The Economic Impact and Consequences of Global Climate Change on Alaska's Infrastructure

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Introduction

The purpose of this study is to begin to assess quantitatively the economic impact of and response to global climate change damages to the geography and built environment of the state of Alaska. The events analyzed will include pipeline construction, permafrost thawing and road repair, the engineering of buildings, the impact on power systems and distribution, transportation modes and other examples. It should be noted that much of the damage to infrastructure that we will discuss—roads, transportation, etc.—could be avoided through adequate planning and public policy.

The Importance of Infrastructure

The infrastructure of the state is its built environment. Infrastructure comprises the system of linkages that facilitate and enable the flow of goods and services by the federal and state government, the private sector, and the citizens of Alaska within the state. These linkages include roads, air routes, river systems, and communication lines. It also includes the built and engineered entities within the state: the more than $25B oil-related construction on the North Slope, the factories, buildings, dams, airports and all that comprise the cities and towns: anything that people need in order to live and carry on their business.

Normally, infrastructure is forgotten as an explicit factor in the economic life of the state: it is so pervasive, affects so many of our activities, and shows up in so many different and seemingly unrelated guises that it is difficult to capture, cost or discuss as a single unit. There is no department of infrastructure in state government. But, as will be suggested, infrastructure is critical to the proper functioning of the state economy: it incurs costs to maintain; it can be damaged, removed, or harmed, and must be taken care of for the state to function properly. In this paper we will begin to explore the economic consequences of infrastructure failure.

Examples of Global Climate Change Effects on Alaska's Infrastructure

a) Permafrost [1,2,3,4]

The warming due to global climate change is one of the most obvious influences on the geography of Alaska. Warming affects the roads and structures of a large part of the state because of a single factor: permafrost. Permafrost is a condition of frozen soil and water in various ratios that has a temperature of 32–28˚F. It creates a hazard for any construction or roads, and special engineering precautions must be taken to build on it successfully. Permafrost exists in a continuous or discontinuous layer underground in much of the state, primarily to the north of Anchorage (Figure 1). The Alaska Department of Transportation and Public Facilities (ADOTPF) must solve the problems presented by permafrost in order to maintain roads and facilities, as do Alyeska and other pipeline owners in order to keep their installations intact.

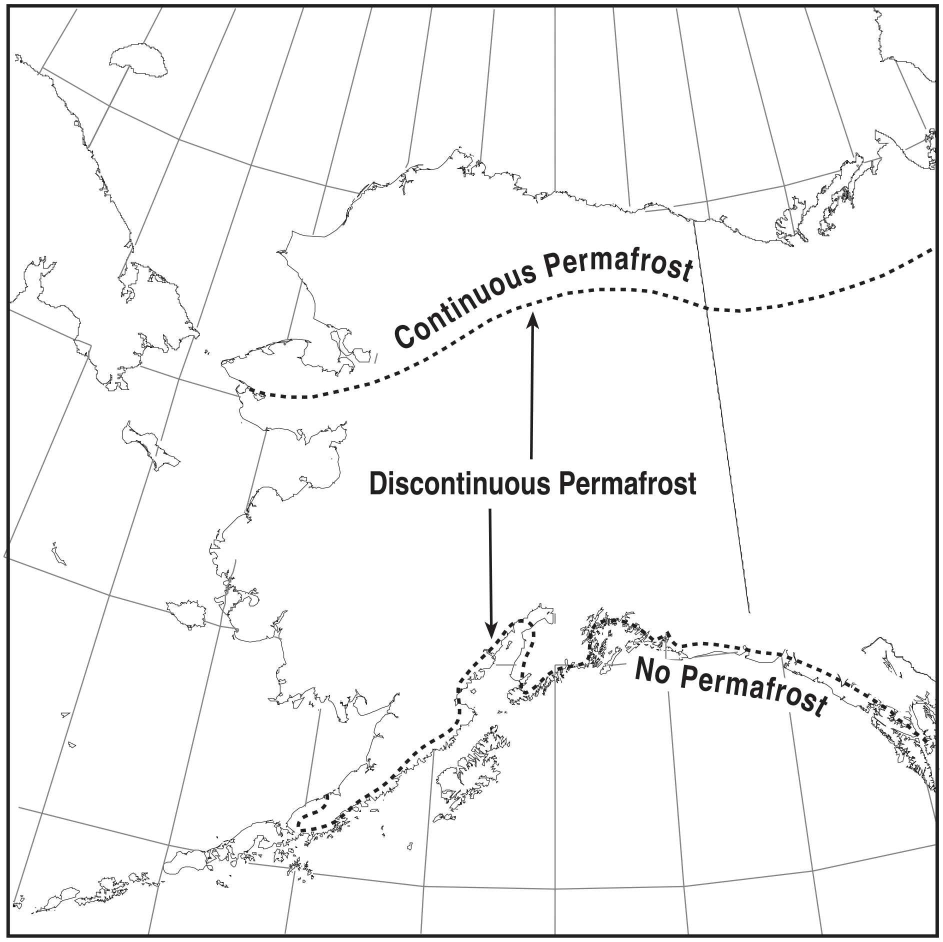

Figure 1. Distribution of continuous and discontinuous permafrost over the Alaskan land mass.

In areas of discontinuous permafrost, a layer of permafrost exists at a depth of about 1 to 50 meters in the ground. Ice or frozen ice lenses in ice-rich permafrost occur in the top of permafrost but the ice can be deeper. The layer of vegetation on the ground serves as a kind of insulation during the summer, preventing extensive thawing of the permafrost. Air temperatures and the depth of snow cover influence the temperature of permafrost. If the depth of the snow cover increases (providing insulation) with no change in air temperature, then permafrost will warm. On the other hand, if there is an increase in the air temperature and the depth of the snow cover is constant, then the warming effects of climate change will be magnified. The thawing of ice-rich permafrost will produce subsidence of the ground surface as the ice volume turns into a slurry. The uneven aspect of the ground as a result of this subsidence produces what is called thermokarst terrain. Thaw settlement has caused problems with human structures being lowered or shifted out of proper alignment.

With warming, the mechanical strength of permafrost decreases, especially in compressive and shear strength, and creep rate increases for frozen ice-rich soils. Adfreeze bond strength between permafrost and piles decreases: if a piling (supporting a pipeline, a bridge or a building) is sitting in permafrost, a change of permafrost temperature from -4 to -1˚C will decrease its load capacity by 70%. Frost heaving may occur because of the thawing of the active layer. The loss of support strength may not occur with thermosyphon supports since they have the capability to freeze the ground in which they are located. But the effective length of a piling will decrease as the frost heave force increases to its maximum. The presence of saline water in the soil, which affects installations near the coast, will decrease the support strength of pilings due to a lower melting temperature for the saline ice.

The active layer lies just below the top surface; it is the soil layer that thaws in summer and freezes again in winter. If the insulating overburden of surface vegetation and underlying organic soil are stripped away during construction, the permafrost will warm by several degrees and the active layer becomes deeper: a talik, or permanently thawed layer, will form. Once a talik forms, the permafrost will thaw continuously from the top down as well as from the bottom upward. If the permafrost in an area or under a road thaws completely and the ice lenses subside, no more change is then able to take place, and the ground will be stable and construction can take place. However, natural thawing of the permafrost layer following surface disturbance is an extremely slow process, often requiring decades to complete unless active thawing is carried out during construction.

Discontinuous permafrost is widespread in Alaska. It stretches from the Yukon River southward, where its temperatures are between 1 and 2˚C. In the continuous permafrost region south of the Brooks Range, the permafrost has warmed by 4˚C and in the discontinuous permafrost region further to the south the warming has been less, 1–2˚C. Some of the continuous permafrost in Alaska has warmed almost continuously since the 1980s. Such warming usually occurs on south-facing slopes where the active layer may thicken. All of AKDOTPF's permafrost research sites along the north-south transect from Prudhoe Bay to Glennallen warmed between the mid-1980s and 1996.

The North Slope of Alaska is an important region of continuous and very deep permafrost that supports billions of dollars of construction for oil production. Changes in thermal characteristics in regions of prospective oil exploration may require changes in engineering practice.

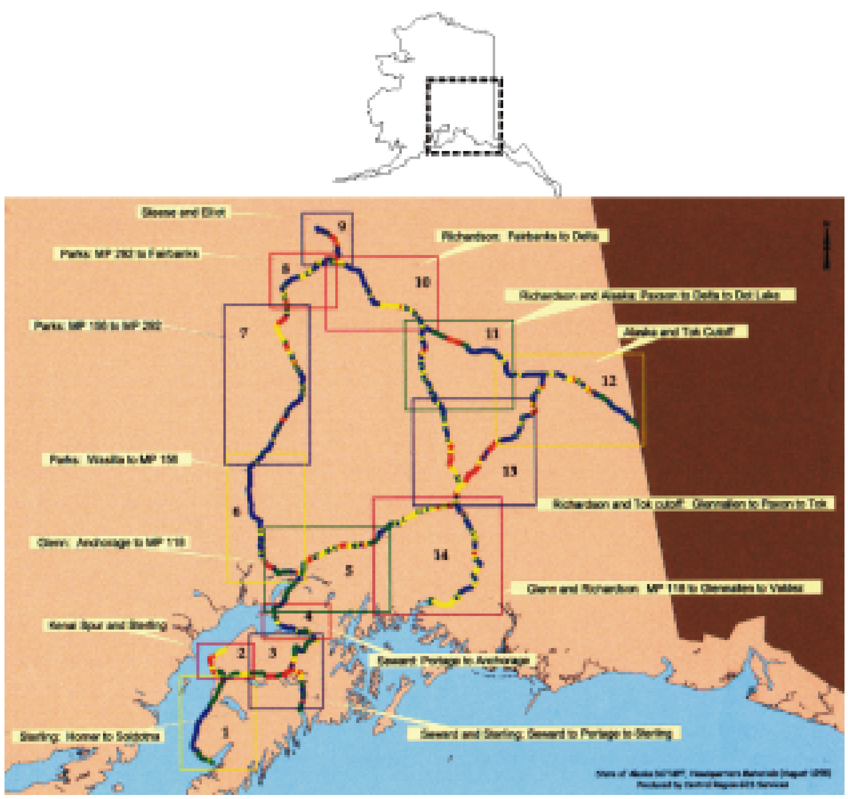

Figure 2. Map of the main surfaced roads in Alaska. The sections in red are at risk due to permafrost; the sections in blue are not.[5]