CHAPTER 4. PUBLIC INFRASTRUCTURE

The Public Infrastructure sector addresses the observed and projected impacts of climate change on Alaska's infrastructure, recommends priority adaptation actions that the State of Alaska should take to address the impacts and vulnerabilities associated with these impacts. Box 4-1 summarizes the mission statement for the sector.

Box 4-1. Public Infrastructure Mission Statement

Develop a system to increase likelihood that Alaska has sustainable infrastructure to support communities in an uncertain environment

Overview of Public Infrastructure Options		
	Option Name	Level of Support
PI-1	Data Collection, Analysis, and Sharing	Unanimous
PI-2	Current Best Practices	Unanimous
PI-3	Build to Last; Build in Resiliency	Unanimous

Impacts and Vulnerabilities

Infrastructure is the platform upon which society functions. Public Infrastructure is defined to include essential facilities and utilities under public, cooperative or private ownership that deliver goods and services to communities. Common examples in Alaska include, but are not limited to:

- Highways and bridges, railways
- Airports, landing strips
- Harbors, docks and ports
- Public buildings (schools, fire stations, health clinics, post offices, etc.)
- Seawalls and river shoreline protection
- Water, sewer, stormwater and solid waste facilities and systems including related pipes and utilidors, sewage lagoons and dumps/landfills
- Publicly owned or essential utilities and communication facilities, distribution systems and power grids
- National defense infrastructure, military installations

Climate change in Alaska is creating the following potential impacts to public infrastructure, with significant regional variation (ACIA 2004):

- Increased flooding and erosion
- Decreased duration (cold season) and extent (warm season) of shore fast sea ice
- Increasing freeze/thaw cycles
- Changing wind and precipitation
- Increased storm frequencies and duration
- Warming and thawing permafrost
- Increased fire risk

These changes are impacting infrastructure in a number of ways.

Problems associated with thawing permafrost, including effects on the foundations of buildings, roads, are well documented and often dramatic. *(See, for example: ACIA 2005, Nelson et al. 2003,,and Robinson et al. (in prep), Larsen et al. 2007, IAWG 2009, Stephani et al. 2008).* As frozen ground thaws existing public buildings, roads, pipelines, utilidors, and airports are likely to be destabilized, requiring substantial maintenance, rebuilding and investment. This is causing pipeline, road, bridge and building instabilities. Thawing permafrost can disrupt community drinking water supply. For instance the community drinking water source lake in Kwigillingok disappeared in June 2005 when the permafrost liner was lost and the lake drained overnight. The same risk of rupture exists for sewage lagoons. The added risk of contamination of surrounding areas is also a concern if the impermeable barrier for a sewage lagoon is lost. Increased failure rates and dramatically increasing operations and maintenance costs are due to freeze/thaw cycles that cause shifting soils in once permanently frozen ground. Transportation routes and pipelines are particularly susceptible and are already being disrupted and disturbed in some places by thawing ground and this problem is likely to expand. Future development will require new design elements to account for ongoing warming (see Public Infrastructure Policy 3).

The Alaska Department of Transportation and Public Facilities (ADOT&PF0) Northern Region is currently spending approximately $10 million to combat warming permafrost on Alaska's highway system. Increased thaw and warming permafrost related to warming temperatures will increase the amount of funding required to address the problem. ADOT&PF has already had to relocate entire airports due to flooding/erosion and there are several other airports that are being studied for relocation.

Utilities have reported that telecommunication towers are settling due to warming permafrost. United Utilities, for example, has said "warm permafrost is a result of global warming" and is seeking funds for cost overruns in the Yukon-Kuskokwim Delta *(see Hamlen, 2004).*

Changes such as declines in river flows and water levels, higher water temperatures, storm surges, and heavier short duration rainfalls may cause impacts such as a decline in hydroelectric power, declining water supplies, water quality problems, flash floods and overtaxing of drainage facilities. The U.S. Army Corps of Engineers (USACE) reports that increasing erosion along the Bering Sea coast means the villages of Shishmaref, Kivalina, and Newtok in western Alaska will need to be moved in the next 10 to 15 years, at an estimated cost of up to $455 million. *(see Larsen et al. 2007.)*

The U.S. General Accountability Office (GAO) has reported that "flooding and erosion affect 184 out of 213, or 84 percent, of Alaska Native villages to some extent. While many of the problems are longstanding, various studies indicate that coastal villages are becoming more susceptible to flooding and erosion caused in part by rising temperatures.

Coastal storms threaten infrastructure critical for community viability (harbors, docks, schools, fuel tanks, runways, power plants, water/sewer provisions and more) by eroding sea walls and other shoreline protection and exposing infrastructure to erosion, flooding and storm surge. In December 2004 a storm surge contaminated the drinking water supply of Nunam Iqua with salt water, creating an emergency that required drinking water to be flown into that community.

In May 2009 the eastern Interior Alaska saw record high temperatures that quickly melted snow, pushing water into the Yukon River. That, combined with a winter of heavy snowfall and thick river ice made perfect conditions for ice jams that can act as dams that flood riverside. In Eagle and Eagle Village an old Native cemetery was flooded, power and phones turned off, the clinic and Village Public Safety Officer (VPSO) Office were lost, and all buildings and houses along the riverfront in the old village were flooded.

Reduced sea ice allows higher waves and storm surges to reach the shore. It will enhance ocean access to northern coastlines. Communities and infrastructure are already threatened; some are being forced to relocate, while others face increasing risks and costs. *(See ACIA 2004, 2005.)*

Ongoing erosion and flooding concerns have caused problems for a number of years in Kivalina. The recently installed seawall was ineffective at arresting erosion and was severely damaged with sections completely destroyed during the minor storm events of 2006. Erosion is threatening the waste storage containment area located at the dump site. This is a potential environmental catastrophe for the surrounding water bodies. *(See IAWG 2008)*

Erosion, flooding, and fires are threatening Koyukuk. The entire village of Koyukuk lies within the floodplain of the Yukon River. Erosion occurs during anytime the river is open and specifically during high flow events on the Yukon River. These events happen throughout the year, including floods during spring breakup ice jam events; spring/ summer/fall significant rainfall events; wind, and permafrost thaw at Koyukuk and upstream. These floods are often severe, inundating a majority of the village and sometimes requiring evacuation of citizens to other villages. These problems have been persistent and serious enough – often flood warnings provide only a 2 hour window to evacuate – that the community has begun planning efforts to relocate themselves to higher ground above the floodplain of the Yukon River upon nearby Koyukuk Mountain. *(See IAWG 2008)*

Projected Coastal Erosion at Newtok, Alaska through 2027 *(see Larsen et al. 2007)*

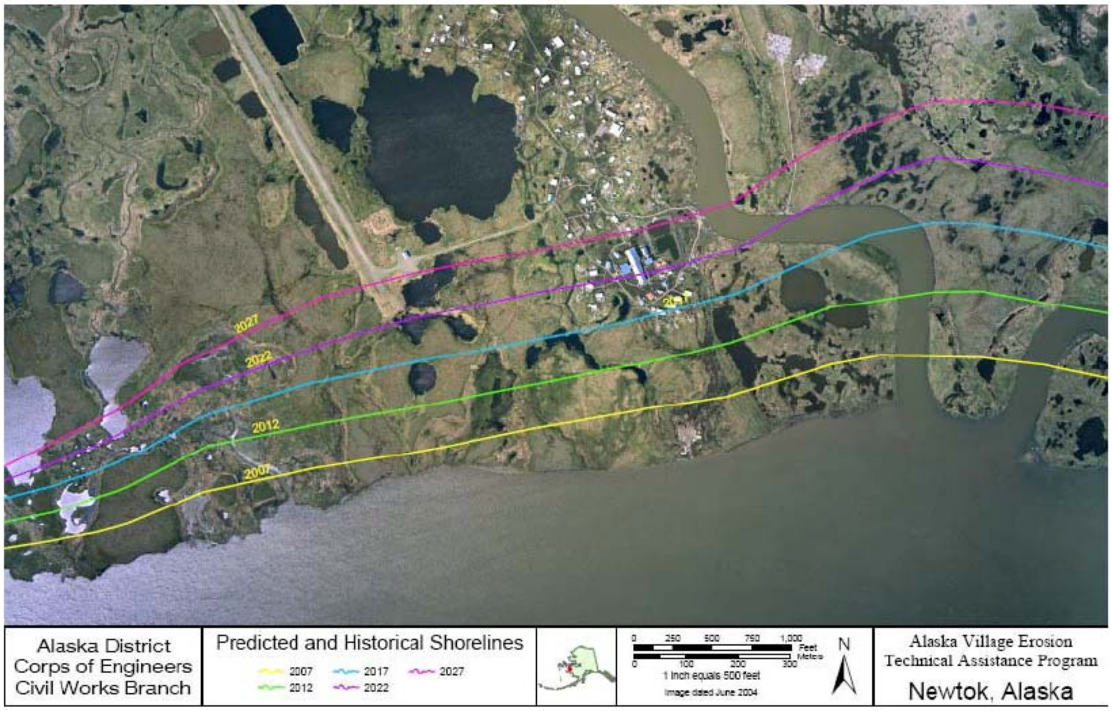


Image Source: Bruce Sexauer, U.S. Army Corps of Engineers, Alaska 2006

Newtok facilities – both public and private – have already been severely damaged by erosion and storm surge flooding due to lack of sea ice, and it's anticipated that continued erosion and destruction of public and private facilities are imminent. Problems endemic to many rural Alaska communities, such as a lack of adequate drinking water and sanitary sewage disposal, have been worsened by the erosion and flooding. *(See IAWG 2008)*

Shishmaref has been threatened by erosion for many years with recent increases due to the lack of sea ice during the fall storm season. A partially completed USACE project is providing protection for portions of the shoreline. *(See IAWG 2008)*

Problems associated with increased rates of coastal erosion are the result of storm activity and wave action eroding shorelines once protected by shore-fast sea ice. The photo on the next page shows how coastal storms have eroded the foundations of structures in western Alaska. This problem is expected to become chronic as the climate warms, sea ice retreats, and coastal storms become more frequent.

The Vulnerability of and Risk to Public Infrastructure is Growing. Most of these impacts are not new to Alaska. What is new is the increased magnitude, rapid development and progression, and increasing geographic extent of these impacts and affected communities. In some locations entire Alaskan villages are at immediate risk. In other locations critical roads and public buildings are at risk. The immediacy and level of risk varies by region and locally within regions, adding challenges which are difficult to predict.

Reliable and sustainable infrastructure is the foundation that the future of Alaska will be built upon. To ensure that Alaska is prepared to optimize investment opportunities and demonstrate that the return on investment for

Alaska's current and future infrastructure provides good value for the state and the nation, an on-going, aligned statewide effort to monitor, analyze and proactively adapt to our changing environment is required.

Adaptive Capacity for Existing Infrastructure is Low; for New Construction it is High. The adaptive capacity of public infrastructure is generally quite low. Most public infrastructure is hard and fixed (for example, roads, airport runways, bridges, buildings) and cannot easily alter its alignment, elevation, or structural foundation to accommodate coastal erosion or increased flood risk. When modification is possible it is typically very expensive. There is high potential for adaptive capacity in new infrastructure and construction through planning for expected climatic changes, updated design and siting.

Increased Communication and Coordination is Critical. Alaska needs an entity that can increase communication and coordination in public infrastructure climate change adaptation across agencies, communities and scientific and applied researchers. Impacted and potentially impacted communities, agency funders, and researchers often do not know about each other's planning efforts, infrastructure improvement projects, funding opportunities, or research, materials testing and demonstration project results. Information is not being shared with all who could benefit. The lack of routine coordination and information sharing raises costs, creates redundancies and adds inefficiencies to efforts to adapt Alaskan infrastructure. An entity is needed to facilitate communication both horizontally among partner agencies and vertically among the various layers of government and organizations.

Left: Impacts from thawing permafrost on Alaska Highway north of Beaver Creek (Source: Prof. Billy Connor, University of Alaska Fairbanks 2009, Permafrost and the Alaska Highway presentation) Below: Storm surge undercutting western Alaskan coast (Source: IAWG Final Report)

Photo courtesy U.S. Army Corps of Engineers, Alaska

"Sink hole" on shoulder of Goldstream Road 5 mi N. of Fairbanks (Source: Prof. Vladimir Romanovsky, University of Alaska Fairbanks; UCAR, 2007)

Thermokarst depression on the edge of the Geophysical Institute UAF parking lot (Fairbanks, Alaska). Surface disturbance related to the parking lot construction triggered the permafrost degradation and ground ice melting. This created a subsurface void within the ground. The roof of this void collapsed when surface and ground waters saturated the soils during spring and beginning of summer. Photo by Prof. Vladimir Romanovsky, University of Alaska Fairbanks.

Bluff erosion & permafrost thaw, Shishmaref (c 2002) Kawerak

Photo 1: Undercutting of river bank in Newtok. (Credit: Stanley Tom)

Photo 5: Flooding during coastal storm in Newtok. (Credit: Stanley Tom)

Four-story apartment building (not public infrastructure) in Cherski, Russia, North-East Yakutia (upper Kolyma River) was destroyed because of permafrost thawing and differential settlement in its foundation. It took only several days between the appearance of first cracks in the walls and the partial collapse of the building. Photo by Prof. Vladimir Romanovsky, University of Alaska Fairbanks.

Public Infrastructure Adaptation Strategy

Box 4-2. Overview of Public Infrastructure Recommendations

This is a systems approach to reduce the impacts of climate change on Alaska's public infrastructure by accomplishing actions under three policies/programs:

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

Baseline data on the condition of current infrastructure and on regional and local environmental conditions needs to be collected. We need to know where and what the problems are. We need to know what is working and what is not working. Based on the best science and collected empirical data we need to predict our future. The Environmental Atlas of Alaska must be updated. The resulting information needs to be available to all interested parties.

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

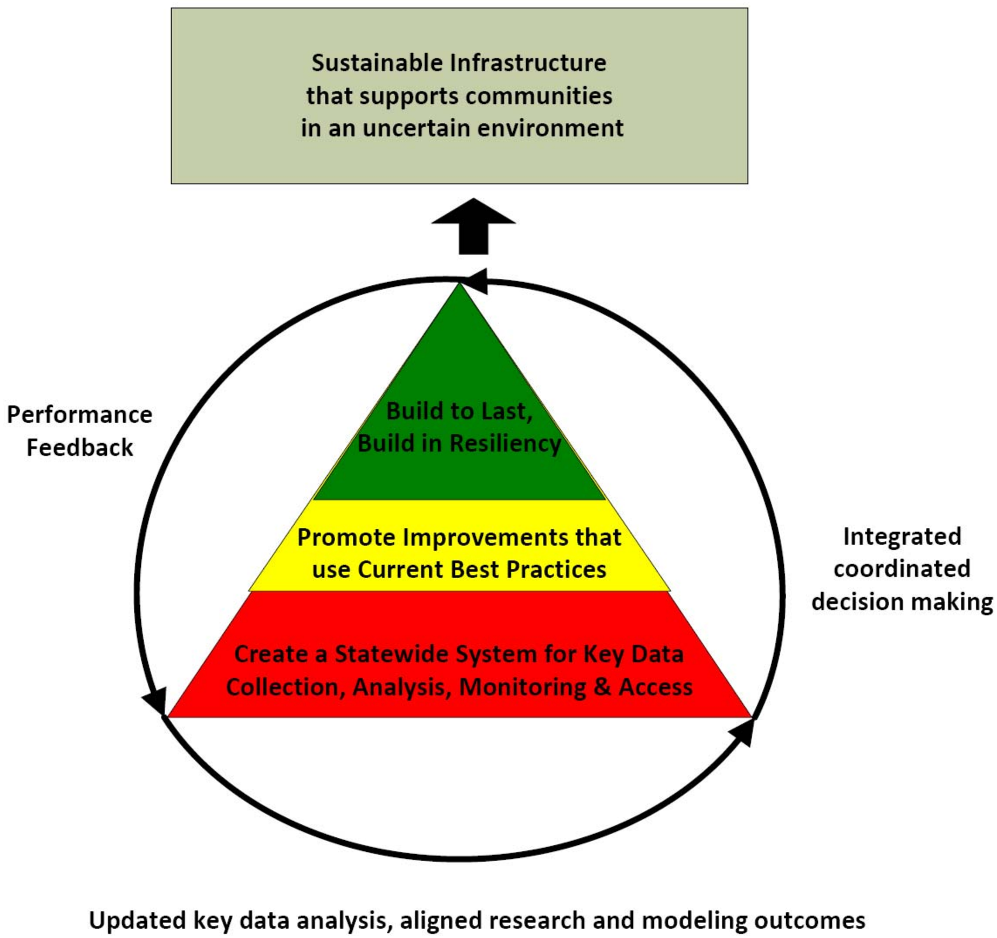
Managing the risks and/or reducing the uncertainties associated with climate change will take time. Promoting sustainability, reducing operating costs, and protecting/extending the service life of existing infrastructure is always worthwhile. Simultaneous with PI-1, improvements to existing infrastructure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

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

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

Box 4-2 summarizes the recommendations for Alaska's public infrastructure. The recommended adaptation options are designed as an integrated system (Figure 4-1). The three policies (in the triangle) build upon and support one another. Continued, routine communication and feedback is essentially to adapt and refine actions taken over time.

Figure 4-1



Required Actions. The Public Infrastructure Technical Work Group (PI TWG) policy system to adapt Alaska's public infrastructure to a changing climate requires that four actions take place for both short and long term success.

1 **There must be across the board improvement in the coordination and accessibility of information**. This includes information on the condition of existing infrastructure and the environment where it is located; information on updated forecasts and trend analysis (such as rate of erosion, permafrost thaw, flooding); and ready access to community plans and infrastructure design.

2 **A program partner should be identified with the capability to organize and host an Information Center or Clearinghouse. Collection, coordination and communication of pertinent information needs to start immediately.** The Center would standardize, coordinate, and link data among the many differing sources to enable queries and integrated use. It would also track and index readily available and cost effective infrastructure development techniques (those that are working and those that didn't work), materials development and testing results, designs development, and contact information.

3. **Create/designate an Immediate Action Work Group (IAWG)-like entity to assume a coordinating role now.** We recommend this group be permanent and be action-oriented, focusing on aligning and coordinating (not regulating) decisions. Impacted and potentially impacted communities, agency funders, and researchers frequently do not know about each other's planning efforts, infrastructure improvement projects, or funding opportunities. An entity such as this is needed to coordinate communication horizontally among partner agencies and vertically among levels of government and other stakeholders. It will streamline processes, eliminate duplicate efforts, minimize unnecessary effort, and minimize transaction costs of developing and carrying out a statewide system. A State of Alaska Executive Order is likely needed to establish this entity or structure. A senior-level executive should be manager. Implementation will be through existing agencies and authorities.
4. Standing still while waiting for improved climate change data and forecasts is not an option, therefore **systematically use current best practice when retrofitting existing and building new infrastructure.** Many of these improvements will be worth doing regardless of climate change effects.

The PI TWG 3-policy system to achieve sustainable infrastructure that supports communities in an uncertain environment is predicated upon these actions.

Research will be a critical part of these recommendations, as described in Box 4-3. The recommendations are also intended to build on existing public and private sector programs and activities as describedin Box 4-4. Both these boxes appear at the end of this chapter.

Description of Public Infrastructure Recommendations

This section describes the options recommended for the Public Infrastructure sector.

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

The goals of Public Infrastructure Policy 1 (PI-1) are to establish a coordinated and integrated system to:

- Observe, collect, catalog, and disseminate data on the existing condition of public infrastructure and the environmental conditions where it is located.
- Use this information to prepare forecasts and trend analysis yielding up-to-date rates of erosion, permafrost thaw, flooding etcetera by region.
- Next, systematically assess the vulnerability of Alaska's public infrastructure in communities to establish the local level of risk.
- Share information in a useable format with communities to enhance understanding of climate change and the affect on the community, and to facilitate and coordinate project planning and development.

Actions needed to achieve these goals include:

1. Standardize information to be gathered. Establish a baseline and benchmarks so that data from differing sources can be compared and to enable analysis over time, regional geographic areas, and across agencies/parties. Set up system to consolidate and link data to enable queries and integrated use.
2. Gather two types of data; on the condition of existing infrastructure and on regional and local environmental conditions. Specific environmental data to gather routinely are:

a. Soil temperature

b. Air temperature

c. Precipitation

d. Surface runoff

e. Shore fast sea ice duration (cold season) and extent (warm season)

f. Coastal wind speed and duration

Organize data around designated climatic regions that are based on geopolitical boundaries. Identify and fill data gaps over time. Use data to run predictive models. Prepare scientifically sound projections of climatic conditions and local environmental conditions including up-to-date rates and maps for:

a. soil temperatures

b. coastal and riverine erosion

c. event intensity

d. 100 year floodplain

Conduct systematic hazard analysis based on up-to-date regional climate data and projection of future conditions. Produce local vulnerability assessments to rank the risk level or vulnerability of existing infrastructure in communities. Determine the status, capability and vulnerability of current infrastructure. Determine the useful life of current infrastructure. Share this information in an easy-to-understand format to facilitate its use by local, tribal, state and federal users. Distribute results to: infrastructure designers, engineers and professional organizations, and to municipal/tribal governments, state/federal agencies and Non-Governmental Organizations (NGOs). The environmental data and modeling completed in this step is also needed to update engineering designs and codes (policy PI-3) to reflect changing conditions.

3 Update the Environmental Atlas of Alaska.

4 Review agency infrastructure plans for consistency and resilience to climate change to identify and resolve conflicts. Ensure future plans for use of current best practices to repair, renovate, retrofit, replace or relocate.

5 Use a performance feedback loop to improve policy coordination, to update analyzes based on new information on weather, economic assumptions, or demographic changes, and to integrate results of research, foundation and material testing. Continually improve data alignment, scenarios, and assumptions for future infrastructure policies and plans.

6 A ‘go to’ Center or Clearinghouse is needed to standardize, coordinate, and link data among the many differing sources to enable queries and integrated use. The State of Alaska can play a coordinating role to bring state and federal agencies, university resources, professional organizations, local and tribal stakeholders and NGOs together. A coordinating agency must determine what technology is needed for systems to ‘talk’ to each other and what funding is needed to systematically identify, collect, analyze and disseminate data.

These efforts are scalable; they can expand (or shrink) overtime as resources are available. Work can begin immediately using existing resources and data – a starting place is to target a region or location known to be at high risk with vulnerable public infrastructure. Enlarge and build the effort overtime.

PI-2 Promote Improvements That Use Current Best Practices

The goal of Public Infrastructure Policy 2 (PI-2) is to use current best practices to make infrastructure improvements that are worth doing regardless of climate change's effects. This is both critical and practical because we can't stand still while we gather and analyze data and reduce the uncertainties associated with climate change. In the interim PI-2 focuses efforts on accomplishing actions that promote sustainability, reduce operating costs, and protect/extend the service life of existing infrastructure.

Examples include:

- The use of existing technology such as adjustable and/or mobile building foundation systems,
- Building foundations that use thermosiphons or thermopiling,
- Protecting facilities from flood or erosion damage,
- Providing energy conservation upgrades,
- Long-term planning and preparedness,
- Building local capacity for operations and maintenance,
- Promoting energy–efficient technologies,
- Using alternative energy sources, or
- Building with better materials.

Implementation of PI-2 can begin immediately by:

1 Routinely gather and make available information on measures and practices that are, and are not, working to adapt infrastructure. A program partner should be identified with the capability to organize and host an Information Center or Clearinghouse for tracking sustainable and resilient best practices. This Center/Clearinghouse could index readily available and cost effective infrastructure development and protection techniques that are working, that didn't work, materials development and testing results, developing designs, contact information, and more.

2 Integrate factors into agency funding and prioritization formulas (such as Alaska DOT&PF Statewide Transportation Improvement Program-STIP evaluation or Village Safe Water Capital Improvement Project) to reward consideration of climate change and use of current best practices. For example, funding agencies could give higher scores to projects that:

- Include an engineering peer review process incorporating current best practices (as catalogued by the to-be-established Information Clearinghouse/Center),
- Include a value engineering review process that demonstrates improved performance, reliability, quality and life cycle costs.
- Present a project site or community vulnerability assessment to document its location compared to expected hazards.

- Commit to a schedule of reporting environmental data and infrastructure performance (to the to-be-established Information Clearinghouse/Center) following project construction.

By systematically rewarding behaviors that promote the construction of more resilient and sustainable infrastructure, the State will be better prepared to meet the future.

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

The goal of Public Infrastructure Policy 3 (PI-3) is to build to last by building resiliency into Alaska's public infrastructure. This can be done by:

- Building in locations outside of hazard zones (that have been updated and defined using climate change modeling),
- Building infrastructure to withstand the expected forces at the location over the life of the infrastructure, or
- Designing and locating public infrastructure to meet acceptable risk limits.

To be successful we will need updated hazard zone locations, revised data on expected local forces and conditions for which infrastructure must be designed, research and testing of foundation designs and construction methods that can adapt to or withstand expected impacts, and modification of some engineering design standards, building codes, and operation and maintenance practices.

Three points to achieve are:

1. Meet or exceed infrastructure design life.
2. Optimize life cycle costs/asset management practices.
3. Create resilience to withstand expected weather events and a changing environment. Design infrastructure using the best science combined with appropriate building codes and engineering standards.

There are many ongoing applied research and technology projects looking to find ways to better predict climate conditions, more routinely locate infrastructure, and design infrastructure to better adapt to new conditions.

The challenge, and why an entity that can increase communication and coordination is so strongly needed, is that impacted and potentially impacted parties do not routinely know about these and other efforts, nor are the results being routinely shared with all who could benefit. The lack of routine coordination and information sharing raises costs, creates redundancies and adds inefficiencies to efforts to adapt Alaskan infrastructure. **To be successful in implementing PI-3, PI-2 and PI-1, create/ designate an IAWG-like entity to assume a coordinating role now.**

Box 4-4. Relevant Current Activities

There are many ongoing applied research and technology projects looking to find ways to better predict climate conditions, more routinely locate infrastructure, and design infrastructure to better adapt to new conditions. The challenge, and why an entity that can increase communication and coordination is so strongly needed, is that impacted and potentially impacted parties do not routinely know about these and other efforts, nor are the results being routinely shared with all who could benefit. The lack of routine coordination and information sharing raises costs, creates redundancies and adds inefficiencies to efforts to adapt Alaskan infrastructure.

Just a few relevant efforts are listed below.

1. SNAP-UAF (University of Alaska Fairbanks) hosts the Scenarios Network for Alaska planning (SNAP), a collaborative organization linking the University of Alaska, state, federal, and local agencies, and NGOs. The primary products of the network are (1) datasets and maps projecting future conditions for selected variables, and (2) rules and models that develop these projections, based on historical conditions and trends. Improvements to make the system and its results more user friendly are needed.

2. UAF Permafrost Research Project (partners: US Federal Highway Administration, Yukon Highways & Public Works, Alaska University Transportation Center, Transport Canada, Université Laval, Public Works and Government Services Canada) A 10-year project is testing 10 adaptive techniques including: Full air convection embankment (ACE), Full heat drain embankment, Covered ACE shoulder treatment, Uncovered ACE shoulder treatment, Heat drain should treatment, Longitudinal convection culverts, Heat drain shoulder treatment with insulation, Snow-free side slopes, Grass covered side slopes, and Light colored bituminous surface treatment (BST).

3. Cold Climate Housing Research Center –Sustainable Northern Shelters Project was developed to address the needs of sustainable rural housing for northern climates.

4. Institute of Social and Economic Research-University of Alaska Anchorage (ISER–UAA) development of a preliminary and limited database of existing public infrastructure created to project the added cost (above normal wear and tear) from the effects of climate change on infrastructure at risk. See Larsen et al. 2007 ISER-UAA (2008) and Foster and Goldsmith 2008

Box 4-5. Public Infrastructure Recommended Research Needs

The Research Needs Work Group identified several needs both to assist implementing the recommendations and to help the State of Alaska better understand the impacts of climate change on its public infrastructure:

. OVERARCHING RESEARCH NEEDS

PI/RN-1 Down-scale. Collect climate data and develop methodologies and capacity to enhance and increase the resolution of climate forecasting models.

PI/RN-2 Develop and deploy effective mechanism(s) to increase the availability and maximize the exchange of authoritative, defensible, and timely information to support analysis and decision-making on issues of climate change adaptation & mitigation, sustainability, and resiliency.

PI/RN-3 Develop a mechanism to systematically identify, collect, and analyze the data that it needs to economically plan, develop, and manage its public infrastructure in a sustainable manner.

SPECIFIC RESEARCH NEEDS

PI/RN-4 Analyze, develop, and update existing engineering and building codes and construction techniques for new infrastructure and structures in vulnerable areas.

PI/RN-5 Establish an integrated baseline inventory on the location and condition of public infrastructure. Collect, assess and monitor data needed to develop sustainable solutions to adapt public infrastructure to the effects of a changing climate.

PI/RN-6 Identify, analyze, and use national and international research results and products as a basis for developing solutions and expanding best management practices in AK.

PI/RN-7 Update the Alaska Environmental Atlas.

For additional information on each recommendation, see Research Needs Work Group (2009).