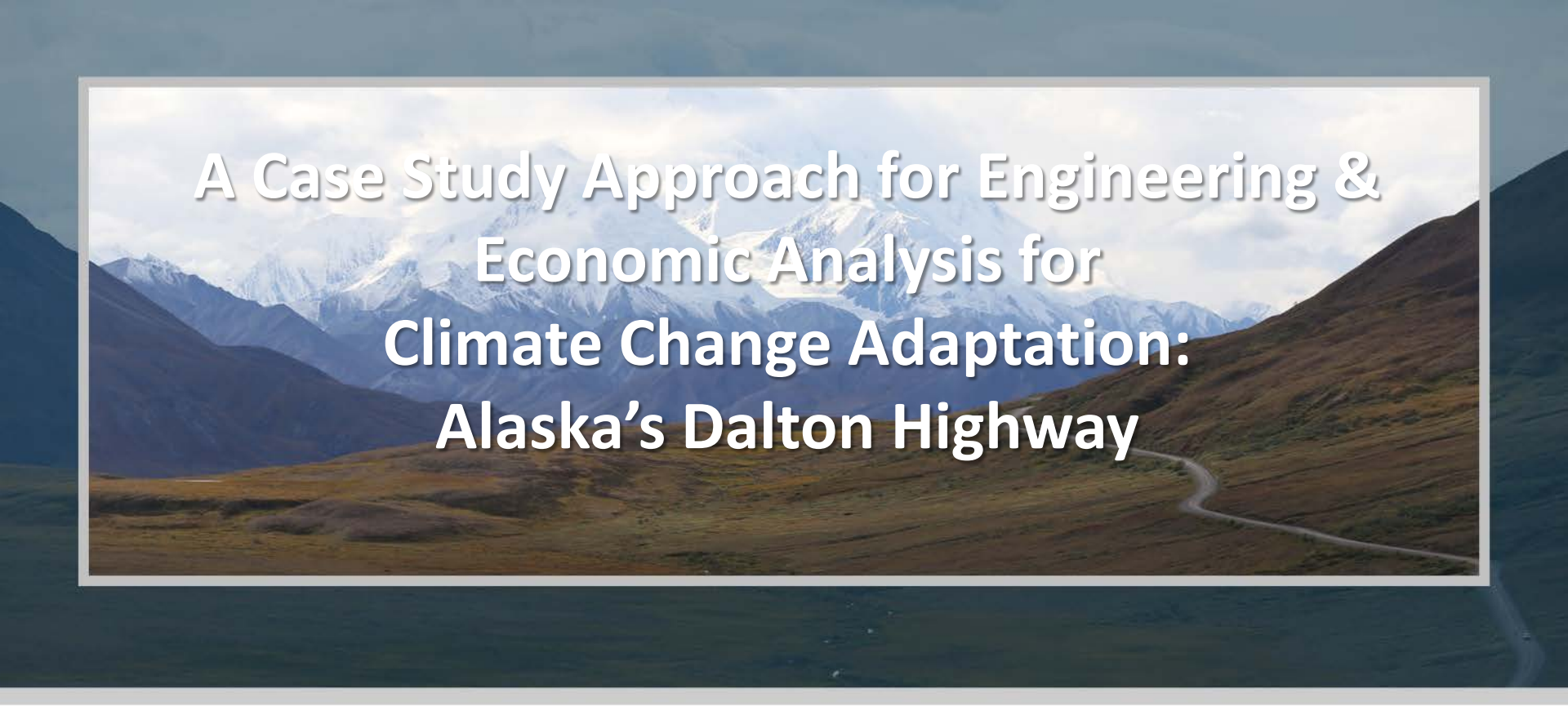

A Case Study Approach for Engineering & Economic Analysis for Climate Change Adaptation: Alaska's Dalton Highway

First International Conference on Surface Transportation System Resilience to Climate Change and Extreme Weather Events

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Participating Agencies:

Disclaimer

- The project is currently under agency review and does not constitute the agency policy and recommendation.
- This presentation only summarizes the results of a ongoing technical study.

Overview

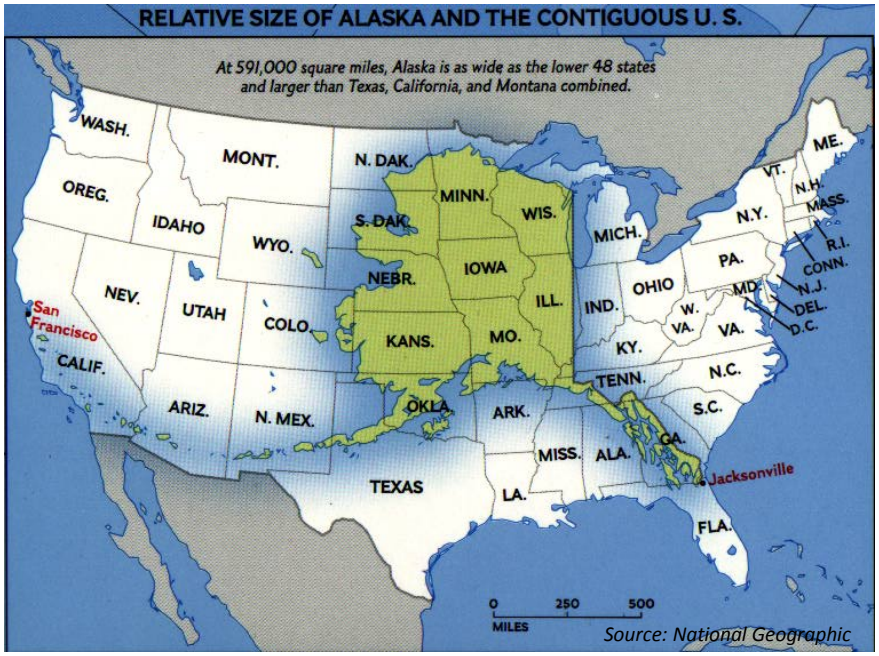
- Part of FHWA climate change adaptation and vulnerability assessment pilot projects
- Commissioned by Alaska DOT&PF and Alaska Federal Land Management Agencies
- Instead of conducting a statewide vulnerability assessment, we focused on detailed case studies at three locations for adaptation option alternative analyses using FHWA framework

Overview

- Pilot Study Goals
  - Demonstrate how representative asset types can be assessed for climate change impacts
  - Illustrate the application of a decision-making framework for selecting an adaptation option
- Case Studies
  - Kivalina Airport – Sea ice changes, sea level rise, and winds
  - Dalton Highway – Permafrost thaw
  - Igloo Creek Landslide – Permafrost thaw, heavier rains

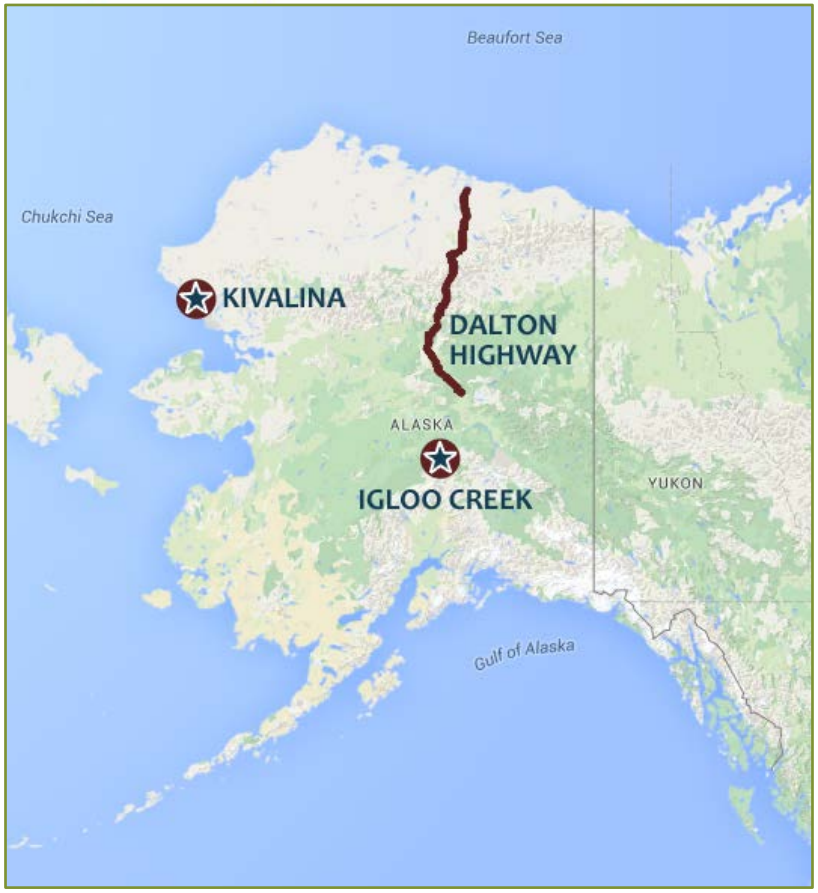
Alaska – In Context

- Bucket List State
  - Remoteness and beauty
  - Conditions unlike any in the lower 48
    - Permafrost, sea ice, accessibility
    - Dynamic climate conditions
  - Slightly higher population than the City of Washington DC



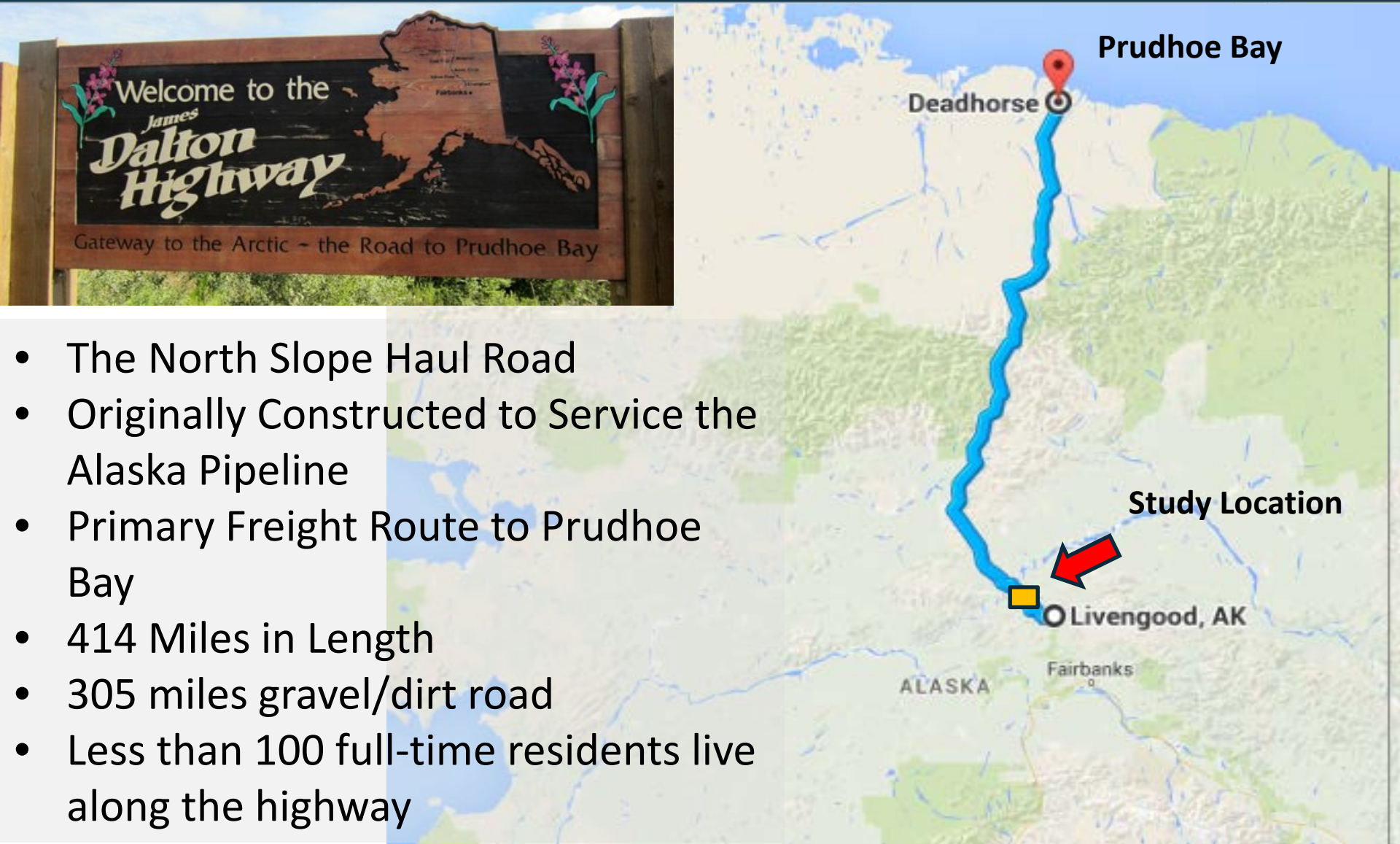
Project Case Study Locations

- Igloo Creek
  - Massive landslide along Denali Park Road
  - Potential contributions:
    - Thawing permafrost
    - Heavy rainfall
    - Steep slopes
    - Soils
- Kivalina
  - Native Alaskan village on the Chukchi Sea
  - Currently protected by sea ice in autumn, a season of major coastal storms
- Dalton Highway
  - Primarily unpaved access road to North Shore sites
  - Permafrost thawing impacting freight and requirements for maintenance



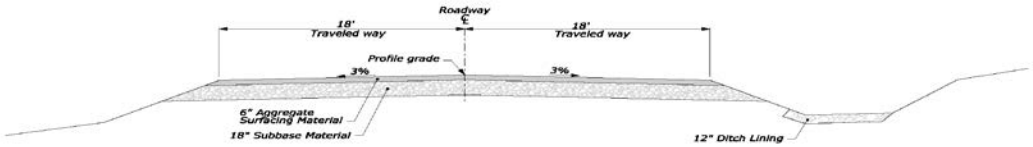
Alaska's Dalton Highway

- The North Slope Haul Road
- Originally Constructed to Service the Alaska Pipeline
- Primary Freight Route to Prudhoe Bay
- 414 Miles in Length
- 305 miles gravel/dirt road
- Less than 100 full-time residents live along the highway



Alaska's Dalton Highway

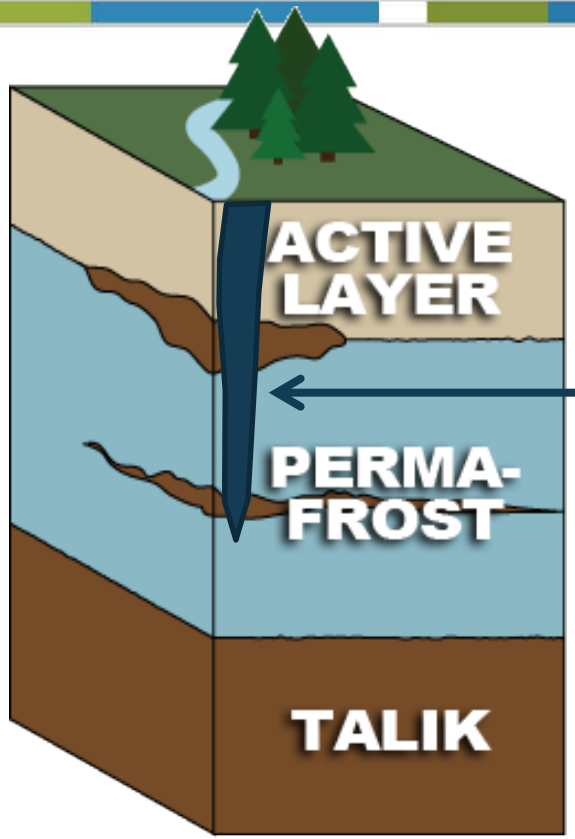
- Usage
  - 150-250 vehicles per day
  - 68% truck traffic
- Maintenance
  - Crews operate two man teams every 50-60 miles
  - Grading in summer, snow removal and treatment in winter
- Design
  - Typical cut/fill sections to construct highway
  - 50 mph design speed



Case Study Objectives

- Assess the effects of permafrost thaw on current roadway surface
- Calculate cost of maintaining the current road for future climate scenario
- Identify adaptation options

Thawing Permafrost and the Highway



Source: Weather Underground

Vegetative Layer (insulates)

Active Layer (freezes and thaws)

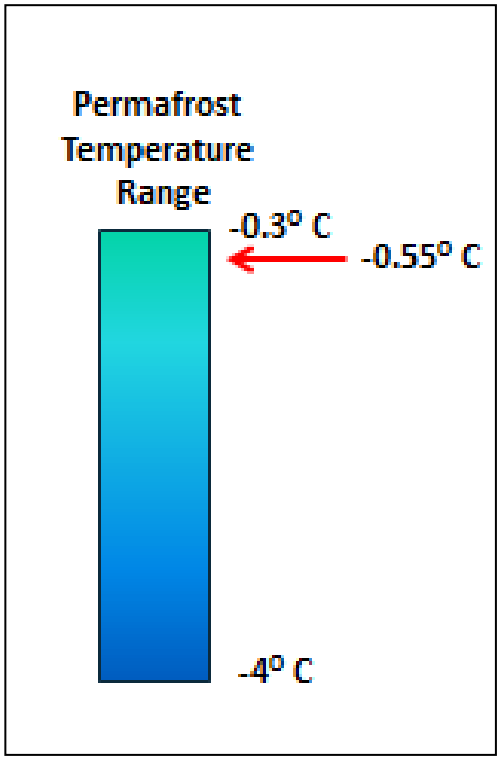
Ice Wedge (mostly frozen water)

Permafrost – frozen water and soil

Talik – soil beneath (or within) the permafrost layer and above bedrock. Insulated from freezing temperatures and warmed by Geothermal heat

Thawing Permafrost and Settlement

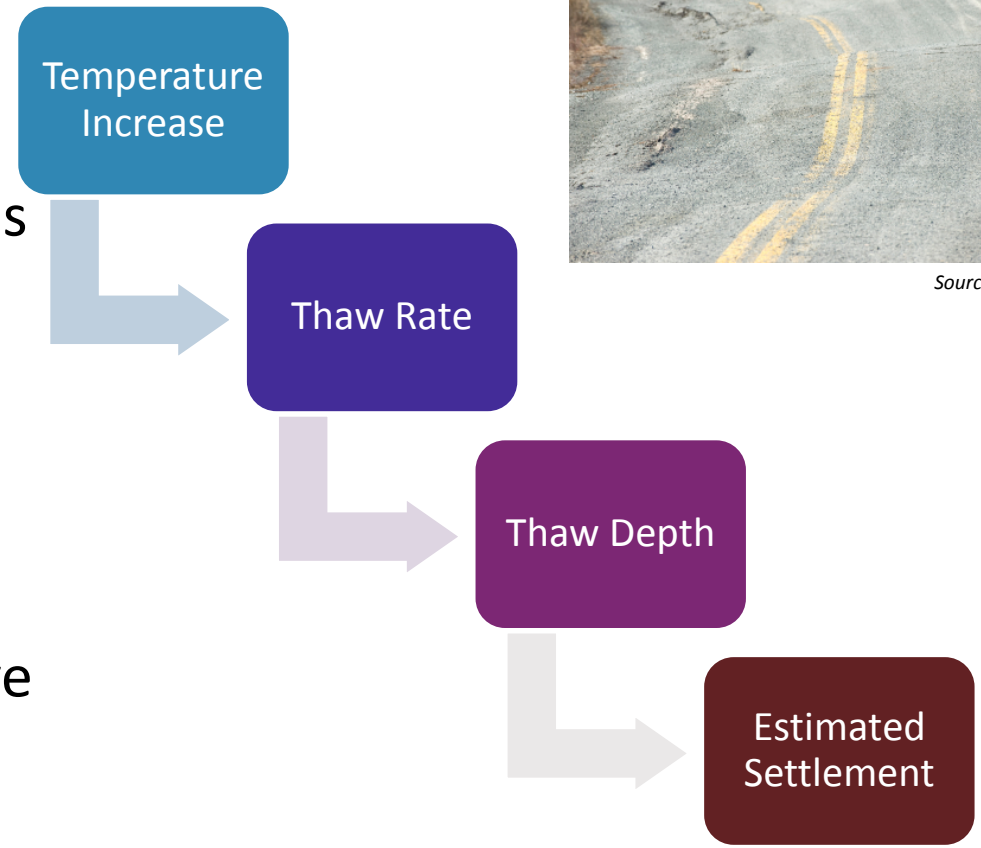
- Temperature of Permafrost
  - 31° Fahrenheit (-0.55°C)
- Thaw and Settlement
  - Settlement
    - 30% settlement factor
      - i.e. – in this area, if permafrost thaws to 10 feet, the ground will settle 3 feet



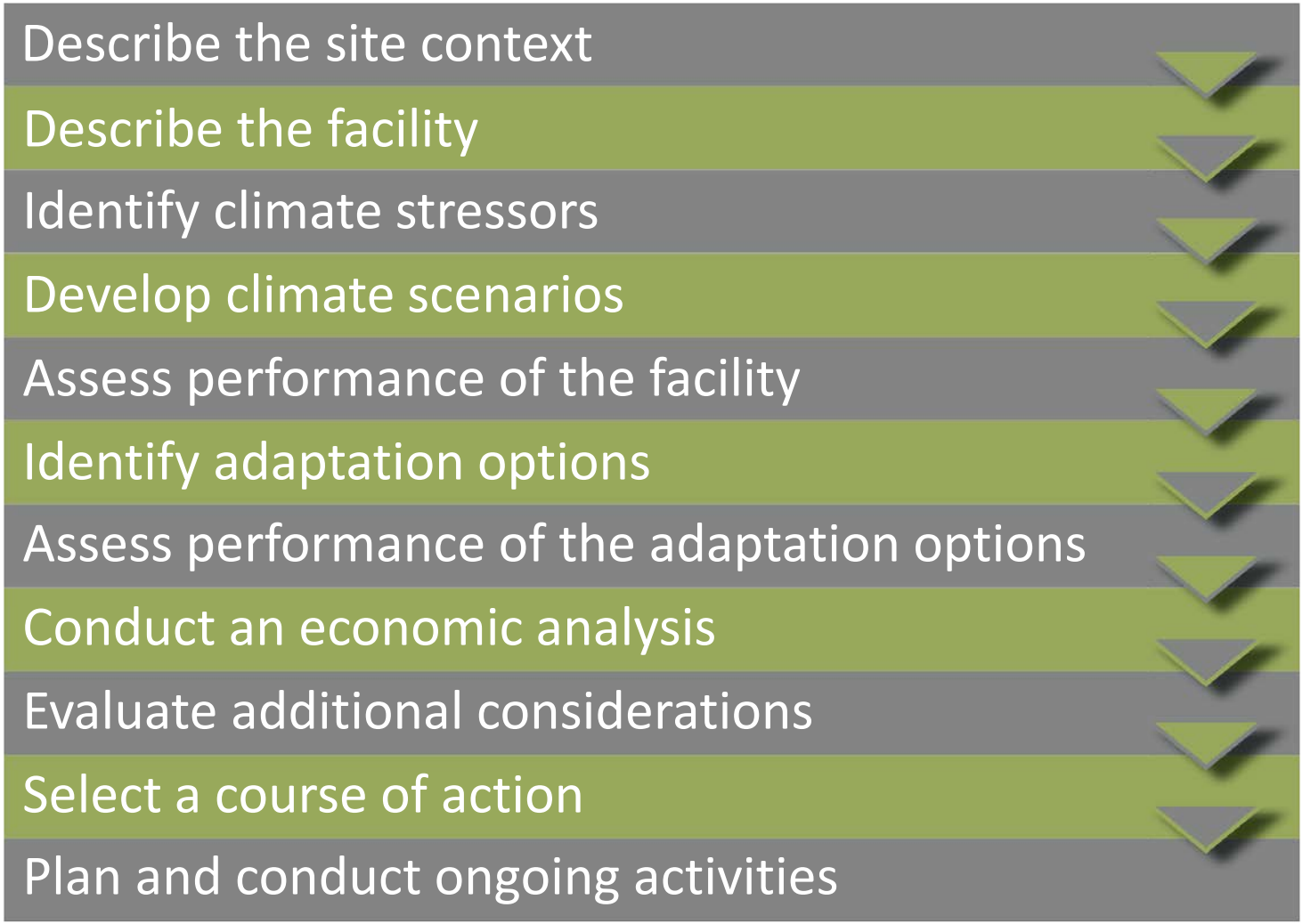
Thawing Permafrost and Settlement

- When Thawing Begins it Should Advance Fairly Quickly Due to Current Local/Permafrost Conditions
- Important to Define a Starting Date and Rate of Change for:
  - Thaw Depth
  - Settlement Rate
- Results of Analysis Will Drive Maintenance Cost Assumptions

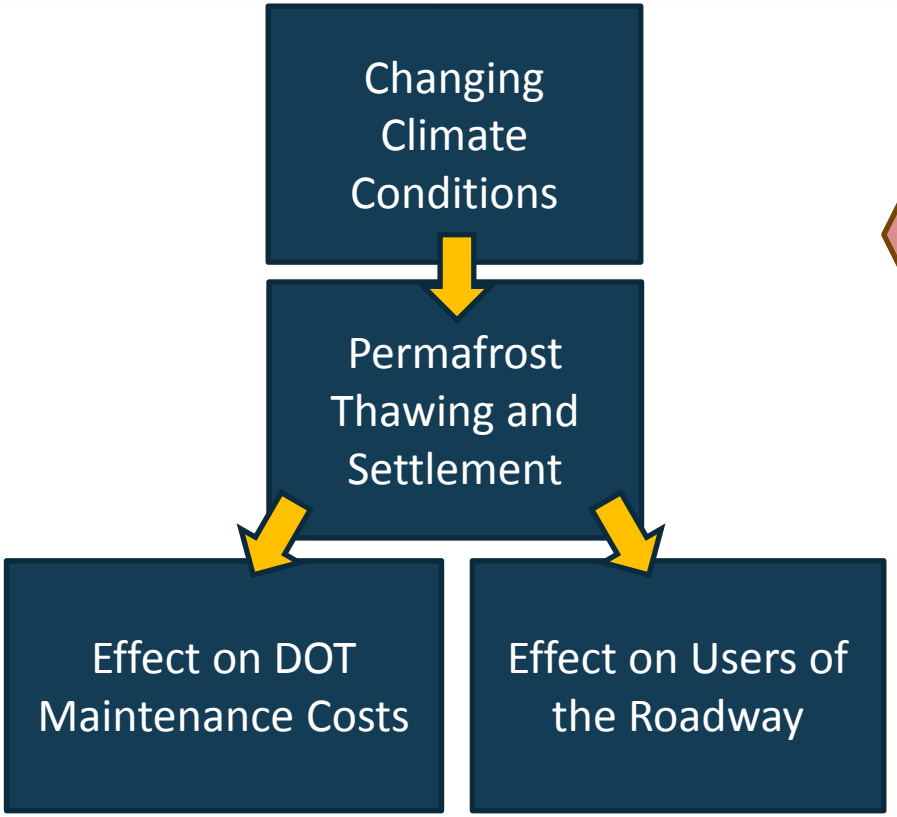
Source: BGS



The 11-Step Assessment Framework



Focus of the Project



Demonstration Project - Present Climate Analysis Methods

Project Timeline

= Present Value Roadway Costs Associated with Climate Change

Defining Changing Climate Conditions and Thawing / Settlement Estimates

Thawing Analysis

- Temperature and Precipitation Changes
- Permafrost thawing
- Land settlement

- Utilize Available Climate Data for two scenarios and models
  - Daily Temperature Data – to 2100
  - RCP 8.5 and 6.0
- Apply Permafrost Thermal Model
  - Input Temperature Data
  - Utilize Field Survey Data Provided by Alaska DOT&PF to Define Conditions
  - Determine Thaw Rates
  - Apply strain percentages

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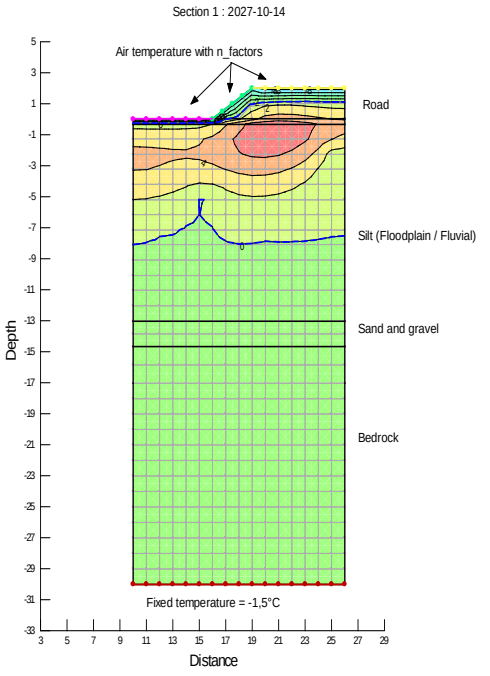
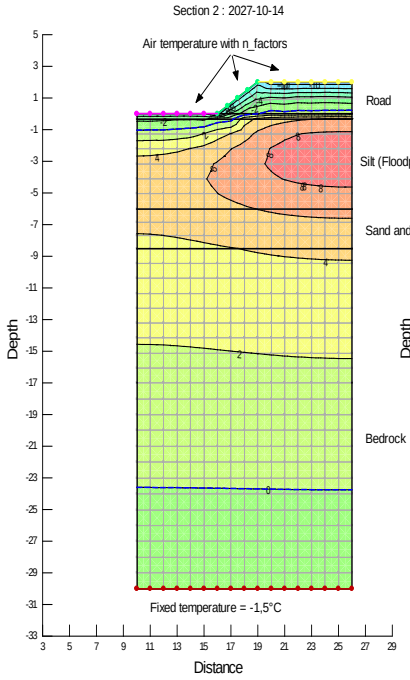
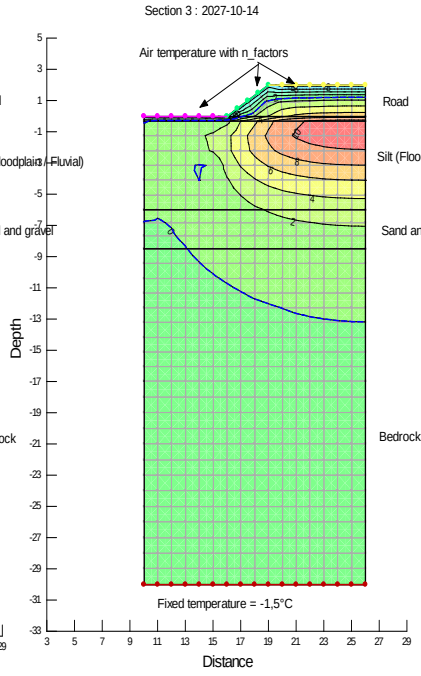
Key: Climate Data Generated or calculated values

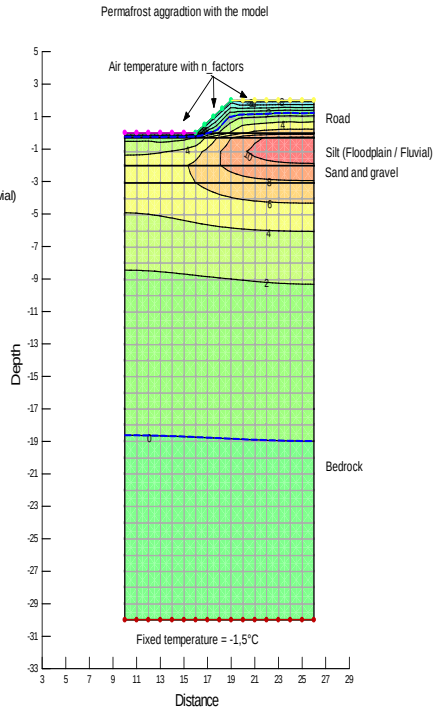
Thermal Modeling for Thaw

- Thermal Model
  - GEO-SLOPE TEMP/W
- Develop Four Cross-Sections for the 2 mile section to reflect varying sub-surface conditions

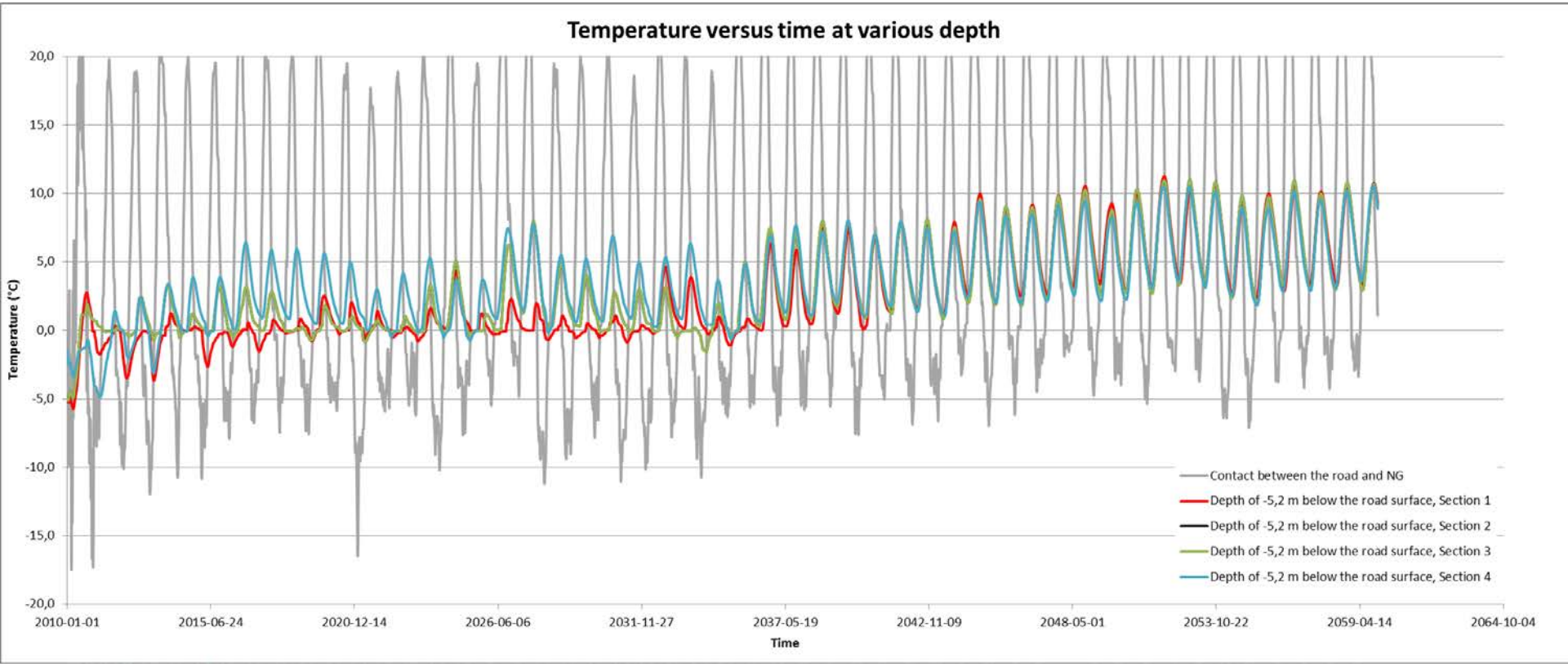




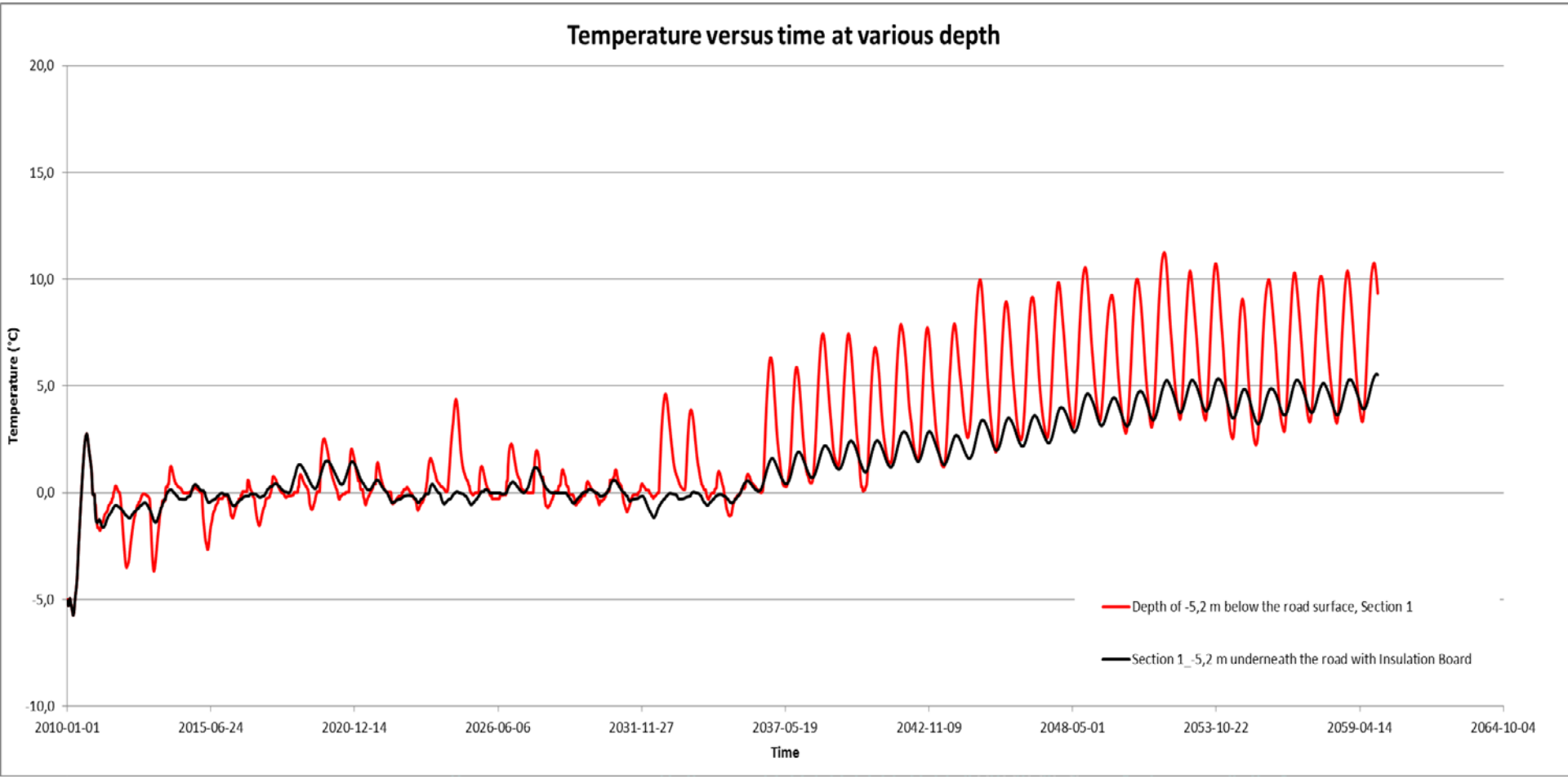




Thermal Modeling for Thaw



Effect of Insulating Material Under Roadway on Permafrost Temperature



Results of Thaw Analysis and Estimated Period Maintenance Costs

Maintenance Cost Based on Ultimate Settlement		
Ultimate Thaw Depth	6	m
Settlement	0.3	m/m (30%)
Settlement	1.8	m
Length of Road	13,000	ft
Width of Road	40	ft
Height of Settlement	6	ft
Volume to be Replaced	3,070,080	cf
Unit weight	135	lb/cf
Tonnage to be replaced	207,230	t
AKDOT cost	32	USD/t
Total cost	6,631,373	USD
Duration of thawing	18	yrs
Avg yearly cost	368,410	USD/yr
Avg yearly cost per mile	150,000	USD/yr/mi

Summary of Costs by Section

Depth of Thaw and Maintenance Costs By Section		
Section	**Thaw Depth by 2033**	**Costs Per Mile**
Section 1:	**6 m**	**$150k/yr/mi**
Section 2	**10 m**	**$250k/yr/mi**
Section 3:	**13 m**	**$325k/yr/mi**

Section 4 is 6 meters deep:
Option to excavate the section and eliminate annual maintenance costs
$1.8M

Estimating Economic Costs To Users

Parameter	Value	Units
AADT	180	Trips per day
Truck %	68%	Percent
Auto %	32%	Percent
Value of Travel Time (truck) per hour	$27.3	$2015 undiscounted
Value of Travel Time (auto) per hour	$16	$2015 undiscounted
Truck costs per mile gravel	$0.79	$2015 undiscounted
Auto costs per mile gravel	$0.31	$2015 undiscounted

Calculating Cumulative Costs

- 3% real discount rate applied to future costs
  - Longer term impacts and lifetime of transportation assets
- Damage/Maintenance costs tallied over a 18 year analysis period to quantify costs
- Costs to Users
  - Assumed an 1% annual ADT growth rate
  - Assumed travel time delays in section due to and increased vehicle maintenance costs

Results

- Total Costs in 2015 Dollars of 18 year analysis period, reflecting climate change effect on maintenance and user costs for the corridor.

	Total Costs
Maintenance Costs	5,218,934
User Costs	1,707,972
Total	6,926,906

Next Steps / Conclusions

- Permafrost thawing costs will increase maintenance cost in the corridor significantly
- Costs to AKDOT&PF for maintaining this section will grow as conditions change
  - Responses can include:
    - Design
      - Insulation Boards, ACE Embankments, Geo-Grid
    - Maintenance/Operations to Address Contributory Effects
      - reducing the speed limit and truck volumes
      - reducing the truck maximum load and utilizing wider tires
      - modifying the snow clearing methods

Questions