Geological Analysis for Assessing Aquifer Thermal Energy Storage (ATES) Feasibility in the Durham Triassic Basin

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LSRC A236

Abstract

Research Objectives: This research aims to evaluate the potential of ATES technology (Figure 1) in Durham, NC, encompassing geological, environmental, and social justice considerations.
I hypothesize that geothermal energy, and specifically ATES, is a viable and just solution for equitable urban energy production by comprehensively researching the geology of the Durham Triassic Basin.
The specific objectives are as follows:
Geological Characterization: Delve into the geological characteristics of Durham, NC, to determine its suitability for ATES implementation. This includes analyzing the permeability, porosity, and fractures of the local aquifers. This will also include mapping out and developing a more sophisticated and better understanding of the geology present near Duke University and Durham, NC (Figure 2). Using well established methods available at Duke University such as Computed Tomography (CT scans), X-Ray Diffraction (XRD), thin section analysis, and permeability measurements[3], I will analyze the cores to better understand the permeability, porosity and fractures that are present in the local geology. Having a comprehensive understanding of the geology in the area will be imperative to understanding the feasibility for ATES.
Environmental Benefits Analysis: Quantify the potential planetary health solutions of ATES systems, particularly in terms of GHG emissions reductions. Compare the environmental impact of ATES to conventional heating and cooling methods and determine the potential to reduce GHG emissions from Duke with the hope of scaling up to Durham, NC.
Social Justice Considerations: Explore the social justice implications of ATES implementation, ensuring that the benefits of this technology are equitably distributed and that marginalized communities are not adversely affected.

Background

In the quest for sustainable energy solutions and the mitigation of climate change, the harnessing of renewable energy sources has emerged as a critical imperative. Among these sources, geothermal energy stands out as a promising contender due to its low environmental impact, sustainable availability, and potential to contribute significantly to local energy grids. This paper seeks to shed light on the pivotal role that geothermal energy can contribute to the sustainable development of Duke University and with the potential to scale up to Durham, North Carolina and further. As a region endowed with unique geological characteristics and a commitment to environmental stewardship, Duke and Durham exemplify a locality where the adoption of geothermal energy could offer a range of benefits, encompassing reduced carbon emissions, enhanced energy security, economic growth, and greater justice for marginalized communities.
Given the pressing crisis presented by climate change, Duke University has made a commitment to achieve climate neutrality by 2024[1]. As outlined in Duke's 2019 Climate Action Plan Update, the university aims to achieve a 78% reduction in its greenhouse gas (GHG) emissions from 2007 levels by 2024, contingent upon the implementation of all suggested measures[1]. This effort could leave approximately 73,000 metric tons of CO^2 to be offset. Even after this objective is accomplished, Duke intends to persist in its endeavors to diminish any remaining GHG emissions on its campus. To realize substantial cuts in emissions, Duke will need to allocate resources towards alternative solutions for its current natural gas-powered district steam and hot water systems, ensuring they fulfill the heating requirements of campus buildings.

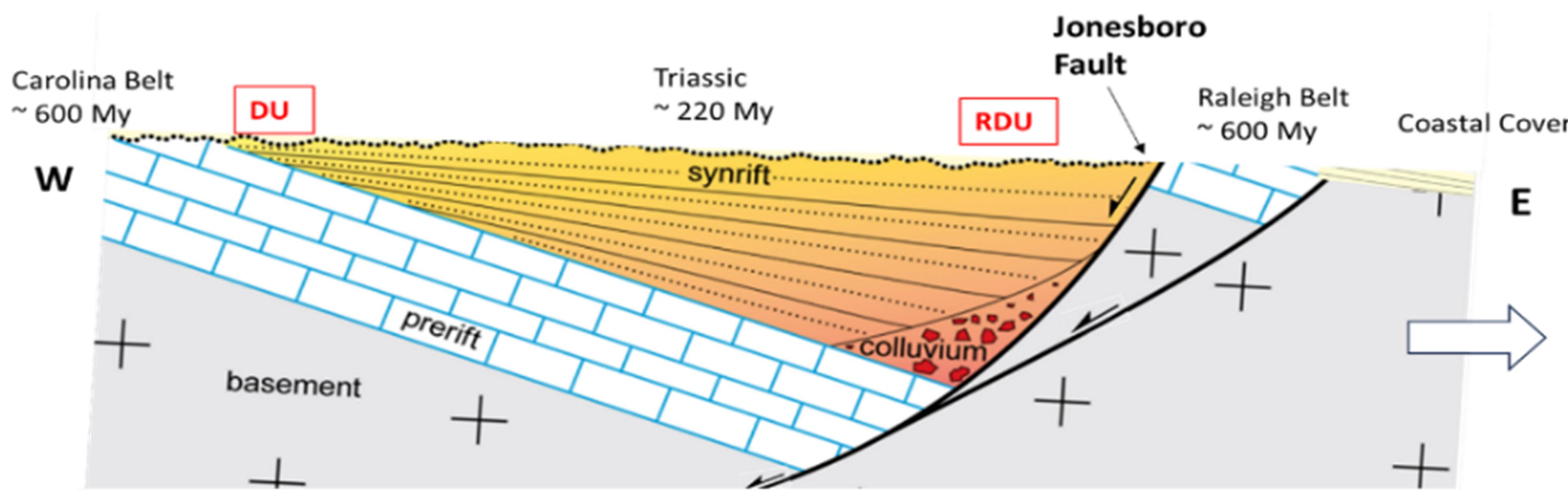


Figure 1. Geology of Duke University and Durham, NC

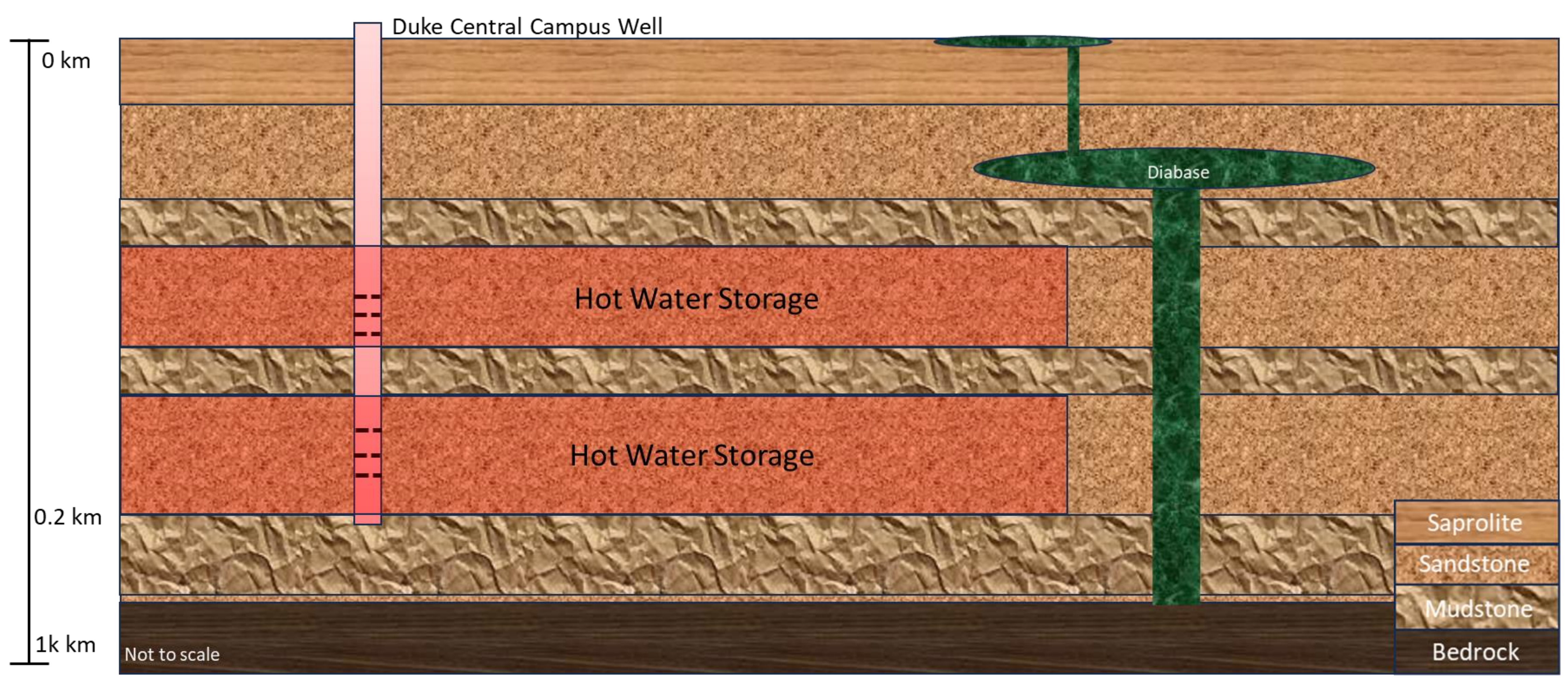


Figure 2. Simplified cross section and aquifer at Duke University

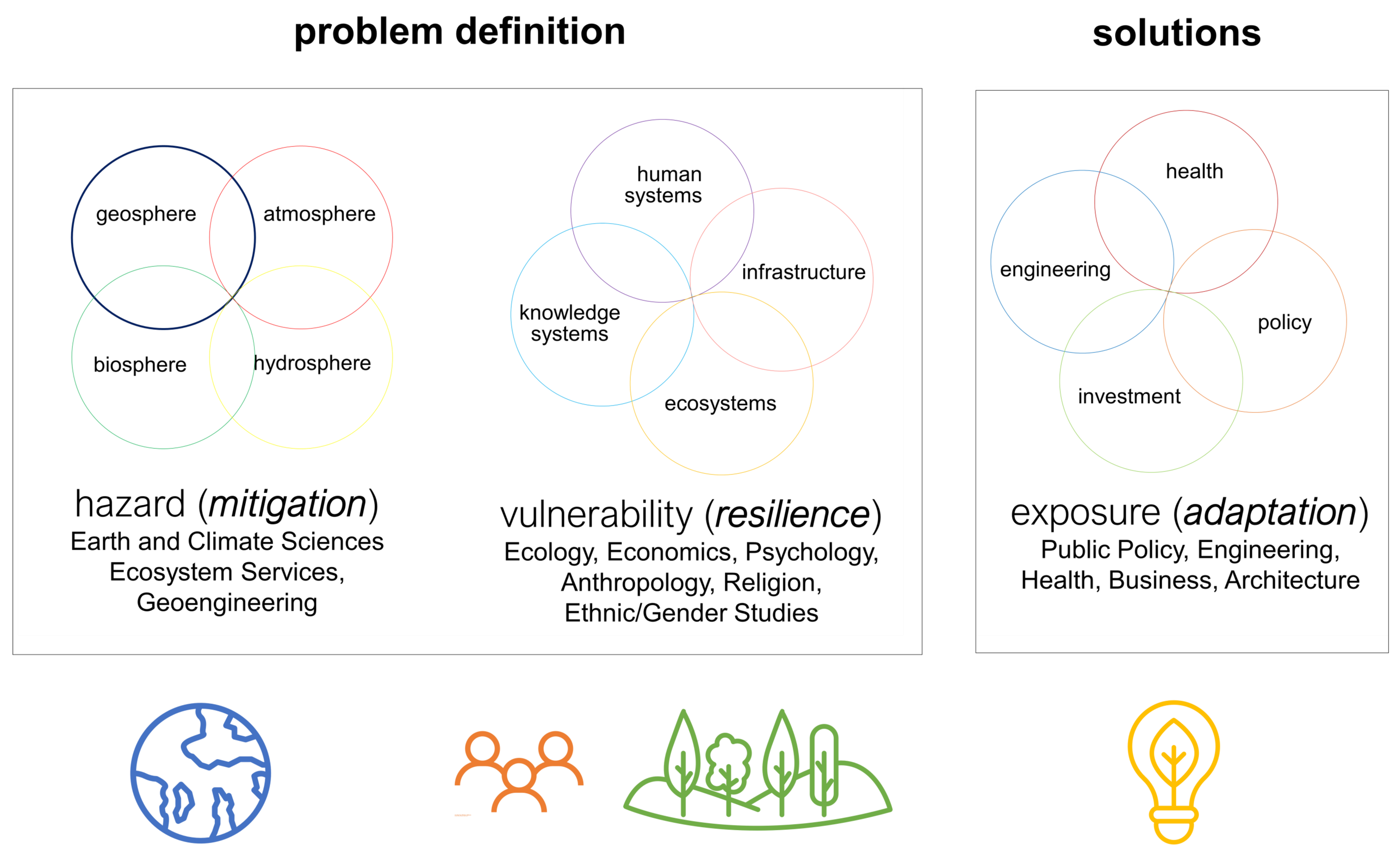


Figure 3. PlanetLab Philosophy

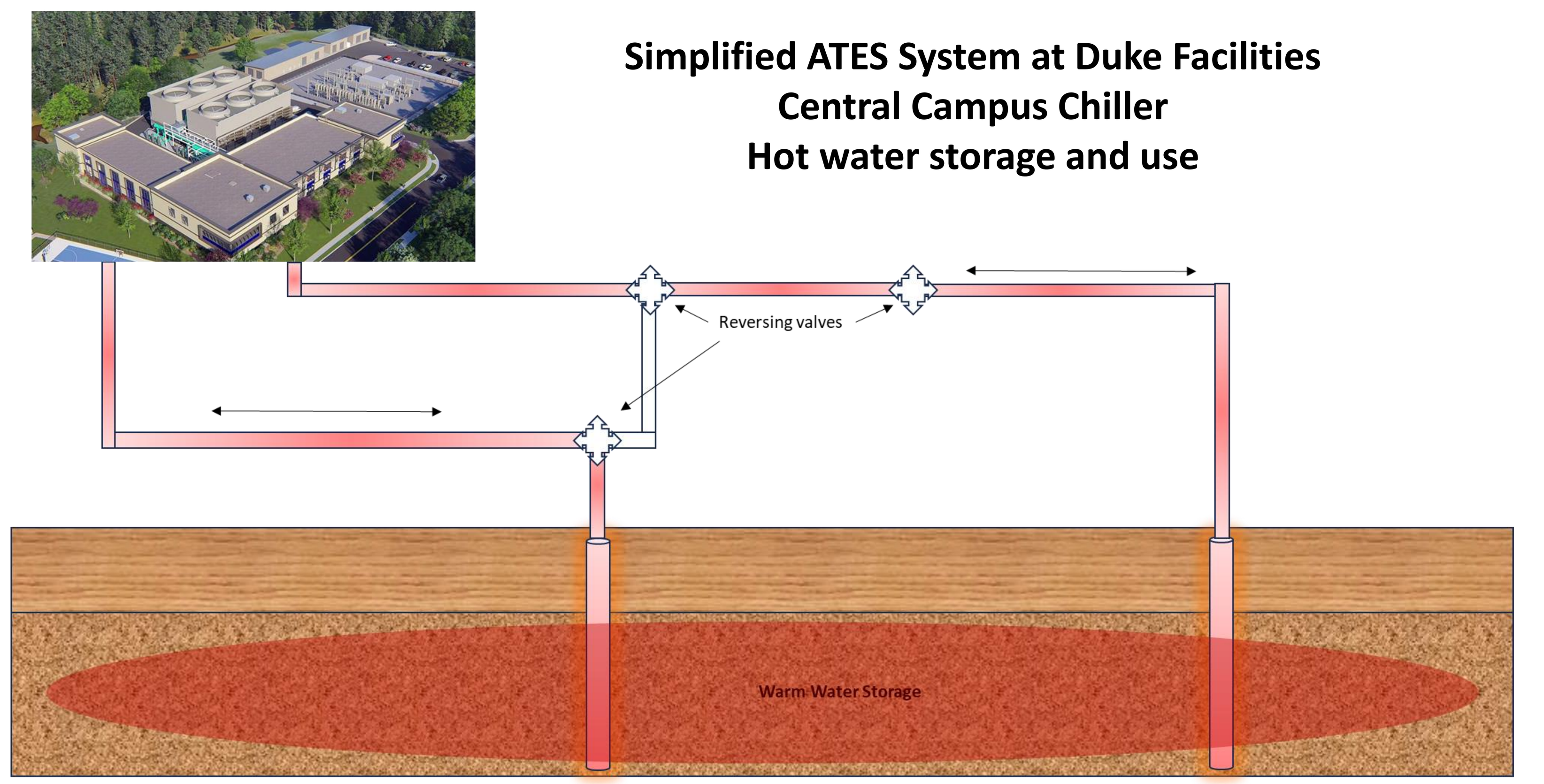


Figure 4. Aquifer Thermal Energy Storage (ATES) System Example Schematic.

Methods

Research Methods: To achieve the outlined objectives, this research will employ a multi-disciplinary approach, bridging the gap between geology, energy engineering, and social sciences.
The specific methods to be utilized include:
Geological Analysis: Analyze cores collected from a 206-meter hole drilled at Duke University to characterize the permeability, porosity, and fractures in the local geology.
Well logging including water temperature & conductivity analysis, dipole and single point resistivity, self-potential, caliper, acoustic televiewer. As we discover more about the data and cores, further geological analysis could arise that we can utilize to better assess ATES systems in the area.
Interdisciplinary Synthesis: Integrate geological insights with energy engineering principles to design and evaluate the performance of ATES systems.
Community Engagement: Collaborate closely with marginalized communities in Durham to understand their perspectives, concerns, and aspirations regarding ATES implementation.
GHG Emissions Modeling: Utilize established models to estimate the potential GHG emissions reductions achievable through ATES technology.

Figure 5. Soil Cores collected from Duke central campus well.

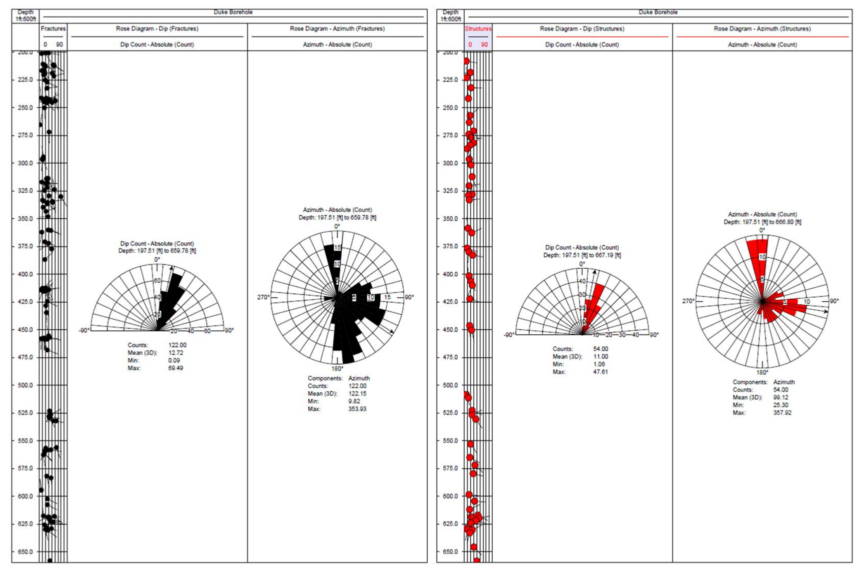
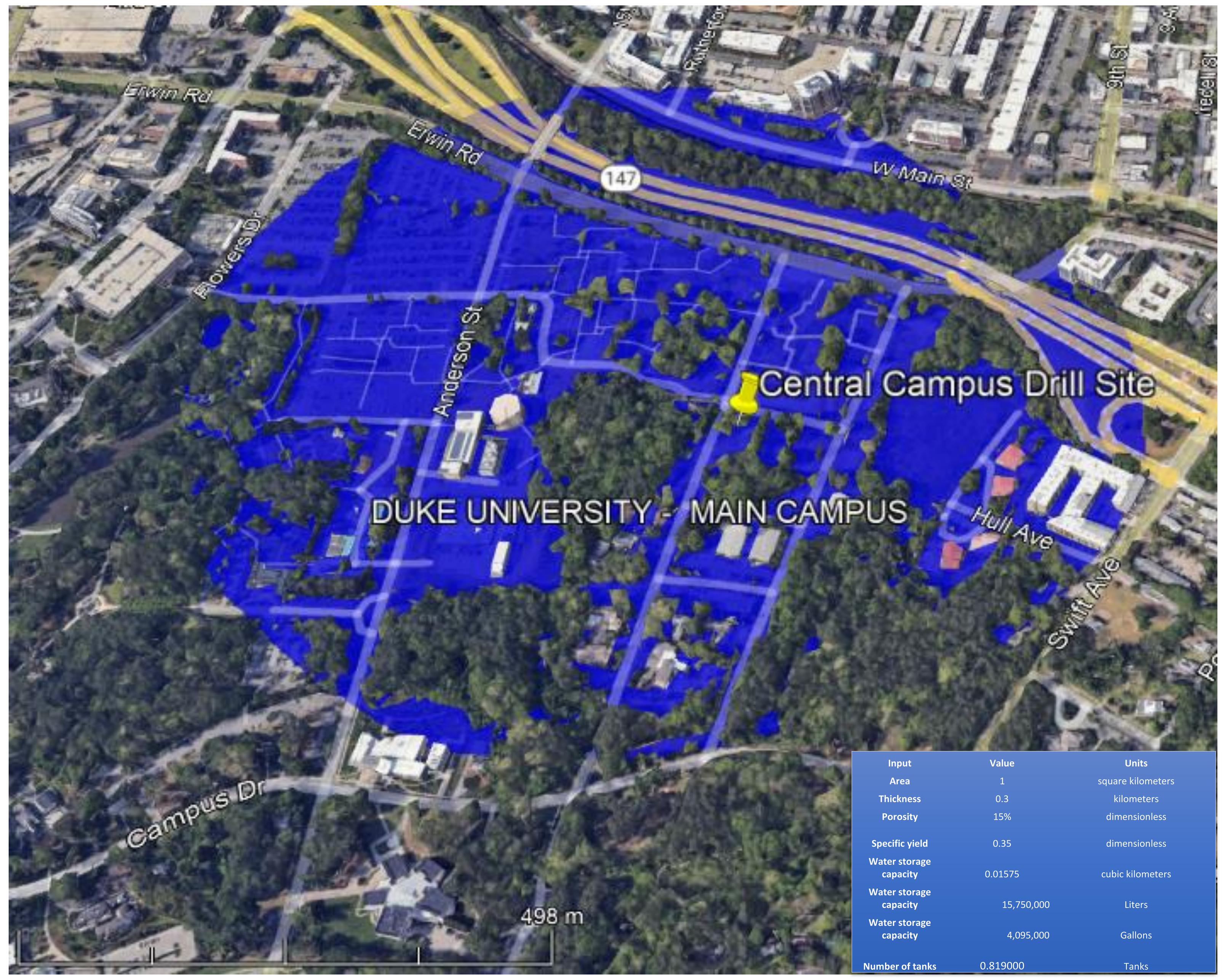


Figure 6. Fracture Rose Plot (Left) and Bedding Rose Plot (Right).



Input	Value	Units
Area	1	square kilometers
Thickness	0.3	kilometers
Porosity	15%	dimensionless
Specific yield	0.35	dimensionless
Water storage capacity	0.01575	cubic kilometers
Water storage capacity	15,750,000	Liters
Water storage capacity	4,095,000	Gallons
Number of tanks	0.819000	Tanks

Figure 7. Proposed Water Storage Area for Aquifer Thermal Energy Storage System Near Duke University and Table with Estimated Water Storage Capacity[5].

Conclusions and Future Work

1.Geological/Core Analysis: Cores collected from the drill site are a crucial starting point. These cores contain geological information about the Durham Triassic Basin.
2.Permeability and Porosity Analysis: Determining the permeability and porosity of the Durham Triassic Basin. These parameters are essential for understanding how easily water can flow through the subsurface rock formations and the amount of pore space available for water storage for ATES and understanding if this is feasible. This can be estimated in several ways in order to cross-check and get the most precise values.
3.Water Storage Capacity Calculation: Calculating the water storage capacity involves assessing the volume of water that can be stored in the geological formations of the Durham Triassic Basin. This information is vital for understanding the potential of the area to accommodate water storage for ATES. Furthermore, understanding water storage capacity will inform if hydraulic stimulation of the aquifer is necessary for this project to be feasible.
4. Hydraulic Conductivity Calculation: Calculating hydraulic conductivity is critical for determining how easily water can move through the subsurface. This parameter is key to understanding the efficiency of the aquifer as a medium for storing and retrieving water for thermal energy.
5. Alignment with Duke Facilities Needs: Ensuring that the determined permeability, porosity, water storage capacity, and hydraulic conductivity align with the needs of Duke facilities is a crucial step. The highest rates required from Duke Facilities from the central campus chiller plant are 3200 gpm or 0.2 m^3/s.
6.Pump Tests for Precise Measurements: Pump tests are instrumental in obtaining real-world data on how water flows within the aquifer. Precise measurements from these tests will enhance the accuracy of our assessments and contribute to the overall feasibility analysis. These pump tests have already been proposed and will occur in 2024.
7. Additional Grants and Funding: Seeking additional grants indicates a proactive approach to obtaining funding for more drill holes and pump tests. These additional tests aim to provide more precise measurements, especially regarding hydraulic conductivity. An investment from the Duke Climate Commitment would be a minimal investment to try and achieve the net-zero goals set by Duke University.

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Acknowledgements

The Duke Endowment
Duke University Bass Connections
Duke Facilities
Duke Utility and Energy Services
Duke Pratt School of Engineering
Phil Bradley, NC DEQ
Hawkston Drilling, LLC
Ryan Emmanuel