Memorandum

Date:	March 12, 2024
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Project:	Franklin Elementary School; Newton, MA
Project No:	7708.7.TA
Subject:	Preliminary Evaluation/Feasibility Study of Geothermal Well System

This memorandum summarizes our preliminary evaluation/feasibility study of using a geothermal well system to provide heating and cooling for Franklin Elementary School in Newton, Massachusetts.

Executive Summary

- A geothermal well system is technically viable for the project.
- Three (3) different well options were studied with varying types (single and double U-bends)/depths (500, 600 and 700 feet)/spacing (20 and 25 feet).
- Typical "rule of thumb" (aka tons/well) lower and upper bound well capacities were used to estimate geothermal system capacities for each well type/depth studied.
- We estimate that sixty (60) wells can be installed at 20-feet-on-center spacing and forty (40) wells can be installed at 25-feet-on-center spacing in the western parking lot.
- Given the peak load estimated of 178 tons, at 20-feet-on-center spacing with 60 wells a geothermal well design with a capacity of 3.0 tons per well is required and at 25-feet-on-center spacing and 40 wells a well capacity of 4.5 tons per well is required.
- 500-foot-deep single U-bends at 20-feet-on-center spacing with 60 wells could provide an estimated 84% and 100% of the peak cooling capacity with the lower and upper bound well capacities, respectively, and 100% of the peak heating capacity.
    - 60 is the maximum number of wells that can readily fit in the proposed western parking lot at 20-feet-on-center spacing.
- 600-foot-deep quad-loops (double U-bends) at 25-feet-on-center spacing with 40 wells could provide an estimated 90% and 100% of the peak cooling capacity with the lower and upper bound well capacities, respectively, and 100% of the peak heating capacity.

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  - 40 is the maximum number of wells that can readily fit in the proposed western parking lot at 25-feet-on-center spacing.

- 700-foot-deep quad-loops at 25-feet-on-center spacing with less than 40 wells could provide an estimated 100% of the peak cooling and heating capacity and 100% of the peak heating capacity with the estimated lower-bound (conservative) well capacity.
- Therefore, to meet peak loads, these capacities will likely need to be accommodated by deeper wells, likely quad-loops, though 500-foot-deep single U-bends may be feasible if the energy model yields lower peak loads.
- These percentages are rough, and well counts will change as the energy model is further developed**.**

Existing Conditions and Project Description

The subject site consists of a rectangular-shaped parcel having a footprint of about 5.4 acres which fronts to the south onto Derby Street and is bounded by residential properties to the north, east and west. A right-of-way access onto Cherry Street is located along the east side of the site. Russell Road terminates at the northern property line near the western end of the site.

The existing elementary school building is located on the eastern half of the site and consists of an approximately 34,000-square-foot irregularly-shaped, two- to three-story school building. The remainder of the site is occupied by at-grade parking, playgrounds, and athletic fields. Ground surface slopes gently down from north to south from about Elevation +98 to Elevation +94. The northeast corner of the site is benched into an existing slope that rises to about Elevation +105 and the grade along Derby Street drops down immediately adjacent to the roadway to about Elevation +90 (**Figure 1**).

The proposed redevelopment of the subject site is understood to include the construction of a new three (3)-story elementary school building on the west-central side of the parcel. The building is planned to have a footprint of about 40,500 square feet and will include up to eighteen (18) classrooms, with enough space for an enrollment of about 400 students.

Figure 1. Proposed redevelopment of the site. Figure is from the HMFH Architects presentation titled "Franklin Elementary School Design Review Committee" dated December 13, 2023.

Geologic Conditions

The Franklin Elementary school site is situated in the western section of the Boston Basin nearby the interior of a meander in the Charles River. The site is located on the southeastern edge of a northwest-southeast trending hill (likely a glacial drumlin). This hill is classified as glacial till on the 1:24,000 scale Massachusetts surficial geology map (**Figure 2**). The hill is a generally oval deposit of "thick till" surrounded by a ring of "thin till". A geologic interpretation of this structure is simply a round hill of till that is thicker in the middle, closer to the top of the hill, and that thins towards the edges of the hill as the topography lowers. The Franklin School site is in the "thin till" classified area that changes to "glacial stratified deposits, coarse" to the southeast as the topography lowers further. **Figure 3** presents a digital elevation model with the approximate location of the site in the context of the local topography. This model shows the site on the edge of the oval hill with lower elevation land on all sides. The Charles River is to the north and west of the site, with deposits of artificial fill and floodplain alluvium filling the areas adjacent to its banks.

McPhail performed preliminary subsurface explorations at Franklin Elementary School and documented the findings in a report titled "Preliminary Foundation Engineering Report Franklin Elementary School Newton, Massachusetts" and dated September 20, 2023. For this report, McPhail contracted Carr Dee Corp. to perform six (6) borings ranging in depth from 16.8 to 21.3 feet below the existing ground surface. McPhail contracted Carr Dee Corp. to perform and additional nine (9) borings ranging in depth from 16.0 to 17.0 feet as part of subsurface explorations for a foundation engineering report currently in development. Based on the explorations performed at the site, the following is a description of the generalized subsurface conditions across the site encountered from ground surface downward.

Fill Material: The fill material generally consists of loose to compact, gray to brown silt, sand, and gravel.

Glacial Sediments: The glacial sediments generally consist of a compact to very dense well graded mixture of silt, sand, and gravel. Cobbles and boulders are also anticipated to be present within the glacial sediments.

Bedrock: The bedrock generally consists of severely to completely weathered kaolinized argillite consisting of compact to very dense purplish-gray to white silt with some sand and rock fragments. The Massachusetts bedrock map classifies the unit as Cambridge Argillite, which is a gray argillite and minor quartzite with rare sandstone and conglomerate. The range of bedrock elevations documented in the two subsurface exploration programs is El. +79.4 to El. +88.8 with evidence of deeper bedrock in one (1) boring with glacial sediments documented to El. +78.1.

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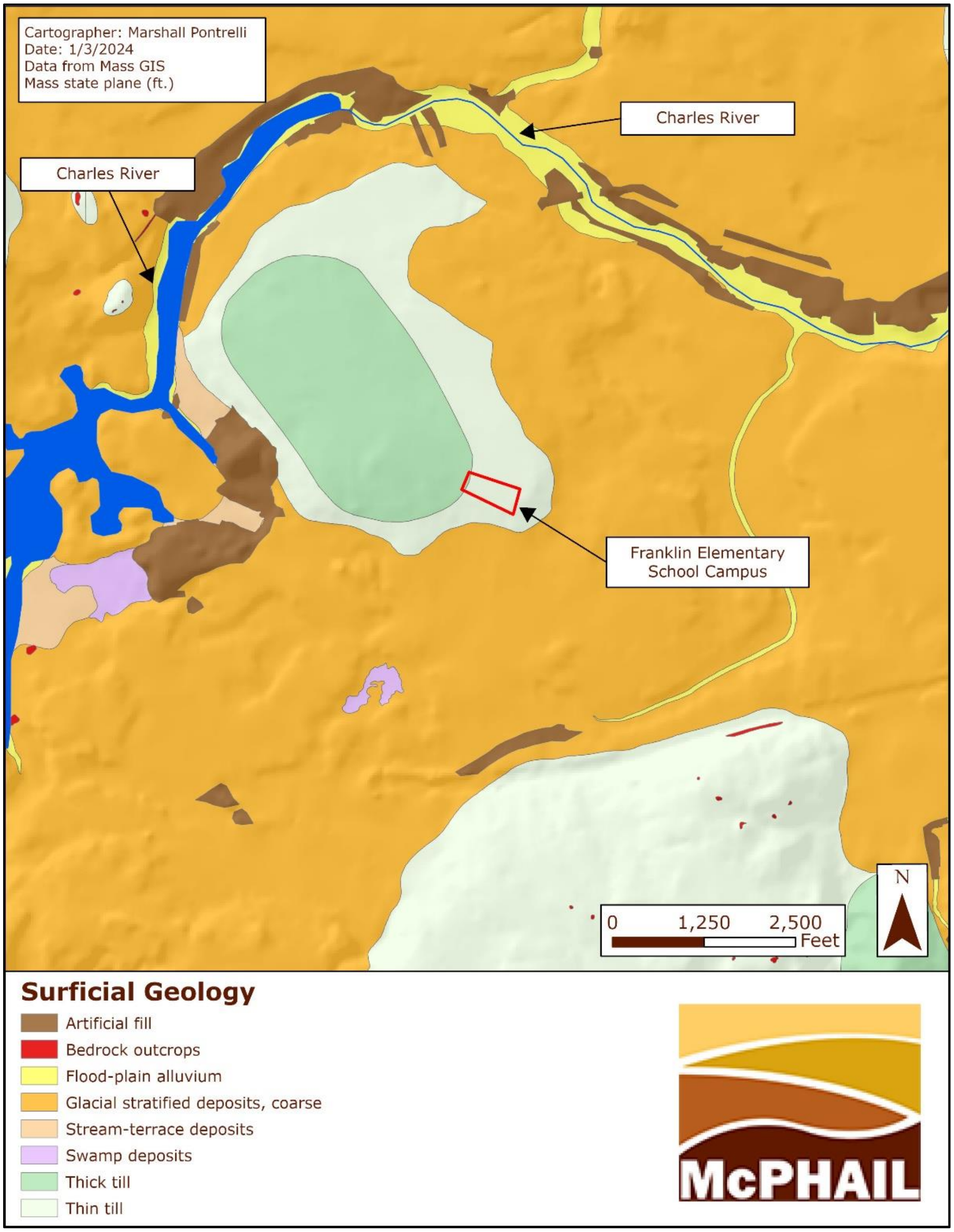

Figure 2. Surficial geology of the area surrounding the Franklin Elementary School.

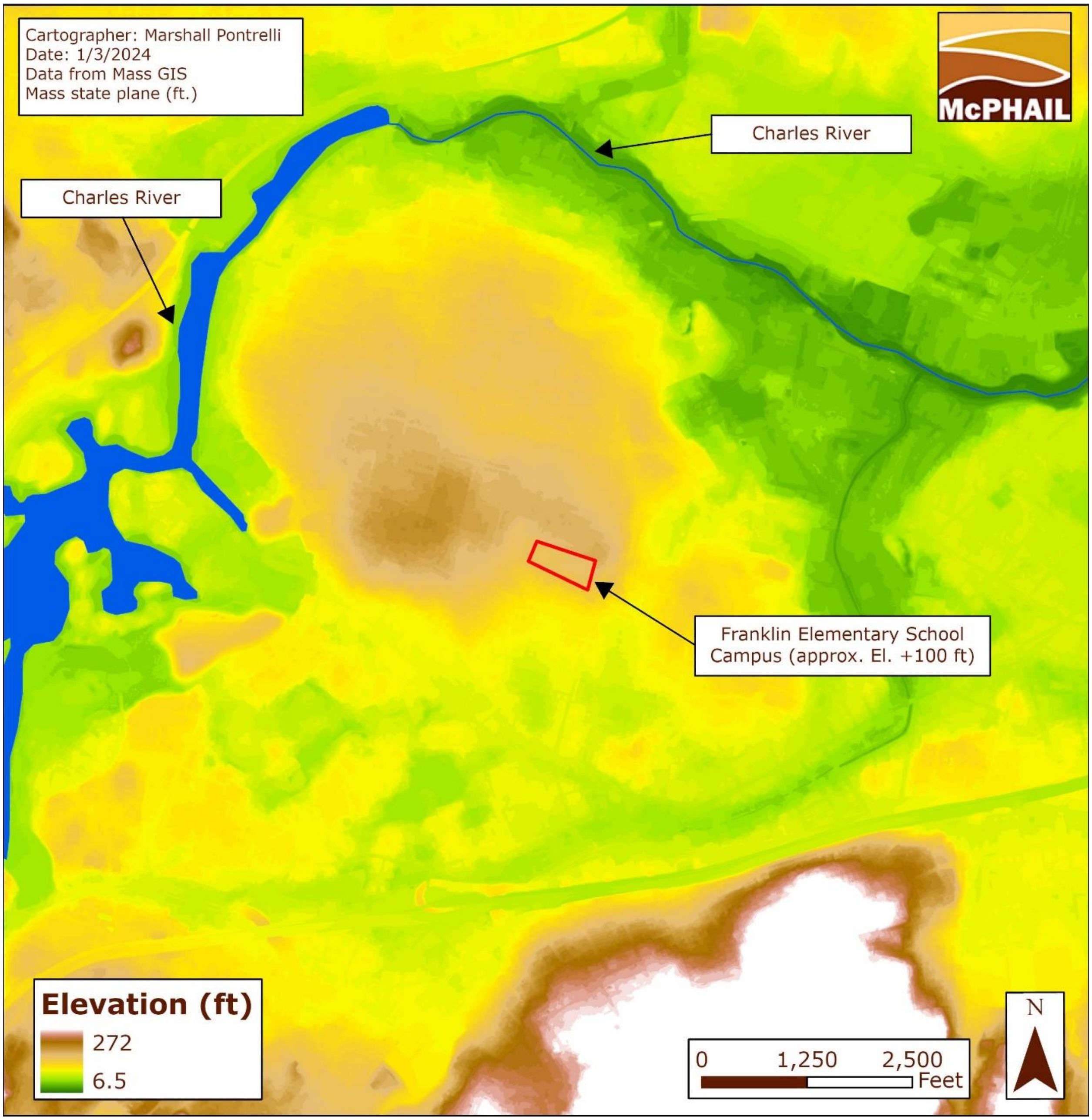

Figure 3. Elevation of the area surrounding the Franklin Elementary School.

Geothermal Overview

Geothermal systems leverage the ground's relatively stable temperature to provide heating and cooling to a building by circulating a fluid through a network of boreholes, efficiently moving heat. In heating mode, geothermal systems extract heat from the ground, use heat pumps to increase the circulating fluid temperature, and release the heat into the desired space. In cooling mode, heat pumps absorb heat from the space to be cooled, use heat pumps to transfer that heat energy to the circulating fluid and release it into the geologic formation surrounding the network of boreholes. Thus, heat is drawn from the ground during the winter and injected into the ground during the summer. A well-designed geothermal system will produce more heat energy than it consumes in the electrical energy it uses to run the pumps.

Geothermal systems typically operate most efficiently when there is an annual balance between heating and cooling loads. Buildings that are not air-conditioned or that have an extreme imbalance of loads are usually not good candidates for geothermal systems. However, it is common for buildings with moderate load imbalances to use a supplemental boiler or cooling device to handle peak loads or seasonal imbalances, with most of the heating and cooling being provided by the geothermal system.

The following are several potential advantages of geothermal systems:

- Environmentally friendly:
    - Use electricity to power the required equipment rather than directly consuming fossil fuel
    - Compatible with potential other renewable energy systems such as solar and/or wind
    - Do not create significant amounts of pollution
    - Sustainable, when using a renewable energy source
    - Lower carbon footprint than conventional systems
- May be eligible for renewable energy tax credits and incentives:
    - Federal Investment Tax Credit
        - 30% to 40% of project cost of geothermal ground loop (vertical wells, horizontal piping, etc.) and building interior mechanical system
    - Mass Save
        - **Path 1**: Net Zero and Low EUI Buildings (10,000 gsf or greater)
            - Building design targets ultra-low site Energy Use Intensity (EUI) and has a minimum of 10,000 gsf. EUI is a metric estimating how efficiently a building heats and cools its space

and is measured in units of energy per area per time of kBTU/sf/year.

- K-12 schools with an EUI target between 26-29 receive construction incentive rate of $1.50/sf.
- K-12 schools with an EUI target less than 25 receive construction incentive rate of $2.00/sf.
- Ground source heat pump incentive of $4,500/ton.

▪ **Path 2**: Whole Building EUI Reduction (50,000 gsf or greater)#

- #Energy-intensive projects less than 50,000 gsf in size may also be allowed to participate.
- Building design team establishes a target EUI and receives incentives based on that target's reduction beyond the Mass Save baseline EUI.
- Construction Incentive Rate between approximately $0.35/sf and $1.25/sf, depending on EUI reduction percentage.
- Ground source heat pump incentive of $4,500/ton

▪ **Path 3**: High Performance Buildings

- Design teams don't set an EUI target, but still may be eligible for incentives.
- Ground source heat pump incentive of $4,500/ton

  - It is recommended that an expert be consulted to determine what tax credits and other incentives may be applicable to the project.

- Contribute to energy efficiency LEED credits
- Significantly more efficient than conventional air-source or variable refrigerant flow systems
- Less fluctuation in annual operating costs
- No exposed outdoor equipment
- Minimize or eliminate the need for cooling towers and condensing units, since most of the heat rejection to the environment occurs in the well field
  - This may have the added benefit of increasing the available roof area for solar arrays.
- Can eliminate the need for flue stacks and ventilation (required for fuel burning equipment)
- No noise associated with outdoor equipment
- Equipment resistant to extreme weather conditions, more reliable HVAC system.

- Less maintenance than conventional systems
  - Closed-loop systems require minimal maintenance. Systems that use antifreeze require loop fluid testing. If antifreeze or corrosion inhibitors are used, yearly testing is recommended to confirm that the fluid is not experiencing degradation, which is uncommon, but may occur if systems are operating for long periods of time outside the design temperature ranges.
- Longevity
  - The materials associated with closed-loop systems typically come with a 50-year manufacturer's warranty. It is anticipated that the piping will outlive the warranty with no capacity degradation over time.
- Access
  - Permanent access is not required for either the vertical well heads or the horizontal circuit piping that runs from well to well and to the manifold in the mechanical room.

The following are several potential disadvantages:

- Higher upfront cost compared to a conventional boiler/chiller system
- Require sufficient area to construct the well field
- Scheduling is challenging and variable
- Noise and vibrations from well drilling can be disruptive to building occupants and abutters
- Imbalanced building loads cause the geologic formation to heat up or cool down, reducing efficiency over time if the geothermal system is poorly designed.

<u>Closed-Loop Geothermal Systems</u>

There are two main types of geothermal systems: closed-loop and open-loop. Open-loop systems draw water directly from a geologic formation as the heat transfer medium. Closed-loop systems circulate water or water-antifreeze solution as the heat transfer medium in a continuous closed piping loop from the well field (where it absorbs or rejects heat), through the heat pumps and mechanical equipment, and back to the well field without the fluid contacting the geologic formation.

In general, open-loop systems are theoretically more efficient and have lower up-front costs than closed-loop systems, but are much riskier to permit, construct, and maintain. A closed-loop system is recommended for this project because of the reduced environmental, and maintenance risks and complexity.

Conventional closed-loop geothermal wells use HDPE U-bends or quad-loops (aka double U-bends) and are typically installed to depths of about 400 to 850 feet below ground surface.

They are typically spaced a minimum of 20- or 25 feet-on-center in wellfields laid out in simple grids or more complex geometries to fit within existing site requirements. These layouts are organized in circuits of boreholes connected in parallel which are collected in a manifold within a mechanical room or in a vault adjacent to the wellfield before reaching the heat pump. Permanent access to the well heads and piping for a closed loop system does not need to be maintained.

Deeper wells on the order of 1,000- to 1,500-feet-deep are also technically possible, but these require a greater minimum spacing between wells (40 to 50 feet), are expensive to drill due to the need of an additional booster to be able to clear the hole of drill cuttings, typically use a proprietary product (aka RYGAN) and may have issues with maintaining vertical tolerance (~5%) which could result in the bottom portion of the wells being drilled beyond the property line.

Geothermal wells are typically installed with truck-mounted drill rigs that can advance 20-foot-long steel drill rods. Since this is new construction, it will be possible to install geothermal wells as part of the construction beneath the building footprint, if required.

Permitting Requirements and Other Considerations

The Massachusetts Department of Environmental Protection (MassDEP) Underground Injection Control (UIC) Program and the United States Environmental Protection Agency (US EPA) categorize closed-loop geothermal wells as Class V injection wells but no longer requires the filing of an Underground Injection Control (UIC) Registration application with MassDEP provided that the well is installed and operated in accordance with MassDEP's Guidelines for Ground Source Heat Pump Wells.

MassDEP does not allow geothermal wells to be located within a Zone I of a public water supply well as defined by 310 CMR 22: the Massachusetts Drinking Water Regulations. Utilizing the online Massachusetts Geographic Information Systems (MassGIS) mapping tool, the site is not located within a Zone I area.

Other key permitting requirements outlined in the MassDEP guidelines include the following:

- Wells are required to be located at least 25 feet from "existing and potential sources of contamination including, but not limited to, septic tanks/fields, lagoons, livestock pens, and oil or hazardous materials storage tanks."
    - According to the Phase I Environmental Site Assessment & Subsurface Investigation by Lord Environmental, Inc. and dated September 29, 2023, the subject site was identified to contain two (2) abandoned in place underground storage tanks (USTs) located at the central portion of the property adjacent to the existing generator and the building's boiler room. It is understood that the results of a targeted subsurface investigation which consisted of the sampling and analysis of select soil samples obtained in the vicinity of the abandoned in place USTs did not identify elevated concentrations of

petroleum constituents in the submitted samples. Further, it is understood that the abandoned USTs will be removed with the permitted approval of the City of Newton Fire Department. Based on this information that was reviewed, there do not appear to be environmental constraints that would prohibit geothermal at the subject site.

- Various design and setback requirements must be followed. Setback requirements include minimum distances as follow:
  - 10 feet from potable water and sewer lines
  - 50 feet from private potable water supply wells
  - 10 feet from surface water bodies
  - 10 feet from property lines, except with the expressed written permission of the abutter
- The anticipated well field location is not in a wetland buffer zone and therefore is not anticipated to be subject to the Wetlands Protection Act regulations which would be governed by the local Conservation Commission.
- Per MassDEP guidelines, closed-loop wells are required to be fully grouted and/or have a permanent steel casing installed a minimum of 15 feet into competent, unweathered bedrock.

A Well Construction Permit would be required from the City of Newton Health and Human Services Department. The City of Newton regulations also contain setback requirements which are understood to apply to geothermal wells in addition to irrigation wells. These setback requirements include minimum distances as follow:

- 5 feet from property line
- 25 feet from roadway
- 100 feet from leaching facility
- 50 feet from septic or pump tank
- 100 feet from underground storage tank
- 50 feet from private or public sewer lines (or 10 feet if constructed of durable, corrosion-resistant material with watertight joints)
- 25 feet from subsurface drains

It should be noted that a variance for the above referenced City of Newton setbacks may be granted by the Commissioner of Health and Human Services if strict compliance with these regulations would manifest injustice and the applicant proves the same degree of protection as required under these regulations can be achieved.

Potential Well Field Layouts

To maximize heating and cooling capacity of the geothermal system, while providing the simplest construction sequencing for the demolition of the existing school, it is anticipated that geothermal wells will be installed in the planned western parking lot in **Figure 1**. The location and future size of the existing and any proposed trees would need to be coordinated with the well field design if wells are placed in any of the landscaped areas. In general, large trees should be avoided near the well field as the roots could potentially damage the horizontal circuit piping. Conversely, the drilling of a well or installation of horizontal piping within the drip line of a tree could damage it. Ornamental trees and bushes near the well field may be acceptable. In this analysis, no wells were placed inside of a drawn tree.

To estimate possible well counts, we prepared a drawing that integrated the landscape CAD file sent in an email by Lemon Brooke on 2/22/24 titled "23-005 L_BASE.dwg" and the utility CAD file sent in an email by Samiotes on 2/27/24 titled "52064 – Franklin Elementary School SD C-4.0 UTILITY.pdf". From these two drawings, we applied the setbacks described in the "Permitting Requirements and Other Considerations" to determine feasible areas for geothermal well installation. Two well spacings are considered: 25-foot-on-center spacing and 20-foot-on-center spacing. The actual number of wells that will fit in the designated area depends on the building heating and cooling loads and the locations of water and sewer lines, and other utilities (**Table 1)**.

Well Spacing (ft)	# of Wells
20	60
25	40

Table 1. Summary table of the estimated number of wells that can fit in the western parking area, from the analysis in Figures 4, and 5 with 20- and 25-foot-on-center well spacing.

Figure 4. Possible wellfield layout in the western parking area at 20-feet-on-center.

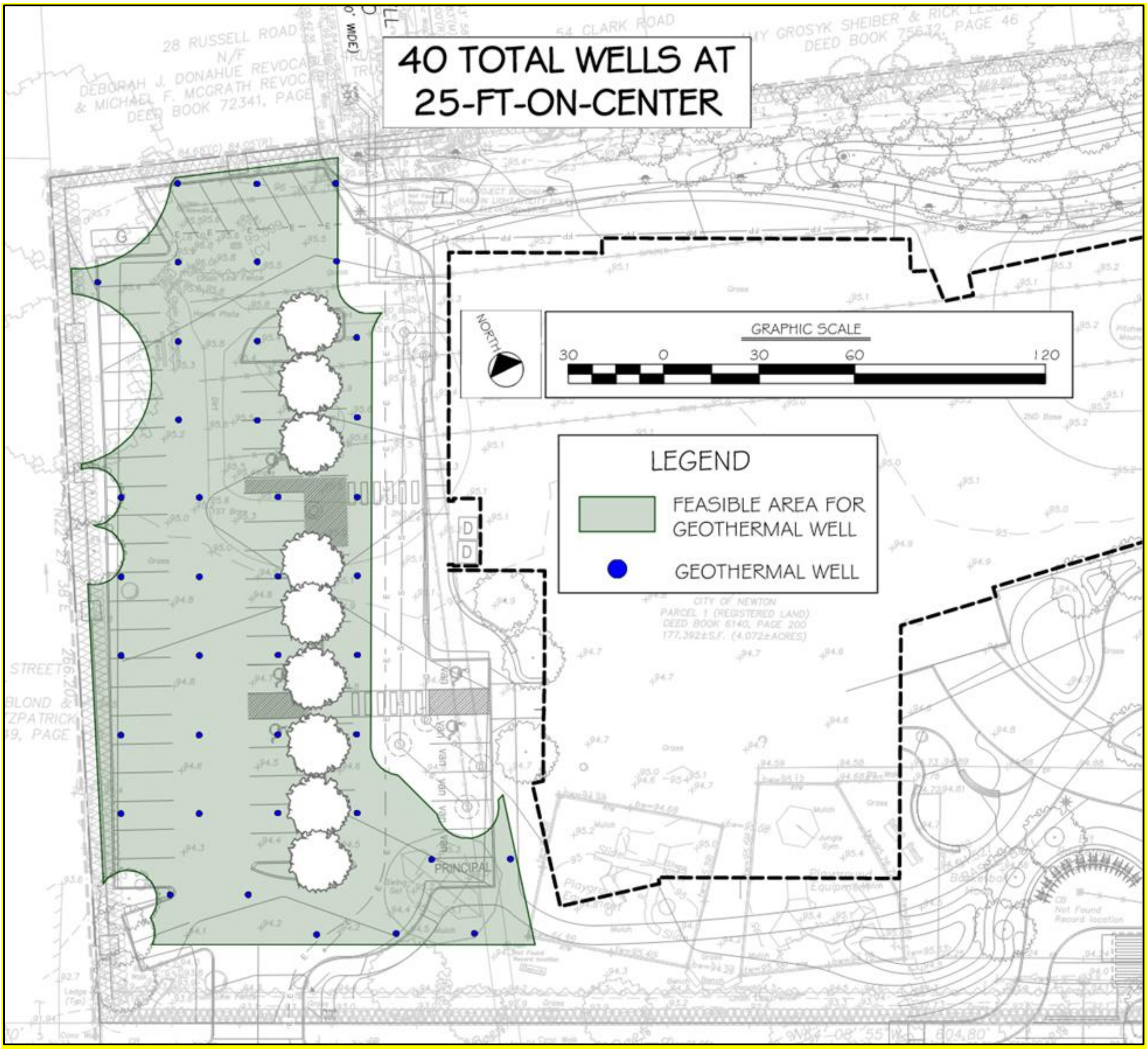

Figure 5. Possible wellfield layout in the western parking area at 25-feet-on-center.

Preliminary Loading Information and Well Field Sizing

McPhail received peak loads of 178 tons in cooling and 150 tons in heating from GGD Consulting Engineers, Inc. on 3/08/2024. Since site-specific geothermal properties from a test well and an hourly or monthly heating and cooling load profile were unavailable, we were not able to perform modeling using ground energy transfer software programs. As such, typical "rules of thumb" were used to estimate the number of wells based on the provided peak loads which is typical for a preliminary evaluation. If the total and peak heating and cooling loads are relatively balanced, then the upper bound capacity per well indicated below may be more applicable.

In this preliminary wellfield analysis, we consider three (3) wellfield types:

- 500-foot-deep single HDPE U-bend at 20-foot spacing
- 600-foot-deep double HDPE U-Bend (quad-loop) at 25-foot spacing
- 700-foot-deep double HDPE U-Bend (quad-loop) at 25-foot spacing

Each wellfield type has a corresponding estimated with lower and upper bound tons per well (capacity) values which are used to estimate the number of wells required to meet 100% of the capacity of the building. HDPE single and quad-loops are non-proprietary and are commonly available from multiple suppliers.

- For the analysis with 500-foot-deep single U-bends at 20-foot spacing, we assumed the following capacities:
  - Lower bound: 2.5 tons per well
  - Upper bound: 3 tons per well
- For the analysis with 600-foot-deep quad-loops at 25-foot spacing, we assumed the following capacities:
  - Lower bound: 4 tons per well
  - Upper bound: 4.8 tons per well
- For the analysis with 700-foot-deep quad-loops at 25-foot spacing, we assumed the following capacities:
  - Lower bound: 4.7 tons per well
  - Upper bound: 5.6 tons per well

500-foot-deep at 20-feet-on-center single U-bends:

Design Case (tons/well)	Estimated capacity per well (tons/well)	Estimated number of wells	Estimated total wellfield capacity (tons)	Estimated percentage of peak cooling load provided	Additional number of wells needed to meet 100% of peak cooling load
Lower bound	2.5	60	150	84%	11
Upper bound	3	60	180	101%	-1

To meet 100% of the cooling capacity with 500-foot-deep single U-bends at 20-feet-on-center with 2.5 tons/well capacity, approximately 71 wells are needed. For 3 tons/well capacity, approximately 59 wells are needed. ***As such, in an estimated best-case scenario, 500-foot-deep single U-bends could meet 100% of the peak cooling and***

heating capacity but in an estimated worse-case scenario may only provide 84% of the peak cooling load.

600-foot-deep at 25-feet-on-center quad-loops:

Design Case (tons/well)	Estimated capacity per well (tons/well)	Estimated number of wells	Estimated total wellfield capacity (tons)	Estimated percentage of peak cooling load provided	Additional number of wells needed to meet 100% of peak cooling load
Lower bound	4	40	160	90%	5
Upper bound	4.8	40	192	108%	-3

To meet 100% of the cooling capacity with 600-foot-deep quad-loops at 25-feet-on-center with 4 tons/well capacity, approximately 45 wells are needed. For 4.8 tons/well capacity, approximately 37 wells are needed. ***As such, in an estimated best-case scenario, 600-foot-deep quad-loops could meet 100% of the peak cooling and heating capacity but in an estimated worse-case scenario may only provide 90% of the peak cooling load.***

700-foot-deep at 25-feet-on-center quad-loops:

Design Case (tons/well)	Estimated capacity per well (tons/well)	Estimated number of wells	Estimated total wellfield capacity (tons)	Estimated percentage of peak cooling load provided	Additional number of wells needed to meet 100% of peak cooling load
Lower bound	4.7	40	188	106%	-2
Upper bound	5.6	40	224	126%	-8

To meet 100% of the cooling capacity with 700-foot-deep quad-loops at 25-feet-on-center with 4.7 tons/well capacity, approximately 38 wells are needed. For 5.6 tons/well capacity, approximately 32 wells are needed. ***As such, 700-foot-deep quad-loops could likely provide 100% of the peak cooling and heating capacity.***

Preliminary Cost Estimate

Using data from past projects, we determined a rough order of magnitude preliminary estimated cost for the three (3) well types discussed in the above section. Specifically, we used these values to estimate a total cost for each of the three (3) well types with both the upper and lower bound capacity. The lower bound capacity of the 500-foot-deep single U-bend and 600-foot-deep quad loop will not reach 100% heating and cooling capacity given the 178 peak tons of cooling; however, both the upper and lower bound capacities of the 700-foot-deep quad loop would reach 100% heating and cooling (**Table 2**).

Well Depth (feet)	Well Type	Spacing (feet)	Total Number of Wells	Capacity (tons/well)	Cost per Well (USD/well)	Total Cost
500	Single U-Bend	20	60	2.5	$33,000.00	$1,980,000.00
500	Single U-Bend	20	59	3	$33,000.00	$1,947,000.00
600	Quad-Loop	25	40	4	$39,000.00	$1,560,000.00
600	Quad-Loop	25	37	4.8	$39,000.00	$1,443,000.00
700	Quad-Loop	25	38	4.7	$42,000.00	$1,596,000.00
700	Quad-Loop	25	32	5.6	$42,000.00	$1,344,000.00

Table 2. Summary of cost estimate for the different scenarios, both lower and upper bound per depth and type of well. Highlighted red rows are scenarios where the well design would likely not meet 100% heating and cooling capacity. Highlighted green rows are scenarios where the well design would likely meet 100% heating and cooling capacity.

Conclusions

The following are our conclusions given the preliminary peak loads received:

- A geothermal well system is technically viable for the project, however, deeper quad-loops may be required to meet 100% of the given peak loads.
- The 700-foot-deep quad-loops at 25-feet-on-center scenario could likely provide 100% of the given peak load of 178 tons even with its lower-bound capacity:
- The remaining two (2) scenarios studied (500-deep single U-bends at 20-feet-on-center and 600-foot-deep quad-loops at 25-feet-on-center) could provide between 84% to 100% of the peak cooling capacity and 100% of the peak heating capacity. These percentages are rough, and well counts will change as the energy model is further developed**.**
- If heating and cooling load estimates decrease as the design process proceeds, 500-deep single U-bends at 20-feet-on-center and 600-foot-deep quad-loops at 25-feet-on-center may become viable designs.

If it is decided to pursue geothermal further, the following should be considered:

- Detailed energy models with hourly heating and cooling loads should be developed to determine the energy performance requirements for the selected geothermal design option. The efficiency of the HVAC equipment (e.g., heat exchanger, heat pump) is a direct function of the geothermal design.
- Using the detailed energy models, modeling using ground energy transfer software programs is recommended to validate the estimated well quantities contained herein to verify that a geothermal well system is technically viable, and which of the proposed well options would meet 100% of both the heating and cooling load.

- Depending on the results of the detailed energy model, the use of a secondary heat sink, such as an air source heat pump, to reduce the peak cooling load may reduce the number of geothermal wells that are required.
- Once it is determined which depth and type of well is most feasible, geothermal test wells should be installed and thermal conductivity tests performed to determine ground conditions for use in modeling a geothermal system.
    - The test wells would provide valuable geologic information for bidding including the depth to bedrock, the approximate amount of steel casing required, the bedrock type, the rate of advancement, and the presence of significant water bearing zones. This information would reduce, but not eliminate, the potential for change orders due to unanticipated geologic conditions.

Closing

We trust that the above is sufficient for your present requirements. Should you have any questions, please do not hesitate to call us.

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