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UAV-Based Type 2 LDAR Surveys

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Changelog

v1.0	Aug 2025	Initial release of the report.

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Project Summary

Project/Contract	Method Statement: Type 2 LDAR Survey Using UAV-Mounted Methane Sensor
Contractor	SurveyLabs
Site Address	14 sites across Ireland: 3 subsea pipelines and 11 bridge crossings
Project Start Date	April 15th 2025
Projected Completion Date	August 2025

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1 Introduction

This method statement outlines the procedures for conducting drone-based leak detection and repair (LDAR) surveys on gas pipeline river crossings. These sites are difficult to complete LDAR surveys on due to access problems. A total of 14 sites will be surveyed, including 11 bridge-mounted pipeline crossings and 3 underwater pipeline crossings. The objective is to safely detect any methane gas leaks from the pipeline infrastructure by using unmanned aerial vehicles (UAVs) equipped with sensitive gas sensors.

Two distinct survey methods are employed based on pipeline type: one for pipelines attached to bridge undersides and another for pipelines buried underwater. All operations will be carried out by qualified drone pilots in compliance with Irish Aviation Authority (IAA) regulations and company safety procedures.

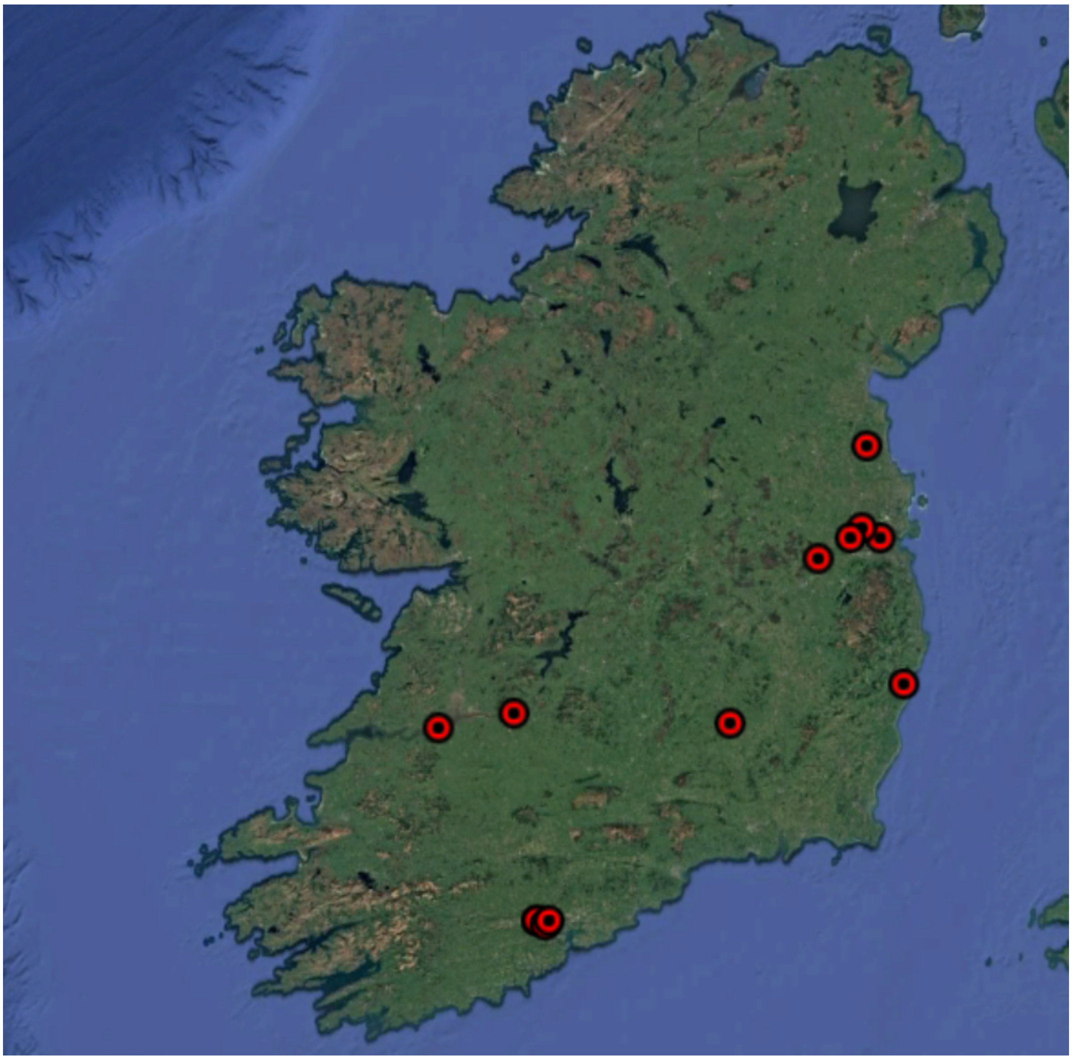


Figure 1: Survey locations - overview.

2 Equipment and Technology

We utilize advanced drone platforms and sensor technology to achieve precise and sensitive gas leak detection in challenging environments. The key equipment includes:

- **DJI Mavic 3 Enterprise (M3E)** – A compact, highly manoeuvrable drone used for close-quarter inspection of pipelines on bridges. It can hover stably near structures and carry a lightweight gas sensor.
- **DJI Matrice 350 RTK (M350 RTK)** – A larger, enterprise-grade drone with Real-Time Kinematic (RTK) positioning. It offers enhanced stability, up to 55 minutes of flight time, and the ability to carry heavier payloads. With RTK enabled, the M350 can hold its position with approximately $\pm$10 cm horizontal accuracy, which is crucial for maintaining a consistent distance from the pipeline or water surface.
- **Methane Gas Sensor (Sniffer4D)** – A high-sensitivity methane detection unit based on direct contact Non-Dispersive Infrared spectroscopy (NDIR) technique. This sensor can detect methane (CH_4) concentration changes on the order of 1 part per million, with a typical range of 0–10,000 ppm. It logs data at 1 Hz (once per second) along with GPS coordinates, enabling the creation of concentration maps.
- **Sampling Hose and Weighted Nozzle** – For over-water surveys, a 2 m flexible sampling hose with a small weighted nozzle is attached to the sensor intake. This allows the drone to draw air from a specific point near the water's surface without the drone itself having to fly dangerously low. The weighted nozzle stays $\sim$1 m above the water, ensuring "near-source" air sampling. This technique, inspired by the SnifferDRONE system (`https://snifferrobotics.com`), captures methane right at the potential leak source with high accuracy. The hose is secured to the drone's payload so that it trails beneath the aircraft during flight.

All equipment is checked and calibrated before each survey. The methane sensor is zero-calibrated in clean air and function-tested to ensure it can detect a known concentration (clean air = 1.8 ppm CH_4) prior to deployment. The drones' batteries, propellers, and control systems are inspected to meet operational safety standards. The RTK base station (or network RTK service) is set up and verified for centimetre-level accuracy before flights.

3 Survey Methodology

The survey methodology is divided into two categories corresponding to the pipeline configuration at each site. Despite the differences, both methods share a common goal: to systematically sniff for any escaping methane by bringing the sensor as close as safely possible to where a leak would emerge (either along an exposed pipeline or just above the water over a submerged pipeline).

Below, we detail the approach for each scenario.

3.1 Bridge-Mounted Pipeline Survey (Type A)

For pipeline sections that are attached to the underside of bridges (above water), we perform close-proximity aerial inspections using the DJI Mavic 3 Enterprise. The drone will fly along the pipeline route beneath the bridge, maintaining a very short distance from the pipe (approximately 20–50 cm separation). This close standoff distance maximizes the likelihood of detecting even small leaks, since any methane escaping the pipe will rapidly dilute in open air.

Figure 2: DJI Mavic 3E with Methane gas sensor mounted.

Procedure for Bridge Pipeline LDAR Survey

1. **Flight Planning:** The survey team reviews the bridge drawings and performs a site visual assessment to understand the pipeline routing under the bridge (length, number of pipe runs, support locations, etc.). A flight path is planned that will guide the drone along the length of the pipeline. If feasible, an automated waypoint mission is programmed to ensure consistent coverage; otherwise, the pilot will manually guide the drone in a stable linear motion under the bridge. The plan includes take-off/landing zones (typically a safe area on the riverbank or bridge approach) and emergency holding positions if needed.
2. **Pre-Flight Checks:** All equipment is set up on site. RTK positioning is activated on the M3E drone to enhance its hovering and flight path precision. Weather conditions (wind, rain) are checked to confirm they are within safe and optimal operating limits (e.g., low wind for steady hovering). We also ensure no bystanders or vehicles will be directly under the drone's flight path; coordination with local authorities is done if required.
3. **Drone Launch and Positioning:** The Mavic 3E takes off and is navigated to the underside of the bridge where the pipeline is located. Using the drone's obstacle sensing and the pilot's line-of-sight observation, the drone is carefully brought to approximately 0.3–0.6 m from the pipeline. The RTK system and vision sensors help hold this close position reliably, allowing the sensor to sample the air right next to the pipe.
4. **Pipeline Sweep:** The drone traverses the entire length of the pipeline, moving slowly (0.5 m/s). If the pipeline is long, the survey may be broken into sections. The sensor continuously sniffs for methane. The pilot may pause at critical points (e.g., pipeline

joints, valves, or flange connections under the bridge) to hover for a few extra seconds, since leaks are more likely at fittings.

5. **Real-Time Monitoring:** A designated team member monitors the sensor readout in real time via a connected ground station. The methane concentration (in ppm) is observed throughout the flight. Normal ambient methane levels are around 1.8–2.0 ppm (typical background). Any significant rise above background (for instance, readings that spike a few ppm higher) is considered a potential leak indication.
6. **Anomaly Investigation:** If an elevated methane reading is observed at a certain location, the pilot will hold the drone at that position and perhaps orbit or reposition slightly to verify the reading. We may perform a brief hover in that spot to collect multiple readings. If readings remain consistently high relative to background, this location is marked (via GPS logging and by noting a visual reference on the structure).
7. **Survey Completion:** After the pipeline section has been fully scanned, the drone is carefully maneuvered back to the take-off point and safely landed. The data from the sensor (methane vs. GPS coordinate and time) is saved for post-processing. Following this, a photogrammetry survey will be prepared and executed.

Throughout the bridge survey, the pilot maintains manual override control and situational awareness. The flight is kept slow and deliberate. Should any instability or risk of contact with the bridge be detected (e.g., sudden wind gusts or loss of GPS under the structure), the drone will back away from the structure immediately and reposition before continuing. Using a small drone (M3E) in this scenario is advantageous due to the tight space; its small form factor and agility reduce the risk of collision while operating in close quarters.

3.2 Over-Water Pipeline Survey (Type B)

For pipeline crossings that run underwater (submerged), the leak detection is performed by sampling the air just above the water surface, directly above and around the buried pipeline route. In these cases, a leak would vent gas into the water; the gas (typically methane) would then rise and disperse just above the water if it reaches the surface. We use the DJI Matrice 350 RTK drone carrying the methane sensor with the attached 2 m sampling hose, which allows us to sniff air extremely close to the water without flying the drone at an unsafe altitude. The Matrice 350 flies approximately 4 m above the water, so that the hose intake nozzle is about 1 m above the water surface. By using this method of near-surface air sampling, we greatly improve detection sensitivity for underwater leaks (since any methane bubble that reaches the surface will be captured at its source before significant dispersion occurs). While the submerged pipelines are submerged, air sampling occurs directly above the buried pipeline meeting requirements of Type 2 LDAR for near-source detection.

Procedure for Over-Water Pipeline LDAR Survey

1. **Flight Planning:** We establish a survey grid or set of parallel transect lines covering the area over the pipeline and a buffer zone around it. Typically, four (4) straight flight lines are used, oriented parallel to the pipeline's direction (covering both along the pipeline path and slightly offset to each side). The transects are spaced such that we cover not only the pipeline's directly overhead path but also a margin where leaking gas might

Figure 3: DJI Matrice 350 UAV with Methane gas sensor and sampling hose.

drift due to water currents or wind. For example, two transects might directly trace the pipeline route (if known) and two additional transects cover downstream or downwind areas. Each transect will extend to the width of the river crossing to ensure a thorough sweep. Waypoints are programmed into the M350's flight software for these lines, including gentle turns and hover points if needed.

2. **Pre-Flight Checks:** The Matrice 350 RTK and sensor are prepared on the riverbank or other safe launch site near the water. The sampling hose is securely attached and its nozzle is checked (the weight ensures it hangs vertically). We verify that the hose intake is clear and will not swing into the drone's props. RTK is initiated to lock in precise altitude (this helps keep the drone at $\sim$4 m AGL with minimal fluctuation). Weather is verified to be suitable, wind is a particularly important factor over water, so we ensure wind speed is within safe limits. The M350 can handle moderate winds, up to 12 m/s, but for data quality we prefer much lower wind during sampling to prevent rapid dispersion of methane plumes. We also check that the area is clear of obstacles such as tall masts, power lines, or birds.
3. **Take-off and Positioning:** The M350 takes off and ascends to the planned survey altitude (around 4 m above water). The pilot then aligns the drone at the start of the first transect line. The weighted hose deploys below the drone upon take-off, with $\sim$1 m distance between nozzle and water surface.
4. **Executing Transects:** The drone autonomously flies along the first transect line at a slow, steady speed (e.g. 1.5 m/s). The sensor continuously samples air through the hose and logs methane concentrations with GPS coordinates. Once the first line is completed, the drone is guided to turn and align with the next transect line. This process is repeated for all 4 transect lines, systematically covering the survey area. The overlap and spacing of these lines ensure that if a methane source is present anywhere in the vicinity (within a few tens of meters of the pipeline), it will be detected on at least one of the passes.
5. **Real-Time Monitoring:** As with the bridge surveys, the live methane readings are monitored on the ground in real time. The team watches for any indication of methane above the normal background level. If the sensor picks up a methane spike on a par-

ticular transect, the pilot is immediately notified.

6. **Focused Investigation of Detections:** If an anomalous reading is observed (e.g. a sudden rise to several ppm), the pilot will halt the automated mission and hover the drone at that location. They may then perform a small localized grid or circle around that spot with the hose near the water to see if the readings persist or if they can delineate the extent of the methane plume. We record the GPS coordinates of any such hotspot. After investigation, the planned survey lines resume to cover the remaining area.
7. **Mission Completion:** After transects are flown and no further anomalies are detected, the drone returns to the launch point and lands. All data is downloaded for analysis.

This over-water method enables detection of very low-volume leaks that could otherwise go unnoticed. By sampling just inches above the water surface, we are essentially capturing methane at the point it emerges from the water. This near-source sampling approach dramatically increases accuracy and sensitivity compared to measuring from higher altitudes or from the shoreline. It is a technique analogous to proven landfill methane surveys where a drone flies with a snorkel hose inches above the ground to pinpoint leak spots. In our case, the same principle is applied over water.

4 Flight Operations and Safety Measures

All drone operations will strictly adhere to the IAA regulations and the company's standard operating procedures for UAV flights. Key safety and compliance measures include:

- **Regulatory Compliance:** Flights are conducted within Visual Line of Sight (VLOS) of the pilots and under the altitude limit of 120 m (though our missions are much lower). We have ensured any required permissions or notifications for flying near bridges or over water are in place. The drones carry necessary identification and fail-safe systems (return-to-home function, geofencing as appropriate). We schedule flights during daylight and suitable weather conditions for maximum safety and sensor effectiveness.
- **Specific Category Flights:** For flight areas within restricted zones, all flight permissions will be sought prior to flight. Additionally, all parameters associated with the specific category flight will be adhered to, including altitude limits, use of parachute recovery systems, and flight termination systems.
- **Pilot Qualifications:** Each drone will be operated by a certified and experienced pilot, with at least one additional crew member as observer/spotter. The pilots are trained in close-quarter flying and emergency manoeuvres. They will maintain situational awareness to avoid hazards like birds, wires, or moving vehicles on or under the bridge. A clear communication protocol is in place between the pilot and the sensor operator (if a separate person is monitoring readings).
- **Pre-Survey Risk Assessment:** Before each flight, a risk assessment is completed. This covers site-specific hazards (e.g., moving water currents, bridge traffic, presence of public) and how they will be mitigated. For bridge sites, if needed, we coordinate with the bridge owner or local authorities to ensure the drone operation does not startle

drivers or pedestrians. For example, if the pipeline is under a busy road bridge, we may place warning signs or conduct the flight during off-peak hours to minimize any distraction. Over water, we ensure any boating traffic is aware of our activity or operate in a closed area if required.

- **Distance and Stability:** A safety buffer is always maintained except for the intentional close approach to the pipeline or water surface. Even then, the approach is controlled and slow. The use of RTK GPS and vision positioning allows the drones to hover and follow flight paths with centimeter-level precision, which is instrumental in preventing accidental contact with the pipeline or water. This technology essentially locks the drone in a fixed 3D position during sensitive sampling, unless commanded to move. Automated flight paths (for transects) are reviewed to avoid any collision course with known obstacles. The Matrice 350's six-directional obstacle sensing is active as an added precaution, though over calm water or under a bridge the sensors may be limited, so pilot vigilance is primary.
- **Emergency Protocols:** Both drones are programmed with a low-battery threshold to return to home well before battery depletion. In case of any system failure or loss of control link, the drones will autonomously ascend to a safe altitude and return to the launch point (this is set high enough to clear the bridge structure if applicable). If a drone were to encounter instability (e.g., from turbulence under a bridge), the pilot will increase distance from the structure and regain stable hover. A fire extinguisher and first aid kit are kept on site as part of the emergency preparedness. The crew also has a plan for water recovery in the unlikely event of a drone ditching (e.g., a small boat or flotation device available).
- **Privacy and Environmental Protection:** No personal data is collected during these surveys; the cameras are used only for operational awareness and documentation of the pipeline. Environmentally, the electric drones produce minimal disturbance. We avoid flying close to wildlife (such as birds on the water) and do not cause any emissions ourselves aside from battery use. If a methane leak is detected, the information will be used to prompt repairs, ultimately benefiting the environment by reducing greenhouse gas release.

All safety measures are documented in the project safety plan and every team member is briefed on emergency procedures. By combining meticulous planning with advanced drone capabilities, we ensure that the survey is executed safely, legally, and with minimal disruption to the surroundings.

5 Data Handling and Reporting

Each survey generates data on methane concentrations correlated with precise GPS locations. The following outlines how we handle and interpret the data, as well as the reporting deliverables:

- **Data Recording:** The methane sensor is interfaced with a logging device that records time-stamped concentration readings along with the drone's GPS coordinates (latitude, longitude, altitude). Additional context data such as temperature, humidity, and atmospheric pressure may also be recorded by the sensor package. During flight, the data is temporarily stored on the onboard unit.

- **Post-Flight Data Retrieval:** After landing, the sensor data is downloaded to a field laptop. We immediately create a backup of the raw data (CSV or similar format) to prevent any loss. Basic sanity checks are performed (e.g., verifying that the timestamps match the flight duration and that no data gaps or errors are present).
- **Data Analysis:** Back at the office, the data from each site is processed to identify any anomalies. This includes:
  - Plotting methane concentration vs. distance along the flight path. Spikes or elevations more than 2ppm above the baseline (ambient background ~ 1.9 ppm CH_4) are flagged.
  - For over-water surveys, spatial mapping of readings on an overhead map of the river crossing. Because we conduct multiple transects, we can interpolate or grid the data to visualize if any particular zone had consistently higher methane levels. The data may be aggregated into a grid (e.g., 5m by 5m cells) and the maximum reading in each cell identified for mapping. This helps in distinguishing a real leak signal from random fluctuations.
- **Quality Control:** All data analysis is reviewed under our quality control procedures. We account for any potential interferences or false positives. For instance, if a spike is very minor (just slightly above background), we consider if it could be due to human activity such as traffic or an environmental source (such as marshy riverbank emitting biogas). Repeated passes or sustained readings are given more weight as evidence of a leak. If needed, we compare readings with upwind/downwind differences to validate that the source is local.
- **Reporting:** A comprehensive report is compiled for each survey site including: Summary, Methodology, Results, Discussion, Recommendations, Data Appendices.
- **SOP Adherence:** All data handling follows our internal SOP for LDAR surveys, which dictates how data is labelled, stored, and protected. We maintain chain-of-custody for the data files and ensure they are archived in the project database. Any anomalies in data collection (such as sensor calibration issues or data dropout) are documented and, if affecting results, the survey may be repeated.

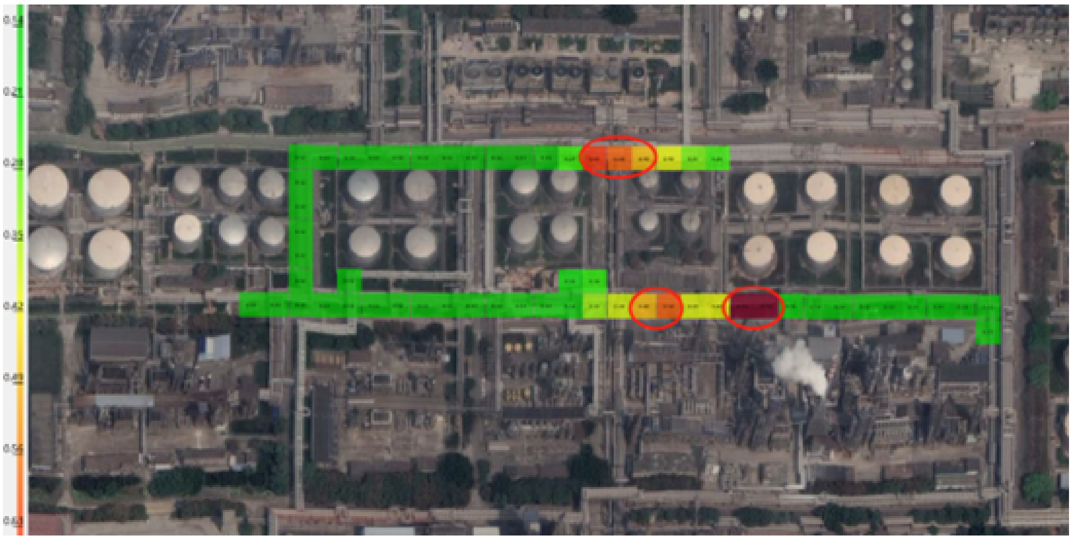
By leveraging robust data analysis and visualization, the final deliverables will allow the pipeline operator to clearly see if and where methane leaks are occurring. The combination of near-source drone sampling and geospatial data mapping provides a powerful tool for early leak detection, facilitating timely repairs and minimizing environmental impact.

6 Survey Outputs

The outputs from the UAV-based methane detection surveys include spatially resolved CH_4 concentration data, environmental parameters (temperature, humidity, pressure), and supporting visualizations. Methane concentration values are recorded at 1 Hz with a resolution of 1 ppm and are georeferenced using RTK GPS.

Data are spatially aggregated into a number of grid cell maps for visual clarity and overlaid on ortho-imagery. Outputs include:

- CH_4 concentration maps (max values per grid cell) for rapid inspection and reporting
- Full-resolution CSV datasets of all sensor readings
- GIS-ready shapefiles and GeoPackages



7 Summary

This method employs advanced drone-mounted methane detection technology to perform Type 2 Leak Detection and Repair (LDAR) surveys in accordance with EU Regulation 2024/1787 and the Irish I.S. 328:2021 standard. Our approach, combining the DJI M3E and Matrice 350 RTK platforms with a Sniffer4D Non-Dispersive Infrared spectroscopy (NDIR) methane sensor, allows for high-resolution surveys of bridge-mounted and underwater gas pipeline crossings. By maintaining a sampling distance of < 2 m from exposed pipelines (bridge surveys) and near-surface air sampling over submerged pipes, we exceed the minimum detection threshold of 500 ppm or 1 g/h as specified for Type 2 LDAR. The system's 1 ppm resolution, validated through regular calibration, ensures high accuracy and early anomaly detection. This methodology:

- Meets the procedural and technical requirements of a Type 2 LDAR survey, as outlined in the Compliance Statement.
- Utilises best available techniques and adheres to a defined Standard Operating Procedure (SOP) for survey execution and data handling.
- Operates under full regulatory compliance, including certified UAV pilots, IAA airspace regulations, and auditable data traceability.

All data and findings are delivered transparently to Gas Networks Ireland for maintenance decision-making and compliance with the EU Methane Strategy. This modern UAV-based approach offers a safe, scalable, and regulatory-aligned solution for pipeline emissions monitoring, and we are confident that it represents a robust and compliant LDAR methodology across all 14 sites.