New Nicollet Redevelopment Project

Darcy Solutions Viability Report

Prepared for:

City of Minneapolis

Prepared by:

Darcy Solutions

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September 30th, 2025

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Background

Darcy Solutions developed this technical analysis for The New Nicollet Redevelopment Project. Darcy specializes in the analysis, design, and installation of groundwater-coupled geothermal heating and cooling systems, with particular expertise in Aquifer Thermal Energy Storage (ATES), groundwater pump-and-reinject (GTED) systems, and our proprietary Darcy Dipole technology, an innovative, patented geothermal technology which produces greater than 50X the energy exchange per borehole as compared to traditional geothermal systems. Our work is rooted in the belief that subsurface energy solutions can deliver low- carbon, high-efficiency, and scalable alternatives to conventional thermal systems.

Our team brings together decades of experience in geologic modeling, hydrogeology, thermal system design, and applied engineering. We've supported groundwater enhanced geothermal energy projects across the Upper Midwest, helping public, private, and institutional clients develop systems that are reliable, resilient, and environmentally responsible. From conceptual model development to detailed simulation and design, Darcy applies a systems-level approach that integrates hydrogeologic insight with practical, field-tested engineering.

Darcy's typical model is to provide detailed design parameters, information and support allowing consultants to complete their design. Darcy will then be contracted to perform construction of the geothermal well field, which includes well construction and installation of all down-well equipment (Darcy's proprietary heat exchanger in dipole applications, submersible pump and supporting components), well-to-building closed loop components, and system controls. In the case of thermal energy networks and similar geothermal systems, Darcy would provide connection of wells into the district loop.

Features of Darcy's technology include the lowest emissions heating and cooling system, greater efficiency than traditional geothermal systems, support for imbalanced heating and cooling loads, more control of produced fluid temperatures, the avoidance of glycol and other potential contaminants in the closed loop, a significantly smaller footprint requirement with related reduction in drilling requirements, and the ability to interface with a wider variety of building HVAC technologies.

Executive Summary

Darcy Solutions was engaged by the City of Minneapolis to assess the feasibility of implementing a groundwater-enabled geothermal system for the New Nicollet Redevelopment Project. The primary objective of this evaluation was to determine the viability of applying Darcy's proprietary Dipole technology at the former Kmart site located at 10 W Lake Street, Minneapolis, MN.

The assessment included a preliminary geologic evaluation, review of regional well logs, analysis of comparable Darcy projects in the immediate area, and a review of the hydrogeologic conditions within the Prairie du Chien–Jordan aquifer system (OPDC + CJDN). This aquifer system is present at the site between approximately 275 and 475 feet below ground surface and is known to provide reliable groundwater production capacity. Supporting data from nearby operational Darcy installations demonstrated favorable aquifer performance, validating expectations of adequate well yields and injectivity for a multi-well system.

A preliminary system design was developed, including production and injection configurations, well spacing and setback guidelines, and estimated thermal performance. The analysis confirms that the Darcy Dipole design can deliver efficient heating and cooling by utilizing stable aquifer temperatures (~52°F), while minimizing geochemical and microbial fouling risks through a closed-loop, in-subsurface heat exchange process. A test bore is recommended as the next step to confirm stratigraphy and finalize well construction parameters.

The financial outlook remains favorable, with federal incentives under the revised Inflation Reduction Act and OBBBA legislation supporting project viability. The availability of long-term Investment Tax Credits and eligibility pathways for district-scale systems provide further flexibility for development models.

Introduction

Darcy Solutions was requested to evaluate the New Nicollet Redevelopment site for its potential usage of a Darcy Dipole groundwater enabled geothermal system. The City of Minneapolis is redeveloping the former Kmart site located at 10 W Lake Street, Minneapolis, Minnesota, 55408. The project site covers 10 acres of land bordered by Blaisdell Ave to the West, Lake Street to the South, 1st Avenue to the East and the Midtown Greenway to the North as shown in Figure *1* below. This image has been extracted from New Nicollet Development: Framework and linked here: (https://lims.minneapolismn.gov/Download/RCAV2/49660/New-Nicollet-Development-Framework.pdf).

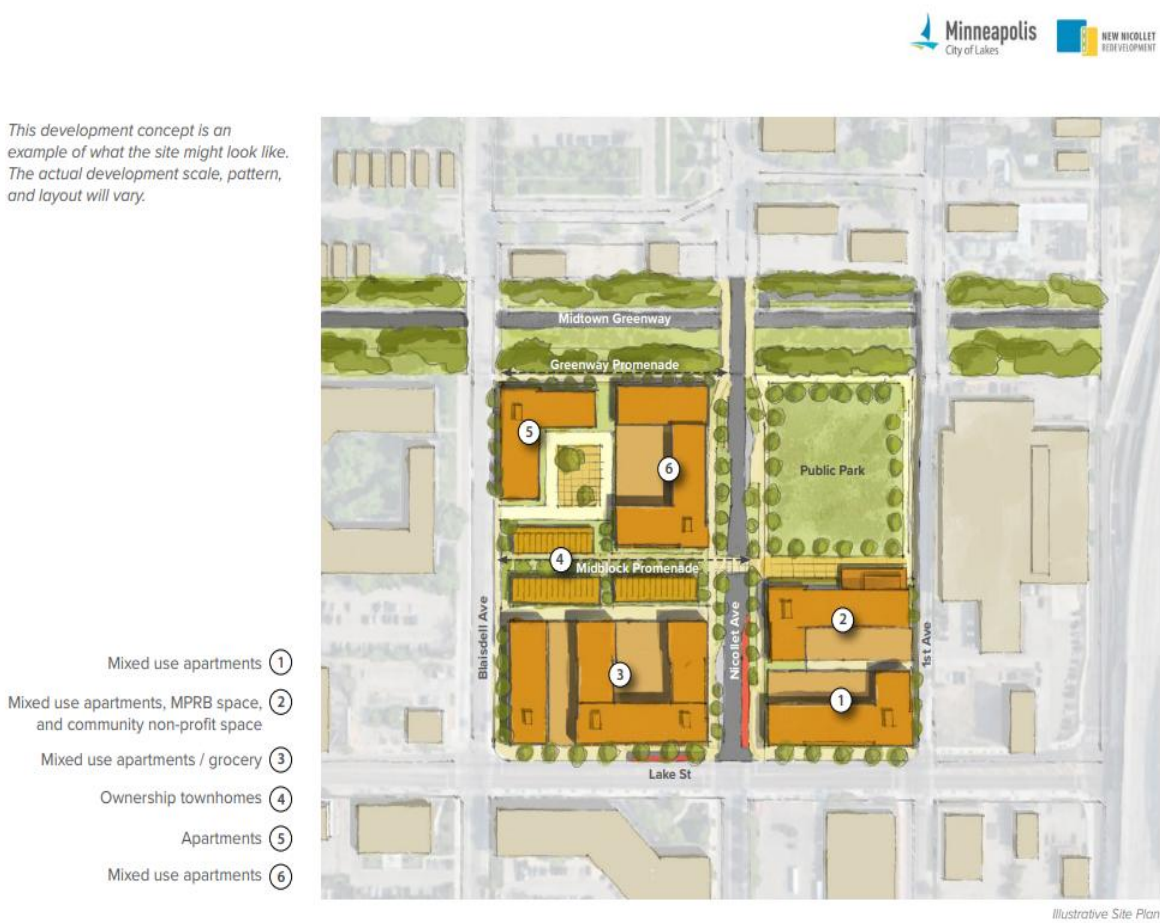


Figure 1: New Nicollet Development: Framework – Site Layout

This report presents the results of Darcy Solutions analysis for the proposed New Nicollet Redevelopment project. To support the viability of the Darcy Dipole system, there was a detailed scope requested by the City of Minneapolis that is included in the report.

The scope of this report includes:

- Preliminary geologic evaluation of the proposed site
- Supporting data for the geologic evaluation including information on comparable wells in the area (from publicly available well logs and Darcy specific projects)
- Information on the target aquifers in the area
- Darcy Dipole System Design Summary
- Preliminary expected performance from each well
- Information on required production well spacing and guidelines on required setbacks
- Scope and budget pricing on required test bore for the site
- OBBBA impacts for geothermal projects
- Summary of expected viability for the Darcy Dipole geothermal system

The sections that follow detail the proposed scope, design considerations and viability of the site for a Darcy system. Our goal is to provide actionable insights that support next-phase decision-making for the system design and implementation at the New Nicollet Redevelopment site.

Preliminary Geologic Evaluation

The preliminary geologic evaluation of this site shows that the site will be optimal for a Darcy Dipole system.

Darcy evaluates the stratigraphy of each site using a variety available data in the region including public atlas reports, well logs in the area and information from other Darcy systems installed in the area. This analysis helps us to determine viability for the Darcy system as well as target aquifers in which our system will be installed.

The top strata (distinct horizontal layer of sedimentary rock or soil) is surficial sands and gravels (QUUU) loosely consolidated on top of the underlying bedrock and is expected to exist from ground surface level to approximately 105 feet bgs (below ground surface). The next strata is expected to be a thin portion of the Platteville (OPVL) bedrock depending on exact locations on site for the production well(s). The first defining layer of bedrock is expected to be the St. Peter (OSTP) located from 110 feet bgs to 275 feet bgs.

The target aquifer for the Darcy system at this site is the Prairie du Chien group consisting of both the Prarie du Chien (OPDC) and Jordan (CJDN) formations. It is important to note that both the OPDC and CJDN formations are considered one aquifer in the majority of Minnesota including at this site. The OPDC and CJDN formations are expected to exist at this site between 275 feet bgs and 475 feet bgs.

The geologic evaluation of this site will require a test bore, whose scope and budget pricing is detailed later in the report. The test bore at this site will be utilized to verify depth to top bedrock and of drilling conditions on site. The results of the boring will allow us to finalize the well design and depths for the production wells.

Details on the expected stratigraphy of the site are detailed in *Figure 2*, below:

Expected Stratigraphy				
Strata	Depth Top (ft bgs)	Depth Bot (ft bgs)	Elev Top (ft amsl)	Elev Bot (ft amsl)
QUUU	0	105	875	770
OPVL	105	110	770	765
OSTP	110	275	765	600
OPDC	275	405	600	470
CJDN	405	475	470	400
CSTL	475	525	400	350
CTCG	525	525	350	350
bottom	525	525	350	

Figure 2: Expected Stratigraphy

Supporting Data – Well Logs

A Darcy system requires a productive aquifer to optimize the design. Productivity of an aquifer relevant to our system is defined by both the amount of water it can produce while being pumped and the associated drawdown (reduction or lowering of the water table) within the aquifer. Part of the geologic evaluation includes analyzing available well logs in the area which can inform us of depth to target aquifers, pumping data and associated drawdowns. Darcy also integrates data from any wells we have drilled and tested locally into this evaluation.

Below in *Figure 3*, is a summary of data in the area used to evaluate this site:

		Depth (ft bgs) to Top							
Well ID	**Distance (ft)**	**OPVL**	**OSTP**	**OPDC**	**CJDN**	**TD**	**SWL**	**diameter (in)**	**open hole (ft)**
201075	700	73	104	271	404	501		10	291 - 501
275526	1900	87	117	275		391		6	290 -391
201079	2200	88	102	268	393	1081	150	6	814 - 1081
235776	2600	66	89	257	378	460			274 - 460
274269	3100	100	111	275	415	496	61	6	300 - 496
233242	4600	70	98	255	385	1117	122	10	826 - 1117
433286	5300	83	106	271	395	481	102	10	405 - 481
238619	5400	-	250	281	400	437	81	12	251 - 437
200652	6100	74	95	259		302	47	4.5	274 - 302
201077	onsite	133	140	240		340	72		
201080	onsite	100	110			240		2	

Figure 3: Well Logs

Darcy solutions also reviews any of our projects in the immediate area for geological feasibility.

In this instance, Darcy has (2) existing projects in the immediate area in different stages of construction with reliable data points. The first site is located at 3030 Nicollet Avenue, approximately 1 block South of the New Nicollet Redevelopment site with (2) wells installed and the project currently being commissioned. The second site is located at 2740 1st Ave South, approximately 1 block North of the New Nicollet Redevelopment site with (2) wells installed and the project currently being commissioned. At both sites, the 12" production wells have been drilled, developed and pump tested in accordance with our standard procedure.

The result of this evaluation is that both sites have optimal aquifer performance characteristics and will support multi-well full-scale Darcy systems.

Target Aquifer Information and Geochemistry

The target aquifer at the New Nicollet Redevelopment site is the OPDC+CJDN. When considering geothermal system design, it is important to understand the geochemistry of the aquifers that are being interacted with. One of the major advantages of the Darcy system is we leave all water in its native aquifer, significantly reducing any risk involved with geochemistry concerns that can be present in other groundwater-based geothermal designs.

Groundwater within the OPDC+CJDN aquifer system exhibits spatially variable geochemistry and redox conditions, which must be carefully considered in system design. Because these two units have distinct chemical profiles, mixed water samples, such as those collected from long-screened wells or during pumping tests, do not accurately characterize individual formation chemistry. Targeted sampling of discrete aquifer intervals is required for reliable design inputs.

Under static subsurface conditions, groundwater remains in geochemical equilibrium with the surrounding rock. However, disturbances such as depressurization, oxygen intrusion, temperature shifts, or mixing of chemically distinct waters can disrupt this equilibrium and initiate a range of undesirable reactions. These include mineral precipitation, biofouling from microbial activity, and scaling, all of which are most likely to occur in surface heat exchangers and injection wells of open-loop systems such as ATES and GTED. In contrast, Darcy Dipole systems, which circulate groundwater entirely within the subsurface, minimize changes in pressure, temperature, and redox conditions, and therefore carry a significantly lower risk of geochemical and microbial fouling.

Water from the OPDC portion of the system is carbonate saturated, being a limestone-dolomite dominated formation. These waters also tend to be more oxygenated and contain elevated nitrate (N-NO_3^-) concentrations. In contrast, CJDN water generally contains several ppm of dissolved iron and/or manganese, is more reducing, and has lower nitrate levels.

If OPDC water is brought to the surface, the pressure drop can cause CO_2 to degas, especially when the water is heated. Consequently, the water will become supersaturated with carbonates, increasing the likelihood of mineral precipitation, especially in heat exchangers where a temperature change occurs. If OPDC water is mixed with CJDN water during this process, the presence of iron and/or manganese additionally creates conditions for biogeochemical reactions – i.e., microbes that were in stable, depleted conditions suddenly are introduced to food. Any oxygen leaks in surface piping will accelerate microbial growth. Even in watertight systems, air can be pulled into pipes via eddies created by bends and junctions in pipes. Biofilms commonly form in heat exchangers, where surface area is abundant, and in injection wells, where slow water velocities, available surfaces, and a continuous supply of nutrients and minerals allow microbial communities to establish and thrive.

For dipole systems, our standard design offers the lowest geochemical risk, as water is not brought to the surface, pressure and redox conditions remain largely unchanged, and oxygen introduction is effectively avoided.

Darcy Dipole System Design Summary

Darcy Solutions is built around the idea of using geothermal energy in a new, practical way to decarbonize heating and cooling in buildings. Traditional geothermal systems require expensive, land-intensive boreholes or wells that limit their adoption. Darcy's design avoids those constraints by taking advantage of advective based thermal transfer interacting with the aquifer water below our feet to tap into stable underground temperatures for efficient heat exchange.

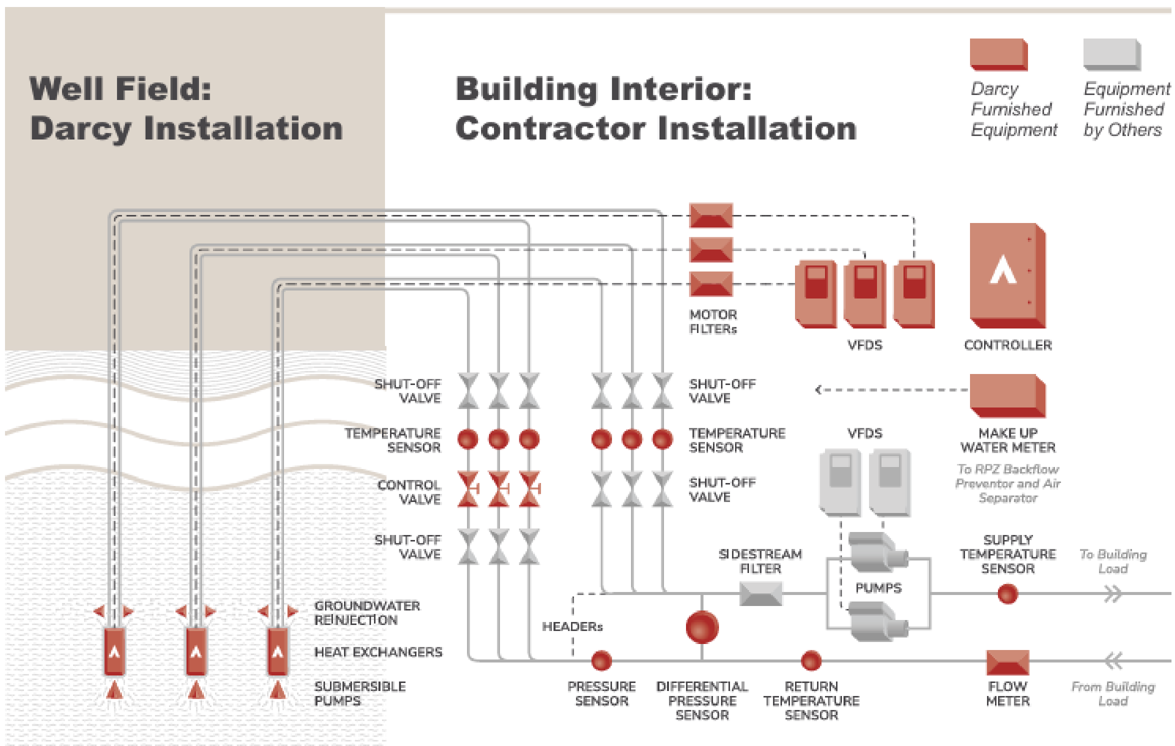
The system is based on a closed-loop heat exchanger that transfers energy between a building's HVAC system and the aquifer. Closed loop water is carried down the well by pumps located inside the mechanical room and through a submersible heat exchanger. Open loop aquifer water is pumped across the heat by the submersible pump installed in each well.

The stable aquifer temperature of approximately 52 degrees Fahrenheit at this site allows us to provide heat to the building in the winter and cooling in the summer with dramatically higher efficiency than conventional systems. During heating season, we are bringing down closed loop water from building at temperatures lower than the aquifer water and warming the closed loop water up. During cooling season, we are bringing down closed loop water from the building at temperatures higher than the aquifer water and cooling the closed loop water down.

The heat exchanger and piping are designed to maintain closed-loop integrity (no mixing of building fluids and groundwater) while maximizing surface area for heat transfer. Darcy's design accounts for thermal drawdown limits in aquifers and uses conservative flow rates to avoid local cooling or heating that would degrade long-term performance.

Darcy acts as a turnkey provider of its system by supporting up-front design work done by the project engineering team with detailed performance estimates, guidance around system controls, assisting in optimizing well siting locations based geologic parameters and local site constraints and providing submittals on our equipment to be integrated into the design plan.

Darcy then typically falls into the construction scope of work as a subcontractor under the owner directly, general contractor or mechanical contractor. Darcy is responsible for well construction and development, installation of all down-well equipment, lateral piping and conduit installation from the well terminated at two feet inside the building wall and commissioning and owner training of the wells and controller. Darcy also supplies, but does not install, various componentry in the mechanical room including submersible pump VFDs, the Darcy controller, motor filters, various temperature and pressure sensors, pressure independent control valves and requisite flow meters for the closed loop. Darcy supports the commissioning of this closed loop componentry as well. *Figure 4* below gives a general overview of the Darcy scope of work.



DARCY INSTALLATION SCOPE:

- Well construction and development
- Down well equipment (HX, submersible pump, sensors)
- Lateral piping and conduit terminated two feet inside building wall
- Commissioning of wells and controller

MECHANICAL / ELECTRICAL / TEMPERATURE CONTROLS CONTRACTOR INSTALLATION SCOPE:

- VFDs for submersible pumps
- Low voltage and line voltage wiring from wellhead to building equipment
- Darcy controller for pumps, valves, and sensors
- Sleeves and core drilling or floor cutting for all Darcy system lateral piping and conduit to enter the building

Figure 4: Darcy Scope of Work

Preliminary Expected Performance

We modeled the Darcy Dipole performance based on previously discussed aquifer characteristics in the area. We assumed the use of the DS008 12" Darcy submersible heat exchanger which is our newest and most highly productive model.

In a groundwater-enabled geothermal system in Minnesota's climate, capacity per well is more constrained in heating than in cooling because the minimum temperature of water in the system is limited by freezing. We assume, therefore, that the minimum temperature in the ambient loop is 35 degrees F, ensuring that when individual buildings tap into the loop, their heat pumps can operate with some flexibility without risking spot temperatures below freezing. The cooling entering water temperature can vary based on system design and connected equipment, but Darcy assumes a temperature of 93 degrees F from the building closed loop going down the well as a starting point.

The following analysis is focused on energy delivered by the Darcy Dipole design and is shown on a per well basis. It is important to note that MBH accepted and rejected per well does not account for heat of compression which is variable based on connected refrigeration equipment of your system. The performance can be seen in *Figure 5*, below:

DARCY

HEAT EXCHANGER PERFORMANCE DATA		
Project		*P1025 Lake Nicollet Redevelopment*
Location		*10 W Lake St, Minneapolis, MN 55408*
Test Well		*Required*
Sales Engineer		*Randy Schock - MMS*
Heat Exchanger Model		DS008
Deep Well Nominal Size (IN)		12
Quantity of Wells		TBD
Groundwater Temperature (°F)		52
Heat Exchanger	Material	Stainless Steel
	Heat Transfer Fluid	Potable H_2O
	Maximum Working Pressure Rating (PSIG)	200
Heating Source (per well)	Closed Loop Flow Rate (GPM)	290
	Closed Loop Water Pressure Drop (FT H_2O)	68
	Heating EWT (°F)	35.0
	Heating LWT (°F)	43.4
	MBH Accepted (see Note 8)	1219
Cooling Source (per well)	Closed Loop Flow Rate (GPM)	240
	Closed Loop Water Pressure Drop (FT H_2O)	35
	Cooling EWT (°F)	93
	Cooling LWT (°F)	67
	MBH Rejected (see Note 9)	3145
Horizontal Pipe	Material	HDPE, DR 11
	Lateral Pipe Diameter To/From Building (IN)	4.0
	Longest Length from Pitless Adapter (FT)	TBD
	Water Pressure Drop (FT H_2O) - S & R	TBD
	Maximum Working Pressure Rating (PSIG)	138.0
Vertical Drop Pipe	Material	PVC
	Maximum Working Pressure Rating (PSIG)	140
Submersible Pump	Variable Speed Submersible Pump (HP)	20.0
	Voltage / Cycle / Phase	460/60/3
	Speed (RPM)	3450.0
	Full Load Ampere - FLA (amperes)	27.0
	Minimum Circuit Ampacity - MCA (amperes)	33.8
	Maximum Overload Protection - MOP (amperes)	60.0

Notes:

1. Review Division 23 5700.11, "Geothermal Heat Exchangers for HVAC" for additional requirements
2. Provide heat exchanger, trenching, excavating, installation, and lateral piping to building perimeter
3. Electrical Contractor shall provide power wiring to each submersible pump
4. Contractor shall provide adequate service clearances to remove heat exchanger for servicing
5. [Provide Hydraulic Conductivity Test if site is questionable]
6. Total Water Pressure Drop includes the sum of the bare Heat Exchanger plus Vertical Drop Tube loss
7. Space heat exchangers 100' apart
8. This does not account for the heat of compression. Consult the manufacturer's equipment literature for exact heat of compression for refrigeration equipment.
9. This does not account for the heat of compression. Consult the manufacturer's equipment literature for exact heat of compression for refrigeration equipment.

Certified by *Mike Lavoie*

Mike Lavoie   Director of Systems Engineering

Date 6/18/2025

Figure 5: Darcy Performance Estimate

Well Spacing and Setbacks

There are considerations that must be made around final well locations and spacing on a site to:

- Optimize the design performance of a multi-well Darcy Dipole system
- Optimize layout to reduce total project costs and minimize final site disruption
- Abide by local setbacks required by the Minnesota Department of Health.

The first consideration is around spacing between wells for a multi-well system. Darcy recommends that wells in a multi-well field be located no closer than 100 feet on center together. This requirement can be reduced on a project level basis depending on some local geological characteristics including the aquifer flow gradient in the area.

The second consideration is optimizing final locations to provide the best total project cost and minimize final site disruption. When installing a Darcy system, open trenching or directional drilling is done to bring the laterals from the well to the building mechanical entrance. It is optimal to locate the wells as close to the mechanical room (or wherever the closed loop is installed) as possible to reduce total project costs. The finished well heads will also be located above ground so this must be considered regarding overall site layout plans. Often, wells are located in greenspace or parking spaces to minimize impact.

The final consideration is centered around isolation distances for a water supply well according to Minnesota Rules, Chapter 4725. Distances from potential water well contamination sources such as storm drains, buried sewers, infiltration basins, gas lines, electric transmission lines and many others must be considered. The distances must be measured horizontally from the water supply well and Minnesota Statutes, section 103I.205, subdivision 6 prohibits constructing, placing or installing an actual or potential contaminant source from a well that is less than the minimum distance prescribed by rule. A full listing of the isolation distances can be found on the MDH website – linked here:
https://www.health.state.mn.us/communities/environment/water/docs/wells/construction/isolate.pdf

Ultimately, it is the project team's responsibility to locate the final production well sites with assistance provided by the Darcy team.

Test Bore Scope and Budget Pricing

Budget pricing and scope for the test bore recommended at the New Nicollet Redevelopment Site is below, a formal proposal with firm pricing can be offered at the request of the owner:

Scope

Darcy Solutions proposes the drilling of a test bore to inform the design parameters for a Darcy well system at **10 W Lake Street, Minneapolis, MN**

- Drill a **4"** test bore to confirm the target aquifer and determine the geologic stratigraphy of the target aquifer to ensure that the hydrogeology will support a Darcy system. Provide hydrogeologic parameters for design of a Darcy production system.
- The specific location of the test bore will be determined jointly by the owner and Darcy. Location to be determined by proximity to proposed production wells and regulatory setback requirements from utilities, flood zones, and buildings.

- The test bore will be conducted by a licensed well contractor, operating under Minnesota well code rules. A Darcy geologist will be on-site to oversee the process.
- A Darcy geologist will log drill cuttings every 5 feet to confirm site stratigraphy, groundwater resource, and geologic conditions that will inform production well construction.
- A Darcy geologist will collect temperature and electrical conductance profiles in the completed test bore.
- Darcy Solutions will provide a summary report, including the site-specific range of heat exchange capacity for typical Darcy wells.
- The test bore will be sealed according to state well code rules after the conclusion of the testing unless otherwise instructed.
- All required drilling permits and public utility locates will be arranged by the driller.

Out of Scope

- Site preparation, landscape work, pavement repair, grading, and excavation.

Pricing

- **BUDGETARY Pricing of $40,000** for the scope of work described above.
    - An additional fee of **$3,500** will be charged for requiring drilling cuttings to be hauled off site at the direction of the owner, otherwise which are expected to be spread at grade.

OBBBA Impacts for Geothermal Projects

The One Big Beautiful Bill Act (OBBBA) was signed into law on July 4th, 2025. This law revised potential incentives (among other things) for geothermal projects that were initiated as part of the Inflation Reduction Act which was signed into law on August 16th, 2022. Much of the existing geothermal incentive language remained the same with some highlights summarized below.

The Geothermal Investment Tax Credit (ITC, Section 48/48E) will still be available for the long term, with the credit starting its phase out period on January 1st, 2033. The tax code should be consulted for specific eligibility on a project level basis, but eligibility percentages remain at 30% for Prevailing Wage and Apprenticeships, 10% for Domestic Content and 10% for Energy Communities. In total, up to 50% of total design and construction of all exterior geothermal equipment and interior applied equipment are available as a tax credit or direct payment from the United States Treasury.

Previous iterations of the law had included a “Limited Use Property” clause which dictated that a geothermal energy project must be the property of the building owner to capture the ITC. The new revision to the law removes that requirement, which allows for developers and financiers to apply different approaches to the development, construction, and operations of these assets including larger Thermal Energy Networks (TENs).

Previous projects qualifying for the ITC also benefitted from accelerated depreciation (MACRS) for a five-year schedule of their energy property equipment. That benefit has been removed for geothermal and other technologies.

The provision allowing for a tax deduction (179D) on projects improving energy efficiency by 25% or more versus the ASHRAE 90.1 standard has been removed for all technologies.

The OBBBA introduces a Foreign Entity of Concern (FEOC) framework meant to eliminate eligibility for energy properties based on ownership and equipment manufacturing origin. Darcy Solutions projects and other ground source heating and cooling projects will not be subject to this framework, though the Domestic Content qualification requirements remain as initially written.

Overall, the adjustments made to the Inflation Reduction Act by the OBBBA are favorable for the viability of geothermal projects with the original tax credits remaining available through 2033.

Conclusion

The New Nicollet Redevelopment site demonstrates strong viability for deployment of a Darcy Dipole geothermal system. Preliminary geologic evaluation, supporting well data, and proximity to other successful Darcy installations confirm that the Prairie du Chien–Jordan aquifer provides sufficient capacity and stable hydrogeologic conditions to support a multi-well system. The system design is expected to deliver low-carbon, high-efficiency heating and cooling consistent with City of Minneapolis sustainability goals, while avoiding the geochemical challenges typically associated with open-loop geothermal systems.