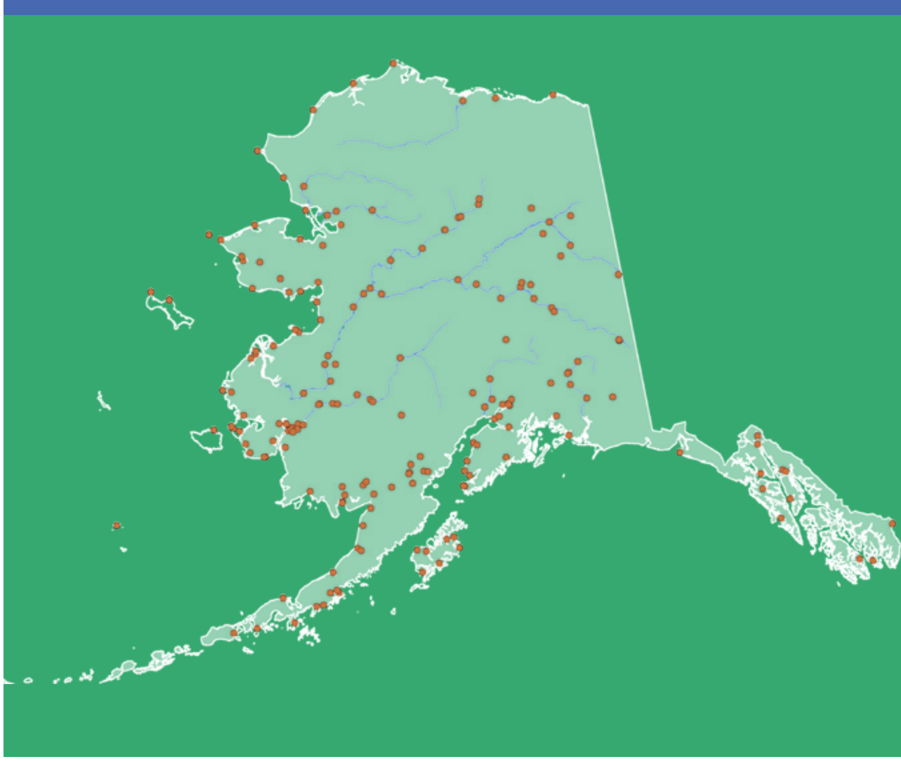
Decision-making for at-risk communities in a changing climate



Prepared by the Alaska Center for Climate Assessment and Policy

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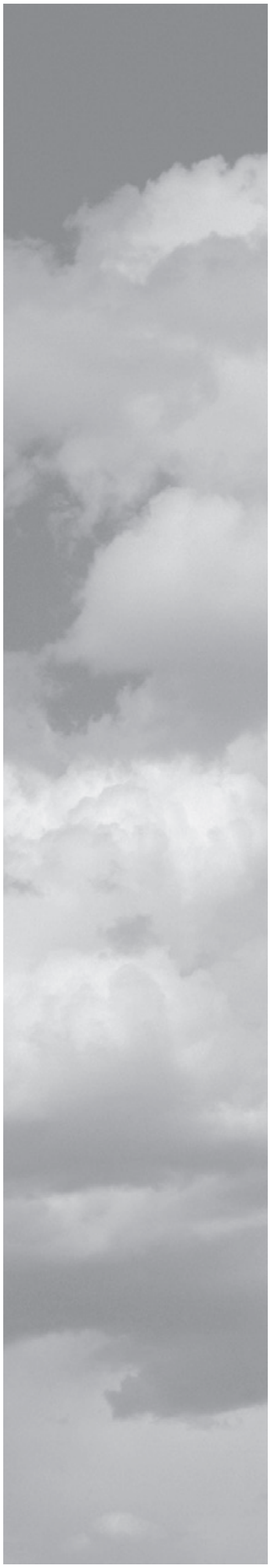

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Executive Summary

Communities across the United States are at-risk due to environmental change. Decision-makers must determine how best to manage community vulnerability in an environment where future environmental change is uncertain. Models project continued climate change, however, the projections have uncertainty associated with them that must be understood when deciding how to mitigate the impacts to communities. This document is intended to inform decision-makers relating to climate change and uncertainty, risk management, and relocation planning.

This report is not intended to be a guide for planning in individual communities where local issues dominate the decision-making. *This report does not address important social, psychological, or cultural issues involved in village relocation.* The contributors to this report believe that at the level of individual communities, locally driven processes working in collaboration with state and federal agencies have been effective. This report is intended to inform decision-makers and not serve as a one size fits all plan for relocating at-risk communities.

In order to understand the likelihood of future climate change scenarios, the driving climate variables need to be defined, including the relevant temporal and spatial resolution. Decision makers should ensure that an accuracy/performance assessment of climate models has been conducted on any model output being used to inform decision. An assessment of the likelihood/uncertainty of model variables should be reported with any model output so that this uncertainty can be balanced with other risks and uncertainties. Relevant spatio-temporal scales for analytical summaries must be defined *a priori* and must specifically address the planning requirements and needs.

The likely impact of climate change on potential relocation sites should be evaluated to determine if the cost of the move would sufficiently reduce the risk to infrastructure. On site adaptation may be an option if on-going mitigation costs have a lower present value than relocation.

Issues addressed regarding the planning process for relocation focus on the steps from planning through execution, perspectives on community engagement, partial relocation, site development costs, and time. In addition, utilities, community structures, schools and homes must be sequenced properly in any relocation effort. Sustainability recommendations focus on defining sustainability, future energy planning, planning for a changing cost of living, the transportation corridors available, and utility sustainability.

The preferred option when faced with a threat will be a factor of both technical and social considerations. Risk analysis evaluates the probability and severity of the threat. Recommended actions should be based on the severity and immediacy of the threat. Long-term costs and benefits must be evaluated in addition to the short term considerations. The cost benefit analysis must include a defensible discount rate.

Contents

1 Introduction

Background

This project was funded by the National Commission on Energy Policy (NCEP). The project was undertaken by the Alaska Center for Climate Assessment and Policy with contributions from state and federal employees, citizens, and faculty from across the University of Alaska (UA). The project coincided with activities of the State of Alaska's subcabinet on Climate Change, headed by Alaska Department of Environmental Conservation (ADEC) Commissioner, Larry Hartig.

Goal

The goal of this project was to provide decision-makers with a matrix approach to important relocation issues so that related decisions are well informed.

Strategy

In order to prepare a decision-maker's matrix for climate change and community relocation, we undertook a four step strategy.

1. We hosted an afternoon workshop to brainstorm about the issue. To this workshop were invited experts from federal and state agencies, the University of Alaska, and Alaska Native organizations.
2. We formed workgroups to address the thematically organized issues. The workgroups consisted of experts in the relevant areas.
3. Workgroups drafted this document to advise decision-makers on how to approach the issues of community relocation and climate change.
4. The draft report was reviewed by NCEP and ADEC Commissioner Larry Hartig. Comments were addressed and additions incorporated.

Considerations

There is much literature on climate change, infrastructure, and relocation of communities. Our effort was to be informed by the literature, but not serve as a literature review per se. The experts we engaged brought the collective wisdom of the literature and added to it their own experiences.

Any community in need of relocation will be faced with a number of difficult but important decisions. Some of the methods that may be used to plan for this difficult task can be applied to all communities but others are community dependent. This document does not address the important social, cultural, and political issues that are best addressed by community engagement for each individual community. It was not the goal of this document to provide a planning document for individual communities. Nor was this document intended to be used as a "one size fits all" approach to community relocation. This document was designed as a tool that decision-makers could use to consider risks, uncertainties, and opportunities related to climate change and at-risk communities so that decisions are well informed.

This report was intended to reference and build upon existing resources related to climate change impacts and community relocation including: The Immediate Action Working Group of the Alaska Governor's Sub-Cabinet on Climate Change, Recommendations Report (April 2008) (**http://www.climatechange.alaska.gov/doc-links.htm**); The Alaska Newtok Planning Group (**http://www.commerce.state.ak.us/dca/planning/Newtok_Planning_Group_Webpage.htm**) and relevant documents prepared by the U.S. Army Corps of Engineers (**http://libweb.erdc.usace.army.mil/**).

Report outline

This report is organized into five main sections. The first section outlines matrices for planning, decisions, and action given severity of damage and immediacy and recurrence of a hazard event. The second section provides an overview for interpreting models and projections for expected future conditions with climate change. Section three provides a framework for risk assessment, community involvement, funding and cost calculations. Section four outlines considerations for planning. The fifth section provides guidance for ensuring that a re-located community is sustainable with regards to energy, utilities and cost of living. Appendix A is a proposed checklist for decision-makers that follows from information in the report. Appendix B is a proposed case study to which the checklist was applied. The completed checklist for the case study in Appendix B can be found in Appendix C.

2 Planning and action matrices

Bottom-line advice to decision-makers

Action strategies for community relocation can be formulated based on consideration of the likelihood of hazard occurrence and the consequence or severity of the impact. Decision matrices are provided here for top-level planning and overview of decision type.

Planning

Planning is vital for any endeavor, but the planning process is often constrained by the time available for planning and the necessity for preliminary actions or investigations to support the planning process. Village relocation planning requires coordinated action by many governmental agencies and multiple levels of private corporate and local governmental ownership and responsibility. This is a difficult and time consuming process. The following conceptual matrices provide a tool to help "plan for the plan." These matrices highlight the need for information to determine the immediacy of the threat and the recurrence interval given climate change.

Table 1 provides an overview of top-level planning and organizational actions given varying degrees of damage severity and risk. A location in which high damage is expected today requires implementation of emergency plans. For severe damage or high risk events expected within one year, temporary actions may be acceptable and the site may require concurrent protection or emergency relocation. High risk or high damage events anticipated within 5 or 10 years allow more time for planning.

In Table 2, the "recurrence interval" refers to the projected time between hazard events such as floods or storm surge. Historically documented intervals should be reassessed to account for a changing climate.

As shown in Table 3, the type of decision that will result from the planning process will be limited by the estimated severity of the damage and the probability of time left between recurrences of the event.

In cases that do not require immediate action, the following steps can serve as a rough guide to the planning process:

1. gather information on risk level, immediacy and recurrence interval,
2. identify and assemble the people who are central to the decision-making process,
3. identify funding sources,
4. understand applicable laws and regulations,
5. identify knowledge gaps (e.g., geological information, weather data, cultural and social information), and
6. begin the consensus building process.

Threat and risk management

A community has economic value that is the sum of the monetary value of its components (assets). The value of the community to its citizens and to the greater society beyond the community is the community's assets plus its non-monetary contributions to the greater society (culture). These assets and culture are investments that are threatened by destruction of the community. In the face of natural predicted disasters, a community might avoid destruction by a planned relocation. The planned relocation could avoid loss of the culture to the greater society, but such relocations would require a monetary investment for new assets. Here we discuss issues that should be considered in evaluating that investment in the context of stages needed to plan relocation: threat analysis, risk assessment, alternative development, public involvement, funding and a management plan.

THREAT ANALYSIS

Whenever a community is threatened, three basic options are available:

- Do nothing
- Protect
- Relocate

The preferred option is a function of the nature and magnitude of the threat. For example, if the community is being threatened by coastal erosion with imminent loss of the community power generation facility, the community may choose to protect the facility. On the other hand, if a home is threatened, the homeowner may choose to move the house or accept its loss. Such decisions are predicated on a number of factors:

- Impact on the community
- Value of the structure
- Cost of the action
- Ownership
- Community values
- Available resources
- Vulnerability

Table 1. Top level planning and organizational actions

Severity of damage or degree of risk	Immediacy — 90% certainty that event will occur within:			
	Today	**1 Year**	**5 Years**	**10 Years**
High	Follow emergency action plan and stabilize	Temporary actions acceptable, may need concurrent protection or emergency relocation	Expedited planning. Gather funding for planning, procure experts	Develop plan.[1] Seek funding for investigations and full planning cycle
Medium	Follow emergency action plan and stabilize	Accept suboptimal planning, may be concurrent with protection	Expedited planning, use available funding to hire experts	Seek funding
Low	Local action	Local/regional action	No action	No action

Table 2. Top level planning and organizational actions

Severity of damage or degree of risk	Recurrence interval			
	Annually	**10 Years**	**50 Years**	**100 Years**
High	Consider protection, relocation or combination	Consider protection, relocation or combination	Consider long term plan for protection or relocation	Evaluate economic value of protection or relocation
Medium	Consider protection, relocation or combination	Consider protection, relocation or combination	Consider limited solutions	Evaluate economic value of protection or relocation
Low	Consider localized solutions	Consider localized solutions	No action	No action

Table 3. Overview of decision type

Severity of damage or degree of risk	Immediacy — 90% certainty that event will occur within:			
	1 Year	**5 Years**	**10 Years**	**100 Years**
High	Emergency protection, emergency relocation	Expedited protection, expedited relocation	Decide to enter into planning cycle. Take the time to seek funding and gather data	Defer action or seek funding for long range planning
Medium	Review emergency plans, public warnings, etc.	Consider relocation or partial or temporary protection	Decide to enter into planning cycle. Take the time to seek funding and gather data	Defer
Low	Tolerate	Protect within available funding	Do nothing	Do nothing

1 Some communities at very high risk may need to accelerate this process so that by 10 years they have executed their action plan/stabilization.

While this is not an exhaustive list, it does show that while many of the factors are quantifiable and can be evaluated in dollars, some factors are intangible. Both quantifiable and intangible factors are important to the decision process.

Risk assessment

A risk assessment seeks to understand:

- The nature of the threat
- The immediacy of the threat
- The probability of the threat
- The severity (likely impacts) of the threat

The risk assessment helps to frame the nature of the threat and dictates the available solutions. We certainly would not apply the same solution to a coastal erosion problem that we would to an imminent volcanic eruption. In the first case some protection might reduce the risk, while none is possible in the second case.

The immediacy of the threat often dictates the decision-making process and the choices available. In the case of flooding, we have no choice but to take immediate action to protect life with limited ability to protect property. However, in the case of erosion, we often have time to plan.

A risk analysis is needed to evaluate the probability and severity of the threat. If a community is located in a floodplain, there is always a chance of flooding. The frequency of flooding will dictate the urgency of action. In coastal areas, storm events can cause coastal erosion which in turn destroys a community. Unfortunately, we can rarely predict when a storm may occur nor can we predict the severity and impact of that storm with certainty. Risk analysis will allow us to examine the probability of the costs and other impacts of the threat.

Here we consider the impact of the threat in relation to the community. If the impacts are low, there is little cause for concern. If the impacts are high, then the community feels urgency. We typically think of monetary impacts to property and the potential for loss of life. However, other impacts may be more subtle including cultural concerns, access to hunting and fishing grounds, access to transportation, energy, communications and other intangibles. All of these issues must be considered when deciding whether to relocate or protect a community.

An ordinal risk matrix that compares probability of events with impacts often helps with these decisions (Figure 1). The matrix shown below was adapted from one used by the Alaska Department of Transportation and Public Facilities. The form of the ordinal risk matrix shown in Figure 1 lists consequences according to project scheduling and costs. However, the consequence table could be modified to fit any spectrum of consequences whether they are purely economic, purely intangible, or a mixture. A given situation may require a series of ordinal risk matrices, the products of which can then be combined, or added to the overall consideration of options.

ASSESSMENT GUIDE

Level	Likelihood
A	Remote
B	Unlikely
C	Likely
D	Highly likely
E	Near certainty

Likelihood

E	M	M	H	H	H
D	L	M	M	H	H
C	L	L	M	M	H
B	L	L	L	M	M
A	L	L	L	L	M
	a	b	c	d	e

Consequence

Level	Schedule	*and/or* Cost
a	Minimal or no impact	Minimal or no impact
b	Additional resources required; able to meet need date	<5%
c	Minor slip in key milestones; not able to meet need date	5-7%
d	Major slip in key milestone or critical path impacted	7-10%
e	Can't achieve key team or major program milestone	>10%

RISK ASSESSMENT

High (Red)
Unacceptable. Major disruption likely. Different approach required. Priority management attention required.

Moderate (Yellow)
Some disruption. Different approach may be required. Additional management attention may be needed.

Low (Green)
Minimum impact. Minimum oversight needed to ensure risk remains low.

Figure 1. Ordinal risk matrix

Community involvement

Each community has an identity established by those who live there. Vulnerability threatens that identity. Consequently, as alternatives are developed, an understanding of how that alternative affects the community must be fully understood and appreciated.

Alternative development

Once the risk assessment is complete, a plan to manage the threat must be developed. Development of a plan requires the analysis of likely alternatives to manage the risk. Such analysis includes:

- Developing an understanding of the desires of the community
- Developing an understanding of both opportunities and constraints
- Listing available alternatives
- Developing benefit/cost analyses for each viable alternative
- Factoring in intangible benefits and costs
- Selecting the most acceptable alternative.

A list of alternatives must be developed. There are always constraints under which decisions must be made. These can include:

- Costs
- Physical constraints such as land, water, and resource availability
- Political and social constraints
- Decision to stop investing in the existing community's assets (O&M) and begin investing in the new community's assets

Opportunities can include:

- Improved living standards
- More energy efficient infrastructure
- Increased accessibility

Once these are understood, a list of feasible alternatives should be developed. At this point, one should not pass judgment on which alternative is best, but rather strive to describe each feasible alternative, including the do-nothing alternative, with the cost and benefits — both monetary and intangible — for each alternative.

EVALUATING THE OPTIONS

Once the managers of the threat have analyzed the likely alternatives, the community must review the analysis and offer input to the decision process. The list of alternatives should now be reviewed and those alternatives that are untenable or are physically impossible should be removed from the list. One must be careful not to accept or reject alternatives unjustly. For example, one may reject moving a community because of the initial costs even though the recurring costs of rebuilding a community are less. It may well be that the relocation cost over a period of time will be less.

Once the alternative list is pared down, develop a probabilistic cost/benefit analysis using accepted practices. Of course most will be estimates, some very approximate estimates, and care is needed not to bias the outcome by inflating or deflating benefits or costs. Recognizing the low level of accuracy of the benefits and costs input into the system, small differences in the B/C ratio may indicate the alternatives are essentially equal.

These analyses can then be applied to a timeline and critical path to see if the alternatives can meet the climate projections. From this, a funding and management plan can be developed and resources sought.

Point of view — qui bono

At this point the analysts must recognize that there are three different points of view: individuals in the community, the community, and the larger political/economic society that includes the community. A cost to one may be a benefit to another. For example the cost to the state of a new state-funded school may be a benefit in wages to the community labor force. In many cases the viewpoint of the analysis will determine whether there is a cost or a benefit.

Another example might be the costs of cleaning up structures if the owner abandons them. A partly destroyed house or other structure may become a fire hazard or other nuisance. It may have fuel and septic tanks which may become health and environmental hazards. If the owner is destitute or bankrupt, ownership of the derelict structure may pass to a lending institution, insurance company, or via unpaid taxes, back to the community. The cost of the clean up might fall to the community or the larger society. Insurance issues related to the community and the threat must be considered.

The location of a community, especially in rural Alaska, may well be a function of where the public infrastructure, such as schools, power generation facilities and transportation infrastructure are located. Consequently, public infrastructure development must often occur before relocating residential infrastructure. Indeed private investment will likely lag public investment.

Existing infrastructure, whether public or private, has value. It can be argued that the value can be established by what a buyer is willing to pay. Consequently, the value of threatened infrastructure can quickly approach $0 plus any salvage value. Salvage value can be established by the value of any materials that can be recycled or can be negative in the case of demolition costs. This is a difficult concept to accept since the utility of the threatened property is the same until the threat materializes. How this infrastructure is funded and insured will reflect the economic viability of the community and willingness for further public and private investment.

Strategic management plan

In order to begin a successful process of relocating a community, a strategy is needed. Not a "good" strategy, but a "great" strategy because that is what it is going to take for federal and state government agencies and other stakeholders to commit to relocating a community. This strategy must provide the framework to develop a new community that is sustainable like no other community development to date, i.e. an unprecedented prototype. If a successful strategy is developed, this strategy could serve as a model for other communities that need to be relocated because of climate change impacts. The strategic management plan should recognize the many difficulties in the process and allow management flexibility during the long process.

The cost of adaptation v. relocation

Adaptation, in providing protection from the risk at a site, may be an option but as has been experienced in communities at-risk in Alaska, expensive. The cost of adaptation at its current site is a function of the climate and the risks presented as well as the availability of materials and logistical support to carry out those adaptation activities. In considering measures to protect the site from the risk and fundamentally adapt the community to the risk on-site is dependent on the life cycle costs of the protection measures in the face of the risk versus moving from the risk. In the context of sustainability (present generation and for future generations) these costs may not be cost effective. However, allowing the community to adapt to the risk while it relocates may be the only investment option that also respects the time, resource, and regulatory constraints facing the community.

3 Decision making for a changing climate

Bottom-line advice to decision-makers

One cannot separate predictions of climate change impacts from the uncertainty of the prediction. All climate variables and all models that predict them have uncertainty. A series of threat/uncertainty matrices should be constructed and considered for prioritizing projects in a constrained funding environment.

Likelihood of future climate scenarios

A decision matrix for climate change and community relocation must take into account the likely severity of the climate change impact as well as the uncertainty associated with the prediction (Table 4). In this case, we can say that if we are certain (i.e., low uncertainty) that a severe climate impact to a community will occur, action is required. If there is a high uncertainty associated with a severe impact, there is less priority assigned relative to one with low uncertainty. This does not mean that the severe, but highly uncertain impact will not occur sooner than the impact with low uncertainty, it only means when forced to prioritize, the impact with lower uncertainty is the most critical.

Table 4. Decision matrix under scientific uncertainty

		Uncertainty in prediction		
		Low	Medium	High
Climate change impact	High	Action required	Action recommended	Planning for future action
	Medium	Action recommended	Planning for future action	Monitoring and assessment
	Low	Planning for future action	Monitoring and assessment	No action

Most communities will be faced with multiple threats. For example, a single community may be threatened with both erosion and flooding. Each threat needs a matrix and the matrices may or may not be coupled. For example, a community on the Yukon River in Alaska may have three threat matrices, one each for flooding, erosion, and fire. The erosion and flooding may be coupled, but mostly independent of the threat due to fire. Each matrix is derived from model predictions. An organization such as the Scenarios Network for Alaska Planning (SNAP) at the University of Alaska could create such matrices and describe how matrices are coupled for use in decision-making. The Alaska Center for Climate Assessment and Policy at the University of Alaska Fairbanks could work with stakeholders and decision-makers in interpreting and working with the scenarios and matrices.

A critical point in assessing future scenarios is to evaluate similar scenarios for potential future sites as well as the existing townsite. No site is without risk. Any planning for risk to a community in a specific location should contain the same analysis of all future locations under consideration. While the analysis procedure is the same, each site contains its own unique set of risks. The potential risk at a new site must also be coupled with the cost of the move. Will the cost of the move sufficiently reduce the risk and cost overall.

Another critical concept is if and when a tipping point may occur. A tipping point refers to the point after which there are no options but to move. The tipping point is something that must be evaluated based on our best understanding of model projections and the nature of the specific variables impacting the current location of the community.

An organization such as SNAP is normally needed to interpret climate models, predictions, uncertainties, and tipping points in order that decision-makers have the ordinal matrices to assess threats and uncertainty. Background on models and decision-making in climate uncertainty are contained in the sections below.

Global climate models

General circulation models (GCMs) are the most widely used tools for projections of global climate change over the timescale of a century. Periodic assessments by the Intergovernmental Panel on Climate Change (IPCC) have relied heavily on global model simulations of future climate driven by various emission scenarios.

The IPCC uses complex coupled atmospheric and oceanic GCMs. These models integrate multiple equations, typically including surface pressure; horizontal layered components of fluid velocity and temperature; solar short wave radiation and terrestrial infrared and long wave radiation; convection; land surface processes; albedo; hydrology; cloud cover; and sea ice dynamics.

GCMs include equations that are iterated over a series of discrete time steps as well as equations that are evaluated simultaneously. Anthropogenic inputs such as changes in atmospheric greenhouse gases can be incorporated into stepped equations. Thus, GCMs can be used to simulate the changes that may occur over long time frames due to many different processes, including the release of greenhouse gases into the atmosphere.

Decision-making with GCM projections

The obvious starting point for assessing the likelihood of various climate projections is how well particular models simulate historical climate. There are several fundamental problems with this approach. One is that there are errors and biases associated with historical observations. These include the problem of short datasets not capturing long-term natural variability, changes in instrumentation, and biases in sensors and their installation. The second fundamental problem is that models that reproduce the past climate well may be overly constrained ('tuned') to do so and may not include realistic variability. This may lead to an inability of these models to project abrupt change. Third, there is some evidence that the modes of variability themselves are changing due to underlying climate mechanisms, so the models that reproduced the past well may not have the appropriate physics to represent the future accurately. Despite these caveats, the ability of the models to reproduce the past is still one measure of intrinsic ability to accurately project the future, albeit one that should be used with caution.

The likelihood of various climate projections also depends on factors that are distinct from historical observations. For example, the future pathway of emissions of various greenhouse gases is closely linked to economic development and policy decisions and therefore highly uncertain. There is also uncertainty associated with how the climate system will respond to perturbations for which there is no recorded historical precedent. One of the largest uncertainties in the projections is the shortcoming of various physical parameterizations due to lack of observational data or model development. Finally, the resolution of the model projections is very coarse and additional uncertainty is associated with downscaling the model output to a scale meaningful for decision-making.

Relative to the number of climate modeling studies, there are a small number of studies that use other models or statistical techniques to assess the likelihood of various climate projections. The inadequacy of these studies is that they focus on only the most basic properties of the future climate. These include mean global surface air temperature change and heat uptake in the ocean. This does little to inform policy makers about the likelihood of climate change impacts to regional water supply or agricultural systems, for example. Thus the burden for assessing climate change impacts is still on policy makers and the research community.

The recommended best practices for assessing the likelihood of future projections must therefore depend on the following:

1. Historical trajectory of climate parameters
2. Understanding of mechanisms that may cause the system to deviate from the historical mean, the long-term trend, or standard deviations from the mean
3. Change in probability distribution functions of key drivers such as surface air temperature and sea level (from the literature and climate service institutions)
4. An understanding of the mechanisms behind extreme events and whether or

not their likelihoods are increasing or decreasing
5. Common sense — the future is uncertain, but the population's vulnerability to climate-related events may in many instances be obvious

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Climate, atmospheric, and other environmental concerns

Following is a list of climate, atmospheric, and other environmental concerns that must be considered. Not all variables apply in all locations. The availability of data to project the future state of the variables and our ability to project differ in spatial and temporal scales.

WAVES

Wind-generated waves represent the most consistent long term source of damaging energy into a coastal zone. Planners require various types of summary information about waves, including:

- Wave statistics:
    - » Large wave return frequency
    - » Analysis of damaging wave source directions/synoptic setup
    - » Mean wave energy
- Changes in wave state and relationship to major climate patterns

SURGES

Wind-induced increases in sea level represent the most damaging aspect of a storm in the coastal zone. Required information includes:

- Statistics of surge occurrence
    - » Return frequency of occurrence
- Weather patterns that bring a surge and changes in their frequency

INFORMATION ABOUT THE COASTAL ENVIRONMENT

Ocean impacts on a coast are filtered through the terrestrial environment. A bluff coast is not susceptible to flooding loss due to surges but is susceptible to bluff base undercut by wave action. Some soils are more susceptible to erosion than others.

- Bluff height
- Soil type

SEA ICE

For arctic regions, sea ice is an important moderating factor. Land fast sea ice protects the coast from wave damage and the presence of ice offshore can mitigate waves by reducing open-water fetch.

- Ice climatology
  - » Ice on and off dates, average position of ice pack offshore
  - » Changes over time, climatic drivers and influencers

WAVE AND SURGE SUPPORTING INFORMATION

Wave and surge modeling require detailed information about topography and bathymetry if they are to perform satisfactorily at fine spatial resolutions, such as is required when supplying information at the local scale.

- Topography
- Bathymetry
- Coastline position and orientation — waves and surges interact with all aspects of the coastal geometry to amplify or mitigate at a fine spatial resolution

FLOODING AND RIVERBED MIGRATION

Flood frequency estimates are used in the design and protection of infrastructure. While flooding due to snowmelt or precipitation can be devastating, ice jamming and bank erosion are other issues that cannot be underestimated in their potential for destruction of infrastructure.

- Precipitation frequency
- Flood frequency
- Topography

MAJOR CLIMATE PATTERNS

Major climate patterns that cause problems for different regions must be identified and their occurrences linked to climatic drivers and return frequencies established. Specific patterns would be defined by region, but examples include:

- Drought patterns
- Rainy patterns
- Patterns that bring a series of storms to a region
- Favorable hurricane patterns (e.g. low shear, many easterly waves)
- Changes back in time, forward in time -perhaps in a given region a threat is growing or even disappearing

4 The planning process

Bottom-line advice to decision-makers

The planning process should include collaboration and partnership on local, regional, state, and federal levels. Key steps are to identify a lead agency, create a responsibility matrix, identify funding, build legislative support, and engage consultants as necessary. Recommended sequencing will be site specific. Low discount rates of 1%-2% are recommended. One possible recommended sequence for relocation is: transportation facilities (roads, airport), utilities, clinic/hospital, post office, community buildings, school and housing.

Interagency cooperation

There are many agencies, local, state and federal, that may be involved both in the planning and funding for relocation as well as its implementation. Agencies must be clear on their authorities and services. A need exists for a more unified/ cross-agency, single access point to facilitate communication engagement.

Key issues for interagency collaboration include:

1. **Identify a lead agency.** If there is an agency that is willing to take the lead in the relocation, that will help facilitate the process. It is especially important to identify which agency will take the lead in conducting the required analyses to comply with the National Environmental Protection Act (NEPA).
2. **Create a responsibility matrix.** Early in the relocation planning, a knowledgeable person or entity must make a "responsibility matrix" of all the players, their responsibilities, key contacts, deadlines, funding availabilities, and so on. Getting individual entities to agree on this is a useful step towards efficient cooperation.
3. **Identify funding**. How will the lead agency fund it efforts? Are such endeavors included in their annual operating budget, or will they need a special appropriation to participate in a high level? Ask them. Similarly, do all the major players have budget to play their roles?
4. **Build legislative support.** Does the relocation have a legislative supporter? Often a strong legislator can encourage agencies to cooperate.
5. **Consider consultants.** What is the role of consultants? If the relocation were

of a large community with a strong solvent government, the government would likely augment its staff with a consultant or special hires to drive the entire process. This concept, a project manager for the relocation, is a good one, and the community may try to get grant money to hire such a person or firm.

WHO SHOULD BE INVOLVED?

Below is a preliminary list of local, state, and federal entities that should be involved and/or consulted in a relocation effort. This is list compiled drawing from the experience of the Newtok Planning Group for relocation of Newtok, Alaska (**http://www.commerce.state.ak.us/dca/planning/Newtok_Planning_Group_Webpage.htm**) and includes federal agencies such as NOAA, USGS, and NASA who may be able to provide relevant weather, climate and geologic data and information. Additional entities may be necessary according to the specific community in question.

Local

- Local city and county/borough government
- Local tribal government (if applicable)

Regional

- Regional School District, Facilities
- Regional Native Non-Profit Organization (if in Alaska)
- Regional Native for profit Corporation (if in Alaska)

State

- State Department of Community and Economic Development, Community Advocacy (DCED)
- State Department of Environmental Conservation, Village Safe Water (if in Alaska) (DEC-VSW)
- State Department of Transportation and Public Facilities (DOT/PF)
- State Division of Homeland Security and Emergency Management (HSEM) Industrial Development and Export Authority / Energy Authority (IDEA/EA)
- State Department of Natural Resources (DNR)
    - » Office of History and Archaeology (OHA)
    - » Office of Project Management and Permitting (OPMP)
- State Public Utility Commission

Federal

- U.S. Army Corps of Engineers (COE)
- Federal Aviation Administration (FAA)
- Housing and Urban Development (HUD)
- U.S. Department of Agriculture, Rural Development (USDA-RD)

- U.S. Postal Service
- State specific Army National Guard (AANG)
- U.S. Fish and Wildlife Service (USFWS)
- National Park Service (NPS)
- U.S. Environmental Protection Agency (EPA)
- U.S. Department of Transportation
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Geological Survey (USGS)
- National Aeronautics and Space Administration (NASA)
- Department of Health and Human Services
- U.S. Coast Guard
- U.S. Department of Energy
- Federal Communications Commission
- U.S. Department of the Interior, Bureau of Indian Affairs (BIA) (if Native village)

Other — Specific to Alaska

- Denali Commission
- Rural Alaska Community Action Program (Rural CAP)

Table 5 provides a quick reference for recommended federal and state agency involvement in infrastructure relocation processes.

Table 5. Guide for federal and state agency involvement

Federal	State	Infrastructure/ Maintenance
Transportation	DOTPF	Access (roads, bridge or dock)
FAA	DOTPF	Access (air)
EPA, BIA (Alaska)	DEC	Water/wastewater systems
DOE	Public Utility Commission	Electric systems
Federal	**State**	**Infrastructure/ Maintenance**
Education	DEED	Schools
Health and Human Services	DHHS	Clinics/hospitals
FCC	RCA	Telecommunications
DOJ	DPS	Public safety facilities
NOAA	DOTPF, DNR	Geodetic control, weather and nautical charts
DOI — USGS, BLM, BIA	DNR	Site characterization, ownership
USPS	None	Mail distribution

It is expected that preliminary planning may begin when the community (stakeholders) and agencies (public stewards) open a dialog and identify the need. From this, the community and respective agency can use mini-grants for establishing feasibility studies and conducting preliminary engineering strategies. These will set preliminary timetables and proposals for environmental impact statements and the development of permits for roads, bridges, water, sewer and power for these communities and subdivisions for housing, schools and other requirements of the community.

Various tools are available for communities and agencies that are charged with aspects of relocation. The first step is to assess (develop and/or foster) the community's commitment to plan and work with the public agencies and develop a mutual level of trust. The second step in planning is to understand the breadth of available financial support and community buy-in (match). Following this, together, a vision of a sustainable community can be developed that allows public investment for infrastructure and community commitment to operations and maintenance.

Financial planning

Financial planning is essential for all stages of a relocation process. Hazard impact planning grants may be an option for some communities. Another consideration is if authorities exist for building in "alternate" locations with federal disaster dollars. Each agency participating in community relocation has different budgeting and funding streams. Agencies need to work together very closely so that the facilities get funded in a reasonable order for construction. The community is essential in this process in working with respective legislatures to assure funds are appropriated to participating agencies.

The level of community/local/non-federal match available is a function of the community, the availability of special authorities, and the source of funding. Only Alaska rural communities, for example, have Section 117 authorities which states that communities threatened by erosion including ice damage may be moved at full federal expense (Division C, Public Law 108-447). Other special authorities may exist that facilitate community investment, including federal Commissions and Authorities or the resource oriented Western Alaska CDQ program and the state Alaska Regional Development Organization program. However, federal and state agencies both have requirements associated with the source of funding and these requirements must be considered. There is almost always the expectation of local match. While this expectation is a demonstration of community investment in its future, communities in distress are often the least able to provide financial match. While local match would be considered private investment, it is not the only source of private investment. Communities may look to private investment from outside the community. This may come in the form of commercial or industrial development and asset management.

Financial instruments available to communities should be thoroughly investigated. These instruments could include funding through state or federal legislation, grants, and mini-grants.

LEGISLATION

Communities may develop funding initiatives for state or federal legislatures and provide area representatives with information as a basis to advocate for these funds. An example of legislative support includes the Tribal Partnership Program, which provides federal funds to investigate issues surrounding erosion of several Alaska Native villages. The Alaska Village Erosion Technical Assistance (AVETA) program is a compilation of efforts in numerous communities funded through the Tribal Partnership Program and subsequent legislation. The authority used for the AVETA study was the Consolidated Appropriations Resolution, 2003 PL 108-7, Division D - Energy and Water Development Appropriations, 2003, Conference Report (H.R. 108-10, page 807) and Senate Report (S.R. 107-220, page 23). Additional authority directing the report to be conducted as a technical study and at full federal cost was provided in HR 108-357, Section 112, page 10, Conference Report Energy and Water Development Appropriations Bill, 2004.

GRANTS AND MINI-GRANTS

In Alaska, one example of a community successfully receiving grant funding is the community of Newtok. Here, the Department of Commerce, Community and Economic Development prepared on behalf of Newtok Traditional Council a grant application for Investment Assistance to the Economic Development Administration (EDA). This resulted in the $800,000 award for design and construction of a Multi-Use Marine Support Facility (barge Ramp, dock and staging area).

Additionally, the Newtok Traditional Council was awarded a Mini-Grant (funded by Denali Commission and administered by DCA) of $26,682 for the development of a community layout plan for the new village site.

Access

Planning for relocation requires access to the new location. The level of transportation infrastructure currently available will make a significant impact on the options available and the ease of relocation. In some cases, where roads in or out of the community do not exist, the move will be delayed until appropriate infrastructure is in place. This may be a port or a road from the current location to the new location. The availability of infrastructure also dictates the mode of movement and the timing. If major infrastructure is moved by barge it will likely be in summer (in arctic regions). If major infrastructure moves are over ice, the move will occur in winter. The type of access and the timing are site dependent.

Land ownership

Consider that in any given community, relocation strategies will be a function of land availability ownership (such as private, public or both). It may be that the community may be completely relocated or in some instances partially relocated. The choices will depend on the community and the risks associated with the purpose of the relocation.

In order for a site to be available, the land must be owned by the community, or transferable. Land ownership may be acquired through land transfer that may include a direct transfer of land from a state, federal or private entity, or an exchange in which land is transferred to the community in exchange for land owned by the community. In addition to the land associated directly with the townsite, its utilities, and transportation corridors may require additional land for excavation of materials or harvest of other natural resources, such as timber. The mechanism of transfer can be direct purchase, exchange, eminent domain, or legislative action. All forms of transfer have occurred in the past.

Partial relocation may be an option if limited land is available in a new site and if the site being threatened is only partially at risk. In the latter case, the partial relocation would be determined based on the level of risk mitigated by the relocation and the duration of the mitigated risk. For example, if sea level rise and storm surge inundation were the threat to be mitigated, the sea level rise may only be affecting the homes and infrastructure nearest to the coast. The risk to infrastructure on higher ground is minimal and the relocation is simply a partial relocation to the higher site where part of the community already exists.

Another cause of partial relocation may be, within the context of the laws, individuals exercising their right not to move. In the past this has imposed a challenge to relocation projects as this presents the potential need for split services such as utilities. If infrastructure, such as bridges and roads must be maintained between the sites, the ongoing cost of partial relocation could be substantial. In addition to the cost, the added stress on utilities, such as medical care, should not be underestimated. Community access to public buildings such as schools and post offices can also be a complicating factor in partial relocation.

The long-term sustainability of the community, including the impacts of climate change, should be factored into any decision for partial relocation. Since climate change is occurring at a rapid rate and may reach non-linear tipping points, it is important to base projections of future change on the best available science and not on past history of change.

Community engagement

There is no doubt that successful relocation efforts start at the community level. A community must drive the process from its inception. Many documents and ongoing special interest groups have already discussed community engagement and the importance of including knowledge from within the community.

It is critical that clear communication and trust between the community and agencies is established and maintained, both in terms of the communication of risk and the communication of the need for action. The communication must go in both directions as each are informed by the other. Assessment of disasters per region by type can provide a model for planning assistance (New DHS&EM report for Alaska (in final review)).

Site development

Site development must occur as an initial step in any move. Site development costs are developed through community involvement in feasibility plans. The magnitude and duration of the feasibility efforts varies widely. The implementation of site development is a function normally of many constraints, including climate, logistics, and equipment availability. Site development is driven by meeting milestones in the feasibility plan. The staging of these will likely follow the sequence of ownership, access, and permits. Permits will have a significant impact on all aspects of a relocation project, but will impact the onset of a project a great deal.

Implementation

Community planning from the ground-up is a rare opportunity. While most the community planning is dealing with planning in an existing community in its existing environs, a few examples may lend some assistance. There are many lessons that can be learned from suburban and rural development. Another case includes lessons from disaster restoration.

Historical and recent moves in Alaska provide many lessons for implementing future moves. Recent actions include the move of Newtok to Mertarvik and Unalakleet to the uplands. For the relocation of Newtok, the barge landing will be built first, followed by quarry development and a road from the barge landing to the community site.

In considering sequencing or phasing of a project, the effort should be community lead, that is, what the community is willing to do. The sequencing of public infrastructure may be different than private infrastructure. In the absence of restrictions, sequencing might look like the following:

- Transportation facilities (1) — traditional approach allowing access
- Fuel, Power, Water (2) — utilities
- Clinic/Hospital, Post Office, and Community Buildings (3)
- School (4)
- Housing (5)

In addition to local preferences and sequencing guidance from past experience there are site specific issues. If there is sufficient risk, can certain permits be delayed to expedite a move? For example, congress can waive NEPA and other permits, though this is difficult and requires congressional action. Some permits may require decades to obtain. It is imperative that regulatory agencies be involved in the planning process so that their permit reviews can be expedited. In addition to risks associated with the hazard driving the move, delays have economic implications. For example, delays will significantly impact freight, labor costs, contracts and procurement. None of these are likely to improve, or become cheaper with time.

5 Sustainability

Bottom-line advice to decision-makers

Construction and design in a new location should include consideration of sustainability. Energy demand and peak load should be evaluated and renewable energy sources considered. Transportation systems should be designed for highest energy efficiency in conjunction with land use planning. Water, sewer and waste management utilities should be designed based on evaluated demand, feasibility, and cost of alternatives, energy efficiency and waste reduction (especially hazardous waste). Planning for a new location should include considerations of sustainable economic development and cost of living.

Sustainability

The common idea for sustainability is using the Brundtland Commission definition of sustainable development, generally used to view a community's present needs "without compromising the ability of future generations (in a rural community) to meet their own needs".

Alaska's small communities are sustainable — viable in the near term — to the extent that they are resilient to interrelated vulnerabilities presented by climatic/ecological changes. Larger communities have a very different scale of sustainability issues facing them. Economic forces increase sensitivity to financial conditions within a community, many times originating outside of an immediate locale, i.e. global energy and resource conglomerates or relocation of fish stocks.

A sustainable community is able to respond to climate impacts, to become resilient, whether organized as a local government, tribal entity or relying on a traditional town hall or congregational meeting structure, including a minimum level of population to continue education, public safety, community water / sewer, and managing the waste stream. Additionally, having viable connections to transportation systems are intrinsic parts of being sustainable. The cost and availability of energy is most critical to maintaining a viable community whether remaining in place or when a physical relocation begins. Again, linking a community's viability to the costs of energy is direct and necessary.

Critical to a community's sustainability is its population. Relocations to larger centers, sometimes called out-migration, reduces a community's population to an unsustainable level and services consequently decrease. Some small communities could be very sustainable while others may be critically impacted. Economic measurements, current energy usage and costs, viable energy alternatives, access to subsistence recourses, population changes, along with state and federal programs influencing the funding of the built, social, cultural and natural environment systems composing a community's physical characteristics must be considered.

Transportation sustainability

In order to be a viable community in a present or future location, transportation infrastructure is critical. The nature of the threat to a community may be, in part, to its transportation infrastructure, such as airport or road erosion. Transportation is key to many aspects of sustainability commerce, safety, and communication as well as social, cultural and subsistence means. Important considerations include:

1. Make connection to the existing corridors in a way that integrates different transportation modes to provide more efficient the movements of people and goods.
2. Provide access to activities and services with a multimodal transportation system. Give priority to less polluting, lower impact modes of transportation in the design of transportation systems and community land use.
3. Provide for more mixed land uses through urban structure and land use policies to limit decentralization.
4. Protect the natural and manmade environment. Balance community values with mobility in the planning, design and construction of transportation facilities.

Utility sustainability

ENERGY SYSTEMS

An energy assessment should first be conducted to determine how much electrical energy the new site will require and what energy sources are available. The types of available energy sources (e.g. diesel-electric, wind, solar, biomass, geothermal, hydro-electric, etc.) also need to be considered as well as the possibilities for implementing new and innovative conservation methods in the new location. Some sources such as wind and solar will be variable and the proper mix of sources and controls will be required to maintain the supply to the load. The types of loads (electrical, heating, and cooling) will also need to be considered. Are the loads relatively constant or do they fluctuate with the seasons and daily activities? Do the loads cause problems with other parts of the system, for example, electrical harmonics, sudden power surges and system voltage drop, and reduced heating or cooling capacity. Will buildings be heated or cooled with a different source of energy? For example, if all residences in a community are to be converted from oil heat to electric heat, can the existing energy infrastructure handle the conversion or would this be the opportune time to replace the power utility infrastructure? This requires a great deal of planning and management since the existing community would need to function until the move occurred.

If the power plant needs to be moved then the energy assessment conducted as part of energy planning would indicate how large the new plant should be. If the power plant stays in its current location, then the energy assessment would indicate whether or not additional power will be required and how to get the power to the new location including the right-of-way. Is it possible to sustain energy needs with other alternative or renewable sources of power mixed in with the current sources or is there enough available power from alternative sources that the current source of power can now be used as a backup?

WATER & SEWER, WATER SANITATION

Careful consideration during the planning, designing, and constructing of water and wastewater infrastructure would be critical to the public and economic health of a relocated community. The first step would be to assess and determine the feasibility of relocating the community's existing water and sewer system. In most cases, it would not be feasible or cost effective to relocate buried water and sewer infrastructure. It may be possible, however, to salvage existing equipment such as pumps, boilers, and structures. Components of the existing systems (e.g., water source and a sewage lagoon) would likely be abandoned at the existing community site and new components would be developed at the new site.

The next step would be to evaluate feasible system alternatives for community water and sewer systems at the new site. The plan would classify water and sewer systems by level of service using type and/or complexity. Typically, there are four service levels for water and sewer systems. For water, the levels from highest to lowest include Level A — Pipe, Level B — Individual Wells, Level C — Vehicle Haul, and Level D- Watering Point /Self Haul. For sewer systems, the four service levels include Level A — Pipe, Level B — Septic, Level C — Vehicle Haul and Level D - Outhouse/Self Haul.

Next, based on the desired level of service, a minimum of two water and sewer system alternatives should be developed and evaluated by the major components of each system. A typical water system is divided into three areas. These areas are source, treatment and distribution. Likewise, a typical sewer system has three components: collection, treatment, and disposal. The life cycle costs for these alternatives would be prepared.

The plan would also develop criteria for selecting the best alternative. Also, the plan would include a business plan for the selected alternative. The business plan would determine if the selected alternative is financially sustainable, in terms of capital investing and operating costs. If not, another alternative would be developed and selected or until an alternative is found that is feasible and affordable.

Design considerations for new systems would begin with an assessment of projected use/needs for the residential, public, and commercial sectors of the community. As the community structure/demographics would potentially change as a result of the relocation process, it would be essential to base the use/needs analysis upon the master design for the new community as opposed to relying on historical data from the currently-existing community. Moreover, as the relocation process would necessitate the construction of new residential and public facilities, sustainable design practices could be incorporated into the new facilities, thus altering per capita use projections. For instance, if low-flow toilets, showerheads, and appliances were incorporated into all of the new facilities, the projected water use and wastewater production would likely decrease. Projected usage rates should therefore reflect the new technologies.

Although some communities may have previously operated without the benefit of public water and wastewater systems, it is likely that new community master plans would call for the construction of public facilities wherever possible (Level A systems as described above). Consequently, water and wastewater treatment and transmission systems should be designed to complement one another. For example, system designers should consider the combined impacts upon the local water resources when selecting the drinking water source and the wastewater discharge stream. In the treatment plants themselves, evolving treatment strategies such as nanofiltration units for drinking water or wetland wastewater treatment cells should be considered as well as conventional treatment strategies. Some of the newer biological treatment technologies demonstrate a high potential for widespread use in sustainable design due to their capacity to produce marketable products (e.g., ornamental plants) using wastewater as a feed source. Older, more conventional sustainable wastewater practices include the marketing of composted biosolids as agricultural amendments. With all such options, life cycle costs and financial sustainability would be crucial considerations.

WASTE MANAGEMENT

Physical relocation of a community provides a timely opportunity to implement sustainable solid waste practices in the new location. Given that many advances have been recently made with respect to contaminant migration modeling, waste separation and recycling practices, understanding of community health issues, and solid waste site layout and design, new sites/practices could be incorporated into the relocated community designs to maximize the impact of these latest advancements. However, prior to embarking on plans for a new facility, managers should first consider the feasibility of continuing to use the current facility. Important factors in this assessment include the age and condition of the existing facility, as well as the transportation costs from the new community location back to the existing facility. Alternatively, regionalization of solid waste facilities has been shown to be an effective management practice for small, dispersed communities. Consequently, community planners should assess the feasibility of combining resources with nearby communities for the construction of state-of-the-art, sustainable regional landfills.

If a new local solid waste facility is to be built one must first consider the waste stream itself. Consideration should include not only evaluation of current or historic waste inputs, but also potential improvements that could be made. For example, although a community may have historically deposited lead acid batteries and soda bottles into their waste dump, designers of a new site may consider separating out hazardous and/or recyclable waste from other components of the waste stream. These types of considerations should include not only the technical feasibility of waste reduction, but also the social feasibility of implementing community-wide changes in practice. Once the new waste stream has been estimated, the new solid waste site could be designed. Considerations impacting the site design include balancing transportation costs versus health and aesthetic concerns with respect to waste site location, geotechnical and environmental issues regarding pollution prevention, and potential implementation of new solid waste technologies (e.g., waste bioreactors). The potential impacts of climate change should be carefully considered in this process, as climate change could influence crucial factors in waste site design such as annual rainfall and soil stability (e.g., permafrost degradation).

Cost of living

In community relocation, cost of living for individual residents and municipal governments is an important aspect of long-term sustainability. If new construction will take place, basic parameters of "communities-as-usual" can be re-conceptualized to dramatically reduce the cost of energy by including multifamily housing, clustered dwellings and district-heat-compatible building layout (see also #1 above, energy planning). In larger communities, structural layout and land-use planning can reduce transportation costs by locating housing in close proximity to shopping, workplace and public transportation corridors. Consulting with local entities involved in economic development can help ensure that the relocated community includes opportunities for sustainable development and economic well-being of the community. Partnering with neighboring communities in projects and resource sharing may also increase cost effectiveness for community agriculture, construction projects and economic sustainability.

6 Conclusions

There are no silver bullets for decision-making in community relocation. This report presents some suggested approaches with respect to the decision-making process. Relocation decisions must be balanced by the uncertainty and severity of the threat at both the present and future locations, the risk associated with staying, moving, and the moving process itself, cost, the present and future value of assets, and sustainability. A critical aspect of the process will also be the community, its values and desires. The social, cultural and political aspects of planning were not addressed in this report as they have been the subject of many other studies.

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APPENDIX A

General Relocation Planning Checklist

This check-list is intended as a general guide for use by communities and state and federal agencies. Successful decision making is a process that includes the following steps, outlined in more detail below:

- ❑ 1. Frame the Problem
- ❑ 2. Collect and Assess Information
- ❑ 3. Prepare Plan
- ❑ 4. Decide and Take Action
- ❑ 5. Learn from Experience

❑ **1. Frame the Problem**

Describe the situation where your community is at risk due to the effects of a changing climate by framing a window that is broad enough to cover all issues in a systematic manner. Identify and assemble people and agencies that are central to the decision-making process. Know your authority, state and federal agency authorities and capabilities and regulations concerning emergency management and adapting to impacts from climate change.

❑ **2. Collect and Assess Information**

❑ **a)** Establish **a community-wide baseline inventory** of the existing infrastructure by collecting the following information:

❑ 1) Inventory existing public infrastructure (examples include roads, boardwalks, airports, harbors, docks, public buildings (schools, health clinics, post office, etc.), seawalls, shoreline protection, water, sewer, storm water, and solid waste facilities and gas, electric, and communication utilities.)

❑ 2) Document current conditions and remaining useful lives of the infrastructure

❑ 3) Estimate the present value replacement costs of the infrastructure

❑ 4) Map the current physical and environmental conditions of the community

❑ **b) Collect and analyze climatic data and output data from climatic models to predict future climate changes**

Such climatic data may include some or more of the following:

- Historical time series data for parameters such as temperature, wind, and precipitation;
- Records covering extreme events such as flooding, high winds, severe storms, etc. Including spatial and temporal information;
- Rate of change estimates for the relevant environmental systems, such as coastal erosion, particularly as they relate to specific drivers of change;
- Data or information about the impact of infrastructures on the environment and vice versa; or
- Modeling data or scenarios of future climate for the region, including such parameters as temperature, precipitation, and frequency of extreme events.
- After collecting and evaluating the climatic and modeling data, use this information for conducting a risk assessment, as described below.

❑ **c) Conduct a risk assessment** to **i**dentify the assets of a community that are susceptible to damage should a climate changing hazard occur.

As a precursor to the assessment, review Figures 1 (p. 7), 2 (p. 7), 3 (p. 8), 4 (p. 11) and 5 (p. 14) to develop a planning horizon for the severity of damage or degree of risk of a hazard and its effects on the community. A risk assessment typically consists of three components as described below:

❑ **1) Hazards Identification** — Identify and profile hazards due to climate change (floods and erosion, fires, thawing permafrost, and severe weather) present in the community and their possible effects on the community.

❑ **2) Vulnerability Assessment** — Identify and profile the community's vulnerability to the indentified hazards and their effects on people, infrastructure and property. Other items to identify include economic elements, areas that require special considerations, historic, cultural and natural resource areas and other jurisdiction-determined important facilities.

❑ **3) Risk Analysis** (p. 9-11) — Calculate the potential losses to determine which hazard will have the greatest impact on the community. Hazards should be considered in terms of their immediacy, frequency of occurrence and potential impact. For instance, a possible hazard may pose a devastating impact on a community but have an extremely low likelihood of occurrence; such a hazard must take lower priority than a hazard with only moderate impact but a very high likelihood of occurrence. Additionally, the risk analysis could include a multi-hazard approach. One such approach might be through a composite loss map showing areas that are vulnerable to multiple hazards. A multi-hazard approach will identify such high-risk areas and indicate where efforts should be concentrated.

❑ **3. Prepare Plan**

Based on the risk assessment, prepare a plan that **identifies and develops alternatives** for adapting and/or mitigating impacts caused by a changing climate on the community. Depending on the urgency and immediacy of the situation, relocating the community may be one of the alternatives. The plan would address the **feasibility of each alternative** (i.e. logistic, cost, social, etc) based on investment and sustainability criteria.

In addition, the plan would **identify potential funding sources**, **potential need for debt service**, and **regulatory or legislative action required**. Funding sources will likely be varied with a variety of constraints as to how the funds can be used. For example, the US Postal Service will only fund a post office, and the US and Alaska DOT's will only fund transportation facilities. In most cases there may be both private and public funds. There may also be low cost loans available for some activities.

Also, regulatory or legislative action may be needed to allow using funds to build beyond what has been damaged, so as to adapt new structures to estimated impacts from future climate change. Legislative action at either the local, state or federal levels probably will be needed for identifying and appropriating levels of match.

Build consensus among stakeholders during the planning with clear vision statements, goals, plan of action and timeline. Stakeholders include community residents, funding and regulatory agencies, local businesses, and other interested parties.

- [ ] **4. Decide and Take Action**
  - [ ] **a)** Select preferred alternative(s) for adaptation and mitigation measures, including relocation.
  - [ ] **b)** Prepare a Strategic Management Plan (SMP) to provide the principle guidance for developing and implementing the decided course of action.
  - [ ] **c)** Develop a Local Hazards Mitigation Plan and/or Comprehensive Community Plan for Relocation.
  - [ ] **d)** Begin the execution phase — design and construction.

- [ ] **5. Learn from Experience**

  Every decision made and every action taken is an opportunity to learn. Seek feedback on what went well or poorly and what should be improved during the decision making process. Document, where possible, what expedited and what impeded the process, including where critical timelines and milestones were met or missed and why.

APPENDIX B

Water and Wastewater Utilities Case Study

The purpose of this case study is to present a situation in which the checklist accompanying the report can be used. While this case study is not about any one community, it is a condition that is likely to exist in Alaska. A similar situation, though not with permafrost, could exist elsewhere in the United States. This case study is intended to focus only on the water wastewater utilities and the issues surrounding this element of the community.

Community location — The community is on the outer bend of a river that has been eroding for decades. Depending on river stage, the outer bank elevation is generally 10 feet above high water.

Community size — 500

Problem: The bank on which the community is located is permafrost. The erosion rate of the river seems to be increasing which may be due to many factors that could include climate change. No studies have been done to determine if and how climate change may be involved. There is no weather or climate data at the community. However, there is a 20 year record of climatological data at an airport approximately 100 miles away. Unfortunately the weather station is in a coastal community and the subject community is not making direct comparison difficult. The wastewater lagoon and a water main are threatened by erosion. The threatened infrastructure is 15-20 feet from the shore of the river.

Water source — The raw water source for domestic use is a small lake, or pond, that overlies an impermeable layer (e.g., permafrost) and receives input from precipitation and occasional overflow from a nearby stream during years of heavy flooding (e.g., ice jamming). The pond is not connected to a stream network. Water is pumped from the pond once per season via a 4 inch, uninsulated, HDPE pipe to a treatment system.

Water treatment — Water is treated by a filtration process that meets the EPA's Enhanced Surface Water Treatment Rule, is treated for corrosiveness using a phosphate supplement, then fluoridated and chlorinated and is pumped to a 1.2 M gallon storage tank.

Water distribution — Water is distributed to users at a central washeteria and through above ground insulated pipe to all buildings in the community, including private residences. Water is connected to homes with pit orifice connections and is not metered.

Wastewater collection — Wastewater is collected through a force main in arctic pipe and piped to a wastewater treatment lagoon.

Wastewater treatment — Wastewater is treated in two, 3 acre lagoons aligned in series. One lagoon is considered a treatment lagoon and the other an infiltration lagoon. The second lagoon is periodically discharged to the adjacent river downstream of the community.

APPENDIX C

Water and Wastewater Utilities Case Study Checklist Application

This document illustrates how the check list would be completed, given the example for a generalized case study of a water/waste water utility described in the document titled: *Decision-making for at-risk communities in a changing climate: Water and Wastewater Utilities Case Study*. This accompanies the report titled: *Decision-making for at-risk communities in a changing climate.*

	Step	Sample Water & Wastewater Case Study Application
1. Frame the problem		
	Describe the situation	**Problem:** The community of interest is located on the bank of a river in an area of continuous permafrost. The rate of bank erosion seems to be increasing which may be due to many factors that could include climate change. No studies have been done to determine if and how climate change may be impacting the erosion rate. There are no weather or climate data for the community; however, there is a 20 year record of climate data at an airport approximately 100 miles away. Unfortunately the weather station is in a coastal community and the subject community is not. The wastewater lagoon and a water main are threatened by erosion. The threatened infrastructure is 15-20 feet from the shore of the river.
	Identify and assemble people and agencies central to the decision-making process	In the water and wastewater utilities case, the lead-in for assembling stakeholders at the city and/or tribe level would be the general manager of a water and wastewater utility, director of the public works department or possibly, the city or tribal administrator. The city council will be a key stakeholder along with the mayor(s) of the city and/or tribe. State agencies of immediate importance to include are representatives from the Alaska Departments of Environmental Conservation, Natural Resources, and Commerce, Community and Economic Development. Federal entities to include at the outset are representatives from the Environmental Protection Agency and the US Army Corps of Engineers. Other sources for information needed for the decision making process may include: • AK DMVA DEM&HS: (**http://www.ak-prepared.com**) • AK DCCED Community Funding: (**http://www.commerce.state.ak.us/dca/commdb/CF_Grants.htm**) • AK DCCED Flood Plain Management: (**http://www.commerce.state.ak.us/dca/nfip/nfip.htm**)

		• FEMA (**http://www.fema.gov/hazard/flood/info.shtm**) • USACE Alaska District – Emergency Management (**http://www.poa.usace.army.mil/EM/EM.html**) • Alaska DEC Division of Environmental Health (**http://www.dec.state.ak.us/EH/index.htm**) • Alaska DEC Division of Water for permitting, operation and compliance (**http://www.dec.state.ak.us/water/MoreAboutWater.htm**) • Alaska DEC Division of Water for water quality assessment & monitoring (**http://www.dec.state.ak.us/water/wqamp/wqamp.htm**) • USACE Alaska District Regulatory Division for protect in place options recognizing work in wetlands/waters (**http://www.poa.usace.army.mil/reg/**) • AK DNR for state ownership of submerged navigable waters (**http://www.dnr.state.ak.us/mlw/nav/rdi/**)
2. Collect and assess information		
	a) Establish community-wide baseline inventory	
	1) Existing infrastructure	The existing infrastructure that has been determined to be at risk is associated with the water and wastewater utilities. Important information includes the dates of construction, upgrades, assessments, and operating history. Original design documents may be housed in the community, in the city/borough offices, the Alaska Department of Environmental Conservation, the Alaska Native Tribal Health Consortium, or the original design or design/build firm responsible for design and construction. As-built diagrams of any improvements may be on record in the same place or a different place as the original design documents, but should be obtained. The improvements record will provide information on what improvements may have occurred and where the documents may be housed (e.g., the name of the design, or design/build firm). While only pieces of the water and wastewater infrastructure are presently at risk, information on all components should be obtained. In addition to the information on the infrastructure itself, important information includes the use of the infrastructure. Is it currently being used, at what volume, and what are future projections for increases or decreases in use? What is the cost of operation? Projections for future use at the time of design as well as changes that have since occurred are important to understand. The original projection for future use is normally on the original design documents or in a water/wastewater master plan if one was done before construction.

	2) Current conditions and useful lives	The current condition of all water and wastewater infrastructure should be obtained. This assessment should be obtained on site by an engineering firm with experience with water and sewer systems. As part of the assessment, the utilities operator and manager assessments should be obtained. The original design documents will have a design life, often 30 years from the time of construction. However, additions, use and environmental impacts significantly increase or decrease this life. For example, while additions and improvements may extend the life well beyond its original design intent, corrosion, or unforeseen environmental impacts, such as ground settlement and frost jacking could significantly decrease the original design life. A new facility may not mean that the existing facility should be salvaged. Conversely, an older facility should not necessarily be abandoned if right-sized expansion and improvement can be accomplished.
	3) Estimate present value and replacement cost	The present value of the existing infrastructure should be obtained. Although the imminent risk is only to a portion of the water and wastewater infrastructure, the entire system should be included, as replacement could include an entire relocation and rebuild. In addition to the present value, the replacement cost should be evaluated. Both the present value and the replacement cost could be obtained from an engineering design and/or cost estimating firm.
	4) Map physical and environmental conditions	All maps relating to the site should be obtained for purposes of assessing the potential for damage as well as potential relocation sites. These include community planning maps created by the state (DCCED), city, tribe or borough planning departments as well as standard US Geological Survey topographic maps, US Army Corps of Engineers maps of flood plains and wetlands, and satellite imagery that can be obtained from Google Earth or other satellite data processing facilities such as the Geographical Information Network of Alaska (**http://www.uaf.edu/GINA**). In this case, of particular interest is the river morphology, including the historic erosion rate, which could be obtained from satellite imagery — available since the mid-1970s and any soils mapping
	b) Collect climate data and projections	
	Historical time series	See Alaska Climate Research Center for climatology (**http://climate.gi.alaska.edu/Climate/index.html**)
	Records of extreme events	Records of extreme events are available in a number of different databases, but are important to assess in this case as an annual or even decadal erosion rate may entirely miss the impact of storms and flooding events. Flooding events may have a significant impact on erosion. In this case, the frequency and trend in extreme events should be charted. These type of records are generally available at the following web sites: • Alaska Storm Track and Historical Track Database (**http://www.cpc.ncep.noaa.gov/products/precip/CWlink/stormtracks/strackhis.shtm**)

		• National Climatic Data Center Storm Events Database for Alaska (**http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms**) • National Weather Service Forecast Office Record Extremes Database (**http://www.weather.gov/climate/xmacis.php?wfo=pafg**)
	Rate of change estimates	In addition to interpretation of satellite data, reference photos may be useful and could be obtained from the Alaska DCCED DCRA Community Profiles web site (**http://www.commerce.state.ak.us/dca/profiles/profile-maps.htm**)
	Information on infrastructure/ environment impacts and interactions	Historic floods or other environmental infrastructure interactions may be available on a number of web sites that archive damage. These include: • USACE Alaska District Flood Plain Management (**http://www.poa.usace.army.mil/en/cw/fld_haz/floodplain_index.htm**) • FEMA for flood hazard mapping and assessment (**http://www.fema.gov/hazard/flood/info.shtm**) • AK DCCED Flood Plain Management for flood mitigation assessment and state flood plain mapping (**http://www.commerce.state.ak.us/dca/nfip/nfip.htm**) • AK DMVA DEM&HS for historic and existing flooding and erosion disasters (**http://www.ak-prepared.com**) • Alaska Baseline Erosion Assessments (USACE-09) (**http://www.poa.usace.army.mil/AKE/Home.html**) • GAO Alaska Native Village Assessment Report (GAO- 09) (**http://www.gao.gov/new.items/d09551.pdf**)
	Future projections of climate conditions	Downscaled climate projections for temperature and precipitation are available for every community in Alaska from the Scenarios Network for Alaska Planning (**http://www.snap.uaf.edu**). Also available from SNAP are state-wide maps, in Google Earth format for temperature and precipitation projections downscaled to 2km resolution state-wide and projections for future permafrost temperature and water availability. SNAP projections are continuously refined and updated. For information on how to access existing data contact SNAP coordinator Nancy Fresco: **ffnlf@uaf.edu**. To discuss options for specific projections not readily available on the SNAP website contact SNAP Director Scott Rupp: **tsrupp@alaska.edu**
	c) Conduct risk assessment	
	1) Hazards identification	The information that has been obtained in the previous elements of the checklist will allow for hazards identification. For example, it is important to identify if the hazard is one of gradual bank erosion or catastrophic flooding. The approach to protection is very different if the critical hazard that we are protecting against is more certain and less dramatic than a highly uncertain dramatic event.

	2) Vulnerability assessment	Here we must determine how vulnerable the water and wastewater infrastructure is to the identified hazard. Will the sections of pipe be exposed by erosion all at once, or will it occur gradually at locations that can be repaired or moved to accommodate erosion? Can the above ground pipe be easily moved? Is there somewhere to move it? Can the bank be protected? What is the vulnerability of the wastewater lagoon? Will the identified hazard cause a single berm failure or will a series of erosion events create a leaky berm?
	3) Risk analysis	In our utilities example, the observed rate of erosion and increase with concerns of thawing permafrost that will increase erosion shows a "medium" risk as there is probable loss of property in as early as 5 years and certainly within 15-20 years. This allows for planning and finding methods to slow the erosion rate (e.g. protect in place). There is a "high" risk of impacts to human health if this infrastructure fails, either through loss of clean water or infection via waterborne pathogens from the sewage lagoon. Based on the other elements of this section of the study we may determine that barring any unusual events, this is not an emergency condition. Based on Figure 1, the community would likely expedite the planning effort and develop a project within the next 5 years. The timeline is set to ensure a reasonable buffer between infrastructure and the river. Based on the data gathered as part of this process, we may conclude that the erosion rate has been relatively constant. However, should a flood event occur during this period, it would likely accelerate erosion? Consequently, flood return periods must be prepared. Further, the selection of design alternatives is predicated on water velocity, water surface elevations, and sediment transport. According to this scenario, erosion will occur on an annual basis and will eventually disrupt the infrastructure. This will probably be a one-time event for the wastewater lagoon, but could become a commonly occurring event for the freshwater piping across the permafrost layer.
3. Prepare Plan		
	Identify and develop alternatives	The alternatives in this case are basically protect or relocate the infrastructure. However, within these are multiple choices. Protection potentially could be accomplished with stone riprap, manufactured riprap, river training structures or sheet piling. If the community chose to relocate the infrastructure, where could it be relocated and how should the process take place. Most residents are likely to want protection since this will cause the least disruption. However, relocating the lagoon and rerouting the utilities may be more cost effective. Even so, funding requirements may have a major impact on the decision process.

	Assess feasibility of each alternative	The model from the USACE Baseline Erosion Assessment Report provides a viable alternative in assessing such situations through surveys and outreach (**http://www.poa.usace.army.mil/AKE/Home.html**). A comparable model has been completed by the State Department of Emergency Management and Homeland Security. Figure 2 provides for planning for recurrence with an annual event, as the river bank will continue to erode unless protection is in place or the infrastructure is moved. Similarly, the thawing permafrost will impact the ground support for the waterline, creating potential for leaks that will increase permafrost thawing or frost heaving on an annual cyclical basis further impacting the line. Using Figure 2 as a guide, based on the "high" and "medium" characterization above, the community should consider protection, relocation or a combination of the facility. This decision must also consider the long term vulnerability of other community components, both physical infrastructure and social and cultural aspects.
	Identify potential funding sources and potential need for dept service	The funding mechanism for a water and wastewater project fits under ADEC's Village Safe Water (VSW) program for the rural Alaska villages (**http://www.dec.state.ak.us/water/vsw/index.htm**) or the Municipal Grants and Loan (MGL) Program for communities not eligible under the VSW program (**http://www.dec.state.ak.us/water/MuniGrantsLoans/index.htm**). Also, funding may be available from USDA Rural Utility Service Water and Waste program (h**ttp://www.usda.gov/rus/water/programs.htm**), for rural Alaska communities or communities outside Alaska. In this case of water and wastewater utilities, funding may be available from VSW or MGL. Other sources of funding may be available including State direct appropriations and funding from other agencies like the BIA, IHS and the COE. Many of these sources require match which will likely require the use of State funding.
	Identify required regulatory or legislative action	In the event of an emergency, some legislative fixes may be needed to allow state emergency funds to build beyond that destroyed in the federally declared disaster. Alaska, in particular will need language expanding authority to meet the federal Stafford Act authorities who allows build beyond or relocate, versus restore to pre-disaster conditions (subject needs more specifics and research).

	Build consensus among stakeholders	Community hazard assessment grants and community planning grants provided under state capital funds have proven successful in addressing risks to communities and finding consensus. Clearly, the Newtok Relocation Committee work of Newtok and DCCED has shown how such a clear vision, goals, plan of action, and timeline can be brought together (**http://www.commerce.state.ak.us/dcra/planning/Newtok_Planning_Group_Webpage.htm**). Having a well organized State-Federal-Stakeholder working group, such as the Immediate Action Working Group under the Governor's Sub-cabinet on Climate Change, is an effective mechanism for taking the situation, developing alternatives, and communicating it with agency leads, legislative officials, and federal and state appropriators (**http://www.climatechange.alaska.gov/iaw.htm**).
4. Decide and take action		
	Select preferred alternatives	The preferred alternative will be the outcome of the consensus process. Most processes require that all alternatives and how the preferred alternative was selected be documented.
	Prepare Strategic Management Plan	The Newtok Planning Group provides all of its strategic planning documents in the "Reports and Documents" drop-down menu (**http://www.commerce.state.ak.us/dcra/planning/Newtok_Planning_Group_Webpage.htm**). The Immediate Action Working Group under the Governor's Sub-cabinet on Climate Change provides all documents concerning its work with the early assessment and development of an action plan addressing climate change impacts on coastal and other vulnerable communities in Alaska (**http://www.climatechange.alaska.gov/iaw.htm**).
	Develop a Local Hazard Mitigation Plan and/or Comprehensive Community Plan for Relocation	The Plans and Preparedness Section of the Division of Homeland Security and Emergency Management has information on hazard mitigation plans and emergency preparedness (**http://ready.alaska.gov/plans/**). The Newtok Planning Group provides its hazard mitigation and relocation planning documents in the "Emergency Response and Relocation" drop-down menu (**http://www.commerce.state.ak.us/dcra/planning/Newtok_Planning_Group_Webpage.htm**) Recommendations provided by the Immediate Action Workgroup under the Governor's Sub-cabinet on Climate Change offer guidance on the state level for development of an action plan addressing climate change impacts on coastal and other vulnerable communities in Alaska (**http://www.climatechange.alaska.gov/iaw.htm**).
5. Learn from experience		
		Learning from experience includes both the experience of others and the iterative experiences of the ongoing planning and design efforts for this decision-making process.

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