Kivalina Consensus Building Project
Kivalina Situation Assessment

Annotated Bibliography of Selected Studies

Prepared by Glenn Gray and Associates – July 2010

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Alaska Department of Transportation and Public Facilities. 1984. *Engineering geology and soils report Kivalina Airport.* Project No. D21332.

This report summarizes findings from a field trip to Kivalina for airport improvements. The authors found that the island is composed of primarily medium sand, but locally sandy gravel is present. Major storms have generated waves that cross the island. Beach grass provides stability and is primary reason the island has not washed away. Local destruction of grass by dogs, 3-wheelers and foot traffic has resulted in some erosion from storms. Test holes of lagoon show thick silt deposits. Permafrost was found beneath the realigned airport "because it was present in sand with relatively low moisture content, settling as a result of the thaw of a few feet of the foundation sand will be minor." The document states that it would be imprudent to borrow material from seaward side of the island because it would magnify the effects from erosion. It also warns that no obstructions should be placed on beach because turbulence will scour beach materials.

ASCG Inc. 2005. *Kivalina, Alaska evacuation and relocation road feasibility study*. Submitted to the Northwest Arctic Borough by ASCG, Inc. Anchorage. October 2005.

The Northwest Arctic Borough contracted with ASCG Inc. in 2005 to produce a feasibility study for an evacuation road. The study found that an evacuation road is needed because it may be 15-20 years before the village is relocated. ASCG evaluated six routes using criteria that included: Evacuation to a site with an elevation of 25 feet, potential for other uses for the route, maintenance requirements, land ownership, and environmental concerns. The report recommended construction of a 24-foot wide gravel road using national and state design standards for a road that could support a semi-trailer for use in relocating the village.

Of the eight alternatives evaluated, ASCG selected Alternative 6 as the preferred option. This route begins in the center of Kivalina and crosses the lagoon using a 0.5-mile earthen causeway and 60-foot long bridge. It would continue and continuing across the tundra 3.6 miles

terminating at the Simiq village relocation site. The cost for this route in 2005 dollars was estimated to be $21.3 million.

The environmental analysis in the document states that a causeway will be less expensive than a long bridge, but there may be concerns raised about damage to fish habitat and effects to sediment transport.

Burch, Ernest S. Jr. 1998. The Inupiaq Eskimo nations. University of Alaska Fairbanks Press.

Chapter 2 of this book addresses the Kivalliñigmiut nation, the people who occupied a portion of the Upper Kukpuk valley and the Kivalina and Wulik river watersheds. The Kivalliñigmiut nation was likely founded in the mid-eighteenth century or earlier. The author includes historic descriptions of area that are useful comparisons to today. For example, records of the 1838 Kashevarov expedition reveal that there were three entrances into Kivalina Lagoon, and the southern end of the island where Kivalina is presently located was 600 yards wide. Burch estimates that there were 280 to 410 people living at Kiniktuuraq.

During the great famine of 1881–1883, there were sharp declines in fish and wildlife populations, and the Kivalliñigmiut moved away from the area, some travelling to Point Hope, Barrow, and Cape Lisburne. Burch estimates that more than half the population died during the famine. After the famine, some of the remaining Kivalliñigmiut returned to the area which was occupied by people from Shishmaref. By 1895, there was a settlement at the current site of Kivalina called Ualliik. When the current community was founded in 1905, it was made up of Kivalliñigmiut and people from Shishmaref, the Lower Noatak, the Upper Noatak, and Kotzebue.

The Kivalliñigmiut had 14 spring settlements along the ocean and 20 inland settlements along the Kivalina and Wulik rivers.

The yearly subsistence cycle began in April or May with hunting of bowhead whales and seals. Around the first week of July, a festival was held in Kivalliik. In the summer, the people hunted caribou and attended the trade fair at Sheshalik. After the caribou hunt in late August, another festival was held at the mouth of the Wulik River. After that, the people headed inland to fish in the rivers. In the fall, the Kivalliñigmiut completed a fall caribou hunt. During March, families began moving to the coast.

_____. 1985. *Subsistence production in Kivalina, Alaska: A twenty-year perspective.* Technical Paper 128. Alaska Department of Fish and Game.

This technical report compares subsistence use in Kivalina during two two-year periods (1964–1966 and 1982–1984). This summary focuses on the significant changes during the 20-year

period, including construction of a new high school, introduction of electricity, a larger store, and replacement of dog teams with snow machines. Spring bowhead whaling resumed in 1966.

Considering all of the changes, the author found many similarities between the two periods. The importance of gathering and using subsistence foods was similar, and all of the same families were represented during both periods. The author found that level of social continuity was high although there appeared to be a significant improvement in the community's morale.

Between 1964-1966, there were one log home, 10 sod homes, 14 frame houses, and a one-room school house. Those living in sod homes spent the summer in tents along the beach.

The study noted the variation in harvests of species from year-to-year and seasonally. The reasons for this variation included many factors: Distribution of species, accessibility of fish and game, availability of alternative species, desirability of alternative species, weather, processing and storage conditions, opportunities for barter of surplus fish and game, desirability of alternative activities, and regulation of subsistence use.

Chapman, R.S., Kim, S.C., and D.J. Mark. 2009. *Storm damage and flooding evaluation: Storm-induced water level prediction study for the Western Coast of Alaska*. U.S. Army Corps of Engineers, Engineer Research and Development Center.

City of Kivalina. 2008. *Local hazards mitigation plan.* Prepared by City of Kivalina, ASCG Inc., and Bechtol Planning and Development. Approved by FEMA September 10, 2008.

The local hazards mitigation plan includes a risk assessment which has three parts: Hazards identification, vulnerability assessment and risk analysis. The assessment will make Kivalina eligible for FEMA hazard mitigation program funds.

<u>Hazards Identification:</u> The plan identifies Kivalina is subject to high flood hazards, high severe weather hazards, high erosion hazards, and low earthquake hazards. There are no tsunami or seiche hazards.

- Winds from the south to southwest general waves that expend their full energy on Kivalina's beaches.
- Flood hazards are almost exclusively from storm surges from south to southeasterly winds. Waves from this direction are more destructive because they can ride atop a storm surge (e.g., October 2004 storm).
- Less common waves from the northwest can be higher, longer and more destructive that waves from other directions.

- Later freezing of marine waters makes the community vulnerable to fall storms where winds can generate higher waves over longer fetches. Since the 1980s, the ice free period has extended from three months to as much as five months.
- Estimates for recurrence of storms are as follows: A 4-foot elevation storm surge can be expected every year, a 6-foot storm surge less than every 5 years, and a 16.3-foot storm surge can be expected every 100 years.[1] Prior to 2004, only two storms flooded portions of the village. FEMA requires elevation of structures above the 100-year flood levels.
- Significant beach erosion occurred during an October 2004 storm requiring relocation of teacher housing.
- During 2005, 2 storms caused significant erosion. One storm had a storm surge estimated to be 8.5 feet above mean sea level.

Vulnerability Assessment: The plan identifies essential facilities, transportation systems and utility systems and their vulnerability to the various hazards.

The mitigation plan identifies state and federal resources and funding opportunities by FEMA and other federal agencies that Kivalina may use to address impacts of natural hazards.

The plan includes mitigation goals and objectives, and Table 12 identifies recommended mitigation projects. These projects include relocation of the sewage treatment plant, relocation of fuel lines to the school, removal of sewage bunkers on the shoreline, replace damaged water tank skins, lagoon erosion control project, evacuation road, structure elevation, assessment of integrity of public buildings, and installation of a siren to warn of a disaster event or severe storm.

This document was meant to be reviewed on an annual basis to determine whether updates to the plan are necessary, including additional sections on hazards related to economic, technical and public health crises. Future revisions should include reports completed since 2006 and any changes needed to incorporate changes to risk as a result of construction of the rock revetment and new flood level estimates currently being developed by the U.S. Army Corps of Engineers.

A presentation by the Native Village of Kivalina to the Inuit Circumpolar Conference is attached as an appendix to the plan.

Cold Climate Housing Research Center. 2009. Sustainable northern shelter project. http://www.cchrc.org/App_Content/files/SNS_Project_Approach_071508.pdf Accessed. November 7, 2009. Fairbanks.

[1] A new 100-year flood estimate is currently being developed by the U.S. Army Corps of Engineers.

The Cold Climate Housing Research Center is a nonprofit located in Fairbanks with the goal of constructing energy efficient, sustainable housing for rural Alaska. It is currently working with the communities of Anaktuvuk Pass, Newtok/Metarvik, Point Lay, and Nuiqsut.

The 2009 demonstration house project in Anaktuvuk Pass involved construction of an energy efficient home. The home was constructed with a light steel frame that is sprayed with a soy-based polyurethane R-60 insulation that was covered on the inside with a plywood skin. A sod roof and earth banking are used on the outside. Energy consumption is estimated to be 110 gallons of fuel oil per year, and the home uses both solar and wind power. The cost of the house, including shipping, was under $150,000. Students from Illisagvik College in Barrow built the house in 4 weeks.

Combellick, Rod. 2007. Memorandum to Randy Bates, Director, Division of Coastal and Ocean Management from Rod Combellick, Deputy Director Division of Geological and Geophysical Surveys, Alaska Department of Natural Resources. November 16, 2007.

This memorandum requested a temporary natural hazards designation for an Alaska Coastal Management Program review of the rock revetment project. The author compared aerial photos taken in 1966, 1997, 2000, and 2007 and found:

- Between 1966 and 2000, there was no measurable erosion of the vegetated backshore, but there was evidence of erosion on the older, vegetated crest along the northern one-third of the town and part of the airstrip.
- "The irregular character of the berm in 1966 suggests it has undergone, and possibly still undergoing, thermal erosion of frozen soil." Subsequent aerial photographs show that the beach has accreted and that the berm became vegetated.
- The 2007 aerial photographs showed that portions of the vegetated berm along the southern one-third of town had receded several feet. They also showed erosion has taken place along the southern one-third of town on the lagoon side probably resulting from flow from the Wulik and Kivalina rivers.
- The Signauk Entrance to the lagoon migrates back and forth over time, and it closes periodically. In 1997, it was located considerably south of where it was located in 2007.
- In 1997, the spit near the entrance extended about 1,200 feet, but by 2000 half of it had eroded, and it completely disappeared by 2007. The beach at the southern end of the island accreted by 200-300 feet by 2007.

The author recommended the effects to natural accretion and erosion of any proposed development or mitigation measures be fully explored.

Denali Commission. 2008. Draft Proposal Transportation system analysis community sites in proximity to the Delong Mountain Terminal. Mike McKinnon, Transportation Program Manager. March 2008.

The Denali Commission developed this draft proposal to conduct a transportation-based analysis of relocating Kivalina to a site close to the Red Dog Mine port. The study would investigate areas north and south of the port that would not have natural hazard risks present at the current village site. The proposed study would accomplish the following:

- Investigate cost savings for fuel, power and freight,
- Investigate opportunities for gravel and rock,
- Evaluate the pros and cons of using existing aviation services while a new airport is constructed,
- Look into costs for a road to river resources if the location is north of the port, and
- Investigate funding partnerships among government agencies.

DOWL Engineers. 1994. *City of Kivalina relocation study, Kivalina, Alaska*. Prepared for Kivalina City Council. Anchorage.

This study involved an analysis of 11 future options for the community, a review of aerial photos and an inventory of buildings. At a public meeting, the community chose Kuugrauq as its preferred option, but part of this site were found to have land ownership problems, and about half of the site was subject to flooding. An analysis of structures in the community found that most of the residences could likely be moved, but major infrastructure buildings probably would not be movable.

This study reviewed the following options.

- Move the airport north and expand the community at the south end of the airport.
- Fill part of the lagoon for community expansion.
- Build a bridge across Singauk Entrance for development along the coast.
- Move to a new location: Imnaaqquaq, Sivutchiaq, Ikpikrauq, Sivu, Kirjiktuuraq, Ushaq, Igrugaivik, or Kuugruaq (sites chosen for consideration at a community meeting).

The project team visited each of the 8 sites to complete a visual reconnaissance, evaluate soil and topography and for two of the sites, take water samples. The study recommended a new community site include at least 60 acres to allow for expansion. The sites were evaluated against 36 weighted criteria. Kuugruaq received the highest score, but during a 1993 flood, half the site was flooded. A Native allotment presented land ownership problems at the site and access to a gravel site. Igrugaivik received the second highest ranking.

It was decided that land at the existing site would be kept in current ownership, but some reclamation of the site would be necessary. The sewage disposal site, dump site and fuel storage areas would need further evaluation before abandonment. The report recommended the dump site be covered with soil after confirming no hazardous materials are present.

A review of aerial photos back to 1952 "does not show conclusive proof that erosion is occurring on the Chukchi Sea side of the island. The beach and the southeast end of the island at the Singuak Entrances are such dynamic systems that at times it is eroding and, at other times, it is adding" (p.3). The study showed, however, that there has been substantial erosion along the lagoon side of the island near Singuak Entrance.

GAO. 2009. Alaska Native villages*: Limited progress has been made on relocating villages threatened by flooding and erosion.* U.S. Government Accountability Office Report to Congressional Requestors. GAO-09-551. June 2009.

This report updates a December 2003 report. The report recommends Congress consider: 1) Directing the Corps to conduct a flooding assessment in Alaska, 2) amend legislation to allow 64 additional villages to be eligible for grants under the Housing and Community Development Act, and 3) Designating a lead federal agency to work with a lead state agency to coordinate relocation efforts.

The 2003 study identified 4 villages in immediate danger and in need of relocation, including Kivalina, Shaktoolik, Newtok, Newtok and Shishmaref. Newtok has made the most progress in relocation efforts. The 2009 report found 12 imminently threatened villages, including Kivalina.

Since 2003, a number of efforts have been initiated. In 2004, the Corps was given authority to erosion control project at full federal expense, but this authority was repealed in March 2009.[2] The Corps conducted an Alaska erosion baseline study. The Corps completed the Alaska Village Technical Assistance Program Assessment in 2006. Also in 2006, the Corps completed that Relocation Planning Project Master Plan for Kivalina. The Corps estimates cost of relocation to be between $95-$125 million. In 2007, the Governor established a Subcabinet on Climate Change which included the Immediate Action Workgroup. An October 11, 2007 congressional field hearing in Anchorage identified the following obstacles faced by federal agencies and villages: Inability of many villages to meet criteria for federal assistance, high cost of protection and relocation projects and the lack of scientific erosion data for sound decision making.

The report stated that Kivalina was declared a flood disaster by the state in 2006. Villagers told the GAO team that the evacuation was so dangerous that it should never be attempted again. The

[2] Section 117 of the FY05 Consolidated Appropriations Act gave the Corps this authority. For FY09, Congress directed $3.328 million to 9 villages, including Kivalina.

Corps provided funding for storm damage in a number of communities, including Kivalina. It evaluated relocation sites for Kivalina, and it provided technical assistance and 10,766 sandbags to Kivalina after flooding in 2006.

The report found that most of the 12 villages considering relocation have made limited progress, except for Newtok. It summarized findings of the 2006 Relocation Planning Project Master Plan for Kivalina and noted that the community requested a third-party assessment of the Corps' report which found the village-preferred site unsuitable due to flooding and erosion.[3] Village officials told the researchers that the Corps-recommended site was too far from the coast, would disrupt subsistence activities and make supply delivery difficult.

The report states that some officials fear erosion control projects in Shishmaref and Kivalina could slow the progress toward relocation because of a false sense of security. The seawalls are expected to protect the villages for 15 years and up to 25 years if maintained.

The report found that the lack of a lead federal agency is an impediment to relocating the villages most threatened. The State of Alaska designated the Department of Commerce, Community and Economic Development as the lead state coordinating agency for relocation assistance in 2008. A $13.6 million state appropriation was made for FY09. The report summarizes grant programs available for communities facing erosion and flooding.

Golder Associates. 1997. *Geophysical groundwater source investigation, Kivalina, Alaska.* October 1997. Reprinted in Appendix B, Community Improvement Feasibility Report, U.S. Army Corps of Engineers, April 1998.

This study investigated groundwater supplies and site geology for potential relocation sites. The study involved use of two different techniques to determine the best location for test wells. It investigated the following sites: Imnakuk, Kuugruaq and Igrugaivik sites.

The study states that the current water occasionally runs dry, and residents must haul ice for a water supply in the winter. Wells drilled near the school produced salt water. Frozen ground was reported from 6' – 137'.

Immediate Action Workgroup. 2009. Recommendations to the Governor's Subcabinet on Climate Change. March 2009.

[3] The report states that the Immediate Action Workgroup (IAW) recommended a state agency complete an assessment of the Corps report. While a recommendation for a third-party review of the Corps relocation assessment reports was included in a March 4, 2008 summary of an IAW meeting summary, this recommendation was not included in the March 2009 recommendations to the Governor's Subcabinet on Climate Change.

This report provides 2009 recommendations the Alaska Governor's Subcabinet on Climate Change. Information presented in the report for Kivalina is summarized below.

- **Planning**: Community planning efforts need to work through issues given that its preferred relocation site has been deemed inadequate by the Corps due to permafrost soils.
- **Revetment:** $3.3 million from the State to the NWAB has leveraged $12.5 million from Corps for the revetment and another $500 thousand for design work.
- **Mapping:** Complete geologic and hazardous mapping to identify sites acceptable for evacuation road and relocation sites ($180,000).
- **Plans:** Complete Emergency Operations, Community Evacuation, and Hazard Mitigation plans. Complete training and drills.
- **Community Mitigation and Relocation Planning and Coordination:** DCRA/DCCED is working with the City and Tribe to develop a proposal for a community planning grant.
- **Leverage Resources:** Reduce state capital budget expenditures by leveraging other resources.
- **DOTPF Preliminary Engineering:** Coordinate state efforts with Corps for design of shoreline protection measures. The estimate for erosion control near airport is considerably higher than estimates from FEMA, and DOTPF is working with FEMA to request additional funding.

_____. 2008. Recommendations to the Governor's Subcabinet on Climate Change: Final Report from the Immediate Action Workgroup. April 17, 2008.

This report provides recommendations to the Alaska Governor's Subcabinet on Climate Change. The Immediate Action Workgroup (IAW) reports to this subcabinet. This report includes community profiles and immediate actions. Kivalina projects are summarized below.

- **Revetment:** The erosion control project involves construction of 2,000 feet on the ocean side ($16 million) and 1,300 feet of revetment on the lagoon side ($26 million).
- **3rd Party Review:** State of Alaska will serve as 3rd party review of geologic aspects of Corps relocation reports ($12,000). Outcome of this review is critical to moving forward on the relocation.
- **Relocation Feasibility Study:** The Department of Natural Resources DGGS will serve as lead of geologic mapping using CIAP funds ($180,000).
- **Emergency Plans:** Complete Emergency Operations Plan, Revise Community Evacuation Plan based on drills, and complete Hazard Mitigation Plan ($75,000 - $100,000).
- **Evacuation Road:** The Denali Commission and NWAB are the lead on the feasibility study.

- **Relocation Plan:** The City, tribe, school, Borough and NANA need to form a local planning committee. Funding will be needed to hire a contractor to work with the community to develop the plan. Need a "how to" guide for steps needed for a relocation plan.

Michels, Denise. 2006. Testimony of Denise Michels, Nome Mayor, to the U.S. Senate Commerce Subcommittee on Disaster Prevention and Prediction for the Western Alaska Winter Storms. March 1, 2006.

Testimony of Mayor Michaels addresses threats to Western Alaska from winter storms. The hazards discussed include storm surges and ice override. The Great Bering Sea storm of 1974 resulted in a storm surge in Nome 12 feet above mean lower low water. An ice override event resulted in a pileup of 30 – 40 feet. Another ice override event in 1980 reached a height of 20 – 25 feet. An October 2002 storm resulted in seas of 14 feet at high tide in Kivalina and Shishmaref. A September 2005 storm eroded 25 – 30 feet of beach in Kivalina. Winter storms are occurring more frequently, and because of a later freeze up, they are doing more damage.

NOAA. 2004. Erosion study report AK0302 – Kivalina. December 27, 2004.

This unpublished report compares aerial photographs from September 2003 and July and August 1952. Two segments were studied, the first included a 10.6-mile area adjacent to Kivalina Lagoon, and the second included the area 10.8 miles south of the Wulik River. It should be emphasized that this study only compared two years, and it does not address year-to-year changes that occurred between those two periods. The report summary states that the accretion patterns "may indicate that this portion of the coast is in the process of normal erosion associated with offshore transport of materials with a net loss of area due to erosion. This may or may not be considered significant erosion from 1952 to 2003" (p.2). The following bullets summarize other findings of the report.

- **Net Erosion:** For the entire study area, there was a net loss of 19 acres with an average loss of 10-35' on the Chukchi Sea coast (27 acres lost on the Chukchi Sea side, and 8 acres accreted within Kivalina Lagoon).
- **Chukchi Sea Shoreline:** Comparing the 1952 and 2003 aerial photos, 13.8 miles of the Chukchi Sea shoreline eroded while 7.6 miles have accreted. A net area of 27 acres was eroded (76 acres eroded and 49 acres accreted). Maximum erosion at a single location was 200 feet and maximum accretion was 100 feet.
- **Lagoon Shoreline:** There has been a net gain of 11 acres on the Kivalina Lagoon side of the island (11 acres of accretion and 3 acres of erosion).
- **Entrances:** The northern channel near the Kivalina River has migrated about 625' to the south. The south lagoon was not connected to the sea in either 1952 or 2003.
- **Wulik River:** The south channel of the Wulik River has remained unchanged between the two periods.

Northwest Arctic Borough. 1999. Community Maps, Kivalina. Prepared by McClintock Land Associates, Inc.

With funding from the Alaska Coastal Management Program, NOAA and NANA, the Northwest Arctic Borough directed development of community maps, including a series of 3 maps for Kivalina. The maps are based on a digital orthophoto which is an aerial photo that has been corrected. The first map indicates contours at 4' intervals and identifies buildings and facilities. The second map identifies subsistence use areas adjacent to the community. The third map identifies wetlands which are mainly represented by emergent wetlands and estuaries.

Replogle, Clinton. 1911. Annual Report of the U.S. Public School for Natives of Kivalina. June 30, 1911. http://www.alaskool.org/native_ed/historicdocs/kivalina/ki900011.htm Accessed on November 2, 2009.

This report includes the following passage which is partially illegible:

> Kivalina is situated on an island in front of Corwin Lagoon, and is very beautifully situated when the weather is nice and calm, but when the wind blows from the south it raises the water in the ocean until it sometimes almost comes over the banks. It washed . . . of the south. East end of the Island . . . and the natives are beginning to talk of moving. We believe that to move would be the wiser if not the safer plan. We experienced some uneasiness last fall, as the beach is only about one hundred feet from the school house and comes closer every year. The water was splashing up over the bank in places for we had a heavy south wind and it lasted for three or four days causing the rise. We believe that if it could be satisfactorily arranged, to consolidate Kivalina and Noatak villages some where on the Noatak river, would be a great place.

Saario, Doris J. 1962. *Human ecological investigations at Kivalina, Alaska. Project Chariot Final Report.* AEC Contract No. AT(043-3)-310. University of Alaska

This report was completed for collection of baseline data for the Project Chariot project at Point Thompson which would have resulted in detonation of a nuclear explosion. The study reports that in 1962 half of the 24 dwellings were sod covered houses clustered in the northwest portion of the village. About 150 people lived in the village, and those who lived in sod houses moved into tents in the summer. Eighty percent of households depended on wood for heating fuel which was supplemented by blubber. Five gallons of blubber lasted about one day. In 1960 whaling was re-instituted at Kivalina. A local jewelry workshop provided income for some of the people.

The report states that one version of how the current village site was selected was that the captain of the ship that brought building supplies unloaded supplies at the beach because some people were there. There was not a traditional settlement there, although there was a summer camp on

the northern part of the island. However, the U.S. Bureau of Education reported that there were 12 sod houses in the immediate vicinity of the school. Residents of the community formed the Kivalina Reindeer Company, but the herd ran off in 1946.

"With specific reference to the possible effect of the proposed nuclear excavation of Project Chariot upon the lives of the Kivalina people, so long as they are able to continue the pattern of their normal lives, particularly with regard to hunting and fishing, the village should suffer no serious repercussions from the detonation." P. 112.

Scheffner, Norman and Martin Miller. 1998. *Development of water surface elevation frequency-of-occurrence relationships for Kivalina, Alaska*. Coastal and Hydraulic Laboratory. Included as Appendix D in Community Improvement Feasibility Report, U.S. Army Corps of Engineers, April 1998. Department of the Army Waterways Experiment Station, Vicksburg, Mississippi.

This report states that the maximum height of the island is 9.8' above MLLW. The study involved use of different 2 models to predict the level of storm surges. Actual data from 30 storms between 1954 and 1984 were used in the models. The models showed that 16 of these storms produced storm surges at Kivalina. The study estimated the 100-year storm surge to be 10.6'. The study found that the maximum wave runup would be about 2 meters (6.56').[4]

State of Alaska. 2009. 2009 Amendment to the Alaska Coastal Impact Assistance Plan. Accessed October 15, 2009. http://dnr.alaska.gov/coastal/CIAP/ciap.htm

The 2009 amendment to the State of Alaska Coastal Impact Assistance Plan includes funding for a project called Geohazard Evaluation and Geologic Mapping for Coastal Communities. The Department of Natural Resources Division of Geological and Geophysical Surveys will complete the project. It involves a geohazards evaluation and production of suficial and engineering-geologic/hazards maps. This project description specifically mentions Kivalina as a priority area for study and states that maps may be produced for potential relocation sites. The agency will work with the local communities and other agencies during the project.

University of Alaska. 2008. *Numerical modeling of long-term permafrost dynamic of the Kiniktuuraq proposed relocation site for the community of Kivalina.* Prepared for the Federal Highway Administration Western Federal Lands Highway Division. Prepared by Permafrost Lab, Geophysical Institute, University of Alaska, Fairbanks. 34 pp.

This report developed a model for long-term permafrost dynamics at the proposed Kiniktuuraq relocation site for Kivalina. The model involved simulations for three different thicknesses of gravel pads (6, 9 and 12 feet) as well as a scenario where a one-foot gravel cap was placed on fine-grained fill. The model was based on the soil characterization from a 2002 report by R&M

[4] Wave runup occurs when waves raise the water level above still water conditions.

Consultants. The model included two climate scenarios where mean annual air temperatures increased 4° C by the end of the century (1st scenario) and by 2°C by the end of the century (2nd scenario).

Without any fill, the model predicts thawing up to 1.5 meters by 2030 under the 1st scenario (4°C rise) but the thawing would not penetrate the ice-bearing permafrost layer under the 2nd scenario (2°C rise). The ice-bearing layer at Kiniktuuraq is located between 0.4-1.0 meters (1.3-3.28').

The report concludes that surface subsidence will occur when permafrost melts down to the ice-bearing horizon which is located 0.4-1.0 m deep. Application of the model found that different thicknesses of gravel fill could delay thawing of the ice-rich permafrost layer, but would not stop the thawing of the permafrost. Under a rapid increase of air temperature (1st scenario above), the ice-rich permafrost layer would melt completely. Under a more moderate increase of air temperature (2nd scenario), the thickness of the gravel pad would likely affect whether the ice-rich permafrost layer thawed completely or partially by 2050. The study found that removal of significant snow accumulations from the gravel fills would be an effective way to protect the permafrost soils.

U.S. Army Corps of Engineers. 2009. *Alaska baseline erosion assessment: Study findings and technical report.* Alaska District.

This report presents the result of the Alaska Baseline Erosion Assessment. The assessment found 178 communities in Alaska reported erosion problems, and it designated 26 communities as Priority Action Communities, including Kivalina.

The assessment summarizes earlier studies about the effects of coastal erosion on selected communities, including Kivalina. The document summarized the results of a 2006 ACOE study that found: 1) The costs of future erosion protection for Kivalina would be $15 million, 2) it would cost between $95 -$125 million to relocate the community, and 3) the community has 10-15 years left at its current site. The document reported that 2006 legislation by Congress provided funds to implement erosion control projects, and an estimated $30 million would be needed to complete erosion control projects in Kivalina

The report states that Kivalina had 9 erosion control projects between 1992 and 2007 at a cost of $325,000. Most of the projects dealt with community and were funded by the Alaska Department of Commerce, Community and Economic Development.

_____. 2008. Draft Memorandum: Summary of Kivalina Water Level Studies. 20 March 2008.

This draft memorandum has not been finalized, but it provides the most current information about revised flooding estimates for Kivalina. It summarizes previous findings from other

reports and recommends adoption of a new 100-year flood estimate of 8.9' above MLLW. This new estimate relies on a 2005 study by Chapman et al.[5]

The 2006 Kivalina Relocation Master Plan used information from a draft 2003 water level study. A 2005 study resulted in an estimate of the 100 year storm surge elevation 7.4 feet lower. The memo analyzes the findings of this study and previous studies.

Because of a lack of site-specific data, hydrodynamic models must be used to predict storm surges. Twenty to 50 years of recorded water levels are needed to make an accurate prediction of surges.

Five previous storm surge analyses have been completed either for Kivalina or the nearby Red Dog Port Site. These analyses are summarized below.

- **1981 Alaska Study:** *Storm Surge Climatology and Forecasting in Alaska* (Wise, Comiskey and Becker 1981). Kivalina was included in the area between Point Hope and Kotzebue Sound. A November 1976 storm was reported to have flooded 20-30% of the community, and the water level was one foot below the lowest home. The study estimated the 100-year flood to be 8.3' above MLLW.
- **1988 Kivalina Study:** *Development of Water Surface Elevation Frequency-of-Occurrence Relationships for Kivalina, Alaska (*Scheffner and Miller 1988). The study used a model that was based on storm wind fields from the North Slope. The methodology is not as accurate as computer-generated models, and did not include effects of sea ice extents, air-sea temperature differences or the inverted barometer set-up. The study estimated the 100-year flood to be 10.6' above MLLW.
- **1999 Port Site Study:** *Delong Mountain Terminal Project Feasibility Study: Metrocean Condition Report* (Triton 1999). The report found that predicting water levels more than a 15 year return is not accurate, but it estimated the 100-year flood to be 14.6' above MLLW.
- **2003 Kivalina Study:** Reformulation of Water-Surface Elevation Frequency-of-Occurrence Relationships for Kivalina, Alaska – Draft (Mark 2003). This study used a similar methodology as the 1988 study using computer generated wind fields. This study did not incorporate tidal effects or effects of sea ice events, and it estimated the 100-year flood to be 16.3 feet above MLLW.
- **2005 West Coast Alaska Study:** *Regional Tide and Storm-Induced Water Level Study for the West Coast of Alaska* (Chapman, Mark and Cialone 2005). The results for the Chukchi Sea-Bering Sea area are considered more representative for Kivalina. A frequency occurrence for Kivalina was developed in 2007 using this model. The study estimated the 100-year flood to be 8.9' above MLLW. This estimate does not include wave setup, wave run-up or the dampening effects of ice cover.

[5] This estimate does not include wave setup, wave run-up or sea level rise.

Other reports have found that the town site has never been inundated due to storm surges. The water has occasionally been within a few feet of flooding on the lagoon side of town. A 1970 flood reached the southern end of the runway and 20-30% of the community flooded, likely from wave run up on the ocean side. A 2004 storm resulted in flooding of the lower portions of town which was recorded at the Port Site as 5.05' above MLLW, likely from wave setup of 1' and wave runup of 6.5'.

The draft memorandum recommends use of the 2005 study which estimated a storm surge of 8.9' above MLLW. The memorandum cautions that the results should be considered preliminary because of the regional nature of model simulations. The model considers tidal action, inverted barometer effect, and storm surge. It did not consider wave run-up, the effects of ice cover or sea level rise. The 1998 study estimates wave setup at 0.75' and wave run-up at 5.6' on a sloping beach. Future improvements to the model should include data collected from Kivalina.

In planning for sea level rise, permafrost melting and resultant subsidence could lead to a higher rate of relative sea level rise. The global average of 0.6' per hundred years of sea level rise is used for Kivalina because of a lack of site-specific data. Using sea level scenarios by the National Research Council, sea-level rise by 2100 would be between 10.5' and 13.7'. An increase in coastal erosion because of sea level rise should also be considered.

The study recommended that a defensible storm surge analysis would be needed for potential low-lying relocation sites that includes consideration of sea level rise, delayed freezing of the ocean and increased erosion. The study states it is reasonable to conclude the entire island where Kivalina is located could be inundated during the predicted 100-year storm surge using the best models for Kivalina. It also states that the 100-year water level estimate for Kiniktuuraq is more of a factor of storm surge levels in the lagoon than from Wulik River discharges.

_____. 2007a. ***Section 117 expedited erosion control project Kivalina, Alaska: Environmental assessment and finding of no significant impact.*** **Prepared by Larry Bartlett, staff biologist. September 2007. 24 pp.**

This document provides the environmental assessment of the rock revetment project that is required under the National Environmental Policy Act. The assessment found that there would be no significant short- or long-term environmental impacts would result, but the revetment would result in minor inconvenience in accessing the beach and could lead to changes to Siguak entrance (from changes to the distribution of sediments known as "longshore drift").

The document reports that 25-30' of shoreline was eroded in 2004 and 2005 storms, and a 2006 storm eroded 50' inland that exposed permafrost in some areas. The sand-filled gabion erosion

protection installed in 2006 failed that same year causing an accelerated rate of erosion. The document states that it would take up to 15 years to relocate the community.

The report assessed 8 alternatives including no action, a sheet pile wall, sandbag revetment, rock revetment, gabion revetment, an offshore berm, an articulated concrete mat, and community relocation. The assessment led to the selection of the rock revetment alternative which involves construction of 3,100 feet of revetment south of the airstrip on both sides of the island.

The assessment acknowledges that potential effects of disruption of longshore drift are poorly understood, but the project could affect transport of sediments and changes to the morphology (structure and form) of Signuak Entrance. The report speculates that Singuak Entrance could move towards Kivalina. There would be fewer sediments moving south because of expected of expected "accretion on the up current side of the structure and erosion on the down current side of the structure" (p. 19).

_____. 2006a. *Relocation planning project master plan, Kivalina,* Alaska. Submitted by Tryck Nyman Hayes and URS Corporation.

This document provides preliminary facility designs, costs, schedule and a decision matrix for the relocation of Kivalina. It compares 8 alternatives including no action, remain at the existing site and relocation to 6 different sites. The Master Plan found that all options would be technically feasible, but it recommends against further consideration of all options other than Tachim Isua and Imnakuk Bluffs. The appendices include detailed information about relocation costs, proposed schedules, geotechnical reports, a site development plan, and a community layout design selected by Kivalina in 2001.

Natural Hazards: This project involves a review of erosion, flooding, permafrost melting and storm surge hazards.

- **Erosion:** The authors reviewed aerial photos taken since the 1980s and found there has been a loss of beach from the Singuak Entrance to the airport. Storms have undercut the vegetative mat on the ocean side of the island.
- **Storm Severity:** Since the 1980s, ocean ice has diminished, and the open water period has increased from 3 months to 5 months. The lack of ice cover leads to longer distances (fetches) where winds generate higher and longer waves that lead to increased erosion.
- **Storm Surges:** The report references different 100-year storm surge estimates including an estimate of 10.5' which it says would result in a 6' flood, assuming the average height of the community is 10'.[6] A 2003 working draft report prepared for the U.S. Army Corps

[6]This report does not reference the height of the storm surges to either mean lower low water (MLLW) or to mean high water (MHW). MLLW is used as the "0 depth" on nautical charts, and MHW is used as the "0-depth" on topographic maps. Using information from the 1999 community maps (Northwest Arctic Borough 1999), MHW is 0.77' higher than MLLW. Assuming the 10.5' storm surge level is referenced to MLLW, the prediction of a 0.6'

of Engineers reports that 1970 "storm of record" had a 13.57' surge that inundated part of the community. This draft report estimated the 100-year storm surge would reach an elevation of 16.1 feet.

- **Sea Level Rise:** Sea level rise is projected to be 1-2' over the next 100 years.
- **Permafrost:** Accelerated permafrost melting will likely result in subsidence and erosion in the region. This may not be an issue for the current townsite because of sandy soils that are not ice-rich. Soils are permanently frozen except in the active layer and active beach zones. 1997 Permafrost 12' deep. 1976 18'-58'.

Existing Townsite Conditions: The report summarizes the current situation in Kivalina. The report states that social Conditions include overcrowding, lack of infrastructure, loss of traditional cultural knowledge, and poor living conditions that have led to feelings of hopelessness.

- **Water:** The current water collection and distribution system is inadequate. Tanks can only be replenished during part of the year, and the storage capacity is insufficient resulting in periodic water shortages. The only buildings with piped water are the washeteria, school and clinic. Households purchase water from a paybox on the eastern side of the washeteria and must haul it to their homes.
- **Human Waste:** Residents use 5 gallon "honey buckets" lined with plastic bags and must transport the waste to a 60' x 60' x 8' metal containment basin adjacent to the dump. This system presents a health hazard due to accidental spills during collection and storage and possible leaching from the containment basin.
- **Solid Waste:** The dump site, built in 1996, is too close to the airport and there is a concern about bird strikes. It occupies a 3.4-acre parcel. The State of Alaska encourages use of burn boxes, but incinerators must meet state regulations.
- **Transportation:** The airstrip is subject to heavy snow drifting because it is perpendicular to prevailing winds. High speed 4-wheeler traffic has displaced gravel from community roads.
- **Housing:** There is no room for future growth, and families have moved away from the village. A new site with adequate room for expansion would likely lead to doubling of the population in 20 years. New housing would be more energy efficient.

Oceanography: The report acknowledges that the ocean currents involve complex dynamics associated with flows between the Bering and Chukchi seas.

- Winds from the south to southwest generate waves that expend their full energy on Kivalina's beach.
- Sediments remain offshore and are available for rebuilding the beach under the action of smaller waves.

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flood in the community may not have taken account for the need to subtract 0.77' since land heights reference MHW.

- Waves from the south to southeast are not as high or long as those from the southwest because of the shorter fetch. More destructive when they are combined with a storm surge. Flooding is almost exclusively responsible for flooding.
- Less common waves from the northwest can be higher, longer and more destructive. Greater fetch.

Remain At Current Site (Cost - $196.2 million): The report found the "do nothing" option unacceptable. Remaining at the current site would require certain improvements.

- Installation of gravel fill to a level of 16.5' for flood protection.
- Structurally-sound buildings would be moved and raised, and other buildings replaced.
- Installation of 4,285' of armor around the community.
- Construction of an infiltration system at the Wulik River for year-round water.
- Development of a package treatment plant for wastewater with a buried drain field.
- Possible addition 24 new homes could be added.[7]
- Addition of a buried utility system.
- The solid waste system does not meet DEC or FAA regulations.[8]
- The current power generation system would need to be upgraded in about 8 years.

The report recommended no further investigation of this site because of risks of erosion. While gravel fill would not be needed for protection of the permafrost, 6.5' of fill would be needed for protection from the 100-year storm surge.

Simiq (Cost - $251.5 million): This site is located 4 miles northeast of Kivalina. Gravel fill would need to be placed to a height of 9'. The report discusses options for transportation and utilities. Subsistence access would be by a road to the lagoon. The report recommended against further consideration of this site because of unstable ice-rich permafrost soils.

Imnakuk Bluff (Cost - $248.7 million): This site is located 5.5 miles northeast of the community above the Kivalina River. Severe winds at this site provide a severe constraint. Ice-rich permafrost at the site would require 9' of fill. The report discusses options for transportation and utilities. Subsistence access would be difficult due to shallow channels in the Kivalina River. The report recommended further investigation of this site because there was no known flooding or erosion.

Tachim Isua (Cost - $154.9 million): This site is located 9 miles north of the community. Fill would only be needed in areas of poor soils. The report discusses options for transportation, and

[7] Presumably, fill would need to be added for the new homes, but the discussion on the bottom of page 44 is incomplete due to an editing error.

[8] No options were proposed for improving the dump site. The existing site does not meet the 5,000' minimum setback required by FAA regulations. The details of noncompliance with DEC regulations were not provided.

utilities would be buried below-ground. A 1.5-mile road would lead to the Chukchi Sea which would provide access for marine-based subsistence activities. The site is close enough to the sea to allow subsistence users to watch for whales. The nearby lagoon is too shallow for boats. The report recommended further investigation of this site because it is out of the flood plain, does not have ice-rich permafrost, it would not need gravel fill, and it has no known erosion.

Kiniktuuraq (Cost - $248.2 million): This site is located on the coast about one mile south of the community at the southern edge of Kivalina Lagoon. The community selected Kiniktuuraq as the preferred site for relocation in a 2000 election. This site would have similar access to subsistence resources as the current site, and boats could be moored in the lagoon. The report recommended this site not be investigated further because the site is sinking, it is subject to erosion and flooding, and the ice-rich permafrost soils are not suitable (mud and ice).

The report summarizes the risks of flooding, erosion and melting permafrost. The report states that the site was flooded by storm-driven waves in 2004 and that it would need to be raised from its current elevation of 10' to 13.5' for flood protection. Along the coast, threats of both thermal degradation and mechanical erosion exist. The site is "swampy underlain by unstable, ice-rich, fine-grained soils, and subject to destruction of the existing thermal regime without the addition of a minimum of 9' of gravel . . ." (p. 77). Prior studies found that addition of gravel would be needed to maintain the integrity of the permafrost, and this report recommends the addition of 9' of gravel. "Mechanical stabilization" would be necessary along the coast. In addition, the report states that this site would be subject to ice override hazards.

A water system similar to that of Kivalina would be needed due to the lack of nearby surface water or groundwater sources. An underground distribution system would be infeasible due to ice wedges in the soil.

The ice-rich soils also pose challenges for wastewater disposal. A vacuum collection system, above ground utilidor and sewage lagoon could be constructed. A solid waste disposal site could be located along the 3.5-mile road to the airport. The dump site would need to be raised with a minimum of 9' of gravel.

Igrugaivik (Cost - $246.1 million): This site is located adjacent to the Kiniktuuraq site about 2 miles east of Kivalina. No visits to the site were made for this report. The report assumes a 9' gravel pad would need to be constructed, and armoring would be needed along the Wulik River. The soils are thaw-unstable and ice-rich. The report outlines options for water, wastewater disposal and other utilities. A road would be constructed through the Kiniktuuraq site to the ocean. The sand spit would likely need to be armored for protection against erosion on all sides.

The report recommended this site not be investigated further because ice-rich permafrost soils are not suitable for construction.

Kuugruaq (Cost - $245.6 million): This site is located directly north of the Igrugaivik site about 2 miles east of Kivalina. No visits to the site were made for this report. The report assumes a 9' gravel pad, and similar to Igrugaivik, armoring would be needed along the Wulik River. Previous reports found that limited parts of the site have thaw-stable soils.

Wastewater disposal could be accomplished with an above ground Arctic pipe, a vacuum collection system and a leach field. Subsurface water sources may be present, but additional investigation would be necessary. A 2 mile road would lead to the barge landing on the Chukchi Sea, and a dump site would be located along this road. Two Native allotments located at this site would require agreement of owners before this site could be used.

The report recommended this option not be investigated further because the area floods in the spring and because of ice-rich permafrost soils.

Rating Criteria: The authors rated each option using 31 siting criteria grouped under 4 categories: Physical environment, construction and utilities, social and access, and cost. These criteria included risks from natural hazards, suitability of soils, and access to subsistence resources. Tatchim Isua received the highest ranking followed by Imnakuk Bluff. All of the sites other than Tatchim Isua and Kivalina have ice-rich soils. None of the other options were recommended for further investigation.

Assumptions: Certain assumptions were made for all of the potential options to reflect community preferences and response to natural hazards.

- All sites would require a gravel pad.
- All sites would use gravel roads rather than boardwalks.
- Water systems would:
    - Use surface water sources,
    - Require a 100,009 gallon tank, and
    - Involve a community-wide distribution system with Arctic pipes.
- The sewer system would involve a piped collection system.
- A new above ground landfill would have an insulating cover and side berms.
- Bulk fuel would be stored in multiple 27,000-gallon single-walled steel tanks.
- A heat recovery system would be used for the generator plant, and wind energy would be used if feasible.
- A 4,000' airstrip would be constructed.
- The community layout would involve a grid system using a 5' gravel pad.

Due to challenges with all of the options considered in this study, the report states that it may be appropriate to consider additional sites, including a higher rocky area behind the Simiq site and a location that could access both the Wulik River and the Red Dog road system.

_____. 2006b. ***Alaska village erosion technical assistance program: An examination of erosion issues in the communities of Bethel, Dillingham, Kaktovik, Kivalina, Newtok, Shishmaref, and Unalakleet.*** **44 pp.**

This report addresses three questions posed by Congress for seven communities in Alaska, including Kivalina: 1) What is the ongoing cost of erosion, 2) What would the cost be to relocate or co-locate these communities, and 3) How long do these communities have left until there is complete failure of land? The study found that it would cost about $15,000 for erosion protection for Kivalina, it would cost between $95 million - $125 million to relocate, and the community has between 10 and 15 years at its current location.

The report states the following criteria would be used for selection of a new site. It would not be in a flood zone, it would have room for community expansion, it would have an accessible water supply, and it would be near important subsistence resources. There would be some costs associated with decommissioning the old site, but some families would likely maintain structures for subsistence use. An estimated 15 – 20 years would be needed for community relocation. In calculating the cost of relocation, this report assumed the villages would be relocated using similar utilities and services as they have presently.

Kivalina receives cyclic erosion and accretion. As a result of global climate change, there is a longer period of open water which leads to increased damage from fall storms. Erosion control efforts by the state between1985-2002 cost $477,000, and efforts during the last 2 years cost $850,000.

Cost of relocation to a new site is estimated to be $125 million. This estimate assumes a minimal level of housing, water and sanitation facilities. Co-location of the community to Kotzebue would cost an estimated $95 million. Cost of future erosion protection in Kivalina is estimated to cost $15 million.

_____. 1998. ***Community improvement feasibility report, Kivalina Alaska*****. U.S. Army Corps of Engineers, Alaska District. April 1998.**

This comprehensive study by the Corps evaluated 2 potential relocation sites as well as staying at the present location. At a special election in February 1998, residents selected relocation to Igrugaivik on the Wulik River as their preferred option. The appendices included a groundwater source investigation, Wulik River flood risk analysis, water supply alternatives at the relocation sites, wastewater options at the sites, community layout alternatives, an implementation plan, and a summary of a model Native village in Quebec.

The City of Kivalina and the Kivalina Relocation Committee participated in the development of the plan. Committee members included Austin Swan, Caleb Adams, Andrew Koenig, Fred Swan, David Swan, Enoch Adams Jr., and Joseph Swan Jr.

For the Igrugaivik site, the surface elevation of the lagoon waters had a greater impact than flooding from the Wulik River. The 100-year flood event for the lagoon was estimated to be 3.6 meters (11.8').

The Southeastern Chukchi Sea is shallow with no areas that are deeper than 50 meters. Mean high tides are estimated to be the same as in Shishmaref which is .975 (3.19') meters above mean sea level. Ice cover dampens the effect of storm surges. Major storms enter the Chukchi Sea from the southwest. When winds shift to the west and northwest, Kivalina is relatively protected from large waves, but strong winds from these directions may lead to a shift in the predominantly northerly coastal current.

Current Site: The report found that the crowded housing conditions are "far below any acceptable standard" (p. 24). The lack of running water results in the inability to maintain healthy standards of cleanliness. The storage and transport of human waste in honey buckets results in spills inside and outside of homes. The long haul of garbage to the dump in winds results in the spread of garbage outside of the dump area. The report describes improvements that can be made to the water supply and wastewater disposal systems. It also included a proposal to expand the area for future growth by using part of the land owned by the State of Alaska for the airport and filling in part of the lagoon. This proposal would involve extending the runway by 185 meters (607').[9]

The report summarizes natural hazards at Kivalina. It states that elders do not recall any instances where a storm flooded the town. The storm surge flooding risk completed for this report found that the village is not above the 100-year flood estimate. It estimated the 100-year storm surge to be 10.6', including wave setup, and wave runup on a natural beach could be an additional 2 meters (6.5').[10] The sea ice at Kivalina forms a barrier to pressure ridges and ice ride-up. Erosion of the shore near Singauk Entrance is a concern since most of the flow from the Kivalina and Wulik rivers flow through this opening. The point of convergence of the two rivers results in chronic erosion to the village.

The study found that there was a continuous sand bar about 300 meters (984') offshore on the Chukchi Sea side of the village. The report states that dredging of offshore sand beyond 400

[9] A December 31, 1997 letter from the Alaska Department of Transportation and Public Facilities included in Appendix M notes that FAA requires 5,000' of separation between the landfill and the runway.
[10] The report states the center of the village is 11.5' above MLLW.

meters (1,313') for beach nourishment would have no significant impacts. It recommends construction of beach fill topped with a sand dike.

Imnakuk Site: This site is located 8 miles north of the current village on the Kivalina River. The report discusses community layout, water supply, wastewater disposal, and a road to the coast. A short road would be constructed to the Kivalina River which would provide boat access upriver. Residents reported that winter winds from the north make this site undesirable.

Igrugaivik Site: This site is located east of the existing townsite on the Wulik River. The report discusses risks of flood and erosion, water supply, waste disposal, community layout, and a road to the coast. The community selected this site as their preferred option in a 1998 election.

The 1994 DOWL study identified flooding concerns for this site, but surveys for this project helped create more accurate topographic maps. The 1998 study found that a substantial portion of the site would be above the 100-year flood. It found that the 100 storm surge in the lagoon would have a greater effect on the site than the Wulik River flooding. The study recommended buildings be set back at least 100' from the river due to erosion concerns. The report notes that silty ice-rich permafrost lies below a shallow layer of peat.

Appendix J provides a summary of a visit to the Ouje-Bougoumou village in Quebec. The report found that one of the keys to success of the village was continuous involvement of the villagers during every step of the planning process.

Western Federal Lands Highway Division. 2008. *Kivalina evacuation road feasibility study.* Prepared for Denali Commission. Project #285-07. February 20. 2008. 8pp.

This project resulted from an agreement between the Denali Commission for the Western Federal Lands Highway Division to prepare preliminary engineering for an evacuation road from Kivalina. This study considered the two most supported routes that were studied by ASGC Inc. in 2005: A Kiniktuuraq alignment ($38,881,000) and the Simiq alignment ($20,265,000). Since an environmental study and detailed engineering would cost $3 - $4 million, the Division recommended the project not be pursed further until a significant portion of the funding is obtained. Further, it warned that Title 23 highway funds would have to be repaid if a project was started but not finished.

The Kiniktuuraq alignment would involve a bridge across Singuak Entrance with a road through Kiniktuuraq with termination of the road 3 miles south. The Simiq alignment would involve a causeway across the lagoon with a road terminating in Simiq 3.5 miles to the east.

Both options included a road to a potential material source (rock) at Kisimiguktuk Hill. Cost estimates were made for both a 24-foot and 14-foot roadway width with additional criteria. Both

routes terminated at an elevation of 25 feet, incorporated rock armoring in the coastal areas to protect against erosion and recommended use of deep foundations for bridges to withstand scour, high winds and waves.

Wise, James, Comiskey, Albert, and Richard Becker Jr. 1981. *Storm surge climatology and forecasting in Alaska.* Arctic Environmental Information and Data Center. University of Alaska.

This project investigated the climatology of storm surges and refined procedures for storm surge forecasting. Storm data for 90 storms since 1954 was used in the study. Intense atmospheric low pressure systems with strong winds onshore or along the shore create storm surges. Winds can develop over several hundred miles of open water (fetch). Gently sloping nearshore areas and sufficient fetch are needed for storm surges. The study found that ice cover generally dampens waves, but 3-foot storm surges have occurred when there was 3' of ice. The upper limit of storm surges is generally 12 feet.

The Chukchi Sea is one of the areas in Alaska conducive to storm surges. Most storm surges in this area occur in the autumn. The study estimated that a 10.6' storm surge could be expected once every 100 years.