening strikes, and dry forest and tundra conditions. Wildfire smoke and dust from wind and summer road traffic can increase the risk of respiratory ailments, as can allergens like tree pollen that may be increasing in Kiana. Air quality monitoring, advisories, and control measures are recommended. *Points of contact: ADEC, ANTHC, Maniilaq, EPA, DOT, Alaska Allergy Center.*

6. Some households are vulnerable to food insecurity. Caribou, the most important subsistence species in the diet of residents from Kiana, is increasingly difficult to hunt and increasingly expensive, as hunters travel further and spend more time in the field to meet their subsistence needs. In 2010 residents reported that many households were unable to harvest any caribou at all, while the harvest for most was insufficient to meet their needs. Regular surveys would help monitor harvest levels of subsistence species and food security. *Points of contact: ADF&G, USF&W, NPS, NWAB, Maniilaq, NANA.*

7. Users of traditional water sources are at risk for waterborne disease. Traditional sources include streams, springs, and lakes commonly used at hunting and fishing camps, or water collected and brought to the village for household use. With climate-driven invasive species and environmental change occurring, traditional sources may become contaminated with disease-causing pathogens. To avoid waterborne illness, boiling or the use of appropriate filters and treatment systems is recommend. *Points of contact: Maniilaq, NWAB, ANTHC.*

8. Adaptation capacity would be improved by establishing local environmental observers. This would involve environmental observers who would monitor environmental change related to climate Including: precipitation, river and coastal conditions, soil temperature, erosion, wildlife change, pollution events, and emerging health concerns. *Points of contact: ANTHC, UAA, NWS, UAF, NOAA, NWAB, USACE.*

This report is about the effects of climate change—both good and bad—on people's lives as described by Kiana's residents and interpreted through the lens of public health.

INTRODUCTION

Kiana is a small Inupiat Eskimo community located on the north bank of the Kobuk River. It is located about 30 miles north of the Arctic Circle, 57 air miles east of Kotzebue and about the same distance upriver from where the Kobuk River terminates into Selawik Lake. Over 90% of the residents are Alaska Native or part Native. Life in Kiana revolves around subsistence and people engage year-round in hunting, fishing, and gathering wild foods and materials they need from the land, the river and the sea. The most important subsistence species are caribou, salmon, whitefish, and moose but over 50 other varieties of plants, waterfowl, fish, and wildlife are also harvested (ADF&G, 2006).

Climate change refers to change over time due to natural variability or as a result of human activity (IPCC, 2008). In Kiana, the rate of climate change can be measured in months, days, or even hours. Residents traveling the river encounter sections of collapsed riverbank that were intact only hours before. In every season of the year, the air temperature is warmer than it was in the past. Summers are more frequently hot, and winters increasingly mild. The season of extreme cold, ice, and snow is also changing. Sea and river ice is thinning making travel more dangerous and the season for ice travel shorter.

Perhaps the most important impact from warming is the thawing of permafrost, along the rivers, under lakes, and across the land. Where once the land was characterized by resilience, today it is increasingly fragile, and vulnerable to erosion and being washed into the rivers and ultimately into the sea. The biota is also changing. New species of plants, insects, fish, birds, and other wildlife are being observed, while the harvest of some traditional food species, such as caribou has in recent years been more difficult, time consuming, and expensive. These changes are influencing food and water security and increasing the potential for disease and injury.

Kiana, Alaska.
Mike Brubaker, 2011.

"We always had to warm our hands because the water was so cold. Now it is really warm when we are fishing."

Gloria Shallabarger

In September of 2010, and July and August of 2011, site visits were performed by ANTHC's Center for Climate and Health using a specialized health impact assessment process (Brubaker et al. 2011). Interviews were performed in offices of local government, in the health clinic, the school, during excursions into the countryside, and in visits to people's homes. Information was collected about impacts, potential health effects, data gaps, and adaptation measures. Local and regional partners reviewed the notes and provided comments on this report. Findings were presented to partner organizations in Kiana and in Kotzebue.

The climate impacts documented in this report are predominately negative. Positive health effects have also been identified such as the potential for new food resources, longer boating season, less ice jam flooding, and warm summer days.

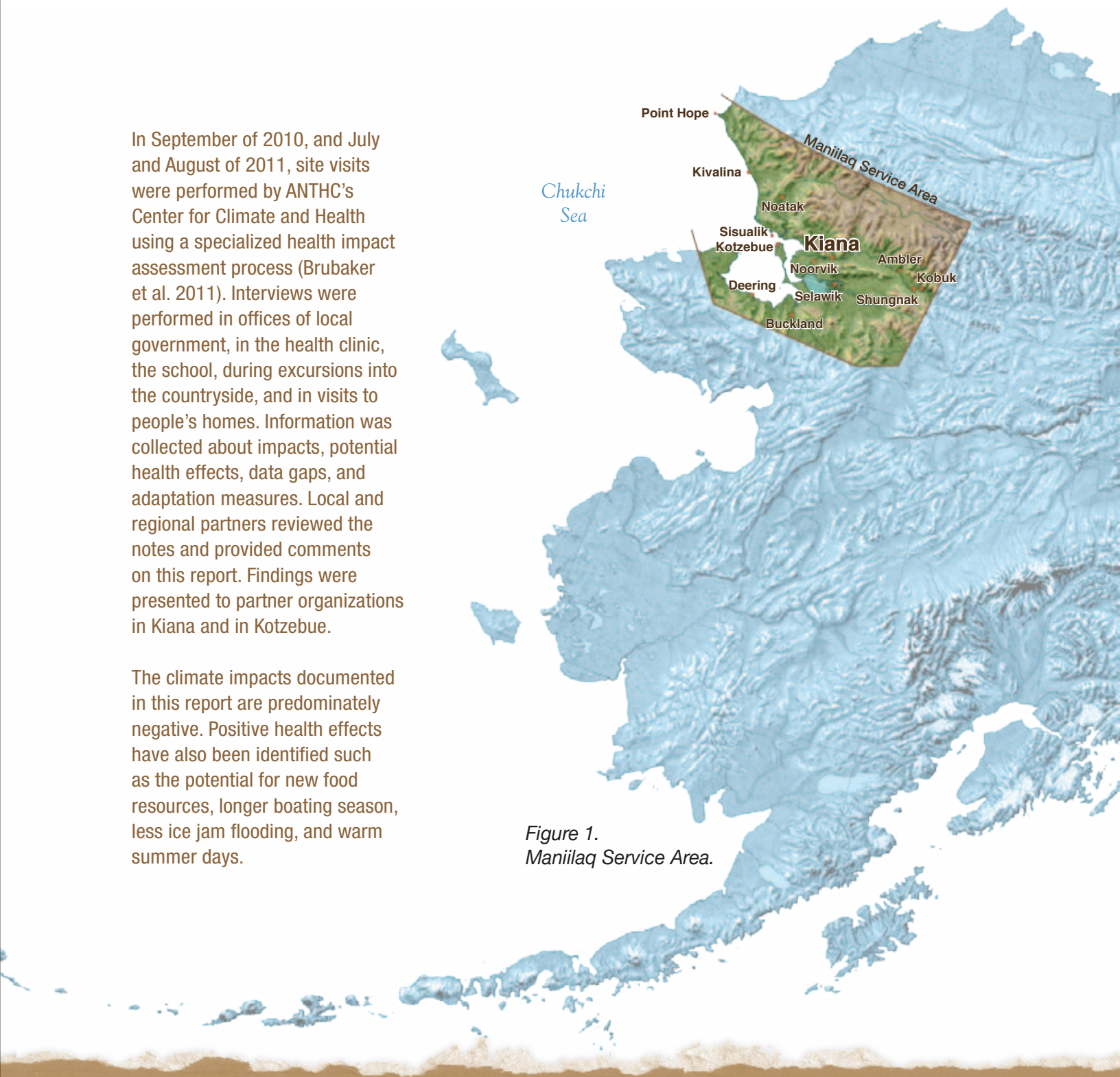


Figure 1.
Maniilaq Service Area.

"My mother asked Auntie if it ever used to get this hot in summer. She said no, never."

Thomas Jackson

COMMUNITY

The Inupiaq name for Kiana, "Katyaaq", means, "place where three rivers meet". The old village was located on the river edge, but most of the buildings today are up on the bluff overlooking the confluence of the Squirrel River and two branches of the Kobuk. The population is about 361 residents. The Inupiat have inhabited this area for thousands of years, and Kiana was founded as the central village of the Kowagmiut Inupiat Eskimos. In 1898 word that gold had been discovered brought thousands of prospectors, only to learn that the discovery was a hoax. But in 1909, mining returned to the Squirrel River and Kiana became a key supply post. One mine located at the tributary to Klery Creek supported as many as 200 miners. A post office was established in 1915, and by 1920 there were 98 residents in Kiana. By 1931, over $600,000 in gold has been removed from claims along Klery and five other creeks. (Read, 1932). A BIA high school was established in the mid 1970s and boarded students came from as far away as Shungnak, Ambler and Noatak. In 1964 Kiana was incorporated as a second class city, and in 1986 Kiana became part of the newly formed Northwest Arctic Borough.

No roads lead to Kiana and the community relies on the river for transportation all year round. The first airplane landed on a sand bar in the summer of 1931. The cost for a ticket to Kotzebue was $50.00. Today the price of a ticket is $160 and planes land on a 3400 foot long gravel runway at the Bob Baker Memorial Airstrip. Barge service by Crowley Marine provides fuel delivery and transport of other freight. In winter, the river serves as an ice road for snow machine travel inland and downriver to Noorvik and Kotzebue. Residents are employed in construction, mining, fishing, guiding, health care, education, traditional crafts, and the government services required to keep a rural Alaska community running.

Along the river, homes are surrounded by black spruce, birch, alder and willow. Inland there is more taiga forest and tundra, across rolling hills. In many ways, Kiana looks like other Arctic villages: there are rows of HUD houses, two churches, tribal and city administrative offices, a health clinic, water plant, school, four stores, boys and girls club, and a bulk fuel storage facility. Snow machines, sleds, and ATVs are parked outside houses, and in summer, there is a landing for small boats down by the river. Homes are typically heated by fuel oil heaters or wood stoves. Water and sewer is managed by the Alaska Rural Utilities Cooperative in association with the City of Kiana. Electricity is provided by diesel generators operated by the Alaska Village Energy Cooperative. Fuel sales are provided by the City of Kiana. In September 2011 the per-gallon price for fuel oil was $7.00 and $7.70 for gasoline.

"It is September 21st and sixty degrees. I think this is why there is no caribou. Usually it is cool by Labor Day and we are getting caribou."

Lorene Walker

Figure 2. Google view of Kiana and region.

The Kiana School is administered by the Northwest Arctic Borough School school district and provides K-12 education for about 112 students. The health clinic is operated by Maniilaq Association and staffed by about eight employees including three certified community health aides. For more advanced health care, residents fly to the Maniilaq Health Center in Kotzebue, or to the Alaska Native Medical Center in Anchorage. The community acquires well water from two wells located along the Kobuk River and a piped re-circulating water system serves approximately 73 homes plus public buildings and businesses. Approximately 19 homes haul water and use honey (sewage) buckets (DCCED 2011). The landfill, recycling and backhaul services are operated by Kiana Traditional Council.

"People are just wasting gas. Someone got a few caribou way up river. But gas is like $6.00 per gallon. You need two jobs to pay for it."

Tori Johnson

CLIMATE

Observed change: *more variable weather, warmer in every month; more precipitation.*
Health concerns: *extreme weather injury, and illness related to environmental change.*
Potential adaptation: *improve local weather observations and capacity for climate analysis.*

The climate in Kiana is getting warmer and wetter. Climate is a measure of long term weather trends, rather then the conditions that we experience each day. Over the past 50 years, Alaska has experienced temperature change and warming at more than twice the rate of the rest of the United States. The annual average temperature in Alaska has increased by 3.4°F, with winters warming by 6.3°F (Fitzpatrick et al., 2008). Average annual temperatures are projected to rise another 3.5°F to 7°F by the middle of this century (U.S. Global Change, 2009).

Thin ice raises concerns about winter travel..
Mike Brubaker, 2010.

"It is dangerous when the ice is thin, We can only travel on the ice now between December and April. In some places the river is not freezing at all."

Jackie Johnson

Kiana is located in a transitional climate zone. Residents report summers that are increasingly hot and dry, and winters that are more variable with sudden and dramatic temperature swings. Air temperature is increasing, and is thought to be warmer today than records from the recent past that averaged -10°F to 15°F during winter; and 40°F to 60°F during summer. In Kiana, temperature extremes have been recorded from -54°F to 87°F, with the lowest temperatures occurring during January and the highest in July. Snow fall has typically averaged about 60 inches per year. Annually precipitation is increasing and now is thought to be exceeding the conventional annual measure of 16 inches per year. The wettest month is August and the driest is May.

Down-scaled temperature and precipitation data and computer model-generated projections are available for Kiana (SNAP, 2011). Comparing two periods: 1961 to 1990 and 2001 to 2010 (see Figure 3 and 4) average temperature increased in every month of the year, with the biggest increase in winter; January temperatures increased by about 4°F. Kotzebue temperatures from the 1940s show an average annual increase of 3.2°F; with the greatest increase (6.8°F) occurring in winter (Shulski, 2007). Precipitation shows increases year round, with the biggest

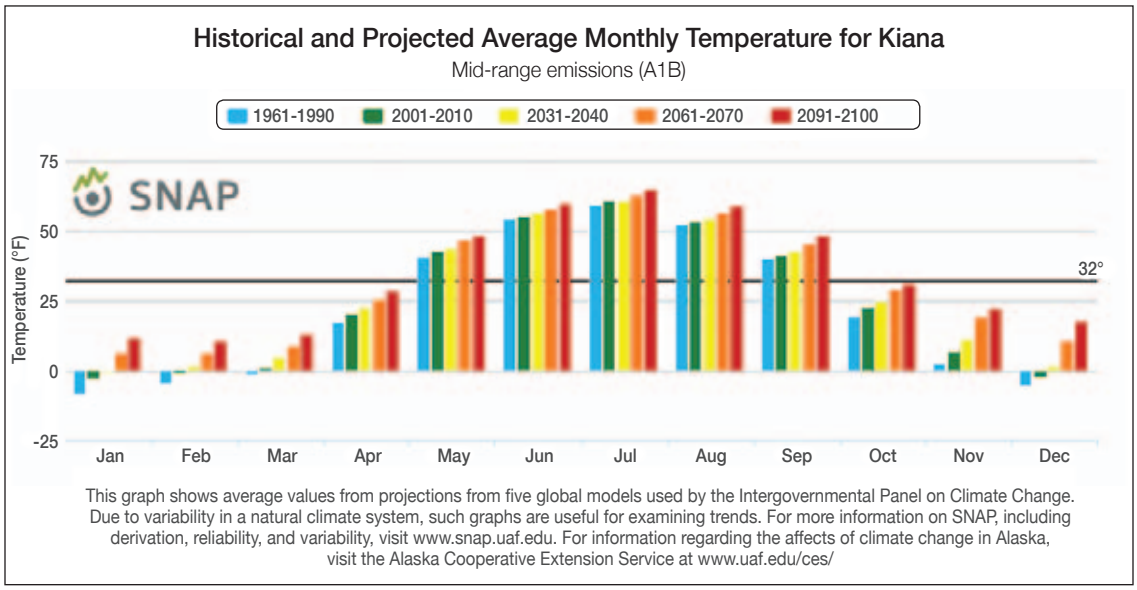


Figure 3. Historic & Projected Temperature,Kiana, Alaska.
UAF, Scenario Network for Alaska Planning 2010.

"In February of 2008 there was a snow storm with lots of wet snow. We lost two boys who were on a snowmachine trip."

Gloria Shallabarger

increase occurring in the fall. Between 1961 and 2010, precipitation increased in every month except July. Projections through 2040 are for continued precipitation increases except in May, June, September and October (SNAP 2011).

Despite higher annual precipitation, a generally drier summer is expected because of increased temperature, evaporation and transpiration, and decreased precipitation. Seasonally, weather has been variable. The summer of 2010 was hot and dry, while 2011 was wet and cold. One question not currently considered by climate models is whether the future will bring more snow or less. Snow depth is important for many reasons including winter travel. Developing snow projections is difficult, as daily precipitation data is not currently collected in Kiana.

Recommendation: Residents rely on local knowledge to make decisions about where and when to travel. They also rely upon forecasts generated by the National Weather Service. Having daily precipitation measures would improve weather forecasting and climate change monitoring. National Weather and Climate services can assistance by increasing resources, capacity and data for community weather observers, and regional climate change analysis.

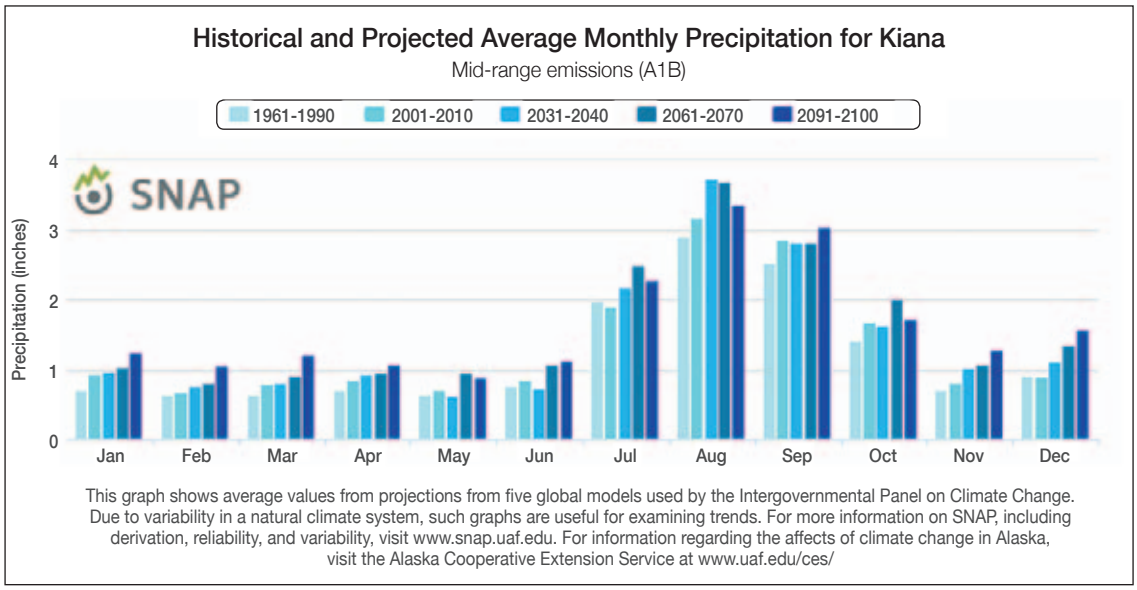


Figure 4. Projected Average Monthly Precipitation, Kiana, Alaska.
UAF, Scenario Network for Alaska Planning 2010.

"We have had rain in the dead of winter. The elders say that it is bad for the caribou."

Thomas Jackson

Garden in Kiana.
Mike Brubaker, 2010.

"The turnip, cabbage and lettuce in my mother's garden are really doing well."

Thomas Jackson

AIR

Observed change: *hot and dry summers; increased wildfires; changing plant species.*
Health concerns: *respiratory ailments aggravated by smoke, dust and potentially allergens.*
Potential adaptation: *fire and road dust management and air quality advisories.*

Air quality is affected by road dust, pollen and smoke from wildfires.

These three categories of air pollutants can increase risk of respiratory ailments, incite asthma and acute bronchitis, and compromise people with respiratory disease. Historically, wildfires were rare in the Northwest Arctic, but between 1950 and 2007, the number of wildfires increased significantly (Joly et al., 2009). More than 10.5 million acres of boreal forest and tundra were burned. Big fires events that typically occurred every 10 years, have been occurring every five; the result of drier summer conditions, more frequent lightening strikes, and an increase in woody plants (Duffy et al. 2005). Residents in Kiana have observed an increased in fire activity and an increase in the regional demand for fire fighting services. Concern about the health effects of smoke from wildfires was expressed by several residents.

Dust is an on-going problem in Kiana and in most other communities in the Northwest Arctic, aggravated in recent years by the increasing use of motor vehicles. In 2001, the State of Alaska Department of Environmental Conservation tested the air quality in Kiana and five other Northwest Arctic communities: Ambler, Buckland, Kotzebue, Noatak and Noorvik. All six had summer dust levels that exceeded the EPA national standard for particulates. This is unhealthy, because dust contains man-made and naturally-occurring pollutants that can be inhaled into the lungs (Battigelli 1969). Inhaled dust can aggravate heart or lung-related conditions such as asthma; particularly in the elderly, infants, or others with respiratory conditions (Weisskopf, 1991). Studies of road

Road dust in Kiana.
Mike Brubaker, 2011.

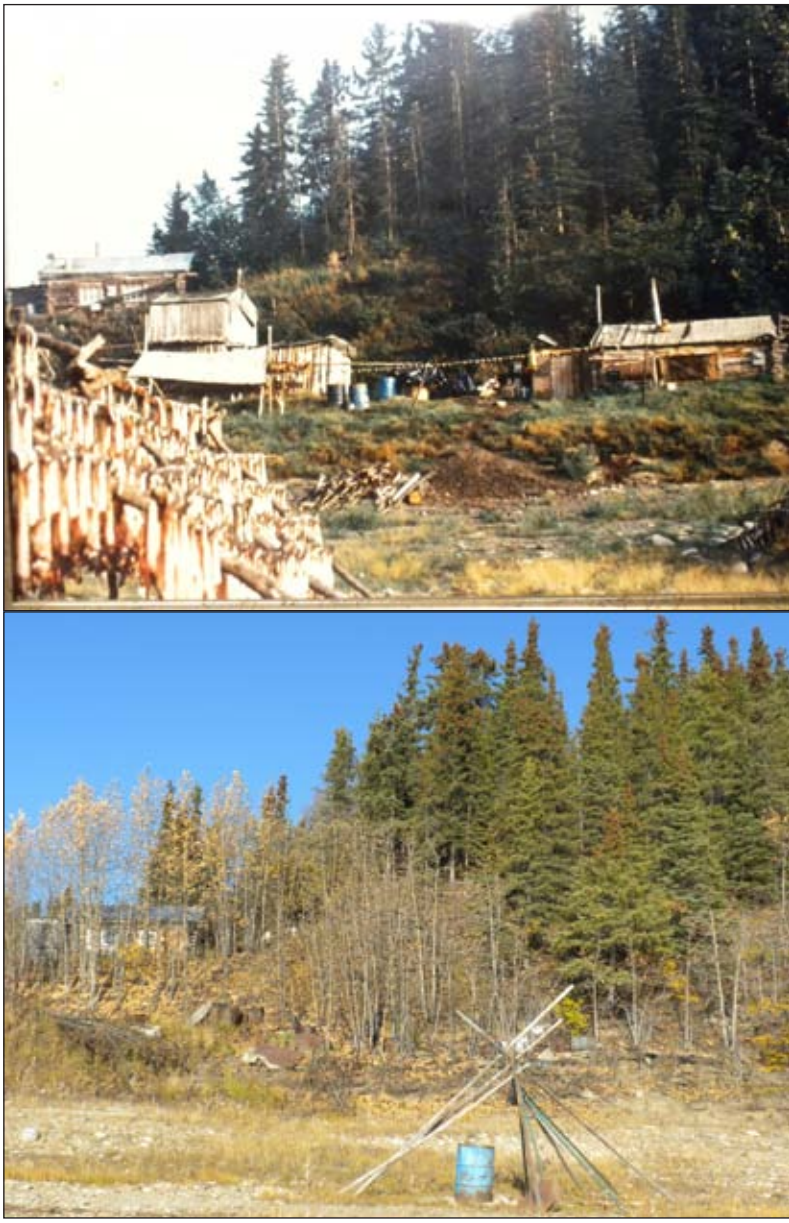
"Putting pine tar on the roads really helped with summer dust."

Thomas Jackson

dust have documented anecdotal evidence of increased visit to regional hospital during high dust periods (Trost, 2003).

How climate change may affect future dust levels in Kiana is uncertain. Studies performed in Kotzebue and Noatak found that the harmful dust levels exceeded federal standards during early May and late July (Withycombe and Dulla, 2006). Increased precipitation could change the timing of the dust season or change the number of dusty days. Short term (20-30 year) climate models for Kiana project hotter and dryer conditions during the dry season, except in July when rain is projected to increase. The Alaska Department of Transportation is currently testing palliative chemicals to suppress road dust in Kiana. Residents have reported good results based upon the test suppressant applied during the summer of 2010.

Recommendation: Clinical staff can provide air quality advisories by VHF radio, when smoke or dust levels are high. Local monitoring of dusts, smoke, and pollen levels and tracking the number of "poor air quality days" is recommended. Sensitive individuals can minimize air quality – related health problems by staying indoors during smoky or dusty conditions. In some cases, vulnerable individuals need to be evacuated. Foods such as berries and fish and meat that are affected by dust can be rinsed before eating and water storage containers can be covered in dusty areas.



New tree species: Roger Attorak house in the 1950s and today.
Mike Brubaker, 2011.

"I only started having allergies since 1996, especially in the Spring. I never had allergies when I was a kid."

Gloria Shallabarger

LAND

Observed change: *rapid permafrost thaw; erosion; subsidence.*
Health concerns: *injury related to hazardous travel conditions; damaged infrastructure.*
Potential adaptation: *travel advisories, erosion prevention; ground temperature monitoring.*

Erosion and subsidence is causing damage to Infrastructure including homes and utilities. Permafrost refers to soil that has been continuously frozen for at least two years. The permafrost beneath Kiana extends to a depth of over 1500 feet (Yoshikawa, 2011). The surface layers thaw and re-freeze seasonally. If natural processes such as game trails or man-made processes such as construction disturb the vegetation, it can increase the active thaw layer (Shur et al., 2011). This can result in ponds, subsidence (sinking), or erosion at construction areas, roads and under buildings.

One of the most dramatic results of permafrost thawing has been the appearance of hundreds of "thermokarsts", areas where thawing permafrost result in land failure, slides, slumps and gullies. Large slumps have been documented along the Kobuk River (Jackie Johnson, personal communication) and in many other areas. Analysis of aerial photos taken since 1980 found an increase of 136 thermokarsts along the upper Noatak River (Balser, 2009). Thermokarsts conditions are expected to continue with implications for hydrology, vegetation, and wildlife (Martin et al., 2008). Warming and thawing of permafrost is associated with vegetation change. Over the past few years residents report rapid grass and tree growth including alder and willow.

Infrastructure in Kiana is being affected by thawing permafrost. Drainage ditches designed to handle seasonal overflow and storm water runoff are particularly vulnerable. Deep erosion ravines have developed on the southwest side of the runway and to the north of the sewage lagoon as the result of storm water runoff or wastewater discharges. Thawing has accelerated rapidly in these disturbed areas due to the warming conditions. Whereas the landscape around Kiana was once resilient to disturbance, now warming is making it fragile. Some homes have thaw ponds underneath them, and are regularly in need of leveling (Crystal Johnson, personal communication). Nearby lakes are also showing signs drying or draining, which could be a function of changes in the permafrost active layer.

"The south side of the runway has totally eroded."

Brad Reich

A soil temperature station was installed in April of 2006 by Dr. Kenji Yoshikawa of the University of Alaska, Fairbanks. At the time of installation, the thaw zone depth was about 15 feet, and the soil temperature at the station was about 15°F. Soil temperatures are projected to increase over the next 30 years but longer term monitoring will be necessary to determine specific temperature conditions and trends for Kiana.

Recommendation: Permafrost monitoring is recommended, especially in the vicinity of critical infrastructure including the water wells, water distribution mains, sewage collection mains, sewage lagoon, fuel tank farms, and homes. New infrastructure should be sited in stable land areas, built in a way to minimize permafrost disturbance, and designed to accommodate future projected conditions. Applying best practices for construction on permafrost is increasingly important. Leveling of homes, if performed regularly will help to prevent serious structural damage.

Erosion on the Kiana bluff.
Mike Brubaker, 2011. Prepared by ANTHC.

"There are houses on the bluff, right above the erosion. The homeowners will be very concerned."

Dale Stotts

RIVERS

Observed change: *less dynamic breakup; decreased water level; bank erosion; decreased navigability.*
Health concerns: *injury from travel accidents; food insecurity.*
Potential adaptation: *river observation system; river gauges; alternative transportation options.*

The Kobuk River is becoming wider, muddier, and increasingly shallow.

The Kobuk is a relatively pristine river that runs west for 280 miles along the southern Brooks Range, from Gates of the Arctic National Park, to the Chukchi Sea. It is fed by mountain snow melt and by outflow from Walker Lake, a remnant of glaciers past. The river basin is largely underlain by continuous permafrost which strengthens the river banks, slows channel migration, and reduces erosion. Because of this, the river is highly vulnerable to climate-driven warming and permafrost thaw (Durand, et al., 2011). Thawing is occurring all along the Kobuk, driven by warming air and water temperatures and changes to vegetation. As a result, the river is becoming wider and more turbid. It may also be affecting river depth and suitability of the river habitat for aquatic organisms.

A recent study of the Kobuk modeled climate change. The study predicted impacts to fish and invertebrate populations because of changes in spring break-up intensity, scour rate, and sediment deposition; and because of permafrost thaw driven increases in thermokarst activity, such as bank erosion and slumping (Durand et al., 2011). Thawing permafrost is causing bank erosion on the Kobuk. Ice can also be a major cause of erosion, but in recent

Low water on the Kobuk – September 2010.
Mike Brubaker, 2010.

"Fifteen years ago you could run a boat to Kobuk without worrying about hitting bottom. Now you have to use a jet boat, and carefully follow the channels."

Jackie Johnson

years Kiana has experienced a soft spring break up, thus limiting the scouring effect. The combination of rapid permafrost thaw and a hard spring break up can be especially destructive. In the spring of 2011, an upriver camp lost an estimated 30 feet of river bank (Dan Douglas, personal communication). Kiana is experiencing gradual erosion from a variety of causes (USACE, 2009). The barge landing and dock area are particularly vulnerable. Large boulders placed to protect the area, have been largely ineffective (USACE 2008).

Boat landing in Kiana.
Mike Brubaker, 2010.

Yet another factor on the river's condition is seasonal change. Past spring breakup events were typically dynamic, with ice breaking loudly into large chunks causing ice jams, flooding and scouring of the river bank. In recent years however, there has been more thermal breakup, the ice becoming soft and dissipating quietly and slowly. Historically the Kobuk River has been navigable from the end of May or early June through early October. Today, break-up is occurring earlier, and the freeze-up is later. This is decreasing the season for ice travel by snow machine. When the ice is thin residents worry about the safety of travelers.

Recommendation: Kiana's location on the bluff above the Kobuk River provides good protection from flooding. But the community is increasingly vulnerable to other impacts of river change. Residents are concerned about travel safety and food security. Observations of ice thickness, including when the ice is no longer safe for travel, may help to reduce injury. Kiana residents are encouraged to work with neighboring communities, agencies and the academic community to increase understanding about river change and effects on subsistence resources.

"Between here and Noorvik there are big places where the permafrost is melting."

Jackie Johnson

WATER

Observed change: *permafrost thaw, decreasing water quality, sewage discharge erosion.*
Health concerns: *water system damage or interruption; increasing risk from traditional sources.*
Potential adaptation: *treat drinking water, monitor permafrost, prevent sewage discharge.*

Permafrost thaw is reducing water quality and damaging water and sewer infrastructure. Water is changing, both in the type of precipitation and in the way water is moving through the landscape. Reduced winter snowpack, rapid spring thaw, reduced summer precipitation, and warm summer temperatures impact the amount and movement of water into the area, and through the Kobuk River watershed. The average air temperatures have been increasing in every month of the year since at least 1961 (SNAP, 2011). Also periods of extreme summer heat have occurred, resulting in a deeper ground thaw. Warming and seasonal thaw are making the land more vulnerable to disturbance, and increasing the frequency of thermokarsts, bank erosion and turbidity (Balser et al. 2009). Warming is also increasing levels of organics in surface water as thawed soil releases stored carbon and nutrients as well as sediments (Bowden et al. 2008). Climate change is also resulting in new challenges for public water supply. The City of Kiana is encountering system failures due to permafrost thaw and buried breaking pipelines. Residents using time honored traditional water sources at subsistence camps may be facing increased risk of waterborne illness.

The Water System

Kiana has two wells: No. 1 at 98 feet deep and No. 2 at 119 feet deep. Together the two wells produce about 45 gallons of water per minute (gpm), a year round supply for the community. The wells are located approximately 850 feet from the water treatment plant and 200 feet from the estimated ordinary high water line of the Kobuk River. Raw water from the well was analyzed in 1999 and determined to be groundwater and not "groundwater under the direct influence of the Kobuk River".

Raw water from the wells is pumped to the water treatment plant through 850 feet of insulated high-density polyethylene (HDPE) pipe. The water is disinfected using chlorine and injected with polyphosphate to sequester manganese. The treated water is stored in a 212,000 gallon water storage tank adjacent to the water treatment plant. The current vulnerability of the water plant and storage tank to permafrost thaw is thought to be low. Installation

"Last year I had to change some old water lines, because they settled. I think it was caused by melting permafrost."

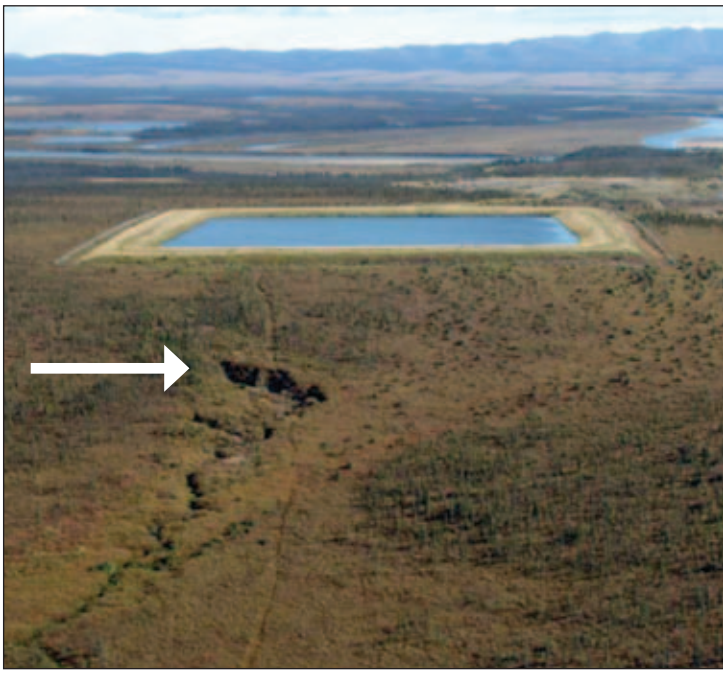
Rollyn Jackson

of buried soil temperature sensors would allow for long term monitoring of permafrost soil temperatures, and could detect developing problems before any serious structural damage occurs.

Once water is treated, it is pressurized, heated and pumped through two buried circulating loops, the East Loop and the West Loop. Recently, ANTHC has added the teacher housing service line to the distribution system. The majority of distribution lines are buried underground and provide water to approximately 117 service connections including homes, the clinic, school, store, post office, and city and tribal council office. Within the last decade more than a dozen water main breaks/leaks were observed and repaired along the east and west water main loops. These have mainly been attributed to thawing permafrost and PVC pipes that are vulnerable to breaks due to ground movement. In 2010, upgrades and replacements to PVC pipelines were made in several sections of the East Loop. ANTHC plans to complete the Willow Street sewer upgrade and remaining water line upgrades during the 2011 construction season.

The Wastewater System

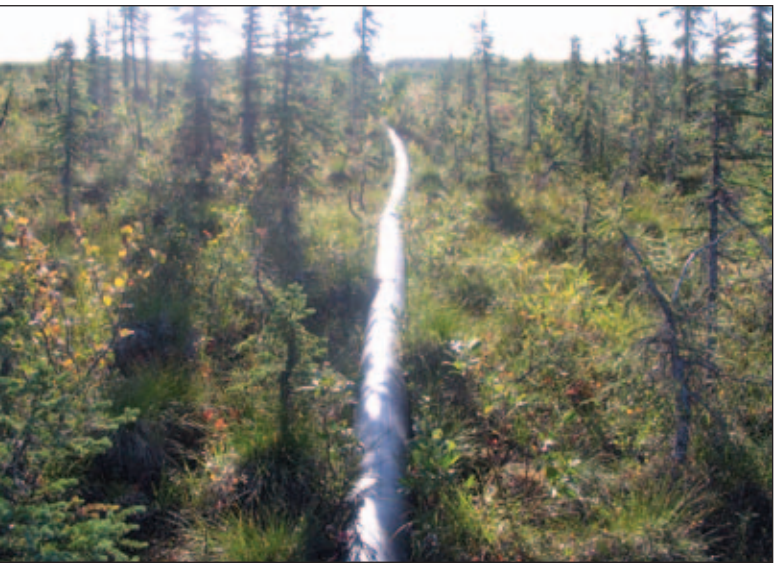
Kiana has about 80 homes that are served with piped water and sewer. The gravity collection system is approximately 8,000 feet in length and terminates at a settling tank and lift station. Clarified wastewater is pumped to a lagoon located approximately one mile away and 240 feet above the lift station. Over the last few years, some sagging of the gravity sewer mains were observed in the north part of the town (especially along Willow St. and along dumpsite road) requiring some flushing. Sagging and broken mains are allowing leaks into the sewer system. The sagged part of the section (along Willow St.) has been replaced and the cause has been attributed to subsidence of the pipelines caused by melting permafrost (Brad Reich, personnel communication). Sewer force main cleanouts along dumpsite road have sustained visible damage due to melting permafrost and need to be repaired. At least one force main cleanout has broken with warm sewage pooling around the structure resulting in increased



Aerial image of ravine 2007.
USACE.

"When we siphoned water from the sewage lagoon it started to form a gully. Now with the rain and the warming, it just keeps getting bigger."

Rollyn Jackson



Lagoon discharge line.
Mike Brubaker, 2011.

Erosion ravine, September 2010.
Mike Brubaker, 2011.

permafrost thaw and subsidence. The lagoon has a siphon for discharging onto the tundra through a 350 foot pipeline. The state permit allows for annual discharge in the fall after wastewater sampling and testing confirm that water quality met standards. In 2003, the discharge of relatively warm effluent eroded vegetation cover and exposed permafrost, creating a gully along the flow path. Seasonal thawing has increased the trench into a ravine measuring approximately 15 ft. deep, 15 ft. wide, and a several hundred feet long. The ravine is visible in satellite images and is increasing in size each year. Similar observations were made at the southwest part of the runway where a storm water ravine has formed. In both locations, removal of vegetation and exposure of permafrost has accelerated ground thaw from warm weather, rainfall, and effluent discharge.

Traditional Water Sources

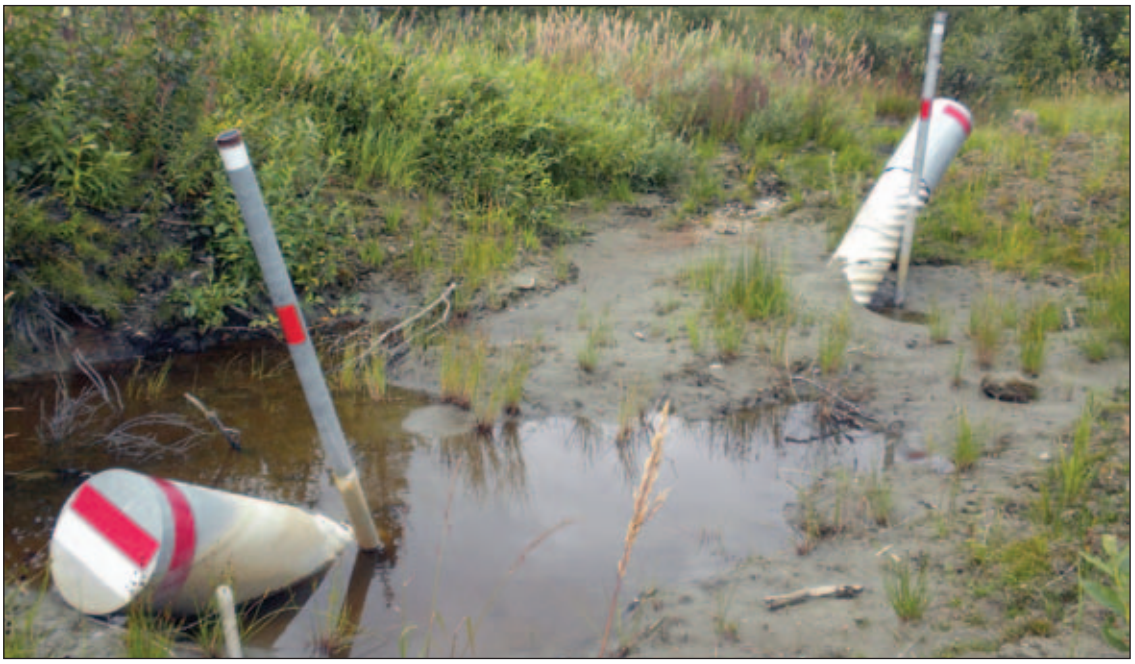
The Kobuk and Squirrel rivers are used as traditional sources of water meaning that people collect water and drink it untreated. This is a common practice in subsistence fishing and hunting camps located up and down river, and less commonly for domestic water in the village. Traditional sources have been used for thousands of years without concern for water safety. However, in recent years Kiana residents have reported increases in the population of beaver in many small tributaries that feed the Kobuk River. This may be related to warming and the growth of more trees along the river. Beaver are among species known to carry giardia lamblia, microscopic protozoa that

"There used to only be beaver up river by Shungnak. Now they have moved all through the river and plugged up the sloughs."

Jackie Johnson

enters the water in animal feces. Muskrats, foxes, musk oxen and people are also known to carry giardia. If ingested, giardia can cause an unpleasant and sometimes serious infection in the small intestines. Proper water treatment prevents exposure to giardia. For residents who are drinking raw water from the Kobuk River, and other traditional sources, giardiasis may be increasing as a health risk.

Recommendations: Permafrost thaw has resulted in damage and breaks to the water distribution and sewage collection systems. Replacement with more durable pipe is on-going. Buried soil temperature sensors near critical infrastructure such as the sewage lagoon and water storage tank would help to monitor soil conditions and to detect potential for subsidence and related structural damage. An alternative that prevents soils erosion should be considered for the system used to siphon sewage from the lagoon. All construction should apply best practices to prevent damage to tundra and permafrost. Users of water from traditional sources can prevent waterborne illness by treating water prior to use.



Sagging sewer main clean outs.
Mike Brubaker, 2011.

"There is erosion next to the sewer main line. One of the clean-outs is sinking."

Linda Stotts

FOOD

Observed change: *decreased harvest, increased cost of subsistence and market foods.*
Health concerns: *increased risk of foodborne illness and food insecurity.*
Potential adaptation: *regular harvest surveys; improve access to food; expand local gardening.*

Changing subsistence harvest raises concerns about food security.

In Kiana, the most important subsistence species are caribou, chum salmon, whitefish, moose, sheefish, burbot, pike, blueberries, coho salmon and bearded seal. In 2006, the average household harvested over 1200 lbs per year of just these ten species. Over 50 varieties of other plants and wildlife were also harvested (Magdanz, et al., 2010). Given the high cost of store-bought foods, a significant decline in any one of these primary sources of food raises serious concerns. A box of milk in Kiana costs $4.79, a dozen eggs is $4.99, and a loaf of Wonder bread is over $5.00.

The most important food resource in Kiana is caribou. In 1999 the average household was harvesting 690 lbs per year. But over the past decade, caribou in several Northwest Arctic communities including Kiana has become less reliable and more difficult to harvest. The reason is uncertain, but climate change is one important potential factor. In 2006 average household harvest had declined to 438 pounds. The 2010 fall caribou season was a disaster with many household harvesting no caribou at all.

Dead chum salmon.
Mike Brubaker, 2011.

"When I was a kid, we would get one or two humpies (pink salmon) in our nets each season. Now we get 4-6 per day. We think the water temperature is causing the chum salmon to die upstream."

Thomas Jackson

Caribou drying at an upriver camp.
Mike Brubaker, 2011.

Kiana hunters made dozens of scouting trips up-river with little luck and at significant cost. By early October no caribou had arrived in the area and with the river beginning to freeze, hunters started looking for alternatives; mostly moose and whitefish. Kiana residents are adapting their harvest and eating practices in order to fill the freezer. Whether the outcomes are healthy or not, depends largely on the type and quantity of food being substituted; moose and fish are healthy alternatives, but some of the available store bought foods are not.

Along with the nutrition and economics, the traditional way of life has many cultural and social benefits. The diet is extremely healthy, providing protection against cardiovascular disease, hypertension, type 2 diabetes, stroke, obesity, osteoporosis, and some cancers. It also provides a wide range of essential micronutrients including iron and vitamins A, D, and E

"If I have to go after a moose, I will. I prefer caribou."

Thomas Jackson

(Bersamin et al., 2007). Subsistence activities can involve considerable risk, but they also provide significant mental health benefits and are the most important source of physical exercise.

The interruption of an important harvest season also raises concerns about food security. Food security means having nutritious foods and not having to live in hunger. No food security data was found for Kiana, but a 2007 household survey in Noatak found that 18% of the population was reporting low food security, as opposed to the all U.S. rate of 11% (Magdanz et al. 2007). For some upriver communities like Noatak, the high cost of transportation (by air or small boat) and fuel cost are the primary factors affecting the price of market foods. Kiana pays lower costs in comparison, due to the regular barge service. On the topic of food acquired from the subsistence harvest, 11% of households in Noatak reported food insecurity and 42% reported not getting enough land mammals, in particular caribou. The most common reasons were distance from the community, scarcity, and changing caribou migration routes. The highest time for food insecurity was during the migration of the Western Arctic Caribou Herd.

Changes in the weather, the river, land and seasons are making subsistence harvest more difficult, more unpredictable and more expensive. Residents reported a shorter season for drying fish. Some residents had to throw fish away because of warm conditions had caused them to spoil. Traditional practices of putting white fish away to age are being abandoned because warm temperatures cause the fish to spoil. More pink salmon are showing up in seine nets, and fewer chum salmon, which residents believe may be related to water temperature. Temperature can also effect fish populations, optimizing conditions for some species, and marginalizing conditions for others. The outcome can be stress that makes fish and wildlife vulnerable to predation and disease.

In a warmer climate, methods for traditional food preparation and storage may be less effective in preventing the growth or introduction of pathogens that cause illness. Sensitive members of the population including pregnant women, infants, the elderly, and those with weakened immune systems are at higher risk for infections that result from eating diseased wildlife, or contaminated food. But taking a few precautions can help prevent food borne disease. On a positive note, a longer growing season is improving conditions for gardening. Some Kiana residents reported increasing success in their vegetable gardens, suggesting attractive new ways for increasing local food security.

"Some people had to throw out a bunch of fish because of how warm it was this summer."

Ruth Sandvik

Recommendation: Kiana residents can exercise care in the preparation and storage of wild foods, especially fermented foods, as there is a clear relationship between temperature and pathogens such as botulism. Foodborne diseases can be prevented by taking precautions such as wearing gloves when harvesting game, thoroughly cleaning cooking surfaces, and by cooking meat adequately prior to consumption. Improved surveillance is recommended to determine levels of disease in subsistence resources. Based on the changes in caribou harvest occurring in the region, a follow up harvest survey is recommended. Condensed harvest surveys would be necessary to monitor harvest conditions on a regular basis.

Anita and Jackie Johnson and their grand daughter.
Mike Brubaker, 2011.

"We don't know what is going on with the caribou migration. They are late again."

Anita Johnson

CONCLUSION

Public health considers climate change based on effects to mental health, injury, disease, infrastructure and food and water safety and security. In Kiana, climate change is increasing the risk of injury related to ice travel on the Kobuk River and damaging infrastructure as a result of permafrost thaw. Climate change may also be increasing vulnerability to food insecurity by contributing to decreasing harvest, and shortening the season for preserving some types of food. This report raises awareness about current, emerging, and potential future climate change. It is hoped that this will help Kiana make informed planning decisions, find community appropriate development strategies, and pursue a safe, healthy, and sustainable future.

For more information, contact the Center for Climate and Health by e-mail at akaclimate@anthc.org or by phone (907) 729-2464.

It is hoped this report will help Kiana make informed planning decisions, and find community-appropriate development strategies.

Figure 6. Climate Change Health Assessment Findings, Kiana, Alaska

Topic	Observation	Impact	Potential Health Effect	Adaptation / Recommendation
Climate	Increased temperature since the 1950s, mostly in winter.	Warmer in every month. Spring ice thaw, rather then "break up." Dry summer conditions.	Spring – ice related injury Summer - heat injury. Fall – ice related injury Winter – cold injury	Travel advisories. Locator beacon loaner program for travelers. Assess buildings for heat hazards.
Air	Hot summer temperatures and low precipitation.	Dry vegetation, increased lightning strikes, wildfire, and dust.	Increase respiratory problems due to smoke, dust and allergens.	Dust suppression. Air quality monitoring. Evacuation of sensitive individuals as needed.
Land	Erosion and subsidence related to permafrost thaw.	Uncontrolled erosion.	Damage to infrastructure. Interruption of services.	Monitor erosion rate and permafrost conditions.
River	Decreased water level in some years. Increased water temperature.	Decreased navigability. Increased erosion. Poor ice conditions.	Increased risk of injury. Increased cost of living. Mental stress.	Travel advisories. Study factors contributing to river change.
Water	Increase in disease vectors. Permafrost thaw, erosion, subsidence.	Lower water level in wells. Lower water quality. Interruption of water services.	Exposure to waterborne disease. Increased cost for operation and maintenance.	Monitor wells. Treat water from traditional sources. Prevent runoff related erosion.
Food	Changing climate, seasonality, and environment.	Change in subsistence timing, quality and availability. Seasonal change in harvest and preservation.	Decreased food security and safety. Potential for increase in acute and chronic disease with food quality or dietary change.	Regular harvest survey updates. Surveillance of wildlife for disease. Improve food delivery system. Dietary surveys.

Overlooking the Kobuk River.
Raj Chavan, 2011.

APPENDIX A

Community and Regional Contributors

Anecdotal data was collected on observations and experiences from local experts in health, wildlife, Inupiat culture, weather, subsistence, education, sanitation, local governance, law enforcement, and emergency services.

	Topic Reference	Position	Name	Association
1	Health / Clinic	Health Aide / CHAP	Thomas Jackson	Maniilaq
2	Health / Clinic	Health Aide / CHAP	Lorena Walker	Maniilaq
3	Health / Clinic	Health Aide/ CHAP	Tori Johnson	Maniilaq
4	Health / Social	Family Assistant	Ely Cyrus	Maniilaq
5	Education	Principal (Acting)	Jim Stewart	NWASD
6	Education	Teacher	Janice Westlake-Reich	NWASD
7	Education	Teacher	Miss Harris	NWASD
8	Youths	Students 2nd,3rd, 5th, 6th	Kiana School	NWASD
9	Youth	Student	Kaelyn Stalkero	Resident
10	Elder	Elder	Ruth Sandvik	Resident
11	Elder	Elder	Roger Atorak	Resident
12	Environmental	Coordinator	Linda Stotts	Kiana IRA
13	Environmental	Coordinator	Jennifer Ipalook	Resident
14	Environmental	Grant Writer	Dale Stotts	Kiana IRA
15	Environmental	Coordinator (former)	Anita Johnson	Resident
16	Environmental	Regional Coordinator	Millie Hawley	Maniilaq
17	Environmental Health	Water Operator (former)	Rollyn Jackson	Resident
18	Environmental Health	Water Operator	Dustin Lee	City of Kiana
19	Environmental Health	Water Operator	Robert Attorak	City of Kiana
20	Environmental Health	Construction Manager	Roger Fuiten	ANTHC
21	Environmental Health	Engineer / Project Manager	Eric Hanssen	ANTHC
22	Environmental Health	Regional Director	Paul Eaton	Maniilaq
23	Environmental Health	Remote Maint. Operator	John Monville	Maniilaq
24	Governance	Mayor	Brad Reich	City of Kiana
25	Governance	Tribal Council President	Jackie Johnson	Kiana IRA
26	Governance	Tribal Administrator	Gloria Shallbarger	Kiana IRA
27	Governance	City Administrator	Crystal Johnson	City of Kiana
28	Governance	Tribal Council	Thomas Jackson	Kiana IRA
29	Governance	Tribal Council	Arlene Richards	Kiana IRA
30	Governance	Tribal Council	Dan Douglas	Kiana IRA
31	Natural Resources	Coordinator	Attamuk Sheidt	Maniilaq
32	Subsistence	Fish	Roselyn Jackson	Resident
33	Subsistence	Caribou	Raymond Stone	Resident
34	Subsistence	River (plants/ birds/ caribou)	Jack Johnson Sr.	Elder
35	Public Safety	VPO	Vernen Aturok	Kiana IRA
36	Public Safety	VPO	Mabel Gooden	Kiana IRA
37	Transportation	River Pilot	Saide Ahmed	Crowley
38	Community	Resident	Lori Atoruk	Resident
40	Subsistence	Bird hunting	Lawrence Morris	Contractor

APPENDIX B

Kiana Climate and Health Web Resources

Topic	Resource	Location
Kiana Profile	State of Alaska Community Database	http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.htm
Kiana Erosion Data	USACE Community Erosion Report, 2009	www.poa.usace.army.mil/AKE/Home.html
Kiana Permafrost	UAF Permafrost Laboratory	www.gi.alaska.edu/snowice/Permafrost-lab/
Kiana Flood Data	USACE Flood Hazard Database	http://www.poa.usace.army.mil/en/cw/fld_haz/Noatak.htm
Kiana Temperature Precipitation Projections	Alaska Center for Climate Assessment & Policy	www.uaf.edu/accap/
Kiana Climate and Health Impacts Reports	ANTHC, Center for Climate and Health	www.anthc.org/chs/ces/climate/links.cfm
Local Weather Observations	NWS Extreme Weather Spotter Program	http://www.weather.gov/skywarn/ Contact: Harry Lind, NWS in Kotzebue (training & equipment).
Local Weather Observations	Community Collaborative Snow Rain and Hail Program	http://www.cocorahs.org/ Contact: Harry Lind, NWS in Kotzebue.
Regional Climate Data	Temperature and Precipitation Data, Kotzebue 1930s-present	climate.gi.alaska.edu/
Regional Climate Data	Center for Global Change and Arctic System Research (UAF)	www.cgc.uaf.edu/
Regional Climate Data	Global Climate Research Center (Barrow)	www.arcticscience.org/
Regional Climate Data	Google Earth climate impact layers	earth.google.com/intl/en/index.html
Regional Weather Data	Extreme Weather Watches, Warnings Advisories, National Weather Service	www.arh.noaa.gov/
Regional River Flood Data	Advanced Hydrologic Prediction Service National Weather Service	http://aprfc.arh.noaa.gov/ahps2/index.php?wfo=pafg3
Regional Health Data	Maniilaq Association, Kotzebue	www.maniilaq.org/
Regional Health Profile	Alaska Native Tribal Health Consortium EpiCenter	www.anthc.org/chs/epicenter/upload/Regional_Health_Profile_Maniilaq_0408.pdf
Federal Climate Response	Alaska Climate Change Response Center	http://alaska.usgs.gov/
State Climate Response	State of Alaska Climate Strategy	www.climatechange.alaska.gov/
Community Based Monitoring - Coastal	National Weather Service Weather/Coastline Observer Program	www.nws.noaa.gov/om/coop/index.htm
Community Based Monitoring - Diet	Nutritional and Food Security Baseline Survey	www.anthc.org/chs/epicenter/upload/traditional_diet.pdf
Community Based Monitoring – Seasonality	U.S. Geological Survey-National Phenology Network	www.usanpn.org/
Community Based Monitoring – Wildlife	National Oceanographic and Atmospheric Administration – Marine Stranding	www.fakr.noaa.gov/protectedresources/strandings.htm

APPENDIX C

General Climate Change Adaptation Guidelines

Local and regional government is challenged with preparing for climate-related impacts, and the need to develop comprehensive adaptation plans. These basic principles are recommended for integrating climate change planning into local decision-making. Other principles may be developed by the community as residents engage in the planning process.

1. Protection of human life and health is the top priority.
2. Use traditional values as guidelines for local and regional decision making.
3. Follow the principles of sustainability "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).
4. Identify valued local resources, such as subsistence areas, cultural sites, critical water sources, and develop plans to protect them.
5. Protect critical ecological systems, wetlands, and subsistence resource areas.
6. Consider climate impacts on erosion, flooding, subsistence, water availability, and transportation in planning, and new infrastructure siting and design.
7. Apply cost benefit analyses when evaluating the social and environmental costs of building and maintaining protection structures.
8. Consider phased abandonment of at risk areas.
9. Natural disasters are inevitable and disaster response and recovery capacity, including evacuation routes, emergency response plans, drills, and shelters, should be reviewed.
10. Building capacity to participate in monitoring, research, and advocacy is critical to facilitate development of effective adaptation strategies.
11. Perform regular monitoring of vulnerable structures, systems and land areas to allow for timely maintenance and repairs.
12. Assess site vulnerability to climate impacts (flood, erosion, drought, permafrost thaw etc.) prior to new construction. Consider future climate conditions in engineering design.
13. Encourage best practices during construction to minimize disturbance of land in fragile permafrost and erosion vulnerable areas and restore or improve disturbed areas to minimize future impacts.
14. Encourage collaborative planning between development groups and projects to achieve compatibility between foundations, connections and operation and maintenance activities.

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Find this report and other information about climate and health at our website:
http://www.anthc.org/chs/ces/climate/index.cfm

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