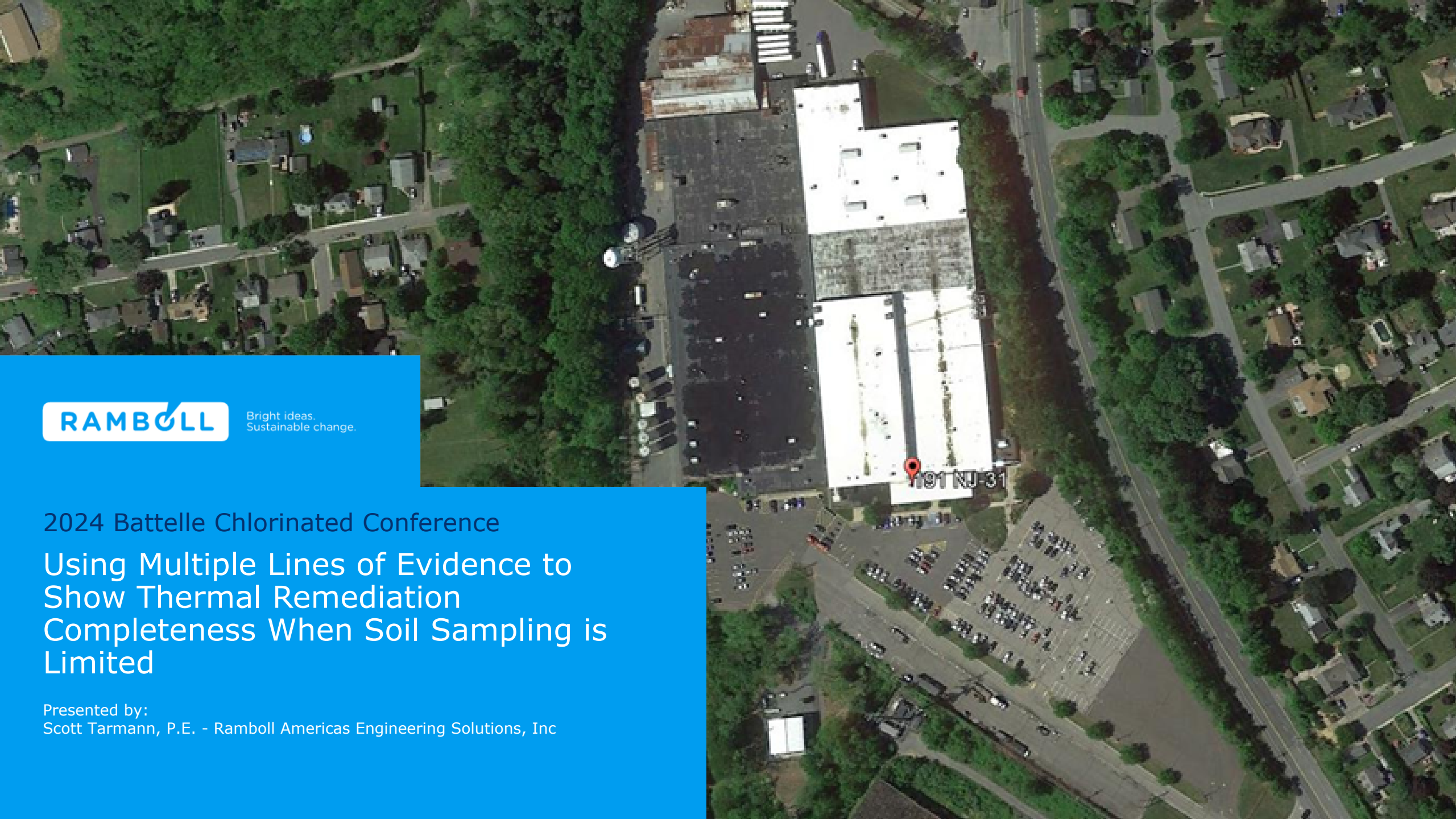

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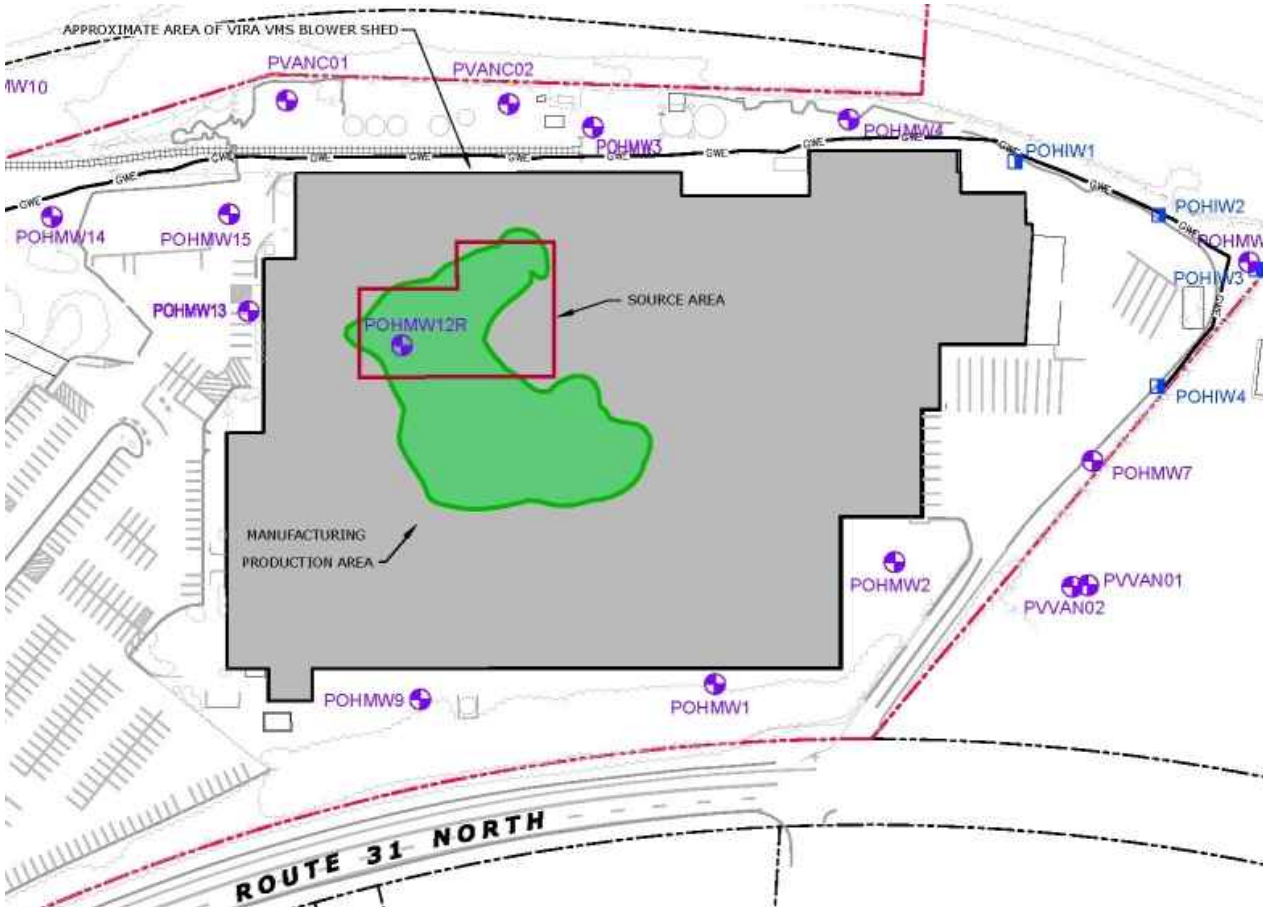
2024 Battelle Chlorinated Conference

Using Multiple Lines of Evidence to Show Thermal Remediation Completeness When Soil Sampling is Limited

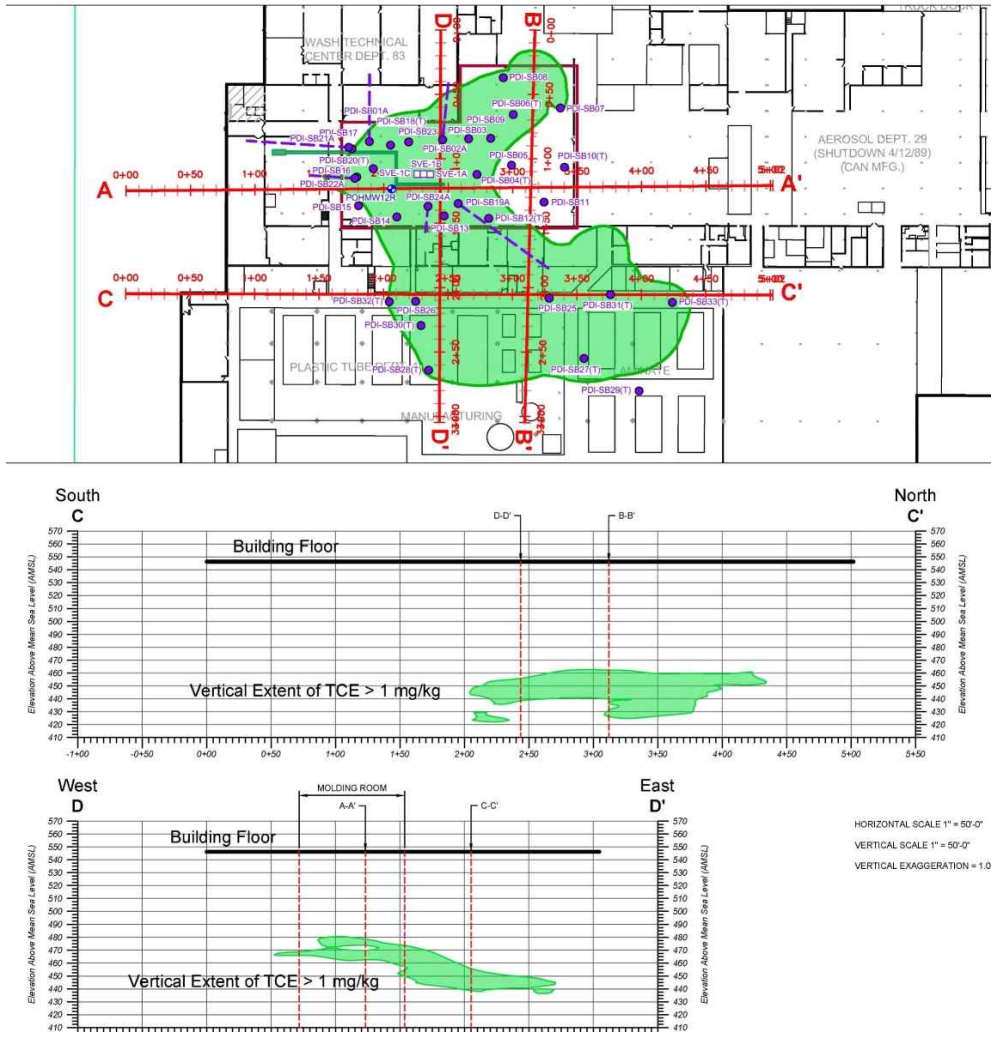
Presented by:
Scott Tarmann, P.E. - Ramboll Americas Engineering Solutions, Inc

Site Setting



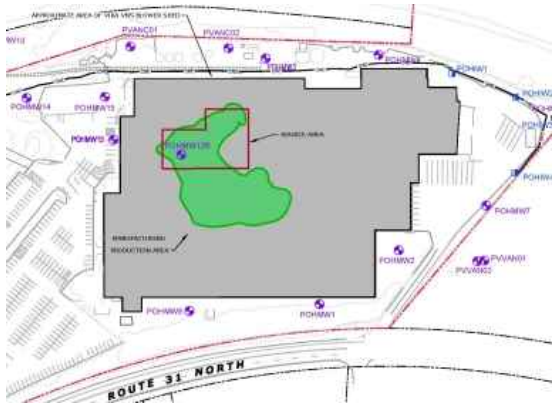
- Superfund site with source soil impacts from legacy manufacturing operations involving the use of trichloroethene (TCE)
- Active facility with hygienically "clean" manufacturing area containing tightly spaced production equipment
- TCE concentrations up to 10 mg/kg were located entirely beneath the 294,000 sq. ft. facility
- In-Situ Thermal Remediation (ISTR) by means of thermal conduction heating (TCH) to achieve a remedial goal (RG) of 1 mg/kg TCE

Site Setting

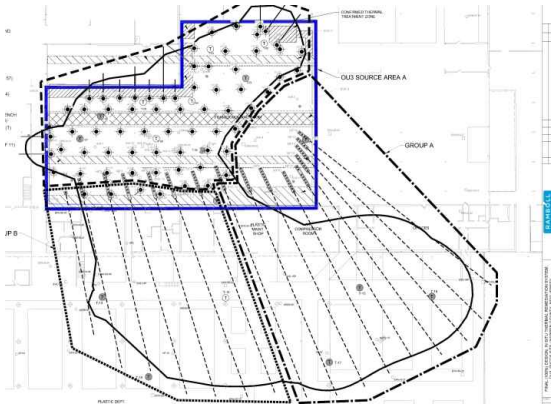


- 23,000 Cu.Yd. target treatment zone (TTZ) located 60 to 120 feet beneath the building floor
- Impacted vadose zone consisting of glacial till with cobbles
- Bedrock surface located at 125 feet with no TCE impacts above remedial goal

Problem Description



- Location, depth and geometry of soil impacts forced the need to install TCH heaters inside building



- Facility operations required ISTR to be undertaken from within a 10,000 ft^2 storage room

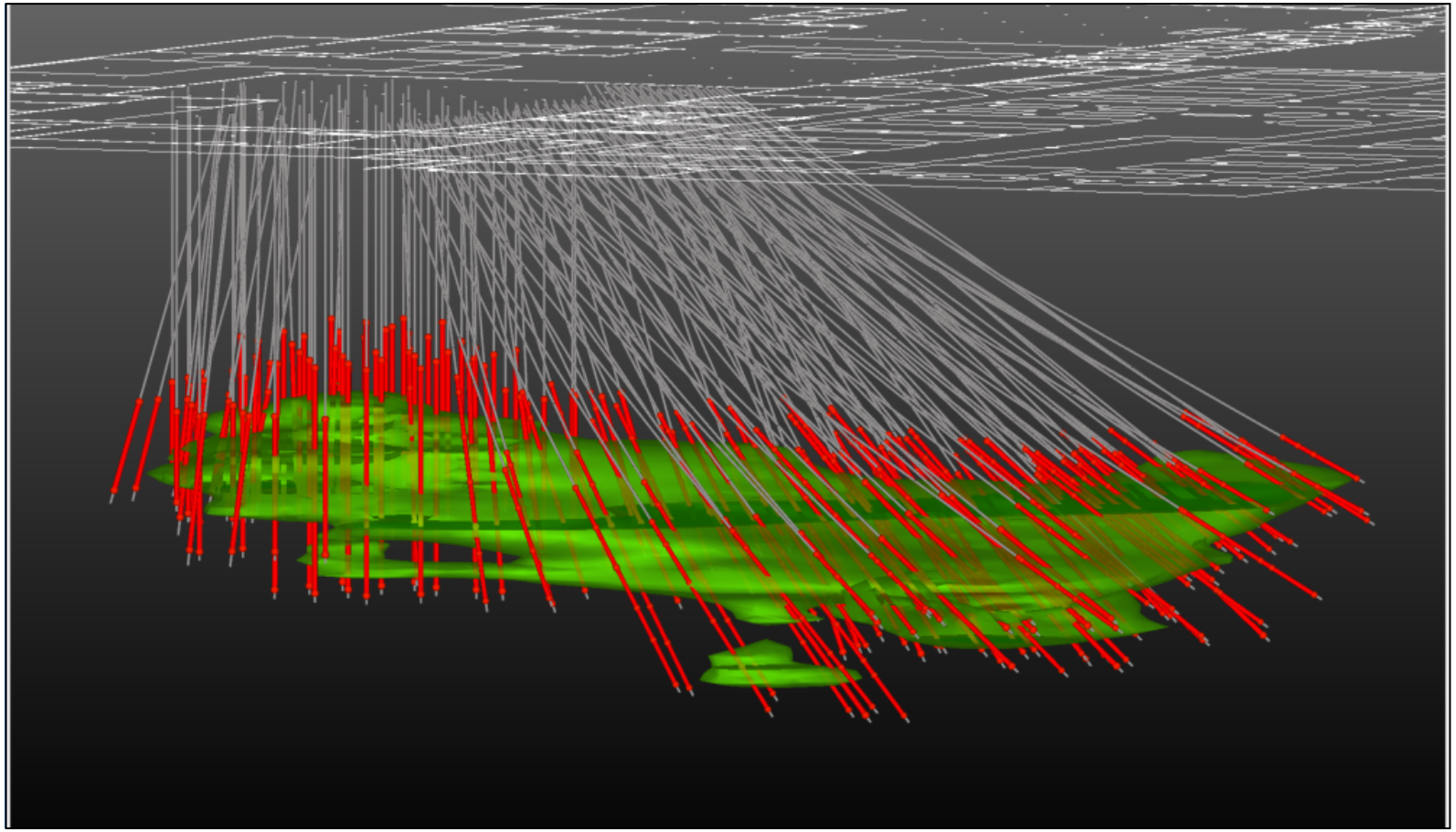
- Once constructed, TCH equipment occupied ~90% of floor space in storage room

- Limited space for ISTR performance verification drilling and soil sampling

TCH System

- A total of 180 TCH heater casings installed (123 angled and 57 vertical)
- Heater borings ranged from 87 to 196 feet in length
- Angled borings between 87 and 30 degrees from horizontal
- Conducted heating in three groups (A, B, and C) to meet project scheduling requirements

3D Illustration of As-Built Heaters



- EVS and thermal modeling used to establish the boundaries of the TTZ and optimize a complex arrangement of 180 thermal conduction heaters

Multiple Lines of Evidence Approach

- Reporting of key performance indicators through PowerBI® data visualization platform in near real-time to demonstrate progress to stakeholders
- Attainment of regulatory agency approval in an expedient manner
- Timely shutdown and decommissioning of the TCH system

Reach a temperature of at least 90°C in 95% of the temperature monitoring sensors within TTZ

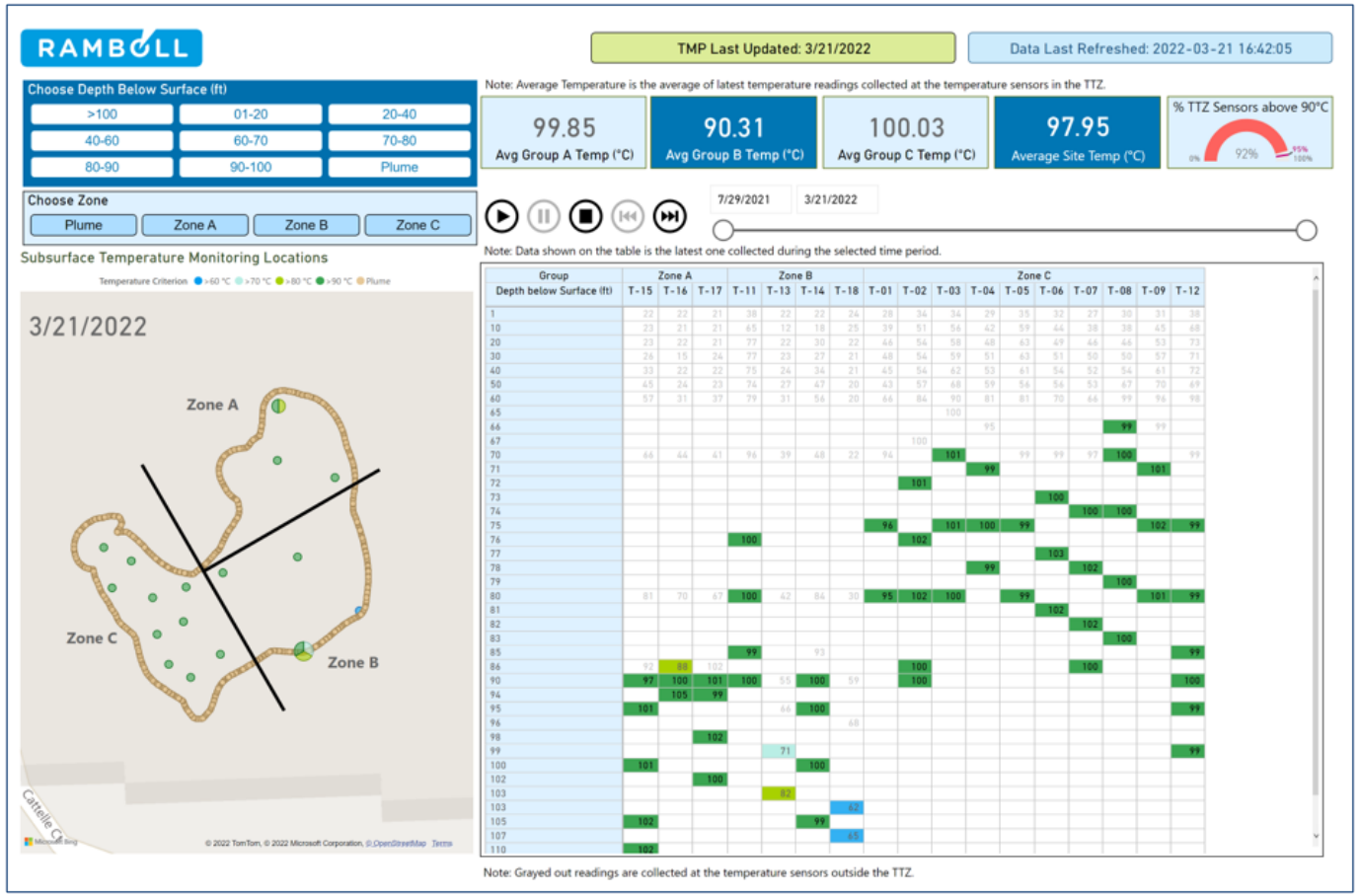
Achieve the subsurface design energy input

Heating Groups A, B and C

Achieve an asymptotic mass removal rate in extracted TCE vapor

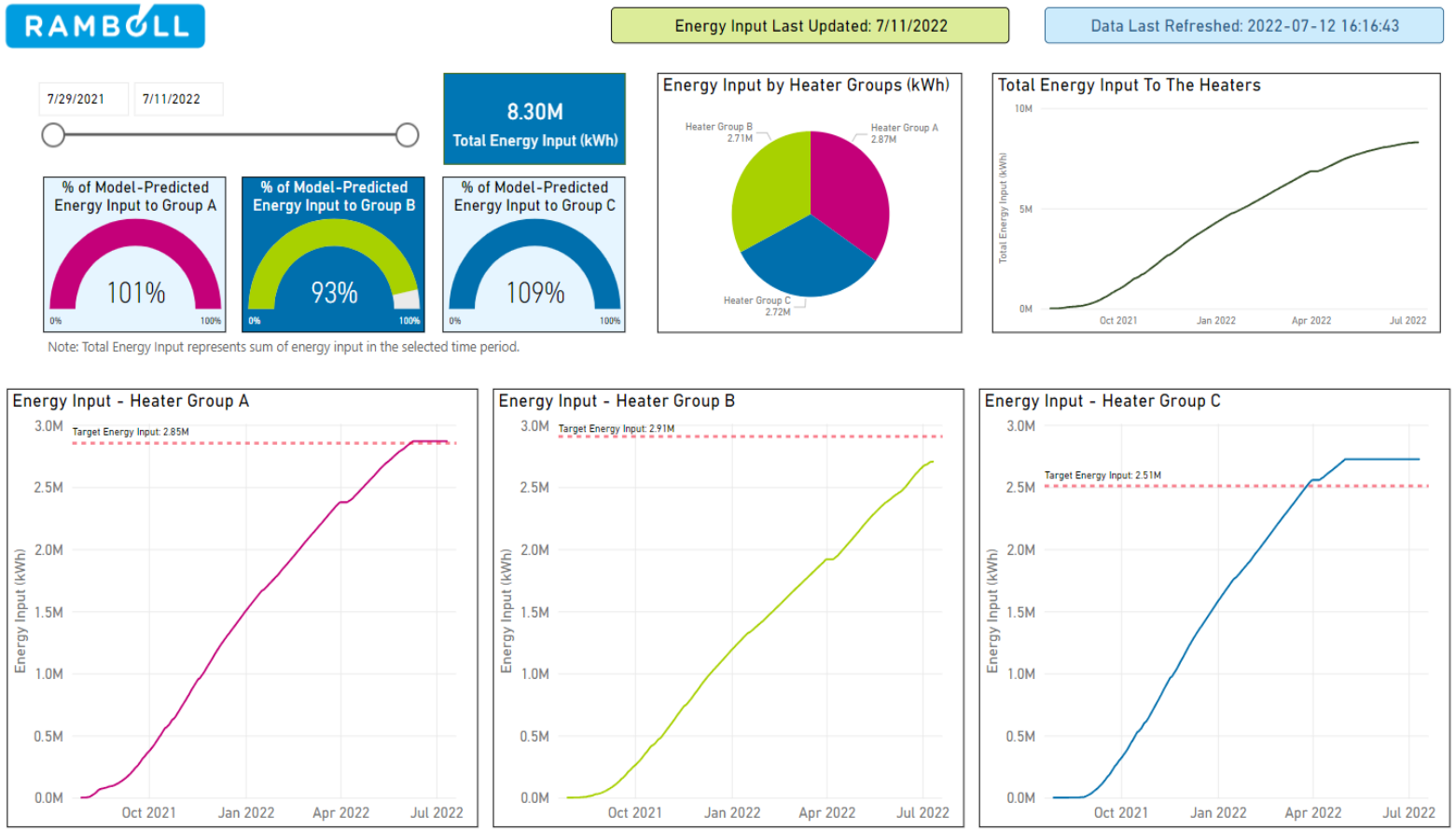
Verification of soil TCE concentration is below the remedial goal of 1 mg/kg

Subsurface Temperature



- Measured average temperature of the TTZ (total as well as individual heating groups)
- After 283 days of heating subsurface temperatures exceeded 90°C at more than 95% of sensors

Energy Input to Heaters



- Total energy input to heaters tracked for each group
- Energy input derived from thermal model established target for each heating group
- Total amount of energy applied was within 1% of the design energy input at end of heating period

Extracted TCE Vapor Concentrations

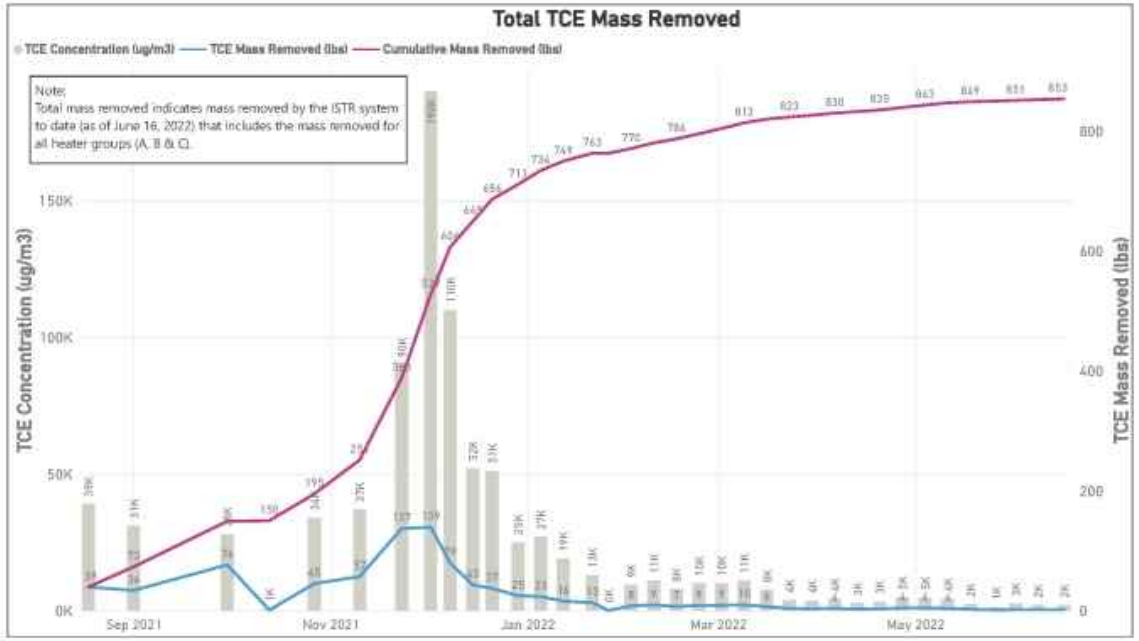
- TCE vapor concentrations tracked for each group
- Asymptotic condition defined by at least three consecutive rounds of vapor sample results less than 10% of peak concentration
- Asymptotic TCE vapor concentrations reached for all three heating groups after 283 days of heating

Performance Verification Soil Sampling

- A total of six soil borings were installed to confirm the RG of 1 mg/kg for TCE was met
- Samples collected at 2 ft vertical intervals based on thickness of TCE impacts at boring location
- A total of 45 soil confirmation samples collected (15 in Group A, 17 in Group B, and 13 in Group C)
- TCE concentrations were more than an order of magnitude below the RG at all sample locations

Results/Lessons Learned

- The key performance indicators were consistently met for all three heating groups after 283 days of heating
- TCE mass recovered over the heating period exceeded design estimates by 147%
- With the robust network of TCH heaters throughout the TTZ, performance verification soil borings were not necessarily needed in all three heating groups after demonstrating that all key performance indicators were met
- Multiple lines of evidence showing remediation completeness was an acceptable approach in lieu of a more robust soil sampling program
- Producing consistent automated reports with the key performance indicators to share with all stakeholders in near real-time facilitated regulatory acceptance and timely shutdown of the TCH system without delay
- The interior room which was occupied by the TCH system infrastructure was able to be placed back into use by the facility ahead of schedule
- Successful partnership and collaboration with the thermal remediation contractor and experts resulted in meeting the project delivery requirements and effective remediation of the deep TCE impacts



Acknowledgements

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