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7 May 2024
File No. 209337-000

Cell Signaling Technology, Inc.
3 Trask Lane
Danvers, MA 01923

Attention: Peter Muto, CFM
Director of Facilities

Subject: Proposed Ground-Source Heat Exchange (GSHE) System
Cell Signaling Technology
Atwater Avenue
Manchester-by-the-Sea, Massachusetts

Dear Mr. Muto:

Haley & Aldrich, Inc. has completed our evaluation of potential effects of the proposed ground-source heat exchange (GSHE) system on groundwater temperatures and potential effects on temperatures in downgradient surface water resources. Our analysis is based on our review of published information, and results of modeling performed by HGA Architects and Engineers, LLC (HGA), the project GSHE designer. We understand one-hundred and sixty (160) GSHE loops are to be installed in a borefield located north/northwest of the building.

Subsurface Conditions

Depth to bedrock is expected to be shallow – 10 ft or less – based on published surficial geology maps and the HGA plan entitled: "Geothermal Site Plan" dated 2 February 2024, which notes bedrock outcrops near the western border of the site. Based on regional topography, groundwater likely flows north and west towards Beaverdam Swamp and Sawmill Brook, respectively (Figure 1).

Published maps indicate the site is underlain by the Cape Ann Granite formation (Dennen, 1991), which, like most crystalline rock types in the New England region, transmit groundwater through discrete fractures and fracture zones separated by much thicker segments of competent bedrock with very few fractures to transmit groundwater flow. As such, the pathways for bedrock groundwater to discharge to surface waters is limited to moderate- to high-angle fractures that "daylight" in the overlying overburden soils, or low-angle exfoliation fractures that are typically limited to depths within the upper 5 to 10 ft of the bedrock surface. Further, the glacial till soils (see Figure 1) that typically mantle the bedrock surface are heterogeneous and poorly sorted with substantial fines content (silt and clay), all of

which limit the hydraulic conductivity and therefore the groundwater flow between the bedrock and the surface waters.

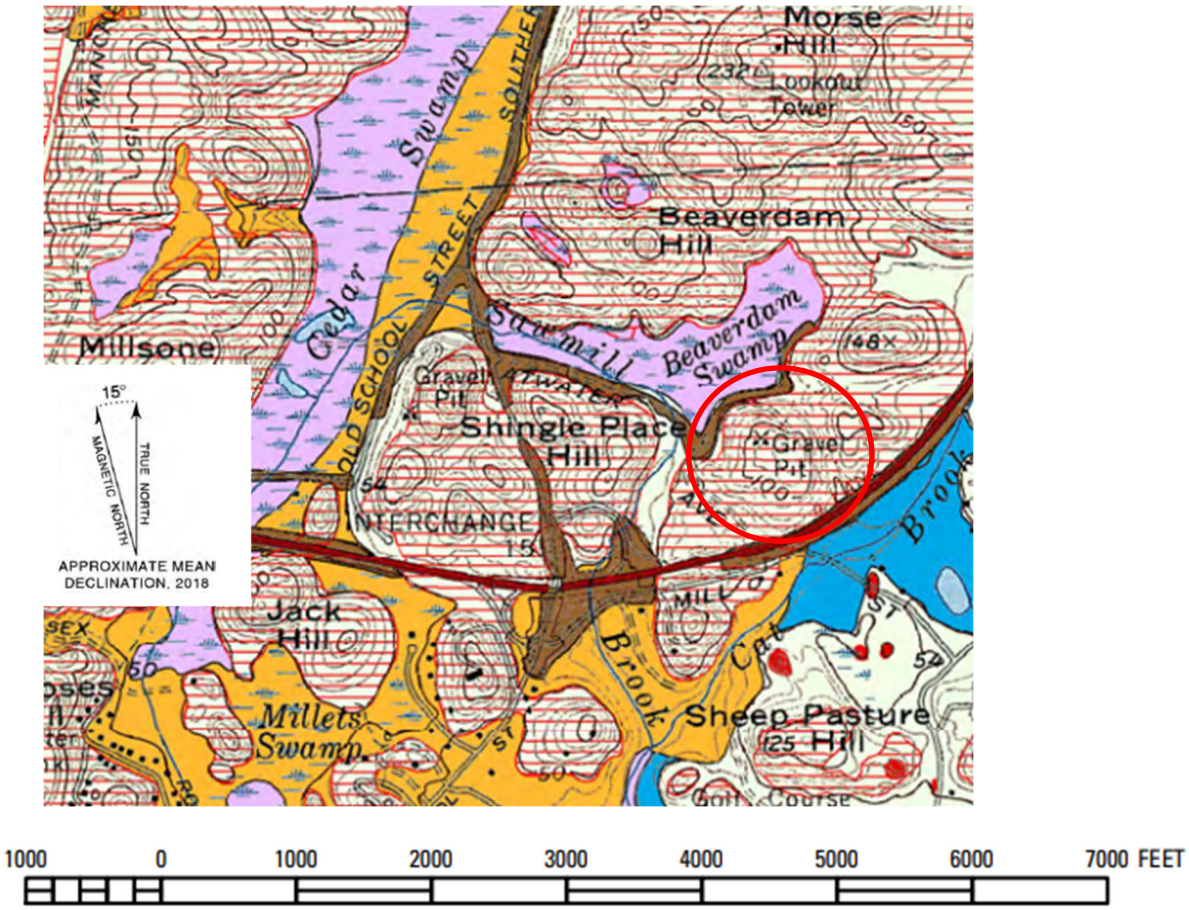
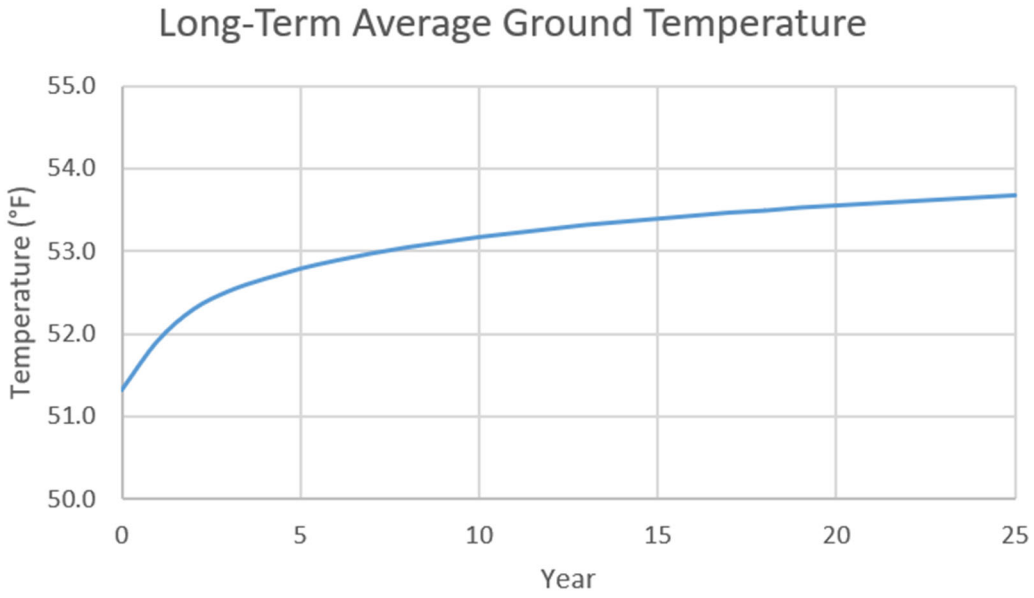


Figure 1 - Regional Surficial Geology; approximate scale shown. Cell Signaling site is circled in red. Geologic mapping units: red cross-hatching: areas of glacial till and shallow bedrock; orange: stratified glacial deposits; purple: swamp deposits: blue: marine deposits; brown: recent fill deposits. Source- U.S. Geological Survey Scientific Investigations Map 3402, Quadrangle 148 – Marblehead North.

GSHE Operation

The proposed GSHE system will serve both heating and cooling needs for the project. A closed-loop system will be installed that circulates fluids in a fully sealed network of vertical piping (in the boreholes) and horizontal piping (supply and return piping to the building), such that no groundwater is pumped from or reinjected to the subsurface. In closed-loop systems a balance of heating and cooling loads is critical to efficient long-term operation insofar as it limits long-term temperature creep that can result from imbalanced loads – downward trends for heating-dominated loads, and upward trends for cooling-dominated loads. With a balanced load, ground temperatures within the bore-field typically show minimal temperature changes as the seasonal effects of heat rejection (cooling mode) are countered in late fall and early winter as heating demands increase, reversing the GSHE system to heat extraction. While temperatures in the circulating GSHE fluids respond to heating and cooling demands, a steep temperature gradient in the surrounding subsurface (rock and soil) translates to minimal changes in temperature in the borefield area between the system loops. In the bedrock and glacial till soils underlying the site, most of the thermal exchange will likely take place through thermal conduction in the rock mass rather than advective transport by groundwater flow.

HGA modeled the temperature changes in the approximate center of the borefield under simulated long-term operating conditions. The following plots model-predicted ground temperatures over a 30-year period of GSHE operation:



The model predicts ground temperatures will increase roughly 2 to 2.5°F over 25 years of operation.

Conclusions

Based on the site subsurface conditions, the effects of operating the proposed GSHE system on downgradient surface water resources, including Beaverdam Swamp and Sawmill Brook, are expected to be negligible considering the following:

1. Subsurface conditions of glacial till over fractured bedrock are not conducive to high groundwater flow from the site GSHE borefield to downgradient surface water resources.

2. In the bedrock and glacial till soils underlying the site, most of the thermal exchange is expected to follow thermal conduction in the rock mass rather than advective transport by groundwater flow.

3. Based on bore-field modeling, modest temperature gains of 2 to 2.5°F are predicted within the GSHE borefield under long-term operation (25 years). This temperature gain will further decrease between the center of the borefield and the surface water resources through the temperature gradient that will develop in the rock mass.

Limitations

This work was undertaken in accordance with standard hydrogeological consulting services applied to ground-source heat exchange, and the terms and conditions of our authorized proposal dated 13 September 2023.

Closure

Thank you for the opportunity to review the proposed project. Please do not hesitate to contact me if you have any questions or need additional information.

Sincerely yours,
HALEY & ALDRICH, INC.

John R. Kastrinos, P.G. (PA), LSP
Lead Hydrogeologist

Reference: Dennen, W.H., 1991. Bedrock Geologic Map of the Marblehead North Quadrangle, Essex County, Massachusetts, Geologic Quadrangle Map GQ-1693