Detection of thermal signatures as a function of transferred heat and weather conditions
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ABSTRACT
The use of infrared imaging equipment at the surface and from the air is permitted during an On-Site Inspection. On this basis, a test was performed using thermal imaging equipment to assess their ability to detect a simulated heat source in the near subsurface.

Recording of input energy, soil and meteorological conditions enabled heat transfer to be modelled, and allowed the sensitivity of thermal imaging cameras under different conditions to be quantified.

Variations in weather conditions enabled the team to evaluate the appropriateness of the application of thermal imaging equipment for the detection of OSI-relevant thermal anomalies under different environmental conditions.

METHODS
A test was conducted to simulate the effect of an underground heat source to study the energy input, the heat transfer of the upper soil layer and heat observables detected by thermal imaging cameras.

A high-density polyethylene water pipe was laid at a depth of 0.40m extending over 10m. After piping the surface was restored and fully recovered by the time the testing commenced. During the five-day-long test, water at 55°C was circulated in the pipe to heat the soil.

A FLIRThermaCAM PM 695 camera was fixed on an elevated platform and set to acquire images of the site at intervals of 10 minutes. Data loggers acquired environmental and test data at intervals of 1s/2minutes. Water heating commenced on 17 December at 00:42, measuring started at 01:40 and circulation at 02:00. Additional thermal images were acquired with an NEC H2640 thermal imaging camera. Measuring continued for several days after water circulation ceased for 124 hours and 30 minutes.

RESULTS
The total amount of electric energy used for heating was 551 kWh, translating to 1985 MJ heat energy. The total quantity of circulated water was: 93.3m3. The transferred heat to the soil during the test was: 1624,605 MJ. The efficiency was 81%. Ambient, surface and water temperatures represented the energy transfer during the test.

Thermal anomalies were detected by both the stationary and hand-held thermal imaging cameras. Anomalies remained visible under adverse weather conditions. Moreover, the detection of heat signatures was more pronounced with dew, white frost and under snow cover.

CONCLUSIONS
Heat transfer in the soil is slow and greatly dependent on soil moisture content. Heat transfer continued for several days after water circulation ceased. Surface thermal anomalies were detected under various weather conditions and periods of the day but were most pronounced prior to sunrise in overcast conditions. Both thermal imaging cameras were capable of detecting the temperature anomaly from a distance of 20m from the target. Findings from the test have the potential to be incorporated into relevant standard operating procedures.