Interim Geotechnical Recommendation			
Client:	Western Federal Lands Highway Division		
Project Name:	AK NPS DENA 10(49) Polychrome Area Improvements		
To:	Jacobs	**Document Number:**	BGC Geotech Memo No. 06 Rev.: 2
Infrastructure Component(s):	Thermosiphons	**Date:**	March 14, 2023

Geotechnical Recommendation Application (check all applicable):		
☐ Investigation	☐ Foundation Preparation	☐ Rock Cuts
☐ Material Parameters	☐ Shallow/Deep Foundations	☐ Retaining Walls
☒ Thermosiphons	☐ Cut/Fill	☐ Other_____

Subject: Preliminary Recommendations for Thermosiphons

Purpose

The purpose of the memorandum is as follows:

- This memorandum provides information to help inform the procurement of appropriate materials for the project as part of a 70% design deliverable for Option W.
- The content of this memorandum, including the design basis, assumptions, analysis and recommendations, including to specifications, details and drawings, will be reviewed and may change as the design is developed.
- The estimated quantities do not include allowances for loss or damage, or means and methods, which the contractor should consider.
- No part of this memorandum or its attachments is content issued for construction. Final BGC recommendations will be issued in BGC reports or memoranda stating such.

Objective

This memorandum provides preliminary recommendations for thermosiphons at Abutment No. 1 (East). The thermosiphons are intended to provide passive cooling at the East abutment to mitigate the potential for degradation (i.e. thawing) of massive subsurface ice located at the interface between the rhyolite and the ash tuff/clay material (BGC's Geotechnical Report 01-22 and Geotechnical Memorandum 40-22). The thermosiphons are designed to keep the subsurface frozen throughout their length for the abutment's service life and aid in mitigating retrogression hazard of the Pretty Rocks Landslide scarp at Abutment No. 1. BGC's scope of work for these elements is to provide recommended layout, quantities, and special contract requirements (SCRs) for the thermosiphons. Jacobs will produce necessary design drawings with BGC support.

Design Basis

- BGC's understanding of the subsurface conditions at the Abutment No. 1 location is based on borings and geophysical surveys in the vicinity of the proposed footings, and visual observations of the outcrops below the road near the proposed footing locations. Based on this understanding, the thermosiphons will be installed into weathered rhyolite, massive ice and ash tuff/clay at Abutment No. 1 (BGC's Geotechnical Report 01-22 and Geotechnical Memorandum 40-22).
- In 2021, BGC completed a three dimensional (3D) thermal model in TempW3D to determine if, over the course of the design life of the foundation, the subsurface massive ice at the interface between the rhyolite and the ash tuff/clay melts. These efforts are documented in BGC's Geotechnical

Modelling Report (BGC, 29 March, 2022) and concluded that given CMIP5 climate projections for the site, permafrost conditions at the site will likely degrade and the massive ice is projected to melt.

- Topographical data from the 2021 photogrammetry for Abutment No. 1 with scarp material removed based on January 2022 aerial photos.
- Ground temperatures measured from instrumented boreholes near Abutment No. 1, including PR19-07 and PR21-02.
- Historical and projected climate data from CMIP6 global climate models, selected to match Alaska, at the site location.
- Wind speed data from site measurements (email from Denny Capps, 5/Dec/2022 via WFLHD) and CMIP6 global climate models, selected to match Alaska, at the site location.
- Thermosiphons should maintain ground temperature of 28°F or colder within the "cooling zone" (i.e. elevations 3570 to 3520 ft) within 20 ft of the Abutment No. 1 footing for the design life of the foundation as determined in the BGC Geotechnical Modelling Report Rev 1 dated 29 March 2022.
- The CM/GC contractor expressed the desire to maintain access across the slide during thermosiphon drilling and installation activities on the north site of Abutment No. 1.
- If thermosiphons are battered, as opposed to vertically installed, there will be a reduction in effectiveness for heat extraction (i.e. ground cooling). Batter angles are optimized to manage this risk.
- Condensers will be located on the south side of Abutment No. 1 and grouped in racks.
- Thermosiphon drill locations should not be located within 3 feet of other subsurface elements, where possible. This includes soil nails (west of Abutment No. 1) and the sub-horizontal micropiles (east of Abutment No. 1).
- Thermosiphons on the west side of Abutment No. 1 will be drilled from the base of footing elevation, approximately 3621 ft.
- Thermosiphons on the south and east of Abutment No. 1 will be drilled from the current grade, approximately 3632 ft, which is lower than the final roadway grade.

Analysis

BGC conducted a 3D thermal model of Abutment No. 1 using topography, geological conditions and similar procedures to those outlined in BGC's Geotechnical Modelling Report Rev 1, 29 March 2022. BGC included thermosiphon boundary conditions in the model at preliminary locations to determine the effectiveness of vertical thermosiphons with 170 square foot (sqft) area condensers terminating at elevation 3520 ft. The model uses a total of 22 thermosiphons spaced in a trapezoid around the abutment footing with two rows west of the footing with eleven thermosiphons, one to the north of the abutment footing centreline, one to the south of the abutment footing centerline, and two rows to the east of the footing with nine thermosiphons each. The reduction in the thermosiphon number (22 modeled vs. 24 in the 30% design) provides a factor of safety for cooling capacity with the battered thermosiphons.

The model was initialized using a steady-state analysis and run for twelve years of model time with the 2021 topography (i.e. roadway in place) and ground temperatures were compared to measured ground temperatures from PR19-07, which is located adjacent to Abutment No. 1. The modeled ground temperatures were consistent with the previous modelling work (BGC, 29 March 2022).

Subsequently, the model was run sequentially for each climate projection step for five years. This five year analysis step is consistent with previous modelling efforts and allows BGC to determine a "snapshot" of the ground temperatures and thermosiphon effectiveness within each climate projection step. Additionally, the model was adjusted to include the following conditions:

- A 50 ft region of material, simulating the evacuation of material from Pretty Rocks Landslide, was removed from the model adjacent to Abutment No. 1.

- Thermosiphon boundary conditions were added at the thermosiphon locations described above. This boundary condition uses the ground temperature, air temperature, and windspeed to determine the heat flux along the modelled length of the thermosiphon. Hayes and Zarling (1988) was used to determine the convection coefficient vs wind speed correlation (12 deg slope angle).

Model results show that ground temperatures within the cooling zone are consistent with the 28°F design expectations, or colder for the duration of the foundation's service life.

Geotechnical Recommendations

Pay items:

- 27003-0000 Drill hole (Thermistor casing materials), LNFT; estimated quantity = 400 LNFT
- 64605-0000 Fixture (Thermosiphon system – Evaporator materials), LPSM; For Information Only quantity = 23 thermosiphons totaling 2600 LNFT.

Note that *thermosiphons* are elements installed to passively cool the ground whereas *thermistors* are instruments used to measure the ground temperature.

Based on the modelling results, BGC recommends 23 thermosiphons be installed surrounding the Abutment No. 1 footing. They will be located such that they are in four rows with decreasing numbers of thermosyphons as the rows progress west to east (i.e., 7, 6, 5 and 4) with one thermosiphon located directly south of the abutment centerline. These designated thermosiphon locations are the points at elevation 3536 ft where the thermosiphons must intersect. BGC has assumed a preliminary surface drill location for each thermosiphon based on our understanding of the construction constraints and determined batter angles and thermosiphon lengths from these locations and elevations. For the thermosiphons on the east side of Abutment No. 1, BGC has assumed most thermosiphon drilling will be completed through the 8 ft spacing of the sub-horizontal micropiles north and south of the roadway centreline.

In total, a length of 2600 linear feet (LNFT) of 3-inch diameter, schedule 40, steel pipe is required for thermosiphon installation in drilled holes. The 23 thermosiphons will range in length between approximately 101 LNFT and 114 LNFT depending on drill start elevation and batter angle. BGC recommends placing a contingency on this quantity as determined by the contractor based on current unknowns about collar elevations and potential conflicts with permanent or temporary construction elements. Any remaining pipe can be used for the horizontal connector pipes of the thermosiphons that connect the drilled lengths to the condenser locations. These horizontal connector pipes are sloped at 8% and thermally insulated using extruded polystyrene boards within the fill section.

In addition to the passive cooling, BGC recommends the addition of three thermistor strings be installed at Abutment No. 1 to monitor ground temperature and verify the effectiveness of the thermosiphons. The estimated quantity of drilling and thermistor string casing is 400 ft. These instruments should be installed to elevation 3500 ft (i.e. twenty feet below the termination elevation of the thermosiphons) in 1-inch diameter, Schedule 80 PVC. The PVC conduit should be twinned (i.e. two per thermistor hole) and installed in a similar manner to the thermosiphons, tremie grouted from the base of the borehole using non-shrink grout. The PVC should be watertight and remain accessible following construction through a surface well mount. The thermistors should be Digital Temperature Cables with sensors at ground surface, 5-ft spacing. All thermistors should be attached to data loggers to collect data on a minimum of four readings daily. The location and type of data logger/collection/transmission system has not yet been selected.

Special Contract Requirements

The applicable Sections of the FP-14 Specifications are Section 646 and 725.20. Preliminary SCRs for these Sections were provided to Jacobs with the Option W SCR package.

BGC ENGINEERING INC.
per:

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Attachments:

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