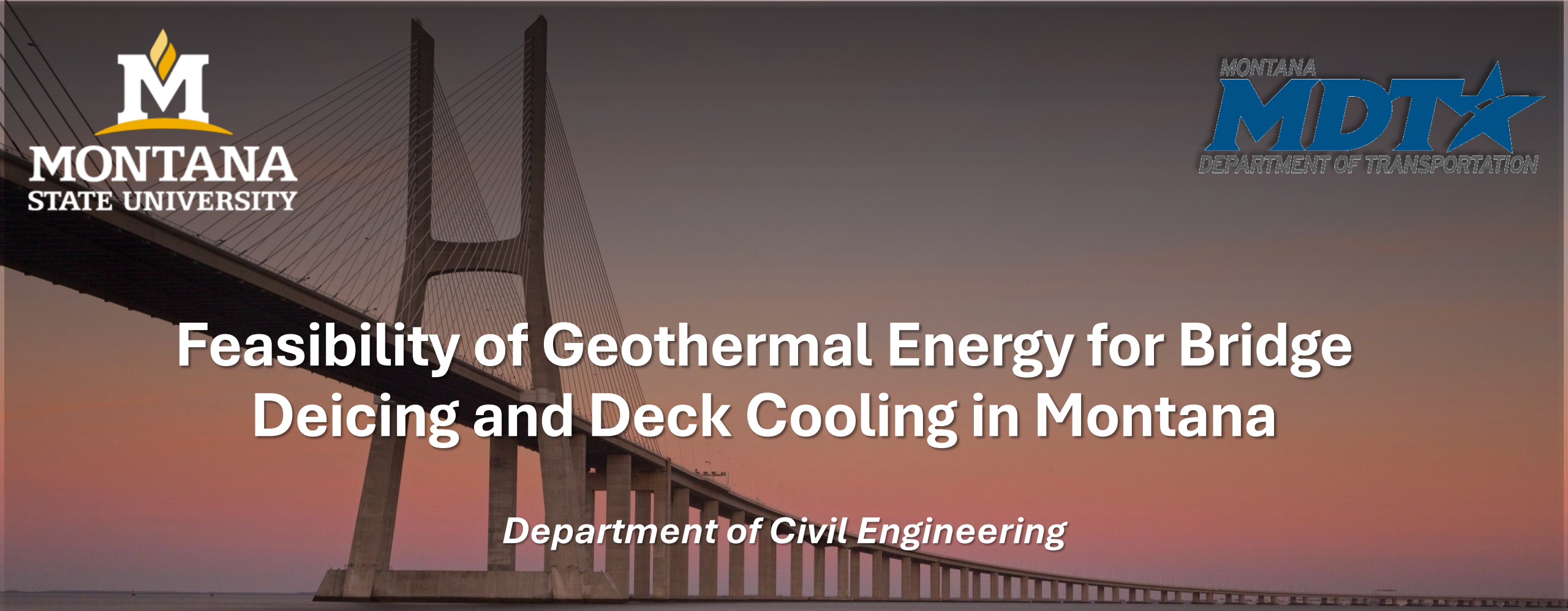


Feasibility of Geothermal Energy for Bridge Deicing and Deck Cooling in Montana

Department of Civil Engineering

Mohammad Khosravi, Katey Plymesser, Kirsten Matteson, Neda Nazemi, Faraz Dadgostari

June 2025

Introduction: Why Bridges

https://wgno.com/weather/the-science-behind-icy-roads-why-bridges-overpasses-freeze-first-during-winter-weather/

Introduction: Bridge Maintenance Issues in Cold Region

Summer

Thermal Expansion

Heat Induced Deterioration

Winter

Reduced Visibility and Safety

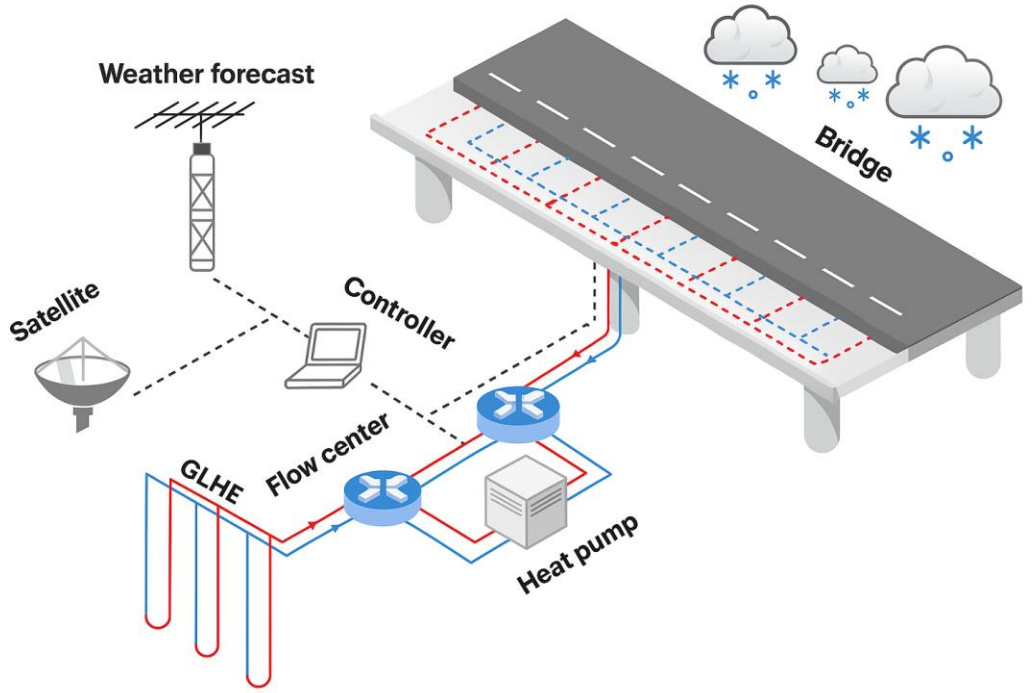
Cracking due to Freeze-Thaw Cycles

Corrosion due to De-icing salts

Introduction: Geothermal Bridge Deck Deicing

Geothermal bridge deck deicing systems transfer energy from the ground to concrete bridge decks through heat exchanger pipes

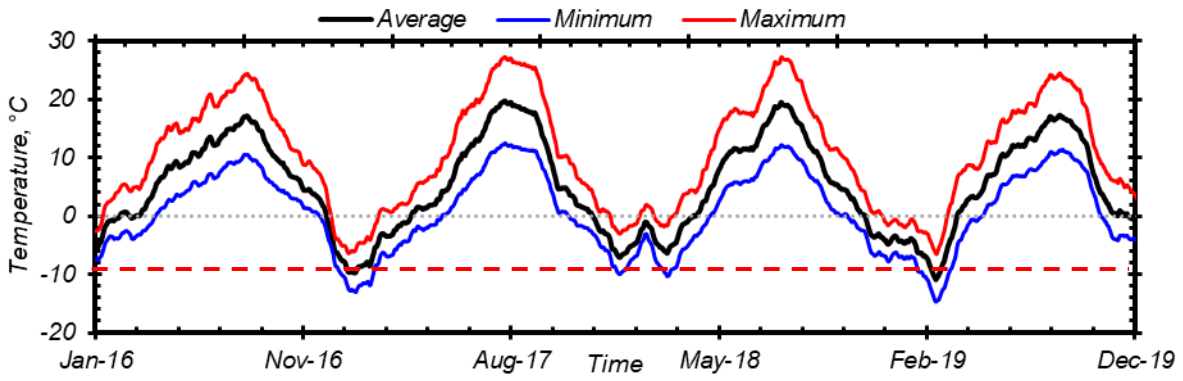
Sidewalk heating in operation (Eugster, 2007)



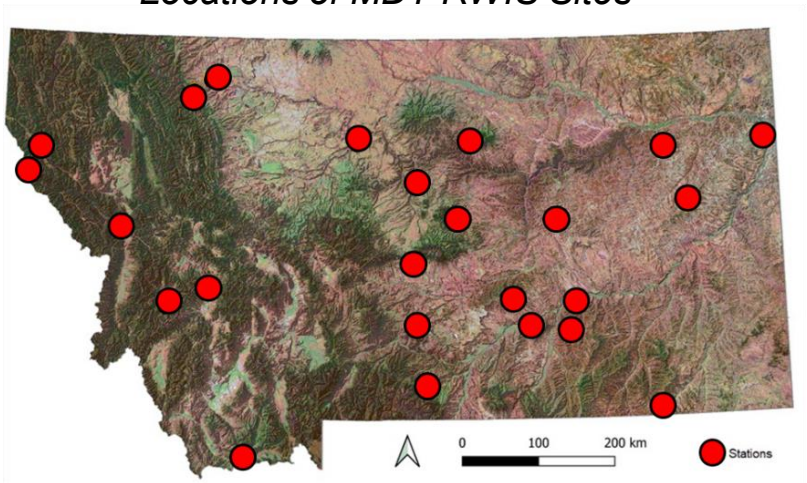
Conceptual diagram of the geothermal heat pump de-icing system (GHDS).

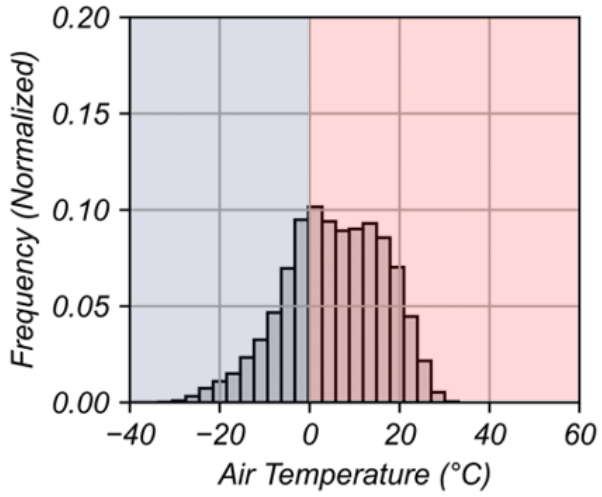
Habibzadeh-Bigdarvish et al. 2019

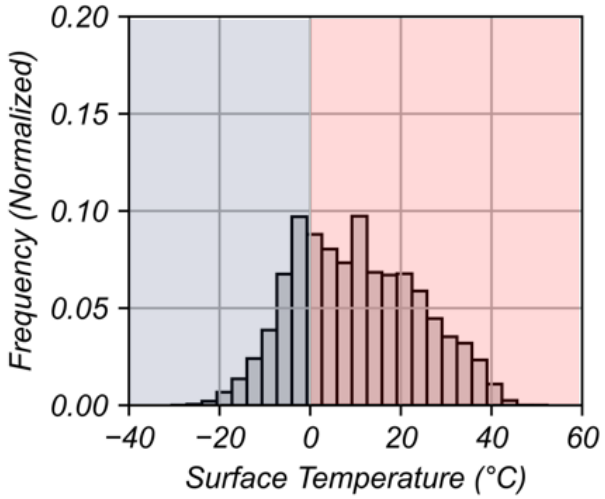
Motivation and Objective: Weather in Montana

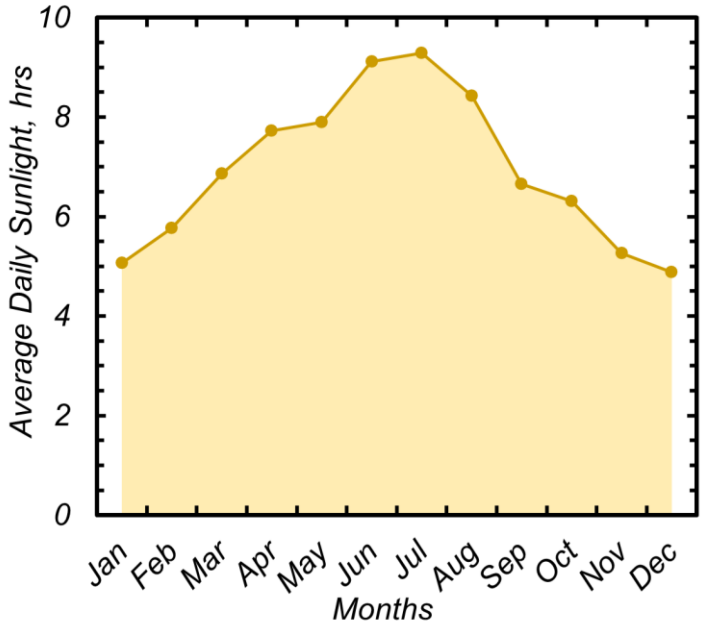


Locations of MDT RWIS Sites

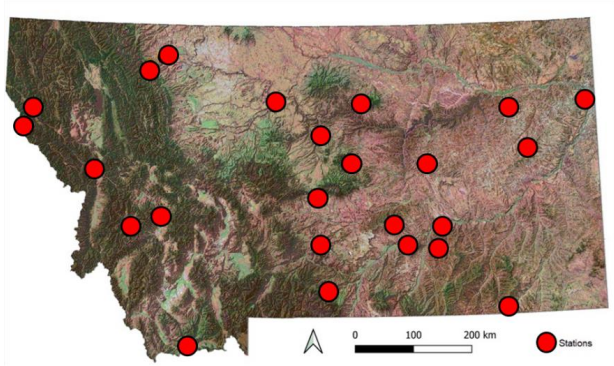


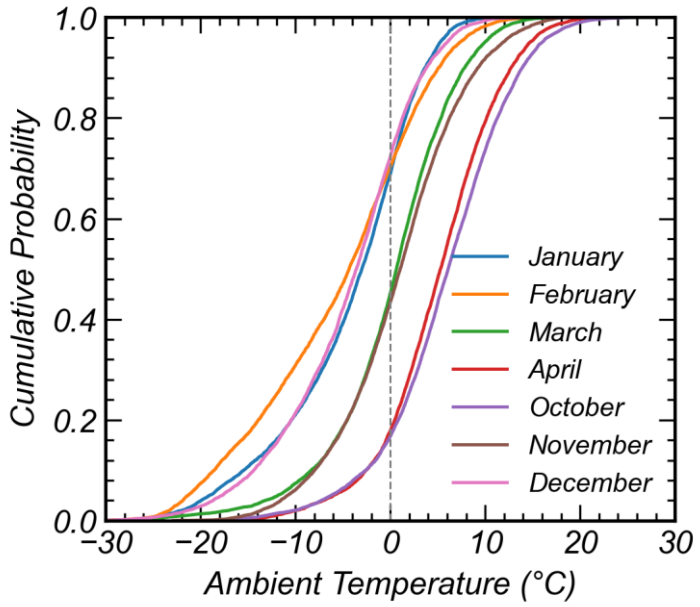


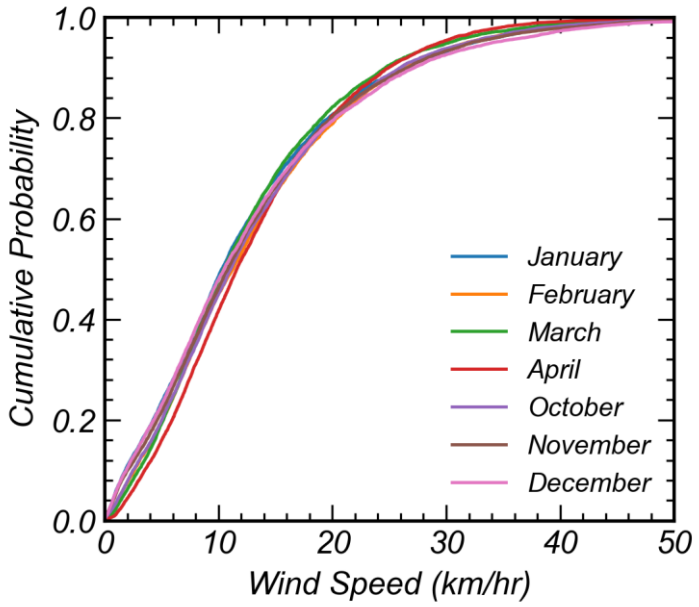


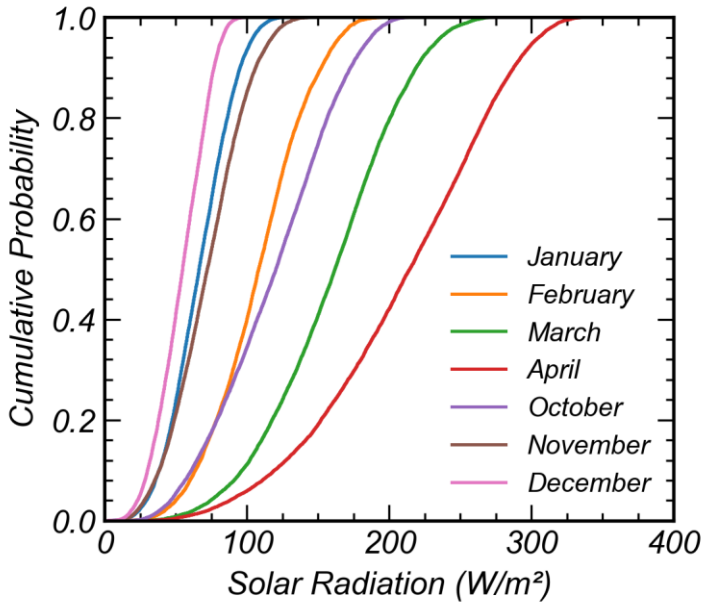


Motivation and Objective: Weather in Montana

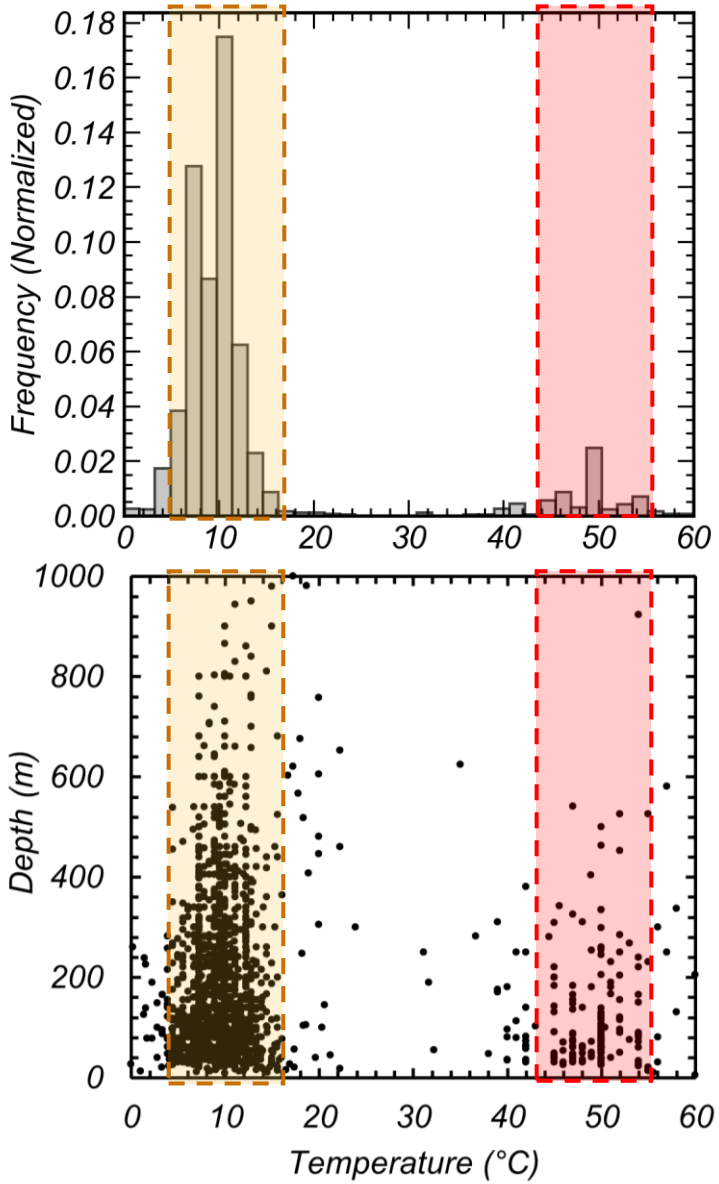




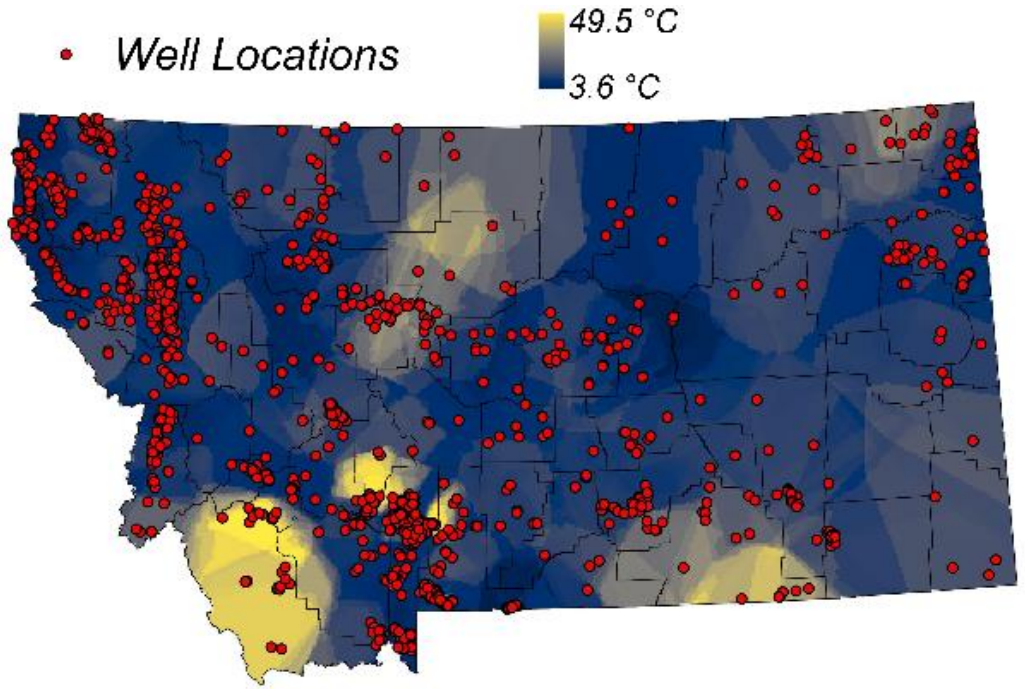




Motivation and Objective: Ground Temperature in Montana



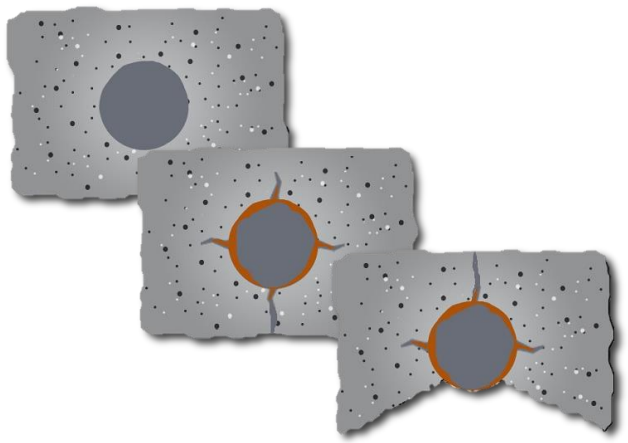
Ground Temperature Distribution in Montana

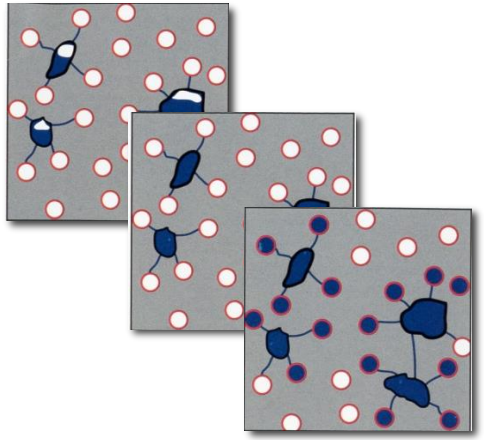


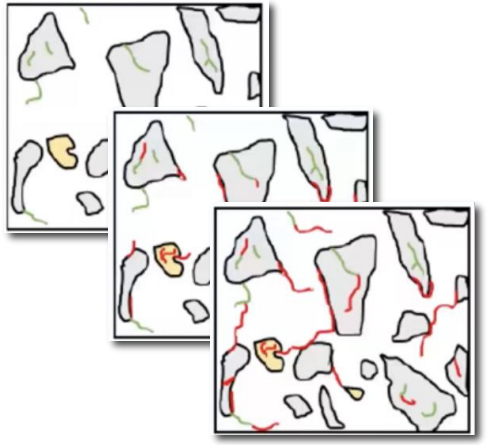
Motivation and Objective

Feasibility of the use of a Ground Source Heat Pump (GSHP) system

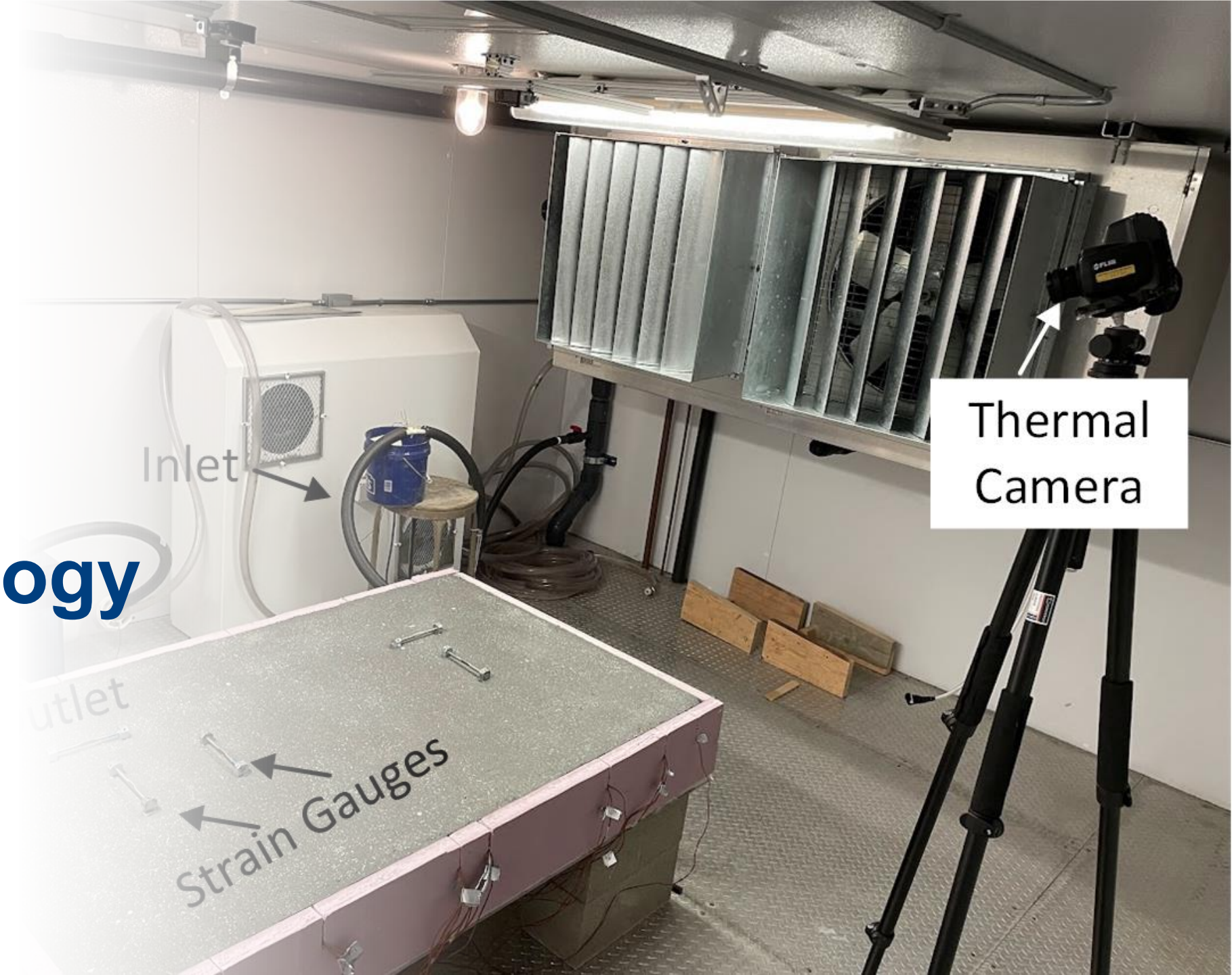
Corrosion due to De-icing salts	Concrete bridge deterioration	Frost Action	Early-age cracking



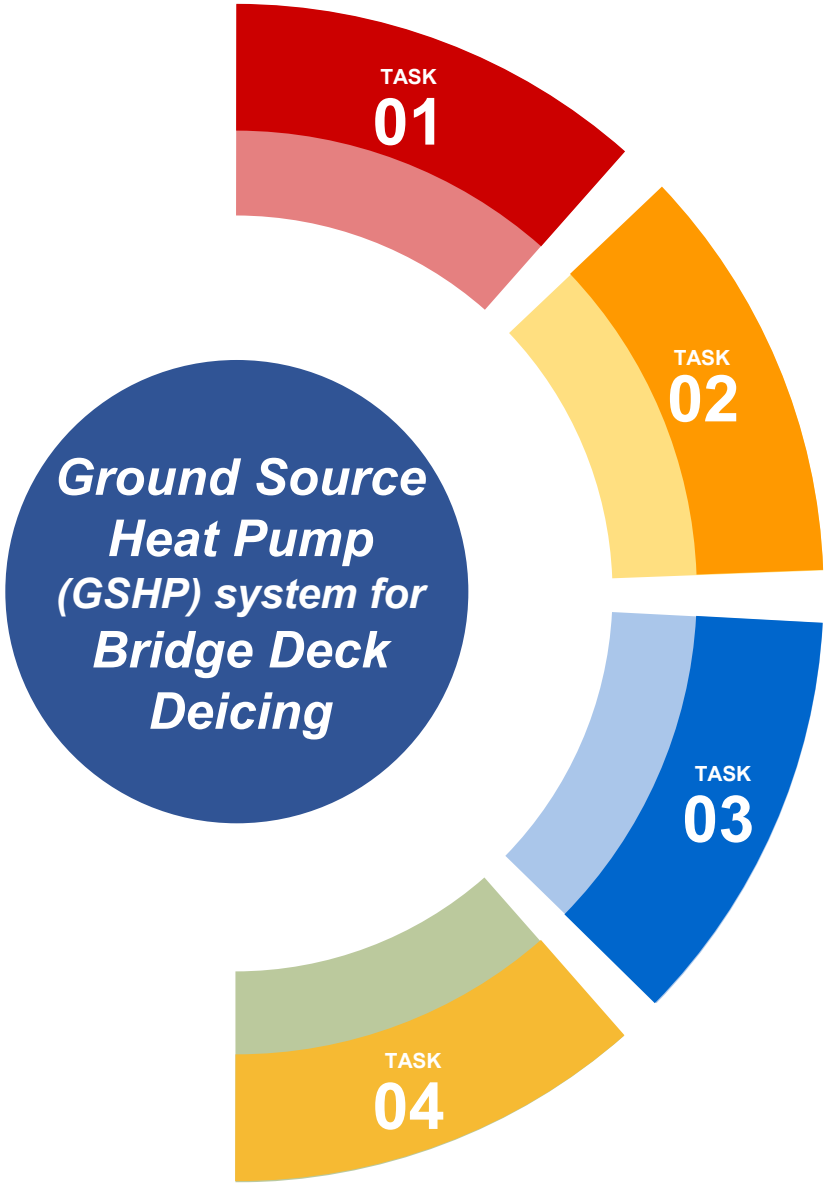


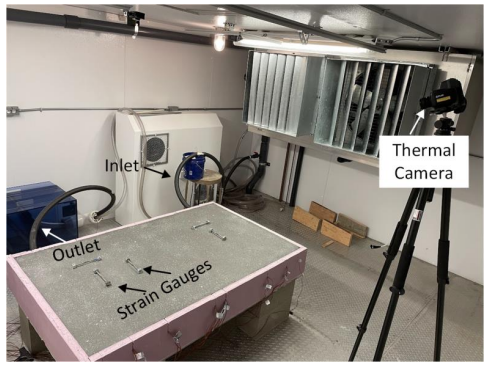


Research Methodology



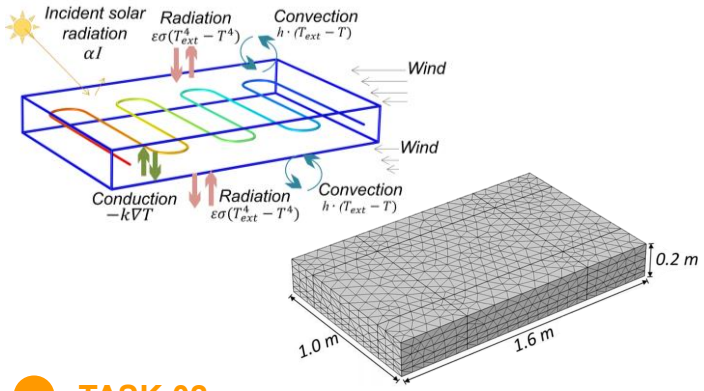
Geothermal Bridge Deck Deicing: Research Methodology





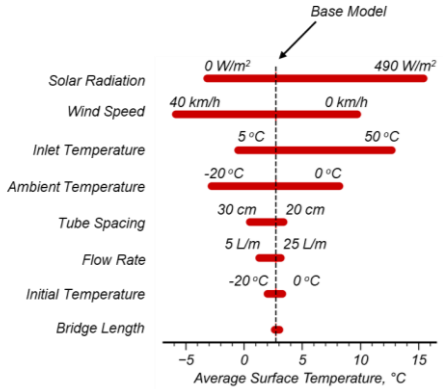
TASK 01

Model Scale Experiments in SRL



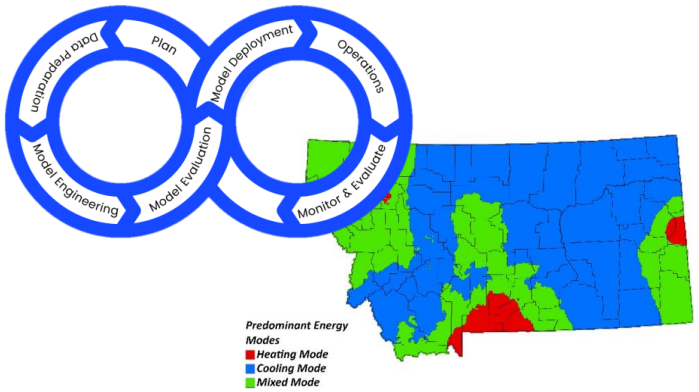
TASK 02

Numerical Model Development and Validation



TASK 03

Parametric Study and Sensitivity Analysis



TASK 04

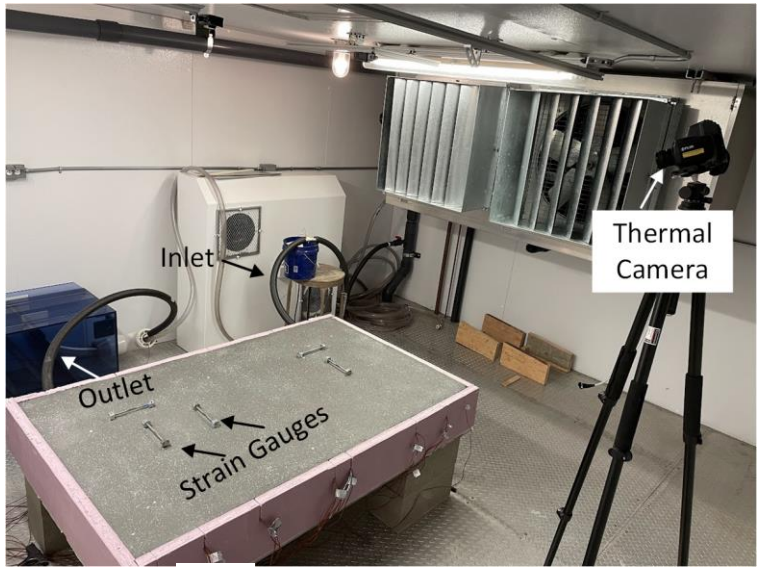
Feasibility Analysis

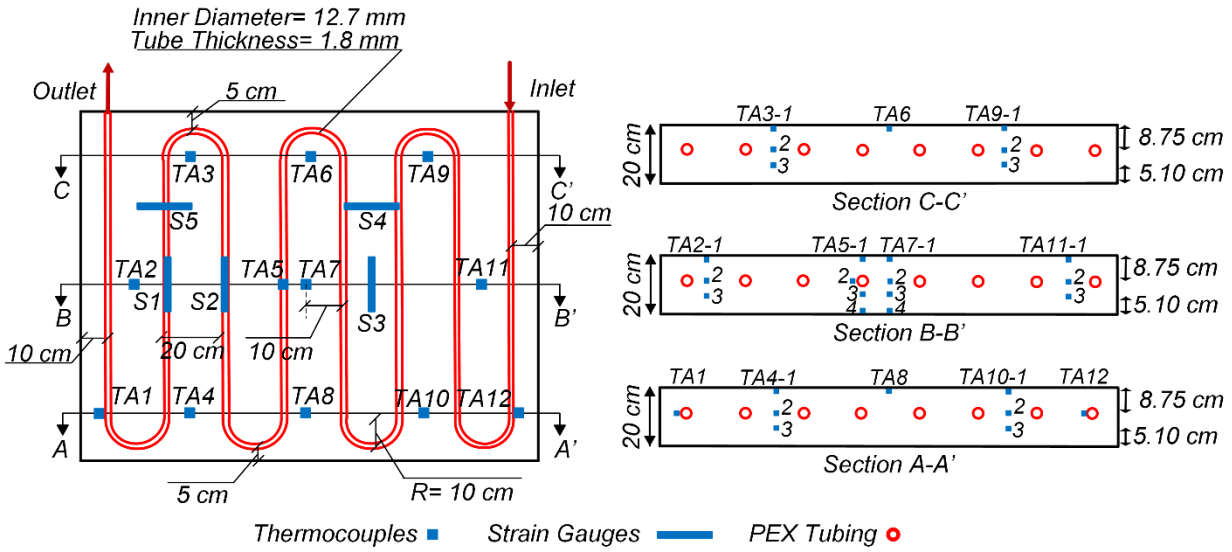
Research Methodology: Model Scale Experiments in SRL

TASK
01

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

Model Scale Experiments in SRL





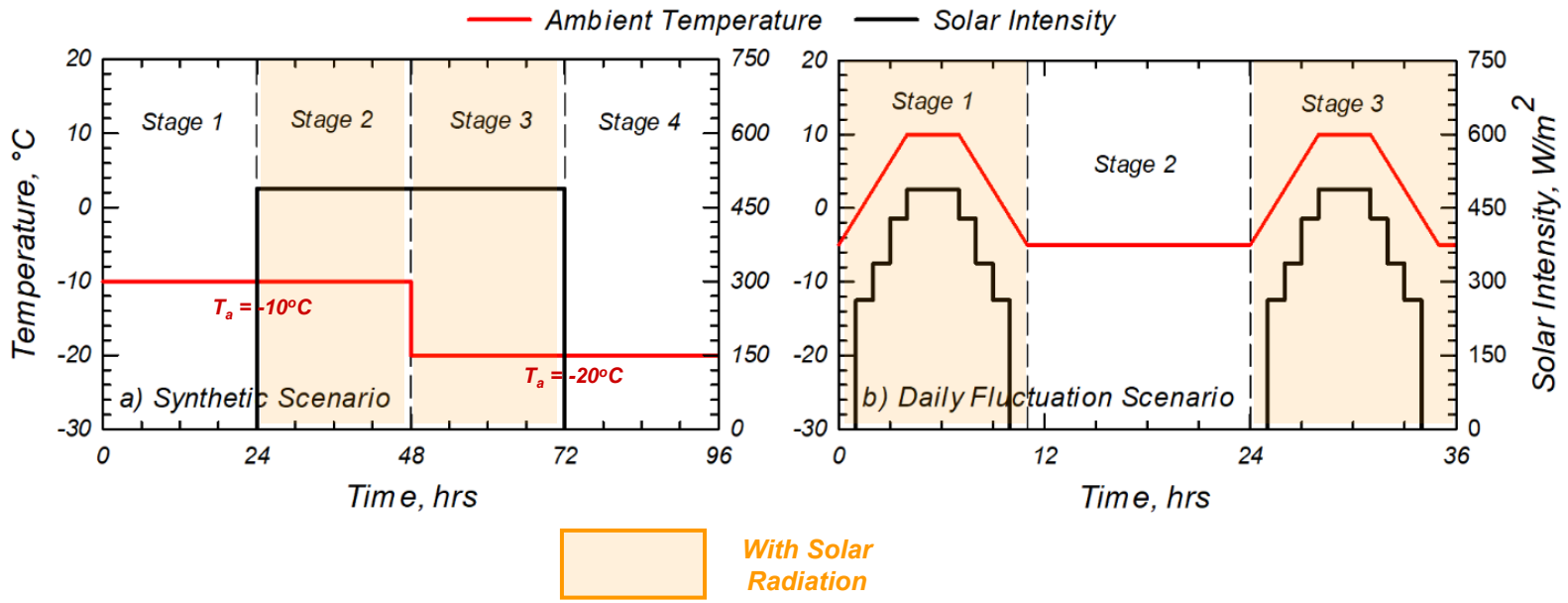
Research Methodology: Model Scale Experiments in SRL

TASK 01

Model Scale Experiments in SRL

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

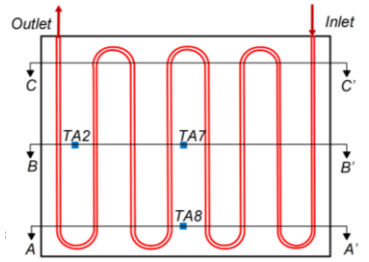
Bridge Deck De-icing	Thermal Movement	Frost Action Theral Gradient	Early-age cracking



Research Methodology: Model Scale Experiments in SRL

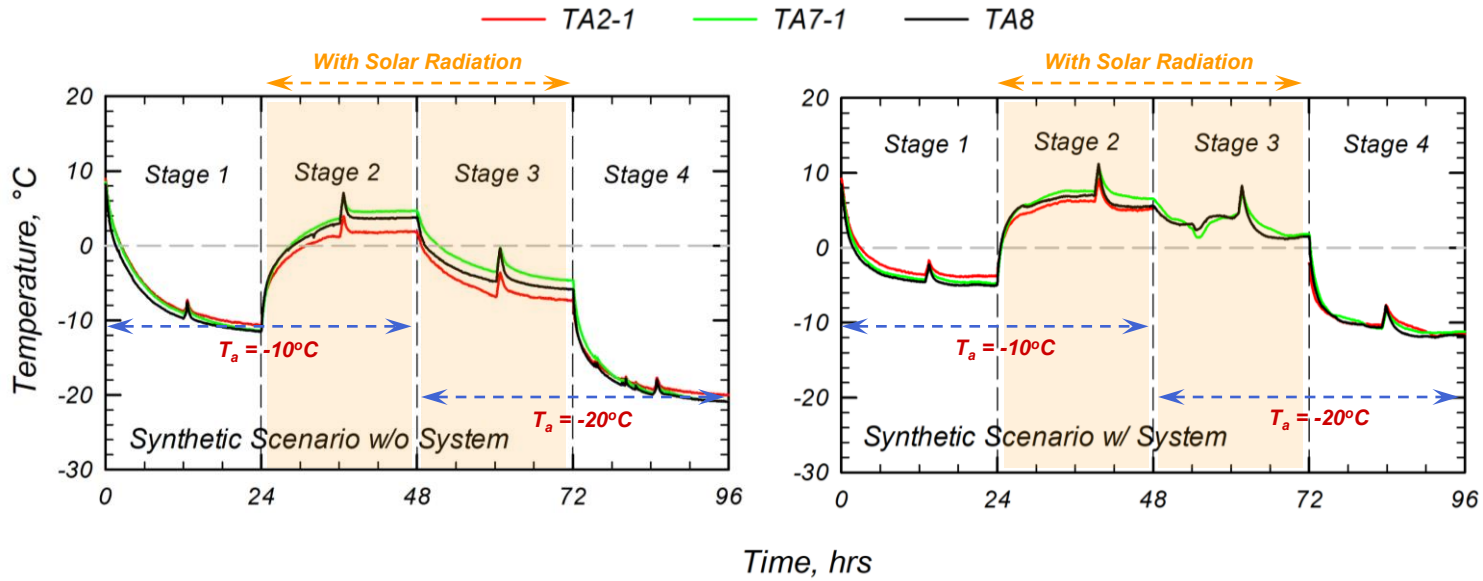
TASK 01

Model Scale Experiments in SRL



Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

Bridge Deck De-icing	Thermal Movement	Frost Action Theral Gradient	Early-age cracking



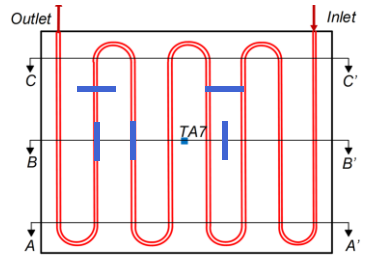
Without Geothermal System

With Geothermal System

Research Methodology: Model Scale Experiments in SRL

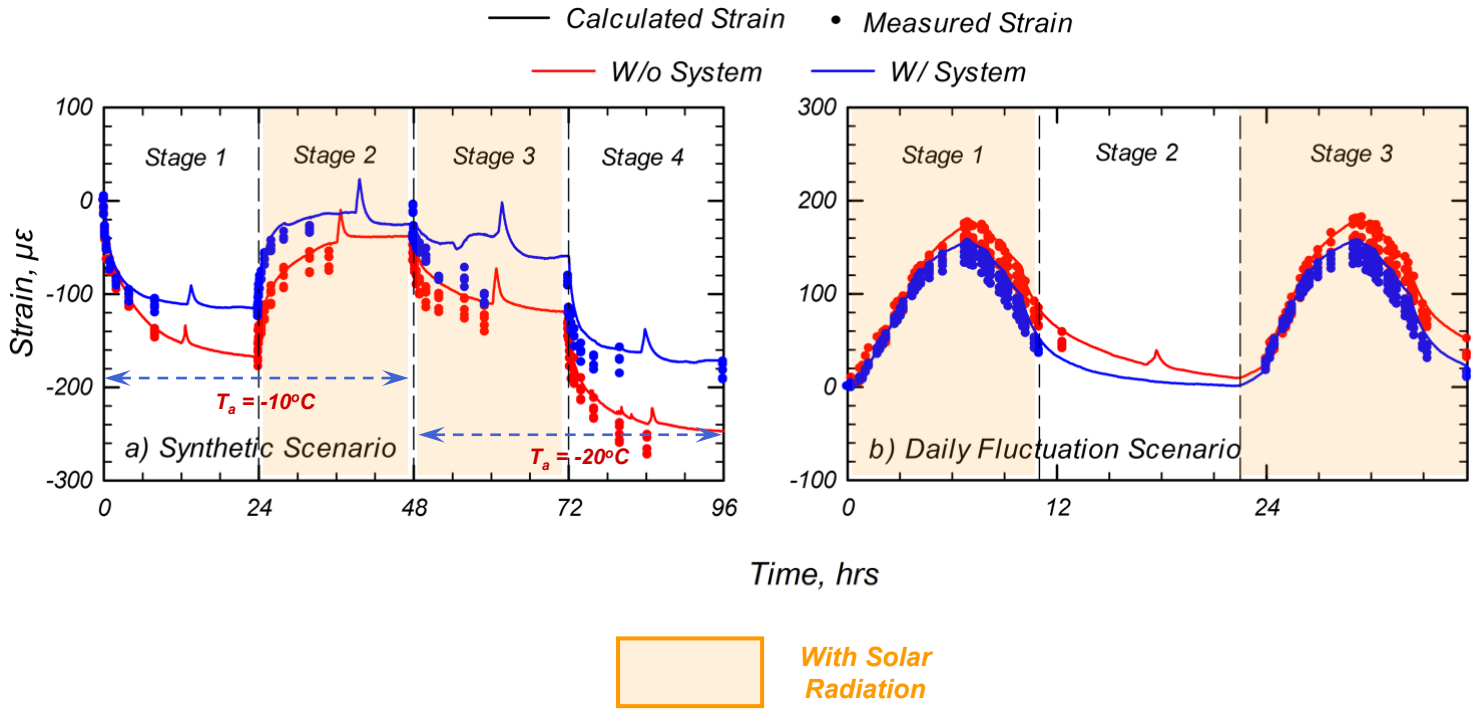
TASK 01

Model Scale Experiments in SRL



Bridge Deck De-icing | **Thermal Movement** | Frost Action Theral Gradient | Early-age cracking

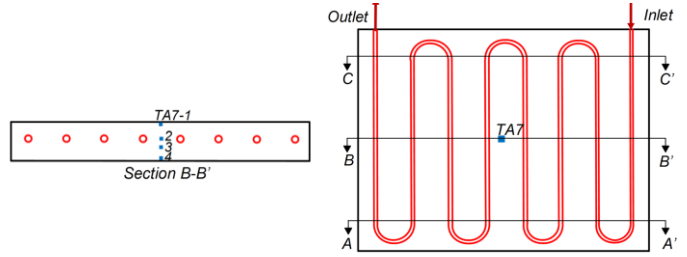
Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing



Research Methodology: Model Scale Experiments in SRL

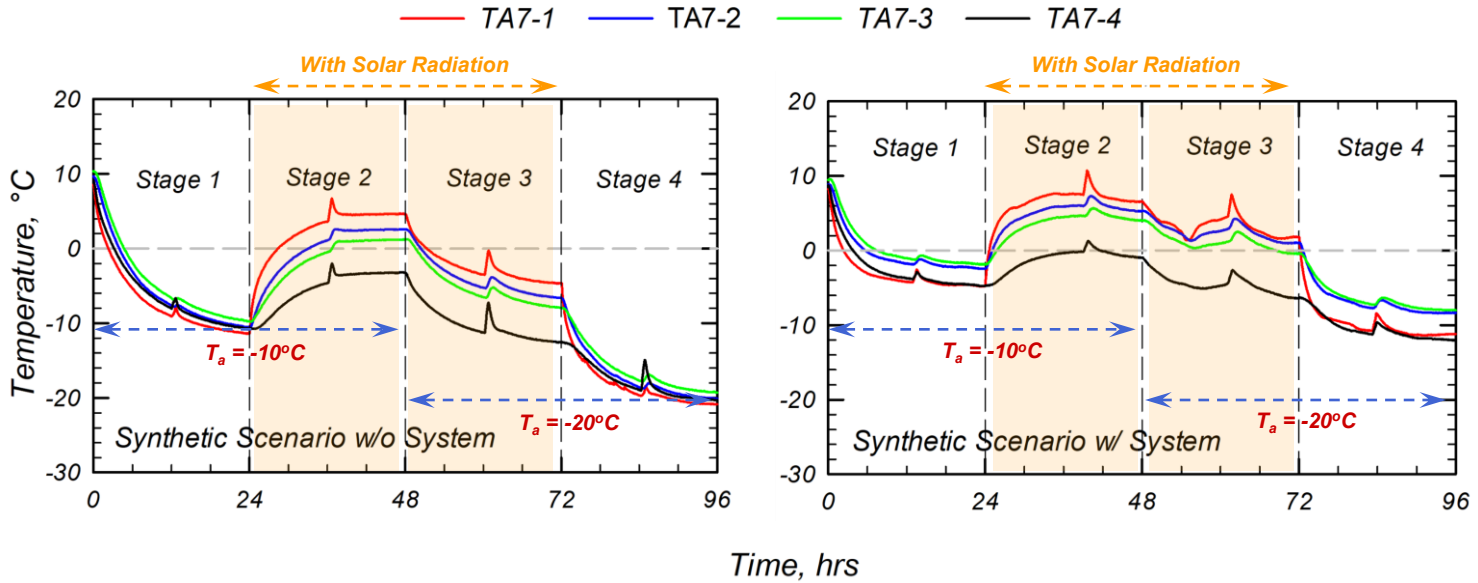
TASK 01

Model Scale Experiments in SRL



Bridge Deck De-icing | Thermal Movement | **Frost Action Theral Gradient** | Early-age cracking

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing



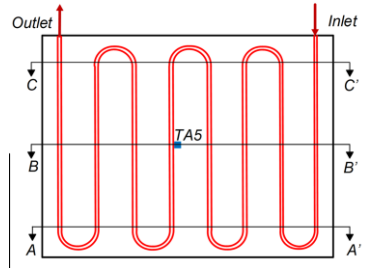
Without Geothermal System

With Geothermal System

Research Methodology: Model Scale Experiments in SRL

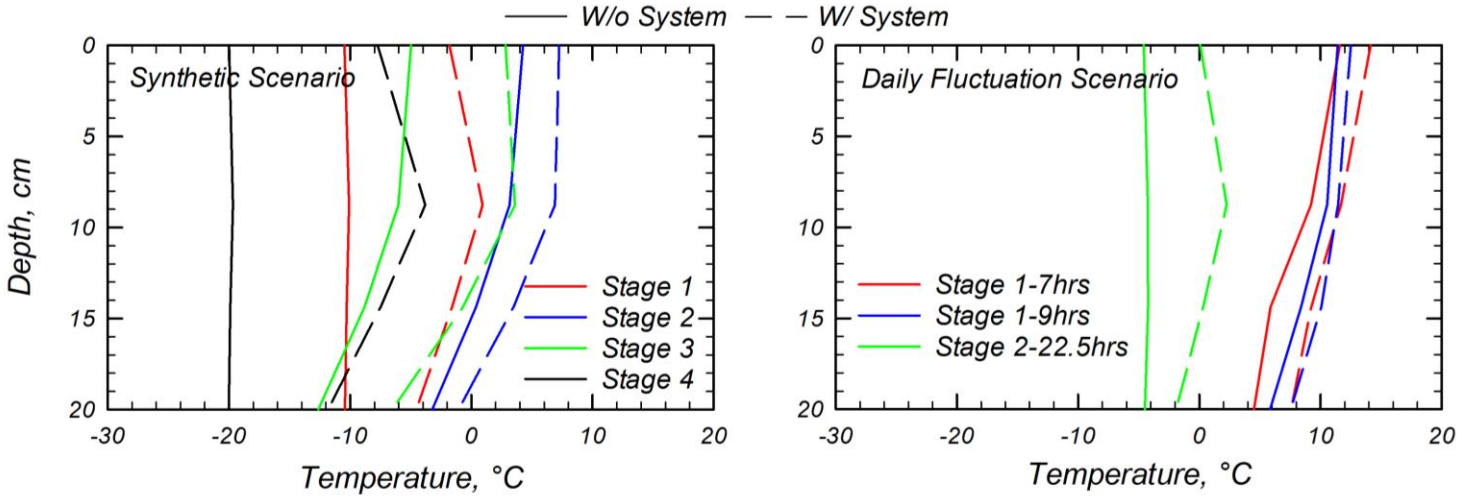
TASK 01

Model Scale Experiments in SRL



Bridge Deck De-icing | Thermal Movement | **Frost Action Theral Gradient** | Early-age cracking

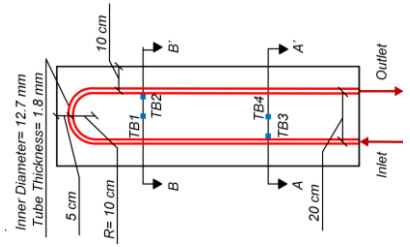
Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing



Research Methodology: Model Scale Experiments in SRL

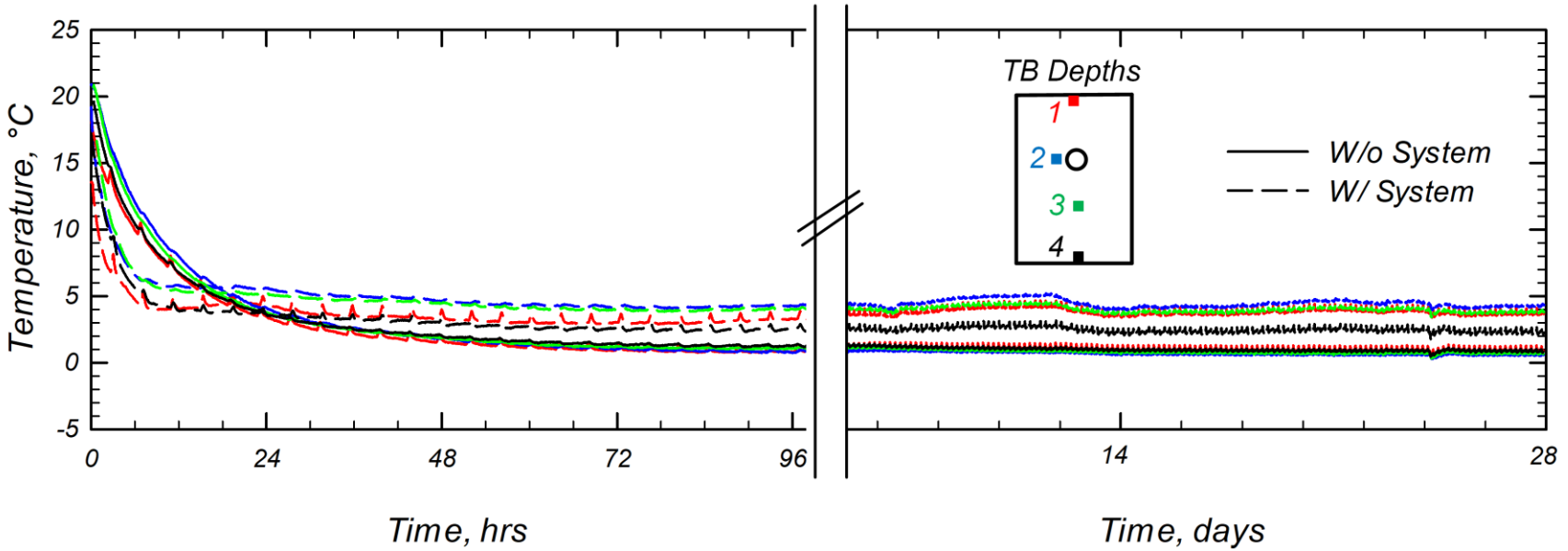
TASK 01

Model Scale Experiments in SRL



Bridge Deck De-icing | Thermal Movement | Frost Action Theral Gradient | **Early-age cracking**

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

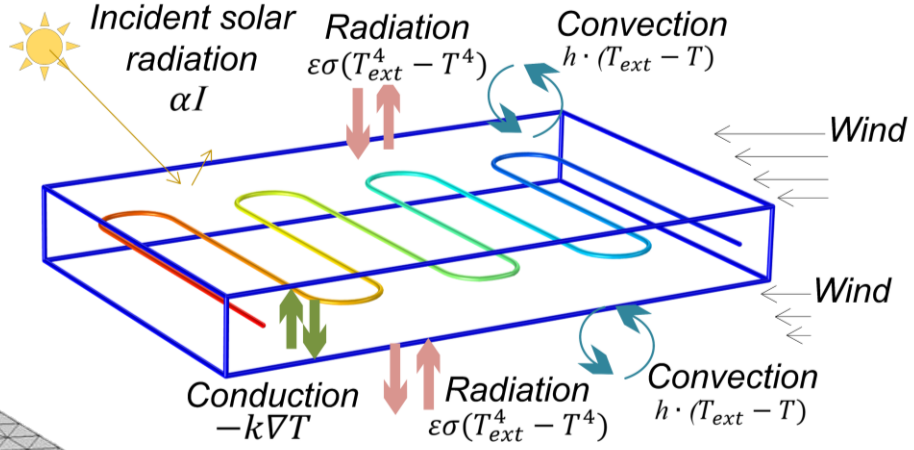


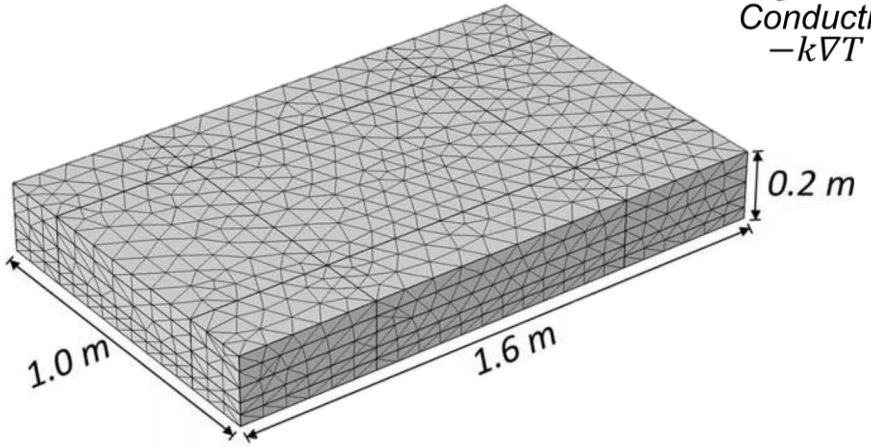
Research Methodology: Numerical Model Development and Validation

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

TASK 02

Numerical Model Development and Validation





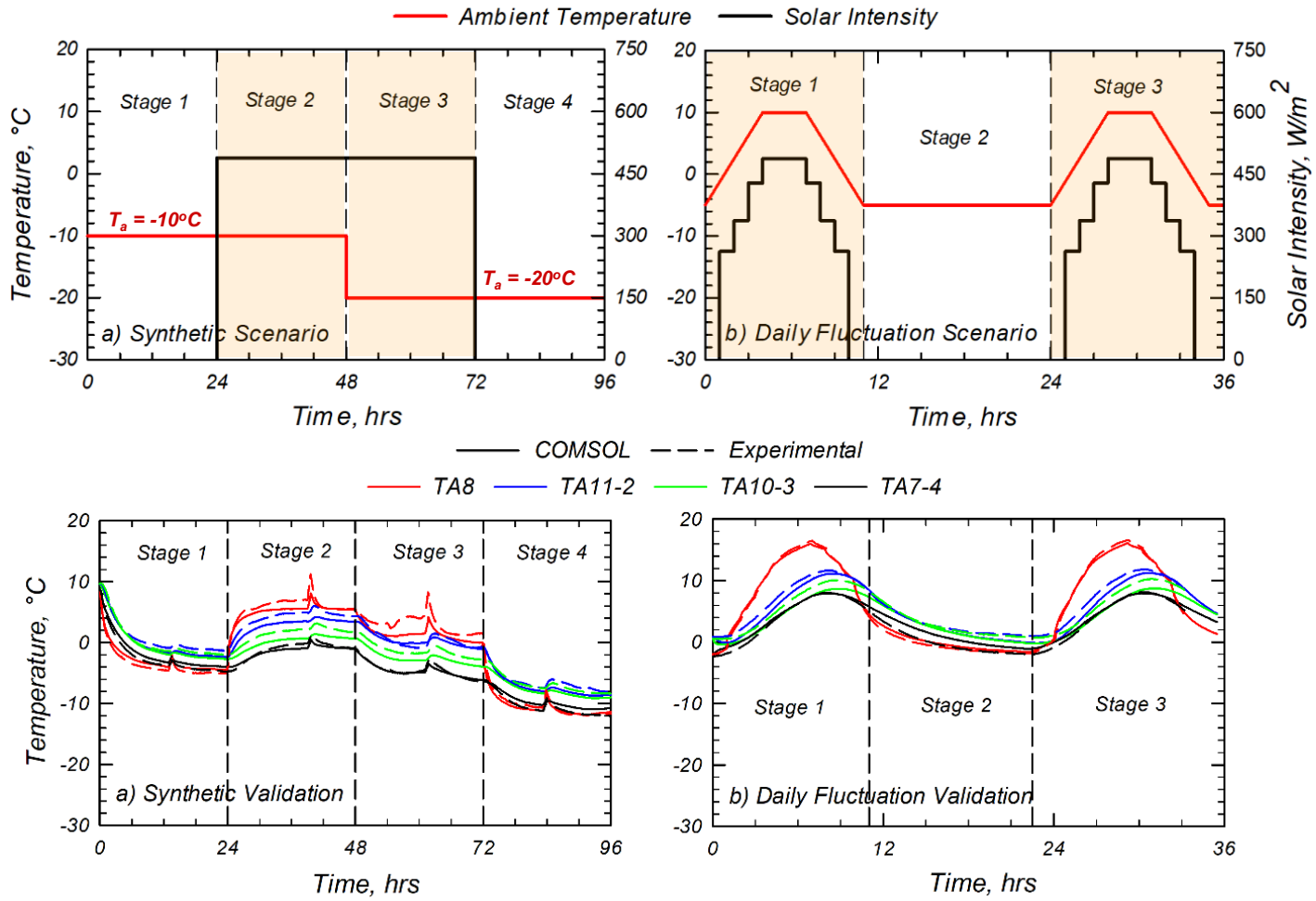
Research Methodology: Numerical Model Development and Validation

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

TASK 02

Numerical Model Development and Validation

With Solar Radiation



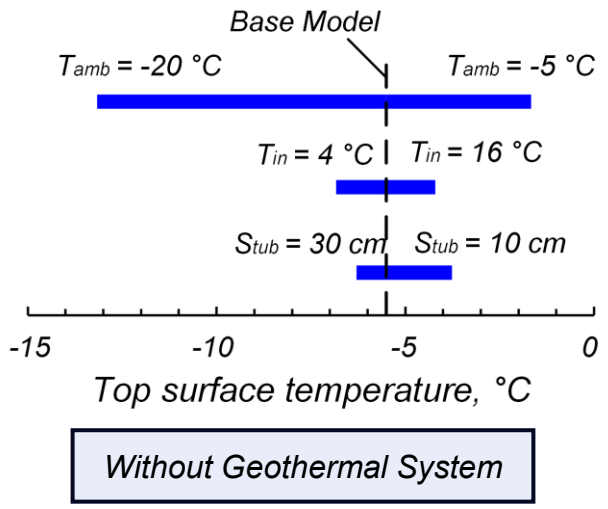
Research Methodology: Parametric Study and Sensitivity Analysis

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

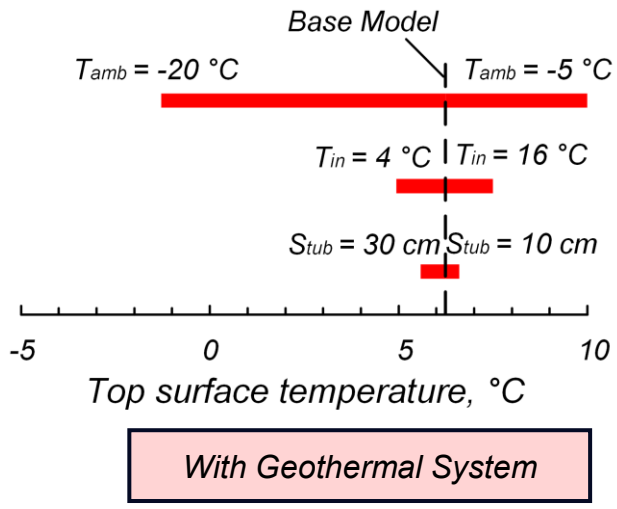
TASK 03

Parametric Study and Sensitivity Analysis

Bridge Deck De-icing	Thermal Movement	Frost Action	Thermal Gradient



Without Geothermal System



With Geothermal System

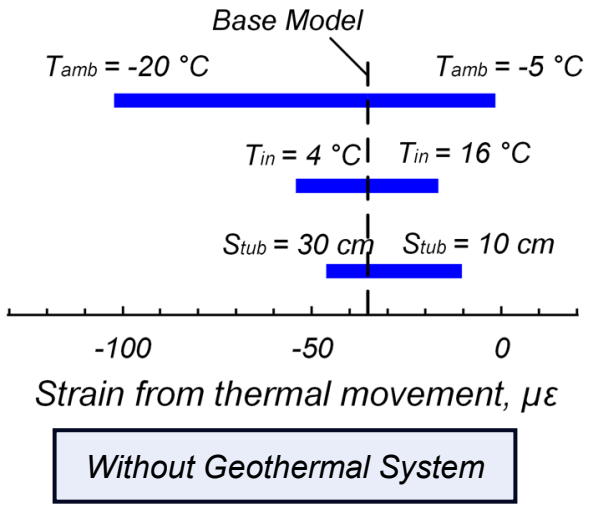
Research Methodology: Parametric Study and Sensitivity Analysis

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

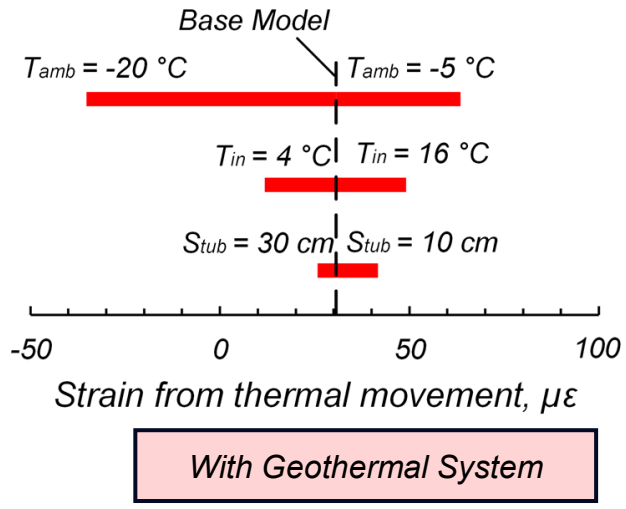
TASK 03

Parametric Study and Sensitivity Analysis

Bridge Deck De-icing	Thermal Movement	Frost Action	Thermal Gradient



Without Geothermal System



With Geothermal System

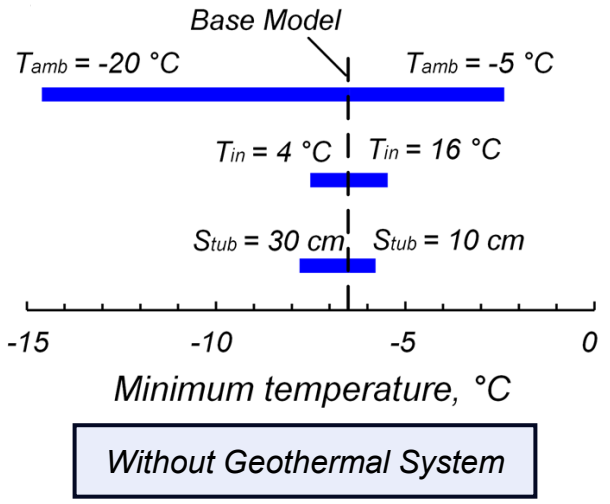
Research Methodology: Parametric Study and Sensitivity Analysis

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

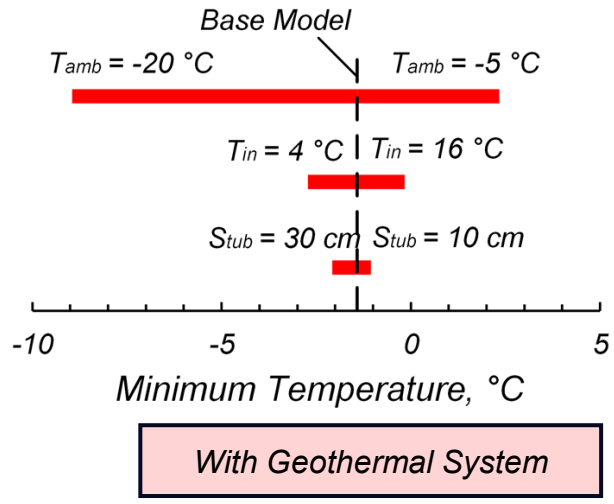
TASK 03

Parametric Study and Sensitivity Analysis

Bridge Deck De-icing	Thermal Movement	**Frost Action**	Thermal Gradient



Without Geothermal System



With Geothermal System

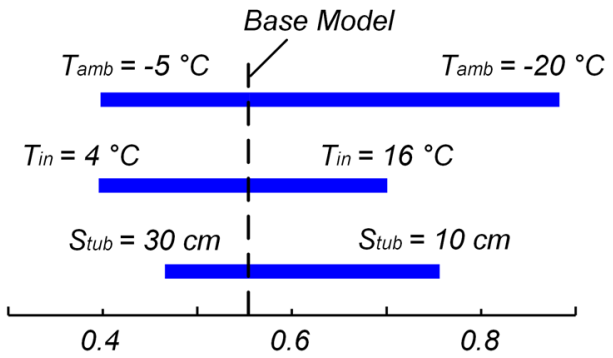
Research Methodology: Parametric Study and Sensitivity Analysis

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

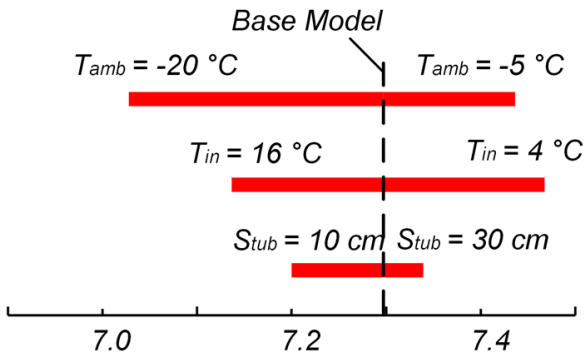
TASK 03

Parametric Study and Sensitivity Analysis

Bridge Deck De-icing	Thermal Movement	Frost Action	Thermal Gradient



Without Geothermal System



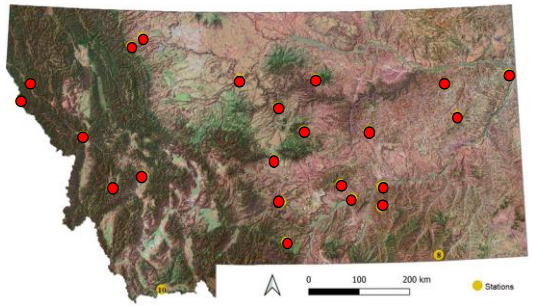
With Geothermal System

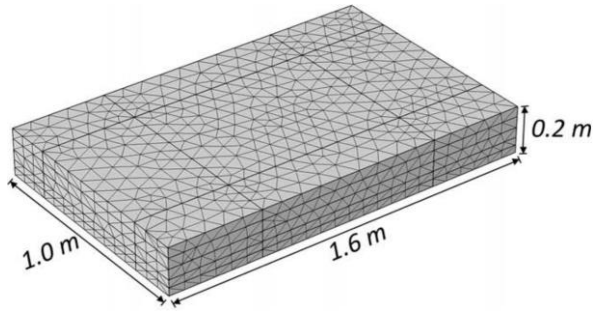
Research Methodology: Surface Prediction and Feasibility Analysis

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

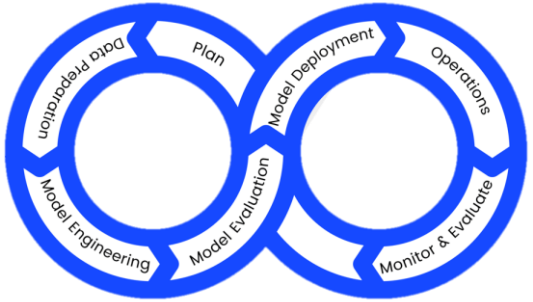
TASK 04

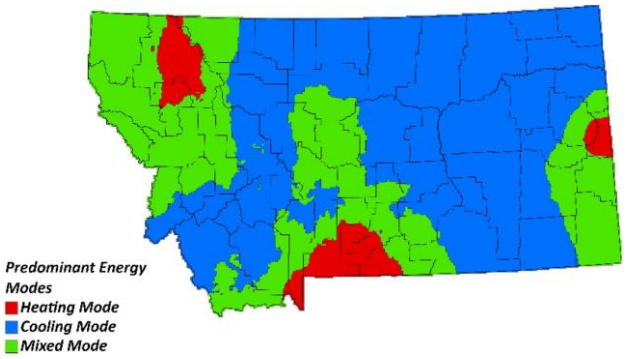
Surface Prediction and Feasibility Analysis





TASK 04-01
Data Collection and Preprocessing



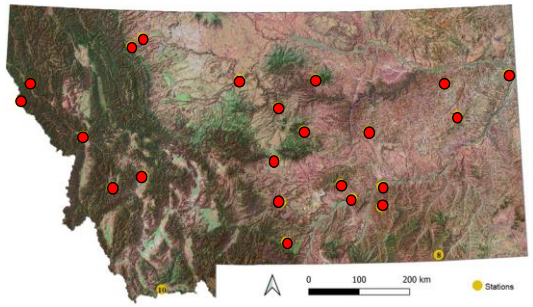


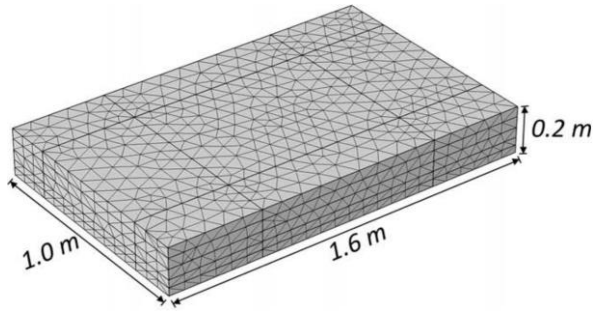
TASK 04-02
Machine Learning Model Development

TASK 04-03
Surface Prediction and Feasibility Analysis

Research Methodology: Surface Prediction and Feasibility Analysis

Surface Prediction and Feasibility Analysis

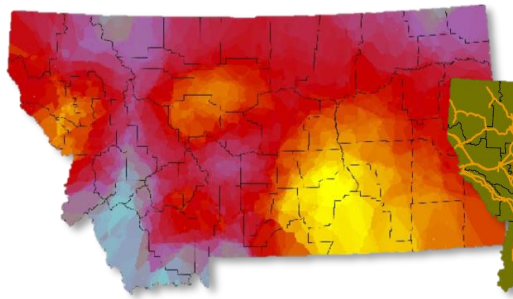




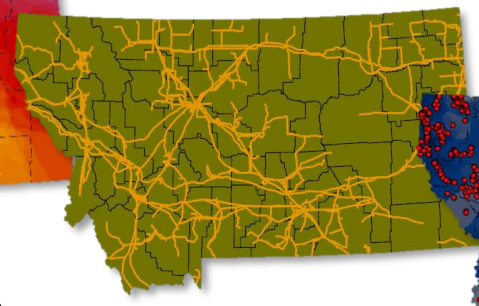
TASK 04-01

Data Collection and Preprocessing

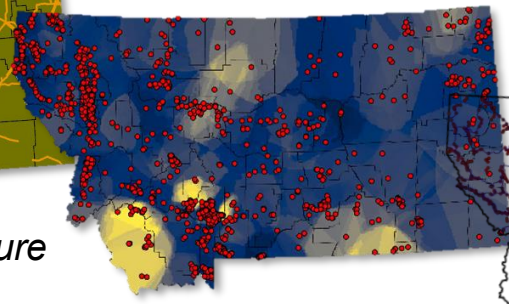
Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing



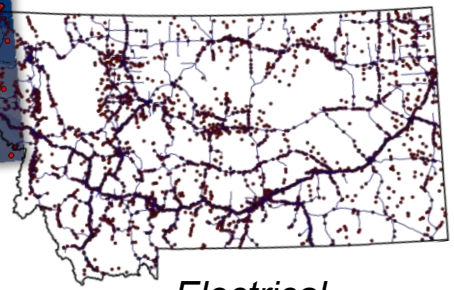
Average Annual Ambient Temperature



Ground Temperature Distribution



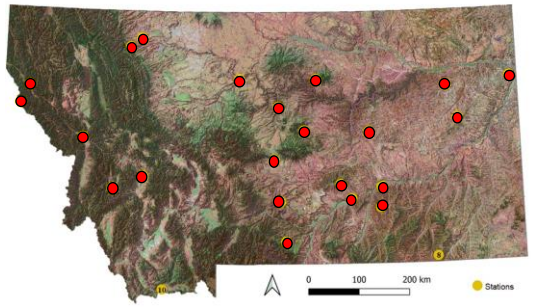
Bridge Deck Locations

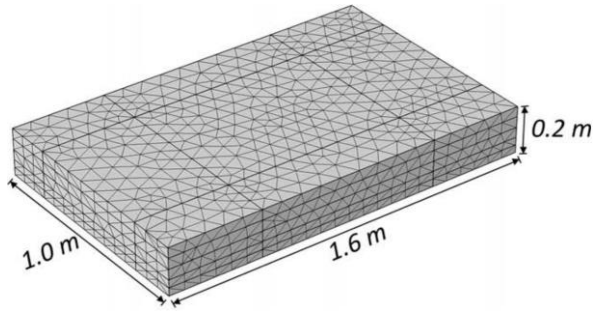


Electrical Transmission Lines

Research Methodology: Surface Prediction and Feasibility Analysis

Surface Prediction and Feasibility Analysis

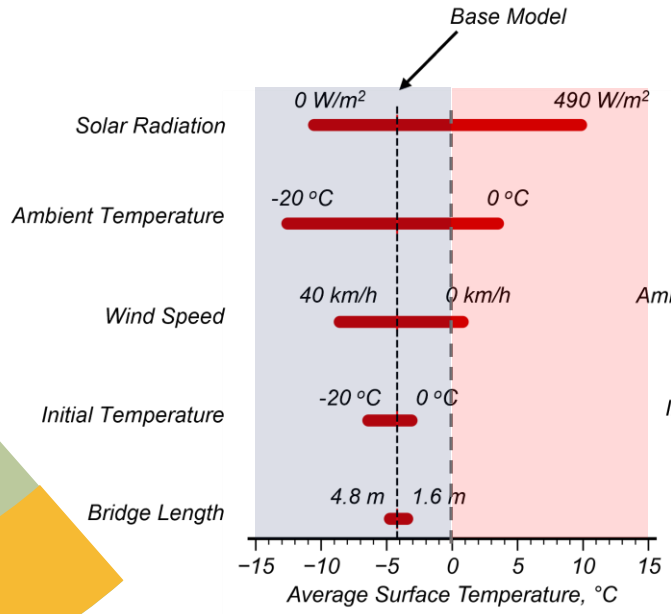


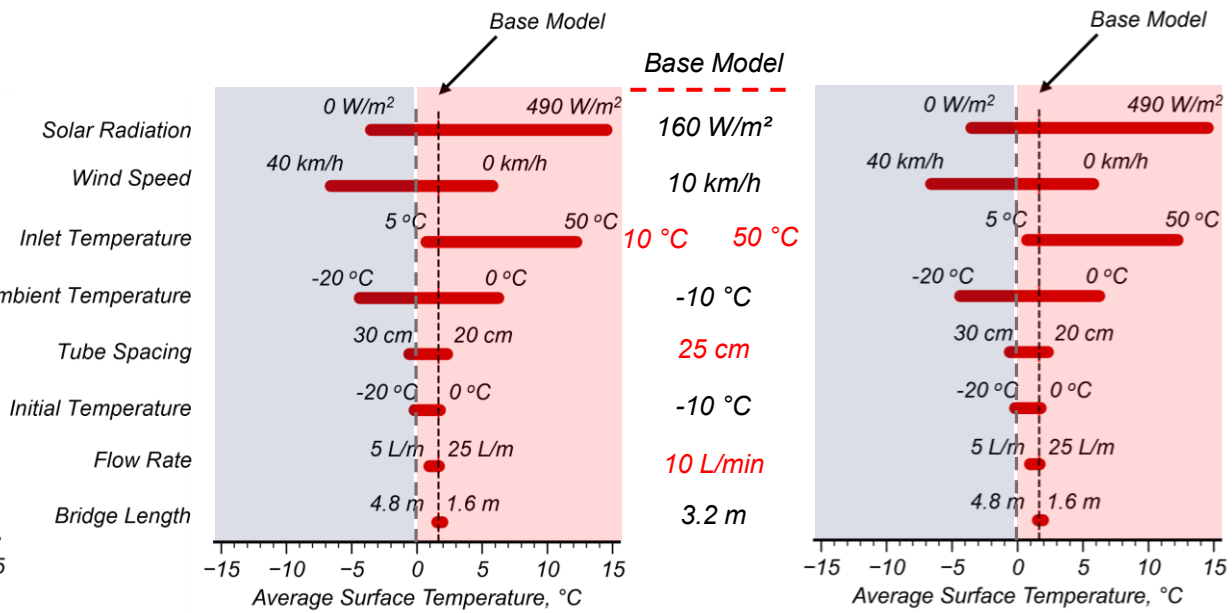


Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

TASK 04-01

Data Collection and Preprocessing





Without Geothermal System

With Geothermal System

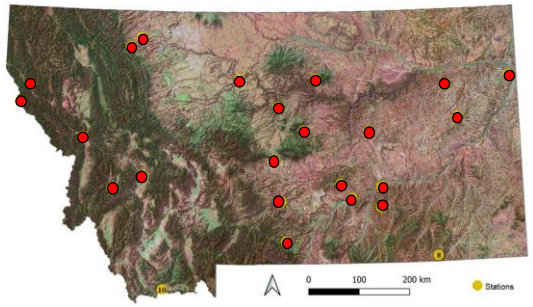
TASK 04

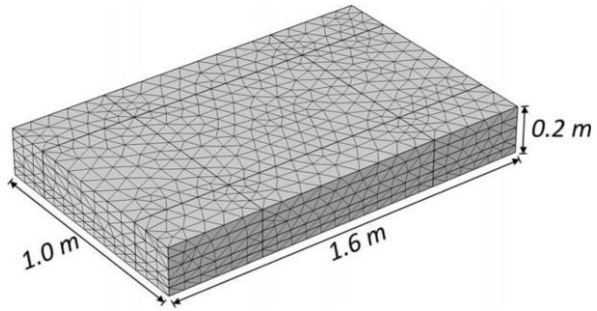
Research Methodology: Surface Prediction and Feasibility Analysis

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

TASK 04

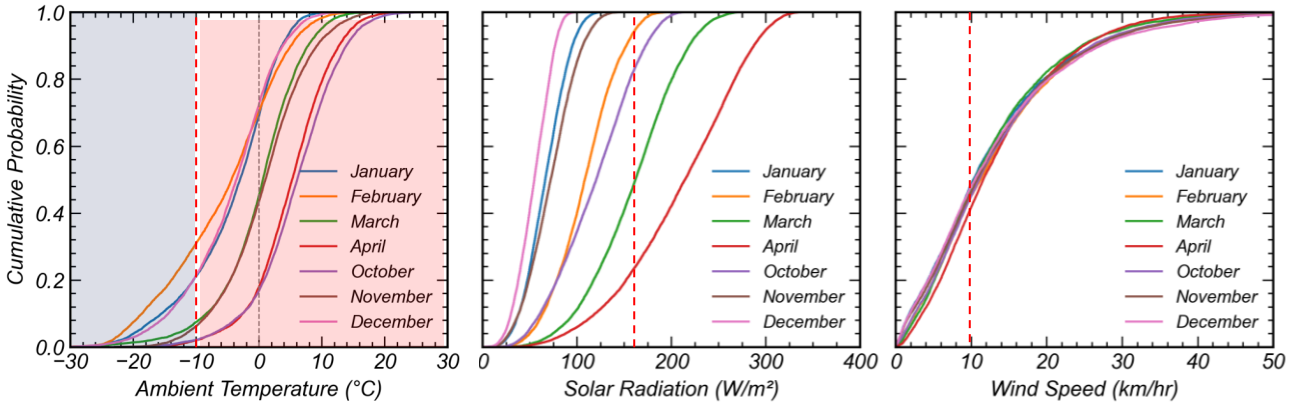
Surface Prediction and Feasibility Analysis





TASK 04-01

Data Collection and Preprocessing



Base Model

Solar Radiation:160 W/m²

Wind Speed: 15 km/h

Inlet Temperature: 10 °C

Ambient Temperature: -10 °C

Tube Spacing: 25 cm

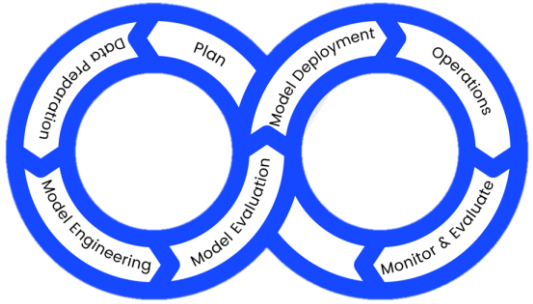
Initial Temperature: -10 °C

Flow Rate: 10 L/min

Bridge Deck Length: 3.2 m

Research Methodology: Surface Prediction and Feasibility Analysis

Surface Prediction and Feasibility Analysis

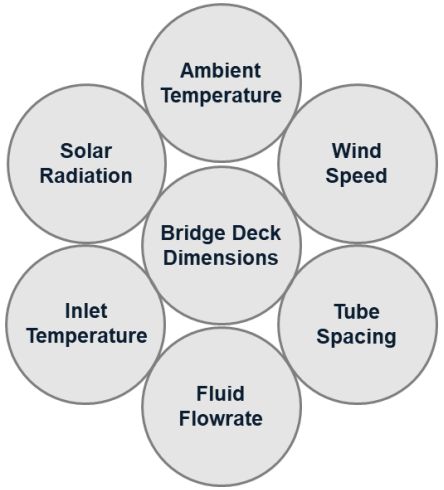


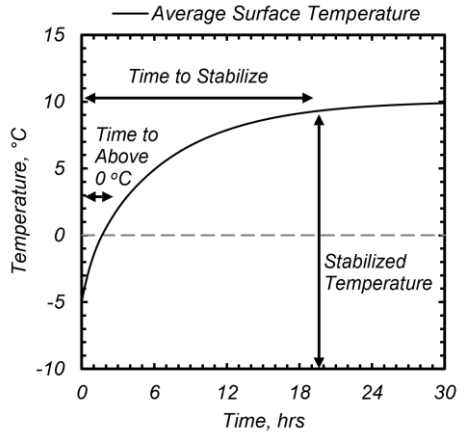
Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

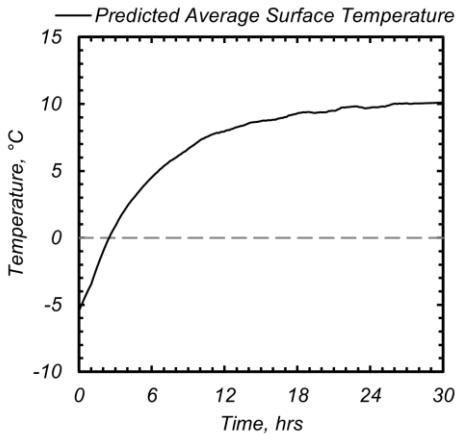
TASK 04-02

Machine Learning Model Development

Features





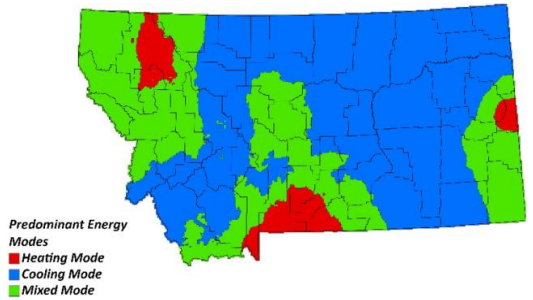


Research Methodology: Surface Prediction and Feasibility Analysis

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

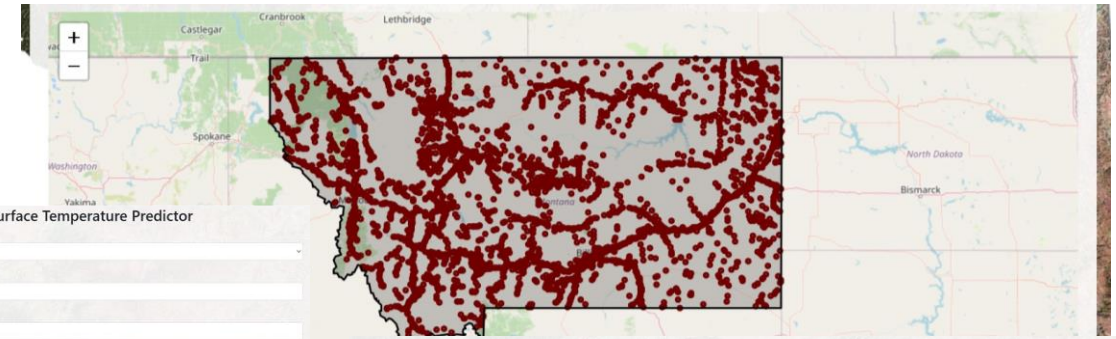
TASK 04

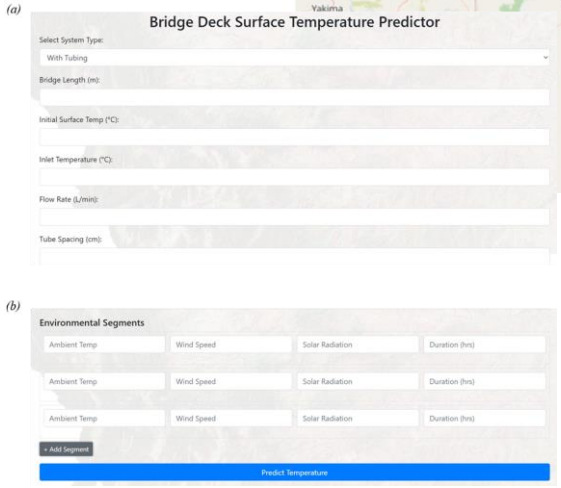
Surface Prediction and Feasibility Analysis

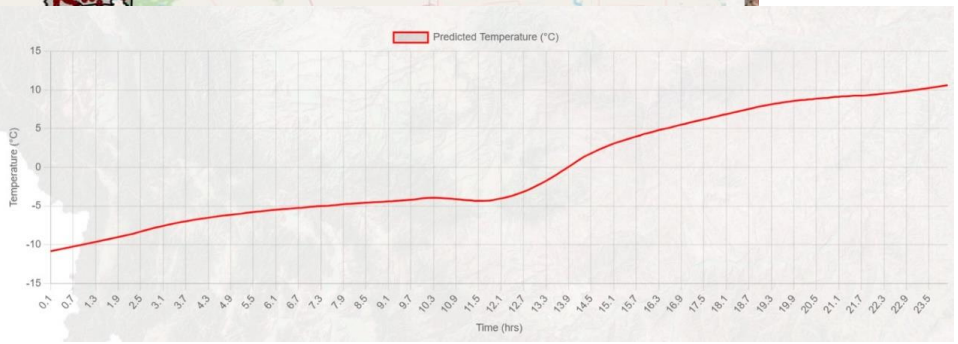


TASK 04-03

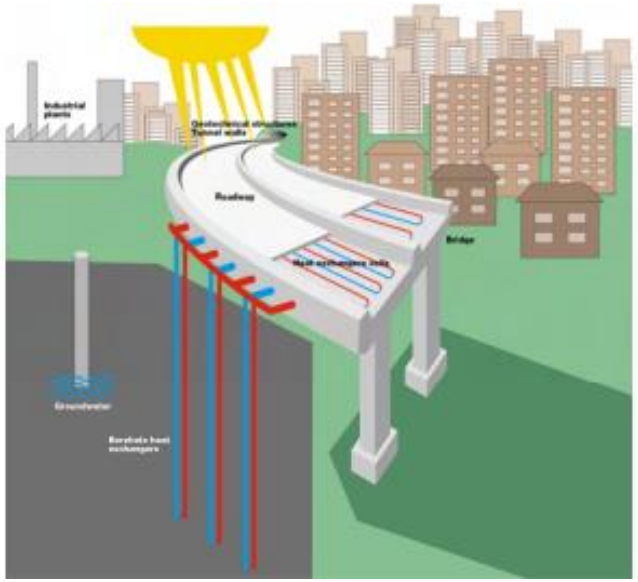
Surface Prediction and Feasibility Analysis

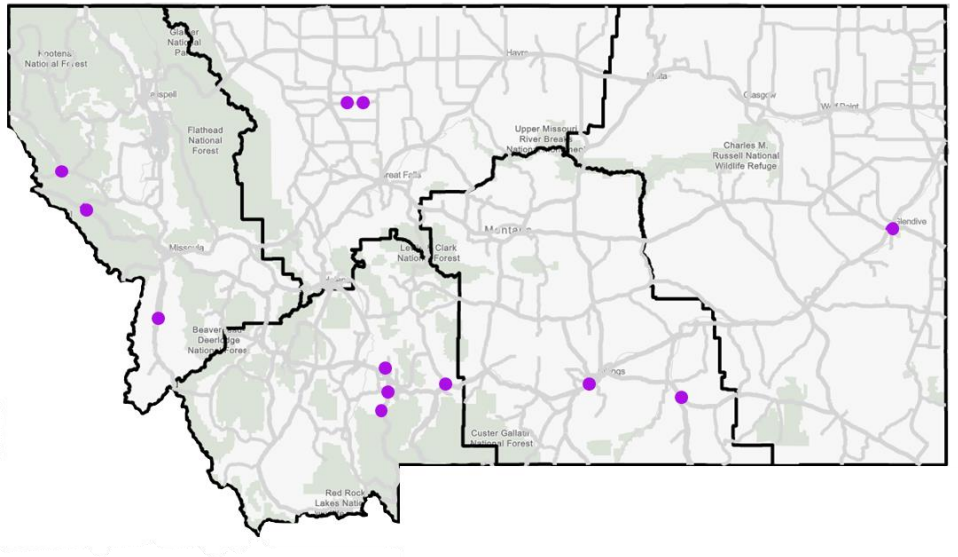




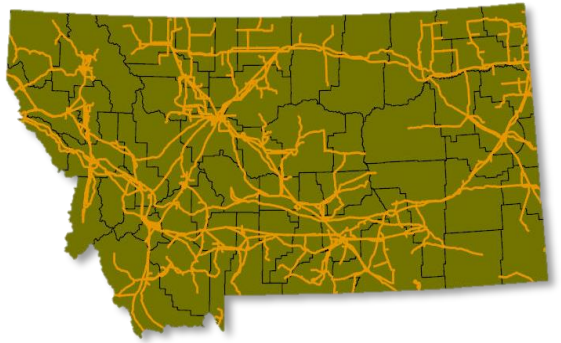


Phase II

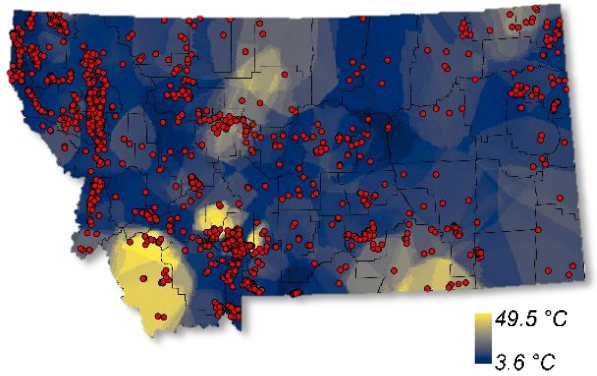



Flathead National Forest
Upper Missouri River Breaks
Charles M. Russell National Wildlife Refuge
Lewis & Clark National Forest
Custer Gallatin National Forest

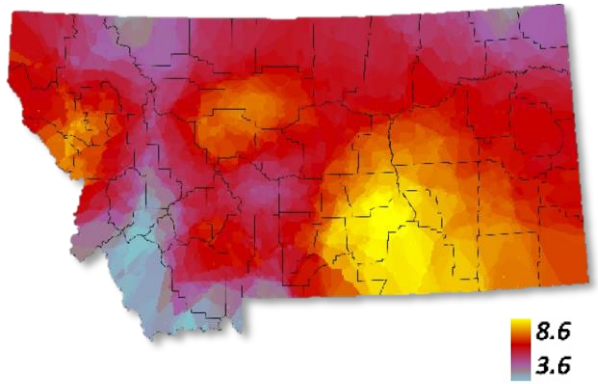
What's Next: Life-Cycle Cost-Benefit Analysis



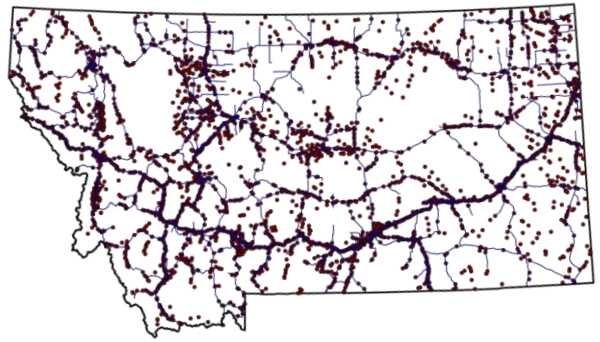
Electrical Transmission Lines



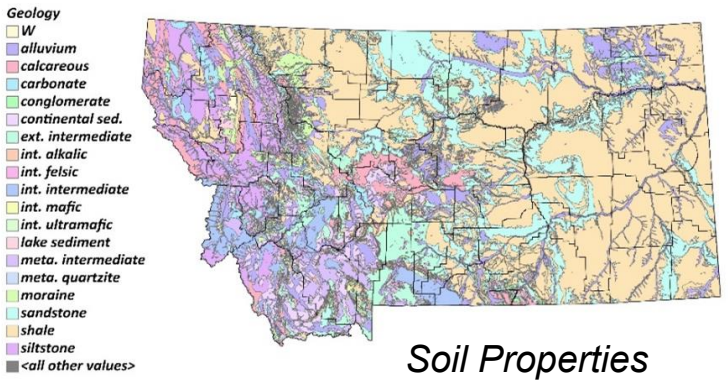
Average Annual Ambient Temperature



Ground Temperature Distribution in Montana

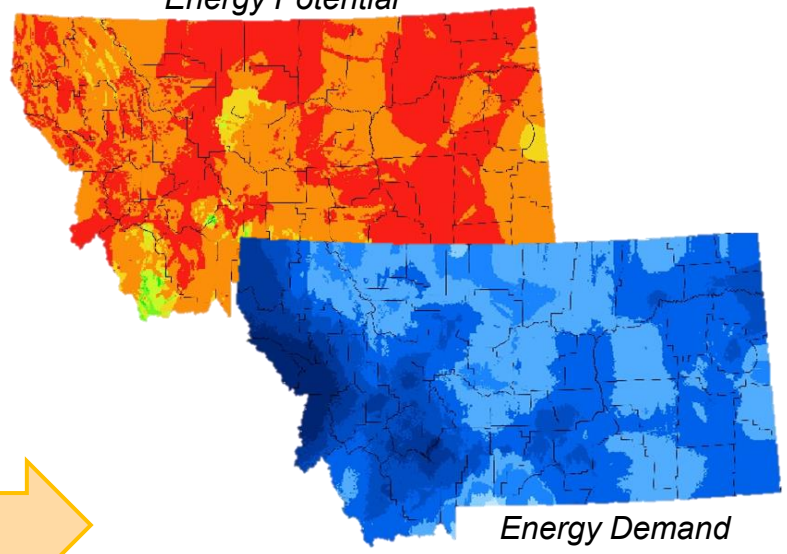


Bridge Deck Locations

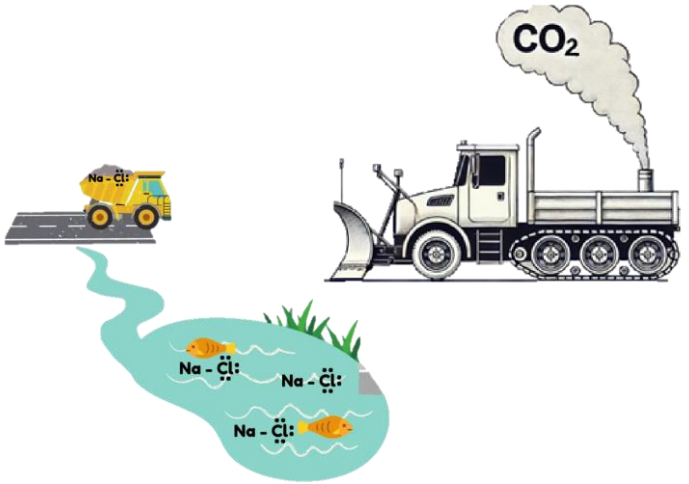


Soil Properties

Energy Potential

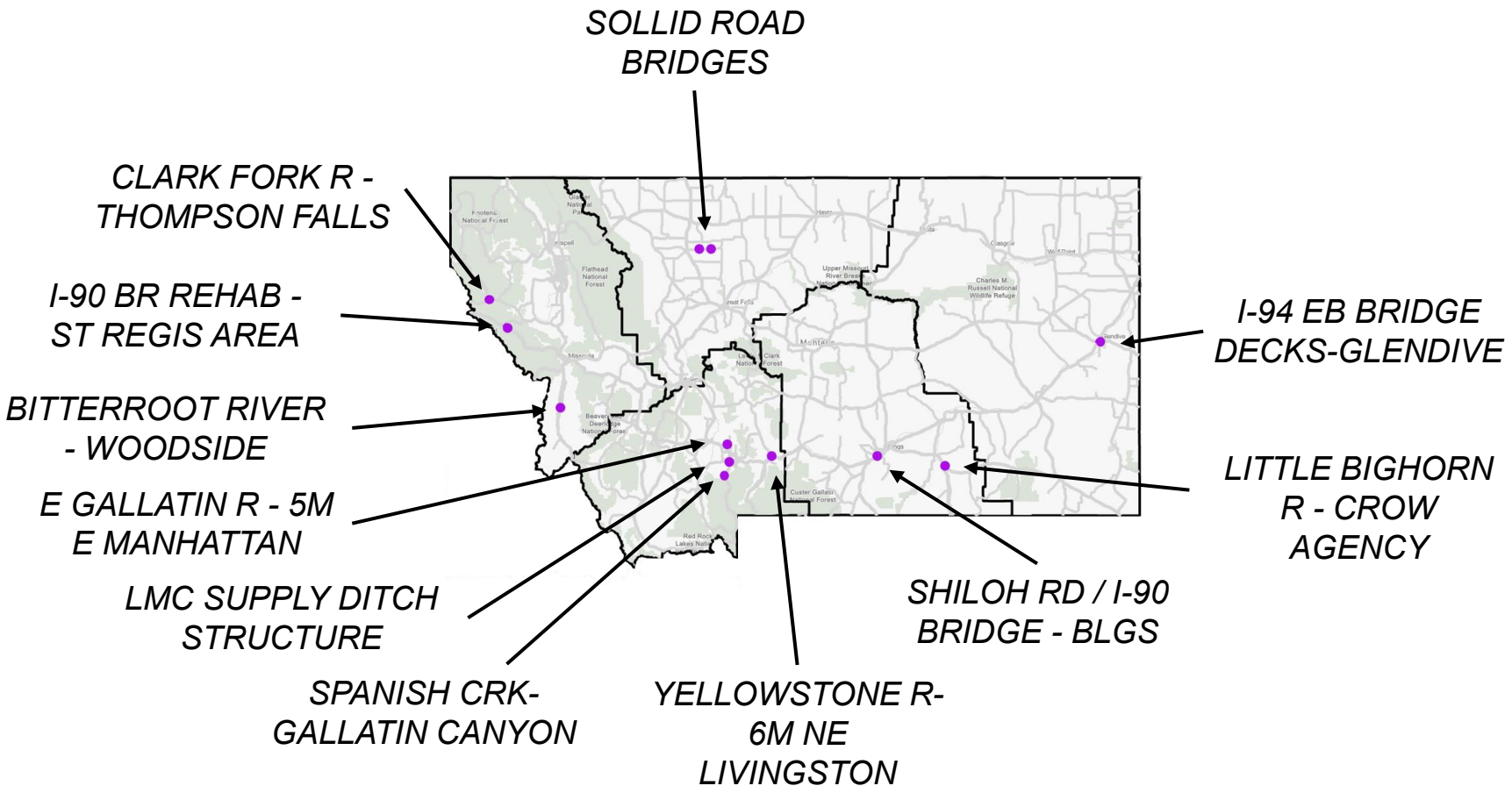


Energy Demand



What's Next: Possible Field Implementation

Planned Projects for 2028-2029



Thank You!

Feasibility Analysis: Data Collection and Preprocessing

Ground Source Heat Pump (GSHP) system for Bridge Deck Deicing

TASK 04

Without Tubing

Parameter	*Value*	
	Range	Values
Ambient Temperature, °C	0 to -20	0, -5, -10, -15, -20
Initial Temperature, °C	-10 to +20 of Ambient Temperature	-10, -5, 0, 5, 10, 20 of Ambient Temperature
Wind Speed, km/h	0 to 40	0, 5, 10, 20, 30, 40
Solar Radiation, W/m^2	0 to 490	0, 160, 260, 360, 490
Bridge Length, m	1.6 to 4.8	1.6, 3.2, 4.8
Total Number of Models	**555**	

With Tubing

Parameter	*Value*	
	Range	Values
Ambient Temperature, °C	0 to -20	0, -5, -10, -15, -20
Initial Temperature, °C	-10 to +20 of Ambient Temperature	-10, -5, 0, 5, 10, 20 of Ambient Temperature
Wind Speed, km/h	0 to 40	0, 5, 10, 20, 30, 40
Solar Radiation, W/m^2	0 to 490	0, 160, 260, 360, 490
Inlet Temperature, °C	8 to 50	8, 10, 50
Fluid Flowrate, L/min	5 to 25	5, 10, 25
Tube Spacing, cm	20 to 30	20, 30
Bridge Length, m	1.6 to 4.8	1.6, 3.2, 4.8
Total Number of Models	**1836**	