Division of Geological & Geophysical Surveys

MISCELLANEOUS PUBLICATION 147H

ANNOTATED BIBLIOGRAPHY SERIES IN SUPPORT OF COASTAL COMMUNITY HAZARD PLANNING—NORTHWEST

KIVALINA, ALASKA

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November 2011

This annotated bibliography is part of a series created to facilitate access to documents useful for coastal geohazard evaluation and community planning in Northwest Alaska. Below is a comprehensive list of community-specific information sources, each with full bibliographic information and an informative-style annotation that highlights content pertaining to the community of Kivalina, Alaska. For a detailed description of the preparation and scope of this resource, please refer to this bibliography series' foreword. Any notable errors and/or omissions may be reported to the Coastal Hazards Program manager at the Alaska Division of Geological & Geophysical Surveys (DGGS).

Alaska Department of Commerce, Community & Economic Development (DCCED), accessed 2011, Division of Community & Regional Affairs (DCRA) Community Profiles [website]: State of Alaska Department of Commerce, Community & Economic Development.

http://www.commerce.state.ak.us/dca/profiles/profile-maps.htm

This website provides access to community profile maps for community-based planning. The maps are available in 24" by 36" and 30" by 42" formats. The Kivalina maps were created in 1999 and 1976 based on land surveys and/or interpretation of aerial imagery. Subsistence hunting grounds, habitat areas, community buildings and public facilities are delineated. Shoreline position and potential erosion zones are included in the map content. All maps have been sponsored by the Alaska Division of Community & Regional Affairs and contracted to local agencies for production.

Alaska Department of Natural Resources, Division of Coastal and Ocean Management (DCOM), December 2010, State of Alaska Coastal Impact Assistance Program December 2010 amendment: State of Alaska Department Natural Resources, Juneau, AK, 40 p.

The 2010 amendment to the State of Alaska Coastal Impact Assistance Plan describes the allocation of federal CIAP funds in the State of Alaska. The plan includes funding for a project called Geohazard Evaluation and Geologic Mapping for Coastal Communities. The Department of Natural Resources Division of Geological & Geophysical Surveys will complete the project. The project involves a geohazards evaluation and production of surficial and engineering-geologic/hazards maps. The project description specifically mentions Kivalina as a priority area for study.

Armstrong, Saundra B., 2009, Native Village of Kivalina, and City of Kivalina vs. ExxonMobil Corporation, et al.: U.S. District Court for the Northern District of California, Oakland Division, Case no. C 08-1138 SBA, 24 p.

The Native Village of Kivalina and City of Kivalina (plaintiff) filed a complaint alleging that the Arctic sea ice that protects the Kivalina coast from winter storms has diminished as a result of global warming, and that subsequent erosion will require the relocation of Kivalina's residents. The plantiff named 24 oil, energy, and utility companies from whom they seek damages under a federal commonlaw claim of nuisance, based on alleged contribution to excess emissions of carbon dioxide and other greenhouse gases, which the plaintiff claims have led to global warming. The court granted the defendants' motions to dismiss for lack of jurisdiction and found the matter suitable for resolution without oral argument.

ASCG Incorporated of Alaska, October 2005, Kivalina, Alaska, evacuation/relocation road feasibility study: Anchorage, Alaska, ASCG Incorporated, 97 p.

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 asl, 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 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 of sediment transport to the lagoon.

Brubaker, Michael, James Berner, Jacob Bell, and John Warren, 2010, Climate change in Kivalina—Alaska strategies for community health: Alaska Native Tribal Health Consortium Center for Climate and Health, 66 p.

http://www.anthc.org/chs/ces/climate/climateandhealthreports.cfm

Rural arctic communitites are vulnerable to climate change and seek adaptation strategies that will protect health and health infrastructure. This report describes climate change impacts on Kivalina, a small Inupiat Eskimo community located on the coast of the Chukchi Sea. Data sources included the observations of local residents, reports from local regional government officials and health professionals, and scientific evidence gathered from published sources. Recommendations include:

- *The lack of adequate sanitation is the most immediate health threat in Kivalina.*
- *Reducing the risk of climate related mental stress, injury, and disease is another priority in Kivalina.*
- *The community water system is vulnerable to climate impacts.*
- *Enhancement of the community environmental monitoring infrastructure is also needed to better understand climate change impacts.*
- *Unusual and unpredictable weather, snow, ice, and water conditions have made travel more hazardous.*
- *Climate change is affecting subsistence activities, and may result in changes to harvest and diet.*

Brubaker, Michael, James Berner, Raj Chavan, and John Warren, 2011, Climate change and health effects in Northwest Alaska: Global Health Action, vol. 4, no. 8445, doi: 10.3402/gha.v4i0.8445, 6 p.

From overview: "This article provides examples of adverse health effects, including weather-related injury, food insecurity, mental health issues, and water infrastructure damage, and the responses to these effects that are currently being applied in two Northwest Alaska communities. The health impact assessment process is effective in raising awareness, encouraging discussion, engaging partners, and implementing adaptation planning. With community-specific information, local leaders are applying health protective adaptation measures."

Carlyle, Delia, ed., 2008, Eroding Alaska town sues 24 oil and energy companies for destruction caused by global warming: Native American Rights Fund Legal Review, vol. 33, no. 1, 4 p.

A lawsuit was filed on behalf of the Village of Kivalina, against industrial corporations that emit large quantities of greenhouse gases. The suit claims damages due to contributions to global warming that invoke the federal common law of public nuisance. This article explains the lawsuit from an Alaska Native perspective.

Chapman, Raymond S., Sung-Chan Kim, and David J. Mark, *for* U.S. Army Corps of Engineers, Alaska District, 2009, Storm damage and flooding evaluation, storm-induced water level prediction study for the western coast of Alaska: Vicksburg, Mississippi, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, 92 p.

The Coastal & Hydraulics Laboratory assessed storm-generated regional water levels and currents at selected sites of ongoing and potential COE projects along the western coast of Alaska. The purpose of this study was to

develop frequency-of-occurrence relationships for storm-generated water levels at 17 communities along the western coast of Alaska. Storm wind, pressure, ice, and surge data were generated for each of the areas, and the bathymetry was updated. Fifty-two storm event simulations were performed and a database of water levels versus return period was developed for each site. This study estimated the 100-year storm surge level to be 7.7 feet above MLLW.

City of Kivalina, ASCG Inc. of Alaska, and Bechtol Planning & Development, Nicole McCullough and Eileen R. Bechtol, eds., November 2007, City of Kivalina, Alaska, local hazards mitigation plan: Division of Homeland Security and the Federal Emergency Management Agency, 71 p.

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

Hazards identification: The plan identifies Kivalina as highly subject to flood hazards, severe weather hazards, and erosion hazards. The community was ranked similarly with regard to earthquake hazards. There are no tsunami or seiche hazards.

- *Winds from the south to southwest generate waves that expend their full energy on Kivalina's beaches.*
- *Flood hazards are almost exclusively from storm surges associated with south to southeasterly winds. Waves from this direction are more destructive because they can ride atop a storm surge (for example, October 2004 storm).*
- *Less common waves from the northwest can be larger and more destructive than 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. 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, two 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, as well as 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, replacement of damaged water tank skins, a lagoon erosion control project, an 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 annually for necessary updates, 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.

Combellick, Rod, November 2007, Memorandum to Randy Bates, Director DCOM, Kivalina hazard area designation: Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys (DGGS), 2 p.

This memorandum requested a temporary natural hazards designation for an Alaska Coastal Management Program review of the COE rock revetment project in Kivalina. The DGGS deputy director 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 is possibly still undergoing, thermal erosion of frozen soil." Subsequent aerial photographs show that the beach has accreted and that the berm has become 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, the inlet was located considerably south of where it was 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 that the effects to natural accretion and erosion of any proposed development or mitigation measures be fully explored.

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

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 Kuugruaq 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 eight 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 Singauk Entrance 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 Singauk Entrance.

D'Souza, A., S. Bandopadhyay, S. Naidu, R. Ganguli, and D. Misra, 2009, Exploration and estimation of gravel resource potential in southeast Chukchi Sea continental shelf off Kivalina, Alaska: Marine Georesources and Geotechnology, vol. 27, p. 255–272.

This study examined the gravel resources of the Chukchi Sea near Kivalina, Alaska, for potential beach nourishment projects along the coast. The study included a seismic survey, collection of grab samples, sediment cores, and grain-size analysis.

Glenn Gray and Associates *for* City of Kivalina, July 2010, Kivalina consensus building project, final report: Alaska Department of Commerce, Community & Economic Development, Division of Community & Regional Affairs, 16 p.

This report is designed to serve as a foundation for community planning in Kivalina, Alaska. The project was funded by a two-part community planning grant from the Alaska State Legislature. The report includes the summary of findings from a door-to-door survey conducted in 2009 as well as an analysis of previous reports pertaining to natural hazards and relocation options.

Golder Associates, *for* U.S. Army Corps of Engineers, Alaska District, October 1998, Geophysical groundwater source investigation, Kivalina, Alaska: Department of the Army, U.S. Army Engineer District, Alaska, 28 p.

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 saltwater. Frozen ground was reported from 6 to 137 feet.

Gorokhovich, Yuri, and Anthony Leiserowiz, 2011, Historical and future coastal changes in Northwest Alaska: Journal of Coastal Research, vol. 28, no. 1A, p. 174–186.

This article presents research sponsored by the National Oceanic and Atmospheric Administration (NOAA) in support of coastal vulnerability mapping for Kotzebue Sound, Alaska. The authors used the digital shoreline analysis system (DSAS) to quantify rates of erosion and accretion from orthorectified aerial imagery that spans a 53-year period (1950–2003). By combining the results of this work with modeled projections of sea level rise in the arctic, the authors estimate mean regional erosion rates of -0.12 to -0.08 m/yr from 1950–2003, and an increase to 0.6–1.65 m/yr from 2000–2100.

Hartig, Larry *of* Alaska Department of Environmental Conservation & Governor's Climate Change Sub-Cabinet, October 2010, State of Alaska and State/Federal Executive Roundtable Activities Regarding the Arctic [presentation]: Anchorage, Alaska, Northern Waters Task Force, 53 p.

http://housemajority.org/coms/anw/pdfs/26/NWTF_Powerpoint_Hartig_01Oct10.pdf

This is a powerpoint presentation about the state and federal executive roundtable activities regarding the Arctic. The discussion includes hazards associated with declining Arctic sea ice extent, melting of permafrost, storm surges, and coastal erosion. Thirty-one villages are identified as imminently threatened: Barrow, Kivalina, Selawik, Allakaket, Hughes, Huslia, Shishmaref, Deering, Teller, Koyukuk, Nulato, Golovin, Shaktoolik, Unalakleet, Saint Michael, Kotlik, McGrath, Emmonak, Alakanuk, Chevak, Newtok, Nunapitchuk, Lime Village, Eyak (Cordova), Napakiak, Akiak, Chefornak, Kwigillingok, Dillingham, Clarks Point, and Port Heiden. Specific photos and engineering initiatives for four communities are discussed, including: Kivalina, Shishmaref, Unalakleet, and Newtok.

Hayes, Tryck Nyman, *for* U.S. Army Corps of Engineers, Alaska District, June 2006, Relocation planning project master plan, Kivalina, Alaska: Anchorage, Alaska, URS Corporation, contract no. DACW85-03-D-0006-0003, 108 p.

This document provides preliminary facility designs, costs, schedule, and decision matrix for the relocation of Kivalina. It compares eight alternatives including no action, remaining at the existing site, and relocation to six 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 review:

- *Erosion: The authors reviewed aerial photos taken since the 1980s and found a loss of beach from the Singauk 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 to 5 months. The lack of ice cover leads to longer distances of exposed water (fetches) where winds can generate larger waves that may lead to increased erosion.*
- *Storm Surges: The report references different 100-year storm surge estimates, including an estimate of a 10.5 foot surge resulting in a 6 foot flood. A 2003 working draft report prepared for the U.S. Army Corps of Engineers reports that 1970 "storm of record" had a 13.57 foot 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: This study projects sea level rise to be 1–2 feet 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.*

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.*
- *Human Waste: Residents use 5 gallon "honey buckets" lined with plastic bags and must transport the waste to a 60′ × 60′ × 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.*
- *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 a doubling of the population in 20 years.*

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.*
- *Waves from the south to southeast are not as large as those from the southwest because of the shorter fetch. Waves from this direction are more destructive when combined with a storm surge.*

Summary of option to 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 feet for flood protection.*
- *Structurally-sound buildings would need to be moved and raised, and other buildings replaced.*
- *Installation of 4,285 feet of armor around the community.*
- *Construction of a filtration system at the Wulik River for year-round water.*
- *Development of a package treatment plant for wastewater with a buried drain field.*
- *Possible addition of 24 new homes.*
- *Addition of a buried utility system.*
- *The solid waste system would need to be brought up to DEC regulations.*
- *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 feet of fill would be needed for protection from the 100-year storm surge.

Summary of Simiq relocation option (cost: $251.5 million): This site is 4 miles northeast of Kivalina. Gravel fill would need to be placed to a height of 9 feet. 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.

Summary of Imnakuk Bluff relocation option (cost: $248.7 million): This site is 5.5 miles northeast of the community, above the Kivalina River. Extreme winds at this site provide a severe constraint. Ice-rich permafrost at the site would require 9 feet 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.

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

would be buried below ground. A 1.5-mile road would lead to the Chukchi Sea to 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 floodplain, does not have ice-rich permafrost, it would not need gravel fill, and it has no known erosion.

Summary of Kiniktuuraq relocation option (cost: $248.2 million): This site is on the coast about 1 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). 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 not be feasible due to ice wedges in the soil.

Summary of Igrugaivik relocation option (cost: $246.1 million): This site is 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 foot 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 on all sides for protection against erosion. The report recommended this site not be investigated further because ice-rich permafrost soils are not suitable for construction.

Summary of Kuugruaq relocation option (cost: $245.6 million): This site is 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 foot 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. The report recommended this option not be investigated further because the area floods in the spring and because of ice-rich permafrost soils.

The authors rated each option using 31 siting criteria grouped under four 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.

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.

Hopkins, David M., 1977, Coastal processes and coastal erosional hazards to the Cape Krusenstern Archaeological Site: Menlo Park, California, U.S. Geological Survey, Open-File report 77-32, 15 p.

This report describes the depositional environment at Cape Krusenstern, Alaska. The sediment sources and longshore drift have been analyzed and used to determine potential changes in the natural system, if a harbor or jetty were constructed at Kivalina.

Hopkins, David M., and F.S. MacNeil, 1960, A marine fauna probably of late Pliocene age near Kivalina, Alaska: Geological Survey Research, vol. 157, p. B339–B342.

This article is a description of the stratigraphic sediment in Kivalina Lagoon, determined by analyzing the fauna present in the clay mud layers.

Immediate Action Workgroup (IAWG), Michael Black and Patricia Opheen, eds., March 2009, Recommendations to the Governor's Subcabinet on Climate Change: Immediate Action Workgroup, 168 p.

The Immediate Action Workgroup was established to address known threats to Alaskan communities caused by coastal erosion, thawing permafrost, flooding, and fires. This report is a follow-up to the recommendations made in April 2008, and provides recommendations for actions and policies to be implemented in 2009 and 2010. Information from the report pertaining to 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 $500,000 for design work.*
- *Mapping: Complete geologic and hazard 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."*

Immediate Action Workgroup (IAWG), Michael Black and Patricia Opheen, eds., April 2008, Recommendations report to the Governor's Subcabinet on Climate Change: Immediate Action Workgroup, 86 p.

This report provides recommendations to the Alaska Governor's Subcabinet on Climate Change. The Immediate Action Workgroup (IAWG) 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).*
- *Third Party Review: State of Alaska will serve as third 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 for 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.*

Kneeland, Patrick, Colin Phillips, and Doug Jerolmack, 2011, Coastal erosion on the Baldwin Peninsula in arctic Alaska [poster]: University of Pennsylvania, Environmental Studies.

http://www.sas.upenn.edu/earth/PatrickKneeland.jpg

This is a poster available online describing coastal erosion research conducted on the Baldwin Peninsula in Kotzebue Sound. Individual erosion hot spots, surveyed in 2009, are analyzed for possible modes of erosion. The potential impacts of erosion in the region are briefly discussed and the trends are interpreted through the context of global climate change.

Lau, David, July 2010, Regional integration team spearheads development of guidance critical to Alaska coastal erosion program: Fort Shafter, HI, U.S. Army Corps of Engineers, Pacific Ocean Division, news release no. 10-05, 2 p.

This release announces that the Secretary of the Army has been authorized to carry out structural and non-structural projects for storm damage prevention and reduction, coastal erosion, and ice and glacial damage in Alaska under the Energy and Water Development Appropriations Act of 2010. This allows for the continuation of projects in Unalakleet, Kivalina, Shishmaref, and Newtok.

Lynn, Kathy, and Ellen Donoghue, April 2011, Climate change—Realities for Alaska Native villages: Eugene, Oregon, Tribal Climate Change Project, University of Oregon, 5 p.

This summary was produced as part of the Tribal Climate Change Profile Project to increase knowledge among tribal and non-tribal organizations through the illustration of innovative approaches to addressing climate change challenges. Included is a brief summary of the issues involved with village relocation in Alaska and the history behind village dependence on federal funding. The residents of Shishmaref began exploring relocation

in 2001. There are worldwide research efforts focused on collecting perspectives on relocation and resettlement in the circumpolar north including Kivalina, Shishmaref, and Koyukuk. This document contains a useful table of publications, websites, video resources, and news articles on the topic of village relocation.

Manley, W.F., J.W. Jordan, L.R. Lestak, O.K. Mason, E.G. Parrish, and D.M. Sanzone, 2007, Coastal erosion since 1950 along the southeast Chukchi Sea, Alaska, based on both GIS and field measurements: Boulder, Colorado, University of Colorado at Boulder, 38th International Arctic Workshop, p. 90–92.

This is an abstract for a poster presentation on the measured changes in the nearshore coastal environment in Northwest Alaska. Field measurements of the region included repeat photography, mapping of sediments and landforms, and ground-truth measurements of coastal profiles. Erosion rates were determined using the USGS DSAS extension to ArcGIS, and attributed to coastal sensitivity the increased "frequency and intensity of storm events, increasing temperatures, permafrost melting, sea-level rise, and the increasing length of summer ice-free season." The erosion rates were found to change temporally and spatially throughout the region, but an average of 0–3 m/yr of erosion was experienced from Wales to Kivalina over the last five decades.

Mark, D., unpublished [2003], Reformulation of water-surface elevation frequency-of-occurrence relationships for Kivalina, Alaska: Vicksburg, Mississippi, U.S. Army Engineer Research and Development Center.

This study used a methodology similar to Scheffner and Miller's (1998) study using computer-generated wind fields more representative of storms that impact Kivalina. This study did not incorporate the effects of tides or the sea ice extents. No calibration or verification of the model was performed and the calculations resulted in an estimate that the 100-year flood is 16.3 feet above MLLW in Kivalina.

Martinson, Mark A.; Harold R. Livingston, ed., December 1984, Engineering geology and soils report, Kivalina Airport: Northern Region Design & Construction, Alaska Department of Transportation & Public Facilities, project no. D21332, 18 p.

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 the primary reason the island has not washed away. Local destruction of grass by dogs, 4-wheelers, and foot traffic has resulted in some erosion from storms. 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 the beach due to the possibility of turbulence scouring beach materials.

Mason, Owen K., and James W. Jordan, 2002, Minimal late Holocene sea level rise in the Chukchi Sea—Arctic insensitivity to global change?: Global and Planetary Changes, vol. 32, p. 13–23.

In this article, Mason and Jordan outline the apparent disconnect between late Holocene global sea level rise and the moderate sea level rise observed in Northwest Alaska. Radiocarbon ages taken from peat and storm deposits in Seward Peninsula lagoons allowed for the reconstruction of a sea-level curve spanning the last 6,000 years. The results indicate that sea level in Northwest Alaska has risen an average of 0.3 mm per year compared to the global average of 1–2 mm per year. The authors suggest several hypotheses for these differing rates, including cold sea surface temperatures (limited steric expansion), geoid variation and/or the development of permafrost. Although observed rates of sea-level rise are moderate for the Chukchi Sea, the article cautions that the response of northern Alaska's coasts to future global climate change remains uncertain and requires continued investigation.

McCulloch, David S., Dwight D. Taylor, and Meyer Rubin, 1965, Stratigraphy, non-marine mollusks, and radiometric dates from Quaternary deposits in the Kotzebue Sound area, western Alaska: Journal of Geology, vol. 73, p. 442–453.

This article provides detailed information and ages of Quaternary stratigraphic units in Kotzebue Sound spanning multiple marine transgressions and glaciations. The defined units are based on analysis of fossil assemblages exposed in the coastal bluff environment that are consistently observed in the regional stratigraphy. Units were assigned ages based on mollusk samples collected from the Baldwin Peninsula and Kobuk River.

McKinnon, M., March 2008, Draft proposal, transportation system analysis, community sites in proximity to the Delong Mountain terminal: Denali Commission.

The Denali Commission developed this draft proposal to conduct a transportation-based analysis of relocating Kivalina to a site near the Red Dog Mine port. The study would investigate areas north and south of the port that would not be exposed to the elevated natural hazard risks 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.*

Mitchell, Janet, ed., accessed January 2012, City of Kivalina, the only whaling community in the Northwest Arctic Borough region! [website]: Kivalina City Council.

http://kivalinacity.com/

The city of Kivalina maintains a website with pages that describe erosion, climate change, the rock revetment, and significant storms from a local perspective. The website is updated periodically and includes extensive local knowledge content, links to presentations made by residents of the community, and photographs.

National Oceanic and Atmospheric Administration (NOAA), unpublished [December 2004], Erosion study report, Kivalina: no. AK0302.

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 feet on the Chukchi Sea coast (27 acres lost on the Chukchi Sea side, and 8 acres accreted in 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 feet 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.*

Olson, Neil F., and Ben T. Crosby, 2007, Digital mapping of coastal erosion on the Baldwin Peninsula, NW Alaska—Past rates, current processes, and future implications [abs. & poster]: American Geophysical Union Transactions Fall Meeting Supplement, vol.88, no. 52, Abstract GC33A-0962.

http://geology.isu.edu/~crosby/research/pubs_posters/Olson_Crosby_Baldwiin_Peninsula_Erosion_AGU_2007.pdf

This poster presents research conducted on the Baldwin Peninsula, Alaska. High-resolution topographic surveys, field observations, and interpretation of aerial imagery were used to determine erosion rates and mechanisms at the narrowest point on the peninsula and to provide a baseline for future measurements. The motivation for conducting this research was to address concern about a potential breach of a narrow (700 m) portion of the peninsula, which would have significant navigation and ecological implications for the area.

Péwé, Troy L., David M. Hopkins, and Arthur H. Lachenbruch, *of* U.S. Geological Survey *for* U.S. Atomic Energy Commission, April 1958, Engineering geology bearing on harbor site selection along the northwest coast of Alaska from Nome to Point Barrow: U.S. Geological Survey trace elements investigations report no. 678, 57 p.

This report provides geologic and oceanographic information from previous investigations, aerial imagery, and reconnaissance field work regarding the optimal location of a deep-water harbor. The harbor was to be constructed with the use of modern nuclear explosives and located at a point along the northwest coast of Alaska between Nome and Point Barrow. The project was not undertaken.

Replogle, Clinton, November 1911, Annual Report of the U.S. Public School for Natives of Kivalina: Institute of Social and Economic Research, University of Alaska, Anchorage, 1 p.

http://alaskool.org/native_ed/historicdocs/kivalina/ki900011.htm

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 100 feet from the schoolhouse 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 somewhere on the Noatak river, would be a great place."

Scheffner, N.W., and M.C. Miller, unpublished [1998], Development of water surface elevation frequency-of-occurrence relationships for Kivalina, Alaska: U.S. Army Corps of Engineers, Coastal and Hydraulic Laboratory.

This report states that the maximum height of the island is 9.8 feet above MLLW. The study involved use of two different models to predict the level of storm surges, including one 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. 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 feet. The study found that the maximum wave runup would be about 2 meters (6.56 feet).

Simpson, J.J., January 1984, Final report, Task Force on Erosion Control: Alaska Department of Transportation & Public Facilities, project no. R-30023, 101 p.

The Erosion Control Task Force was appointed to investigate and inventory potential erosion problems on a statewide basis, to prioritize the erosion problem sites by severity and need, and to provide preliminary design plans where immediate remedial action is required. Sites were rated based on public safety, public property, private property, time of projected loss, ability to move, approximate replacement value, and economic value. Projected costs of erosion protection measures were analyzed and totaled $16,802,300 for all projects. This report outlines specific engineering projects to reduce the effects of coastal and riverine erosion for communities throughout Alaska.

Erosion at Kivalina is predominantly at the north end of the airport and alongside the lagoon. For the erosion at the lagoon side, sand bags and gabion baskets are suggested along with backfill and replanting of beach grass. At the airport, gabion baskets are also suggested, but at a steeper angle. Because of the low grade slope of the beach, structures that would increase turbulence should not be used.

Triton, June 1999, DeLong Mountain Terminal project feasibility study, metocean conditions report: Triton Consultants, Ltd. Vancouver, BC, Canada, vol. 7a.

This study used measured wind data from Kotzebue to construct a spatially constant wind field that was fed into a hydrodynamic model to calculate preliminary water level statistics for annual maximum water levels at the Red Dog Port site south of Kivalina. 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 feet above MLLW.

University of Alaska Fairbanks (UAF), Geophysical Institute, Permafrost Lab, *for* Federal Highway Administration, Western Federal Lands Highway Division, October 2008, Numerical modeling of long-term permafrost dynamics of the Kiniktuuraq proposed relocation site for the community of Kivalina: Federal Highway Administration Report, 34 p.

The UAF Permafrost Lab 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 1-foot gravel cap was placed on fine-grained fill. The model was based on the soil characterization from a 2002 report by R&M Consultants. The model included two climate scenarios where mean annual air temperatures increased 4°C by the end of the century (first scenario) and by 2°C by the end of the century (second scenario).

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

The report concludes that surface subsidence will occur when permafrost melts down to the ice-bearing horizon between 0.4 and 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 (first scenario above), the ice-rich permafrost layer would melt completely. Under a more moderate increase of air temperature (second 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, accessed 2011, Civil works floodplain management services [website]: U.S. Army Corps of Engineers, Alaska District.

http://www.poa.usace.army.mil/en/cw/fld_haz/floodplain_index.htm

This website provides flood hazard data for communities throughout Alaska. A link to a flood-hazard-specific bibliography, maintained by the U.S. Army Corps of Engineers, is provided. The 100-year storm surge height has been calculated as 10.6 feet MLLW for Kivalina. Kivalina has also been listed as not participating in the National Flood Insurance Program.

U.S. Army Corps of Engineers, March 2009, Study findings and technical report—Alaska baseline erosion assessment: Elmendorf Air Force Base, AK, U.S. Army Corps of Engineers, Alaska District, 68 p.

http://www.poa.usace.army.mil/AKE/Home.html

This statewide assessment was conducted by the U.S. Army Corps of Engineers to coordinate, plan, and prioritize responses to erosion throughout Alaska. The report designated 26 communities, including Kivalina, as priority action communities. The assessment summarizes earlier studies about the effects of coastal erosion on selected communities, including Kivalina. The document summarized the results of a 2006 COE study that found:

1. *The costs of future erosion protection for Kivalina would be $15 million,*
2. *It would cost between $95 and $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 nine 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 & Economic Development.

Online access to this document includes a link to Erosion Information Papers specific to each community. These Alaska Village Erosion Technical Assistance (AVETA) program reports include a description of the community setting, erosion problem, and potential damages as well as historic/predicted shoreline position maps (based on approximated erosion rates) and community-provided photos of erosion.

U.S. Army Corps of Engineers, December 1991, Geotechnical investigation—Kivalina borrow material exploration, Kivalina, Alaska, site investigation: U.S. Army Corps of Engineers, Alaska District, no. DACA85-97-D-0004, 26 p.

This report consists of an overview of existing gravel material source studies and identification of potential material sources for the relocation of Kivalina to the proposed Igrugaivik site. The report includes approximations of construction material requirements for the new site based on work done in previous communities and keeping the community above the 100-year floodplain.

U.S. Army Corps of Engineers, Timothy J. Gallagher, ed., April 2006, Alaska Village Erosion Technical Assistance program—An examination of erosion issues in the communities of Bethel, Dillingham, Kaktovik, Kivalina, Newtok, Shishmaref, and Unalakleet: U.S. Army Corps of Engineers, Alaska District, 44 p.

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 approximately $15 million to construct erosion protection for Kivalina; it would cost between $95 million and $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:Iit 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 between 1985 and 2002 cost $477,000, and efforts during the last 2 years cost $850,000.

Cost of relocating Kivalina 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.

U.S. Army Corps of Engineers, Orson Smith, ed., April 1998, Community improvement feasibility report, Kivalina Alaska: U.S. Army Corps of Engineers, Alaska District, 164 p.

This comprehensive study by the Corps evaluated two potential relocation sites as well as remaining 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.

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 feet).

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 meters (3.19 feet) 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 feet).

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 feet, including wave setup, and wave runup on a natural beach could be an additional 2 meters (6.5 feet). 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 water from the Kivalina and Wulik rivers flows 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 feet) offshore on the Chukchi Sea side of the village. The report states that dredging of offshore sand beyond 400 meters (1,313 feet) for beach nourishment would have no significant impacts. It recommends construction of beach fill topped with a sand dike.

Imnakuk Site: This site is 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 to provide boat access upriver. Residents reported that winter winds from the north make this site undesirable.

Igrugaivik Site: This site is 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-year 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 feet 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.

U.S. Army Corps of Engineers, Kevin J. Wilson, ed., September 2007, Environmental assessment and finding of no significant impact, section 117 expedited erosion control project, Kivalina, Alaska: U.S. Army Corps of Engineers, Alaska District, PL 108-447, 24 p.

This document provides the environmental assessment required under the National Environmental Policy Act for an emergency rock revetment project. The assessment found that there would be no significant short- or long-term environmental impacts as a result of this project, but the revetment would result in a minor inconvenience in accessing the beach and could lead to changes to the shape of Singauk Entrance (due to altered sediment patterns, or "longshore drift").

The report indicates that 25–30 feet of shoreline was eroded during 2004 and 2005 storms, and that a 2006 storm eroded 50 feet inland and 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 eight 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 that involves construction of 3,100 feet of revetment south of the airstrip on both sides of the island.

The assessment acknowledges that the potential effects of disrupting the longshore drift are poorly understood and that the project could affect transport of sediments leading to changes in the morphology (structure and form) of Singauk Entrance. The report speculates that Singauk Entrance could move toward Kivalina. There would be fewer sediments moving south because of expected of expected "accretion on the upcurrent side of the structure and erosion on the downcurrent side of the structure" (p. 19).

U.S. Government Accountability Office (GAO), June 2009, Report to congressional requestors—Alaska Native villages, limited progress has been made on relocating villages threatened by flooding and erosion: U.S. General Accountability Office Report GAO-040895T, 53 p.

http://www.gao.gov/products/GAO-09-551

This report is a follow up to the 2003 GAO report on flooding and erosion in Alaska Native villages and was completed to identify concerns due to climate change that have increased the urgency of federal and state efforts. The GAO developed recommendations for Congress that include:

1. *A flooding assessment to augment the erosion assessment completed by the Army Corps of Engineers.*
2. *An amendment to federal legislation that would allow 64 more villages to be eligible for grants.*
3. *The designation of a federal entity to oversee and coordinate village relocation efforts.*

The 2003 study identified four villages in immediate danger and in need of relocation, including Kivalina, Shaktoolik, 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 conduct an erosion control project at full federal expense, but this authority was repealed in March 2009. 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 and $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 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. 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—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 in 2008 designated the Department of Commerce, Community & Economic Development as the lead state coordinating agency for relocation assistance. A $13.6 million state appropriation was made for FY09. The report summarizes grant programs available for communities facing erosion and flooding.

U.S. Government Accounting Office (GAO), 2003 [2004], Alaska Native villages—Most are affected by flooding and erosion, but few qualify for federal assistance: U.S. General Accounting Office Report GAO-04-142, 82 p.

http://www.gao.gov/products/GAO-04-142

This study was conducted to provide recommendations to Congress that would improve how state and federal agencies respond to flooding and erosion in Alaska. This was done by:

1. *Determining the extent to which these villages were affected.*
2. *Identifying federal and state flooding and erosion programs.*
3. *Determining the current status of efforts to respond to flooding and erosion in nine villages.*
4. *Identifying alternatives that Congress may wish to consider when providing assistance for flooding and erosion (from "Highlights" section).*

The recommendations provide alternatives to current actions taken during flooding and erosion responses by including federal agencies and the Denali Commission. The adoption of policies by the Denali Commission would guide investments in infrastructure for Alaska Native villages affected by flooding and erosion. Kivalina was recognized as one of the 31 Alaska Native villages facing an imminent threat from flooding and erosion.

Western Federal Lands Highway Division *for* Denali Commission, February 2008, Draft Kivalina evacuation road feasibility study: Denali Commission, project no. 285-07, 8 p.

This project resulted from an agreement between the Denali Commission and 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 ASCG Inc. in 2005: A Kiniktuuraq alignment ($38,881,000) and Simiq alignment ($20,265,000). An environmental and detailed engineering study would cost $3–4 million; the Division recommended that the project not be pursued further until funding is obtained and 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 Singauk Entrance with a road through Kiniktuuraq and 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 Kisimigiuktuk 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 L., Albert L. Comiskey, and Richard Becker, 1981, Storm surge climatology and forecasting in Alaska: Anchorage, Alaska, Arctic Environmental Information and Data Center, University of Alaska, 26 p.

The objective of this study was to improve the quality of life and the security of property in coastal areas susceptible to flooding by enhancing the decision-making process for human activities and development. This study compiles historical climate data to develop a surge forecast regression equation. The Seward Peninsula, Norton Sound, and Lower Yukon area are identified as having the greatest frequency of reported storms. One storm, from 1976, was documented for Kivalina and used for this study; it was reported to have flooded 20–30% of the community and the water level was 1 foot below the lowest home. This study estimated the 100-year flood level in Kivalina to be 8.3 feet above MLLW.