Imperiled Community Water Resources Analysis

Prepared for

Immediate Action Workgroup
An Advisory Group of the Governor's Climate Change Sub-Cabinet

Prepared by

TETRA TECH

3200 Chapel Hill-Nelson Hwy, Suite 105 • PO Box 14409
Research Triangle Park, NC 27709

1400 Shore Drive, Anchorage, AK 99515

June 30, 2010

Cover Photo Credit: Photo courtesy of the City of McGrath taken in July 2003 from a boat on the Kuskokwim River with the Captain Snow Center in the background that houses the water treatment plant, public showers and laundromat, and other city offices. In 2007 the Captain Snow Center was 96 ft. 9 inches from the eroding riverbank. The city water storage tank is also visible in the photo. An estimated 5 ft. additional riverbank has eroded since 2007, bringing the Kuskokwim River ever closer to these important city facilities.

Funding Source:

Environmental Protection Agency, Water Quality Management Planning Grant, Section 604(b)

Funded by the American Recovery and Reinvestment Act of 2009

Table of Contents

Index of Tables

Index of Figures

(This page left intentionally blank.)

Executive Summary

Since the early 1980s, significant progress has been made in providing rural Alaska communities with safe drinking water and sanitary wastewater disposal by building affordable infrastructure. However, many of these communities are located near rivers and coastal waters, on which residents rely to support their subsistence lifestyles. Since these communities are sited close to these waters, their water and wastewater systems are often prone to flooding, erosion, and other natural hazards, whose impacts may be made worse in frequency and severity by the effects of climate change.

Climate change is increasing both average temperatures and precipitation across most of Alaska, which has impacts on water resources and water/wastewater infrastructure. For example, increases in average temperatures are degrading permafrost which both undermines existing infrastructure while potentially exacerbating erosion. The increased evapotranspiration associated with rising temperatures is projected to more than offset increased precipitation, leaving some communities with decreasing water supplies. Retreating sea ice leaves communities and their existing infrastructure more vulnerable to coastal storms.

In 2009, the *Immediate Action Work Group of the Governor's Subcabinet on Climate Change* (IAWG) identified six critically imperiled Alaskan communities along with recommended immediate actions to assist these communities. Also, a statewide baseline erosion assessment was also completed by the Alaska District of the U.S. Army Corps of Engineers which indicated that an additional 17 communities deserved priority action status with respect to coastal and riverine erosion threats.

The current analysis, described in this report, involved a *screening-level* assessment of potentially imperiled communities based upon documented and/or anecdotal climate-related threats to water resources and water/wastewater infrastructure, such as flooding and saltwater intrusion, loss of surface water supplies (permafrost lakes draining), erosion of critical infrastructure or surface water resources leading to sedimentation of potable water sources, and other potential impacts.

Risk analysis evaluates the probability, frequency, and severity of a threat and is a major factor in prioritizing communities according to their adaptation or mitigation needs. Unfortunately, sufficient data for a robust evaluation of risks are generally not available for the majority of these communities. Accordingly, additional work is needed to continue to collect necessary data, evaluate existing information and conditions in the field, and further refine analyses as necessary to prioritize communities for mitigation or adaptation actions. Due to its compressed timeframe and limited budget, this analysis should be viewed as only the first step in evaluating the climate-related risks to water resources and water/wastewater infrastructure, as needed to prioritize imperiled communities that need assistance.

This analysis included an initial cursory evaluation of the climate-related risks (primarily flooding and erosion) associated with 214 communities eligible for funding by the Alaska Department of Environmental Conservation (ADEC) Village Safe Water (VSW) Program. From this broad master list of communities, 26 communities were initially identified and designated as the study group. An additional 44 communities were also identified as having potential climate risks to water resources and water/wastewater infrastructure, but either initially had lower perceived threats or required additional information to more confidently assess those risks. The analysis was limited to second class cities and unincorporated villages managed by tribal councils and did not extend to first class cities.

Readily available information for the study group was collected using a combination of professional staff interviews, and reviews of online databases, written reports, community maps, and other information. Relevant information for each study group community was summarized in community profiles that document the climate-related risks to water resources and water/wastewater infrastructure across the following risk factors, which were loosely based on established IAWG community ranking methodology: Likelihood and Frequency of Impacts; Severity of Impacts; Historical Impact/Trends; and Mitigation of Impacts.

Based on this analysis, the following study group of 25 communities was identified as likely to face near-term climate change related impacts to their water and wastewater infrastructure.

- Alakanuk
- Aniak
- Atmautlauk
- Brevig Mission
- Buckland
- Chalkyitsik
- Chignik Lagoon
- Deering
- Diomede
- Emmonak
- Fort Yukon
- Golovin
- Gulkana
- Hughes
- Huslia
- McGrath
- Nelson Lagoon
- Noatak
- Quinhagak
- Saint Michael
- Selawik
- Stebbins
- Teller
- Venetie
- Wales

This analysis should be viewed as an initial step in identifying and prioritizing at-risk communities, rather than a definitive assessment. These initial community-specific characterizations should be refined through an iterative process where necessary additional information is collected and reviewed, and vetted with more analysis.

Recommendations are provided to help collect better data, measure local climate impacts, refine assessments, prioritize communities for action, and develop mitigation plans, where applicable. Specific recommendations include:

1. Supplementing this analysis with more detailed analysis
2. Collecting additional hydrologic data
3. Increasing permafrost monitoring
4. Adopting prevention and adaptation strategies for managing water and wastewater assets
5. Mitigating landfill and tank farm risk
6. Implementing relevant Adaption Advisory Group recommendations to the Governor's Climate Change Subcabinet

(This page left intentionally blank.)

1 Introduction

1.1 BACKGROUND

Challenges providing rural Alaskans with safe and reliable sanitation facilities and quality potable water began with modest efforts in the 1960s and 1970s by the Indian Health Service. The passage of the Village Safe Water Act in 1972 engaged state government in the process, yielding broad improvements in sanitation services and potable water supplies in many communities. However, even communities with established infrastructure face significant challenges managing their water and wastewater systems due to often inhospitable weather and the impacts of climate change, which are already causing widespread disruptions in Alaska.

In 2003, a congressionally-directed study (USGAO, 2004) found that 184 of 213 Native Alaskan villages (86 percent) are affected to some extent by flooding and erosion. The report stated that "while the problems are long standing, various studies indicate that coastal villages are becoming more susceptible to flooding and erosion due in part to rising temperatures" (USGAO, 2004).

Alaska has more than 33,000 miles of coastline, mostly inhabited by indigenous populations which depend on subsistence resources to maintain their livelihood and cultural integrity. Much of Alaska's coastline is impacted to varying degrees by erosion resulting from permafrost degradation exacerbated by increasing temperatures, exposing these indigenous communities to the impacts and continued uncertainties of a changing environment.

In 2006, the Alaska Climate Impact Commission was established by the Alaska Legislature to hear testimony and report on climate impacts. In 2007, the Alaska Climate Change Subcabinet was established by Governor's Administrative Order 238 (Palin, 2007) to advise the Office of the Governor on the preparation and implementation of Alaska's climate change strategy. Four climate change advisory groups were established (see http://www.climatechange.alaska.gov/index.htm for information on each of the groups):

- Adaptation Advisory Group
- Mitigation Advisory Group
- Immediate Action Work Group
- Research Needs Work Group

The Immediate Action Workgroup (IAWG) was established to address known threats to communities caused by coastal erosion, thawing permafrost, flooding, and fires. In their March 2009 report, *Immediate Action Work Group Recommendations to the Governor's Subcabinet on Climate Change*, the third of four recommendations for implementation in 2009-2010 included the following:

> *Identify the communities at risk, timeframe, and the true needs to address climate change impacts.* Once communities at risk are identified and the timeframe established before major damages/losses occur, recognize that communities in jeopardy under all plausible scenarios warrant special consideration.
>
> *Develop a methodology for prioritization of needs based on the risk to lives, health, infrastructure, homes, businesses, subsistence harvests, significant cultural attributes, and the quality of life.* Villages with declining populations, which already cannot support continuation of vital services such as a school, would likely be a lower priority than those which are likely to sustain viable communities during the foreseeable future.

> *Next, determine the true needs of coastal communities subjected to climate change impacts.* Do they require additional land for population growth; are coastal storm damages increasing to potentially catastrophic levels; is melting permafrost destroying the foundation for structures in the community; will sufficient numbers of future subsistence resources be available to sustain the community at its current location; when will key facilities (airport, power, school, water supply, etc.) be lost so the community could not continue to function with dignity; and, is the community frequently needing emergency declarations to cope with disasters and impending disasters? (IAWG, 2009)

Six communities were identified by the IAWG along with immediate actions that must take place over the subsequent 18-24 months to assist these communities. Studies completed since the establishment of the IAWG indicated that the number of imminently threatened communities is likely much higher than the communities originally identified; however a methodology for how these additional communities will be identified has not been developed.

A statewide baseline erosion assessment completed by the Alaska District Corps of Engineers in March 2009 indicated that an additional 17 communities deserved priority action status with respect to coastal and riverine erosion threats (USACE, 2009).

Another recent study evaluated climate change and health impacts in Point Hope, Alaska (Brubaker et al., 2009). Two public health concerns were identified in Point Hope: food security and water quality. First, permafrost that cools traditional underground food storage cellars is thawing, and there are no community alternatives for storage. The second issue, which aligns with the purpose of this study, is that warming is contributing to changes in Point Hope's community drinking water source. Temperature-influenced blooms of organic material have impaired source water quality and challenged treatment by clogging filters prematurely.

1.2 Scope of Current Analysis

The analysis described in this report involved a screening-level assessment of potentially imperiled communities based upon documented climate-related threats to water resources and water/wastewater infrastructure (hereinafter water resources and water/wastewater infrastructure will simply be called "water infrastructure"), such as flooding and saltwater intrusion, loss of surface water supplies (permafrost lakes draining), erosion of critical infrastructure or surface water resources leading to sedimentation of potable water sources, etc. The analysis approach used IAWG criteria as a basis for assessing the nature and extent of impacts to water infrastructure in imperiled Alaskan communities.

The three primary objectives of this analysis were to:

1. Identify and select study group communities whose water infrastructure is threatened
2. Collect information on the threatened water infrastructure for the study group communities
3. Analyze information to determine the climate-related impacts to study group community water infrastructure

The following IAWG criteria, in particular, were used to assess communities in the study group (IAWG, 2009): (1) life/safety risk during storm/flood events; (2) loss of critical infrastructure; (3) public health threats (as defined by CDC or Alaska's Regional Health Corporations); (4) loss of 10 percent or more of residential dwellings.

"*Community,*" as used in this report, refers to the Village Safe Water (VSW) Program definition of: (a) an *unincorporated community* that has between 25 and 600 people; (b) a second class city (no population limits); or (c) a first class city with not more than 600 residents. Sustainability criteria, particularly with regard to population thresholds as described in IAWG (2009) were also considered as a fundamental element of the community assessments. A study group of communities whose water infrastructure was initially thought to be threatened, primarily by flooding and/or erosion, was developed, and readily available data on the threatened water infrastructure in these communities was collected and analyzed to determine potential impacts. More detail is provided in Section 3 on the process for identifying study group communities for this project given its budgetary and scheduling demands.

In addition to documenting basic climatologic and water resource and infrastructure characteristics, four key factors were evaluated in an effort to assess the relative risks to water infrastructure in the study group communities: 1) likelihood and frequency of impacts, 2) severity of impacts, 3) historical impact to water infrastructure, and 4) mitigation efforts.

This report generally only considers those direct, climate-related impacts to water infrastructure. Other indirect impacts, including the effects of fuel spills on water supplies; landfills impacted by flooding and erosion; wildland or community fires; and naturally occurring source water quality changes are beyond the scope of this analysis.

(This page left intentionally blank.)

2 Climate-related Impacts on Water Infrastructure in Alaskan Communities

Ice, snow, and permafrost are prominent features of the Alaskan landscape. Over the past few decades, climate change has been warming and thawing the permafrost, and the Arctic sea ice has been retreating and growing thinner. The thawing permafrost is causing subsidence, which has resulted in damage to buildings, roads, and other infrastructure. In addition, sea ice reduction allows larger storm surges which have impacted coastal villages with severe flooding and erosion, thus destroying and damaging more infrastructure (Magee, 2007).

To understand the climate related impacts on water infrastructure in Alaskan communities, a brief discussion of the general geographic, hydrographic, and climatologic characteristics of the state is provided.

2.1 GEOGRAPHIC AND CLIMATOLOGIC OVERVIEW

Alaska is the largest and northernmost state in the United States. Its east-west span covers a distance of 2,000 miles, and from north to south, a distance of 1,100 miles. Its location as the westernmost extension of the North American Continent and its extensive coastline (over 33,000 miles of tidal shoreline) exposes Alaska's dispersed communities to a wide variety of climatological conditions (Figure 1**Error! Reference source not found.**) (Western Regional Climate Center, 2010). Alaska includes a wide range of physical, climatic, and ecological diversity in its rainforests, mountain glaciers, boreal spruce forests, and vast tundra, peatlands, and meadows. Relative to its size (approx. 586,412 square miles of land), Alaska is lightly populated (614,000 people) with a growth rate of about 1.5 percent per year. Direct human pressures on the state's land environment are relatively light. Diverse subsistence livelihoods, practiced primarily by native communities, depend on fish, marine mammals, and other wildlife, and play crucial social and cultural roles (US GCRP, 2010).

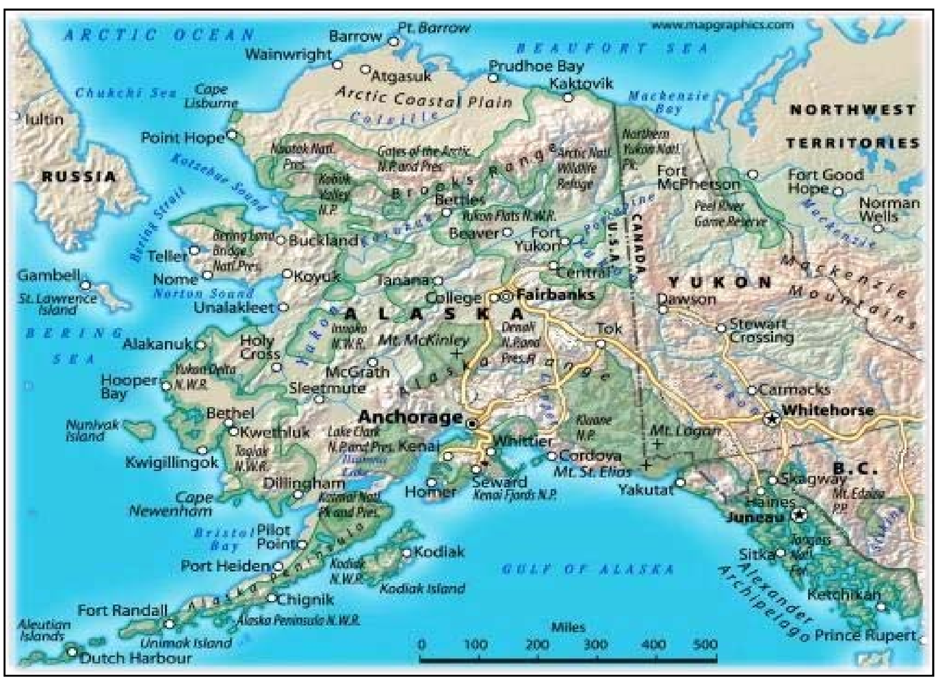


Figure 1 Geographic Map of Alaska (US DOT, 2010)

In addition to the prominent Aleutian Islands, hundreds of other islands, mostly undeveloped, are found along the northern coast of the Gulf of Alaska, the Alaska Peninsula, and the Bering Sea Coast. Alaska contains 375 million acres of land and many thousands of lakes. There are 12 major rivers plus three major tributaries of the Yukon, all of which drain two-thirds of the State. Four rivers, the Yukon, Stikine, Alsek, and Taku, can be classed as major international rivers (Western Regional Climate Center, 2010). The hydrography of Alaska is illustrated in Figure 2.

Figure 2 Hyrdography of Alaska

As shown in the physiographic map in Figure 3, Alaska's most significant mountain ranges are the Brooks Range, which separates the Arctic region from the interior, and the Alaska-Aleutian Range, which extends westward along the Alaska Peninsula and the Aleutian Islands, and northward about 200 miles from the Peninsula, then eastward to Canada. Other shorter but important ranges are the Chugach Mountains which form a rim to the central north Gulf of Alaska, and the Wrangell Mountains lying to the northeast of the Chugach Range and south of the Alaska Range. Both of these shorter ranges merge with the St. Elias Mountains, extending southeastward through Canada and across southeastern Alaska as the Coast Range. Many peaks tower above 16,000 feet; however, nearly all of the inhabited sections of the State are at 1,000 feet of elevation or less (Western Regional Climate Center 2010).

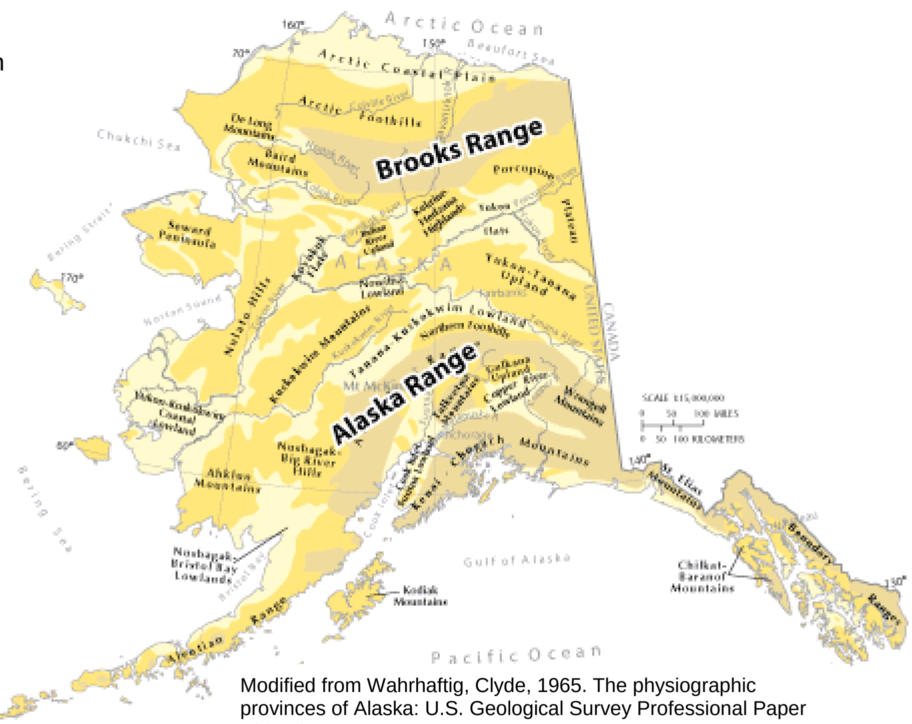
Figure 3. Large chains and ranges of high, rugged mountains in southern Alaska are separated from the Brooks Range in northern Alaska by wide areas of low mountains, plateaus, highlands, and lowlands. The lowlands are located primarily along the courses of major streams.

EXPLANATION

Lowland—Less than 1,000 feet above sea level

Low mountains, plateaus, and highlands—Summits from 1,000 to 5,000 feet above sea level

High, rugged mountains—Summits greater than 5,000 feet above sea level



Modified from Wahrhaftig, Clyde, 1965. The physiographic provinces of Alaska: U.S. Geological Survey Professional Paper 482, 52p.
Base modified from U.S. Geological Survey digital data.

Figure 3 Physiographic Divisions of Alaska (Pittman, 2010)

As illustrated in Figure 4, Alaska's climate can be subdivided into five major zones: (1) a maritime zone which includes southeastern Alaska, the south coast, and southwestern islands; (2) a maritime continental zone which includes the western portions of Bristol Bay and west-central zones; (3) a transition zone between the maritime and continental zones in the southern portion of the Copper River area, the Cook Inlet area, and the northern extremes of the south coast area; (4) a continental zone made up of the remainders of the Copper River and west-central divisions, and the interior basin; and (5) an arctic zone (Western Regional Climate Center, 2010).

Figure 4 Climatic Regions of Alaska (Alaska History & Cultural Studies, 2010)

2.2 TEMPERATURE AND PRECIPITATION

As shown in Figure 5, mean annual temperatures in Alaska range from the low 40s (ºF) under the maritime influence in the south to about 10 ºF along the Arctic Slope north of the Brooks Mountain Range. The greatest temperature contrast between seasons is found in the central and eastern portion of the continental interior. In this area, summer heating produces average maximum temperatures in the upper 70s (ºF) with extreme readings above 90 ºF. In winter, the lack of sunshine keeps average winter minimum temperatures approximately -20 to -30 ºF. In the maritime zones, by contrast, the annual range of average temperatures is from near 60 ºF to the 20s (ºF). In the transitional zone, average temperatures range from the low 60s to near 0 ºF; in the maritime-continental zones, the range is from the low 60s to -

10 ºF. Summer temperatures along the Arctic slope average 40 ºF. Daily minimums are below freezing 324 days a year. Mean annual temperature is 10 ºF (Western Regional Climate Center, 2010).

Winter temperatures play a principal role in the flow of most of Alaska's rivers. From autumn to spring, thick layers of ice often form and several rivers cease to flow completely during the coldest months (Western Regional Climate Center, 2010).

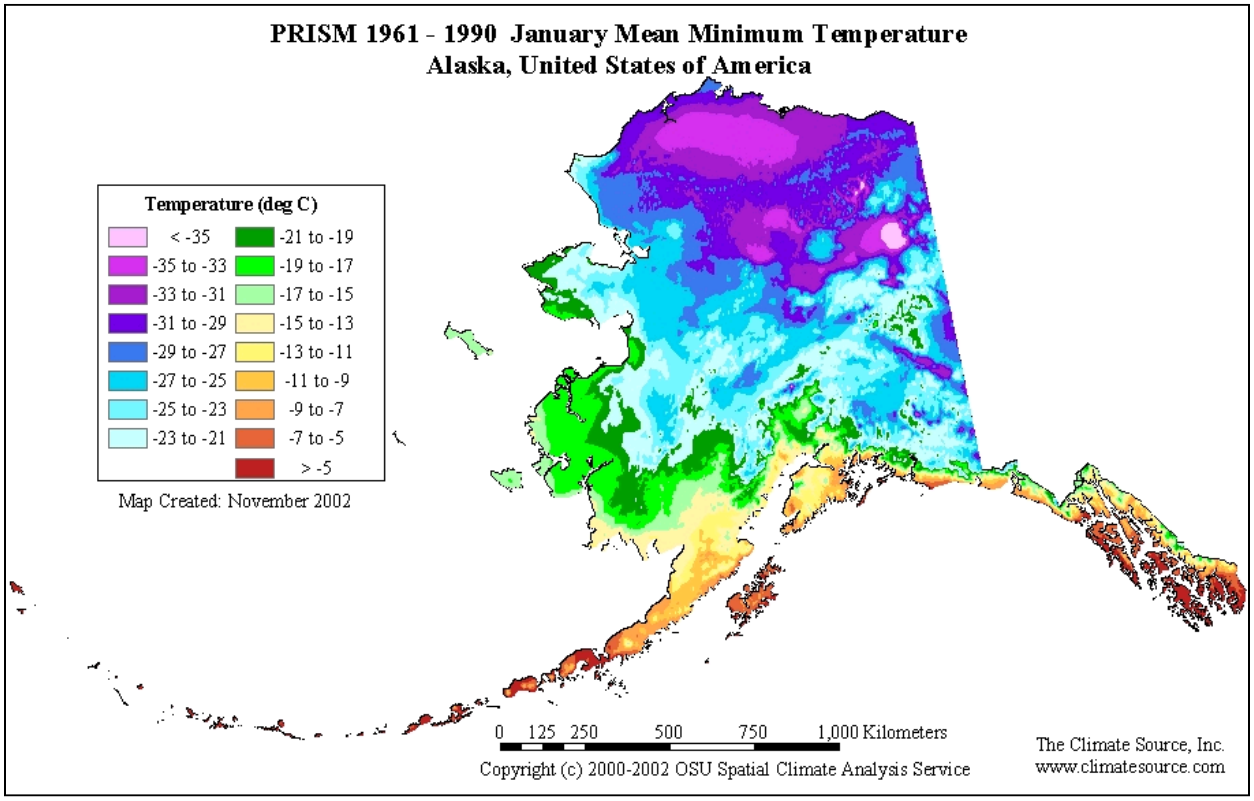


Figure 5 Mean Annual Temperature Map of Alaska (1961-1990) (Climate Source, 2010)

As illustrated in Figure 6 and Figure 7, Alaska has warmed substantially during the 20th century. Average warming since 1950 has been about 4 ºF (2 ºC). Seasonally, increases were highest in winter and spring and lowest in summer; fall was the only season in which slight decreases were observed. Much of this warming appears to have occurred during a sudden Arctic atmospheric and ocean regime shift around 1977 (USFWS, 2010). The greatest magnitude of warming over this period, about 7 ºF (4 ºC), has occurred in the interior in winter (USGCRP, 2010).

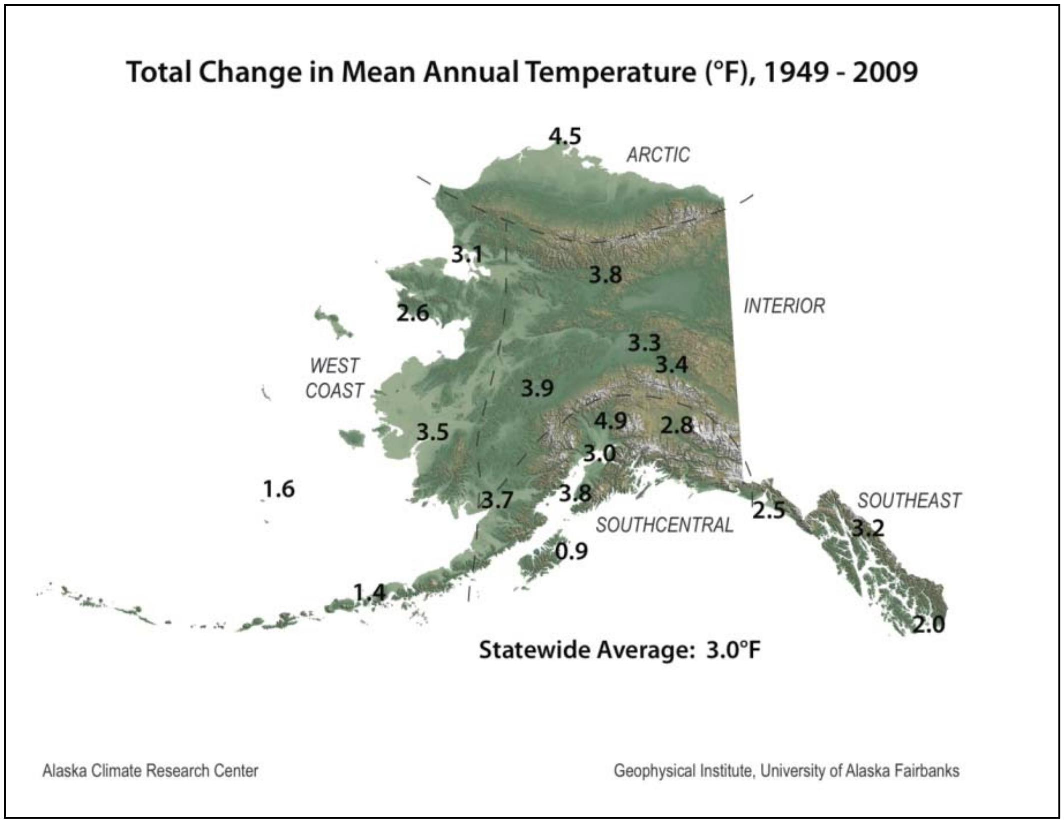


Figure 6 Change in Mean Annual Temperature between 1949 and 2009 (Alaska Climate Research Center, 2010)

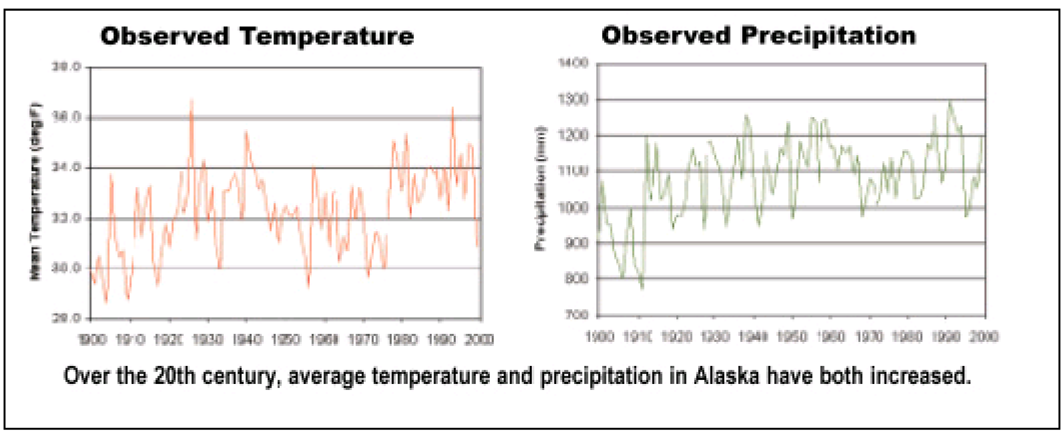


Figure 7 Observed Average Temperature and Precipitation in Alaska in the 20th Century (USGCRP, 2010)

As shown in Figure 8, Alaska's maritime zones have annual precipitation averages ranging from approximately 200 inches in the southeastern panhandle, to 150 inches along the northern coast of the Gulf of Alaska, to nearly 60 inches on the southern side of the Alaska Range in the Alaska Peninsula and Aleutian Island sections. Annual precipitation amounts decrease dramatically north of the lower maritime regions, with an average of only about 12 inches in the continental zone and less than 6 inches in some areas in the arctic region. Snowfall makes up a large portion of the total annual precipitation (Western Regional Climate Center, 2010).

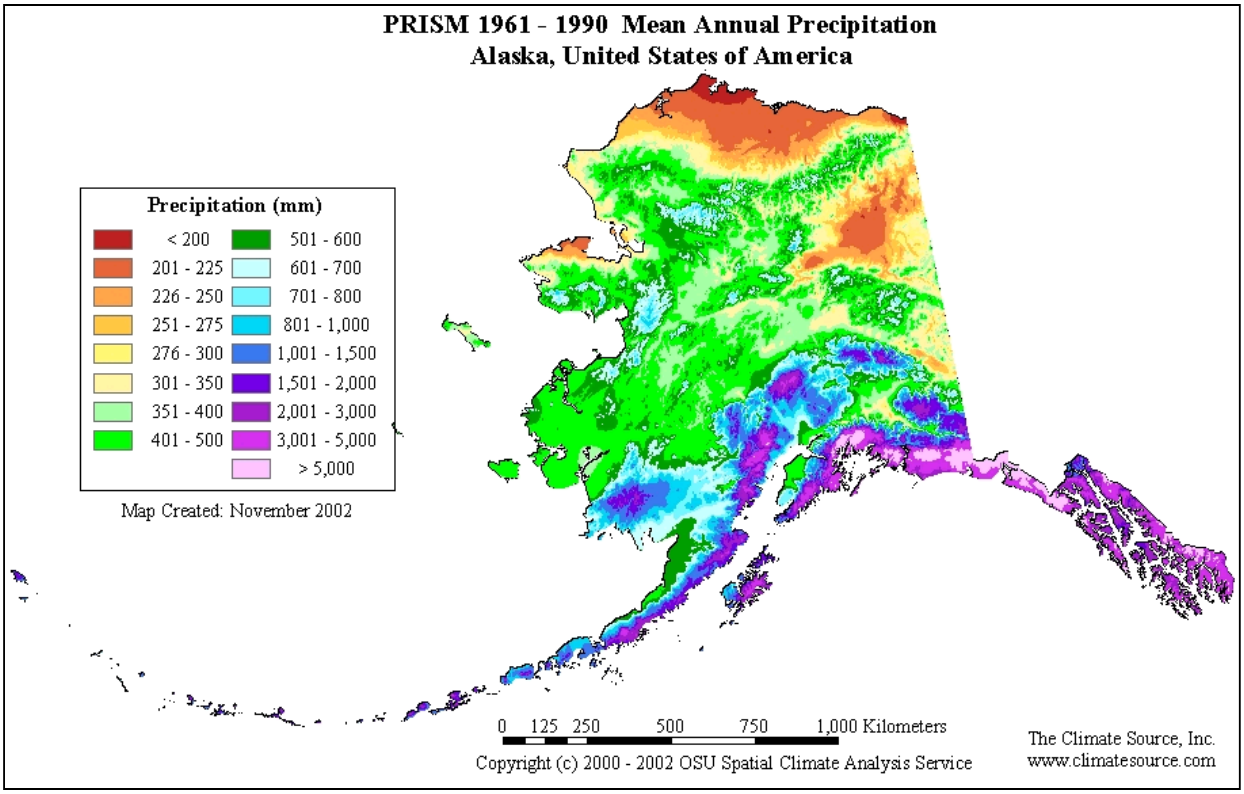


Figure 8 Mean Annual Precipitation Map of Alaska (1961-1990) (Climate Source, 2010)

In addition to temperature, as shown in Figure 7, average annual precipitation has also increased over most of the state, with an average increase of about 30 percent between 1968 and 1990 (USGCRP, 2010). Total precipitation in the Arctic has increased at a rate of about 1 percent per decade over the past century. However, on the Kenai Peninsula, precipitation records between 1944 and 2002 indicate a nearly 40 percent decrease in the mean annual water balance (the difference between precipitation and potential evapotranspiration) (USFWS, 2010).

According to the US Global Change Research Program (Figure 9), long-range climate models project that rapid Arctic warming will continue. For Alaska, the Hadley and Canadian models project 1.5-5 ºF (1-3 ºC) more warming by 2030, and 5-12 ºF (3-6.5 ºC) (Hadley) or 7-18 ºF (4-10 ºC) (Canadian) by 2100. The warming is projected to be strongest in the north and in winter. Both models also project continued precipitation increases across most of the state, reaching 20-25 percent in the north and northwest, with areas of up to 10 percent decrease along the south coast. Projections indicate that increased evaporation from warming will more than offset increased precipitation, however, making soils drier throughout most of the state (USGCRP, 2010).

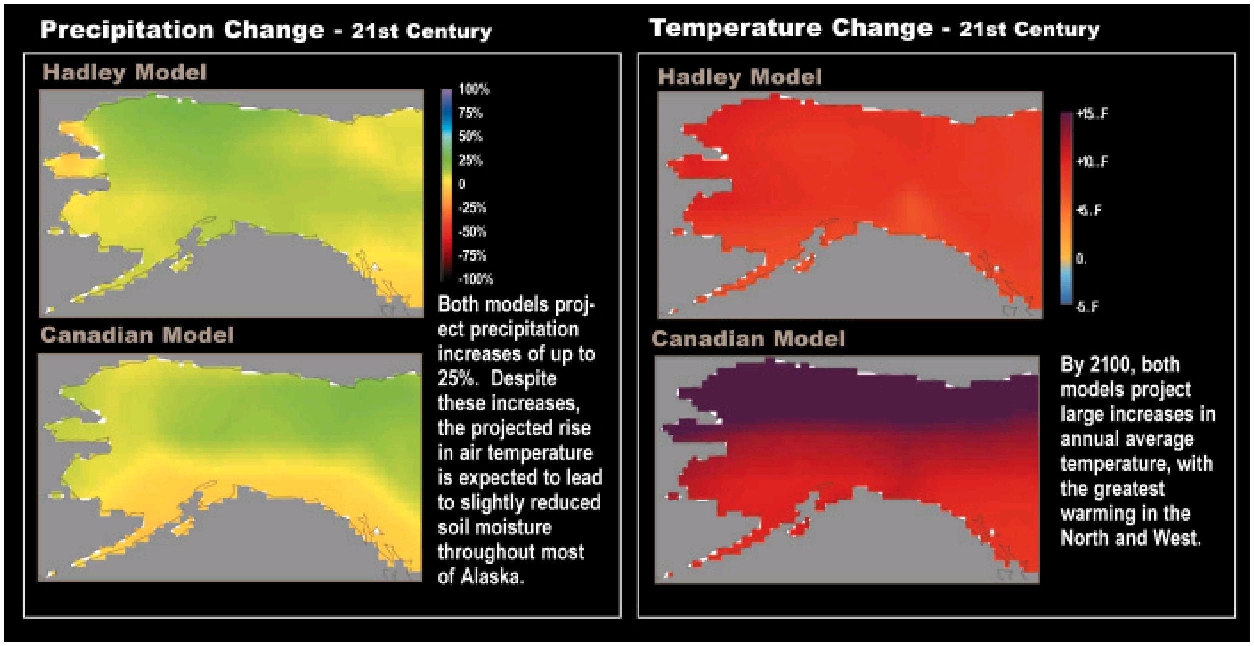


Figure 9 Projected Average Precipitation and Temperature Changes for Alaska by 2100 (USGCRP, 2010)

As indicated, increasing temperatures are expected to increase evapotranspirative water losses. These losses are expected to more than offset projected precipitation increases and thus can be expected to adversely impact water supply availability. Additionally, increasing temperatures may have adverse impacts on communities that rely on snowmelt for their water supply. Projected increases in precipitation, particularly in rainfall, which may come in less frequent, more intense, storm events, is expected to exacerbate erosion, which may affect villages adjacent to rivers both by potentially increasing erosive sediment loading to surface water supplies and by physically undermining existing water treatment and/or conveyance infrastructure (e.g., treatment plants, collection and distribution piping). Finally, increasing surface temperatures are already affecting the extent of permafrost and sea ice, which has serious potential implications for water infrastructure as described in the following sections.

2.3 SEA ICE

According to the Intergovernmental Panel on Climate Change, satellite data indicate that snow-cover extent in the Northern Hemisphere has decreased by about 10 percent since the late 1960s (ACIA, 2005). The area of multi-year Arctic sea ice has decreased 14 percent since 1978, with an apparent sharp increase in the annual rate of loss in the 1990s. Since the 1960s, sea ice over large areas of the Arctic basin has thinned by 3 to 6 feet (1 to 2 meters), losing about 40 percent of its total thickness (USGCRP, 2010). September Arctic sea ice extent declined by 7.8 percent per decade from 1953 to 2006 and by 11.7 percent per decade from 1979 to 2008 (Stroeve, et al., 2007). During the 2007 melt season, Arctic sea ice reached its lowest extent since satellite measurements began in 1979. At 1.65 million square miles, sea ice extent for the month of September 2007 was 23 percent lower than the previous September record set in 2005, and 39 percent below the long-term average from 1979 to 2007. Minimum ice extent in September 2008 was 9 percent greater than 2007, making 2008 the second lowest year on record. Sea ice researchers note that the extent of thin, first-year ice was high in 2008, and that such ice was prone to rapid melting the following summer. Because thicker multi-year ice is rapidly declining and is being replaced by thin first-year ice during the winter, the total volume of arctic sea ice is believed to have reached a record low in 2008 (USFWS, 2010).

All climate models project large continued loss of sea ice (Figure 10), with year-round ice disappearing completely in the Canadian model by 2100. In some regions, shorelines have retreated more than 1,500 feet (400 meters) due to erosion over the past few decades (USGCRP, 2010). The primary effects of sea ice retreat on water infrastructure are associated with the secondary impacts of larger storm surges in coastal areas, which potentially exacerbate their inundation and erosion. Inundation of water and wastewater systems can result in mechanical failures and overflows that can impact public and environmental health. Additionally, saltwater inundation of fresh water aquifers or surface supplies can impact treatment efficacy or the suitability of supply. Erosion can physically undermine water and wastewater treatment and conveyance systems.

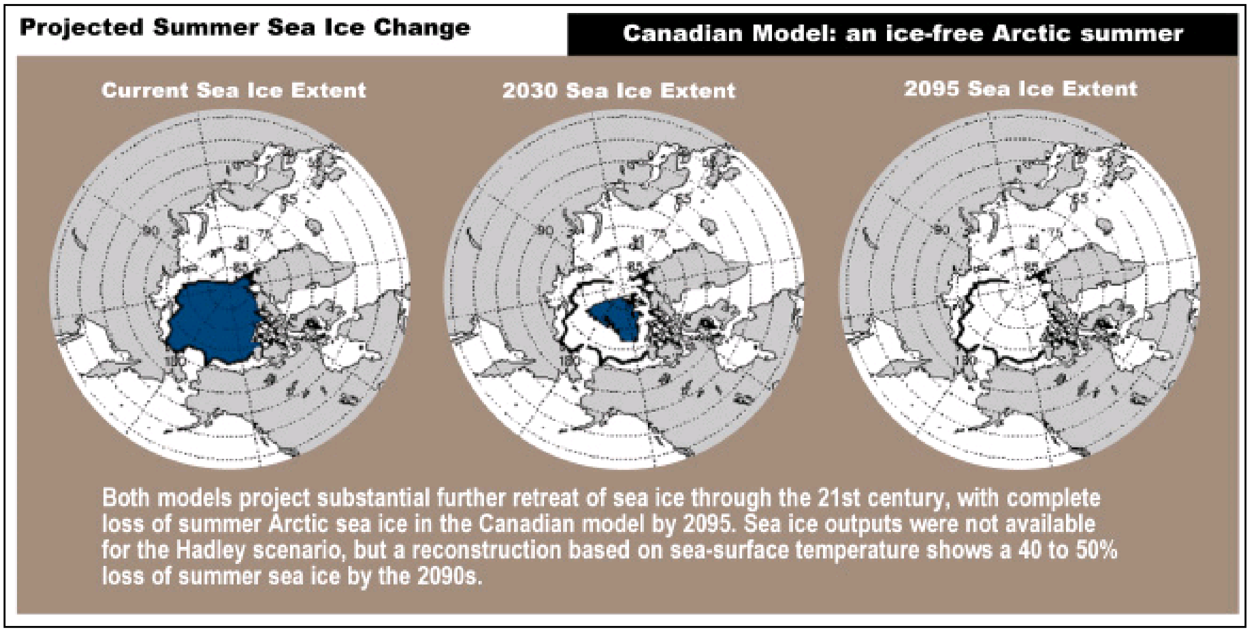


Figure 10 Current and Projected Arctic Sea Ice Coverage (USGCRP, 2010)

2.4 PERMAFROST

Permafrost is permanently or perennially frozen ground. Defined by temperature only, it is a combination of soil, rock, water, and other buried materials that has been frozen naturally at 0 degrees Celsius (32 degrees Fahrenheit) or less for two consecutive years or more (ADEC, 1999). Permafrost may include various amounts of frozen soil and ice, ranging from relatively dry frozen gravel to virtually pure ice or brackish water that remains liquid at temperatures less than freezing (Selby, 1990). Permafrost physically supports the ground surface, controls soil temperature and moisture, modifies microtopography, controls subsurface hydrology and rooting zones, and influences nutrient cycling.

Permafrost covers most of the northern third of Alaska (Figure 11). Discontinuous or isolated patches also exist over the central portions in an overall area covering nearly another third of the State. Permafrost exists only in isolated patches in the south-central and southern coastal portions, and is found only high in the mountains in southeastern Alaska, the Alaska Peninsula, and the Aleutian chain (Alaska Public Lands Information Center, 2010; Western Regional Climate Center, 2010). North of the Brooks Range, permafrost occurs as a continuous sheet extending from a few inches below the surface down as much as 1,000 feet. For permafrost to form and persist, average annual air and ground surface temperatures must be below 0 °C (32 °F). It can extend to depths of 2,000 feet below ground surface in the continuous permafrost zone across Alaska’s Arctic Coastal Plain (USGS, 1999).

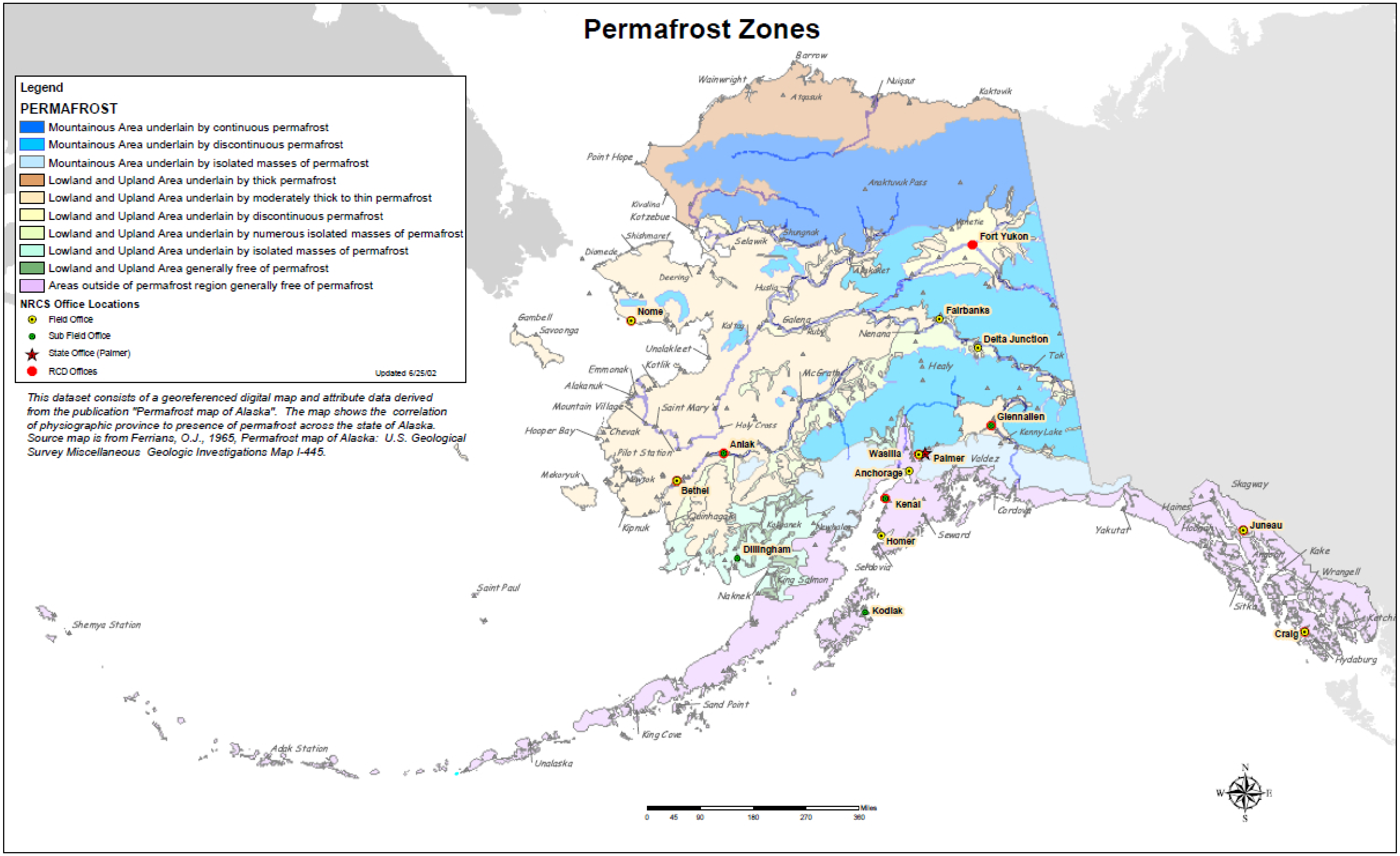


Figure 11 Extent of Permafrost Coverage of Alaska (USGS, 2010)

According to Magee and Rice (2002), “the average annual temperature of the ground surface, thermal properties of the subsurface materials, and geothermal gradient of the earth primarily determine the thickness of permafrost.” Other factors that affect the occurrence and thickness of permafrost include the vegetation layer, snow cover, slope and aspect of the surface, surface water, and groundwater. Removing vegetation and its insulating effect usually causes the surface temperature to rise and underlying permafrost to thaw during summer months. The insulating effect of deep snow tends to prevent the formation of permafrost. Southward-facing slopes receive more solar radiation and are less likely to be underlain by permafrost than are northward-facing slopes.

> Warming effects of streams, rivers, lakes, and oceans can cause permafrost beneath these water bodies to be thin or absent.” Permafrost is impervious to infiltration of water and affects the movement and discharge of surface water and groundwater. Water on top of the permafrost table can perch in the active layer (suprapermafrost aquifer) and can surface above ground. Discharge of groundwater beneath the permafrost (subpermafrost aquifer) is only possible through unfrozen zones. Sand and gravel deposits may contain flowing groundwater that conducts sufficient heat to melt the permafrost or keep permafrost from forming.
>
> Soil type and water content affects the presence of permafrost, as different types of soils and rocks conduct heat at different rates. In discontinuous permafrost areas, silt in alluvial and glacial deposits is more likely to contain permafrost than sand and gravel embedded in silt.
>
> The top of the permafrost is called the permafrost table (Figure 12). Above the permafrost table is the active layer, layers of vegetation, and soils that freeze in winter and thaw during summer. Thickness of the active layer depends on soil type and presence of vegetation on top. Depth of thaw varies greatly with latitude, climate, and soil type (USGS, 1999).

The active layer is very fragile. It is highly susceptible to damage if disturbed during summer. When the active layer is removed or disturbed, permafrost is no longer insulated from the summer heat. Within the first 2 years of disturbance, for example, settlement from thawing permafrost can be 10 percent to 25 percent of the original frozen depth, depending on actual water content and soil type (NSB, 2000; USAF, 2000).

“Disturbing the active layer also disrupts the thermal balance, which may take years to restabilize. During that time, ponds may develop from melting ice wedges and ice-rich permafrost. This can alter terrain and change vegetation cover over decades of time. Results of this process are similar to thermokarsting, which is a natural phenomenon in permafrost regions. Thermokarsting is caused by melting and freezing cycles that gradually cause ground to subside, especially in ice-saturated soils. This natural process is extremely slow but can result in widening depressions that fill with water” (Selby, 1990).

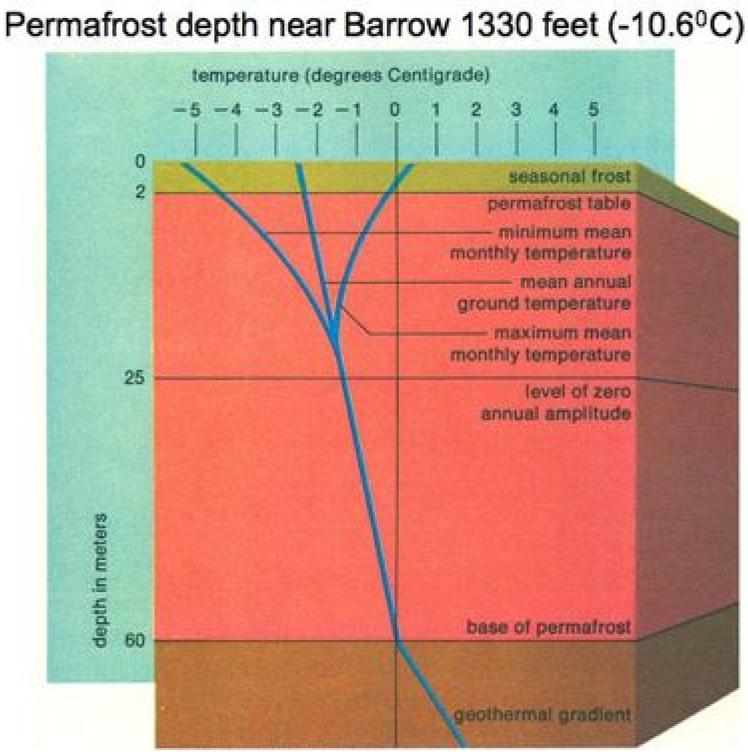


Figure 12 Permafrost Depth Profile near Barrow, Alaska (Salmon, 2008)

There is a considerable and growing body of evidence that the rapid warming Alaska is experiencing is increasing soil temperature and active layer thickness (ALT), and that permafrost is degrading at unprecedented rates, causing increased erosion, landslides, sinking of the ground surface, and disruption and damage to forests, buildings, and infrastructure. Continuous permafrost in Alaska, which has been stable over hundreds, or even thousands, of years, has experienced an abrupt increase in degradation since 1982 (Brook et al., 2008).

Borehole measurements taken along a north-south transect of Alaska document permafrost warming throughout most of the region. Total warming at the permafrost surface from 1977 through 2003 was 3 to 4 °C for the Arctic Coastal Plain, 1 to 2 °C for the Brooks Range including its northern and southern foothills, and 0.3 to 1 °C south of the Yukon River (Osterkamp, 2005). Thawing is projected to accelerate under future warming, with as much as the top 30 to 35 feet (10 meters) of discontinuous permafrost thawing by 2100 (USGCRP, 2010).

Rising temperatures, degradation of permafrost, and loss of shorefast ice along Alaska's coasts exposes coastlines and coastal villages to increased coastal erosion and vulnerability to storm surges (USFWS, 2010). The permafrost that underlies most of Alaska is ice-rich, and it supports much of the infrastructure in Alaska. Thawing permafrost is causing subsidence, (a downward shift or collapse of the ground surface) and other geophysical phenomena that seriously undermine existing infrastructure systems, including those for conveying and treating water and wastewater. When overlying vegetation is removed or disturbed, its insulating qualities are lost and the permafrost begins to melt. Waterlogged ground becomes soft and collapses. A number of permafrost foundations under water storage tanks, washeterias, and water treatment plants are thawing, which has caused damage to buildings and equipment. In some cases, aboveground utilidors and buried pipelines are breaking because of thawing permafrost. However, it is not known if these failures were caused by climate change. Other reasons are possible, including poor planning, design, and construction (Magee, 2007). Alaskans continue to develop innovative techniques for building on permafrost so it will not melt. Houses in permafrost areas are frequently built on pilings so they will not transfer heat to the ground. Floors may be insulated. Water and sewer pipes are often installed above ground.

In addition to structural impacts, permafrost thaw may alter the distribution of wetlands and lakes through soil subsidence and changes in local hydrological conditions (Brook et al., 2008). Increased surface ponding and wetland formation have been observed in warming permafrost regions (Jorgenson et al., 2001). These increases are driven primarily by permafrost-thaw-induced slumping and collapsing terrain features (thermokarsts) that subsequently fill with water. For the Tanana Flats region in central Alaska, large-scale degradation of permafrost over the period 1949-95 is associated with substantial losses of birch forest and expansion of wetland fens (Jorgenson et al., 2001), as illustrated in *Photos courtesy of*

Figure 13. *http://www.arctic.noaa.gov/detect/land-tundra.shtml*

Photos courtesy of *http://www.arctic.noaa.gov/detect/land-tundra.shtml*

Figure 13 Transition from Tundra (left, 1978) to Wetlands (right, 1998) Due to Permafrost Degradation over a Period of 20 Years (Jorgensen et al., 2001), Photos Taken from the Same Location in Tanana Flats in Central Alaska

2.5 EROSION DUE TO SEA LEVEL RISE, STORM SURGE, AND FLOODING

Global sea level has undergone a rising trend for at least a century. Based upon careful analysis of observations and climate model simulations, the Intergovernmental Panel on Climate Change stated that a best estimate of global sea level rise by 2030 would be 18 cm, and 44 cm by 2070. Although tide gauges are not routinely used to measure sea level in the Alaskan coastal region, and projections of sea level rise are not readily available (University of Colorado, 2010), areas most vulnerable to future sea level change generally correspond to those with low relief which are already experiencing high erosion rates.

Alaska's low tundra coastline is heavily indented with shallow bays and lagoons, and its continental shelf is relatively narrow, extending 50 to 100 km off the coast between Barrow and Prudhoe. The coast is predominantly low-lying wetland tundra, dotted by numerous thaw lakes. The coast has a gently sloping bathymetry with relatively flat terrain inland. Offshore islands and shoals moderate the influence of pack ice where they occur. Most of these islands are sand and gravel barrier islands, bounding shallow lagoons, while others are relics of earlier coastal retreat processes and lie farther offshore. These islands and stretches of unprotected mainland coast are subject to considerable erosion by wave action. Aided by thermal erosion of the tundra, erosion rates average 1 to 3 m per year, but in some locations may reach 38 m in a single severe storm (University of Colorado, 2010).

Because of this geography, much of the Chukchi-Beaufort coast is vulnerable to storm surges. Fall storm season is the most dangerous time of the year, when high winds, wind driven high tides, and coastal flooding are common. The areas around and east of Barrow and the east end of Kotzebue Sound are particularly susceptible. Barrow is exposed to a long stretch of open ocean in an arc of over 200º, allowing a long fetch – or length of water over which a given wind can blow unimpeded – where strong winds can generate maximum waves and swell before being broken up by land (University of Colorado, 2010).

Increasing amounts of open water in the arctic seas combined with rising sea level and the coastal geography will contribute to increased harshness of meteorological events on coastal areas, often resulting in damages from high winds, storm surge, flooding, and shoreline erosion. Storm surges are greater when the air temperature is colder than the water and when the sea has little ice cover, due to increased fetch. Changes in the persistence of landfast ice (sea ice that has frozen along coasts, along the shoals, or to the sea floor over shallow parts of the continental shelf, and extends out from land into sea) along the coast is also an important factor, since landfast ice provides coastlines with protection from erosion (University of Colorado, 2010).

The USGS reports that "floods in the interior of Alaska generally are the result of one of three processes: (1) rainfall, usually occurring during the late summer such as the flood of August 1994; (2) snowmelt, usually occurring during late spring, such as a flood in June 1964; and (3) ice jams, usually occurring during mid to late spring. Rainfall and snowmelt floods are meteorologically generated. Ice jams occur at channel constrictions, bridges, sandbars, or other obstructions to flow, and flooding may result from backwater behind blocks of river ice".

Coastal and riverine erosion can structurally undermine water and wastewater infrastructure, and also make communities and their infrastructure systems more susceptible to flooding (Figure 14). Erosion can adversely affect source water quality because of increased sedimentation and/or saltwater inundation and intrusion.

Photo and caption courtesy of the Division of Homeland Security and Emergency Management (DHSEM)

Figure 14 Nulato, Alaska Flood (May 27, 2001) when the Nine-Mile Jam was in Action and Just Before Water got Eyeball Deep as the Jam Moved Down to Halfway Island

(This page left intentionally blank.)

3 Process for Identifying and Ranking Study Group Communities

The primary objective of this screening-level analysis was to determine the nature and extent of climate-related impacts to water infrastructure in a study group of Alaska communities using existing, readily available information. The following criteria developed by the Immediate Action Work Group (IAWG) of the Governor's Subcabinet on Climate Change were used as the basis for selecting and ranking priority study group communities with regard to their water infrastructure:

1. Life/safety risk during storm/flood events
2. Loss of critical infrastructure
3. Public health threats (as defined by CDC or Alaska's Regional Health Corporations)
4. Loss of 10 percent or more of residential dwellings

With regard to the water infrastructure focus of this analysis, criteria 2 and 3 were most relevant, while criterion 1 was used to help identify study group communities. Accordingly, the IAWG criteria were adapted to be more specific and responsive to an assessment of the vulnerability of water infrastructure in rural Alaskan communities.

The study group selection processes ultimately resulted in the development of two sets of communities – 26 study group communities initially believed to face some degree of water infrastructure threats, and a broader list of 44 communities that may face water infrastructure threats, but either initially had lesser perceived threats or required additional information to confidently assess those risks.

The first group of 26 communities had short profiles prepared describing climate-related impacts to their water infrastructure (profiles are included in Appendix A), while the additional 44 communities had cursory information collected, as summarized in Appendix B. As a result of this evaluation, some communities from the primary study group of 26 were determined not to be immediately imperiled, while some communities from the secondary group of 44 appear to have documented water infrastructure risks. For both groups, additional analysis exceeding the scope of this initial screening-level analysis is needed to prioritize communities for action.

3.1 Development of Study Group Lists

A master list of communities (Appendix C) was created by entering VSW funding eligible communities, a total of 214 in all, into a spreadsheet-based database. This master list was cross referenced with two other relevant lists of potentially imperiled communities: the Army Corps of Engineers, Alaska District (USACE) Alaska Baseline Erosion Assessments (ABEA) list of 181 communities, which further groups communities by the categories of "High Priority," "Moderate or Monitoring," and "no known or least risk" communities (USACE, 2009); and the list in the *IAWG Recommendations Report* (IAWG, 2009).

Of these, only the ABEA dataset indicated whether water infrastructure were among the "at risk" resources; however, this information was generally based only on telephone interviews with community members. All of the ABEA Community Erosion Information Papers (EIPs) were reviewed in order to determine whether water infrastructure were indicated by interviewees to be threatened. Using this information, potential study group communities were identified based on perceived water resource and/or water/wastewater infrastructure risks, or in some cases, documentation of flooding or erosion of areas known to host water infrastructure such as water supplies, treatment plants, and conveyance piping.

Because the ABEA data were developed as part of an erosion assessment process, the primary threats identified were associated with river or coastal erosion processes, including sea ice changes, ice run-up, flooding, and permafrost melt. The ABEA data were based on existing USACE reports, community reports available on the internet, and telephone surveys completed with local officials in each community. The USACE also made site visits and more detailed assessments in "priority action" communities; however, not all of the USACE "priority action" communities were believed to have water infrastructure at risk.

The USACE Floodplain Management Services also has an online database (USACE, 2010) for community flood hazards that was reviewed as part of the study group selection process. As stated in the introduction to the database:

> The amount and accuracy of floodplain information on Alaska locations varies widely from place to place. Detailed floodplain studies have been completed on many of the larger communities and on the more populated areas of some rivers. The Federal Emergency Management Agency (FEMA) has published Flood Insurance Rate Maps (FIRMs) that show floodplain boundaries and flood elevations for communities participating in the National Flood Insurance Program…In contrast little or no documented floodplain information exists on most of the smaller communities or on populated areas on the fringes of the larger cities.

3.2 STUDY GROUP COMMUNITY SELECTION

There are 145 city governments (as of 2001) and 246 federally recognized tribal governments in Alaska. The "community" definition used by the VSW Program for financial eligibility purposes includes the following criteria: (a) an unincorporated community that has between 25 and 600 people; (b) a second class city (no population limits); or (c) a first class city with not more than 600 residents. Accordingly, these and other criteria, developed in collaboration with ADEC-VSW, were used to generate the list of study group communities. Development of the study group list used the following filtering criteria:

- Communities that the IAWG is already assisting and considered in peril were excluded from the study groups. These include Kivalina, Koyukuk, Newtok, Shaktoolik, Shishmaref, and Unalakleet.
- First Class/Home Rule Cities, although included on the USACE or VSW "High Priority" list in the IAWG final report, were excluded from the study groups, including Barrow, Cordova, Dillingham, Homer, Kenai, Palmer, and Seward (note that all of these cities have had or continue to have climate-related flooding and/or erosion impacts to some portion of their water infrastructure).
- Communities with a population of 50 or less according to 2009 Department of Labor estimates, were excluded from the study group, including Alatna, Birch Creek, Dot Lake Village, Ekuk, Elfin Cove, False Pass, Karluk, Healy Lake, Ivanof Bay, Lime Village, Point Baker, Portage Creek, Red Devil, Rampart, Stony River, and Ugashik.

All of the study group communities were either second-class cities or unincorporated communities, the majority with tribal governments. The average population of the 26 communities in the primary study group was 386. Four communities in the study group had a Kindergarten-12 school enrollment of 20 students or less per the Department of Education and Early Childhood Development records as of October 1, 2009 including Nelson Lagoon (8), Hughes (12), Chignik Lagoon (16), and Chalkyitsik (20).

3.3 DATA COLLECTION METHODOLOGY

Several complimentary processes were used to collect community-specific data needed to develop profiles of the study group of potentially imperiled communities, including:

- Targeted interviews with VSW engineers, ANTHC engineers and ANTHC Center for Climate and Health staff.
- Review of online resources, including:
  - DCRA Community online database, capital projects database, community funding database, community profiles (maps), community infrastructure library (CIL), community plans library; Rural Utilities Business Advisor (RUBA) community status reports
  - Department of Labor and Workforce Development, Research and Analysis Borough/Census area population (2009 estimates) or DCRA populations
  - Department of Education and Early Childhood Development 2009 K-12 school enrollment
  - USACE floodplain management service community flood data
  - NOAA Sea Level charts for Alaska
- Review of written reports, including:
  - Sanitation master plans
  - Community Plans and economic development plans
  - IAWG Recommendations Report to the Governor's Subcabinet on Climate Change
  - USACE Alaska Baseline Erosion Assessment
- Review of spatial data for communities, including:
  - Georeferenced Autocad files for communities showing the major infrastructure, such as footprints of buildings, utility line locations, roads, etc., from the Division of Community and Regional Affairs (DCRA), Department of Commerce, Community & Economic Development
  - GIS data layers for major roads, hydrography (streams and lakes), shoreline, aerial photos for each community, locations of major cities and towns, borough boundaries, glacier locations, ANCSA Corporation boundaries, and an infrastructure layer, from the Alaska State Geo-spatial Data Clearinghouse and the DCRA

3.4 DATA COMPILATION AND ANALYSIS METHODOLOGY

Based on the information collected per the methods detailed above, climate-related factors were described for each study group community and used to assess the vulnerability of each community with respect to their water infrastructure.

Basic information characterizing each community was summarized in profiles for the 26 primary study group communities. These included:

- Community setting
  - Population
  - Incorporation type
  - Local governance
  - Borough/tribal corporation

  - Landform/location
  - Climatologic summary
- Description of water infrastructure
  - Water supply(ies)
  - Water system(s)
  - Wastewater system(s)
- Climate related factors, effects and potential effects on water infrastructure

Because flooding is a contributing risk factor for water infrastructure impacts, Corps of Engineers flood hazard information was often used to provide background information on community setting and geographic location.

In addition to this basic characterization information, each community's water infrastructure was described and qualitatively assessed across several risk factors, loosely based on the IAWG ranking methodology indicated in Table 1.

Table 1 IAWG Imperiled Community Ranking Matrix

Risk Factor	Ranking	Criteria
Critical Infrastructure	Low impact	Population of less than 50 people impacted Damage could be repaired or alternative service restored locally in less than 1 month with little disruption
	Medium impact	Loss would not result in loss of community sustainability Damage could be repaired or alternative service restored between 1 and 6 months Population of less than 50 people impacted
	High impact	Critical community water infrastructure at risk Loss would impact community sustainability; more than 50 people could be impacted by loss or damage to infrastructure
Human Health and Safety	Low impact	Situations that would cause life safety concerns or negatively affect ability to provide emergency services are not likely Ingress/egress to/from community not at risk Community has ability to mitigate or avoid life safety concerns
	Medium impact	Only rare events would threaten life safety Access to or from community by land or airport threatened Quick and easy access to emergency services is available
	High impact	"Climate change phenomena" is expected to result in public health threats (#3 IAWG Criteria) to water resources Critical health/safety services facility at risk

Risk Factor	Ranking	Criteria
Community Setting/Community Geographic Location	Low impact	Land is readily available in areas outside climate impact zones for new development or relocations Soils, hydrology/hydraulic conditions not conducive to flooding, erosion Land use controls in place and/or safe land area between shoreline and development exists
	Medium impact	Lands in climate impact zones are limited, precluding new development or relocations into safe areas Soils and hydrologic/hydraulic conditions conducive to erosion Limited distance between shoreline and development but safe zones available and some local resources to assist with mitigating problem
	High impact	High erosion rates and/or flooding; life/safety risk during storm flood events (#1 IAWG criteria) Poor soils conducive to erosion, permafrost melt possible added impact; saltwater intrusion during storms/high tides No or limited safe land areas to move structures; community on barrier islands or spit Sea level rise will impact; low topography

Although the information collected was not sufficient to rate or rank the communities' relative risks with confidence, each community profile includes narrative descriptions of the following risk factors:

- Likelihood and Frequency of Impacts
- Severity of Impacts
- Historical Impact/Trends
- Mitigation of Impacts

This qualitative characterization of community water infrastructure risk should be viewed as an initial step in identifying and prioritizing at-risk communities, rather than a definitive assessment, and minimally needs to be reviewed by VSW and ANTHC staff who are assigned to each community. In their report to Congress on the statewide community erosion assessment, the Alaska District, Corps of Engineers were required to rank the communities. As indicated in the USACE Alaska Baseline Erosion Assessment and reiterated on page 91 of the IAWG final report, "no single person should believe they can make the determinations of what criteria are to be used, how to scale the criteria, how to weight the criteria, or assigning values for criteria for items being ranked. A typical approach to develop these items is to assemble an "expert panel" of individuals from the area of expertise needed. These experts are typically not policy makers or agency executives. These individuals are those who work most closely to the actual problems and are integrally involved in formulating, describing, and developing solutions."

It is recommended that these initial screening-level community-specific characterizations be run through an iterative process of refinement where additional information is collected and reviewed, and vetted through an "expert panel" (which should include applicable VSW engineers and ANTHC engineering project managers, community leaders, and climate experts, at a minimum).

3.4.1 Data Analysis Definitions

For the purposes of this analysis, the following definitions were used:

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2008).

Adaptation to climate change involves a response by humans or natural systems to actual or expected climatic effects, in order to minimize harm and to maximize benefits (IPCC, 2008).

Mitigation refers to structural techniques used to limit future climate-related impacts. Mitigation efforts can limit future impacts, but cannot eliminate the need for adaptation (IPCC, 2008).

Climate change phenomena, as identified in the IAWG Final Report (2009), includes:

- Lack of sea ice
- Change in extent of sea ice
- Timing of sea ice
- Increased effects of storm surges unbuffered by shorefast ice
- Flooding
- Permafrost melt
- Erosion due to flooding or permafrost melt
- Wildfires (not considered in this report)

Water infrastructure, as used in this report, includes:

- Washeterias, centrally located community buildings with flush toilets, drinking water to haul home, and laundry and shower facilities
- Septic tanks and sewage lagoons
- Wells, rivers, and other community water sources approved by DEC
- Piped water and wastewater systems (both above ground and underground)
- Tank haul systems which include separate holding tanks for storing potable water and wastewater at each home
- Honeybuckets, which are buckets that have a plastic bag liner and are used in place of a flush toilet in communities that lack a waterborne sewage system; more common in permafrost and flood prone areas

This analysis generally only considered direct, climate-related impacts to water infrastructure. Although other indirect impacts, including the effects of fuel spills on water supplies; landfills impacted by flooding and erosion; wildland, or community fires; and naturally occurring source water quality changes are beyond the scope of this analysis, they may still be important. Climate-related impacts to landfills and tank farms that have the potential to impact water supplies are described in community profiles, and their management is addressed in the recommendations section.

Table 2 lists the climate-related factors considered during this analysis, as discussed in detail in Section 2. The potential effects of each factor are listed in the second column of

Table 2, and potential impacts on community water infrastructure are listed in the third column.

Table 2 Climate Related Factors, Effects, and Potential Impacts on Water Infrastructure

Climate Related Factor	Potential Effects	Potential Water Resource Impacts
Precipitation changes	Flooding Drought	Water damage Water supply scarcity
Storm Surge	Flooding Wave impact	Water damage Contamination of fresh water supplies Physical damage Saltwater contamination Erosion
Sea Ice Changes	Loss of sea ice Timing of sea ice Loss of shorefast ice	Physical damage Increased fall storm (frequency period) Unbuffered storm surge impacts
Erosion	Increased coastal erosion Increased riverine erosion	Undermined infrastructure Flooding susceptibility Sedimentation of water supplies
Temperature changes	Glacier loss Increased melting/evaporation Sea ice loss Permafrost melt	Increased sedimentation Change in glacial dammed lakes Water supply scarcity (see below) (see below)
Sea Ice Changes	Loss of sea ice Timing of sea ice Loss of shorefast ice	Physical damage Increased fall storm (frequency period) Unbuffered storm surge impacts
Permafrost melt	Subsidence	Saltwater intrusion Undermined infrastructure Increased erosion

(This page left intentionally blank.)

4 Study Group Community Results

As previously indicated**,** 26 communities with suspected significant, climate-related water infrastructure impacts were initially selected as the study group. Most of the communities on the study group list were not believed to have previously been analyzed in detail for potential climate change impacts. The communities represent a variety of water infrastructure that may be at-risk including washeterias, water wells, surface water infiltration galleries, storage tanks, sewage lagoons, and drainfields. The study group also represents a cross section of sub-regions of the state including the following:

- Alaska Peninsula (Nelson Lagoon, Chignik Lagoon)
- Southcentral/Mat-Su Borough (Talkeetna)
- Yukon-Kuskokwim Delta (Atmautlauk, Chevak, Emmonak, Quinhagak)
- Bering Sea (Diomede)
- Interior river (Chalkyitsik, Fort Yukon, Huslia, Hughes, Gulkana, McGrath, Noatak, Venetie)

Communities built on spits, barrier islands, or low-lying coastlines are particularly susceptible to climate impacts. Unalakleet, Kivalina, Shaktoolik, and Shishmaref, already on the IAWG imperiled communities action list, are on coastal spits or islands (Kivalina at the tip of an 8-mile barrier reef, and Shishmaref on Sarichef Island, 5 miles from the mainland just north of Bering Strait). Among the study group, Nelson Lagoon, Ninilchik, Golovin, St. Michael, Deering, Wales, Teller, and Stebbins are located on spits or islands.

Study group communities also represent a broad cross-section of "climate change phenomena" including:

- Lack of sea ice and timing of sea ice – Deering, Wales, Golovin, St. Michael
- Change in extent of sea ice – Nelson Lagoon
- Increased effects of storm surges unbuffered by shorefast ice – Nelson Lagoon, Golovin, St. Michael, Deering
- Flooding – Emmonak, Fort Yukon, Huslia, Gulkana, McGrath, Venetie (also Alaknuk and Buckland, which were originally on the secondary group of communities evaluated)
- Permafrost melt – Atmautlauk, Kotlik, Chevak

Brief summaries of the imperiled infrastructure and climate risks associated with these 26 communities are provided in Table 3, while detailed profiles for each community are provided in Appendix A. As a result of the initial analyses conducted for each of these communities, it was determined that several communities – Chevak, New Stuyahok, and Talkeetna – face relatively low risks to their water infrastructure, while others have improvements under construction (as noted in the community profiles in Appendix A) that when completed will mitigate identified risks significantly.

Another subset of 44 communities was also evaluated in less detail. These communities either were initially viewed as having lesser risks or requiring additional information to determine their potential climate-related water infrastructure impacts. A cursory summary of the potential water infrastructure impacts associated with each of these additional 44 communities is provided in Appendix B. As a result of the cursory analysis conducted for each of these communities, Alakanuk and Buckland appear to face more significant risks to their water infrastructure and thus should be prioritized for additional analysis in future efforts to refine the list of imperiled communities needing near-term action. A number of other communities were determined to be in need of more detailed assessments (or continued monitoring at a minimum) including Anvik, Arctic Village, Bristol Bay Borough including South Naknek, Clark's Point, Eek, Kipnuk, Kobuk, Kotlik, Koyuk, Kwethluk, Kwigillingok, Levelock, Lowell Point, Lower Kalskag, Marshall, Napakiak, Napaskiak, Nightmute, Nulato's old townsite, Nunam Iqua, Oscarville, Red Devil, Russian Mission, Scammon Bay, Sleetmute, and Stevens Village. Note that some of these communities have populations of less than 50 and future viability of the community may be a factor in listing such communities as priorities for immediate action. ANTHC or VSW may have other communities to add to this list of communities needing more detailed analysis to better assess their potential water infrastructure risks.

Table 3 Summary of Primary Study Group Communities*

Community	Water Resource/Infrastructure Risks	Climate-Related Impacts
Aniak	Wells, sewage lagoon, lift stations	Kuskokwim River flooding
Atmautlauk	Proximity of boardwalks to honeybucket stations - if spilled, walkways could become contaminated; proximity of lagoon to community well	Permafrost melt, flooding
Brevig Mission	Sewage is disposed in drainfield above current flood levels; may be impacted if flood levels change. Row of homes on Point Clarence subject to storms.	Coastal storms and erosion
Chalkyitsik	Water treatment plant, washeteria, and clinic building <100' from the river; buildings elevated	Black River flooding and erosion
Chevak	No serious threats	River erosion, permafrost melt
Chignik Lagoon	Water came close to sewer lift station near school, December 2007; erosion at Packers Point; erosion of sewage lagoon berm	Storm erosion and flooding
Deering	Sewage lagoon near shoreline not rip-rapped; water main is located near the shoreline	Coastal and Inmachuk River erosion, melting permafrost
Diomede	Water tanks	Coastal Bering Sea storms
Emmonak	Above-ground piping subject to flood damage; entire community in 100-yr floodplain	Yukon River
Fort Yukon	Sewage lagoon; most of community in 100-yr floodplain	Yukon River erosion and flooding
Golovin	Community water storage tank and lines; some septic lines, are less than 100' from shoreline	Melting permafrost, coastal and river erosion ("ivu" ice override)
Gulkana	Community well is approx. 15 ft from river	Gulkana River erosion
Hughes	Washeteria below floodlevel (@ 269.8 ft; 1965 flood @ 272 ft, 1994 flood @ 270 ft)	Koyukuk River flooding
Huslia	Some sewer and water lines in the older part of village are near river, mostly mitigated	Koyukuk River erosion
McGrath	City water intake, Captain Snow Building (which houses the water treatment plant and washeteria), water main, and water storage tanks	Kuskokwim River erosion (~5'-10' per year), flooding (approx. every 5-20 years)

Community	Water Resource/Infrastructure Risks	Climate-Related Impacts
Nelson Lagoon	10.5 mi. water line (replaced 3 times)	Coastal erosion to spit, coastal storms
New Stuyahok	Community sewer lagoon approx. 100' from river	Nushagak River erosion (20' in 20 yrs, 3' in 2007)
Noatak	Wellhead (received ANTHC grant for wellhead protection in 2003)	Noatak River erosion
Quinhagak	River channel has shifted farther from the infiltration gallery reducing the pumping rate and requiring more extensive water filtration	Water quality changes from river channel migration
Saint Michael	Water tanks; water & sewer lines, sewage lagoon	Coastal erosion, permafrost melt
Selawik	Water tanks and water lines	Permafrost melt and thermokarsting
Stebbins	Water tank (@ 15.4') below flood level (7 floods between 1959 and 1988 ranged from 12'-16.9' MLLW)	Norton Sound coastal storms
Talkeetna	Sewage lagoon, sewer lines	River erosion and flooding
Teller	Sewage lagoon	Coastal flooding
Venetie	Impacts to new well possible but have not yet occurred according to ANTHC; village site is approx. 30 feet above floodplain	Chandalar River flooding, erosion
Wales	Washeteria <100 ft from active erosion area; sewerlines; leachfield close to shore	Bering Strait coastal storms, erosion

*****See Appendix A for more complete description.

(This page left intentionally blank.)

5 Conclusions and Recommendations

This qualitative, screening-level characterization of community water infrastructure risk found that a number of villages in rural Alaska face persistent and in many cases, increasing, climate-related threats to their water infrastructure. Some of the most serious impacts were discovered to be related to erosion and flooding along rivers and ocean shorelines, melting permafrost in interior and northern regions, and increased storm exposure along coasts, in some cases due to a loss of sea or shorefast ice that would otherwise provide some buffer against winds and storm surge. In nearly all of these cases, impacts are worsening or projected to worsen as a result of climate change, which is already being felt across Alaska. Increasing temperature, for example, is driving the loss of sea ice and permafrost, while often exacerbating erosion. A reduction in source water quantity and quality associated with a changing climate was less frequently observed, but still significant in some communities. Although precipitation is generally expected to increase in Alaska, the increase in evapotranspiration as a result of warmer temperatures is projected to more than offset any addition to the overall water balance.

As a result of this analysis, 25 communities were determined to be in need of additional data collection and evaluation in order to prioritize them for adaptation and mitigation responses. Other communities were identified which need a similar screening-level analysis to assess their potential water infrastructure impacts. Still more communities may be imperiled and in need of additional analysis or near-term action – the methodologies used in this analysis can serve as a basis for continuing to identify additional communities and prioritizing those already identified. This analysis should be viewed as only an initial step in identifying and prioritizing at-risk communities, rather than a definitive assessment. Additional work is needed. Specific recommendations, described in more detail below, include:

1. **Supplement this analysis with more detailed analysis.** The results of this screening-level analysis should be immediately followed with the collection and processing of the more detailed information as needed to prioritize imperiled communities for action. The results of this and any follow-up prioritization studies should be iteratively refined by a panel of experts which should include VSW and ANTHC staff familiar with the communities at a minimum, while also drawing on the expertise of climate scientists, community leaders, arctic engineers and scientists, and others as needed.
2. **Collect additional hydrologic data.** Basic hydrologic assessments that document shorelines and flood levels and predict future erosion rates are needed in many communities as basic information for the design of more sustainable infrastructure. This data can also be used to help prioritize infrastructure for mitigation activities.
3. **Increase permafrost monitoring.** Increased use of thermistors to monitor permafrost conditions is recommended in particular. The results of continued permafrost monitoring can be used to evaluate rates of permafrost melt and prioritize adaptation and mitigation responses.
4. **Adopt prevention and adaptation strategies for managing water and wastewater assets.** Water and wastewater infrastructure planning and design should explicitly consider climate impacts and the potential future effects of climate change. Water/wastewater asset management programs, where they exist, should be refined to adapt operations and capital programs to consider climate change. Communities without formal asset management programs should be encouraged to adopt even simple programs focused on risk management and mitigation.
5. **Mitigate landfill and tank farm risk.** A number of study group communities were determined to have landfills sited up-river of their water sources. Many such landfills were sited along riverbanks and subject to erosion and flooding, introducing some degree of risk to community water supplies. A risk assessment of existing landfills is needed, particularly in communities

where water supplies may be impacted. Where landfills are determined to be substandard, mitigation activities (which may include remediation) may be warranted.

6. **Implement relevant Adaption Advisory Group recommendations to the Governor's Climate Change Subcabinet**, including the following (described in more detail below):
    a. Improve Availability of Mapping, Surveying, Charting, and Imagery Data
    b. Assess Sanitation and Infrastructure Practices
    c. Create a Coordinated and Accessible Statewide System for Key Data Collection, Analysis, and Monitoring
    d. Promote Improvements that Use the Current Best Practice
    e. Build to Last; Build Resiliency into Alaska's Public Infrastructure

5.1 SUPPLEMENTAL WATER INFRASTRUCTURE ANALYSES

The role of the Village Safe Water Program is to help rural communities develop sustainable sanitation facilities, which include both potable water and wastewater management. Climate change is increasing the risks to VSW infrastructure investments in rural Alaskan communities. Over time, thawing permafrost or erosion could render water infrastructure facilities nonfunctional with resultant public health threats to these communities (Magee, 2007). Imperiled communities must be adequately prepared to both mitigate or prevent climate change impacts and to adapt to changes that occur.

Accordingly, the results of this screening-level analysis are a critical first step in identifying communities to prioritize for mitigation and adaption activities; future efforts need to focus on further evaluating these communities' needs and helping them implement projects that enhance the sustainability of their water infrastructure. Specific recommendations include:

- Refine water resource and infrastructure assessments. Future efforts beyond this initial screening analysis should focus on using the findings of this report as a basis for additional data collection, field investigations, and evaluation in an effort to prioritize communities for action, which may include the development of mitigation or relocation plans and the upgrade of infrastructure.
- Leverage existing funding sources and programs. The Alaska Climate Change Impact Mitigation Program (ACCIMP) offers mini-grants for hazard impact assessments. Department of Homeland Security and Emergency Management (DHSEM) multi-hazard mitigation planning and community comprehensive planning are other efforts that can be used to consider potential impacts to water infrastructure.
- Support development of local ordinances promoting sustainable growth. Local regulations limiting re-development in high risk areas should be adopted. In some of the highest risk areas immediately adjacent to the riverbank or coastline, communities should be encouraged to limit any new housing, and discourage the installation of water and sewer lines without adequate protections.

5.2 HYDROLOGIC DATA COLLECTION

DCRA publications on erosion dating back to 1982 (DCRA, 1982), the US Army Corps of Engineers *Alaska Baseline Erosion Assessment* (2009), and other documents recommend measuring setback distances between riverbanks and high water lines to points set throughout community. In addition to developing standard minimum setback requirements for critical water infrastructure based on known or anticipated erosion rates, actual distances between waterbodies and infrastructure should be measured periodically. This data should be archived electronically and used to help develop erosion rate maps or estimates that can help inform community infrastructure planning and design.

As an alternative – or to supplement the suggestion above – an analysis of aerial photography can be conducted to give a broad overview of what is happening along the entire riverbank or coastline, potentially allowing for an estimation of erosion rates that can be used for infrastructure planning and design. Ideally, the aerial photograph analysis would be supplemented and validated with field measurements.

Basic hydrologic investigations can also be conducted to help estimate the recurrence intervals of floods. Any such hydrologic analysis should also attempt to identify the impacts of ice jams.

5.3 Increased Permafrost Monitoring

Thermistors should be inventoried in all high risk communities, and thermistors should be included in all future VSW sanitation construction projects in communities where permafrost is an important characteristic. The following recommendation from the Draft Atmautlauk Hazard Impact Assessment (April 2010) is provided as a guide:

> *Adopt a Requirement that any Future Geotechnical Design Study Conducted Leave at Least One Usable Thermistor String Casing in the Ground - Two difficulties encountered while attempting to quantify any statistically significant changes in the ground temperature with time is the lack of a data record over time and the lack of ability to collect new data from old thermistor locations.*
>
> *Recommendation: Future projects require at least one thermistor casing be installed and made of materials such as PVC that will not be subject to corrosion. These casings should also be filled with a non-toxic anti-freeze (such as a propylene glycol/water mixture) to reduce the potential for ice formation within the casing and allow measurements to be taken. The actual measurement of data would also have a cost associated with it. It may be possible that academic agencies, such as the Permafrost Borehole Monitoring Program (Permafrost Health) conducted by the University of Alaska, Institute of Northern Engineering (2010), may be able to provide thermistor strings and dataloggers to measure soil temperatures versus time for academic purposes…*

5.4 Prevention and Adaptation Strategies for Managing Water and Wastewater Assets

Climate-related impacts to water infrastructure should be considered from master planning through field verification.

Water infrastructure improvements, replacements, and retrofits should explicitly consider climate-related impacts and the potential impacts resulting from climate change. At a minimum, siting criteria should ensure that critical infrastructure is watertight and located at least 2 feet above the 100-year flood elevation. As suggested previously, context-specific minimum setback distances from other known natural hazards should be required for any new water infrastructure systems. Facility planning for each community's water infrastructure should include emergency response provisions specific to the natural hazards identified.

All water and wastewater master plans have descriptions of community flooding risks, which are usually derived directly from the USACE Flood Plain Management Services community flood hazard data. Although much of this is good historic data, the resulting flood elevations sometimes have been superseded by greater flood heights or storm surges. Additionally, master plans rarely consider climatic risks to existing infrastructure. Examples of items that should be considered in master plans include the location of existing water infrastructure relative to the floodplain and the 100-year flood elevation/high water mark of record.

5.5 Landfill and Tank Farm Risk Mitigation

Landfilling municipal solid waste in Alaska's permafrost regions presents unique challenges. For many years, landfills in the Arctic were built and operated much like conventional landfills in the continental United States. However, little consideration was given to the effects of the arctic environment on landfills, particularly when permafrost was disturbed. Today, many of these landfills are considered dumps, and have become environmental liabilities and hazards to public health and safety. During the short summer months of the far north, these dumps become quagmires of garbage and water caused by melting permafrost and ground settlement (Magee and Rice, 2002).

Several of the communities studied had landfills sited adjacent to surface water that in some cases represented serious risks with respect to erosion and their location upstream of the community water supply. Tank farms, although not water-related infrastructure, may also be threatened by climate-related impacts, potentially imperiling community water supplies. Accordingly, a plan should be conducted to determine if those known landfills that flood or are being eroded into receiving waters pose health risks, and to include an evaluation of existing tank farms into community water resource vulnerability assessments. Subsequently, immediate action plans should be developed for those communities where additional safeguards for water intakes, or remediation or mitigation of landfills and tank farms are warranted.

5.6 Adaptation Advisory Group Recommendations

Pertinent recommendations that apply directly to climate impacts to the State's water infrastructure from the Governor's Climate Change Sub-Cabinet, *Adaptation Advisory Group Draft Final Report* (AAG, 2010) Economic Activities (EA) adaptation strategies are reprinted below:

> ***EA-3 Improve Availability of Mapping, Surveying, Charting, and Imagery Data***
>
> *Accurate, timely, and high resolution information about the distribution and magnitude of topographic changes resulting from climate change is needed to better address economic challenges and opportunities. To assess change, a good baseline of existing conditions is needed along with real-time updating of rapidly changing conditions, such as shorelines and coastal areas.*
>
> *This option proposes that the State of Alaska and others invest in an accurate and high-resolution statewide digital base map that includes a digital elevation model and an acquisition system for imagery. The State also must ensure that the associated data are available to all users. This option would improve the availability of real-time mapping, surveying, charting, digital elevation models, and imagery data to provide a means to better track changing conditions and understand economic impacts of climate change, and opportunities to address the impacts. Additionally, this option would provide support for ongoing management and distribution of this spatial information through a geographic information system and open standards web service. This option recommends using the existing program that is creating a digital base map, the Statewide Digital Mapping Initiative (SDMI), as a vehicle of implementation, as well as continued coordination with University of Alaska (UA) Research Centers, the U.S. Coast Guard, and the National Oceanic Atmospheric Administration (NOAA).*

Applicable Health and Cultural (HC) recommendations follow:

HC-3 Assess Sanitation and Infrastructure Practices

…Facility and program performance design is based on historical environmental factors. However, these design factors are shifting due to climate change. Current community sanitation policies are insufficient to address these risks and need to be modified.

…There is a growing scientific consensus that climate change has affected the distribution, including incidence and geographic range, of infectious and non-infectious diseases that sanitation systems are intended to minimize. Additionally, changes in water quality—such as acidification and temperature that can affect human and wildlife toxic exposures—are occurring in Alaska. Changes in drinking water supply (both quality and quantity) and location may occur with the changing hydrology regime. Permafrost, utilized in some cases as a waste liner for sewage lagoons and solid waste facilities, and riverbanks that support treatment cells and infrastructure are eroding. Additionally, permafrost laden soils, in some cases, serve as structural elements in the foundation of water storage tanks, buildings that are part of the community sanitation infrastructure, and/or earthen berms that may contain fresh water for drinking or corral effluent from a sewage collection system. These phenomena are a concern as rural sanitation differs from urban and semi-rural facilities.

The agencies currently tasked with the responsibility for rural sanitation and solid waste management include the ADEC, the ANTHC, regional tribal health organizations, local environmental programs, U.S. Department of Agriculture (USDA), and U.S. Environmental Protection Agency (USEPA). Alaska DHSS, ADF&G, and U.S. Fish and Wildlife (USFWS) are indirectly involved in identification and control for human and aquatic life negative health outcomes that may emanate from inadequate system performance.

The recommendations presented in this option will require augmentation of existing sanitation and waste management or human and aquatic life health efforts performed by programs within these agencies. Implementation of the option recommendations will require increased human and material resources, including methods and tools, within existing programs, as well as new and augmented partnerships with the public and private sectors.

Additionally, these recommendations will require an update of existing environmental data sets (temperature and climate projections) in order that facilities can be constructed and/or renovated to meet future changing environmental conditions.

A number of these recommendations, while focused on health-related concerns, also overlap with public infrastructure.

Targets include:

- *Provide a portion of distressed community operation & maintenance (O&M) costs in order to adequately protect system investment via annuity or other mechanism. Non-traditional approaches such as the Alaska Rural Utilities Collaborative may be considered for more widespread utilization.*
- *Collaborate with statewide sanitation and environmental health entities currently conducting infrastructure inspections to design inspection/evaluation protocols addressing severity, nature, and timing of climate change impacts.*
- *Review existing Class III solid waste management guidelines (for rural and remote, non-hub communities) to adapt the regulations, recommendations, and community outreach to anticipate continued climate change impacts.*

- *Review the State of Alaska Capital Improvement Project (CIP) list for solid waste projects and priority classifications in relation to substantial and relevant climate change issues.*
- *Make available financial resources or incentives for development of more efficient and lower-cost systems (e.g., Alaska-based manufacturing of road mats, modular treatment systems).*
- *Establish a Memorandum of Understanding (MOU) between agencies related to responsibilities.*
- *Assure to the extent possible that existing sanitation facilities are protected against system failure due to climatic events such as flooding, wind, erosion, permafrost melt, etc.*
- *Plan and design for new sanitation facilities to account for potential future climate changes that could damage or destroy these facilities*

The Climate Change Adaptation Advisory Group (AAG, 2010) report to the Governor's Climate Change Sub-Cabinet states that "the vulnerability of and risk to public infrastructure is growing. Most of these impacts are not new to Alaska. What is new is the increased magnitude, rapid development and progression, and increasing geographic extent of these impacts and affected communities." Pertinent Public Infrastructure (PI) recommendations from the Adaptation Advisory Group report are included as direct excerpts:

PI-1: Create a Coordinated and Accessible Statewide System for Key Data Collection, Analysis, and Monitoring

Baseline data on the condition of current infrastructure and on regional and local environmental conditions needs to be collected. The locations and characteristics of the problems need to be identified as well as information on what is working and what is not working. Based on the best science and collected empirical data, Alaska needs to predict its future. The ***Environmental Atlas of Alaska*** *must be updated. The resulting information needs to be available to all interested parties.*

(NOTE: Much of the climate summary used time and again in Sanitation Facility Master Plans, then the short profiles included in Appendix A of this report have as their basis the Environmental Atlas of Alaska published by the institute of Water Resources, University of Alaska Fairbanks in 1968 with a 2nd edition in 1978.

PI-2: Promote Improvements that Use the Current Best Practice

Managing the risks and/or reducing the uncertainties associated with climate change will take time. Promoting sustainability, reducing operating costs, and protecting/extending the service life of existing infrastructure is always worthwhile. Simultaneous with PI-1, improvements to existing infrastructure that are worth doing regardless of climate change effects should be enacted.

PI-3: Build to Last; Build Resiliency into Alaska's Public Infrastructure

As PI-1 and PI-2 are enacted and we learn more as a result, new and upgraded infrastructure needs to be sited, planned, designed, and built to be resilient and sustainable in an uncertain environment. Systematic feedback with a performance review and analysis needs to be integrated into public infrastructure funding, development, construction, and operations so that planners and builders use "what works" and codes and standards are assessed and improved as needed to achieve the best results.

6 References

AAG. 2010. *Alaska's Climate Change Strategy: Addressing Impacts in Alaska, Final Report Submitted by the Adaptation Advisory Group to the Alaska Climate Change Sub-Cabinet***.** Adaptation Advisory Group. January 2010. http://www.climatechange.alaska.gov/aag/aag.htm

ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press, 1042p. (pdf)

ACCAP. 2009. Decision-making for at-risk communities in a changing climate, Alaska Center for Climate Assessment and Policy, University of Alaska Fairbanks.

ADEC. 1999. Solid Waste Management Regulations, Alaska Department of Environmental Conservation, 18 AAC 60, as amended through July 11, 1999.

Alaska Climate Research Center. 2010. University of Alaska Fairbanks. http://climate.gi.alaska.edu/ClimTrends/Change/graphics/temp_ch_map-49-09F.jpg. Accessed June 2010.

Alaska Department of Education and Early Development, Assessment and Accountability. 2010. Enrollment by School and Grade as of October 1, 2009, FY2010, (2/04/2010).

Alaska Department of Labor and Workforce Development. 2010. Table 4.3 Alaska Places 2000-2009 Population.

Alaska History & Cultural Studies. 2010. http://www.akhistorycourse.org/images/geography/large/ps3.jpg. Accessed June 2010.

Alaska Public Lands Information Center. 2010. http://www.alaskacenters.gov/ Accessed June 2010.

Brook, E., D. Archer, E. Dlugokencky, S. Frolking, and D. Lawrence. 2008. Potential for abrupt changes in atmospheric methane. In: *Abrupt Climate Change*. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Geological Survey, Reston, VA, pp. 163–201.

Brubaker, M, J. Berner, J. Bell, J. Warren, and A. Rolin. 2009. Climate Change and Health Impacts Point Hope, Alaska, October 2009, Center for Climate and Health, Alaska Native Tribal Health Consortium.

Climate Source. 2010. http://www.climatesource.com. Accessed June 2010.

DCRA. 1982. Understanding and Evaluating Erosion, Woodward-Clyde Consultants for DCRA, March 1982.

IAWG. 2009. Immediate Action Workgroup Recommendations to the Governor's Subcabinet on Climate Change - Final Report, (March 12, 2009). http://www.climatechange.alaska.gov/docs/iaw_finalrpt_12mar09.pdf

IPCC. 2008. "Appendix I: Glossary," in Climate Change 2007 Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry et al., eds., Cambridge University Press, pp. 869-883.

Jorgenson, M.T., C.H. Racine, J.C. Walters, and T.E. Osterkamp. 2001. Permafrost degradation and ecological changes associated with a warming climate in central Alaska. Climatic Change, 48(4), 551-571.

Magee, G.L. and W.J. Rice. 2002. Rethinking Landfill Development and Operation in Permafrost Regions. 2002. http://www.ccthita-swan.org/pdf/LF_Dev_Ops_Permafrost.pdf .

Magee, G.L. 2007. Climate Change Impacts on Water and Sewer Systems Funded by the State of Alaska – Village Safe Water Program. Village Safe Water. January 29, 2007.

Palin, S. 2007. Governor's Administrative Order 238. State of Alaska. Office of the Governor. September 14, 2007.

Perry, M., J. Palutikof, C. Hanson, and J. Lowe. 2008. Commentary-Climate Policy: Squaring up to Reality. Nature Reports Climate Change. Available: http://www/nature.com/climate/2008/0806/full/climate.2008.50.html

NSB. 2000. North Slope Borough, Class III Municipal Solid Waste Application for the Anaktuvuk Pass Landfill, Permit No. 9931-BA014. Prepared by MWH, 4 pp. plus attachments.

Nowinski, N, L. Taneva, S. Trumbore, and J.M. Welker. 2010. Permafrost thaw in a long-term snow manipulation: Age and rates of soil respiration. Oecologia (*in press*). UAA, ENRI http://www.uaa.alaska.edu/enri/publications/index.cfm.

Osternkamp, T.E. 2005. The recent warming of permafrost in Alaska. Global and Planetary Change. Vol. 49, Issue 3-4: pg. 187-202.

Permafrost Laboratory. 2010. http://www.gi.alaska.edu/snowice/Permafrost-lab/projects/projects_active/proj_processes.html#fin. Accessed June 2010.

Pittman, J.G. 2010. http://www.geojeff.org/course-materials/historical-geology-lab/lab-5-geologic-structure/geologic-maps/alaska-physiography.png. Accessed June 2010.

Salmon, R. 2008. Land and Permafrost. International Polar Year. May 12, 2008. http://ipy.arcticportal.org/index.php?option=com_k2&id=1621&view=item&Itemid=10

Selby, M.J. 1990. Earth's Changing Surface. Oxford University Press, New York. 607 pp.

Stroeve, J., M.M. Holland, W. Meier, T. Scambos, and M. Serreze. 2007. Arctic sea ice decline: Faster than forecast? Geophysical Research Abstracts, Vol. 9, 01362. (pdf)

University of Colorado. 2010. Integrated Assessment of the Impacts of Climate Variability on the Alaskan North Slope Coastal Region. http://nome.colorado.edu/HARC_noframes/Background/environ.html. Accessed June 2010.

USAF. 2000. United States Air Force Solid Waste Application – Cape Lisburne LRRS, Alaska, Coverage Under Renewal Permit No. 9631-BA009. Performed by MWH. 6 pp. plus attachments.

USACE. 2009. Alaska Baseline Erosion Assessment. US Army Corps of Engineers, Alaska District. http://www.poa.usace.army.mil/AKE/Home.html.

USACE. 2010. USACE Floodplain Management Services online database. http://www.poa.usace.army.mil/en/cw/fld_haz/floodplain_index.htm. Accessed June 2010.

USDOT. 2010. http://www.fhwa.dot.gov/akdiv/images/alaska_map.jpg. Accessed June 2010.

USFWS. 2010. www.alaska.fws.gov/climate/inak.htm. United States Fish and Wildlife Service. Accessed June 2010.

USGAO. 2004. Alaska Native Villages – Villages Affected by Flooding and Erosion Have Difficulty Qualifying for Federal Assistance, June 29, 2009, GAO-04-895T.

USGS. 1999. Ground Water Atlas of the United States, Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands, U.S. Geological Survey, HA 730-N. http://capp.water.usgs.gov/gwa/chn (November 25, 2001).

USGS. 2008. Workshop on Sea-Level-Rise Impacts Held in Menlo Park, California, by Eric Grossman and Sam Johnson, United States Geological Survey. Jan./Feb. 2008. http://soundwaves.usgs.gov/2008/01/meetings.html.

USGS. 2010. U.S. Geological Survey, National Snow and Ice Data Center, Global Change Program Land Data Systems – Arctic Land Processes Studies, Permafrost Map of Alaska, scale 1 to 2,500,000 http://nsidc.org/data/ggd320.html. Accessed June 2010.

USGCRP. 2010. United States Global Change Research Program. http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewalaska.htm#Permafrost%20Thawing%20and%20Sea%20Ice%20Melting. Accessed June 2010.

Western Regional Climate Center. 2010. Western Regional Climate Center of the National Oceanic and Atmospheric Administration; http://www.wrcc.dri.edu/. Accessed June 2010.

Web links to other relevant bibliographic resources are provided in Appendix D.

(This page left intentionally blank.)

Acknowledgements

Thanks to all who gave their time and energy to provide comments and recommendations in support of this analysis. Interviewee insights and perspectives helped to shape the information about each of the communities, and some of the interviewees were contacted multiple times to elicit additional information and clarification. To the following people, we extend our thanks.

VSW Project Leads:

Project Manager: Greg Magee, Village Safe Water, Program Manager

Assistant Project Manager: Emily Kloc, Village Safe Water Engineer Assistant

Department of Environmental Conservation, Village Safe Water Program

Lynn Marino

VSW Engineers:

George Wilson

Debra Addie

David Longtin

Phillip Gagnon

Doug Poage

Susan Randlett

Summer Jawson

Matt Walker

Department of Commerce, Community and Economic Development, Division of Community and Regional Affairs:

Sally Russell Cox, Program Manager, Community Coastal Impact and Climate Change Programs;

Taunnie Boothby, CFM, Floodplain Management Programs Manager

George Plumley, Planner, Division of Community and Regional Affairs

Department of Education and Early Development:

Mindy Lobaugh, School Finance Specialist II

Alaska Native Tribal Health Consortium:

John Warren

Art Ronimus

John Hutchison

Devan Currier

Kelly Larson

Kelly Leseman

Brad Blackstone

Eric Hanssen

Mike Roberts

Shad Schoppert

U.S. Army Corps of Engineers, Alaska District:

Bruce Sexauer

David Williams

Matanuska-Susitna Borough:

Pamela Ness, Code Compliance Officer / Certified Floodplain Manager

City of McGrath:

Natalie Baumgartner, City Administrator

This project was funded using monies from the American Recovery and Reinvestment Act of 2009.

Appendix A Priority Study Group Community Profiles

Aniak

Community Setting

Population: 485 (Department of Labor, 2009 estimate)
Incorporation Type: 2nd class city
Local governance: City of Aniak
Borough Located In: Unorganized Borough
Regional Native Corporation: Calista Corporation

Landform and Climate:

Aniak is located on the south bank of the Kuskokwim River at the head of Aniak Slough, 92 miles northeast of Bethel, and 59 miles southeast of Russian Mission in the Yukon-Kuskokwim Delta. Local terrain is relatively flat and is forested with spruce and cottonwood trees. The City of Aniak is located on a large island within the Kuskokwim River. Aniak is in the floodplains of both the Kuskokwim and Aniak Rivers.

Climate is maritime in the summer and continental in winter. Recorded temperatures have ranged between -55 and 87 °F. Average yearly precipitation is 19 inches, and average yearly snowfall is 60 inches. The Kuskokwim is ice-free from mid-June through October according to the Division of Community and Regional Affairs Community Database Online.

Water Resources Infrastructure Description

(descriptions are from the DCRA Community Database Online)

a. Water supply(ies): Groundwater wells (individual wells are owned and operated by property owners and a community well is owned and operated by the city).

b. Water system(s): The majority of homes (207) are plumbed and have individual wells. A central well was completed in 1988 by the village corporation. There are also wells at Auntie Marie Nicoli School and the Joe Parent Voc Ed Center. Only 21 households haul water.

c. Wastewater system(s): A centralized sewage system serves most residents, with the exception of East Aniak across Aniak Slough, which are on individual or small cluster treatment systems. The wastewater collection and conveyance system has six lift stations, and wastewater is treated using a lagoon. Some homes use individual septic tanks, but the presence of permafrost has caused drainfield problems, so most of the un-served homes instead use pit privies. The city provides septic tank pumping services. A washeteria is operated by the village council.

Climate Related Factors and Potential Effects on Water Infrastructure

The Aniak All-Hazard Mitigation Plan describes the community as surrounded by water, with topographic relief in Aniak at less than 19 feet with the land sloping gently to the south and southwest. There are numerous abandoned channels between Aniak Slough and the village which provide drainage to the south and west of the village. Water tends to back up in these drainage channels during high water events and ice-jam floods, which occur annually. The presence of numerous abandoned channels, oxbow lakes and sloughs is an indication that the channel configuration of the Kuskokwim River is rapidly changing the area surrounding Aniak.

Aniak is in the floodplains of both the Kuskokwim and Aniak Rivers. Most of the flood events in Aniak occur due to ice-jam flooding. A levee was started in 1951 by the Federal Aviation Administration (FAA) on the Kuskokwim and Aniak Slough on the eastside to protect the airport. The levee was repaired and extended in 1968, and in 1978 another levee was constructed along the north side of the city. The levees along the river and slough are effective in keeping ice out of the community but flooding is still prevalent because the Kuskokwim River has several features, downstream of Aniak, that act to produce ice-jams and their associated floods. One feature is a large sand bar on the north bank of the river approximately 1.9 miles downstream of Aniak. Another river constriction, in the form of a tight meander with several rock outcroppings, occurs 3.7 miles downstream of Aniak. Records of floods have been kept since 1960, and major floods have occurred in 1962, 1968, 1972, 1975, 1976, 1986, and 2002 when the city's disaster declaration noted "the sewer system was inundated and will require extensive cleaning and may require major repairs."

Erosion is occurring at the levee toe and at areas not protected by levee. One primary area of erosion is directly downstream of the end of the dike along the Kuskokwim River.

Likelihood and Frequency of Impacts

Aniak depends mostly on individual wells which can, and have been, contaminated in the past by flood waters. None of the well heads are known to be above 100-year flood levels. Lack of an alternative water source is a significant concern for flood victims, especially if the flood has been extensive enough to contaminate the public water supply according to the Aniak All-Hazard Mitigation Plan.

For the wastewater system, all of the lift stations are being re-built with a VSW project. All of the lift stations are situated on mounds above the flood plain to minimize contamination during flooding conditions.

Severity of Impacts

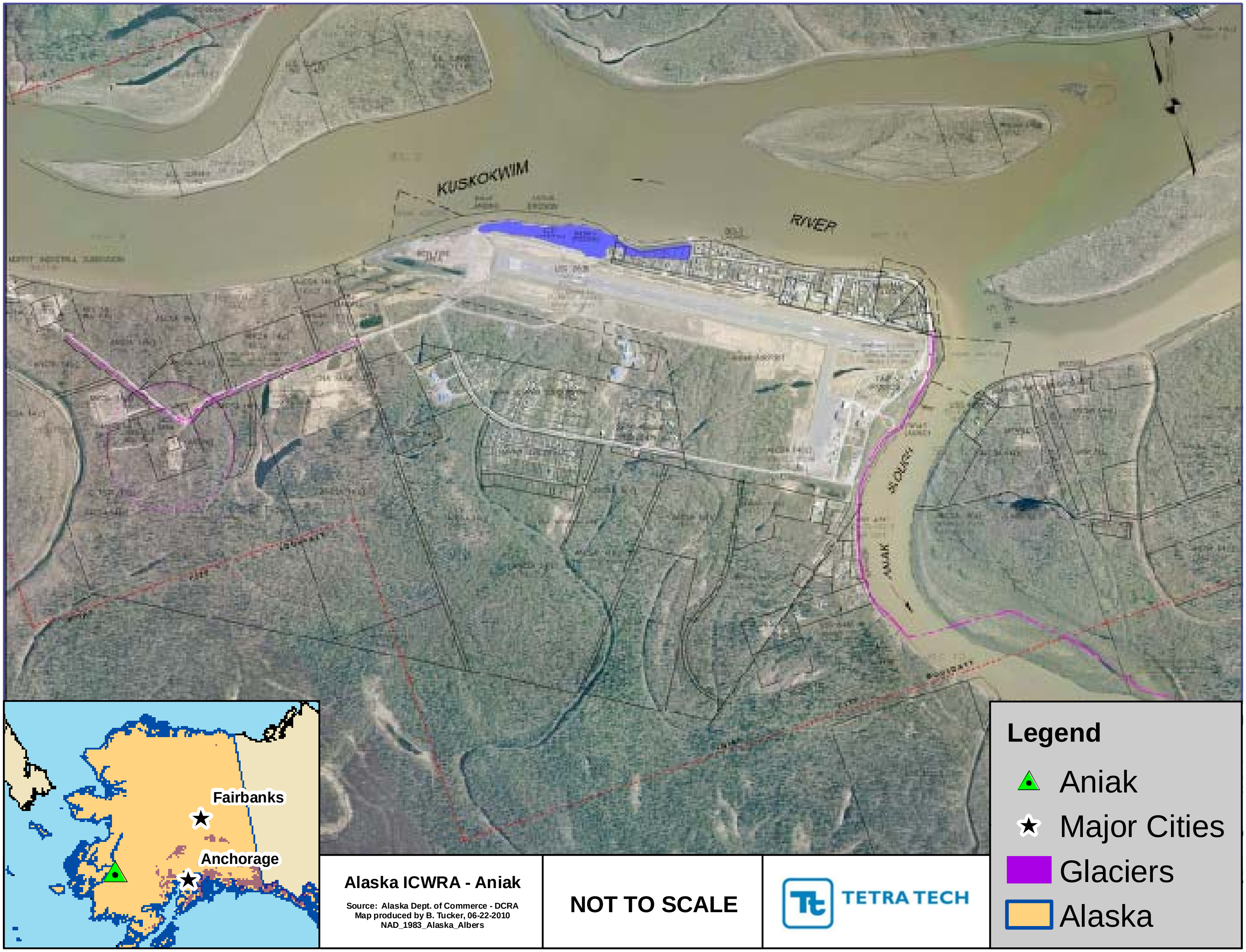
Private well contamination is the most severe impact anticipated to continue due to the high number of private wells and the propensity for Aniak to flood.

Historical Impact to Water Infrastructure

As indicated above, water supply wells have been contaminated periodically during previous flood events.

Mitigation of Impacts to Water Infrastructure

The levee provides protection from direct ice overrun into the community but does not completely prevent flooding. Ice-jam flood elevations are estimated to be one-to-two feet above the elevation of the levee dike. The city has Flood Insurance Rate Maps and participates in the National Flood Insurance Program, but well heads were not floodproofed or elevated above flood levels. Elevation of the new lift stations and controls above flood levels is a good example of design that mitigates flooding impact to water resources.


KUSKOKWIM
RIVER
SLOUGH
ANIAK
Fairbanks
Anchorage
Legend
Aniak
Major Cities
Glaciers
Alaska
Alaska ICWRA - Aniak
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-22-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH

Selected Photo Documentation

View from the air of Aniak flooding during the 2002 flood event. Old Aniak is between the airport and the ice-jammed Kuskokwim River. Photo courtesy of the Division of Homeland Security and Emergency Management.

View from the ground looking during 2002 flooding. Old Aniak is to the right, and the airport to the left in this photo courtesy of the Division of Homeland Security and Emergency Management.

References

Aniak All-Hazards Mitigation Plan, prepared by City of Aniak and Bectol Planning and Development, (November 23, 2005). http://www.commerce.state.ak.us/dca/planning/nfip/Hazard_Mitigation_Plans/Aniak_HMP.pdf

Division of Community and Regional Affairs, Community Database Online, http://www.commerce.state.ak.us/dca/commdb/CF_COMDB.htm

Division of Homeland Security and Emergency Management, Aniak's 2002 disaster declaration, http://ready.alaska.gov/community_services/acrobat_docs/aniak.pdf

Division of Homeland Security and Emergency Management, Aniak flood photos (2002).

Sewer Extension Feasibility Study for City of Aniak, Alaska, prepared by Kuskokwim Architects and Engineers, Inc. (September 1999)

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Atmautluak

(aht-MOUTH-luck)

Community Setting

Population:	296 (Department of Labor 2009 estimate)
Incorporation Type:	Unincorporated
Local governance:	Atmautluak Traditional Council, federally recognized tribal council
Borough Located In:	Unorganized
Regional Native Corporation:	Calista Corporation

Landform and Climate:

Atmautluak is located on the west bank of the Pitmiktakik River (alternate spelling: Petmigtalek) in the Yukon-Kuskokwim Delta, 20 air miles northwest of Bethel. The area encompasses 0.6 sq. miles of land and 2.7 sq. miles of water. The area averages 16 inches of precipitation, with snowfall of 50 inches. Summer temperatures range from 42 to 62 degrees F; winter temperatures from -2 to 19 degrees F.

The *Atmautluak Hazard Impact Assessment* also states that "In August 1997, the Alaska Department of Transportation and Public Facilities (ADOT&PF) conducted a geotechnical investigation in support of runway upgrades in Atmautluak. The ADOT&PF identified Atmautluak as being in an area of discontinuous permafrost, which is different from many documents, which identify the area as being in an area of continuous permafrost.

Water Infrastructure Description

a. Water supply(ies): The Division of Community and Regional Affairs (DCRA) Rural Utilities Business Advisor (RUBA) status report dated April 1, 2010 indicates that Atmautluak residents haul treated well water, or water from the Pitmiktakik River. The Draft Atmautluak Hazard Impact Assessment (April 2010) prepared for the Atmautluak Traditional Council states that *"in 2004, the Alaska Department of Environmental Conservation (ADEC) prepared a source water assessment for the Atmautluak water system. A source water assessment is prepared to identify potential and current sources of contamination with the public drinking water supplies. In this report, they identify a single well, located under the washeteria structure, as being the source of drinking water in Atmautluak. ADEC records indicate that the village gets its water from a confined aquifer from a well that is screened 272.5 to 284 feet below the ground surface. The aquifer is reported to be confined by frozen sand approximately 273 feet thick. This permafrost generally isolates the aquifer from potential surface impact. However, it should be noted that the extent of the permafrost in the area is generally unknown."*

b. Water system(s): Water is available through a limited system from the water plant that serves the school, teacher housing, at the washeteria, and at a water distribution faucet located near the washeteria according to the Atmautluak Hazard Impact Assessment. The school is connected to the water plant.

c. Wastewater system(s): Honeybuckets are hauled by residents to sewage bunkers. None of the homes have plumbing. According to the *Atmautluak Hazard Impact Assessment* prepared by WHPacific and Shannon & Wilson (2010), the wastewater infrastructure in the community consists of the two sewage lagoons, the new wastewater treatment plant serving the school and teacher housing, the lift station and wastewater pipeline to the northern lagoon, and the honey bucket collection system. There are two wastewater disposal lagoons, an older lagoon that served the school located near the center of town and a newer facility located northwest of the community. Most of the wastewater from the sewage bunkers, as well as wastewater from the school and teacher housing, is disposed in the unlined sewage lagoon approximately 1,000 feet northwest of the town. The lagoon is located approximately 600 feet north of the edge of the lake that borders the western part of town. The lagoon is also approximately 400 feet southeast of another large lake. In addition to the honeybuckets, there is an insulated wastewater line that connects the village to the lagoon. The school, teacher housing, and washeteria are connected to this line. The line is primarily gravity fed with one lift station located in the central part of the town. Historically, the wastewater from the town, and in particular the school and teacher housing, was disposed in an unlined (fenced) lagoon in the central part of town, approximately 200 feet from the primary water well. A new wastewater treatment plant has been constructed to treat the wastewater from the school and the teacher housing.

<u>Climate Related Factors and Potential Effects on Water Infrastructure</u>

A 1972 ice jam flood is believed to represent the base or one percent (100 year) flood level according to the Corps of Engineers Floodplain Management website. High Water Elevation signs were placed at two locations in the community. The first floor of the washeteria is 9 feet above the estimated 1972 flood level. The only water resource infrastructure thought to be at risk in Atmautluak are honeybucket stations because of their proximity to boardwalks next to the riverfront. All water resource infrastructure buildings are elevated above the 1972 flood level.

<u>Likelihood and Frequency of Impacts</u>

Buildings housing water resource infrastructure are elevated well above flood levels, and do not appear to be threatened by the slow moving river erosion and erosion along the lake shore in the vicinity of the HUD housing.

Severity of Impacts

Permafrost melt is possible, as is flooding of the well head. A 1997 DOT/PF report cited in the *Atmautluak Hazard Impact Assessment* indicated the nearer the land is to the warming influence of the Kuskokwim River and its sloughs and tributaries, the less likely that permafrost is present. Detailed descriptions of soil borings are included in the Hazard Impact Assessment and indicate that permafrost extent is discontinuous.

Historical Impact to Water Infrastructure

The Disaster Cost Index in the State of Alaska All-Hazard Mitigation Plan (September 2004) does not list Atmautluak as receiving disaster assistance, although the community may have had damages that are not included in this summary document of declared disasters.

Mitigation of Impacts to Water Infrastructure

The DCRA capital projects database includes $2,534,000 in ANTHC funding for heat recovery system, water and sewer haul vehicles, installing in-home plumbing, modifications to the existing lagoon, and a new haul vehicle garage. The same amount of funding is indicated by VSW for Phase III of a Flush and Haul System. Atmautluak has been unable to comply with the RUBA requirements, however, and the funding may be reprogrammed.

In fiscal year 2002 Atmautluak received a grant through the municipal matching grants program for $51,404 for “materials purchased and shipped to construct a barrier between the river bank and the water from the river, and also lakes.”


Fairbanks
Anchorage
Alaska ICWRA - Atmautlauk
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 04-31-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH
Legend
Atmautlauk
Major Cities
Glaciers
Alaska

Selected Photographic Documentation

© 2006 Photo of play area with a sewage bunker is courtesy of the Division of Community and Regional Affairs, online community photos.

References

Division of Community and Regional Affairs (DCRA) capital projects data base online, http://www.commerce.state.ak.us/dca/commdb/CF_RAPIDS.cfm

DCRA Online Community Data Base, http://www.commerce.state.ak.us/dca/commdb/CF_COMDB.htm

DCRA Online Community Photo Library Atmautluak © http://www.commerce.state.ak.us/dca/photos/comm_list.cfm

Division of Homeland Security and Emergency Management, State of Alaska All-Hazard Mitigation Plan (September 2004)

USACE, Alaska Baseline Erosion Assessment, Atmautluak Erosion Information Paper (August 27, 2007), http://www.poa.usace.army.mil/AKE/Home.html

USACE. 1998. *Atmautluak Trip Report.* Alaska District, U.S. Army Corps of Engineers.

USACE. 2000. *Atmautluak Trip Report.* Alaska District, U.S. Army Corps of Engineers.

WHPacific with Shannon and Wilson, Inc. 2010. Draft Atmautluak Hazard Impact Assessment (April 2010) prepared for the Atmautluak Traditional Council.

Brevig Mission

Community Setting

Population:	358, Department of Labor 2009 estimate
Incorporation Type:	2^{nd} class city
Local governance:	City of Brevig Mission
Borough Located In:	Unorganized borough
Regional Native Corporation:	Bering Straits Native Corporation

Landform and Climate:
Brevig Mission is located at the mouth of Shelman Creek on Port Clarence, 5 miles northwest of Teller and 65 miles northwest of Nome.

Brevig Mission has a maritime climate with continental influences when the Bering Sea freezes. Summer temperatures average 44 to 57 °F. Winter temperatures average -9 to 8 °F. Annual precipitation averages 11.5 inches, and annual snowfall averages 50 inches. Port Clarence is generally ice-free between early June and mid-November.

According to the *Brevig Mission Local Economic Development Plan (LEDP) 2007-2012,* the community lies on a gently sloping coastal plain, three miles to the southwest of Red Mountain (elevation 1,380 feet). Soils in the area are generally a poorly drained mixture of clay, sand, and gravel, with a peaty surface layer. Permafrost underlies much of Brevig Mission, at depths that show substantial variation, particularly near the shoreline. A soil core taken by the Bureau of Indian Affairs (BIA) to a depth of 255 feet found clay, gravel and sand in the first 14 feet below the surface, various frozen layers of mixed clay, sand, gravel and seashells to a depth of 112 feet, and unfrozen clays and gravels from 112 to 255 feet.

Brevig Mission is susceptible to flooding and erosion caused by storm surges and storm-driven waves from the Bering Sea and Port Clarence. All buildings along the beach lie in the Army Corps of Engineers designated 100-year floodplain and were subjected to major flooding in 1970 and 1974. The elevation of the 1974 flood of record was said to be 1 to 1.5 feet below the seaward end of the tramway bridge over the lagoon.

Water Resources Infrastructure Description

a. Water supply: Water is supplied by two wells located near Shelman Creek.

b. Water system(s): Water is treated and stored in a 100,000-gallon tank at the washeteria. The tank is filled monthly. Water is piped into the school from the city's water mains.

   The *Brevig Mission LEPD* states that, as of 2007, only a few housing units on the beach are without plumbing. Although one house was moved to an area where water service can be connected, some of the other homes are too old to be moved. All remaining homeowners seek to be added to the system.

c. Wastewater system(s): Brevig Mission completed construction of a four-phase, $8.5 million piped water and sewer system and new landfill in November 2002, with additional extensions of the system completed in 2007. The community sewage drainfield was built above the 100-year flood elevation. According to the *Brevig Mission LEPD*, families that live on the west end of the beach must still use honeybuckets and haul water; the community recognizes that the homes there are very susceptible to flooding and fall storms.

Climate Related Factors and Potential Effects on Water Infrastructure

ANTHC indicated the row of houses on Point Clarence is most susceptible to storm impacts.

The Division of Community and Regional Affairs (DCRA) Brevig Mission Community Profile Map (dated June 13, 2004) shows that an estimated 15 residential structures, the Armory building, city garage and several other nonresidential structures on the beach side of Brevig Lagoon are within the coastal flood hazard area, although some structures may have been relocated since the date of the mapping. The Bering Straits Comprehensive Economic Development Strategy (CEDS) indicates that 55 of the 63 Brevig Mission homes have piped water or covered haul as of March 2009, and that eight housing units are considered unserviceable (presumably the aforementioned flood-prone beachfront structures).

Likelihood and Frequency of Impacts

There is a strong likelihood of impacts to the relatively small percentage of residences on the Port Clarence (west) end of Brevig Mission and directly on the waterfront. Since these structures are only served by honeybuckets and haul water, broader community water resource impacts are minimal.

Severity of Impacts

As indicated above, all structures on the beach side of Brevig Lagoon are considered at high risk of flooding, storm surge, and erosion; however, they are generally served by individual honeybuckets and haul water, so shared community water resources aren't at risk. Other areas of the village served by the piped water/sewer system are located away from the coastline and at lower risk.

Historical Impact to Water Infrastructure

The USACE reports that major floods caused by storm surges occurred in 1970, 1974, and 1986, with an estimated 50 feet lost from erosion during the 1974 storm. However, local residents indicate that erosion generally does not occur on an annual basic. Historical impacts to water or sanitation facilities are not known.

Mitigation of Impacts to Water Infrastructure

The relatively new water and sewer system is sited to prevent climate-related damages, including floodproof design of the new drainfield.

Legend

- Brevig Mission
- Major Cities
- Glaciers
- Alaska

Alaska ICWRA - Brevig Mission

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 04-31-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Alaska Native Tribal Health Consortium (ANTHC), engineering project manager, John Hutchinson telephone interview.

Brevig Mission Local Economic Development Plan 2007-2012, prepared by Kawerak Inc, submitted to Village of Brevig Mission and the Bering Strait Development Council (November 13, 2007)

Bering Strait Comprehensive Economic Development Plan Strategy (CEDS) 2009-2013, by Kawerak and Bering Strait Development Council (2009): http://www.kawerak.org/servicedivisions/csd/cpd/index.html

Division of Community and Regional Affairs, Community Database Online at: http://www.dced.state.ak.us/dca/commdb/cf_block.htm

U.S. Army Corps of Engineers, *Alaskan Community Flood Hazard Data,* online at: http://www.poa.usace.army.mil/en/cw/fld_haz/nome.htm

Chalkyitsik

Community Setting & Climate Related Impacts

Population:	60 (Department of Labor 2009 estimate)
K-12 School Enrollment:	20 (as of 10/1/2009)
Incorporation Type:	Unincorporated
Local governance:	Chalkyitsik Village, federally recognized tribal council
Borough Located In:	Unorganized
Regional Native Corporation:	Doyon, Limited

Chalkyitsik is located on the Black River about 50 miles east of Fort Yukon. Chalkyitsik has a continental arctic climate, characterized by seasonal extremes of temperature. Winters are long and harsh, and summers warm and short. The average high temperature during July ranges from 65 to 72 degrees Fahrenheit. The average low temperature during January is well below zero. Extended periods of -50 to -60 degrees Fahrenheit are common. Extreme temperatures have been measured, ranging from a low of -71 to a high of 97 degrees Fahrenheit. Annual precipitation averages 6.5 inches and annual snowfall averages 43.4 inches. The Black River is ice-free from mid-June to mid-October, all according to the DCRA Community Database Online. The Black River is a flat-water, meandering stream, flowing 160 miles from its source to its mouth at the Porcupine River near the City of Fort Yukon. The river passes through forested lowlands of willow, with birch and white spruce on high banks of well-drained soil. The river moves, abandoning old channels and cutting new ones. A "river oxbow" next to Chalkyitsik is intermittently dry and then flowing as the river shifts.

Water Infrastructure Description

a. Water supply: Water is sourced from the Black River.

b. Water system: Water is treated and stored in a 100,000 gallon tank. The village also provides water to the school. The community water plant is elevated on a Triodetic® multipoint foundation system (based on a 1999 photo) which elevates the structure above flood heights and allows for floor leveling if settling should occur. Most residents haul water from the water treatment plant/washeteria.

c. Wastewater system: Most residents use honeybuckets or outhouses for sewage management. A master plan was completed to study improvements needed to provide a community system.

Concerns listed on a survey prepared for the Yukon River Unified Watershed Assessment include:

- *"There are six oil tanks by the school, which have pipes under the ground to pump oil into the school and into the power plant. The community does not know what impacts this practice has.*

- *An active open dump also is a concern for the community. Garbage is scattered all over and is located not far from the river, as well as buried garbage.*
- *A sewage lagoon by the school that drains into a dry slough, and when the water gets high it drains into the Black River. It's at least 40 or 50 yards away from the water."*

Climate Related Factors and Potential Effects on Water Infrastructure

According to the U.S. Army Corps of Engineers (USACE) flood hazard data online, floods in Chalkyitsik occurred almost yearly from the 1920's through the 1940's to a depth of about 3.5 feet deep on the road along the riverfront. Significant flooding occurred in 1937, 1947 or 1948, and 1967. The flood of 1937 which was caused by snow melt was the most severe. Although the flood level was not measured, flood waters were reported to be above all of the existing buildings present at the time. The 1967 flood is the highest measurable flood on record. The flood height was estimated to be 3½ feet below the peak of the roof of the first building toward the river from the St. Timothy Episcopal Church. The 1947 or 1948 flood was nearly as severe as the 1967 flood.

The Corps' erosion information paper for Chalkyitsik indicated that the erosion rate in 2000 was about 1 foot per year. In 1997, about 10 feet of loss occurred inland along a 300 foot length of river adjacent to the village. In 1987, about 3 feet of erosion occurred. According to the village, the Black River is less than 100 feet from the water treatment plant/washeteria/clinic building. No erosion mitigation projects are known to have occurred in the village, all according to an *Alaska Community Erosion Survey*, submitted by fax from the village in November 2007.

Likelihood and Frequency of Impacts

According to the USACE online database, floods occurred almost annually from the 1920s to the 1940s. The 100-year flood is most likely represented by the 1937 flood, which may have been as much as 3 ft higher than the 1967 flood. The flood gauge has been removed and possibly reinstalled by the local residents. The gauge can no longer be considered to be reliable datum.

Severity of Impacts

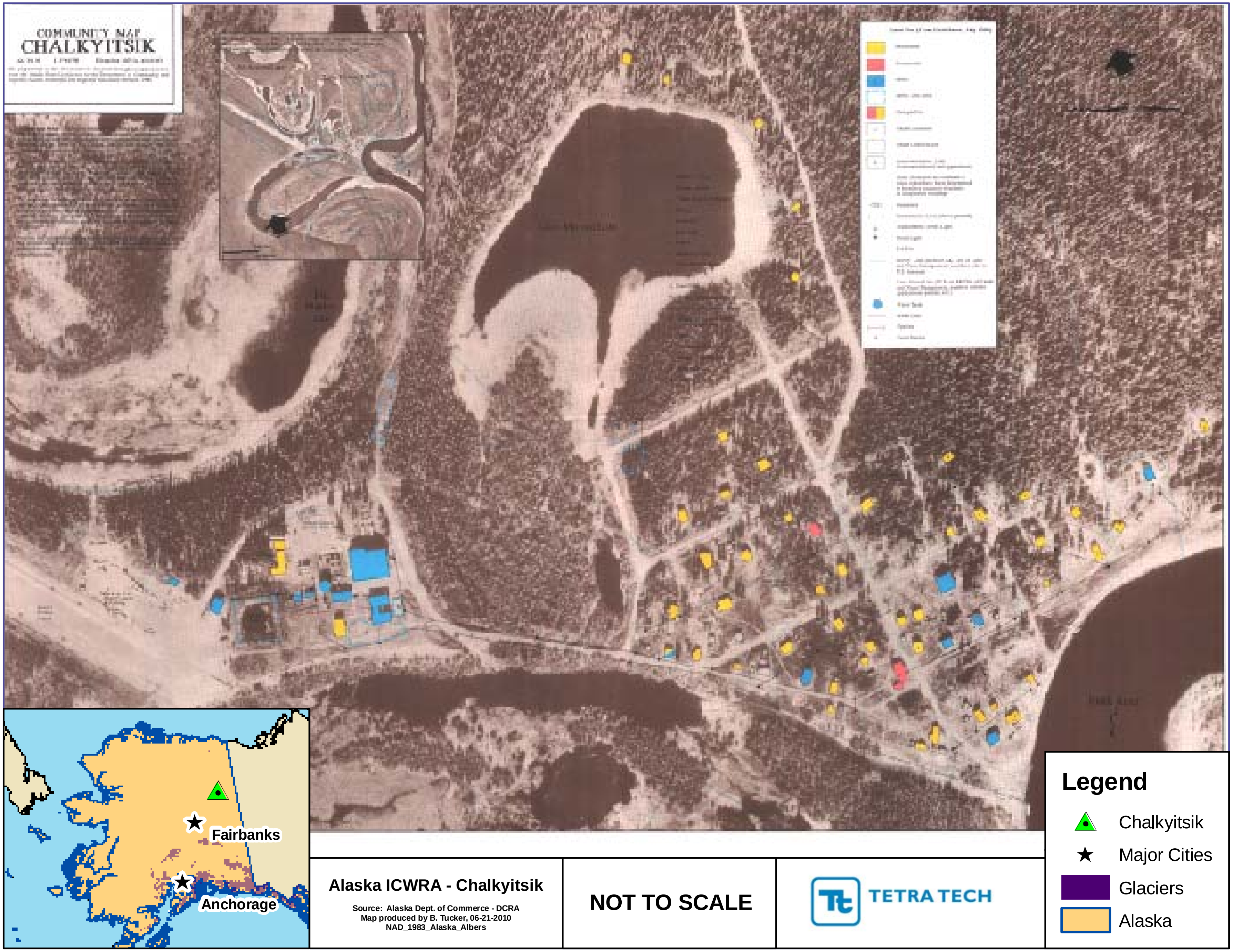
No known damage has occurred to water resources infrastructure from flooding, erosion or permafrost.

Historical Impact to Water Infrastructure

No direct impacts to water resource infrastructure are known to have occurred.

<u>Mitigation of Impacts to Water Infrastructure</u>

As indicated previously, no erosion mitigation projects are known to have occurred in the village according to a 2007 *Alaska Community Erosion Survey*. However, Chalkyitsik has been funded by ANTHC for $799,690 for water treatment improvements, connecting the school and ten homes on the west side to piped water and sewer, and a community watering point. They have also been funded by DEC/VSW for $192,400 for Phase 2 of the project, and USDA, Rural Development for $405,700 for Phase 3, according to the Rural Utilities Business Advisor (RUBA) quarterly report dated May 7, 2010. Assuming that some level of flood mitigation is included in the water/wastewater improvements, the risks to Chalkyitsik's water resources from flooding should be decreased.



COMMUNITY MAP
CHALKYITSIK
Fairbanks
Anchorage
Alaska ICWRA - Chalkyitsik
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH
Legend
Chalkyitsik
Major Cities
Glaciers
Alaska

Selected Photographic Documentation

© Chalkyitsik's raw water tank. Photo taken in 2009 courtesy of the Division of Community and Regional Affairs online community photo library.

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Division of Community and Regional Affairs, Online Community Database http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA Rural Utility Business Advisor Quarterly Status Report (May 7, 2010) http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=649&isRuba=1

Yukon River Unified Watershed Assessment, Yukon River Inter-Tribal Watershed Council (June 2002) http://www.yritwc.org/Portals/0/PDFs/UnifiedWatershedAssessment.pdf

USACE, Flood Hazard Data Online for Chalkyitsik, http://www.poa.usace.army.mil/en/cw/fld_haz/chalkyitsik.htm

USACE, *Alaska Baseline Erosion Assessment, Erosion Information Paper- Chalkyitsik, Alaska*, November 3, 2007.

DCRA, Chalkyitsik raw water tank photo is courtesy of the DCRA photos online at: http://www.commerce.state.ak.us/dca/photos/comm_photos.cfm?StartRow=1 (Photo has a copyright restriction.)

Chevak

Community Setting

Population	945 (Department of Labor 2009 estimate)
Incorporation Type:	2nd class city
Local governance:	City of Chevak
Borough Located In:	Unorganized
Regional Native Corporation:	Calista Corporation

Landform and Climate

Chevak is located on the north bank, outside bend, of the Ninglikfak (alternate spelling: Niglikfak) River, 17 miles east of Hooper Bay in the Yukon-Kuskokwim Delta. Chevak's location near the Bering Sea renders the area subject to heavy winds and rain. The community is located on the outside, or cutting edge, of a meander of the river. The river is not tidally influenced at Chevak but could be considered brackish according to the *Chevak Sanitation Facility Feasibility Study and Master Plan.*

Chevak is considered to be in a transitional zone between continental and maritime climates, experiencing maritime conditions in the summer and continental conditions in the winter when sheet ice forms over the Bering Sea. July temperatures average 52 °F and January temperatures average 10 °F with significant surface winds year round according to the *Chevak Community Plan*. Measured temperature extremes range from -25 to 79 °F. Snowfall averages 60 inches per year. Freeze-up occurs at the end of October. Break-up occurs in June according to the DCRA Community Database Online. The DCRA community history states that the current location is known as New Chevak, because residents inhabited another village called Chevak before 1950. "Old" Chevak, on the north bank of the Keoklevik River, 9 miles east of Hooper Bay, was abandoned because of flooding from high storm tides. The name Chevak refers to "a connecting slough," on which "Old" Chevak was situated.

Water Infrastructure Description

a. Water supply: Wells supply water to the community and are of very good quality for the delta region according to the sanitation master plan.

b. Water system(s): The City of Chevak operates a piped water system, and a central watering point.

c. Wastewater system(s): The City of Chevak operates a vacuum sewer system and treatment lagoon.

   Construction began in 1995 to provide piped water and sewer to homes and the school. Currently all homes and public buildings in Chevak are connected to piped water and sewer services. The project was completed in 2000, and included a new landfill, washeteria renovation, new watering point, water treatment plant, 150,000 gallon water storage tank, sewage lagoon, and a vacuum sewer collection system. The sewage lagoon is now located at a higher elevation than the previous lagoon which was located in a low-lying floodplain. In several sections of the oldest portion of the system, sewer pipes are sagging, as a result of shifting permafrost, according to the *Chevak Community Plan*. However, ANTHC indicated that the sagging lines were more likely a result of substandard design, and did not believe a deepening of the active layer, or permafrost melt was occurring. The DCRA Rural Utilities Business Advisor (RUBA) quarterly report indicated that Chevak has 193 units connected to water/sewer, and services are offered to all except one home. However, some homes still have rain catchments (cisterns), likely out of personal choice or to reduce water costs, according to ANTHC.

Climate Related Factors and Potential Effects on Water Infrastructure

River erosion is the primary problem facing Chevak. The boat and barge landing area flood annually in the fall according to the community plan. A community survey completed in January 2008 by the Chevak tribal administrator as part of the US Army Corps of Engineers (USACE) Alaska Baseline Erosion Assessment *Chevak Erosion Information Paper* indicates that water tanks and lines may be at risk from erosion. However this was not noted in other community plans or the sanitation feasibility plan for Chevak, and ANTHC did not know of any water tanks or lines at risk.

Most of the development in Chevak is on a 30-foot bluff with areas most likely for growth to the north along the sides of Chevak Lake, and the west along the bluff, although buildable land is limited according to the *Chevak Community Plan*. The area to the south is the site of honeybucket and solid waste dumping sites. The *Chevak Sanitation Facilities Feasibility Study and Master Plan*, completed in 1993, states: *"At Chevak, a low terrace adjacent to the river is completely eroded away at the apex of the meander and the river has been eroding into the upper terrace upon which the city resides. The rate at which this erosion is occurring is not known from available data but should be determined through analysis of historic and modem aerial photography."*

The Chevak Community Plan states that *"Riverbank erosion is a natural process which is typical of meandering rivers such as the Niglikfak. Certain measures however must be taken to mitigate the impacts of erosion on the community. The most heavily impacted area is the bend between the two boat landings with the majority of damage occurring during fall flooding. Chevak has already relocated several buildings and roads as a result of the erosion. Approximately 10 years ago, the Economic Development Administration and the Army Corps of Engineers installed chain and sandbag reinforcements to the bank. The project was designed to last for 5 years however it continues to perform to date. More updated erosion control strategies however are needed."*

Likelihood and Frequency of Impacts

The new water and wastewater systems are believed to be safe from flooding and erosion, although some sags in the west loop lines which was constructed in one a marshy area and the method for providing tundra supports for above-ground lines are concerns according to ANTHC.

Severity of Impacts

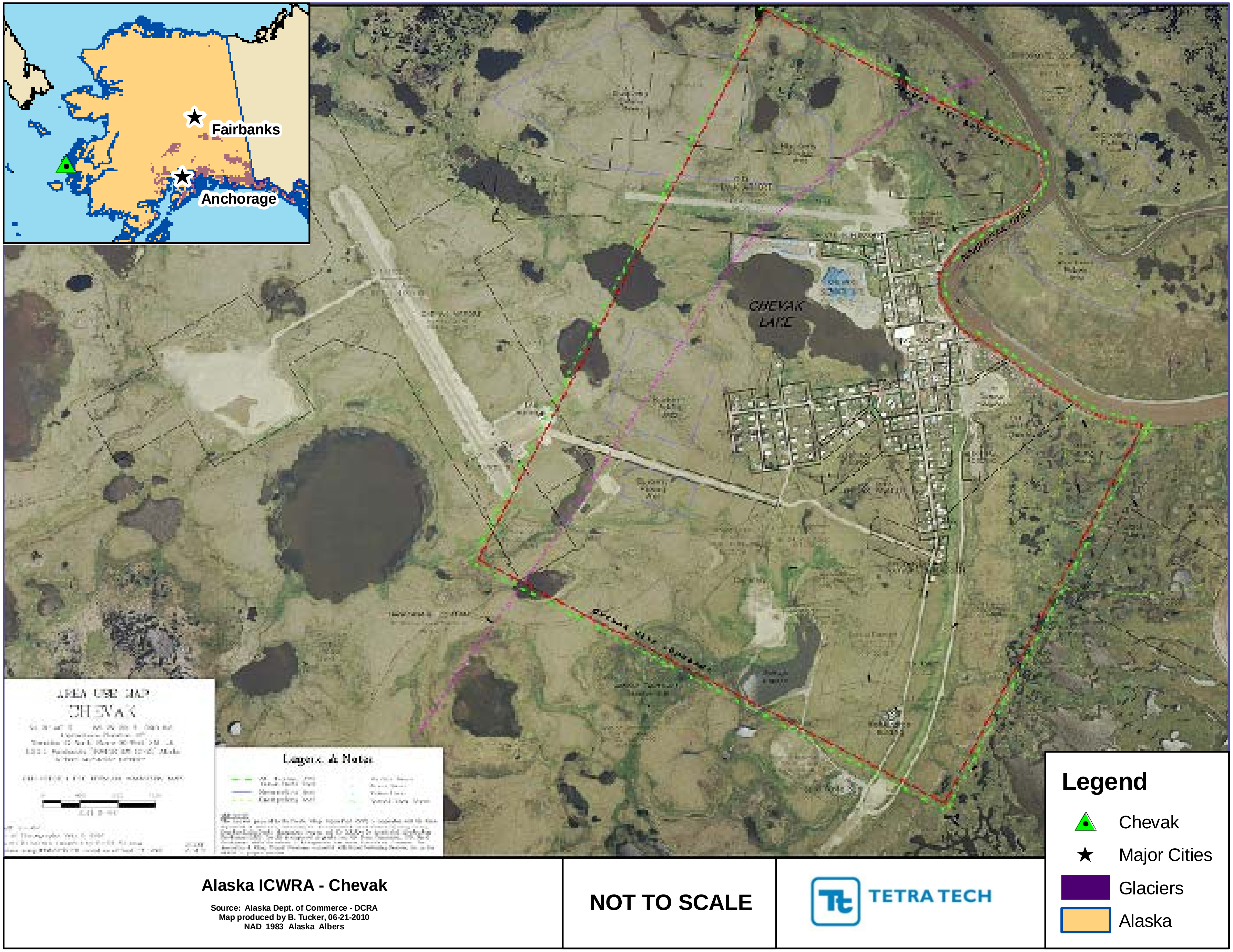
There are no known impacts or threats to water resources or infrastructure according to ANTHC.

Historical Impact to Water Infrastructure

No direct impacts to water resources have been documented.

Mitigation of Impacts to Water Infrastructure

As part of the water and wastewater system improvements implemented in the late 1990s, the sewage lagoon was moved out of the floodplain to higher ground.


Fairbanks
Anchorage
CHEVAK LAKE
AREA USE MAP
CHEVAK
Legend & Notes
Legend
Chevak
Major Cities
Glaciers
Alaska
Alaska ICWRA - Chevak
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH

Selected Photographic Documentation

Niglikfak River boat storage area. Photo courtesy of the Chevak Community Plan.

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Alaska Native Tribal Health Consortium (ANTHC), telephone interview with Shad Schoppert, Engineering Project Manager (June 2, 2010)

Division of Community and Regional Affairs, Online Community Database Chevak http://www.commerce.state.ak.us/dca/commdb/CIS.cfm

Chevak Community Plan, by the Chevak Community Planning Team and the residents of Chevak with assistance from Rural Alaska Community Action Program (RURAL CAP) and The Denali Commission, (August 2009).

Chevak Community Plan, by the Chevak Community Planning Team and the residents of Chevak with assistance from Rural Alaska Community Action Program (RURAL CAP) and The Denali Commission, (August 2007).

City of Chevak Sanitation Facilities Feasibility Study and Master Plan, prepared by HDR Engineering (August 1993).

USACE, Alaska Baseline Erosion Assessment, Erosion Information Paper, *Alaska Community Erosion Survey, OMB approved number 07100001*, expires September 30, 2009, completed by RB Slats, Chevak tribal administrator, submitted January 14, 2008.

Chignik Lagoon

Community Setting

Population:	73, Department of Labor 2009 estimate
K-12 School Enrollment:	16 (as of 10/1/2009)
Incorporation Type:	Unincorporated
Local governance:	Native Village of Chignik Lagoon, Federally-recognized tribe
Borough Located In:	Lake and Peninsula Borough
Regional Native Corporation:	Bristol Bay Native Corporation

Landform and Climate:

Chignik Lagoon is located on the south shore of the Alaska Peninsula, 450 miles southwest of Anchorage. It lies 180 air miles south of King Salmon, 8 1/2 miles west of Chignik, and 16 miles east of Chignik Lake and 280 miles east of Unimak Pass (the separation between the Alaska Peninsula and the Aleutian Islands) according to the Lake and Peninsula Borough website community description.

The community experiences a maritime climate, characterized by cool summers and relatively warm, wet winters. Thick cloud cover and heavy winds are prevalent during winter months. Summer temperatures range from 39 to 60°F. Winter temperatures range from 21 to 36°F. Precipitation averages 127 inches annually, with an average annual snowfall of 58 inches according to the Division of Community and Regional Affairs Community Database Online.

Chignik Lagoon is located at the mouth of Packer Creek on an alluvial fan formed by the creek. Alluvial fans are high-hazard flood areas. These fan-shaped geomorphic landforms occur when a creek flows from steep, mountainous terrain onto a flat outwash plain. The channel can readily migrate over the fan from even minor floods; however, Packer Creek has been confined to protect the airport that crosses the community. Low-lying areas of Chignik Lagoon adjacent to the coast are subject to coastal flooding and erosion, however a breakwater across the point provides some protection.

Water Infrastructure Description

a. Water supply(ies): Chignik Lagoon uses an infiltration gallery to draw water from a surface source, and a few households have individual wells. The raw water pump house is not within the erosion area of Packer Creek or the coastal flood areas as depicted on the Lake & Peninsula Borough, Chignik Lagoon community maps.

b. Water system(s): A piped water system serves most homes. In 2001, ANTHC completed a project to install a new water treatment plant (WTP) and water storage tank, according to the DCRA Community Database Online. The DCRA infrastructure database indicates that additional work completed in 2002 included the installation of water service laterals, WTP instrumentation, and the demolition and removal of the old water storage tank.

c. Wastewater system(s): Nearly all residences have complete plumbing, using individual septic tanks or the community wastewater system. The sewage lagoon is the only water/wastewater infrastructure known to have some erosion impacts, although no direct damage is believed to have occurred to the lagoon. The DCRA infrastructure database indicates that additional work completed in 2002 included the installation of sewer service laterals, individual septic tanks, gravity sewer mains, a residential sewage lift station, and a drainfield.

Climate Related Factors and Potential Effects on Water Infrastructure

Chignik Lagoon is subject to flooding brought on by extreme weather combined with high tides and high winds. One fall storm caused severe erosion to the landfill road, and the exterior wall of the sewage lagoon was damaged by wind driven waves and runoff. The Corps of Engineers Alaska Baseline Erosion Assessment (ABEA) rated Chignik Lagoon as a “community to monitor”.

Flood waters during December 2007 approached a wastewater lift station near the school according to the Chignik Lagoon Tribal Council (during a 2008 telephone interview for the Corps of Engineers erosion information paper, prepared for Chignik Lagoon).

Severity of Impacts

The sewage lagoon appears to be most at risk from erosion and/or flooding, although documented impacts to date have been negligible.

Historical Impact to Water Infrastructure (based on the Lake and Peninsula Borough Multijurisdictional Hazard Mitigation Plan, February 2009)

Floods are documented to have occurred in 1986, 2002, 2003, and 2007, typically in November and/or December. Flooding caused significant damage in Chignik Lagoon in 2002 when Packer’s Creek breached its banks, eroding away the north end of the runway. Coastal and riverine areas of the community are particularly vulnerable to erosion. Erosion caused by flooding and wave damage can affect the entire coastline of the community during large storms, and regular wave action causes slow, steady coastal erosion. Residents report a loss of about 1 foot of shoreline per year, and more near the old fuel farm. Packer’s Creek breaches its banks yearly, and has been reinforced with riprap and other types of erosion control in response. It is not yet clear how effective these measures will be.

Likelihood and Frequency of Infrastructure

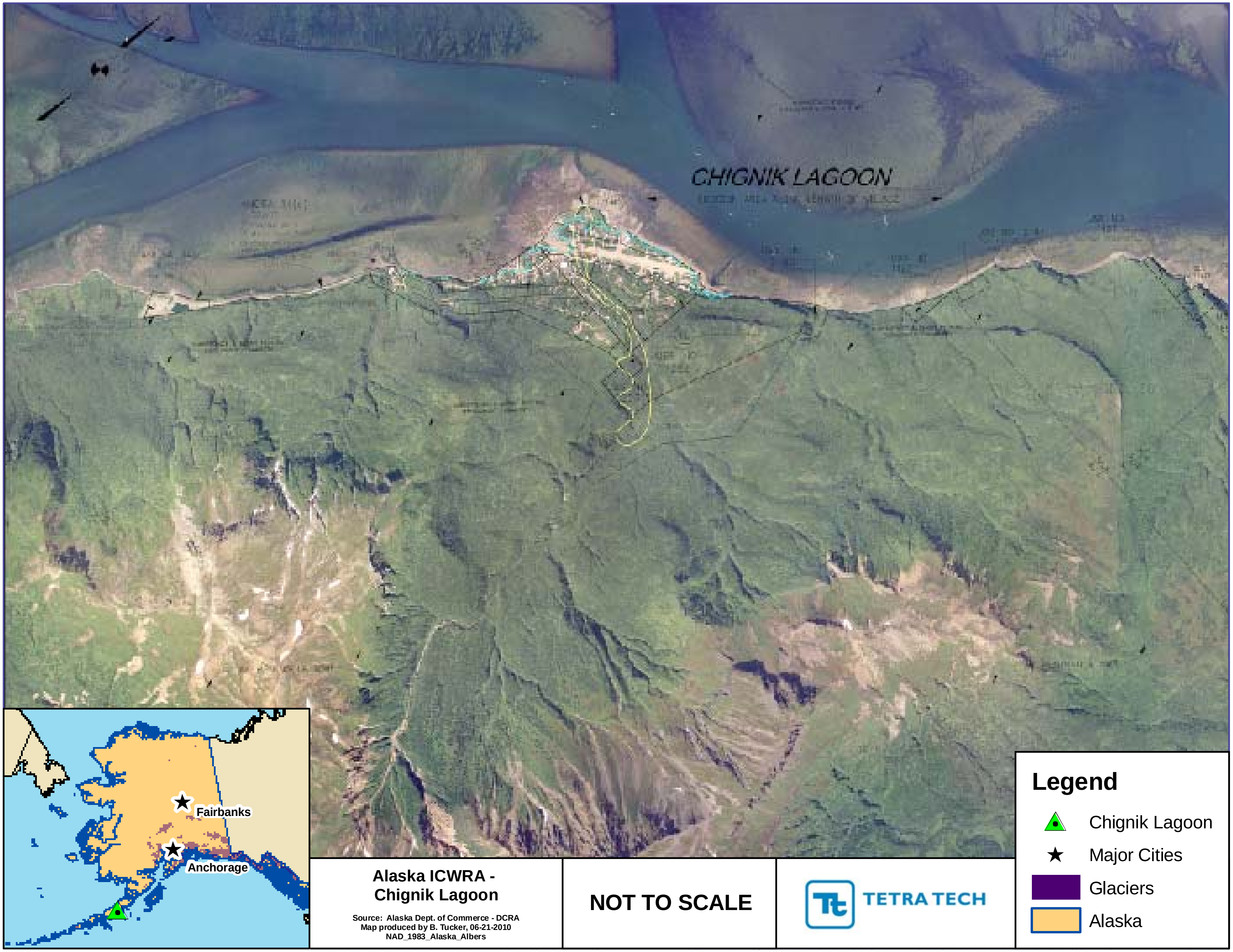
In the areas shown on the Chignik Lagoon Community Profile maps as erosion- and flood-prone, the likelihood of damage is high. Outside but immediately adjacent to these areas, the likelihood of impacts drops. Flood zone maps for Chignik Lagoon are not known to exist; only areas that have previously been known to flood are mapped by the Lake and Peninsula Borough.

Severity of Impacts

Damage to the lagoon is expected to be incremental and repairs would likely be performed without long-term community disruption.

Mitigation of Impacts to Water Resources

Some flood mitigation measures have been installed on Packer's Creek by the Department of Transportation and Public Facilities (DOT/PF). Airport safety improvements for $1.8 million were also approved in fiscal year 2011 state capital budget. According to a DOT/PF supplemental budget request, the shoreline around the northeast end of the Chignik Lagoon runway is continuing to erode, reducing runway length and width. Phase 1 of the project lengthened the runway from a length of less than 1800 feet to 1935 feet, and adding additional embankment and length in Phase 2 will continue to substantially improve safety.


CHIGNIK LAGOON
Fairbanks
Anchorage
Alaska ICWRA -
Chignik Lagoon
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH
Legend
Chignik Lagoon
Major Cities
Glaciers
Alaska

Selected Photographic Documentation

Erosion around the perimeter of the Chignik Lagoon sewage lagoon caused by flooding. Photo taken January 29, 2003 courtesy of Lake and Peninsula Borough.

An overflow channel of Packer Creek cuts past the sewage lagoon during January, 2003 flooding. Photo courtesy of Lake and Peninsula Borough

Playground awash during 2002 flooding at Chignik Lagoon. Photo courtesy of Lake and Peninsula Borough.

References

Alaska Department of Transportation and Public Facilities, Chignik Lagoon Airport Safety Improvements, FY2011 Request, Reference No. AMD 43010

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Alaska Division of Community and Regional Affairs (DCRA) Community Database Online http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

Lake and Peninsula Borough Multi-Hazard Mitigation Plan, February 2009

Lake and Peninsula Borough Chignik Lagoon community description on line at: http://www.lakeandpen.com/index.asp?Type=B_BASIC&SEC={838653AE-07D9-4C0E-89DF-ACADEB410964}

Lake and Peninsula Borough Chignik Lagoon Community Profile Maps, online at: http://www.lakeandpen.com/index.asp?Type=B_BASIC&SEC={838653AE-07D9-4C0E-89DF-ACADEB410964}&DE={EB255867-D602-4221-835A-EC2687B07145}

Lake and Peninsula Borough photos by Marv Smith

Army Corps of Engineers (USACE), Alaska District, Alaska Baseline Erosion Assessment (ABEA), Chignik Lagoon Erosion Information Paper, January 4, 2008

USACE, Alaska District, *Evaluation of Flood Damage, Chignik Lagoon trip report*, (1977)

Deering

Community Setting

Population:	118, Department of Labor 2009
Incorporation Type:	2nd Class City
Local governance:	City of Deering
Borough Located In:	Northwest Arctic Borough
Regional Native Corporation:	NANA Regional Corporation

Landform and Climate:

Deering is located on the north side of the Seward Peninsula at the mouth of the Inmachuk River on Kotzebue Sound, 57 miles southwest of Kotzebue. It is built on a flat sand and gravel spit approximately 300 feet wide and a half-mile long. The Inmachuk River is tidally influenced.

Deering is located in the transitional climate zone, which is characterized by long, cold winters and cool summers. The average low temperature during January is -18 °F. The average high during July is 63 °F. Temperature extremes from a low of -60 to a high of 85 °F have been measured. Annual snowfall averages 36 inches, and total precipitation averages 9 inches per year. Kotzebue Sound is ice-free from early July until mid-October, according to the Division of Community and Regional Affairs Community Database Online.

Water Infrastructure Description

a. Water supply: Water is sourced from the Inmachuk River.

b. Water system(s): Water is treated and pumped to a 400,000-gallon insulated storage tank. The water transmission line crosses the floodplain of the Inmachuk River. The installation of an additional water storage tank was completed in 2006. The DCRA Community Database Online capital project list includes a statement on funding ($845,650 in 2009) for installation of a raw water transmission line and repairs to the infiltration gallery and pump house. The raw water transmission line has been installed and the repairs to the infiltration gallery and pump house are under construction. Residents pay to have water delivered to their homes.

c. Wastewater system(s): The sewage collection system is a vacuum sewer that conveys sewage to a treatment lagoon located on the spit adjacent to the river.

   The City of Deering operates the piped sewer and water haul system, as well as a central washeteria according to the DCRA, Rural Utilities Business Advisor (RUBA) quarterly report.

Climate Related Factors and Potential Effects on Water Infrastructure

Because of Deering's setting on a spit adjacent to the Inmachuk River, storm events will continue to impact the community and with climate change-induced sea level rise, the community will be increasingly at risk.

Likelihood and Frequency of Impacts

According to the US Army Corps of Engineers' flooding and erosion summary for Deering, storm surges and wind-driven waves cause coastal flooding every 40-60 years. A major flood in 1973 caused extensive damage to homes, and villagers were temporarily evacuated to a mining camp 22 miles upriver. Severe erosion of the beach had been occurring in the past, threatening an important road and other areas. In the late 1990s, the Corps constructed an emergency bank protection structure along the Inmachuk River for the road that parallels the Inmachuk River between Deering and the former mining community of Utica, 19 miles to the southwest. During the 1993 ice breakup, a number of locations were severely eroded, the most critical being the 600-foot-long section of road between the city and the airport. The water transmission line also runs along this road and crosses the floodplain.

Severity of Impacts

There continues to be some risk of flooding and storm damage to the new water transmission line installed in 2009, the sewage lagoon, and the water treatment plant. Additionally, structural problems (which may be more related to design than climate impacts) with the wastewater treatment lagoon have been documented. Alaska DEC is working with an engineering consultant on a more in-depth study to determine whether repair or replacement of the sewage lagoon is warranted. Village Safe Water staff indicates that there are cracks in the lagoon and that the lagoon and the sewage system are not rip-rapped. The system will need to be anchored at some point.

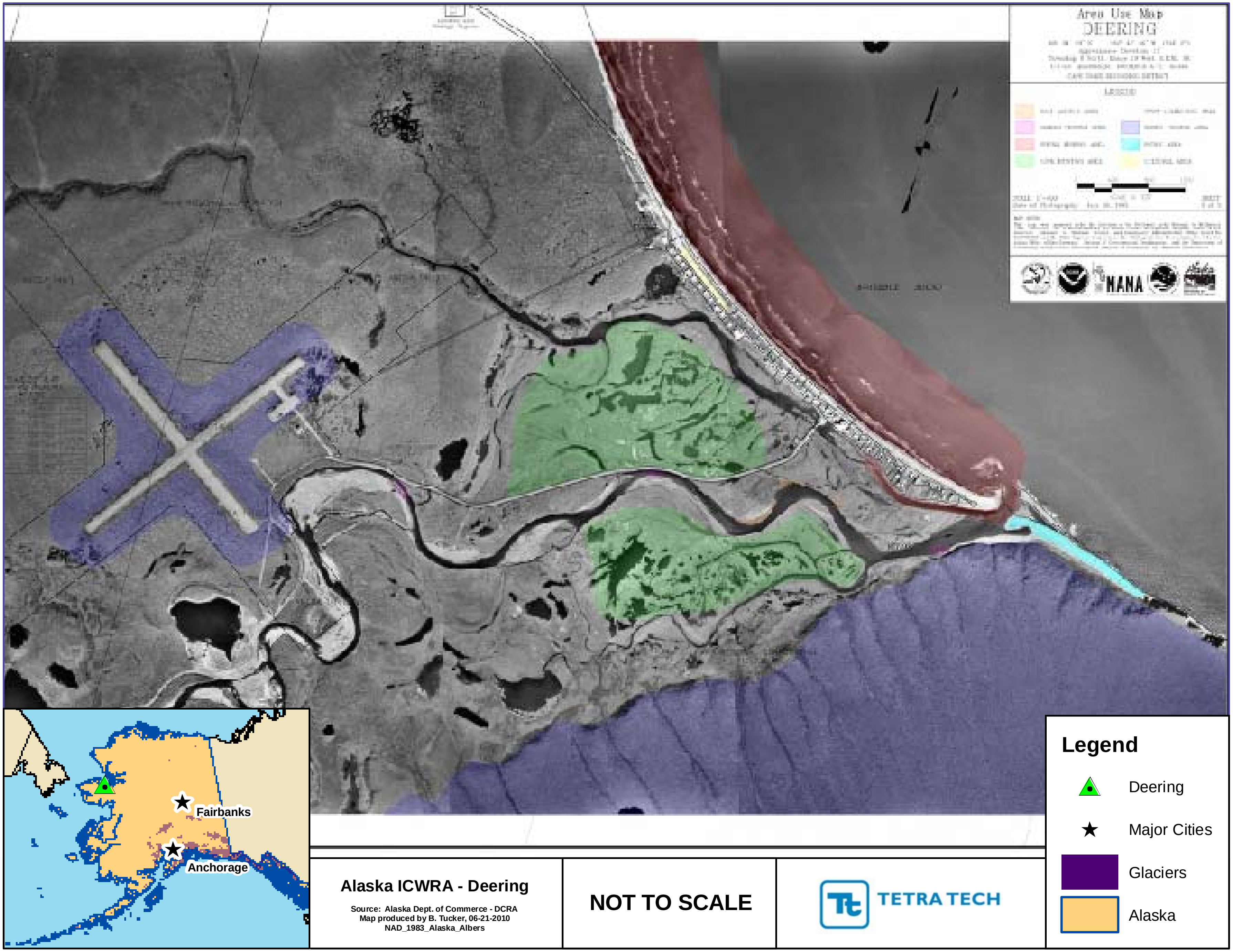
Historical Impact to Water Infrastructure

Historical impact to water resources is unknown, although it is noted that most of the water-related infrastructure currently serving Deering have been installed in recent years.

Mitigation of Impacts to Water Infrastructure

The impacts of river erosion on the water transmission line have been reduced, but not eliminated, due to the aforementioned erosion mitigation along the river. The Corps constructed rip-rap erosion control revetments in 1997 for a combined length of 1,400 feet at a cost of just over $700,000. A 2005 inspection report of this project stated, with regard to the revetment closest to town: "Erosion of the stream bank downstream of the project is evident and ongoing. Fractures in the soil on the top of the bank and sloughed riverbank can be seen in this area…The revetment appears to be overall in good condition…Downstream of the first revetment there is also evidence of erosion (sloughed riverbank). While it does not appear to be as severe as the erosion upstream and closer to town, it should continue to be monitored. The revetment closer to the airport appears to be in similar condition to that of the revetment closer to town. The amount of debris accumulated on this revetment was less and there appeared to be more rock fractures…There was very little erosion upstream of the revetment near the airport."

The potential impacts of coastal erosion and flooding to the sewage lagoon and water treatment plant are believed to be significant because of the proximity of these systems to the river and their location on the spit, for which coastal storm surge flooding and erosion has been documented.


Area Use Map
DEERING
Fairbanks
Anchorage
Alaska ICWRA - Deering
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH
Legend
Deering
Major Cities
Glaciers
Alaska

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Division of Community and Regional Affairs Online Community Data Base, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA, RUBA Quarterly Report, (updated April 5, 2010).

Deering Comprehensive Community Development Plan 2009-2016, prepared by Northwest Arctic Borough, 2006

US Army Corps of Engineers (USACE), Alaska District, Section 14 Emergency Bank Protection Draft Detailed Project Report and Environmental Assessment Deering Alaska (June 1994)

USACE, Alaska Baseline Erosion Assessment, Study Findings and Technical Report (March 2009), http://www.poa.usace.army.mil/en/cw/planning_current%20projects%20info/Alaska%20Baseline%20Erosion%20Assessment%20(BEA)%20Main%20Report.pdf

USACE, Memorandum Inspection of Completed Works, Deering Emergency Streambank Stabilization, Deering, Alaska, 20 September 2005, Mary Wilson, Hydraulic Engineer.

Diomede

Community Setting

Population:	117, Department of Labor, 2009 estimate
Incorporation Type:	2nd class city
Local governance:	City of Diomede and Native Village of Diomede IRA Council
Borough Located In:	Unorganized borough
Regional Native Corporation:	Bering Straits Regional Corporation

Landform and Climate: Diomede is located on the west coast of Little Diomede Island in the Bering Strait, 80 miles northwest of Teller and 130 miles northwest of Nome. The island, which is located only 2.5 miles from Big Diomede Island, Russia, is a mass of boulders and has a land area of approximately 2.8 square miles. There is a small rocky beach immediately west of the village and from there, the land rises steeply on all sides to 1,250 feet. The top is broken tableland with no trees or scrubs and scant vegetation. The international boundary between the United States and the Russian Federation lies between the islands. Little Diomede is flat-topped, steep-sided and very isolated by its location, by rough seas, and by the persistent fog that shrouds the island during the warmer months.

Summer temperatures average 40 to 50 °F. Winter temperatures average from -10 to 6 °F. Annual precipitation averages 10 inches, and annual snowfall averages 30 inches. During summer months, cloudy skies and fog prevail. Winds blow consistently from the north, averaging 15 knots, with gusts of 60 to 80 mph. Due to constant winds from the north, accessibility is often limited. The Bering Strait is generally frozen between mid-December and mid-June.

Water Infrastructure Description

a. Water supply: Water is drawn from a mountain spring in the summer months (families also haul water from this source) and sometimes by desalinization of sea water.

b. Water system(s): Spring water is filtered and chlorinated at the water treatment plant prior to being stored in a 434,000-gallon steel tank from which families haul water. The tank is filled for winter use, but the water supply typically runs out around March, when the washeteria is closed and residents must melt snow and ice for drinking water

   ANTHC is working on the design of a new, approximately 400,000-gallon water storage tank which will nearly double the community's existing water storage. A new water transmission line has recently been completed along with improvements to the water intake. The improvements are intended to better catch some of the early snowmelt, rather than relying on summer flows which can have high nitrates resulting from bird droppings.

c. Wastewater system(s): All Diomede households use privies and/or honeybuckets; the waste is dumped on the beach in the summer and on pack ice in the winter. The clinic is connected to a septic system and seepage pit serving the washeteria. The school has a similar system that disposes effluent on the beach. Due to the soil conditions, lack of ground cover, and steep terrain, waste disposal methods are currently limited to disposal on the beach or on the sea ice in the winter. ANTHC is currently preparing a sanitation master plan for Diomede.

(above information compiled from an ANTHC interview, the Diomede Local Economic Development Plan, the Division of Community and Regional Affairs (DCRA) Community Database Online, and the DCRA Rural Utilities Business Advisor (RUBA) status report)

Climate Related Factors and Potential Effects on Water Infrastructure

As one of the most remote communities in Alaska, along with its frequently adverse weather conditions, it is not uncommon for Diomede to be inaccessible by air for long periods of time. There is no airstrip due to the steep slopes and rocky terrain, so skiplanes must land on an ice strip in winter. A significant seasonal change occurred in winter 2008-09 when winter conditions were too warm and shifting ice prevented sufficient freeze-up to create a safe winter runaway on the sea ice to allow for Bering Air to fly to Diomede. This lack of access significantly hampered the community and among other impacts stopped progress on the sanitation and water improvements project. More frequent warm winters, or low snowfall exacerbated by climate change could impact both access and available water supply.

Likelihood and Frequency of Impacts

It is not definitively known how frequent warm winters or low snowfall could re-occur; however, the community water supply remains susceptible since water supply improvements for the community are currently dependent primarily on additional catchment of snowmelt runoff.

Severity of Impacts

The documented impacts affecting access to the community and its current reliance on snowmelt as a water source are described above. The community's existing water supply challenges are significant (although are being mitigated) and there is little in the way of effective wastewater management in the community, creating potential public health and/or environmental risks. On the other hand, given that the community has relatively little centralized water infrastructure, catastrophic climate-related impacts are unlikely.

Historical Impact to Water Infrastructure

Annually, the current water storage is insufficient to meet the needs of the community and the large returning bird population creates a treatment challenge because of the high nitrate levels of the surface runoff.

Mitigation of Impacts to Water Infrastructure

In fiscal year 2008, ANTHC was funded $648,126 to build a new storage tank and improvements to the existing water treatment plant and transmission line, as previously described.

Alaska ICWRA - Diomede

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

A Local Economic Development Plan for Diomede 2009 Updated Priorities, City of Diomede and Diomede community workshop members, online at: http://www.commerce.state.ak.us/dca/commdb/CF_Results.cfm

Division of Community and Regional Affairs (DCRA) Online Community Database: http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.htm

DCRA Rural Utilities Business Advisor (RUBA) status report (April 3, 2010), http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=758&isRuba=0

Department of Health and Social Services, Section of Epidemiology, H1N1press release (November 4, 2009)

Emmonak

Community Setting

Population:	774, Department of Labor, 2009 population estimate
Incorporation Type:	2nd class city
Local governance:	City of Emmonak
Borough Located In:	Unorganized borough
Regional Native Corporation:	Calista Corporation

Landform and Climate:

Emmonak is located at the mouth of the Yukon River, 10 miles from the Bering Sea, on the north bank of Kwiguk Pass.

Emmonak has a cold maritime climate. Temperatures have ranged from -25 to 79 °F. Precipitation averages 19 inches per year, while snowfall averages 50 to 60 inches per year. Freeze-up occurs during October; break-up occurs in June according to the DCRA Community Database Online.

Much of the region has moderately thick permafrost to a maximum depth of 600 feet. However, the areas around large water bodies are generally free of permafrost and, due to their proximity to the Yukon River, this is likely to be the case for some of the developed areas of Emmonak. The soils of the region are poorly drained and predominantly consist of stratified silts, loams, and sands commonly overlain with a thick layer of peat according to the VSW Engineering Study of Water, Sewer, and Solid Waste Facilities.

The entire community and immediate surrounding area is located in the floodplain of the Yukon River. Emmonak is a participant in the national Flood insurance Program and has a mapped floodplain along with a long history of flooding. The high water mark which represents the 100-year or one percent annual chance flood, is 4.3 above ground level at the city hall building which is equal to 20 feet above mean sea level (MSL). Major floods were documented in 1972, May 1992, and May 2005 with the most severe flooding event on record having occurred in 1972.

Water Infrastructure Description

This infrastructure description is based on the Water, Sewer and Solid Waste Facilities study dated December 2001, the local hazard mitigation plan, the DCRA Community Database Online, and information provided by VSW.

a. Water supply(ies): Water is sourced from the Yukon River.

b. Water system(s): Piped water service has recently been expanded to the west side. In total, 206 connections, including homes, businesses, and the school are estimated to be served with the above ground circulating water system and vacuum sewage system. Water storage capacity has been doubled to accommodate the system expansion and a new washeteria is under construction according to the Emmonak Local Hazard Mitigation Plan. The Water Treatment Plant (WTP), installed in 1985/1986, is a package filtration plant fabricated by Water Tech, which is no longer in business. The plant is designed to treat high turbidity source water, especially in the summer. A high level of operator attention is needed to produce quality potable water.

c. Wastewater system(s): Wastewater is collected using a vacuum sewer system, which conveys sewage to a central vacuum collection station that is housed in the same building as the WTP. This facility has been in use since 1986, and has provided dependable service to the community. Along with potable water, sewer service has recently expanded to west side homes, businesses, and the school which are now served by the vacuum sewer system. Houses that are not on the sewer systems use honeybuckets.

   The water distribution and sewage collection lines are typically constructed above ground on anchored, treated wood “sleepers”. The piping systems were constructed in two phases. Phase 1 piping systems was completed in 1988 with additional service connections and system improvements implemented through the early 1990s.

   Currently, there are 206 connections to the piped water and sewer system. Out of those connected, there are 185 residential homes and 23 businesses in service. The next water/sewer Village Safe Water funding will connect six new Emmonak tribal housing units.

Climate Related Factors and Potential Effects on Water Infrastructure

Flooding and erosion from the Yukon River have on several occasions caused some movement of the above ground vacuum sewer and water piping. The systems are sensitive to elevation and when the piping is moved during floods, regrading is often necessary to restore proper function. According to VSW, a severe flood in May 2009 damaged the water and sewer service boxes and undermined the soil beneath the wooden boards (sleepers) supporting the vacuum sewer system. The vacuum sewer system will not maintain the proper grade during these flood conditions with the current type of foundation. A $16 million VSW/USDA Rural Development grant will replace foundations with helical piers to properly support the system, while also replacing wooden service connection boxes with aluminum boxes.

According to VSW, approaching river bank erosion is expected to eventually undermine a landfill that is upriver of the community and a road that fronts the river.

The following are some of the relevant water resource vulnerabilities or concerns related to flooding and erosion taken from the *Emmonak Local Hazard Mitigation Plan* based on a site visit on July 18, 2006:

- The island across from Emmonak in the channel of the Yukon River is eroding. High winds from the south cause waves to build momentum, and without the island as a buffer, Emmonak's shoreline is expected to erode at an accelerated rate.
- A project to repair and expand the existing revetment is needed to protect the Village from further loss of land.
- The worst flooding occurs during spring and fall, although the community is in year-round danger from erosion and flooding.
- During the 2006 spring flood, the entire village was under water except for the clinic.
- The river next to Emmonak continues to rise causing more severe river bank erosion. Ice override causes more damage than flooding.
- Culverts need to be replaced in several areas of the village.
- Melting permafrost has led to additional basements being flooded in the village.
- One of the fuel tanks in the village was pushed over on its side during the 2006 flood.

Likelihood and Frequency of Impacts

Major flooding has historically been documented in Emmonak and without substantive impact mitigation efforts, can reasonably be expected to continue, potentially exacerbated by accelerated river bank erosion up stream of the community and impacting the old landfill. The community's water intake is down stream of this old landfill which floods and is threatened by erosion.

Severity of Impacts

Flooding has been documented to disrupt sewer and water service by dislocating conveyance piping. To date, it appears that these disruptions are temporary and manageable, although there remains a potential of a more devastating flood that would broadly disrupt water and sewer service for an extended period of time, with potential associated public health impacts. Additionally, the location of landfill adjacent to the river upstream of the community water source and reported erosion vulnerability suggest that water quality impacts are possible, although their potential severity is unclear.

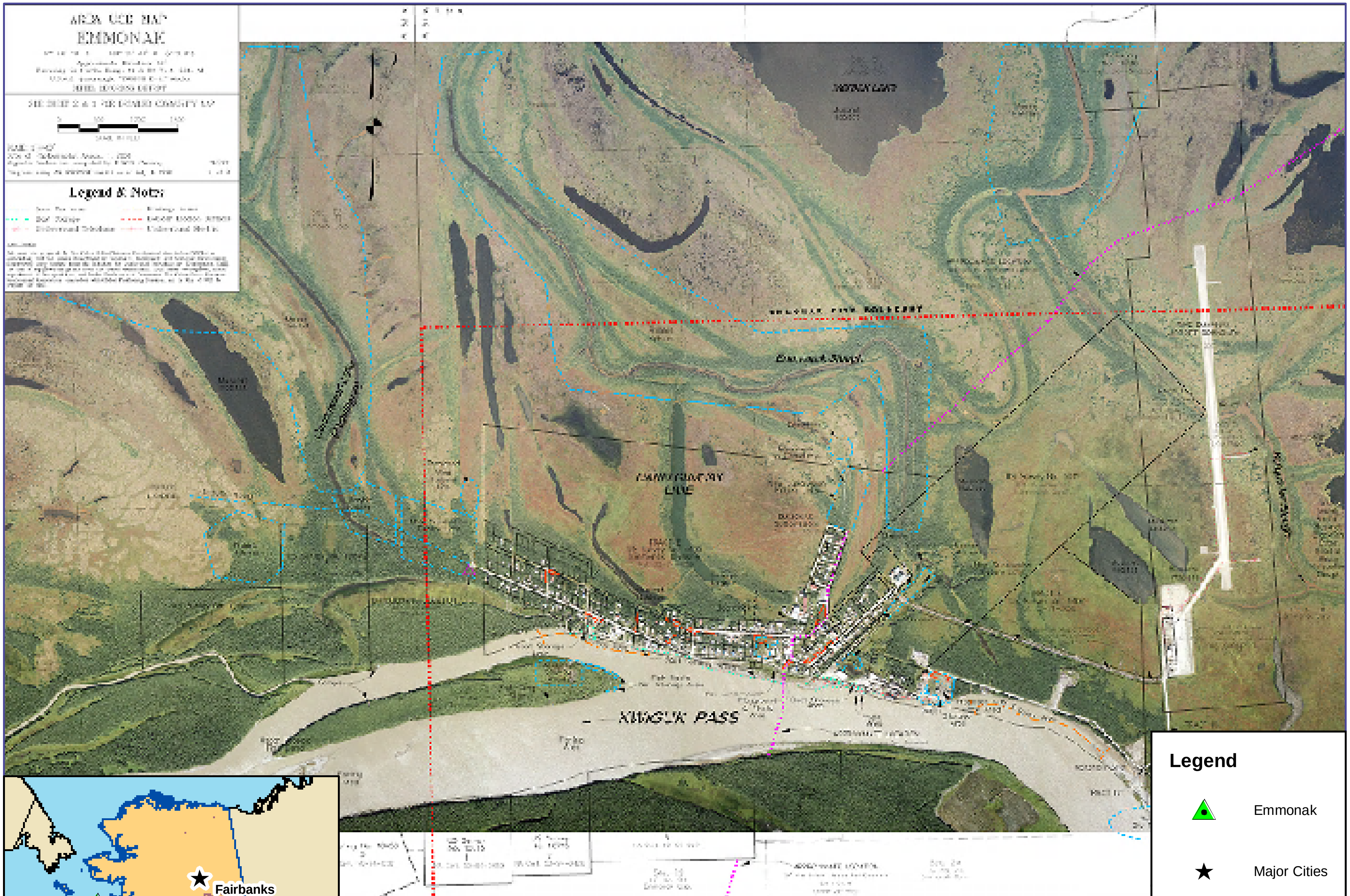
Historical Impact to Water Infrastructure

During spring breakup, beginning May 13, 2005, a large ice jam blocked the mouth of the Lower Yukon River and caused widespread flooding in Emmonak. Several roads were inundated and eroded by the floodwaters. Floodwaters also inundated city infrastructure including the above-ground water and vacuum sewage systems which were displaced and/or knocked off their mounting supports according to the Division of Homeland Security and Emergency Services. An old garbage dump was also flooded and is upriver from the source water intake.

Mitigation of Impacts to Water Infrastructure

There is a $16 million grant from USDA Rural Development to upgrade the sewer system at some point in the future.

According to the Emmonak Erosion Information Paper, most of the community is protected from erosion by two riprap revetment projects. The first project was constructed with State legislative grant funds and a USACE Section 14 1946 Flood Control Act project constructed in 1998 at a cost of about $1.1 million. This provided erosion protection along a 1,443 foot portion in front of the Yukon Delta fish co-op processing plant, Alaska Commercial company store, and other erosion threatened structures. The landfill is not protected by erosion control.



Legend

- Emmonak
- Major Cities
- Glaciers
- Alaska

Alaska ICWRA - Emmonak

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

City of Emmonak Local Hazard Mitigation Plan, prepared by City of Bethel, WHPacific and Bectol Planning and Development (March 9, 2008)

Division of Community and Regional Affairs, Community Database Online at http://www.commerce.state.ak.us/dca/commdb/CIS.cfm

Engineering Study of Water, Sewer, and Solid Waste Facilities City of Emmonak, prepared for City of Emmonak and Alaska Department of Environmental Conservation, Village Safe Water, by Bristol Environmental and Engineering Services Corporation (December 2001)

Ruba Status Report, State of Alaska, Department of Commerce, Division of Community and Regional Affairs. http://www.commerce.alaska.gov/dca/ruba/report/Ruba_public_report.cfm?rID=695&isRuba=1

US Army Corps of Engineers, Alaska District (USACE), Emmonak Erosion Information Report completed for the Alaska Baseline Erosion Assessment, (August 5, 2007)

Fort Yukon

Community Setting

Population	585 (Department of Labor 2009 estimate)
Incorporation Type:	2nd Class City
Local governance:	City of Fort Yukon, and Native Village of Fort Yukon, Federally-recognized tribe
Borough Located In:	Unorganized borough
Regional Native Corporation:	Doyon, Limited

Landform and Climate:

Fort Yukon is located in the Alaska interior on the north bank of the Yukon River and its confluence of the Porcupine River. The city is five miles north of the Arctic Circle, about 145 air miles northeast of Fairbanks, with access only by air and water transportation via river barges and boats during the summer months. Winters are long and harsh with periods of -60 ºF to -50 ºF not uncommon. The lowest temperature ever recorded at Fort Yukon was -76 ºF. NOAA weather reports the highest temperature ever recorded in Alaska occurring in Fort Yukon on June 27, 1915, reaching 100 ºF. Total annual precipitation averages 6.58 inches and about 64 percent of this occurs from June to August. Average winter snowfall is about 43.4 inches. Ground accumulation also averages more than 40 inches according to the Sanitation Feasibility Study Final Report.

The Yukon Flats region is covered with lakes, ponds, and swamps, which form a network of rivers, tributaries and streams. The Yukon River flows through the flats as an intricately braided stream with many channels. At high water, the river overflows from the main channels into hundreds of sloughs. Typically, the flow rises gradually within about two weeks of mid-May. Precipitation is normally low in the spring, and rain does not contribute significantly to spring peak. Summer rains have not been documented to have produced a flood at Fort Yukon.

Water Infrastructure Description

a. Water supply(ies): Water is supplied by two shallow water wells, each 35 feet deep and 200 feet away from the water treatment plant.

b. Water system(s): The city water treatment plant is located east of town beside Yllota Slough, a channel of the Yukon River. By the summer of 2011, a project to site the existing water treatment plant and new water storage tanks above the flood levels is expected be complete.

c. Wastewater system(s): A new 7-acre sewage lagoon and piped sewer system was completed in 2009. The new sewage lagoon is no longer floodprone. Lift stations continue to be located in the floodplain, however construction techniques may limit exposure to flood damage compared to earlier installations.

Climate Related Factors, Effects and Potential Effects on Water Infrastructure

Almost the entire Fort Yukon town site is subject to flooding except the eastern portion called Crow Town and the Air Force communications area. The floods resulting from spring runoff usually are aggravated by ice jams and come from the Yukon River, the Porcupine River, and the "hitherlands" near the Sucker River. Riverbank erosion has always been a problem, especially since 1955, when a large amount of gravel was removed from the Yukon River for construction of the Air Force site. The increased velocity of the river added to the erosion caused from periodic flooding and permafrost thaw. Along some stretches of the river through Fort Yukon, several hundred feet of bank has eroded away. The USACE completed a slough closure dike upstream from the town site in 1967. This dike diverted slough flow through the main channel and alleviated the major erosion problem. The USDA, Natural Resources Conservation Service built 7 finger dikes along the northern Yukon River in 1991 and 1992. Flooding has since washed away some of the dike material. The Federal Emergency Management Agency (FEMA) sponsored a *Conceptual Design Study Report for Flood Damage Reduction at Fort Yukon* in 1994, which resulted in the construction of a ring levee in 1995 that provides protection from the 20 to 25 year flood event; this did not include the fuel tank farm which has its own 4-foot-dike.

The dominant soils in the area are water-deposited silts and fine sands. In some areas, the sediments are covered by a windblown layer of silty loam ranging in depth from a few inches to several feet. The permafrost tables here are usually four or more feet below the surface and may be absent close to the river. These well-drained soils also have the best potential for construction if the particular area is not subject to flooding. A secondary soil type in the Yukon flats is found in the many shallow sloughs and old stream channels. This soil is poorly drained and is perennially frozen at shallow depths; permafrost tables are within two feet of the surface in some areas. Maintaining vegetation in these areas is important for keeping the permafrost tables at existing levels. If vegetation is removed, the permafrost tables lower, resulting is settling of the ground surface, and erosion along the river.

Permafrost is discontinuous in the Yukon Flats, but in poorly drained areas it may occur to a considerable depth. At Fort Yukon, the depth of permafrost was found to exceed 320 feet. Because of permafrost, there is little available groundwater except near streams; the yield from wells is low.

Likelihood and Frequency of Impacts

The new sewage lagoon is located on higher ground that is not flood prone. Sewer lift stations and a portion of the sewer main remain in the flood zone.

Until the construction of new water storage tanks is completed (planned by summer 2011), the risk of flood damage is significant. The well heads near Yllota Slough could potentially be contaminated by flood waters, but these impacts may be somewhat mitigated since the source water is treated prior to distribution.

Severity of Impacts

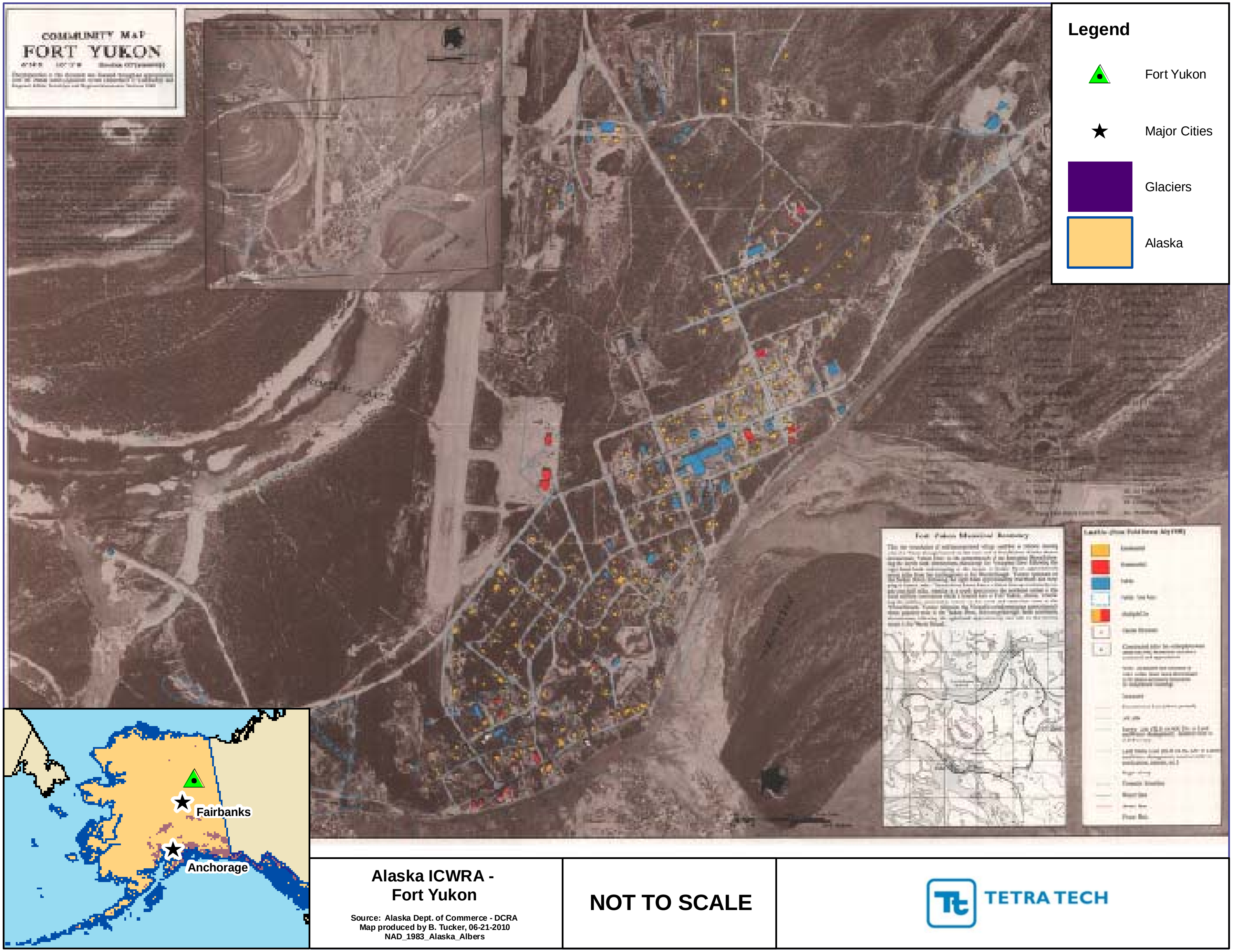
Public health threats from flooding have been or will be largely mitigated by summer 2011.

Historical Impact to Water Infrastructure

Impact has caused infrequent, temporary, or moderate public health threat. The water line has been broken by storm surge induced erosion on at least three occasions.

Mitigation of Impacts to Water Infrastructure

Mitigation measures are being or have been constructed.


COMMUNITY MAP
FORT YUKON
Legend
Fort Yukon
Major Cities
Glaciers
Alaska
Fairbanks
Anchorage
Alaska ICWRA -
Fort Yukon
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH

References

City of Fort Yukon Comprehensive Plan, 1996.

City of Fort Yukon Sanitation Feasibility Study Final Report (July 1997), prepared by ADEC, Facility Construction and Operation, Village Safe Water.

Conceptual Design Study Report for Flood Damage Reduction at Fort Yukon, (1994) Federal Emergency Management Agency.

NOAA Weather Radio All Hazards Information Alaska Weather Interesting Facts and Records.

Golovin

Community Setting & Climate Related Impacts

Population	154, Department of Labor 2009 estimate
Incorporation Type:	2^{nd} Class City
Local governance:	City of Golovin Chinik Eskimo Community is the Federally-recognized tribe
Borough Located In:	Unorganized
Regional Native Corporation:	Bering Straits Corporation

Landform and Climate:

Golovin is located on a point of land between Golovnin Bay and Golovnin Lagoon on the Seward Peninsula. Marine climatic influences prevail during the summer when the sea is ice-free. Summer temperatures average 40 to 60 °F; winter temperatures average -2 to 19 °F. Extremes from -40 to 80 °F have been recorded. Average annual precipitation is 19 inches, with 40 inches average of snowfall. Golovnin Bay is frozen from early November to mid-May.

Water Infrastructure Description

a. Water supply: Water is a summer-only “fill and draw” system. Water is drawn from Chinik Creek and pumped 2.5 miles to the community. According to the *City of Golovin Revised Water and Sewer Utilities Business Plan*, prepared for the Alaska Native Tribal Health Consortium (ANTHC) in November 2004, a new infiltration gallery that would allow for year-round water draw from Chinak Creek is planned for 2009-2010 construction.

b. Water system(s): Water is treated using filtration and chlorination and stored in a 1.2 million-gallon water tank that was constructed in 1999-2000. A new washeteria is under construction according to an April 4, 2010 Rural Utilities Business Advisor (RUBA) status report. A transfer line distributes water to the washeteria and to a 400,000 gallon storage tank that supplies the school. Heated water is used to prevent freezing in the storage tank. In conjunction with ANTHC, a community-wide piped water and sewer system was constructed in 2009. This consisted of a “lower” water loop enclosed in 4,700 ft of buried arctic pipe, a “lower” water circulation plant, an “upper” water loop enclosed in 3,600 ft. of buried arctic pipe, upgrades to the water treatment plant that include an “upper” water circulation system and treatment for disinfection byproducts, and a 1,300 “upper” loop extension of buried arctic pipe for the airport.

c. Wastewater system: The 2009 water/sewer improvements include the installation of a “lower” gravity sewer system enclosed in 3,600 ft. of buried arctic pipe for the airport, a sewage lift station with a force main enclosed in 1,800 ft. of buried arctic pipe and two septic tanks and a drainfield. It is not known if all of these described water and sewer improvements have been completed. The sewage lagoon is approximately 2 miles north of the community.

Climate Related Factors and Potential Effects on Water Infrastructure

According to the U.S. Army Corps of Engineers (USACE), frequent flooding and coastal erosion is caused by severe Bering Sea fall and winter storm surges and tides through Norton Sound impacting Golovnin Bay and Golovnin Lagoon. The community extends from high ground out onto a sand point. The shoreline along the south side of the sand point is eroding toward the first row of buildings. Chinik Creek is also named as a cause of erosion. Lower parts of the community, including the old runway, are commonly flooded. In addition to high tides, storm surges, wind, and waves, according to a community erosion survey completed for the USACE Alaska Baseline Erosion Assessment, conditions that cause the erosion to be more severe include melting permafrost, late forming coastal ice, extended warm periods during winter with extremely high tides potentially causing an ivu event (ice override over land), and removal of beach sand.

Recent major flooding events that also resulted in shoreline erosion occurred in October 1992, September 2003, October 2004, and September 2005.

Likelihood and Frequency of Impacts

Storm impacts are likely to continue to impact the lower portions of the community and land areas around Chinik Creek. The *Golovin Hazard Mitigation Plan* indicates that major erosion and flooding is likely to occur in approximately one out of every three years. Due to Golovin's location on a point of land, sea level rise, flooding and erosion impacts may increase.

Severity of Impacts

Although Golovin is highly susceptible to flooding**,** water infrastructure and siting improvements have mitigated potential impacts to a great extent**.** Above-ground water storage tanks remaining in the lower portion of the community on the point are in danger of continued flooding, but the impacts to this infrastructure are relatively minor. The piped water and sewer lines are buried and thought to be of low vulnerability to storm surge; however long-term erosion, if unchecked, could threaten buried lines near the shoreline, particularly the southern shore.

Historical Impact to Water Infrastructure

The water main has been damaged by storm surge induced erosion on at least three occasions. A 1992 high water mark set by the USACE that was approximately 3.5 ft. above ground level was exceeded by the September 23, 2005 flood event, inundating much of the lower village. Although newly constructed storage tanks are elevated, water tanks have been surrounded by flood waters during the September and October 2005 storms.

Mitigation of Impacts to Water Infrastructure

In addition to the water and wastewater infrastructure improvements described previously, local community members and organizations raised over $100,000 in funding for erosion and flood control projects to protect private and public property according to the 2009 *Golvoin Local Economic Development Plan.*

Alaska ICWRA - Golovin

Map Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

Selected Photographic Documentation

Golovin lower village during September 23, 2005 Bering Sea Storm. Photo Credit: City of Golovin, *Golovin Multi-Hazard Mitigation Plan.*

References

City of Golovin Multi-Hazard Mitigation Plan, by City of Golovin Hazard Mitigation Planning Team and URS, July 2008. http://www.ak-prepared.com/acrobat_docs/Draft%20Golovin%20HMP.pdf

City of Golovin photo September 2005 flood event.

City of Golovin Revised Water and Sewer Utilities Business Plan, for ANTHC by CRW Engineering Group, LLC (November 2004)

City of Golovin Master Plan for Water and Sewer Facilities, by Montgomery Watson for City of Golovin in association with ANTHC (June, 1999)

Golovin Local Economic Development Plan - 2009-2013. See: DCRA Community Plans and Community Infrastructure Library http://www.commerce.state.ak.us/dca/commdb/CF_Plans.cfm

Rural Utilities Advisor (RUBA) Status Report, Division of Community and Regional Affairs (April 4, 2010) http://www.commerce.state.ak.us/dca/ruba/report/Ruba_ComProf.cfm?rID=678

USACE, Alaska Baseline Erosion Assessment, Golovin Erosion Information Paper, http://www.poa.usace.army.mil/AKE/Home.html

USACE, Floodplain Management Services online flood data base http://www.poa.usace.army.mil/en/cw/fld_haz/floodplain_index.htm

Gulkana

Community Setting

Population:	244, Department of Labor, 2009 estimate
Incorporation Type:	Unincorporated
Local governance:	Gulkana Tribal Council, BIA-recognized tribe
Borough Located In:	Unorganized borough
Regional Native Corporation:	Ahtna, Incorporated

Landform and Climate:

Gulkana is on the east bank of the Gulkana (a.k.a. Kulkana) River at its confluence with the Copper River. It is located near mile 127 of the Richardson Highway, 14 miles north of Glennallen.

Gulkana is located within the continental climate zone, with long, cold winters and relatively warm summers. Temperature extremes range from -65 to 91 °F. Annual snowfall averages 47 inches, with 11 inches of precipitation according to the Division of Community and Regional Affairs, Community Database Online.

Water Infrastructure Description

(all infrastructure descriptions are according to the Rural Utilities Business Advisor quarterly status report)

a. Water supply: Water is currently derived from a well that is approximately 15 feet from the river bank. According to the Economic Development Plan, "subsurface water throughout much of the area is under artesian pressure beneath fine-grained material and/or permafrost. Water availability and quality varies dramatically throughout the region. Wells drilled in Glennallen, Gulkana, and Gakona have produced water that is somewhat saline." Alaska Native Tribal Health Consortium (ANTHC) reported that a directional drilled well will be installed in the summer of 2011, about 30 feet from the shore. Although the well will still be located within the floodplain, the wellhead will be contained in a water-proof vault. The intake will be an infiltration gallery installed 5 to 10 feet into the gravel layer. ANTHC indicates that because groundwater availability is spotty in the region, shallow wells perform better.

b. Water system: Water is chlorinated and stored in a 100,000-gallon tank. Volcanic ash associated with a 2009 flood plugged filtration capabilities according to ANTHC; the existing water treatment plant is not filtering for the removal of giardia or cryptosporidium, and is thus considered non-compliant. New infiltration galleries on the Gulkana River and water treatment improvements are being constructed to address high iron and magnesium levels, estimated to be on line by the fall of 2012. A piped water and sewer system serves 47 of 82 homes in Gulkana proper.

c. Wastewater system: The community is served by two 10,000 gallon septic tanks which discharge to a percolation cell, although a number of residences use individual wells and septic tanks. A master plan has been completed for connecting all homes to a new wastewater system and the village is working on constructing a sewage lagoon. The Public Health Service (PHS) constructed a laundromat in 1976, but it is not functioning.

Climate Related Factors and Potential Effects on Water Infrastructure

Although permafrost and high groundwater tables can be problematic for water resource infrastructure in this region, primary risks to the community are erosion and flooding from the Gulkana River.

According to the U.S. Army Corps of Engineers, Erosion Information Paper completed for the community as part of the Alaska Baseline Erosion Assessment, the Gulkana River is on the south side of the community about 150 feet from the center of the developed area with areas of active erosion along the river bank. River flows, spring break up, and ice scouring of the river banks all contribute to erosion. The actively eroding area is estimated to be 150 to 200 linear feet with an average erosion rate of about 1 to 2 feet a year. Approximately 15 feet of river bank eroded away between 2005 and 2007.

Likelihood and Frequency of Impacts

Overall impacts to the majority of the community and its water resources infrastructure are minimal; however, the water treatment plant (WTP) is currently considered by ANTHC to be a relatively high risk because of its inability to filter and treat for the pathogens giardia and cryptosporidium, both of which require physical removal prior to chlorination for inactivation. This is an ongoing problem, although no outbreaks of waterborne disease in the community have been documented.

According to the local tribal administrator, the well site is within 15 feet of the riverbank; however, the installation of a new infiltration gallery will mitigate potential impacts.

Severity of Impacts

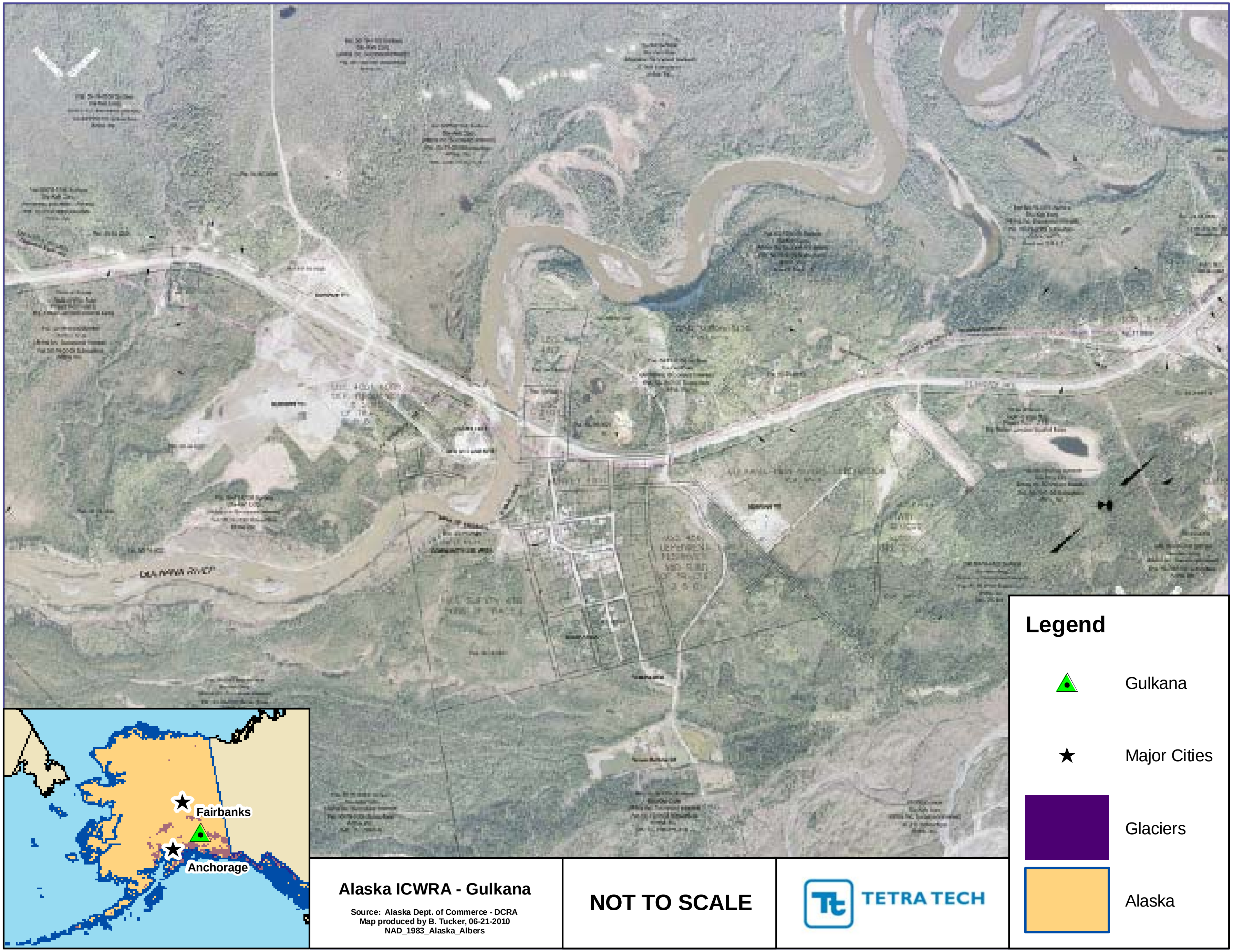
The current lack of water filtration creates a risk of waterborne disease outbreak.

Historical Impact to Water Infrastructure

Besides the documented impacts of source water quality on the water filtration systems, no other direct impacts or damages to water resource infrastructure have been documented.

Mitigation of Impacts to Water Infrastructure

Impacts to the well should be mitigated by summer 2011, while the new WTP is projected to come online by fall 2012.



Alaska ICWRA - Gulkana

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

References

ANTHC engineering project manager, Mike Roberts, telephone interview (June 2, 2010).

Copper Valley Regional Plan, Community Economic Development Strategies, prepared by the Copper Valley Development Association, Inc., with assistance from Rural Alaska Community Action Program (RurAL CAP) and funding from the Department of Commerce, Community and Regional Affairs and the U.S. Economic Development Administration, 2003: http://www.commerce.state.ak.us/oed/oedp/pubs/Copper_CEDS_2003.pdf

Division of Community and Regional Affairs (DCRA), Community Database Online: http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA, RUBA Status Report (June 1, 2010): http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=617&isRuba=1

DCRA, Gulkana Community Map (2005): http://dcra.commerce.alaska.gov/profiles/Color/Gulkana2005.sid

USACE, Alaska Baseline Erosion Assessment, Gulkana Erosion Information Paper, and the *Alaska Community Erosion Survey,* completed by Lamonica Claw, Gulkana village council administrator (January 4, 2008). http://www.poa.usace.army.mil/AKE/Home.html

Hughes

Community Setting

Population:	79, Department of Labor, 2009 population estimate
Incorporation Type:	2nd class city
Local governance:	City of Hughes and Hughes Village Council is the BIA-Recognized Traditional Council; a.k.a. Hut'odleekkaakk'et Tribe
Borough Located In:	Unorganized Borough
Regional Native Corporation:	Doyon, Ltd. is the regional Native Corporation. K'oyitl'ots'ina, Ltd. is the merged village corporations of Alatna, Allakaket, Hughes, and Huslia.

Landform and Climate:

Hughes is on the east bank of the Koyukuk River, 215 air miles northwest of Fairbanks, and contrary to many descriptions of Hughes as located "atop a 500 foot bluff," much of Hughes is still in the floodplain of the Koyukuk River, although the new clinic, some residential, and other buildings are gradually being built out of the floodplain on the bluff.

The area experiences a cold, continental climate with extreme temperature differences. According to the Hughes Comprehensive Plan, mean January temperatures range from a minimum of -18 º F to a maximum of -8 º F, with annual extremes to -72 º F. The summer is short with mean July temperatures ranging from a minimum of 48 º F, to a maximum of 70 º F. Residents report highs of 85 º F every summer. Starting in June, the sun stays above the horizon almost continuously, with nearly 24 hours of daylight daily for about 10 weeks. By late December however, the sun barely rises above the horizon providing little more than 4 hours of twilight. Snow can be expected from October through April. The Koyukuk River is ice-free from June through October.

The soils are generally loams (medium) and silty loess, and are poorly drained with a peaty surface layer. Erosion potential is medium to high. Unconsolidated deposits are mostly sand and gravel, silt, and clay. Permafrost, often ice rich, is present throughout the region except under major waterways. The permafrost table is shallow and permafrost may extend to depths of several hundred feet. Thawing of the top three to four feet occur during the summer. Because of discontinuous areas of permafrost, often caused by migration of Koyukuk River channels, extensive geotechnical investigations would likely be needed before new water systems could be constructed in the upper, non-floodprone bluff area (from Hughes Comprehensive Plan).

Water Infrastructure Description

a. Water supply: Hughes has a community water supply well (DEC permit 300272). The existing well is probably located within the thaw bulb of the river. The well is

45 feet deep with water at 36 feet. It has a 6 inch well casing and produces approximately 10 gallons/minute. The well is within the footprint of the Water Treatment Plant in the lower village. The wellhead is not water tight or above the flood levels. ANTHC is looking for a new water source.

b. Water system(s): Well water is chlorinated, fluoridated, and filtered at a water treatment plant (WTP) prior to distribution. According to the Hughes Comprehensive Plan, the Rural Utilities Business Advisor (RUBA) status report, and ANTHC, 11 or 12 homes on the north side of Hughes, plus the school, teacher's apartments, the clinic and the city/tribal offices have piped water. Several additional homes are expected to be connected in the summer of 2010. Preliminary water treatment improvements are also expected to be completed in 2010. The balance of Hughes residents receive their water by hauling it from the water tap that is located at the washeteria.

c. Wastewater system(s): The RUBA status report also indicates the same 11 homes on the north side of town, plus the school, teacher's apartments, the clinic and the city/tribal offices are served by septic systems. The balance of residences in Hughes rely on outhouses/privies for sewage disposal. A new community sewage lagoon is expected to be completed in 2010. ANTHC plans to provide water and sewer service to the rest of the village, an estimated 13-15 homes.

Climate Related Factors and Potential Effects on Water Infrastructure

The low, flat floodplain area adjacent to the Koyukuk River is prone to flooding and generally lacks permafrost, whereas on the hillside where the new clinic has been constructed, and other homes are being built, ice-rich permafrost is present.

Likelihood and Frequency of Impacts

The Comprehensive Plan also states, (page I-6): “Hughes is less than 2 miles downstream from a meander on the Alatna River that is very near to being cut off. This is expected to occur within 10 to 20 years. It will cause diversion of the channel in a new direction, probably to the southeast, but the direction in not very predictable. Therefore, it is not known how this cut-off will affect the existing Hughes townsite.”

Because of the repeated flood history, the floodplain area of Hughes where the well, water treatment plant and water and pressure sewer serving the lower village are located are at risk of flood damage.

Severity of Impacts

The 1994 Koyukuk River flood is the historical flood of record, with a reported 22 of 29 occupied houses in Hughes severely damaged or destroyed according to the Comprehensive Plan completed following the flood disaster. Only moderate impacts to the water and wastewater systems due to future flooding are expected according to ANTHC.

Historical Impact to Water Infrastructure

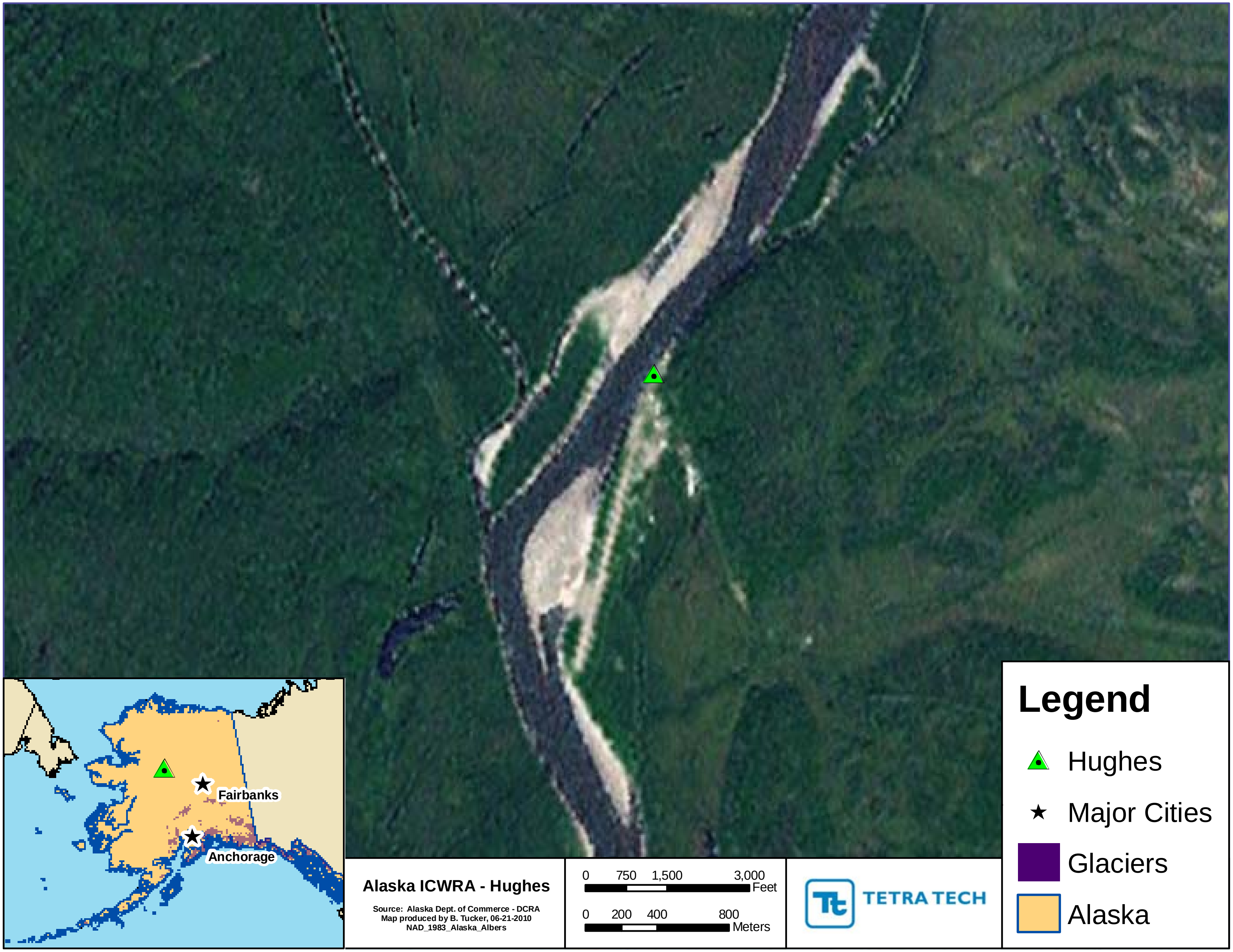
Hughes has had a history of frequent flooding, with floods reported in 1937, 1938, 1963, 1964, 1965, 1966, 1968, 1972, 1989 and 1994. The worst flood occurred in 1994, caused by heavy rains falling throughout the month of August. More than 12 inches fell in less than 30 days. The state and federal governments declared the event a major disaster, and residents had to be evacuated by helicopter to Fairbanks. Many homes and public structures were flooded.

According to the DCRA Community Database Online, a community water distribution system and individual household septic tanks were constructed in 1968. Initially the system worked well, and it was expanded in 1973. However, the system froze in 1983, leaving only a few facilities operational. In 1984, 30 outhouses were constructed to replace the damaged septic systems.

The *Hughes Comprehensive Plan*, completed after the 1994 flood of record, reported that the washeteria was damaged and renovated to its pre-existing condition. Repairs made to the housing stock included “outhouse hole and structure replacement”.

Mitigation of Impacts to Water Infrastructure

Efforts to mitigate climate-related impacts are being implemented as new infrastructure is installed.



Fairbanks
Anchorage
Alaska ICWRA - Hughes
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
0 750 1,500 3,000 Feet
0 200 400 800 Meters
TETRA TECH
Legend
Hughes
Major Cities
Glaciers
Alaska

Hughes during the August 1994 flood, photo courtesy of the DCRA photo library, from the Division of Homeland Security and Emergency Management. The Hughes School is the red roofed building in the center of the photo.

References

Alaska Tribal Health Consortium, engineering project manager, Devan Currier, telephone interview (June 8, 2010).

Division of Community and Regional Affairs, Online Community Photos, *http://www.commerce.state.ak.us/dca/photos/comm_list.cfm*

Hughes: The Comprehensive Plan - A Constitutional Mandate for Long-Term Survival, prepared for the City of Hughes, Alaska Division of Emergency Services, Federal Emergency Management Agency, and H.C. Price, by Kelley Hegarty and Associates Planning Consultants, (May 1995)

Hughes Bulk Fuel Facilities Field Report, by LCMF Ltd. to H.C. Price (March 10, 1995).

Huslia

Community Setting

Population:	265, Department of Labor, 2009 population estimate
Incorporation Type:	2nd class city
Local governance:	City of Huslia
Borough Located In:	Unorganized borough
Regional Native Corporation:	Doyon, Ltd. is the regional Native Corporation. K'oyitl'ots'ina, Limited is the merged village corporations of Alatna, Allakaket, Hughes, Huslia

Landform and Climate:

Huslia is located on the north bank of the Koyukuk River, about 170 river miles northwest of Galena and 290 air miles west of Fairbanks, close to the Arctic Circle. It lies within the Koyukuk National Wildlife Refuge. Huslia is located in the Koyukuk Flats, an area of extensive lowlands generally centered around the junction of the Yukon and Koyukuk Rivers. The area is characterized by floodplains, marshes, thaw lakes, and muskeg type vegetation.

The frost level is estimated to penetrate 7.5 to 8 feet in the permafrost-free sand bench on which the community is located. A low-lying area just west of the community contains permafrost and has an active layer of 2 to 3 feet according to the Huslia Sanitation Master Plan completed in September 2002.

The area has a cold, continental climate with extreme temperature differences. The average daily maximum temperature is 72 °F during July; the average minimum is below 0 °F during January. Temperature extremes have ranged between -65 and 90 °F. The annual precipitation averages 13 inches, with 70 inches of snowfall. The Koyukuk River is ice-free from May through September.

Water Infrastructure Description

a. Water supply: Water is sourced from a community well.

b. Water system(s): The City of Huslia operates a piped water and sewer system and maintains a central watering point where residents not on the piped water system come to haul water. According to ANTHC, a waterline project to serve the homes nearest the river will include the installation of some lines within 200 feet of the riverbank. According to a 2002 Huslia Comprehensive Plan, over 85 percent of residents were served by piped water.

c. Wastewater system(s): The city operates a washeteria. The community wastewater is managed using an infiltrating sewage lagoon and is not known to be at risk for erosion or flooding.

Climate Related Factors and Potential Effects on Water Infrastructure

The Koyukuk River in the vicinity of Huslia eroded an estimated 15-20 feet in 2009. River erosion is threatening those water lines still serving homes nearest to the river. Some old sewer lines may still be protruding out along the eroding river bank but are not in use according to ANTHC.

According to information from the U.S. Army Corps of Engineers (USACE), the riverbank has been eroding at a rate of 10-30 feet per year due to undercutting and ice damage. The townsite is at a relatively low flood hazard risk. High water in the Koyukuk River occurs during spring breakup, but the location of the community on the sandy, silty bench is generally high enough to escape flooding.

Likelihood and Frequency of Impacts

Because of continuing erosion, the water lines that serve the homes closest to the river are likely to be impacted; however, they could be relocated if necessary. Huslia’s other water/wastewater infrastructure is not considered at risk.

Severity of Impacts

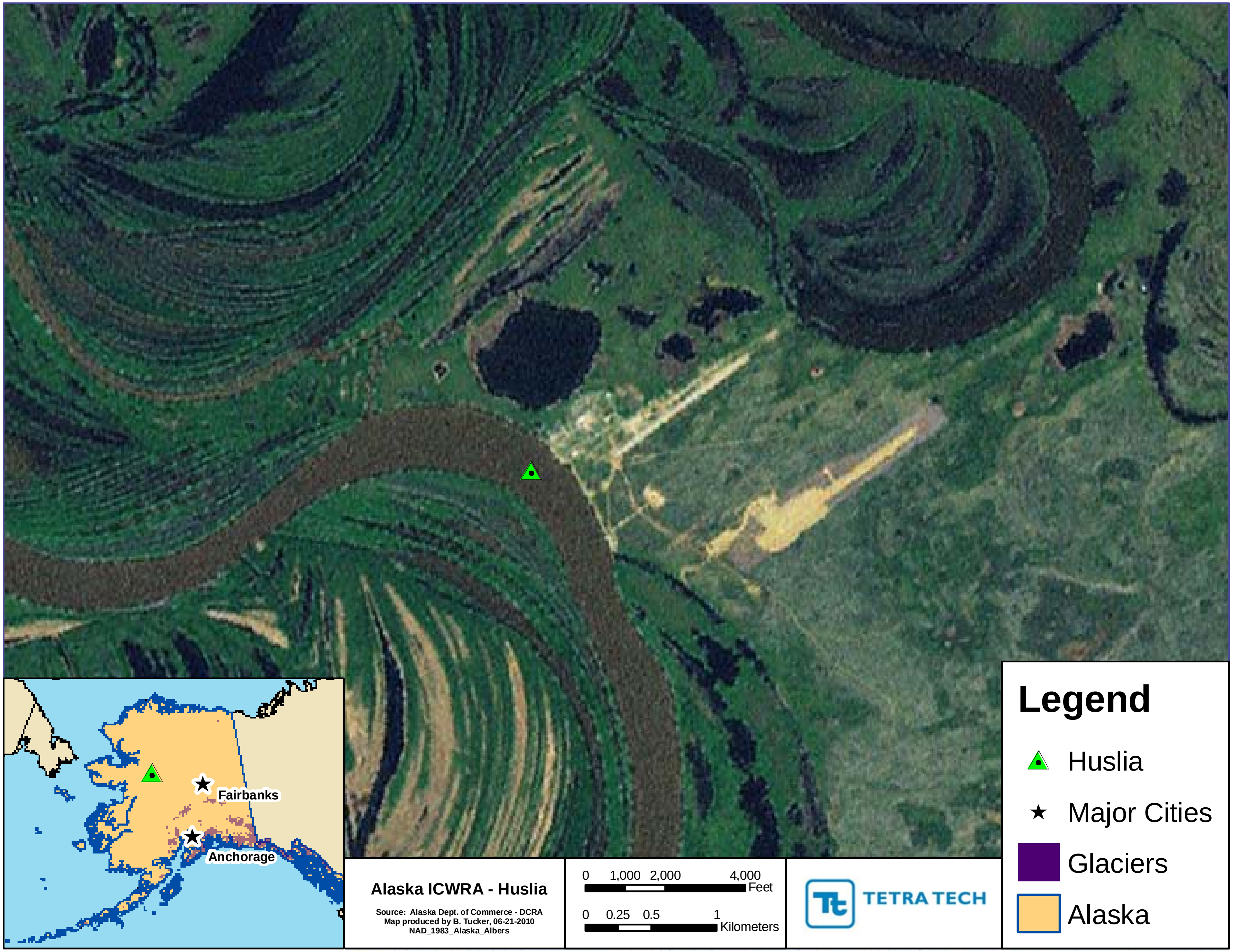
The potential severity of impacts to those few water lines serving homes that remain along the river bank is moderate. If the water lines were impacted and out of service, riverfront residents could haul water.

Historical Impact to Water Infrastructure

The USACE Alaskan Communities Flood Hazard Database indicates that a floodplain information report has not been prepared for Huslia. However, in the spring of 1989, high water topped the old lagoon and washed out its westerly side. Additionally, some old sewer lines may still be protruding out along the eroding river bank, as previously indicated. The community has lost previously constructed structural erosion protection, and continues to need to move structures as the river advances.

Mitigation of Impacts to Water Infrastructure

Past erosion control and bank stabilization efforts have been largely unsuccessful, whereas gradual relocation of homes and other threatened structures and infrastructure of value has been successful at avoiding losses. Moving away from the eroding Koyukuk River has also proven successful in avoiding loss to the bulk fuel facility in 1993. Some water service lines serving riverfront homes may need to be relocated as the river advances.


Fairbanks
Anchorage
Alaska ICWRA - Huslia
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
0 1,000 2,000 4,000
Feet
0 0.25 0.5 1
Kilometers
TETRA TECH
Legend
Huslia
Major Cities
Glaciers
Alaska

Selected Photographic Documentation

© Koyukuk River erosion in Huslia. This undated photo was provided by community residents and is courtesy of the DCRA online photo library. The Koyukuk River caused an additional 15 to 20 feet of erosion in 2009 according to ANTHC.

References

Alaska Native Tribal Health Consortium engineering project manager, Devan Currier, telephone interview (June 8, 2010)

Division of Community and Regional Affairs Online Community Database, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA, Capital Projects Database, http://www.commerce.state.ak.us/dca/commdb/CF_RAPIDS.htm

DCRA, Community Photos Online, http://dcra.commerce.alaska.gov/PHOTOS/Huslia/HUSLIA6.JPG

DOE Tribal Energy Program, Interior Regional Housing Authority, online, http://apps1.eere.energy.gov/tribalenergy/pdfs/0811review_30carlo.pdf

Huslia Comprehensive Community Development Plan, prepared by Huslia Tribal Council, (July 1999), http://www.commerce.state.ak.us/dca/commdb/CF_Results.cfm

Huslia Sanitation Master Plan, (September 2002), http://www.commerce.state.ak.us/dca/commdb/CF_Results.cfm

USACE, Floodplain management Services, Alaskan Communities Flood Hazard Data (2000)

McGrath

Community Setting

Population	322, Department of Labor 2009 estimate
Incorporation Type:	2nd Class city
Local governance:	City of McGrath, and the federally recognized tribe is the McGrath Native Village Council
Borough Located In:	Unorganized borough
Regional Native Corporation:	Doyon, Limited

Landform and Climate:

McGrath lies entirely within the active floodplain of the Kuskokwim River, directly south of its confluence with the Takotna River. The Kuskokwim River, with a drainage area comprising approximately 11 percent of the state, is the largest river in Alaska draining entirely within the state. The USACE Section 205 Reconnaissance Report for Flood Damage Reduction describes the terrain as forested, interspersed with swamps, tundra and thaw lakes. The lowland soils immediately adjacent to the Kuskokwim River are classified as poorly drained.

According to the DCRA Community Database Online, the Old Town McGrath site was originally across the river from its present location. In 1904, a trading post was established at the old site. In 1906, gold was discovered in the Innoko District and at Ganes Creek in 1907. Since McGrath is the northernmost point on the Kuskokwim River accessible by large riverboats, it became a regional supply center. By 1907, a town was established and named for Peter McGrath. After a major flood in 1933, some residents decided to move to the south bank of the river. Changes in the course of the river eventually left the old site on a slough, useless as a river stop. The McGrath area has a cold, continental climate. Average temperatures range from 62 to 80 °F in the summer and -64 to 0 °F in the winter. Precipitation is light, averaging 10 inches per year, with an average snowfall of 86 inches. The Kuskokwim River is generally ice-free from June through October.

Water Infrastructure Description

a. Water supply(ies): Water intake on the Kuskokwim River is pumped directly to the Water Treatment Plant (WTP) that is housed in the Captain Snow Center.

b. Water system(s): McGrath operates a piped water system that serves nearly all 178 households; a few homes have individual wells or haul water. The FAA operates its own water system for the airport. In August 2007, the City of McGrath provided a detailed listing of land and structures at risk to erosion and flooding and at that time the Captain Snow Center that houses the WTP and showers was 96 feet, 9 inches from river's edge. The City Manager estimated 5 feet of additional riverbank has been lost since 2007 in this location of the riverbank, but cautioned that the City has not collected updated measurements. He also estimated that upriver areas have lost about 30 feet of bank.

c. Wastewater system(s): Individual septic tanks are used by the majority of residents; a limited city-operated sewage system serves approximately 34 homes. The Washeteria is also housed in the Captain Snow Center.

   The City Manager in a 2010 telephone interview indicated that the City has been able to discharge water treatment plant backwash water directly into the river; however, 20 feet of this pipe was lost due to erosion. Planned wastewater system improvements will include a pre-sediment pond to handle the backwash discharge. This new pond, if constructed without the protection of erosion control would likely be threatened by Kuskokwim River erosion. However, the Natural Resources Conservation Service (NRCS) is pursuing the stabilization of a second portion of the threatened riverbank area according to the City Manager. Funding has not yet been secured for this protection.

Climate Related Factors and Potential Effects on Water Infrastructure

Erosion and flooding are the most frequent natural hazards facing McGrath as the community lies within the active floodplain of the Kuskokwim River. Also, wildfire and the impacts of drought are potential climate-related impacts. Low river flows as a result of drought may continue to limit barge access to McGrath. The City Manager indicated that McGrath has seen periods of drought and heavy rains that are possible effects of climate change. For example, heavy snowfall in the winter 2008-09 was followed by little precipitation in 2009, and by August, barges could not get up-river to McGrath, creating a fuel shortage that required it to be flown in at high cost.

The NRCS Emergency Watershed Protection (EWP) project repaired and provided riprap armoring for approximately 1100 feet of McGrath's levee. The EWP project was awarded in August 2008 and riprap bank protection is complete. Levee work was scheduled to be completed in spring 2010. An additional project involving 1,900 feet of bank protection has been submitted for funding. The City Manager indicated in a telephone interview that McGrath is counting on this second phase of the NRCS EWP project to be constructed for erosion and flood control across from the Post Office. The plan is to integrate a new water intake system with the Phase II project during the summer 2011.

A US Army Corps of Engineers (USACE) Streambank Stabilization Study for McGrath, underway in 2007, is no longer moving forward due to congressional repeal of a USACE authority that did not require local nonfederal match that had allowed USACE participation. The USACE had been able to utilize the engineering model HEC-RAS to predict and map the magnitude of flooding that may occur in McGrath and the erosion control project area.

Likelihood and Frequency of Impacts

McGrath faces near certain impacts from erosion and flooding. According to the USACE Floodplain Information Study at McGrath, the entire community could expect to be inundated once every 5 to 20 years.

Severity of Impacts

A significant hydraulic event occurred just after spring breakup in 2001, when the Kuskokwim River created a cut-off channel across an oxbow approximately one mile downstream of McGrath. The presence of this new channel resulted in a significant acceleration in the erosion rates along the riverbank of the "McGrath oxbow" where the city is located. According to a USACE flood damage reduction report, erosion rates in McGrath had typically been estimated at between 5 to 10 feet per year. In a 1999 USACE trip report, the erosion rate was reported to be as high as 10 to 20 feet near the log haul-out ramp near the upstream end of the city. The trip report stated the most critical erosion areas where rates seem to be highest include a point from the log haul-out, downstream past the area across from the Captain Snow Center Community at the city water intake point, to the Russell Ivey property. Although other areas of erosion throughout the community were noted, this is the point where water resources are most at-risk.

Historical Impact to Water Infrastructure

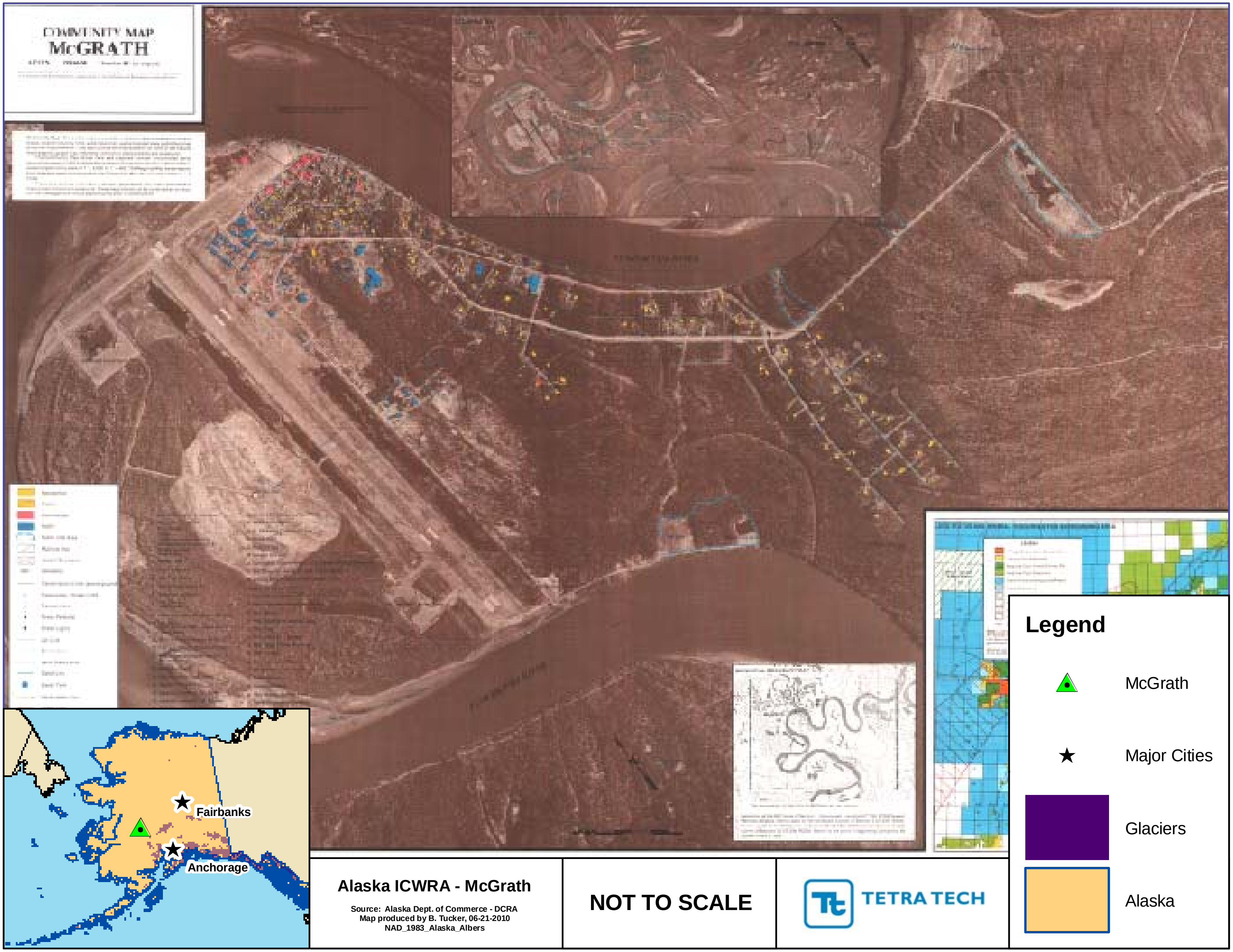
The Division of Homeland Security and Emergency Management (DHSEM) reported that beginning May 3, 2005, ice jam flooding eroded several local roads, including Takotna Avenue and Cranberry Ridge Road, and unusually high water levels threatened city infrastructure and private homes in the City of McGrath. Takotna Avenue is a main transportation avenue in town. The road also serves as a levee against rising river water that, if breeched, would threaten a large portion of the City of McGrath. Community water resource infrastructure at risk from erosion include the Captain Snow Center Community building which houses the City Offices, the WTP, health clinic, fire station, washeteria, and State Trooper office; and the utility corridor containing power and water lines. Althought the Captain Snow building is located on relatively high ground area and may not be in the 100-year flood zone, erosion continues to be a threat.

The 2005 event occurred when wind caused the added problem of wave impact. Erosion rates vary; in some areas, sink holes form in a line which gives some warning about where the next sections may develop fissures that may cause large pieces of earth to erode into the river. Erosion is estimated by the City to be at least 6 feet per year in many areas, according to the USACE Erosion Information Paper and telephone interviews.

Mitigation of Impacts to Water Infrastructure

Numerous drums and other debris, pipes and related items were observed occasionally throughout the entire area of erosion according to a June 11-14, 2007 Corps site visit. The DCRA online capital projects database indicates that a Community Development Block Grant of $350,000 was awarded to McGrath in 2001 for riverside stabilization at the water intake point.

Through the Emergency Watershed Protection program, the City and the NRCS completed the first phase of a levee and river bank armoring project to mitigate erosion and flooding. The project site is on the south bank of the Kuskokwim River and extends approximately 1,100 feet downstream from the log haul-out along Takotna Avenue according to information provided by the USDA, Natural Resource Conservation Service. In mid-May 2008, NRCS solicited bids for the approximately $1,895,200 project which they anticipated awarding by the end of July 2008.



COMMUNITY MAP
McGRATH
Legend
McGrath
Major Cities
Glaciers
Alaska
Fairbanks
Anchorage
Alaska ICWRA - McGrath
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH

Photographic Documentation

Erosion along Takotna Avenue May 2005. Photo courtesy Division of Homeland Security and Emergency Management

Friday, May 12, 2006 Takotna Avenue closed near log haul. Photo courtesy of Natalie Baumgartner.

Aerial photo from ***McGrath Flood and All Hazards Mitigation Plan***, December 21, 2007

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Baumgartner, Natalie, McGrath City Manager telephone interview (May 7, 2010)

City of McGrath Flood Hazard Mitigation Plan,

Darbyshire & Associates, *McGrath Relocation Feasibility Study and McGrath Comprehensive Development Plan*, 1981

Division of Community and Regional Affairs, Online community data base

Division of Homeland Security and Emergency Management, 2005 Spring Flooding, online: http://www.ak-prepared.com/community_services/2005_spring_floods/default.htm

USDA, Natural Resources Conservation Service, State Conservation Engineer Brett Nelson. brett.nelson@ak.usda.gov

USACE, *Alaska Baseline Erosion Assessment, Erosion Information Paper- McGrath, Alaska*, May 21, 2008

USACE, *Floodplain Information Study at McGrath*, 1977.

USACE, *Section 205 Reconnaissance Report for Flood Damage Reduction*: McGrath, AK (May 1992)

USACE, Feasibility Study Peer Review Plan, Streambank Stabilization Study, McGrath, Alaska (August 21, 2007)

USACE, *Trip Report of Erosion, Memorandum for Record*, (November 2, 1999)

USACE Site Visit Summary McGrath Streambank Stabilization, (June 11-14, 2007)

USACE, Bruce Sexauer, telephone interview, (May 13, 2010)

U.S. Geological Survey, Spatial Distribution of Chemical Constituents in the Kuskokwim River, Alaskaby Bronwen Wang, Water-Resources Investigations Report 99-4177

Nelson Lagoon

Community Setting

Population	60, Department of Labor 2009 estimate
Incorporation Type:	Unincorporated
Local governance:	Federally-recognized tribe is the Native Village of Nelson Lagoon
Borough Located In:	Aleutians East Borough (AEB)
Regional Native Corporation:	Aleut Corporation

Landform and Climate:

Nelson Lagoon is located on the northern coast of the Alaska Peninsula, on a narrow sand spit that separates the lagoon from the Bering Sea. It is 580 miles southwest of Anchorage.

Nelson Lagoon lies within an extensive complex of low-lying marshy coastline, tidal flats, coastal inlets, lakes and lagoons. The community is located on a sandy spit built from former beach ridges which have been partially stabilized by vegetative cover. The beaches are composed of dark sands and gravel. The area around Nelson Lagoon is treeless, low-profile tundra dominated by grass, forbs and mosses. To the south, the landscape is dominated by the magnificent Aleutian Range, made up of many mountains and volcanoes, including Mt. Dana (4,300 feet) 25- miles south, Mt. Pavlov (8,261 feet), and active volcanoes which often release steam and smoke. Mt. Veniaminof (8,225 feet) is 75 miles east-northeast.

Nelson Lagoon lies in the maritime climate zone. Frequent and dramatic weather changes occur; with a consistent prevailing wind of 20 to 25 MPH. Temperatures average 25ºF to 50ºF, with a range from -15ºF to 75ºF. Snowfall averages 56 inches, with a total annual precipitation of 33 inches. Many times during the winter, high winds produce a severe wind chill factor, sometimes as low as - 50 ºF, but seldom does it stay extremely cold for long periods of time. Fog, rain and cloud cover dominate the summer months.

Water Infrastructure Description

a. Water supply(ies): Water is derived from a lake about 10.5 miles from Nelson Lagoon. A buried water line brings water from the lake to the community's water treatment plant (WTP).

b. Water system(s): Water is treated and stored in a tank with a capacity of 850,000 gallons. The water storage tank, installed around 1983, is in poor condition with roof damage, according to ANTHC. All homes are connected to the piped water system. The water system needs major improvements, including repair of the distribution system, replacement of about 3 miles of distribution line, and a new storage tank. Construction on water intake and a pump house is due to begin construction in 2010.

c. Wastewater system(s): Households are served by individual septic systems. A new washeteria was completed in August 1999.

Climate Related Factors and Potential Effects on Water Infrastructure

No storm surge analysis or flood frequency mapping or studies were found for Nelson Lagoon so the return intervals for coastal storm impacts to the community are not known. However, relatively frequent, moderate flooding occurs during high tides coupled with strong winds. The roads to the airport and parts of the runway are often flooded during these times.

Erosion along the spit occurs at a rate of approximately -2 feet per year. During a 2008 telephone interview, the community reported erosion on both the Bering Sea and Nelson Lagoon sides of the spit, and river erosion from the Nelson and Sapsuk Rivers. The Alaska Climate Impact Assessment Commission report states, in part "…residents in Nelson Lagoon observe that erosion has increased noticeably in the last six to eight years. According to the borough manager, this is due to later and lighter freeze-up activity, which has historically served as a buffer to fall and winter storm-related tidal encroachment. This is not unique or unprecedented as all areas on the north side of the Alaska Peninsula are susceptible to erosion and coastal flooding associated with strong winds and lack of sea ice protection."

Likelihood and Frequency of Impacts

There is a relatively high likelihood of impacts to water line running along the spit; erosion due to storm surge has been on the increase.

Severity of Impacts

Loss of the waterline serving Nelson Lagoon, though repairable, would create a hardship in the community.

Historical Impact to Water Infrastructure

1998 storm event resulted in the exposure of 3,000 feet of the village's water line, which then froze. The community requested the Alaska District Corps of Engineers' assistance in burying the water line. According to a September 1999 trip report by the Corps there was no federal interest in providing erosion protection for the water line, as the erosion cannot be tied to one specific location along the spit. The beach tends to wash out in one place and then rebuild in another according to that 1999 trip report. Undertaking an effective erosion control project will be necessary in the future to ensure the safety of the water system and other community infrastructure according to the

Aleutians East Borough Community Development Director interviewed for the USACE, Nelson Lagoon erosion information paper. Erosion poses a threat to the 10.5 mile long water transmission line, which requires major repairs as part of an overall water system upgrade project.

Mitigation of Impacts to Water Infrastructure

Measures have been implemented but are not sufficient to completely mitigate risks to the water line.

The following protective measures that have been taken by the community to limit damage from erosion:

- Gabions have been used to anchor the existing wood in the breakwater at a cost of over $60,000, but the measure has been less than successful due to high winds and tides according to the community. This protection project appears to correspond to *Alaska Legislative Appropriations for Flood and Erosion Control* summary collected by the Division of Community Advocacy (DCA) showing Nelson Lagoon received funding for erosion control including dock protection totaling $80,000 (1986-1989).
- A demonstration project funded by a $100,000 Coastal Impact Assistance Program (CIAP) grant to the AEB funding the placement of geotube containment structures consisting of sediment-filled sleeves of geotextile fabric. The community installed 300 feet of the geotube, completed in September 2005.

According to ANTHC, the community has discussed three possible alternatives to limit risk to the waterline: 1) realign and reroute a new waterline inland, 2) bury the waterline deeper to avoid coastal storm erosion, 3) armoring, which would be the least practicable and most costly. No actions are currently underway on any of these alternatives.

U.S. Senator Mark Begich requested funding for Nelson Lagoon’s water tank replacement ($825,000) and to replace and relocate the waterline ($715,000) in a March 2010 letter to the U.S. Senate Appropriations Committee.

Alaska ICWRA - Nelson Lagoon

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

References

Alaska Community Erosion Survey, USACE. 2007 from Justine Gunderson, Nelson Lagoon Village Administrator on August 27, 2007, with additional information provided by Sharon Boyette, then director of community development, Aleutians East Borough on September 19, 2007.

Alaska Legislative Appropriations for Flood and Erosion Control summary collected by Division of Community Advocacy

All Hazards Mitigation Plan, Aleutians East Borough, (Jan. 2, 2009). http://www.aleutianseast.org/vertical/Sites/{EBDABE05-9D39-4ED4-98D4-908383A7714A}/uploads/{5F7E9057-83A3-4DBA-B144-073C3F6461D6}.PDF

Rural Utility Business Advisor (RUBA) October 27-30, 2009 site visit, January 2010 Quarterly Report. http://www.commerce.state.ak.us/dca/ruba/report/Ruba_Report.cfm

Strategic Economic and Community Development Plan, prepared for Nelson Lagoon by Stadum Group, (November, 2001).

Division of Community and Regional Affairs:

Online Community Plans and Infrastructure Library, http://www.commerce.state.ak.us/dca/commdb/CF_Plans.cfm

Community Database Online, http://www.commerce.state.ak.us/dca/commdb/CF_COMDB.htm

Final Commission Report, Alaska Climate Impact Assessment Commission, Alaska State Legislature (March 17, 2008)

Historical and Average Monthly Temperature Chart SNAPS: http://www.snap.uaf.edu/community-charts?c=nelson-lagoon

Projected Average Monthly Precipitation Chart SNAPS: http://www.snap.uaf.edu/community-charts?c=nelson-lagoon

New Stuyahok

Community Setting

Population:	519, Department of Labor, 2009 population estimate
Incorporation Type:	2nd class city
Local governance:	City of New Stuyahok
Borough Located In:	Unincorporated borough
Regional Native Corporation:	Bristol Bay Native Corporation

Landform and Climate:

New Stuyahok is located on the Nushagak River, about 12 miles upriver from Ekwok and 52 miles northeast of Dillingham in Bristol Bay. The village was established at the current location in 1942. The village has been constructed at two elevations -- one 25 feet above river level and one about 40 feet above river level.

New Stuyahok is located in a climatic transition zone. The primary influence is maritime, although a continental climate affects the weather. Average summer temperatures range from 37 to 66 °F; winter temperatures average 4 to 30 °F. Annual precipitation ranges from 20 to 35 inches. Fog and low clouds are common during the summer; strong winds often preclude access during the winter. The river is ice-free from June through mid-November.

According to a US Army Corps of Engineers (USACE) flood survey field trip report to New Stuyahok, a May 2002 ice jam flood is the flood of record. An ice jam flood, most likely in 1957, was said by local residents to be higher than the 2002 flood, but with no indication of how much higher. These two floods are the only notable floods at New Stuyahok. The lowest portion of the village is built on a bench about 25 feet above the river. Floodwaters overflowed low areas around the village but did not overflow this portion of the bank and no structures were flooded. The USACE determined the flood elevation based on information provided by residents and established that the May 2002 ice jam flood elevation was 103.5 feet[1]

Water Infrastructure Description

a. Water supply: Water is derived from a well and treated. Some residents are on individual wells.

[1] Flood elevation was determined using a U.S. Bureau of Land Management (BLM) monument marked as S4495, C1NST, C1TR2, 1966 with a location of N59° 27.089 and W157° 19.337. The elevation of the monument is 277.53 feet. The vertical datum is NAVD 88.

b. Water system(s): Water is chlorinated but not filtered. The majority of the community (roughly 94 households), including the school are connected to piped water systems installed in 1971 and have complete plumbing.

c. Wastewater system(s): The majority of the community (roughly 94 households), including the school are connected to piped sewer systems installed in 1971 and have complete plumbing. According to the Alaska Native Tribal Health Consortium, Division of Environmental Health and Engineering's webpage, New Stuyahok's new four-acre sewage lagoon expansion was completed in 2009. Some residents use individual septic systems, and roughly six homes are without complete plumbing. The Splish Splash Washout Center is the washeteria operated by the New Stuyahok Village Council.

Climate Related Factors and Potential Effects on Water Infrastructure

New Stuyahok was rated as minimally erosion prone community by the US Army Corps of Engineers as part of their Alaska Baseline Erosion Assessment. During a telephone survey with the city administrator in January 2008, the administrator did not remember any major erosion events that have occurred in the last 20 years. He did estimate that approximately 20 feet of bank has been lost in the last 20 years and that during 2007, approximately 3 feet of bank was lost.

Likelihood and Frequency of Impacts

No water infrastructure is located within the floodplain. Erosion though present, does not appear to be a risk; localized drainage is a concern but can be mitigated.

Severity of Impacts

No direct impacts or threats to water resources infrastructure are known. There are three sewage lagoons in the community, with the newest lagoon located farthest from the river.

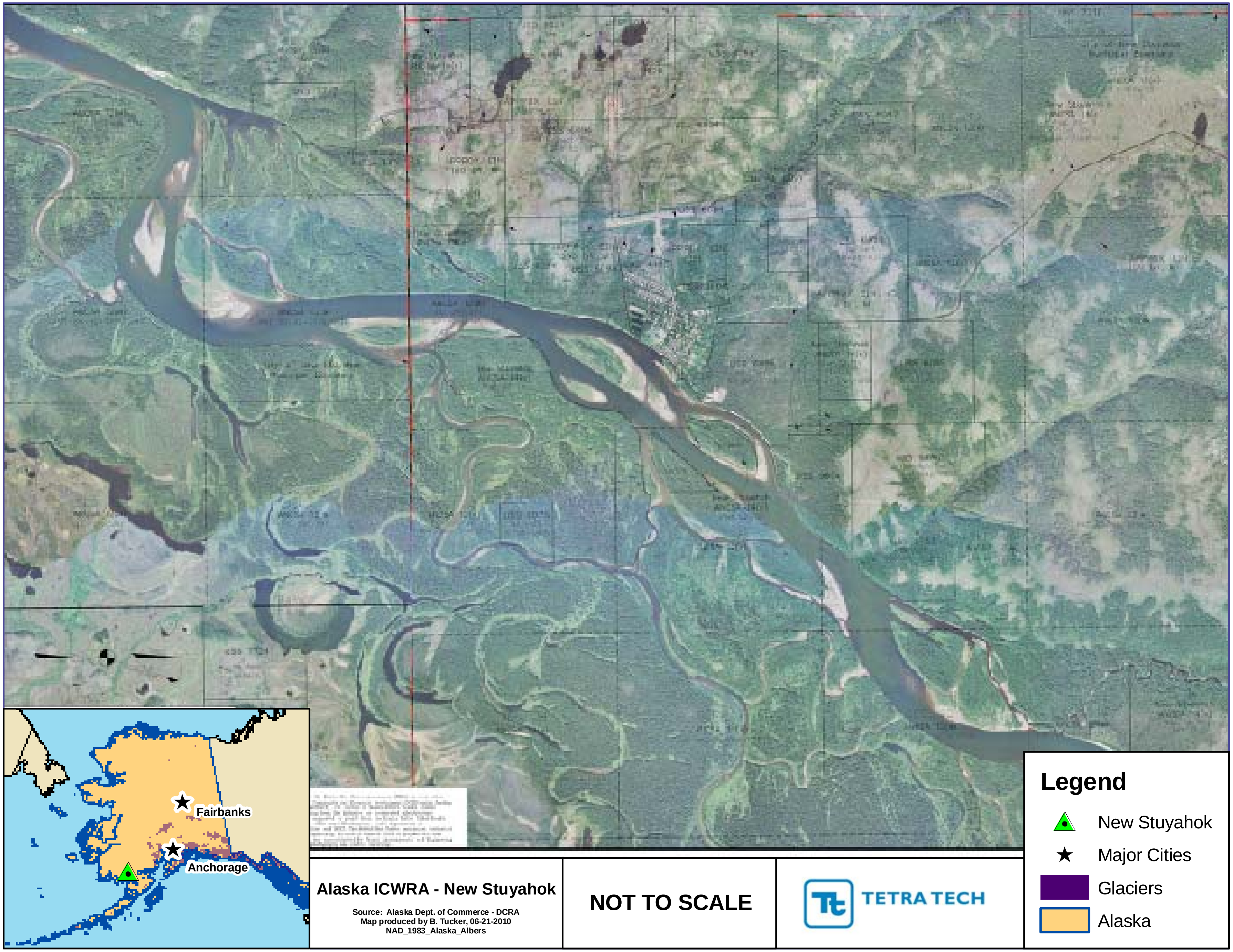
Historical Impact to Water Infrastructure

According to USACE information, two significant floods have occurred at New Stuyahok. In 1957, an ice jam caused the water level to rise about 10 feet, but it was stated that erosion was not a problem. A May 2002 ice jam flood raised the water level about eight feet. There were no known impacts to water resources infrastructure as a result of these floods.

Mitigation of Impacts to Water Resources

In planning future development, flood-prone areas in the lower village should be carefully considered or avoided, and one of the land use goals noted in the *New Stuyahok Comprehensive Plan* is to mitigate erosion at the village site. Slopes, drainage ditches, and downhill trails in the village all need special attention in order to minimize the effects of erosion.

Mitigation efforts have been considered in siting the new sewage lagoon. The lagoon nearest the river's edge is estimated to be 170 feet from banks edge, with the third lagoon an estimated 550 feet away.



Alaska ICWRA - New Stuyahok

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

Legend

- New Stuyahok
- Major Cities
- Glaciers
- Alaska

Selected Photographic Documentation

New Stuyahok sewage lagoon. Photos are courtesy of the ANTHC, Division of Environmental Health
and Engineering's webpage.

Aerial view of New Stuyahok's three sewage lagoons, the new school, and new housing.

References

ANTHC, Division of Environmental Health and Engineering photos from website, http://www.anthc.org/cs/dehe/2009projects/index.cfm

Division of Community and Regional Affairs, Rural Utilities Business Advisor (RUBA) status report (May 5, 2010), http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=749&isRuba=0

Division of Community and Regional Affairs, Community Database Online, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.htm

New Stuyahok Comprehensive Plan, by the New Stuyahok Planning Team, City of New Stuyahok, New Stuyahok Traditional Council, Stuyahok, Ltd. with assistance from Agnew::Beck Consulting, LLC. (*2005).*

US Army Corps of Engineers Alaska District (USACE) *Alaska Community Erosion Survey,* New Stuyahok city administrator, William Peterson, Jr., (January 9, 2008).

USACE, *New Stuyahok, Alaska Flood Survey Field Trip Report,* by Harlan Legare, Flood Plain Management Services, Hydraulic and Hydrology Section, USACE, *(2002).*

Noatak

Community Setting

Population:	486, Department of Labor, 2009 population estimate
Incorporation Type:	Unincorporated
Local governance:	Native Village of Noatak is the BIA-Recognized tribal council
Borough Located In:	Northwest Arctic Borough
Regional Native Corporation:	NANA Regional Corporation

Landform and Climate:

Noatak is located on the west bank of the Noatak River, 55 miles north of Kotzebue and 70 miles north of the Arctic Circle. This is the only settlement on the 396 mile-long Noatak River, just west of the 66-million acre Noatak National Preserve

Noatak is located in the transitional climate zone. Temperatures average -21 to 15 °F during winter and 40 to 60 °F during summer. Temperature extremes have been recorded from -59 to 75 °F. Annual snowfall averages 48 inches, with 10 to 13 inches of total precipitation.

The Noatak River is navigable by shallow-draft boats from early June to early October. Noatak is primarily accessed by air. There are currently no barge services to Noatak.

The community is located on high ground.

The Alaska Department of Transportation and Public Facilities (DOTPF) *Task Force on Erosion Control Final Report* confirmed that westward migration of the river is taking place, chiefly because the west bank is composed of ice-rich frozen silt. The Noatak is a braided river that has a fairly heavy bed of medium-sized gravel. The westward migration of the river is made much easier by the presence of ice-rich silt that can be eroded away far more easily than moving gravel. The river takes the easier course by cutting into the ice-rich silt during summer months, rather than carrying a heavy bed load of gravel.

Water Infrastructure Description

(according to the Division of Community and Regional Affairs Community Database Online)

a. Water supply: Water is derived using a well sited on the Noatak River; the wellhead has had to be protected from river erosion on several occasions. The primary well occasionally runs dry; deeper groundwater wells have been unsuccessful in the area.

b. Water system: A water tank is located north of the airport on Main Street and can supply the community with water through the winter months. The capacity of the system is currently sufficient; however, a new system will need to be constructed to meet future demands as the population grows, per the *Noatak Comprehensive Community Development Plan 2006-2016.* A piped re-circulating water distribution system serves 84 homes, the school, and businesses in Noatak. The *Comprehensive Community Development Plan* indicates that the system was constructed in 1971 and upgraded in 2002, and that most homes are connected. Those few that are not connected haul water.

c. Wastewater system(s): A piped re-circulating sewer system serves 84 homes, the school, and businesses in Noatak. The *Comprehensive Community Development Plan* indicates that the system was constructed in 1971 and upgraded in 2002, and that most homes are connected. Those few that aren't connected use honeybuckets. There is no washeteria.

Climate Related Factors Potential Effects on Water Infrastructure

Soil erosion along the Noatak riverbanks is considered severe, but most of the erosion is occurring downstream of an "armorform" erosion control structure. Most of the erosion occurs during spring breakup when high volumes of water scour the riverbanks and carry sediment downstream. In places where waters contact ground ice in the riverbanks, thermal erosion can occur. As the ice melts, banks are undercut and sediments are swept downstream. Additional erosion can occur during high precipitation and storm periods in summer.

Likelihood and Frequency of Impacts

Erosion is likely to continue, thus the threat to the water supply well remains.

Severity of Impacts

The loss of the community water supply would be significant.

Historical Impact to Water Infrastructure

Besides the ongoing threats to the wellhead, and lack of a reliable groundwaters supply, no documented impacts to water infrastructure were discovered.

Mitigation of Impacts to Water Infrastructure

The community wellhead sited in the Noatak River floodplain has been protected. No other water resource infrastructure is known to be at risk.

Various types of protective measures have been constructed to slow or stop riverbank erosion adjacent to the community. In 1980-1981 a 1,500 foot Armorform Revetment System (grout-filled polypropylene bags cabled together placed on a gravel dike) was constructed using approximately $3.4 million of Alaska Legislative appropriations, according to the DOTPF erosion task force report and *State Legislative Appropriations for Flood and Erosion Control*, collected by the Division of Community Advocacy (DCA). The tribal administrator reports that although this structure has partially collapsed, (wherein the upper blanket of grout filled polypropylene bags slid down the inclined face of the gravel bank causing wrinkles in the concrete mat), it has proven successful in preventing erosion along the length where it is installed.

The U.S. Department of Agriculture funded construction of a treated wood retaining wall constructed with wood beams in the 1990's which was completely destroyed during spring breakup the year after it was constructed, based on information obtained from the Corps trip report and the tribal administrator.

Alaska ICWRA - Noatak

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

Legend

- Noatak
- Major Cities
- Glaciers
- Alaska

Selected Photographic Documentation

Armorform Revetment System installed with State Legislative Grant funds in early 1980's. Photo courtesy of the Noatak Comprehensive Community Development Plan, prepared by NAB Planning Department and Maniilaq.

References

DCRA, Community Database Online, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA report *State Legislative Appropriations for Flood and Erosion Control*

Noatak Comprehensive Community Development Plan 2006-2016, prepared by Northwest Arctic Borough (NABand Maniilaq, for the Native Village of Noatak (May and September 2006)

Quinhagak
(Kwinhagak)

Community Setting

Population:	680, Department of Labor, 2009 population estimate
Incorporation Type:	2nd class city
Local governance:	City of Quinhagak and the Native Village of Kwinhagak
Borough Located In:	Unorganized borough
Regional Native Corporation:	Calista Corporation

Landform and Climate:

Quinhagak is on the south bank Kanektok River on the east shore of Kuskokwim Bay, less than a mile from the Bering Sea coast. It lies 71 miles southwest of Bethel.

The land surrounding Quinhagak is characterized by intertidal areas, wetlands, and swampy floodplains. The topography of the area ranges in elevation from less than six feet to approximately 22 feet above mean sea level.

In addition to the above description, the Division of Community and Regional Affairs (DCRA), Community Database Online includes a history of Quinhagak which explains the Yup'ik name is Kuinerraq, meaning "new river channel". Quinhagak is a long-established village whose origin has been dated to 1000 AD. It was the first village on the lower Kuskokwim to have sustained contact with Europeans. After the purchase of Alaska in 1867, the Alaska Commercial Company sent annual supply ships to Quinhagak with goods for Kuskokwim River trading posts. Supplies were lightered to shore from the ship and stored in a building on Warehouse Creek. A Moravian mission was built in 1893. In 1904, a mission store opened, followed by a post office in 1905, a school in 1909, the first electric plant opened in 1928 and the first mail plane arrived in 1934. The city was incorporated in 1975.

Quinhagak is located in a transitional climate between maritime and continental conditions. Precipitation averages 22 inches a year, with 43 inches of snowfall. Summer temperatures average between 41 to 57 °F, and winter temperatures average between 6 to 24 °F. The average air temperature is 30 °F with extremes measured from 82 to -34 °F.

The developed areas of Quinhagak are adjacent to the floodplain of the Kanektok River. The U.S. Army Corps of Engineers (USACE) rates flood hazards in Quinhagak as high, noting that the Kanektok River is subject to constantly changing channels and severe bank erosion.

Water Infrastructure Description

All services are provided by the Native Village of Kwinhagak, under agreement with the city.

a. Water supply(ies): The community's water source is a river bank infiltration gallery located on the west bank of the Kenektok River. The Kenektok River has shifted away from the water intake.

b. Water system(s): The Native Village operates a water treatment plant, central watering point, water and sewer haul, washeteria, and piped water and sewer system. A community-wide piped water and sewer system is currently under construction. Homes are being brought onto the system one service area at a time. Homes that are located too far out from the central residential area to be served with piped water and sewer will be served with a haul system.

c. Wastewater system(s): A low pressure sewer system is currently under construction. Homes that have not yet been served by the piped sewer system are served by a small haul system or are on honey buckets. The community has a new lagoon that is serving the piped sewer system. The old lagoons for the school, washeteria, and honeybucket haul are to be abandoned.

Climate Related Factors and Potential Effects on Water Infrastructure

VSW indicates that main climate-related water resource factors for Quinhagak include water quality and hydraulic changes due to a shift in the river channel away from the water infiltration gallery.

The *Quinhagak Community Development Plan* emphasizes the need for long range planning to take into consideration global warming and how to protect or restore critical sites before additional erosion creates a new river channel. It indicates that erosion near the village be addressed by building new roads further away from river and beach.

Under the USACE's Alaska Baseline Erosion Assessment (ABEA) process, Quinhagak was placed in the "Monitor Conditions" group meaning there are significant impacts related to erosion, but those impacts are not likely to affect the viability of the community.

Likelihood and Frequency of Impacts

Source water quality and quantity changes have occurred and are expected to continue to occur and become more critical.

The Footprint Lake sewage lagoon is a known and continuing public health risk; however, its problems do not appear to be directly related to climate. Additionally, it has been replaced.

Severity of Impacts

Changes affecting the water intake and treatment systems, as previously described, have created some challenges, but don't yet pose catastrophic risks.

As indicated above, the Footprint Lake sewage lagoon is a known and continuing public health risk which is being addressed.

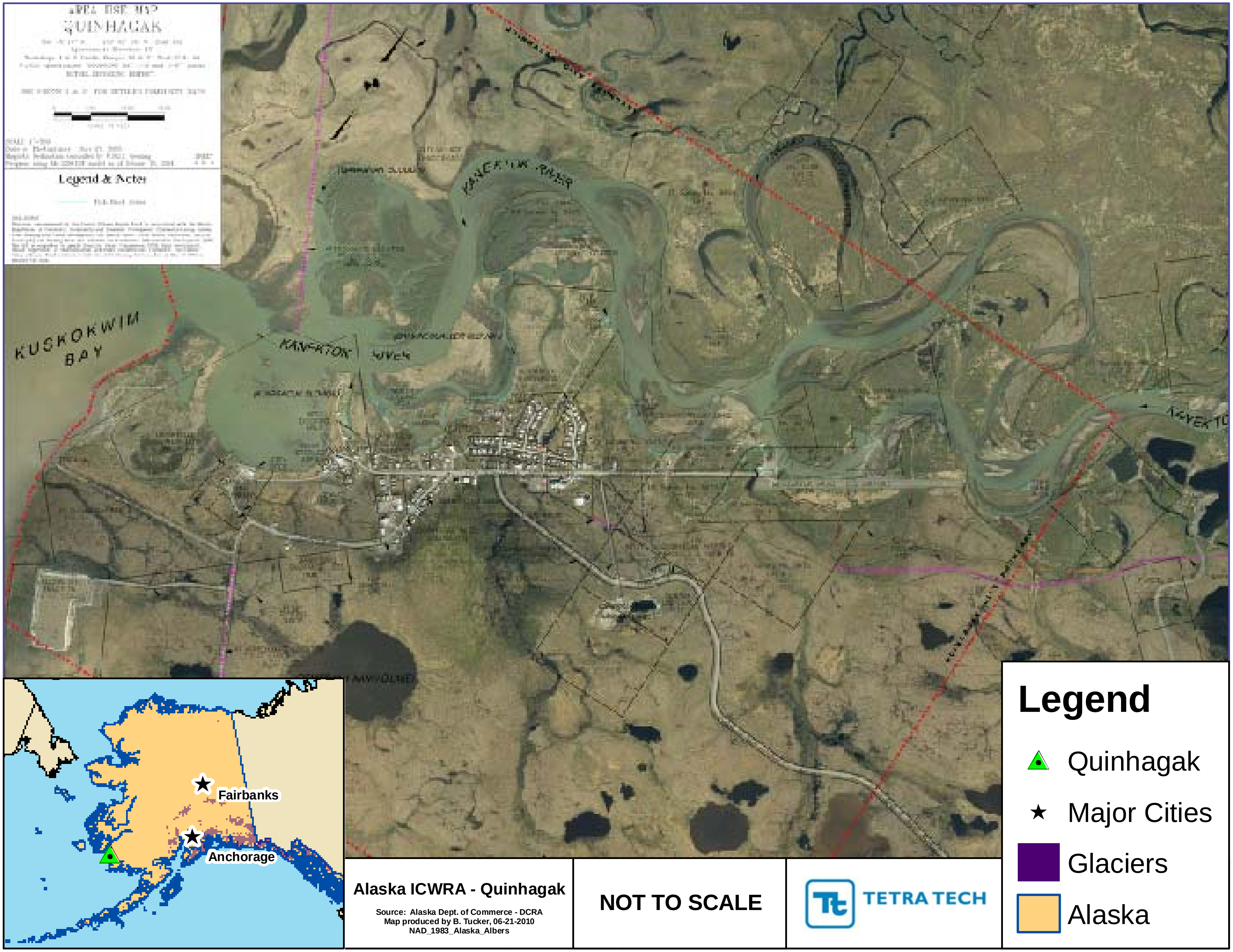
Historical Impact to Water Infrastructure

There are no known historical impacts to water resources directly resulting from climatic conditions; however, decreased efficacy of the source water intake gallery has been documented due to changes in the river course over the years.

Mitigation of Impacts to Water Infrastructure

Village Safe Water is monitoring the water source intake (infiltration gallery). Shoreline erosion near the newly constructed lagoon should be monitored.

The existing, problematic lagoon has been replaced with a new community lagoon.


AREA USE MAP
QUINHAGAK
Legend & Notes
KUSKOKWIM BAY
KANEKTOK RIVER
Fairbanks
Anchorage
Alaska ICWRA - Quinhagak
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH
Legend
Quinhagak
Major Cities
Glaciers
Alaska

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Division of Community and Regional Affairs, Community Data Base Online, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA, RUBA status report (January 22, 2010),http://www.commerce.state.ak.us/dca/ruba/report/Ruba_ComProf.cfm?rID=661

Native Village of Kwinhagak Piped Water and Sewer Feasibility Study, prepared for the native village of Kwinhagak, by CRW Engineering Group (May 10, 2002).

Quinhagak Online Community Development Plan, spearheaded by Henry and Tony Mark, Tribal Administrator, and General Administrator,

with the assistance of Northern Management and funded by Coastal Villages Region Fund, (September 26, 2008 and March 9, 2010), www.docmeister.com

USDA Rural Development Funding Improves Sanitation in the Western Alaska Community of Quinhagak, online at http://www.rurdev.usda.gov/rd/stories/AKQuinhagak%20SUCCESS1.pdf

Village Safe Water program manager, Greg Magee, P.E., interview/meeting (March 8, 2010)

Saint Michael

Community Setting

Population: 446, Department of Labor, 2009 population estimate
Incorporation Type: 2nd Class City
Local governance: City of Saint Michael
Borough Located In: Unorganized Borough
Regional Native Corporation: Bering Straits Regional Corporation

Landform and Climate:

St. Michael is located on the east coast of St. Michael Island in Norton Sound. It lies 125 miles southeast of Nome and 48 miles southwest of Unalakleet.

Most of the community is perched on a bluff from 20 to 30 feet high separating it from the beach and the sound. The U.S. Army Corps of Engineers (USACE) indicates that the entire town is above the 100-year floodplain. The lowest building in town has never been flooded, though it has had water reach its footings, according to a 1993 USAC trip report.

St. Michael has a subarctic climate with maritime influences during the summer. Summer temperatures average 40 to 60 °F; winters average -4 to 16 °F. Extremes from -55 to 70 °F have been recorded. Annual precipitation averages 12 inches, with 38 inches of snow. Summers are rainy, and fog is common. Norton Sound is ice free from early June to mid-November.

Water Infrastructure Description

a. Water supply: Water is pumped seasonally from Clear Lake, approximately five miles north of the community. The Department of Transportation and Public Facilities (DOT/PF) constructed a road leading to the water source and the airport. A water source intake structure near the inlet of the lake was constructed to replace the old structure.

b. Water system(s): Water is stored in a 1.2 million gallon water storage tank. The water is then pumped from the 1.2 million gallon tank, filtered, disinfected, and stored in a 400,000-gallon water storage tank for consumption. The system includes water delivery/holding tanks for homes and in 2005, a piped water system was completed. The water treatment plant is under renovation to meet compliance with the Surface Water Treatment Rule and is expected to be completed in 2007.

c. Wastewater system(s): Wastewater is collected using vacuum sewer collection system and pumped via force main to a wastewater treatment area northeast of the community. A new sanitation system was completed during the summer of 2005 to provide vacuum sewer service and residential plumbing to the homes in the community. The RUBA status report indicates 99% of the homes are served by the new system. The washeteria was completely renovated in 2004.

In FY 2010 ANTHC was funded for the final phase of the piped water and sewer system that included power to the new water source, water treatment plant renovations, new services, and the close-out of the honeybucket lagoon.

Climate Related Factors and Potential Effects on Water Infrastructure

Statements in the report *Bluff Erosion and Its Mitigation, St. Michael, Alaska,* by Jones (1994), indicates that erosion has increased at Saint Michael. The beach and bluff are exposed to waves from the east and south but protected from waves approaching from the north and west. Apparently, until 1992, the bluff was quite stable and then it began to erode at an accelerated rate.

Likelihood and Frequency of Impacts

Although erosion is occurring, no direct threats to water infrastructure were documented, suggesting that the likelihood of future impacts is low. However, the referenced report by Jones (1994), states that "…there are presently six residences in danger of being lost with additional bluff erosion…besides buildings, there are a couple of roads (ownership unknown) and the water distribution system that might need to be moved if erosion continues."

Severity of Impacts

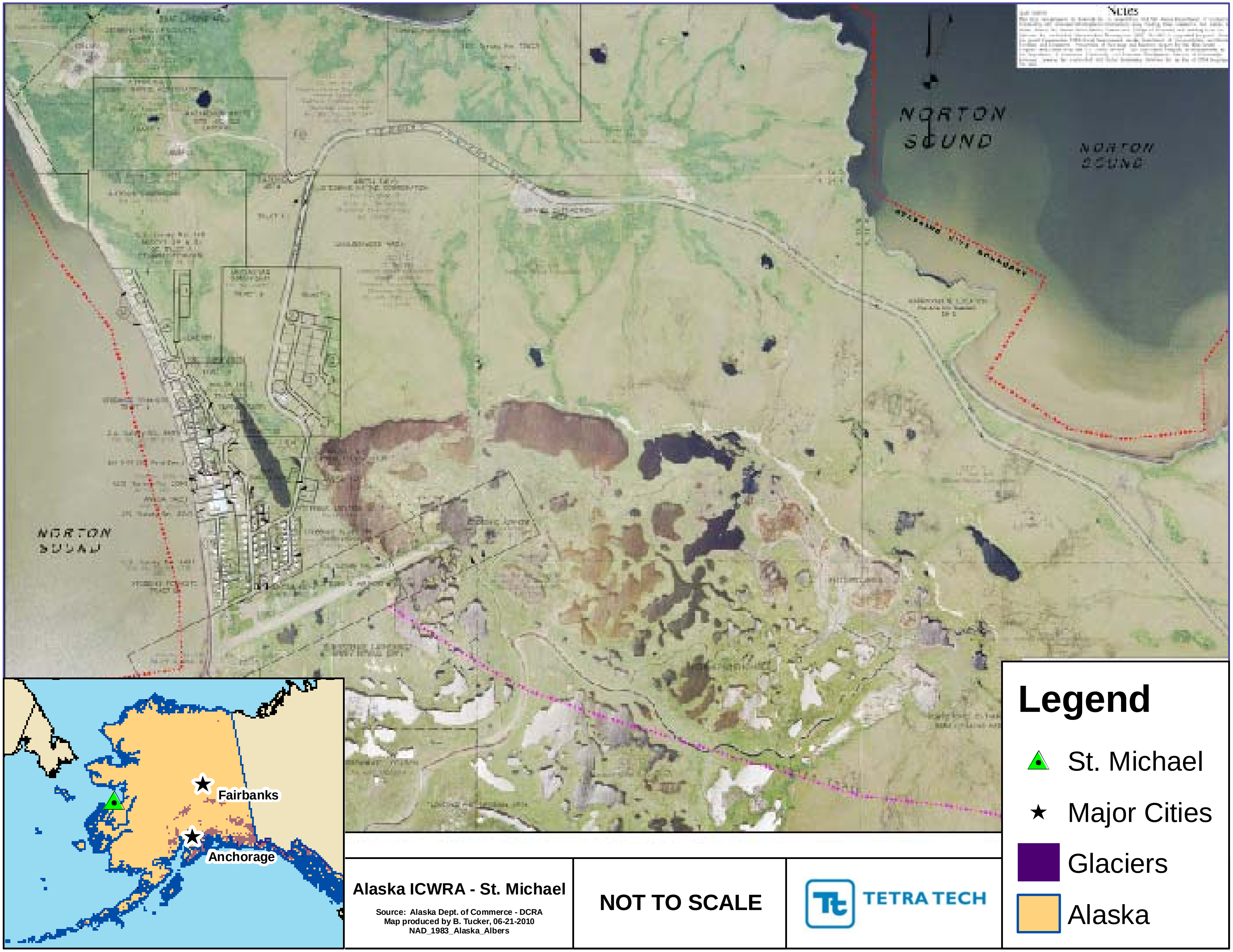
No direct impacts to water infrastructure have been documented and because of the slow progression of erosion, adaption or mitigation actions should be able to be implemented to avoid any direct impact.

Historical Impact to Water Infrastructure

None have been documented.

Mitigation of Impacts to Water Infrastructure

No documented mitigation measures have been implemented to date. The referenced report by Jones (1994) recommended "that local rock be used to construct structures to prevent further bluff erosion. It should be most cost effective, and it can be accomplished using all local resources. Since neither scheme places material at the toe of the bluff, the current eroded bluffs are expected to erode until some equilibrium is established between the bluff slope and the size of the bluff material. Slopes will be steeper and the bluff migration less if vegetation will grow back on the bluffs once most of the wave energy is kept from impacting directly on them. The village might also initiate a program to revegetate the bluffs."



Alaska ICWRA - St. Michael

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

Selected Photographic Documentation

Boardwalk crossing the piped water/vacuum sewer line. Photo courtesy of the St. Michael LEPD completed by Kawerak Inc. in April 2004.

1.2 million gallon water tank. Photo courtesy of the St. Michael LEPD completed by Kawerak Inc. in April 2004.

400,000 gallon water tank. Photo courtesy of the St. Michael LEPD completed by Kawerak Inc. in April 2004.

St. Michael's water/vacuum sewer lines. Photo courtesy of the St. Michael LEPD completed by Kawerak Inc. in April 2004.

References

Division of Community and Regional Affairs, RUBA May 3, 2006 status report (April 4, 2010 update) http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=710&isRuba=0

Jones, D.F. 1994. *Bluff Erosion and Its Mitigation, St. Michael, Alaska,* by Douglas F. Jones, Coastline Engineering, prepared for the Bering Straits Housing Authority (August 31, 1994)

Local Economic Development Plan (LEDP) Saint Michael 2005-2010, prepared by Kawerak, Inc. for the community of Saint Michael and the Bering Straits Development Council, (April, 2004)

Saint Michael Long Range Transportation Plan, Indian Reservation Roads Program. Rodney P. Kinney Associates, Inc. 2002, prepared for Saint Michael IRA Council in cooperation with Kawerak Transportation Program.

US Army Corps of Engineers (USACE), Field Trip, Saint Michael and Stebbins, (December 14, 1993)

Task Force on Erosion Control Final Report, Department of Transportation and Public Facilities, (January 3, 1994)

USACE. *St. Michael Erosion Information Paper, Alaska Community Erosion Survey*, submitted by Virginia Washington, St. Michael city administrator on August 28, 2007 and emails with Frank Myomick, Kawerak transportation planner and St. Michael city council member in September 2007.

Selawik

Community Setting

Population: 849, Department of Labor, 2009 population estimate
Incorporation Type: 2nd Class City
Local governance: City of Selawik
Borough Located In: Northwest Arctic Borough
Regional Native Corporation: NANA Regional Corporation

Landform and Climate:

Selawik is located at the mouth of the Selawik River, where it empties into Selawik Lake, about 90 miles east of Kotzebue. It lies 670 miles northwest of Anchorage. The community is situated on both banks of the Selawik River and on Middle Island, between the two channels of the river. The city is near the Selawik National Wildlife Refuge, a key breeding and resting spot for migratory waterfowl.

The *Selawik Community Comprehensive Development Plan* indicates the soils in the Selawik area typically consist of an organic surface layer underlain by silt. Permafrost is present except under the Selawik River and larger water bodies. The soils have high ice content and are unstable when thawed. Ground temperatures are not well characterized but are estimated to be 25 °F. The active layer, or the soil that thaws during summers, is estimated to be 1.5 to 2.0 feet on average, but can be 4 to 6 feet thick in un-vegetated areas. Thaw consolidation of 1-2 feet can be expected if permafrost is degraded.

Flooding occurs during spring breakup, but has not been a problem since the town cut a channel from the Selawik river to Selawik Lake according to a flooding and erosion summary from the U.S. Army Corps of Engineers. The summary suggests that 20 percent of the community could be periodically flooded generally in the spring with ice jams in the Selawik River. Coastal flooding also can occur when fall high tides and west wind storms cause swells in Selawik Lake according to the community comprehensive plan. The plan indicates that two types of riverbank erosion are predominate: erosion due to waves generated by small boats or from barges running engines when unloading fuel, and erosion from overland flow into the river.

The community is located in the transitional climate zone. Temperatures average -10 to 15 °F during winter and 40 to 65 °F during summer. Temperature extremes have been recorded from -50 to 83 °F. Annual snowfall averages 35 to 40 inches, with 10 inches of precipitation. The Selawik River is navigable from early June to mid-October.

Water Infrastructure Description
(based on RUBA status report as of April 30, 2010)

a. Water supply: The community sources its water from the Selawik River. Groundwater wells have been unsuccessful.

b. Water system(s): Source water is pumped from the Selawik River to a water treatment plant, providing up to 8,000 gallons of potable a day. A circulating water system provides service to about 100 homes. The water treatment plant and source water pumping system are being evaluated now for possible future projects. ADEC has been in Selawik to do a comprehensive evaluation of source water quality, which will be helpful in determining what water treatment changes may need to be implemented.

c. Wastewater system(s): A circulating vacuum sewer system provides service to about 100 homes. The community has piped water and sewer throughout most of the community; 96% of the homes are fully plumbed.

Climate Related Factors and Potential Effects on Water Infrastructure

Riverbank erosion along the Selawik River, particularly the more southerly facing slopes which are suffering from permafrost thaw slumps. The river erodes the shoreline and exposes the permafrost, which melts when the temperature rises above freezing. A community survey submitted as part of the USACE Alaska Baseline Erosion Assessment also indicated that erosion is approaching several homes.

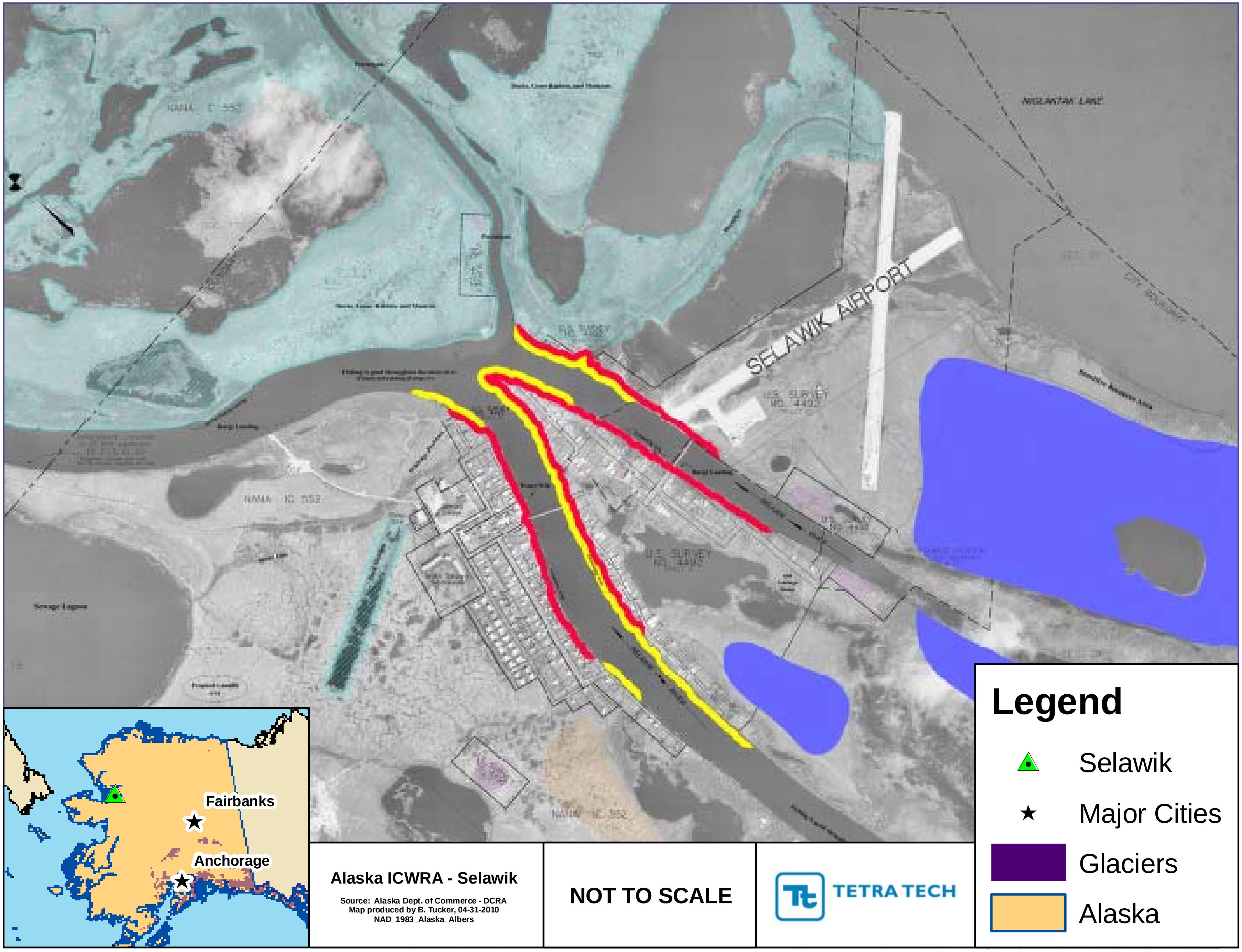
The Northwest Arctic Borough, Alaska Native Tribal Health Consortium (ANTHC), Center for Climate and Health and the University of Alaska Fairbanks are collaborating on a climate adaptation plan and methodology to assist communities. However, no specifics were provided for Selawik as to potential water infrastructure impacts.

Likelihood and Frequency of Impacts
Unknown.

Severity of Impacts
Unknown.

Historical Impact to Water Infrastructure
No documentation found.

Mitigation of Impacts to Water Infrastructure
None known.



NIGLAKTAK LAKE
NANA IC 552
SELAWIK AIRPORT
U.S. SURVEY NO. 4492
U.S. SURVEY NO. 4492
U.S. SURVEY NO. 4492
NANA IC 552
NANA IC 552
Sewage Lagoon
Fairbanks
Anchorage
Alaska ICWRA - Selawik
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 04-31-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH
Legend
Selawik
Major Cities
Glaciers
Alaska

References

Alaska Native Tribal Health Consortium (ANTHC), Center for Climate and Health, contact John Warren or Art Ronimus

Division of Community and Regional Affairs, community Database Online, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.htm

DCRA, Rural Utilities Business Advisor, (April 30, 2010)

US Army Corps of Engineers, Alaska Baseline Erosion Assessment, *Alaska Community Erosion Survey,* submitted via fax to USACE Raven Sheldon, native village of Selawik, environmental director September 30, 2009)

Stebbins

Community Setting

Population:	605, Department of Labor
Incorporation Type:	2nd class city
Local governance:	City of Stebbins
Borough Located In:	Unorganized borough
Regional Native Corporation:	Bering Straits Regional Native Corporation

Landform and Climate:

Stebbins is located at on the northwest coast of Saint Michael Island on the southern coast of Norton Sound, which connects with the Bering Sea. The community is approximately 120 miles southeast of Nome and eight miles northwest of the community of Saint Michael.

The community of Stebbins is located along a sand spit connecting Bonok Point with Cape Stephens. The south coast of Norton Sound is generally of low relief and Stebbins has experienced a number of coastal flooding events from storm surges. Norton Sound is shallow with a gently sloping sea floor, which is favorable for the development of storm surge. The range of wind direction for surge development is limited to west-southwest to west according to the *Stebbins Hydrology and Hydraulic Report*, published April 6, 2006.

Stebbins has a subarctic climate with a maritime influence during the summer. Norton Sound is ice-free from June to November, but clouds and fog are common. Average summer temperatures are 40 to 60 °F; winter temperatures range from -4 to 16 °F. Extremes have been measured from -55 to 77 °F. Annual precipitation averages 12 inches, with 38 inches of snowfall.

Water Infrastructure Description

a. Water supply(ies): Water is derived from Big Clear Creek or Clear Lake during the summer.

b. Water system(s): Water is transported via an insulated water transmission main from the water source to the water treatment plant where it is treated and stored in a 1,000,000-gallon and 500,000-gallon steel water tank. Residents haul water from the washeteria/watering point.

c. Wastewater system(s): Residents deposit honeybucket waste in bins, according to the RUBA status report as of April 22, 2010 and the *Stebbins Local Economic Development Plan (LEDP).*

The RUBA report states that major improvements have been planned and funded for the installation of a piped water and sewer system, with household plumbing. The Stebbins LEDP (2004) also indicates that major improvements for a piped water and vacuum sewer system are under construction, with a new water storage tank proposed to alleviate winter water shortages. The status of this project is unknown.

Climate Related Factors and Potential Effects on Water Infrastructure

Stebbins has experienced numerous damaging floods with water inundating the village from both Norton Sound to the west and the lowland marshes to the east according to the U.S. Army Corps of Engineers (USACE) Flood Damage Reduction Section 205 Reconnaissance Report.

Likelihood and Frequency of Impacts

The *Stebbins Hydrology and Hydraulic (H&H) Report* prepared by Baker and Coastal Frontiers establishes final design elevations based on floodwater elevations for the airport. The report includes flood frequency analyses for Stebbins' 100-year floodwater elevation which wasestablished in 1967 by the U.S. Army Corps of Engineers for the Bureau of Land Management (BLM); the stage frequency analysis developed by the USACE in 1987 and 1988; and survey data. The H&H report states that "it has been estimated that the USACE data represents the seven largest events between 1959 and 1987. Finally, it has been demonstrated that the magnitude of flooding between 1988 and 2003 was relatively calm. Therefore, the period of record is accepted to be 46 years and the recommended 100-year flood elevation for Stebbins is 18.1 feet Mean Lower Low Water (MLLW)." The analyses offered in this report considered all existing available flood data for Stebbins and the surrounding communities. The overall coastal hazard assessment classifies the Stebbins coastline as susceptible to a moderate risk of shoreline change, overwash, storm surge, and storm and wave damage.

Severity of Impacts

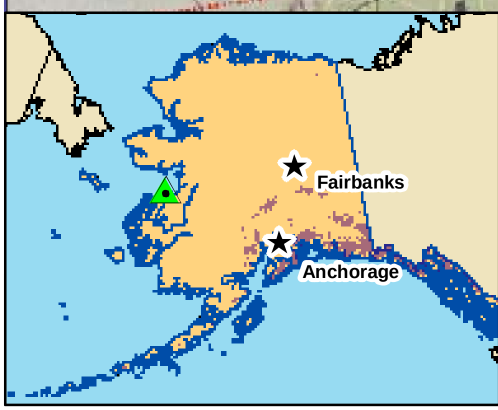
Unknown.

Historical Impact to Water Infrastructure

No documentation found.

Mitigation of Impacts to Water Infrastructure

None known.



Legend

- Stebbins
- Major Cities
- Glaciers
- Alaska

Alaska ICWRA - Stebbins

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

Selected Photographic Documentation

Stebbins Water Plant, photo courtesy of Stebbins LEDP, April 2004

Washeteria and external watering point, photo courtesy of Stebbins LEDP, April 2004

Washeteria and water tank, photo courtesy of Stebbins LEDP, Kawerak, Inc., April 2004

References

Division of Community and Regional Affairs, Rural Utilities Business Advisor, DCRA, Community Database Online, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.htm

Stebbins Hydrologic & Hydraulic Report, by Michael Baker, Inc. and Coastal Frontiers Corporation for Department of Transportation and

Public Facilities, Northern Region (April 6, 2007)

Stebbins Local Economic Development Plan 2005-2010, prepared by Kawerak Inc. for the community of Stebbins and the Bering Straits Economic Development Council (April 2004)

US Army Corps of Engineers, Alaska district (USACE) Storm Damage Reduction Report Section 205 Reconnaissance Report Stebbins, Alaska (December 1988)

Talkeetna

Community Setting

Population:	894 (DOL, 2009 estimate)
Incorporation Type:	Unincorporated
Local governance:	Unincorporated, so there are no city or borough "officials" in this community. Talkeetna Community Council and the Talkeetna Chamber of Commerce.
Borough Located In:	Matanuska-Susitna Borough
Regional Native Corporation:	Not Applicable

Landform and Climate:

The community of Talkeetna is located at the junction of the Talkeetna and Susitna Rivers. The Talkeetna and Chulitna Rivers join the Susitna River at Talkeetna. This unincorporated, non-Native community lies 115 miles north of Anchorage at mile 226.7 of the Alaska Railroad. The paved Talkeetna Spur Road runs 14 miles east off the George Parks Highway, at Milepost 98.7.

The Susitna River is about 200 miles long with a drainage area of 11,035 square miles upriver from Talkeetna. The Susitna floodplain at Talkeetna is approximately 1 mile wide. Both the Susitna and the Talkeetna are glacier-fed rivers characterized as meandering, braided, and subject to high runoff.

According to the Talkeetna Comprehensive Plan, the Talkeetna River is about 80 miles long and has a total drainage area of approximately 2,015 square miles. It is about 900 feet wide at its mouth where it junctions with the Susitna River. Upstream of the Alaska Railroad Bridge, the Talkeetna River divides into two channels, encircles a small island, and then joins again. Originally, the channel flowed along the right bank crossing to the left bank below the Alaska Railroad bridge. In an effort to protect the bridge, the Alaska Railroad realigned the channel immediately upstream of the bridge to flow along the left bank of the river above the bridge. However, it was later observed that the main channel was returning to the right bank above the bridge.

The Talkeetna Comprehensive Plan describes the climate as transitional between coastal maritime and interior continental. Because of its inland location, Talkeetna has moderately warm summers, cold winters, and pronounced temperature variations. The coldest months (December/January) average about 10 degrees Fahrenheit. January temperatures can range from -33 to 33 degrees Fahrenheit; and July temperatures can range from 42 to 83 degrees Fahrenheit. Average annual precipitation is 28 inches, with 70 inches of snowfall. Talkeetna experiences five months per year when average temperatures are below freezing, plus another two months when average temperatures are very close to freezing.

A plan has been prepared for the 75-acres of land near the riverfront that is largely open space. According to the Talkeetna Riverfront Park Land Use Plan and Economic Development Strategy, residents and visitors enjoy the riverfront area for walking, picnicking, camping, fishing, bird watching, and great views of the mountains. More developed recreational activities, located east of the bridge, include a public boat launch, campsites, and the starting point for commercial tours. The plan indicates that over the last decade, growth in visitation to Talkeetna has been substantial. Spurred by the opening of two new hotels, the number of visitors to Talkeetna jumped from 20,000 to 30,000 people per year in the mid 1990's to nearly 150,000 annually in 2003. Between 1990 and 2000, Talkeetna population grew about 3.3% per year, twice the growth rate of the state as a whole. Interest in vacation and second homes continues to increase.

Water Infrastructure Description

a. Water supply: A community well serves the piped water system maintained by the Matanuska-Susitna Borough (MSB), but many homes still have individual wells.

b. Water system: The public water system is operated by the MSB; however, the school and many individual residences still have private wells. The public water treatment system is downtown on the west side of the Alaska Railroad tracks that cross through the center of Talkeetna. It is located within the 500-year floodplain.

c. Wastewater system(s): Residents are serviced by a community sewage lagoon, although many outside of the core service area still have individual septic systems or outhouses. The lagoon is upriver on the right bank but inland of the Talkeetna River.

Climate Related Factors and Potential Effects on Water Infrastructure

Flood control and riverbank stabilization are issues of concern brought up in the Talkeetna Riverfront Park Land Use Plan.

Likelihood and Frequency of Impacts

Much of Talkeetna is in the 1 percent (100-year) or .02 percent (500-year) annual chance floodplain of either the Talkeetna River, east of the railroad tracks, or of the Susitna River, west of the railroad.

The sewage lagoon and the public water system near downtown are both located in the 500-year floodplain on the new Flood Insurance Rate Maps (FIRM) which are currently under public review. The sewage lagoon is estimated to be between 150-200 feet from a small slough/stream, and about 1,100-1200 feet from an active channel of the Talkeetna River.

Severity of Impacts

Temporary loss of either the sewage lagoon or water treatment would be disruptive, but the likelihood of the loss of either is low.

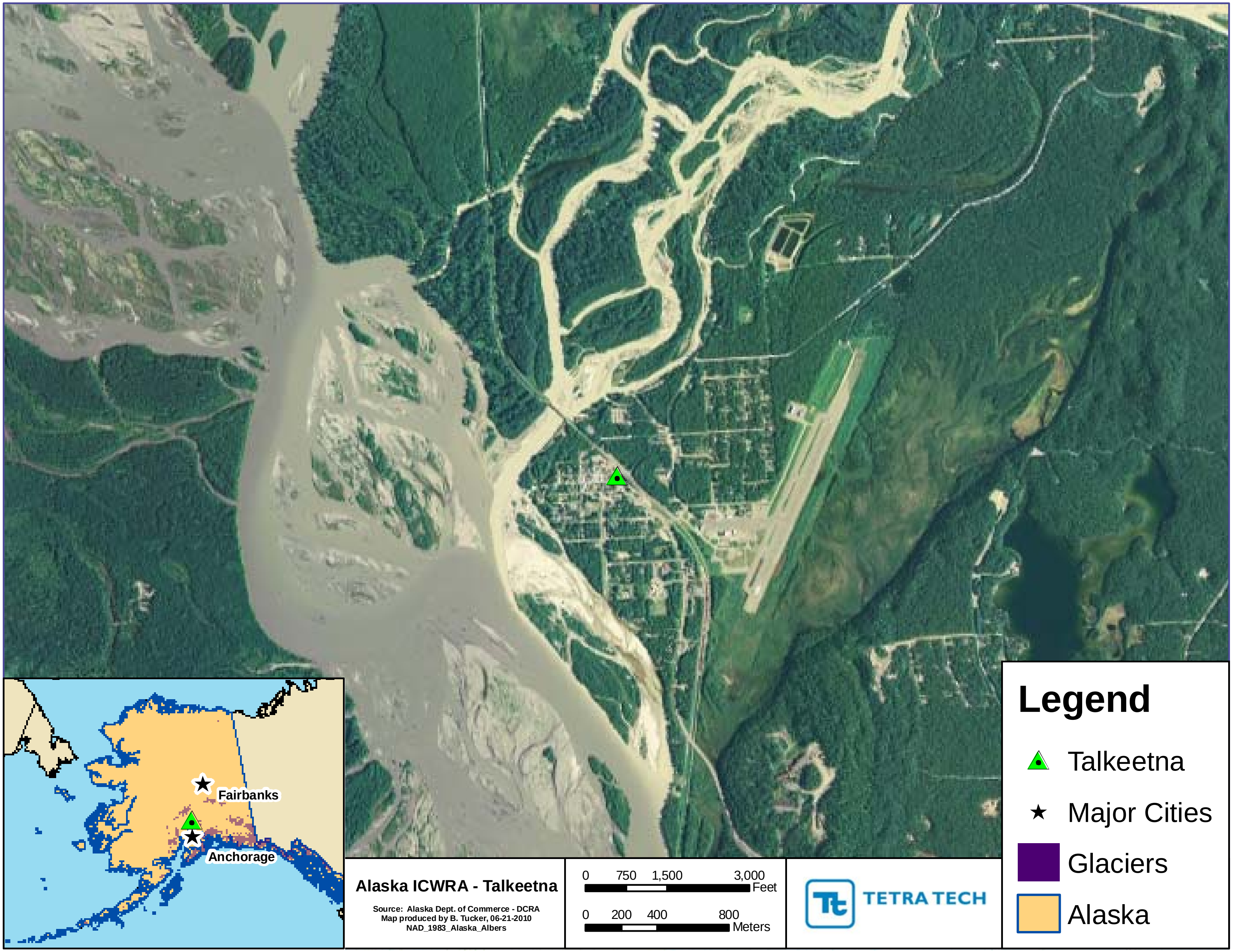
Historical Impact to Water Infrastructure

The largest recorded flood in this area occurred in September 1942 in which the Talkeetna River rose six feet, flooding homes and businesses in the community. Other more recent floods have occurred in August 1971 and October 1986. Water infrastructure is not known to have been impacted, but the sewage lagoon and the public water system have been built since the last major flood event according to a MSB Code Compliance Officer in a telephone interview.

Mitigation of Impacts to Water Infrastructure

The Talkeetna Wastewater Treatment Facility (WWTF) received at least $3,759,200 between December 2002 and November 2005 for improvements to maintain its regulatory compliance, construct a maintenance facility, build the lagoon and backup percolation cell, reconstruct upgrade lift stations, install remote monitoring and controls, provide for maintenance of the force main, implement a freeze protection program, and raise and protect manholes, according to the DCRA Community Database Online.

The river side of the lagoon is protected by an earthen dike, thereby lowering the risk to the facility from flooding.



Fairbanks
Anchorage
Alaska ICWRA - Talkeetna
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
0 750 1,500 3,000 Feet
0 200 400 800 Meters
TETRA TECH
Legend
Talkeetna
Major Cities
Glaciers
Alaska

References

Division of Community and Regional Affairs, Online Community Database, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

Ness, Pamela, MSB, Code Compliance and a Certified Floodplain Manager, telephone interview (May 25, 2010).

Talkeetna Comprehensive Plan, Matanuska-Susitna Borough, Adopted January 1998, amended March 1999

Talkeetna Riverfront Park Land Use Plan & Economic Development Strategy, Agnew::Beck Consulting and Land Design North, (October 6, 2003 community approved plan)

Teller

Community Setting

Population:	261, Department of Labor population estimate
Incorporation Type:	2nd Class city
Local governance:	City of Teller
Borough Located In:	Unorganized borough
Regional Native Corporation:	Bering Straits Native Corporation

Landform and Climate:

Teller is located on a spit between Port Clarence and Grantley Harbor, 72 miles northwest of Nome, on the Seward Peninsula. The main town of Teller is situated on beach deposits, which form a northerly trending spit separating Port Clarence from Grantley Harbor. Little vacant land exists in the town site area, according to the *Sanitation Facilities Master Plan.* In the late 1980's, relocation of the town was attempted through the construction of a new housing site near Coyote Creek approximately 1½ miles from the original town site.

The Sanitation Facilities Master Plan states "Continuing erosion along the south side of the Teller spit with a small likelihood of a major seawall project places the town site in jeopardy. The current erosion pattern along the south side of the spit indicates that over time the loss of protection from the ice rich "hill" to the south of the developed town site will cause a major breach into Freshwater Lake and isolate the remaining spit area from the mainland. The potential for significant growth in the town site is unlikely."

The climate is maritime when ice-free, and then changes to a continental climate after freezing. Grantley Harbor is generally ice-free from early June to mid-October. Average summer temperatures range from 44 to 57 °F; winter temperatures average -9 to 8 °F. Extremes have been measured from -45 to 82 °F. Annual precipitation averages 11.5 inches, with 50 inches of snowfall.

Water Infrastructure Description

Descriptions are based on the Division of Community and Regional Affairs (DCRA) community database online and the DCRA RUBA reports.

a. Water supply(ies): An infiltration galley in Coyote Creek provides a seasonal water source, as Coyote Creek has no winter flow. A few residents use their own ATVs or snowmobiles to haul water. During winter, treated water is delivered from a large storage tank at the washeteria; and sometimes melted ice from area creeks is used.

b. Water system(s): During the summer, water is pumped from the Coyote Creek infiltration gallery through an 11,500-foot 4-inch HDPE above ground raw water line to a water treatment plant located at the town's washeteria. Water treatment includes sand filtration and chlorination. Treated water is pumped to a 1,000,000 gallon insulated water storage tank near the school.

c. Wastewater system(s): The school operates its own sewer system, discharging to an undersized lagoon located immediately adjacent to the school. Several different reports indicate that between 42 and 67 residents and 15 businesses use honeybuckets, which are hauled by the city. The city hauls honeybuckets from residences to a honeybucket disposal cell at the city landfill. A few homes and other buildings use individual septic tank systems.

Climate Related Factors and Potential Effects on Water Infrastructure

The most likely and frequent climate-related community impacts are flooding and continued erosion of the spit.

Another concern is the potential impact of climate change on Coyote Creek, the community's drinking water source, as described in a research paper prepared by the University of Alaska, Fairbanks (UAF) and published in the Journal of Geophysical Research in 2007 (*Potential impacts of a changing Arctic on community water sources on the Seward Peninsula, Alaska)*. In this paper, vulnerability factors for the community water sources for five Seward Peninsula communities (Elim, Golovin, Teller, Wales, and White Mountain), were developed with consideration given to watershed area, groundwater contribution to stream flow, and projected changes to permafrost distribution. Teller is dependent on a particularly small watershed with no groundwater flow contribution in the winter. Teller's vulnerability factor/value was highest at 5, with 0-20% groundwater contribution and no winter flow, for a watershed less the 5 square kilometers. Areas trending toward permafrost degradation or loss were considered more vulnerable, highlighting the importance of permafrost in local hydrology. Teller showed particular vulnerability with respect to low groundwater contributions. Additionally, Teller's municipal water source watershed was rated highly vulnerable, as conditions are expected to change from discontinuous permafrost to thawing permafrost, which could potentially lead to reduced surface flows as a result of greater precipitation, infiltration, and drainage to groundwater aquifers.

Likelihood and Frequency of Impacts

In ranking communities in the Alaska Baseline Erosion Assessment, the US Army Corps of Engineers placed Teller on the high priority list.

The school's sewage lagoon is located in an area vulnerable to flooding, erosion, and structural damage. Availability of water is currently seasonal and existing supplies are trending toward lower availability as a result of climate-induced changes.

Severity of Impacts

Seasonal water shortages are likely, although more difficult to access sources are available. Erosion to the sewage lagoon could result in a lack of school wastewater treatment and public health risks associated with loss of treatment and/or sewage overflows onto land or water supplies.

Historical Impact to Water Infrastructure

Although specific impacts to water resources from flooding are not known, the U.S. Army Corps of Engineers *Alaskan Communities Flood Hazard Data* lists floods of record in 1973 and 1974 with depths of 3 to 4 feet in the town site area. Spring floods may include wind-blown ice that can cause significant structural damage. Storm winds from the west and southwest have the greatest potential for causing damage at Teller, and major flooding occurred in 1913 and 1974. The 1974 storm was especially severe, as large chunks of ice were driven into the village by strong winds.

Mitigation of Impacts to Water Infrastructure

There is a seawall along a portion of the old Teller town site located on the seaward side of the sewage lagoon in an attempt to slow erosion during storms.

While several sources of water are potentially available, the most readily available source from Coyote Creek is threatened.

Legend & Notes
GRANTLEY HARBOR
PORT CLARENCE
FRESHWATER LAKE
Fairbanks
Anchorage
Legend
Teller
Major Cities
Glaciers
Alaska
Alaska ICWRA - Teller
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH

Selected Photographic Documentation

Waves hitting Teller seawall, the sewage lagoon that serves the school is to the left out of view of this photo; photo courtesy of David E. Atkinson, University of Alaska Fairbanks, International Arctic Research Center, (2007).

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Chambers, M.D, D. White, R. Busey, L. Hinzman, I. Alessa, and A. Kliskey (2007) *Potential impacts of a changing Arctic on community water sources on the Seward Peninsula, Alaska*, Journal of Geophysical Research, Vol. 112

Division of Community and Regional Affairs (DCRA) community database online: http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA, Rural Utilities Business Advisor report (April 25, 2010): http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=635&isRuba=0

Teller, Alaska Sanitation Facilities Master Plan, prepared by CE2 Engineers Inc. in cooperation with Village Safe Water (May 2005)

Teller Community Profile, prepared by Environmental Services Limited under contract with the Alaska Department of community and Regional Affairs, Division of Community Planning, (September 1980)

Teller Community Map Scale, prepared by Kawerak Inc. in cooperation with the Alaska Department of Commerce, Community and Economic Development, (1”=100’, 2’ contours, date of aerial photography June 28, 2004)

U.S. Army Corps of Engineers, Floodplain Management Services, Flood Hazard Community Data online: http://www.poa.usace.army.mil/en/cw/fld_haz/floodplain_index.htm

Venetie

Community Setting

Population:	185, Department of Labor population estimate
Incorporation Type:	Unincorporated
Local governance:	Native Village of Venetie Tribal Government BIA-Recognized IRA Council; Combined Venetie and Arctic Villages. Did not participate in ANCSA; full title to former reservation lands.)
Borough Located In:	Unorganized borough
Regional Native Corporation:	Not Applicable

Landform and Climate:

Venetie is located on the north side of the Chandalar River, 45 miles northwest of Fort Yukon. Between 1972 and 1977 the village was relocated from the south side of the Chandalar River to a higher terrace about 30 feet above the river.

The winters are long and harsh, and the summers are short but warm. Daily minimum temperatures between November and March are usually below 0 °F. Extended periods of -50 to -60 °F are common. Summer high temperatures run 65 to 72 °F; a high of 97 °F has been recorded. Total annual precipitation averages 6.6 inches, with 43 inches of snowfall. The Chandalar River is ice-free from the end of May through mid-September, all according to the Division of Community and Regional Affairs Community Database Online and the Venetie Sanitation Facilities Master Plan.

Water Infrastructure Description

a. Water supply: Water is derived from a well near the Chandalar River. Some residents indicate that river water is still hauled for personal use by some members of the village according to the Venetie Sanitation Facilities Master Plan.

b. Water system(s): Water is treated and stored in a tank. The existing well has an interim permit pending determination of whether it is to be classified as groundwater or groundwater under the direct influence of surface water (GWUDISW). A circulating water distribution system and septic system constructed in 1980 failed within two years of construction. A water transmission line froze in 2009, and the utility is still using 'fire hoses' on a portion of its water transmission line, until funding is available for a more permanent solution.

c. Wastewater system(s): Currently six homes and the health clinic are on a flush/haul system. A washeteria constructed in the early 1990's has six washers and six dryers, plus shower facilities, according to the RUBA report. The washeteria building had foundation problems and the equipment was in need of repair, but was upgraded in 2002 by a project funded by the Denali Commission. Construction of a new sewage lagoon was completed in 2005, and it has been operating satisfactorily. There are plans for construction of 15 more water/sewer flush haul services.

Climate Related Factors and Potential Effects on Water Infrastructure

The village site is about 30 feet above the active floodplain of the Chandalar River in an area of discontinuous permafrost. Soils underlying the village consist of alluvium deposits from the Yukon River or from more recent floodplain deposits of the Chandalar River.

The US Army Corp of Engineers (USACE) indicates that the new village site is above the floodplain of the Chandalar River estimating the elevation of the floodplain as 558 feet mean sea level (MSL) at the area below the village. The village is located at an approximate elevation ranging from 590 to 600 feet MSL.

Likelihood and Frequency of Impacts

According to ANTHC, flooding or erosion in the vicinity of the well is possible, but have not yet occurred.

Severity of Impacts

Potential impacts to the well from flooding and/or erosion are likely to be only temporary and not catastrophic.

Historical Impact to Water Infrastructure

The old well near the river has periodically been damaged by flooding and erosion. In 2004, ANTHC drilled four test wells but only one provided adequate water. That well is now the current water source for Venetie.

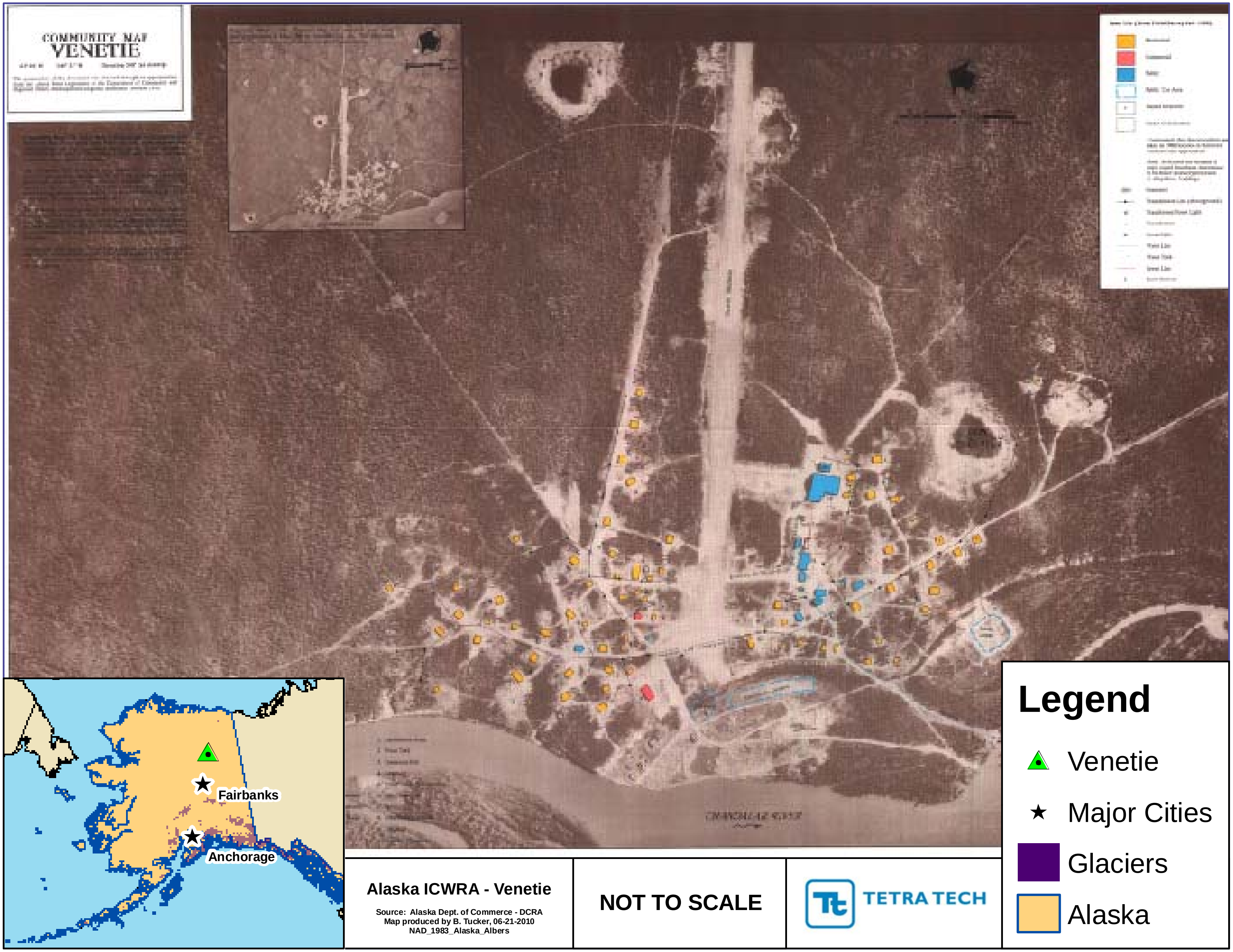
The old sewage lagoon flooded in 1998 due to rapid snowmelt and heavy rainfall according to the USACE. Additionally, as indicated earlier, a water transmission line froze in 2009.

Mitigation of Impacts to Water Infrastructure

Mitigation efforts have been implemented in the construction of the new sewage lagoon.

The wellhead, which is protected by a well house, may be susceptible to flooding or erosion eventually, as it is the only built water infrastructure near the river. Relocation of the well seems unlikely, as nine borings were drilled in 1978 by the Public Health Service for the purpose of locating the water supply well. This investigation found no available groundwater in a boring drilled on the terrace above the Chandalar River. However, borings drilled near the river were successful and the existing well was established near the river.

A new water transmission line (to replace the temporary fire hoses) is being constructed by ANTHC.


COMMUNITY MAP
VENETIE
CHANDALAR RIVER
Fairbanks
Anchorage
Alaska ICWRA - Venetie
Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers
NOT TO SCALE
TETRA TECH
Legend
Venetie
Major Cities
Glaciers
Alaska

References

Alaska Native Tribal Health Consortium engineering project manager, Devan Currier, telephone interview (June 8, 2010).

Division of Community and Regional Affairs (DCRA), Community Database Online, http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA, Rural Utilities Business Advisor (RUBA) status report (April 1, 2010), http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=703&isRuba=1

Venetie Sanitation Facilities Master Plan/Feasibility Study, prepared for the Venetie Village Council and the Alaska Native Tribal Health Consortium by ASCG, Incorporated, (January 2005).

USACE, *Alaskan Communities Flood Hazard Data*, (2000).

Wales

Community Setting

Population:	185, Department of Labor population estimate
Incorporation Type:	2nd Class City
Local governance:	City of Wales
Borough Located In:	Unorganized borough
Regional Native Corporation:	Bering Straits Native Corporation

Landform and Climate:

Wales is located on Cape Prince of Wales, at the western tip of the Seward Peninsula, 111 miles northwest of Nome. It is the westernmost community on the North American Continent. The city is located at the contact of a long, narrow coastal plain and a small granitic stock expressed topographically by 2,289-foot Cape Mountain. On a clear day, Little Diomede Island (U.S. Territory) and Big Diomede Island (Russian Territory) are visible about 30 miles westerly in the Bering Sea. The community lies primarily along the ocean beach on both sides of Village Creek, west of the Razorback Ridge, a prominent geologic feature northeast of Cape Mountain. Gilbert Creek is on the southerly edge of the city.

Wales has a maritime climate when the Bering Strait is ice-free, usually June to November. After the freeze, there is an abrupt change to a cold continental climate. Average summer temperatures range from 40 to 50 °F; winter temperatures range from -10 to 6 °F. Annual precipitation is 10 inches, with 35 inches of snow. Frequent fog, wind, and blizzards limit access to Wales, according to the Division of Community and Regional Affairs (DCRA), Community Database Online. Wales experiences extreme snow drifting each winter.

Water Infrastructure Description

The following information is from the DCRA, Rural Utilities Business Advisor (RUBA) status report, and the *City of Wales Sanitation Master Plan.*

a. Water supply(ies): Currently, water is sourced from Gilbert Creek to the south of the city during the summer to provide a seasonal supply to a city storage tank, and from Village Creek northeast of the city. Two groundwater wells were drilled and capped on the lower north slope of Razorback Mountain along the road to Tin City in July 2001. These wells are about one mile from the center of the city according to the *City of Wales Sanitation Master Plan*. The wells meet all requirements for potable water without treatment according to the 2002 *Master Plan*.

b. Water system(s): Residents haul treated water from a 500,000-gallon storage tank at the washeteria. The school, clinic, and city building are served by piped water.

c. Wastewater system(s): Almost all residents use honeybuckets (five gallon plastic pails with polyethylene bag liners) to manage human waste. The honeybuckets are dumped in collection bins located around the city, which city personnel haul and dump in a bermed sewage disposal cell northwest of the city according to the *Sanitation Master Plan*. Very few homes currently have plumbing. There are two septic systems -- one for the school and a second for teacher's housing, the clinic, and city building. The new clinic has a 300-gallon holding tank that is pumped, on an as-needed basis.

   Village Safe Water is applying for sanitation grants for the community to upgrade the washeteria. The new facility will most likely be a multi-purpose facility to include the washeteria, water plant, and a new clinic. A condemned city-owned dome-shaped igloo building will probably be torn down and its location used for the new multi-purpose facility.

Climate Related Factors and Potential Effects on Water Infrastructure

As excerpted from the *Sanitation Master Plan*, the 1 percent annual chance, or 100-year floodplain, as estimated by the U.S. Army Corps of Engineers Alaska District (USACE) is at 14 feet Mean Sea Level (MSL), based only on a flood of record from a storm surge that occurred in November 1974. Storm surges cause Village Creek to be inundated for several thousand feet inland. According to local residents, the open tundra area in the vicinity of a 1990 housing development flooded to a depth of two to three feet. The USACE recommended building level is 16.0 feet MSL, or two feet above the 1974 flood level. No detailed storm surge flood study has been prepared for Wales. The main street through the center of the community ranges in elevation from 12 to 16 feet MSL.

The USACE Alaska Baseline Erosion Assessment lists Wales as a community to continue monitoring for coastal erosion. The *Wales Erosion Information Paper* prepared by the USACE on October 15, 2007 indicated that major erosion - reported to be the worst in the last 20 years – was caused by a Bering Sea storm on October 19, 2004. This storm generated high tides and winds, causing flooding and erosion in three areas in Wales. The erosion left the washeteria and the city's dome-shaped igloo building less than 100 feet from the active erosion area.

Soil test pits on the beach excavated on September 2, 2002 found permafrost at six to seven feet of depth according to the *Sanitation Master Plan.*

Likelihood and Frequency of Impacts

Coastal storms are likely to continue to impact the honeybucket disposal cell and septic systems, which are both located in the floodplain.

Severity of Impacts

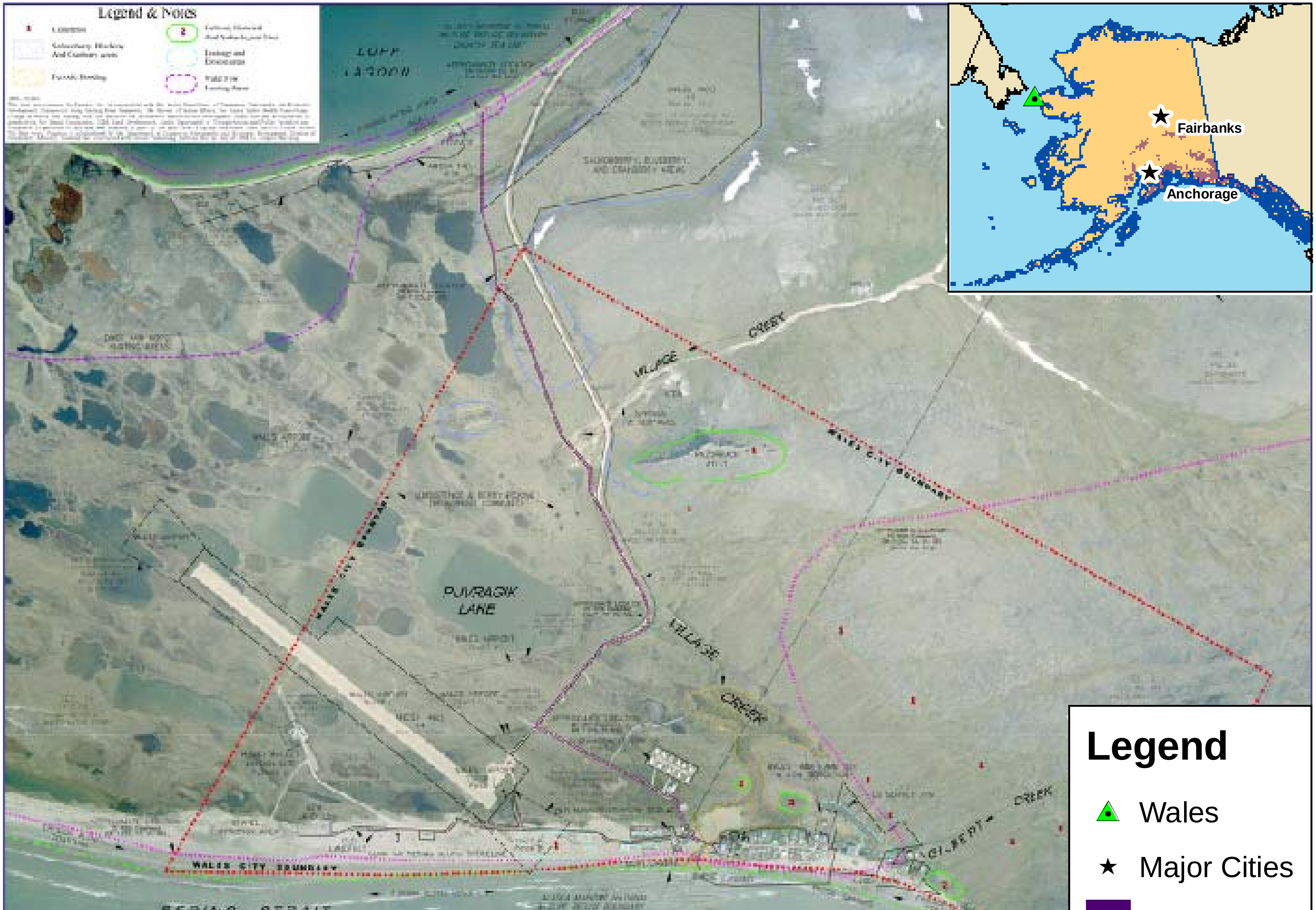
Impacts from the 2004 storm were disruptive but not catastropic. However, as erosion continues to advance toward city infrastructure, the severity of storm impacts may accelerate.

Historical Impact to Water Infrastructure

The 2004 coastal storm reportedly damaged the sewage outfall. Reports of a strong storm in 1974 may have caused damage, but documentation of impacts was not discovered.

Mitigation of Impacts to Water Infrastructure

The relatively new city water supply wells are located outside of the floodplain which will help mitigate climate-related water resource impacts in the future. However, sanitation facilities and water distribution lines are still located in the floodplain and are thus subject to periodic flood hazards.



Alaska ICWRA - Wales

Source: Alaska Dept. of Commerce - DCRA
Map produced by B. Tucker, 06-21-2010
NAD_1983_Alaska_Albers

NOT TO SCALE

TETRA TECH

References

Alaska Department of Education and Early Development, Assessment and Accountability, Enrollment by School and Grade as of October 1, 2009, FY 2010

Division of Community and Regional Affairs Community Database Online: http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm

DCRA, Rural Utilities Business Advisor status report, (April 4, 2010), http://www.commerce.state.ak.us/dca/ruba/report/Ruba_public_report.cfm?rID=651&isRuba=0

City of Wales Sanitation Facilities Master Plan, prepared by CE2 Engineers, Inc. (September 2002)

USACE, Alaska Baseline Erosion Assessment, Erosion Information Paper Wales, AK (October 15, 2007): http://www.poa.usace.army.mil/AKE/Home.html

USACE, Flood Hazard Data-Wales, Alaska online at: http://www.poa.usace.army.mil/en/cw/fld_haz/wales.htm

Appendix B Other Communities of Concern – Summaries

Community	Potential Water infrastructure Risk	Climate-Related Impact
Akhiok	Sewer outfall discharges into Alitak Bay where retaining wall was destroyed during November 2007 storm	Erosion caused by coastal storm and seasonal waves
Alakanuk	Listed as 'Priority Action" community by USACE in ABEA. VSW designed and built above-ground water and sanitation system after erosion rate map was prepared by USACE. Erosion rates may need re-evaluation as analysis is more than 10 years old. VSW indicates that the Federal Emergency Management Agency will not give any more funding for preventative measures. There are above-ground water distribution systems that shift out of line during flooding. VSW indicates that community needs a system with "helical anchors" to prevent it from shifting every time there is a flood. Division of Homeland Security and Emergency Services (DHSEM) reported: "Beginning May 13, 2005, a large ice jam blocked the mouth of the Lower Yukon River and caused widespread flooding to the cities of Emmonak and Alakanuk. In both cities, several roads were inundated and eroded by the floodwaters. Floodwaters also inundated city infrastructure to include the above-ground circulating water and vacuum sewage systems which were displaced and/or knocked off their mounting supports." See: http://ready.alaska.gov/community_services/2005_spring_floods/default.htm (includes additional photos of 2005 flooding.)	Lower Yukon River, Alakanuk Pass, Erosion and flooding
Anvik	High flood levels – water infrastructure susceptibility unknown in lower portion of community	Yukon River flooding
Arctic Village	Washeteria floor is at 96.6'. The berm around the sewage lagoon is at roughly 93.3 per USACE, Flood Plain Management Services. The 1956 flood approximated 100' and 1945 flood 98'.	East Fork, Chandalar River flooding
Buckland	Water intake structure damaged during 2010 spring breakup. New sewage lagoon has large dikes that provide flood protection and multi-plate culverts designed for flood runoff. A new buried water and sewer system is being installed which should have lower risk to flooding. The sewage lagoon was constructed in 2007 and flooding was taken into consideration with the design. There is a road project that has very significant flooding issues according to VSW. Buckland, because of its location in the floodplain of the Buckland River, has a long history of ice jam flooding. The pump house that had been at the river's edge was moved in the early 1990's. Erosion continues along the river.	Buckland River icejam flooding and erosion
Clark's Point	The community is going dry according to VSW. Community mostly relocated onto bluff, some structures still remain in floodplain.	Bristol Bay & Nushagak River

Evansville	Unknown	Koyukuk River erosion
Eek	Eek is located on the south bank of the Eek River, 12 miles east of the mouth of the Kuskokwim River. Eek currently provides treated water and hauls honeybucket waste. ANTHC has contracted for a geotechnical study which shows the permafrost temperatures are at 31.5 ºF, considered unstable permafrost. The active layer is relatively shallow at about 2 to 3 feet. ANTHC had been planning on a shallow bury water/sewer system but is now planning to install an above-ground system. The only evidence of the permafrost degradation is houses needing more shims under foundations and twisting of the boardwalks which may be due to some water channeling, per ANTHC. Eek's "Solid Waste Management Plan" from September 2005 states that solid and honeybucket wastes are currently deposited on land and in water at a dumpsite. Eek is located on wetlands. The Geology and Soils section of the Solid Waste Management Plan states: "The Yukon-Kuskokwim Delta area lies within the discontinuous permafrost region of Alaska. Much of the delta is underlain by fine-grained, ice rich soil varying in thickness from tens to hundreds of feet. Permafrost may be locally absent under and near large bodies of water. The Yukon-Kuskokwim Delta largely consists of three very similar geologic units consisting of silt, sands, silty sands, and organic soils (peat bogs). In Eek, the active layer above the permafrost generally consists of 2 to 5 feet. The permafrost is relatively warm and icy, with the average temperatures just below 32 °F. This means that the permafrost must be kept frozen or large settlements can occur with only a slight warming of the soil. Because of this, typical construction methods include aboveground pipe systems with building foundations using thermosyphons and other methods to keep the soil frozen and stable." The solid waste study included summaries of nine geotechnical summaries conducted in Eek between November 1978 and July 2004.  **Two-stage surface water treatment system in Eek, Alaska. The**	Permafrost melt

	system is designed to treat surface water with periodically high levels of organics, turbidity, iron and manganese. Photo and caption courtesy of ANTHC, Division of Environmental Health and Engineering (DEHE) (http://www.anthc.org/cs/dehe/civeng/)	
Kaltag	Unknown water resource threats. The community is located on a bluff overlooking the Yukon River. However, the northern section of town may be subject to flooding. (USACE)	Yukon River
Kipnuk	Unknown water resource threats. Coastal storm or high river may flood community 4 miles upstream from Kinak Bay.	Coastal and river flooding
Kobuk	Unknown water resource threats. Kobuk River flooding occurs most years. 1937 flood of record is at 98.3'.	Kobuk River ice jam flooding
Kotlik	Hazard Mitigation plan (URS, 2007) indicated 60 percent of community was at risk from erosion, and 100 percent is susceptible to flooding. No water infrastructure was listed at risk but the landfill was included in critical facilities at risk.  Children at play along the eroding water front in Kotlik. Photo courtesy of the City of Kotlik, June 2007.	Yukon River, coastal surge
Koyuk	Unknown water resource threats. Coastal large wind setup occurs from Norton Bay.	Coastal storm surge
Kwethluk	According to the DCRA Community Database Online, a joint Kwethluk Utilities Commission has formed to provide water treatment, honeybucket, washeteria, and refuse services. The school and teachers' housing have individual systems. Residents haul water for household use. There are sewage container disposal bins; these are hauled to the sewage lagoon. None of the 147 homes have complete plumbing, but many residents have steambaths. Flooding and erosion are problems.	Flooding and erosion

Kwigillingok	Unknown water resource threats. Potential flood risk.	Coastal storm surge flooding
Levelock	Septic and leach fields.	Kvichak River
Lowell Point	Lowell Point, population 88, is an unincorporated area approximately 2 miles south of the City of Seward that is located outside the Seward city limits but within the Kenai Peninsula Borough. Spruce Creek traverses along the northern border of the alluvial fan that is Lowell Point; on the east is Resurrection Bay. The climate, influenced by the north waters of the Pacific Ocean, is generally mild. However the glacial ice fields that overlook the area can produce strong winds and heavy precipitation. On average, January is the coolest month, with temperatures averaging 21 degrees Fahrenheit. July is the warmest month with temperatures averaging 62 degrees Fahrenheit (www.weather.com). Seward's sewer line runs along the open coastline along the 2 mile Lowell Point Road that leads to Lowell Point where it crosses the Lowell Creek tunnel outfall and Spruce Creek leading to the sewage lagoon and treatment plant. Lowell Point residents are not serviced by city sewer but are on individual septic systems. The Seward Public Works director is very concerned about coastal storms undermining the sewer line and road, and flooding threats to the sewage lagoon from Spruce Creek. Although it is diked, the lagoon is on an alluvial fan. Lowell Point Road has been repeatedly buried by Lowell Creek Tunnel outfall. There are localized problems with septic system flooding in Lowell Point according to VSW. Many of the waterfront structures have privately installed beach stabilization structures designed to resist the onslaught of waves. Revetments on Lowell Point are typically built from natural stone known riprap up to 3 ft. in diameter, ranging in height from several feet to well over ten feet tall according to a ***Lowell Point Beach Sediment Study***, by University of Alaska Anchorage CE A676 Coastal Engineering students (Nathan Epps, Tyler Johnson, Daniel Ottenbriet, Joe Taylor, and Delmer Zahn, May 4, 7007).	Coastal flooding, Spruce Creek flooding and erosion
Lower Kalskag	Unknown water resource threats. Well had been very close to a bulk fuel facility, but it is not known whether a new well has been installed or if the wellhead has been protected.	Kuskokwim River Flood and erosion
Marshall	Unknown water resource threats. Significant Yukon River flooding in 1937, 1956, 1962, 1965, and 19'89.	Yukon River flooding
Napakiak	Unknown water resource threats.	Flooding
Napaskiak	Unknown water resource threats. Documented flooding of the landfill.	Erosion and flooding
Nightmute	There is a potential for sewage lagoon flooding, according to VSW. No buildings are known to flood.	Coastal flooding and erosion
Ninilchik	Some water lines are in floodplain, but impacts are not that severe.	Ninilchik River
Nulato, old town site	VSW indicated that the worst flood was in 1965. Melting permafrost is causing the dikes for the sewage lagoon and water supply to sag, threatening the water supply for the community. There is work being	Flooding, permafrost melt

	done to mitigate these impacts.	
Nunam Iqua (formerly known as Sheldon Point)	According to the USACE, water was reported to be about 1.5 ft deep in the area of the new school and came to about 6 inches below the skirting of the old BIA school during the 1972 flood (the school was reported to be settling, and the skirting in Sept.1993 was about 1 foot above the ground). Water covered much of the land, but no houses were reported flooded. The floodplain is extremely broad so that a large increase in flood flow would result in a small increase in flood elevation. According to the ABEA, Erosion Information Paper, "Active erosion is occurring <100 ft from community water intake pump."	Erosion
Oscarville	Unknown water resource threats.	River flooding
Pilot Point	A new drainfield is being built within 1,500 feet of Ugashik Bay in a floodplain. It will be complete in September 2010 and it is being built with flooding considerations in mind. This new drainfield is replacing a current drainfield that floods according to VSW.	Coastal storms
Pilot Station	Newer residential development is outside of the floodplain.	Yukon River flooding
Platinum	Very slow erosion occurring according to VSW.	Kuskokwim Bay coastal flooding
Point Hope	Threat quantified in Oct. 2009 ANTHC, Center for Climate and Health report *Climate Change and Health Impacts Point Hope*	Water quality and permafrost melt
Port Heiden	Landfill and contamination are potential threats to commercial and subsistence use water resources. Although significant erosion occurs along the beach in different locations, homes have been built or moved inland and are generally not threatened. All are on individual wells and septic systems, so no public water systems are threatened.	Coastal erosion
Port Protection (K-12 school enrollment = 12)	Unincorporated community in the unorganized borough with an estimated population of 66 (DCRA 2008 non-certified). Located on the northern tip of Prince of Wales Island. Spring water is available from a water tank maintained by the Community Association. Homes are fully plumbed. Most residents use outdoor privies or outfall pipes for sewage disposal, although a few individual septic tanks exist. Port Protection has infrastructure in floodplains, but mitigation measures are taken into consideration during design, per VSW. Design and construction is also taking flooding risk into account.	Coastal erosion, storm surge
Red Devil (school may be closed due to low enrollment)	Red Devil has very high flood levels from the Kuskokwim River and no flood protection Water is derived from individual wells or hauled from the school well. Four of the 17 occupied homes are fully plumbed. Sewage is disposed of on an individual basis. The school and teacher's housing uses individual septic tanks and drainfields; others use pit privies according to the DCRA Community Database Online.	Kuskokwim River flooding
Russian Mission	1989 is the flood of record. ANTHC has recently completed a new Water/Sewer Master Plan for Russian Mission. 20-25 homes in the floodplain portion of Russian Mission experience some level of flooding almost annually. Drinking water mains and service lines are also impacted.	Yukon River flooding

	The berms around the sewage lagoon are not high enough and the sewage is overflowing into a slough. This is a reoccurring problem, regardless of a flood event that would compound the health hazard. A lift station in the low-lying floodprone portion of town was designed to pump up to the lagoon on the hill where new housing has been built but the lift station was too expensive to operate and the community has discontinued its use.	
Scammon Bay	Scammon Bay is on the south bank of the Kun River, one mile from the Bering Sea. It lies to the north of the 2,300-foot Askinuk Mountains on the Yukon-Kuskokwim Delta. The USACE online floodplain management services http://www.poa.usace.army.mil/en/cw/fld_haz/communities.htm#K reports: "The community is located on a hillside above the Kun River which periodically floods overbank to a depth of 4 to 5 ft. Floodwaters have come near buildings, but no buildings have been reported flooded." Erosion problems have not been reported from the Kun River, however ANTHC reported that the community has massive erosion issues from several areas that are built on substandard fill. The SE corner of the community where a lift station is located is sliding downhill. AVCP constructed six new homes in 2009 and there are 2-3 foot channels around the homes, resulting from a blown out road where a fill embankment was constructed with non-UV resistant stabilization material that is failing.	Permafrost melt
Sleetmute	High flood levels and no flood protection.	Flooding
Shageluk	Unknown water resource threats. Slow, periodic erosion	Innoko River erosion
South Naknek	South Naknek suffers from coastal erosion by Bristol Bay and from riverine erosion caused by the Naknek River. The erosion is undercutting the 70 foot high banks, and is less than 100 feet (horizontally) away, in the vicinity of the village docks and other community improvements. The average erosion rate appears to be about 2 to 5 feet per year and is accelerated during extreme storm events and extreme tides. The erosion is occurring along the entire coast and river shoreline, per the USACE, ABEA South Naknek Erosion Information Paper. Threats to sewer lines and sewage lagoon described in a community survey submitted for the ABEA were not able to be verified with ANTHC.	Erosion
Stevens Village	The 1964 flood of record is at 105.6'. Severe ice jam flooding occurred in May 2009 village. Erosion is slow according to VSW. Refer to FEMA Best Practices "Living Simply in Rural Alaska" http://www.ak-prepared.com/plans/pdf_docs/Stevens%20village%20BestPractices.pdf.pdf to see description of flooding, and erosion of about 4 feet per year in some locations. The USACE Flood Plain Management Services, as of September 1995, placed the following flood gauge on a utility pole in front of and just upstream of Oliver Ben's house along the river. High Water Elevation (HWE) signs were placed on Ted Stevens' house, approximately 5.8 ft above ground, and on Hilda Stevens' house (highest in the village),	Ice jam flooding

	approximately 10 inches above the ground. The HWE signs were placed with the sign's water symbol at the elevation of the 1964 flood. Hilda Stevens' house is located one house east of the church and four houses east of George's Store. The gauge is at the level of the 1964 flood at 1045.6 with the recommended building elevation two feet above this level. It is not known if the 2009 ice jam flood exceeded this previous high water mark of record.  *Photo courtesy of the Alaska District Corps of Engineers, Flood Plain Management Services* Flood Gauge in Stevens Village, Alaska. http://www.poa.usace.army.mil/en/cw/fld_haz/stevens_village.htm	
Thorne Bay	Thorne Bay has infrastructure in floodplains, but mitigation measures are being taken into consideration during design, according to VSW.	Coastal storms and erosion
Togiak	USACE High Water Marks placed. ANTHC did not know of any impacts to water infrastructure. Quite a bit of new housing is being built in Blueberry Ridge subdivision out of the floodplain.	Coastal flooding
Tuluksak	Kuskokwim River/coastal. 1970s flood level 3.9’, recommended building elevation 5.9’. Worst floods remembered by residents were those of the 1970s. The flood of record was based on water marks on the pilings under the school. High Water Elevation (HWE) signs were placed at three locations in the community at the elevation of the water marks with the sign's water symbol at the flood elevation. Source: USACE Flood Data online.	Flooding
Tuntutuliak	Kuskokwim Bay and river.	Coastal storm surge and flooding
Tununak	Community is on Spit, waves have overtopped spit between town site and airstrip but no known buildings flooded.	Coastal storm surge and flooding
Upper Kalskag	No flood protection. The lower part is flood prone and the upper part is fine. The lagoons do not get flooded according to VSW.	Kuskokwim River flooding and erosion
Wainwright	High potential for beach erosion on the Arctic Ocean. The community is well-elevated, little chance of flooding. Stormwater outfall has had HESCO basket erosion protection installed.	Coastal erosion, permafrost melt

(This page left intentionally blank.)

Appendix C Master List of Village Safe Water Communities

Appendix C. Master List of Village Safe Water Communities

#	Community	2009 DOL Population Estimate	Community Class City/Tribe	K-12 school enrollment for communities with 20 or less	Imperiled Community Priority Study Group*	Imperiled Community Additional Study Group**	IAWG Designated Priority At-Risk Communities	USACE, ABEA Priority Action Communities
1	Adak	165	2nd Class City					
2	Akhiok	51	2nd	18				
3	Akiachak	645	Tribal Council					
4	Akiak	346	2nd					Yes
5	Akutan	846	2nd	10				
6	Alakanuk	686	2nd		Yes			Yes
7	Alatna	22	Tribal Council					
8	Aleknagik	229	2nd					
9	Allakaket	137	2nd					
10	Ambler	261	2nd					
11	Anaktuvuk Pass	287	2nd					
12	Anchor Point	1,772	Unincorporated, KPB					
13	Anderson	275	2nd					
14	Angoon	442	2nd					
15	Aniak	485	2nd		Yes			
16	Anvik	75	2nd			Yes		
17	Arctic Village	139	Tribal Council			Yes		
18	Atka	71	2nd	15				
19	Atmautluak	296	Tribal Council		Yes			
20	Atqasuk	287	2nd					
21	Beaver	58	2nd	13				
22	Bethel	5,803	2nd					
23	Birch Creek	31	Tribal Council					
24	Brevig Mission	358	2nd		Yes			
25	Buckland	432	2nd		Yes			
26	Cantwell	200	Tribal Council					
27	Central	96		10				
28	Chalkyitsik	60	Tribal Council	20	Yes			
29	Chefornak	475	2nd					Yes
30	Chenega Bay	71	Tribal Council					
31	Chevak	945	2nd					
32	Chignik (Bay)	62	2nd	15				
33	Chignik Lagoon	73	Tribal Council	16	Yes			
34	Chignik Lake	105	Tribal Council	17				
35	Chistochina	76	Tribal Council	11				
36	Chitina	117	Tribal Council					
37	Chitina	117	Tribal Council					
38	Chuathbaluk	98	2nd					
39	Circle	99	Unincorporated/ Tribal Council	19				
40	Clark's Point	61	2nd	11		Yes		Yes
41	Coffman Cove	152	2nd	15				
42	Cold Bay	84	2nd	11				
43	Copper Center	297	Unincorporated/ Tribal Council					
44	Craig	1400	1st					
45	Crooked Creek	131	Tribal Council					
46	Deering	118	2nd / NAB		Yes			Yes
47	Delta Junction	1,128	2nd					
48	Diomede	117	2nd		Yes			
49	Dot Lake village	37	Tribal Council					
50	Eagle village	61	Tribal Council					
51	Eek	282	2nd/ Lower Kuskokwim Region			Yes		
52	Egegik	73	2nd	12				
53	Ekuk	0	Tribal Council					
54	Ekwok	109	2nd	13				
55	Elfin Cove	25	Unincorporated					
56	Elim	288	2nd					
57	Emmonak	774	2nd		Yes			Yes
58	Evansville/Bettles	39 & 13	Tribal Council					
59	False Pass	41	2nd	5				
60	Fort Yukon	585	2nd		Yes			
61	Galena	564	1st					
62	Gambell	666	2nd					
63	Glenallen	473	Unincorporated					
64	Golovin	154	2nd		Yes			Yes
65	Goodnews Bay	237	2nd					
66	Grayling	177	2nd					
67	Gulkana	244	Tribal Council		Yes			
68	Gustavus	451	2nd					
69	Healy Lake	10	Tribal Council					
70	Hollis	193		12				
71	Holy Cross	187	2nd					
72	Hoonah	764	1st					
73	Hooper Bay	1158	2nd					
74	Hughes	79	2nd	12	Yes			
75	Huslia	265	2nd		Yes			Yes
76	Hydaburg	340	1st					
77	Hyder	87	Unincorporated					
78	Igiugig	48	Tribal \LPB	13				

#	Community	2009 DOL Population Estimate	Community Class City/Tribe	K-12 school enrollment for communities with 20 or less	Imperiled Community Priority Study Group*	Imperiled Community Additional Study Group**	IAWG Designated Priority At-Risk Communities	USACE, ABEA Priority Action Communities
79	**Iliamna**	91	Tribal\LPB					
80	**Ivanof Bay**	0	Tribal\LPB					
81	**Kake**	497	1st					
82	**Kaktovik**	286	2nd					
83	**Kaltag**	172	2nd					
84	**Karluk**	38	Tribal\KIB	13				
85	**Kasaan**	56	2nd	10				
86	**Kasigluk (old village)**	567	Tribal Council					
87	**Kennicott / McCarthy**	51	Unincorporated					
88	**Kiana**	374	2nd					
89	**King Cove**	744	1st					
90	**King Salmon**	373	BBB					
91	**Kipnuk**	671	Tribal Council			Yes		
92	**Kivalina**	410	2nd\NAB				Yes	Yes
93	**Klawock**	782	1st					
94	**Klukwan**	72	Tribal					
95	**Kobuk**	122	2nd			Yes		
96	**Kokhanok**	184	Tribal Council					
97	**Koliganek**	182	Tribal Council					
98	**Kongiganak**	465	Tribal Council					
99	**Kotlik**	618	2nd					Yes
100	**Kotzebue**	3,154	2nd					
101	**Koyuk**	358	2nd					
102	**Koyukuk**	105	2nd	10			Yes	
103	**Kwethluk**	723	2nd			Yes		
104	**Kwigillingok**	365	Tribal Council			Yes		Yes
105	**Larsen Bay**	79	2nd	11				
106	**Levelock**	88	Tribal Council	19		Yes		
107	**Lime Village**	19	Tribal Council					Yes
108	**Lowell Point**	92				Yes		
109	**Lower Kalskag**	251	2nd			Yes		
110	**Manley Hot Springs**	81		13				
111	**Manokotak**	438	2nd					
112	**Marshall**	414				Yes		
113	**McGrath**	322	2nd		Yes			Yes
114	**Mekoryuk**	174	2nd					
115	**Mentasta Lake**	120	Tribal Council					
116	**Metlakatla**	1,330	Tribal Council					
117	**Minto**	191	Tribal Council					
118	**Mountain Village**	782	2nd					
119	**Naknek**	516 cdp	BBB					
120	**Nanwalek**	226	Tribal Council					
121	**Napakiak**	337	2nd			Yes		Yes
122	**Napaskiak**	428	2nd			Yes		
123	**Naukati West**	118	Unincorporated	15				
124	**Nelson Lagoon**	60	Tribe, Aleutians East Borough	8	Yes			
125	**Nenana**	353	Home Rule					
126	**New Stuyahok**	519	2nd					
127	**Newhalen**	162	Tribal Council					
128	**Newtok**	355	Tribal Council				Yes	Yes
129	**Nightmute**	264	2nd			Yes		
130	**Nikolaevsk**	315	Unincorporated					
131	**Nikolai**	87	2nd					
132	**Nikolski**	33	Tribal Council					
133	**Ninilchik**	824	Tribal Council					
134	**Noatak**	486	Tribe, NAB		Yes			
135	**Nome**	3468	1st					
136	**Nondalton**	186	2nd					
137	**Noorvik**	628	2nd					
138	**Northway Village**	76	Tribal Council					
139	**Nuiqsut**	402	2nd					
140	**Nulato**	240	2nd			Yes		
141	**Nunam Iqua (a.k.a.Sheldon Point)**	156	2nd			Yes		
142	**Nunapitchuk**	539	2nd					Yes
143	**Old Harbor**	193	2nd					
144	**Old Minto**	191	Tribal Council					
145	**Oscarville**	109	Tribal Council			Yes		
146	**Ouzinkie**	170	2nd					
147	**Pedro Bay**	48	Tribal Council	12				
148	**Pelican**	122	1st	13				
149	**Perryville**	122	Tribal Council					
150	**Pilot Point**	66	2nd	11				
151	**Pilot Station**	577	2nd					
152	**Pitka's Point**	113	Tribal Council	20				
153	**Platinum**	57	2nd	12				
154	**Point Baker**	11	Unincorporated					
155	**Point Hope**	705	Tribe, NSB					
156	**Point Lay**	234	Tribal Council					
157	**Port Alexander**	61	2nd	11				
158	**Port Alsworth**	118	Unincorporated					
159	**Port Graham**	137	2nd					

#	Community	2009 DOL Population Estimate	Community Class City/Tribe	K-12 school enrollment for communities with 20 or less	Imperiled Community Priority Study Group*	Imperiled Community Additional Study Group**	IAWG Designated Priority At-Risk Communities	USACE, ABEA Priority Action Communities
160	**Port Heiden**	83	2nd, L&PB					Yes
161	**Port Lions**	200	2nd					
162	**Port Protection**	72	Unincorporated	6				
163	**Portage Creek**	7	Tribal Council					
164	**Quinhagak**	680	2nd		Yes			
165	**Rampart**	12	Tribal Council					
166	**Red Devil**	44	Tribal Council			Yes		
167	**Ruby**	149	2nd					
168	**Russian Mission**	363	2nd			Yes		
169	**Saint George**	111	2nd					
170	**Saint Mary's**	553	1st					
171	**Saint Michael**	446	2nd		Yes			Yes
172	**Saint Paul**	459	2nd					
173	**Savoonga**	721	2nd					
174	**Saxman**	434	2nd					
175	**Scammon Bay**	528	2nd			Yes		
176	**Selawik**	849	2nd, NAB		Yes			Yes
177	**Seldovia**	407	1st					
178	**Shageluk**	97	2nd	17				
179	**Shaktoolik**	231	2nd				Yes	Yes
180	**Shishmaref**	606	2nd				Yes	Yes
181	**Shungnak**	270	2nd					
182	**Slana**	102	Unincorporated	13				
183	**Sleetmute**	71	Tribal Council	13		Yes		
184	**South Naknek (Bristol Bay Borough)**	68	Tribal Council/BBB			Yes		
185	**Stebbins**	605	2nd		Yes			
186	**Stevens Village**	64	Tribal Council	15		Yes		
187	**Stony River**	48	Tribal Council					
188	**Takotna**	53	Tribal Council	13				
189	**Talkeetna**	894	Unincorporated/ MSB					
190	**Tanacross Village**	203	Tribal Council					
191	**Tanana**	251	1st					
192	**Tatitlek**	83	Tribal Council					
193	**Tazlina**	207	Tribal Council					
194	**Teller**	261	2nd		Yes			
195	**Tenakee Springs**	104	2nd					
196	**Tetlin**	169	Tribal Council					
197	**Thorne Bay**	424	2nd					
198	**Togiak**	820	2nd					
199	**Toksook Bay**	596	2nd					
200	**Tuluksak**	471	Tribal Council					
201	**Tuntutuliak**	384	Tribal Council					
202	**Tununak**	330	Tribal Council					
203	**Twin Hills**	74	Tribal Council	14				
204	**Tyonek**	166	Tribal Council					
205	**Ugashik**	15	Tribal Council					
206	**Unalakleet**	725	2nd				Yes	Yes
207	**Upper Kalskag**	223	2nd	12				
208	**Venetie**	185	Tribal Council		Yes			
209	**Voznesenka**	~40 families	Unincorporated\ KPB					
210	**Wainwright**	551	2nd, NSB					
211	**Wales**	148	2nd		Yes			
212	**Whale Pass**	60	Unincorporated					
213	**White Mountain**	202	2nd					
214	**Whittier**	159	2nd					

* This is the group of communities that appear to have climate related water infrastructure impacts which warrant additional analysis.

** This is the group of communities which require more information to determine whether they are likely to have climate related water infrastructure impacts.

Appendix D Other Bibliographic Resources

Intergovernmental Panel on Climate Change (IPCC) 2007 Sea Level Rise Projections.
http://www.realclimate.org/index.php/archives/2007/03/the-ipcc-sea-level-numbers/

The **International Arctic Research Center [IARC]** serves as a focal point of integrating/synthesizing arctic research efforts in terms of climate change and communicates the results to the global climate research community. http://www.iarc.uaf.edu/

The **Arctic Research Consortium of the United States (ARCUS)** was formed in 1988 to identify and bring together the distributed human and facilities resources of the Arctic research community – to create a synergy for the Arctic in which each resource, when combined with others, can result in a strength that enables the community to rise to the many challenges facing the Arctic and the United States. ARCUS provides a mechanism for the Arctic community to complement the advisory roles of other national organizations, such as the US Arctic Research Commission (USARC), the Polar Research Board (PRB), and Interagency Arctic Research Policy Committee (IARPC) that are concerned with the Arctic.
http://siempre.arcus.org/4DACTION/wi_ai_getArcticInfo/3606

The **SEARCH Sea Ice Outlook** effort, which emerged from discussions at the "Arctic Observation Integration Workshops" held March 2008 in Palisades, NY, is a response by the scientific community to the need for better understanding of the Arctic sea ice system, given the drastic and unexpected sea ice decline witnessed in 2007. The Sea Ice Outlook produces monthly reports during the Arctic sea ice season, based on an open and inclusive process that synthesizes input from a broad range of scientific perspectives. http://www.arcus.org/search/seaiceoutlook/background.php

The **North Slope Science Initiative (NSSI)** was developed by federal, state and local governments with trust responsibilities for land and ocean management, to facilitate and improve collection and dissemination of ecosystem information pertaining to the Alaskan North Slope region, including coastal and offshore regions. The mission of the NSSI is to improve scientific and regulatory understanding of terrestrial, aquatic and marine ecosystems for consideration in the context of resource development activities and climate change. The vision of the NSSI is to identify those data and information needs management agencies and governments will need in the future to develop management scenarios using the best information and mitigation to conserve the environments of the North Slope. The NSSI adopts a strategic framework to provide resource managers with the data and analyses they need to help evaluate multiple simultaneous goals and objectives related to each agency's mission on the North Slope. The NSSI uses and complements the information produced under other North Slope science programs, both internal and external. The NSSI also facilitates information sharing among agencies, non-governmental organizations, industry, academia, international programs and members of the public to increase communication and reduce redundancy among science programs. http://www.northslope.org/

The **Alaska Climate Research Center** is a research and service organization at the Geophysical Institute, University of Alaska Fairbanks. Our group conducts research focusing on Alaska and polar regions climatology and we archive climatological data for Alaska. http://climate.gi.alaska.edu/

The mission of the **Alaska Center for Climate Assessment and Policy** is to assess the socio-economic and biophysical impacts of climate variability in Alaska, make this information available to local and regional decision-makers, and improve the ability of Alaskans to adapt to a changing climate.
http://www.uaf.edu/accap/

Scenarios Network for Alaska Planning (SNAP) is a collaborative network of the University of Alaska, state, federal, and local agencies, and NGOs. The primary products of the network are (1) datasets and maps projecting future conditions for selected variables, and (2) rules and models that develop these projections, based on historical conditions and trends. http://www.snap.uaf.edu/home

The **Climate Change Sub-Cabinet** advises the Office of the Governor on the preparation and implementation of an Alaska climate change strategy. The Sub-Cabinet was created in 2007 under Administrative Order 238. http://www.climatechange.alaska.gov/

The National Snow and Ice Data Center supports research into the world's frozen realms: the snow, ice, glacier, frozen ground, and climate interactions that make up Earth's cryosphere. Scientific data, whether taken in the field or relayed from satellites orbiting Earth, form the foundation for the scientific research that informs the world about our planet and our climate systems. http://nsidc.org/

The U.S. Global Change Research Program (USGCRP) supports research on the interactions of natural and human-induced changes in the global environment and their implications for society. The USGCRP began as a presidential initiative in 1989 and was codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606), which mandates development of a coordinated interagency research program. http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewalaska.htm

NOAA Arctic Theme Page. http://www.arctic.noaa.gov/index.shtml

USGS Alaska Coastal Erosion. USGS scientists recently completed a quantitative analysis, published in the July 2007 issue of *Geology*, documenting effects of accelerated coastal land loss and thermokarst lake expansion and drainage along a section of the Alaska North Slope coastline. http://energy.usgs.gov/alaska/ak_coastalerosion.html