



# **Developing an Interactive GIS Application for Identifying Suitable Earthquake Monitoring Sites in the UK**

School of Geosciences

A Dissertation Submitted in Partial Fulfilment of the Requirements for the  
Degree of Master of Science in Geographical Information Science

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6<sup>th</sup> of August, 2025

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**Part 1**

**Research Paper**

## Abstract

The British Geological Survey (BGS) monitors seismic activity across the UK. In collaboration with BGS, a web-based application was developed to improve current methods for selecting suitable locations for new earthquake monitoring stations. An ArcGIS Dashboard was built to provide a more efficient, dynamic and repeatable approach to site selection. It enables users to filter buffer layers of anthropogenic and environmental seismic noise sources to identify suitable locations for monitoring stations.

The dashboard was refined through testing and user feedback, with performance optimisation techniques improving both speed and usability. While the primary focus was a desktop version, a conceptual mobile version was also developed, highlighting potential for future field-based deployment. The final product functions effectively as a decision support tool, offering BGS a more robust method for evaluating site suitability.

Overall, this work demonstrates the value of combining spatial analysis with user-centred design to support infrastructure planning and drive innovation in seismic monitoring.

## Accessing the Dashboard

The final version of the Earthquake Monitoring Site Suitability Dashboard can be accessed here:

<https://www.arcgis.com/apps/dashboards/097d97308e61489896ee5e492b023997>

\*Please note that access permissions are valid at the time of submission, however, availability may be subject to change in the future depending on institutional or platform settings.

## Abbreviations

**BGS** British Geological Survey

**CSV** Comma Separated Values

**EIDC** Environmental Information Data Centre

**EMS** Earthquake Monitoring Station

**GIS** Geographical Information Science

**GPU** Graphics Processing Unit

**OS** Ordnance Survey

**UI** User Interface

**UKRI** UK Research and Innovation

**UX** User Experience

# 1 Introduction

Earthquake monitoring provides essential data for understanding seismic activity, assessing hazards and improving knowledge of Earth's interior structure. Globally, seismic networks support hazard mitigation efforts such as earthquake early warnings and tsunami detection, especially in tectonically active regions like Japan and Indonesia (Manfredi & Zschau, 2007). In contrast, seismic monitoring in low-seismicity countries like the UK serves a primarily research-oriented role, contributing to the study of geological faults and background seismicity. The British Geological Survey (BGS) operates the national earthquake monitoring network, collecting and disseminating seismic data to government, industry and the public. While the UK's seismicity is low, maintaining and expanding the Earthquake Monitoring Station (EMS) network is important for high-quality data collection and supporting research. BGS's current method for identifying optimal sites for new EMS installations is a relatively inefficient and time-consuming process, requiring manual assessments of geographic variables. Developments in GIS and web technologies offer new opportunities to improve site selection for EMS expansion. A web-based GIS application can improve efficiency, process data more quickly, and deliver a better user experience through an interactive platform that simplifies analysis and decision-making. This dissertation explores the application of a web-based GIS tool to support BGS in identifying suitable sites for new sensors, with the goal of expanding network coverage.

## 1.1 Importance of Sensor Placement

Monitoring seismic activity at a national scale requires careful planning and configuration, as the spatial arrangement of stations directly influences the quality and reliability of the data (Scudero et al., 2013). When expanding an EMS network, there are two key factors to consider: network geometry and site selection (Fuggi et al., 2024). As BGS manages network design, the primary focus is identifying suitable sites for EMS installation.

Effective site selection involves evaluating multiple criteria, including background seismic noise, geological conditions and access to technical infrastructure (Trnkoczy et al., 2012). External vibration sources, including environmental factors (e.g., rivers, wind) and anthropological activities (e.g., roads, cities), can substantially degrade data quality, especially when detecting small magnitude events, as local noise conditions may obscure weak seismic activity. As sources of vibration can often be recorded several kilometres from the origin, identifying locations that minimise seismic interference is essential for BGS to collect high-quality, reliable data.

## **1.2 BGS's Existing Methods and the Need for a Decision-Support Tool**

The demand for an improved site selection tool arises from the limitations of current practices. Seismic site selection has traditionally relied on expert judgement informed by topographic maps and on-site noise measurements (Moustafa et al., 2022). This approach often lacks quantitative consistency between assessments and individuals, making objective comparisons and justifications challenging. Such subjectivity complicates efforts to demonstrate that appropriate seismic monitoring has been established, a key consideration for funders like UKRI-NERC (British Geological Survey, n.d.).

At present, BGS identifies candidate areas by manually consulting multiple datasets - such as road networks, geology, satellite imagery and local infrastructure - and cross-referencing them. This process is inefficient, labour-intensive and difficult to standardise. It provides limited means to quantify or document the rationale for site selection, complicating comparisons across locations and networks. Consultations with BGS staff have demonstrated that this manual approach is time-consuming for their workflow, requiring repeated cross-referencing between separate maps and datasets.

A GIS-based approach can address these challenges by integrating spatial datasets into a single platform, enabling rapid comparison of potential sites through configurable distance buffers and suitability mapping. With such a tool, BGS staff could filter, analyse and visualise results far more effectively and quickly. It supports transparent, reproducible decision-making while reducing time and effort (Ozdilek & Seker, 2004). By automating and streamlining the assessment process, a decision tool will improve existing methods by integrating data to identify suitable sites for new sensors, enhancing spatial coverage of the EMS network.

## **1.3 Research Question and Objectives**

### **Research Question**

How can a web-based GIS tool be used to support site selection for expanding the UK earthquake monitoring network, based on proximity to vibration sources?

### **Objectives**

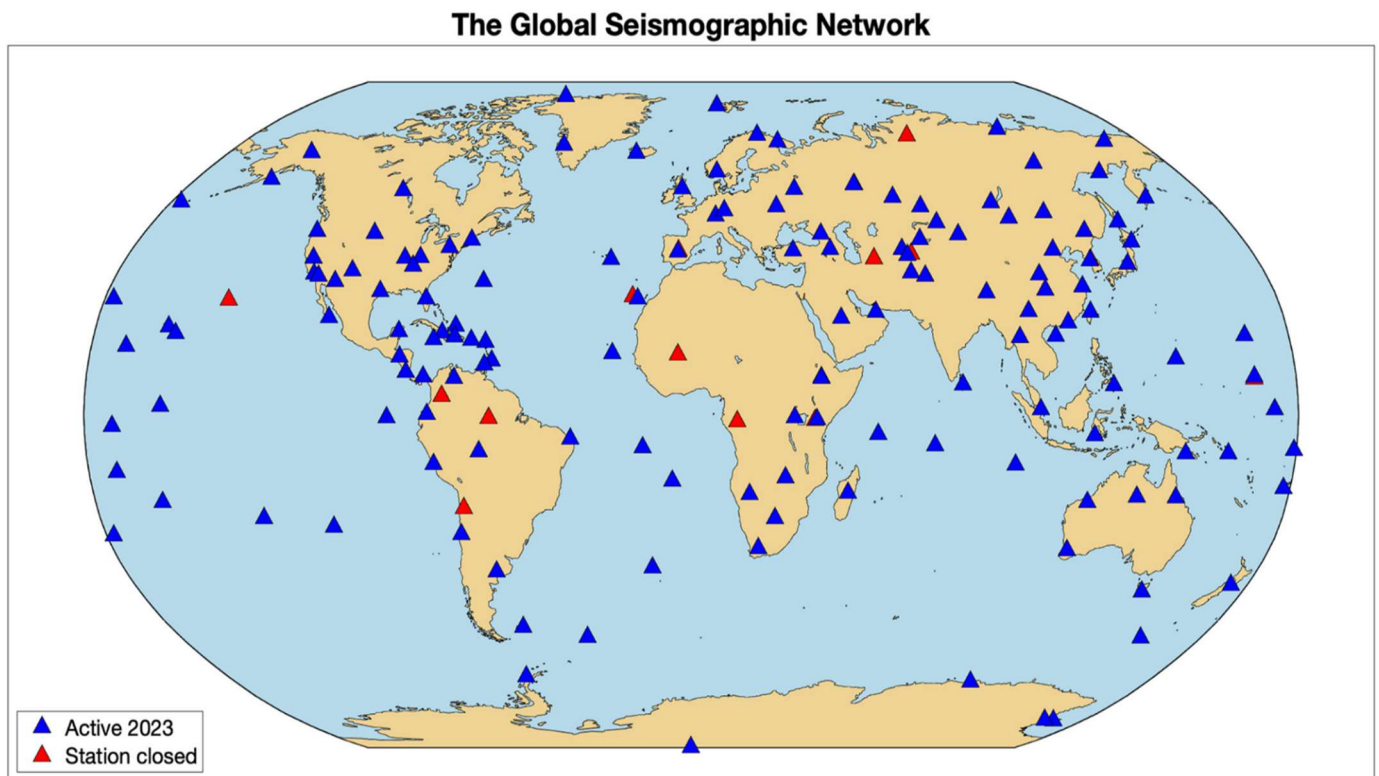
- To design and implement an interactive dashboard for users to filter spatial layers and assess site suitability based on configurable criteria.
- To integrate multiple open-access geospatial datasets representing seismic noise sources and infrastructure constraints.
- To optimise the dashboard for usability, performance and clarity at a national scale through iterative design and user testing.
- To evaluate the dashboard's effectiveness in meeting BGS user requirements through performance metrics and structured feedback.

## 2 Literature Review

### 2.1 History and Context of Earthquake Monitoring

Earthquakes are a globally occurring form of seismic activity, defined by the transmission of seismic waves (vibrations) resulting from the sudden fracture and movement of rocks, typically along tectonic plate boundaries (Adagunodo & Sunmonu, 2015). Early records relied on human observation, narratives and archaeological evidence (Guidoboni & Stucchi, 1993). By the late 19th century, instrumental seismology emerged, facilitating systematic monitoring and contributing to scientific understanding of Earth's interior, plate tectonics and seismic hazards (Oliveira, 2022; Lee & Wu, 2009).

The establishment of seismographic networks, consisting of arrays of EMS linked to a central system, represented a major advance. This infrastructure enabled real-time monitoring, leading to national systems such as Taiwan's Earthquake Early Warning System (Wu & Mittal, 2021), Mexico's Seismic Alert System (Suárez et al., 2009), and Indonesia's InaTEWS (Puspito et al., 2024). Internationally, organisations compiled regional and global catalogues (Storchak et al., 2015), culminating in initiatives like the Global Seismographic Network (GSN) (Figure 1), which includes one station in the UK, located in Eskdalemuir, Scotland.

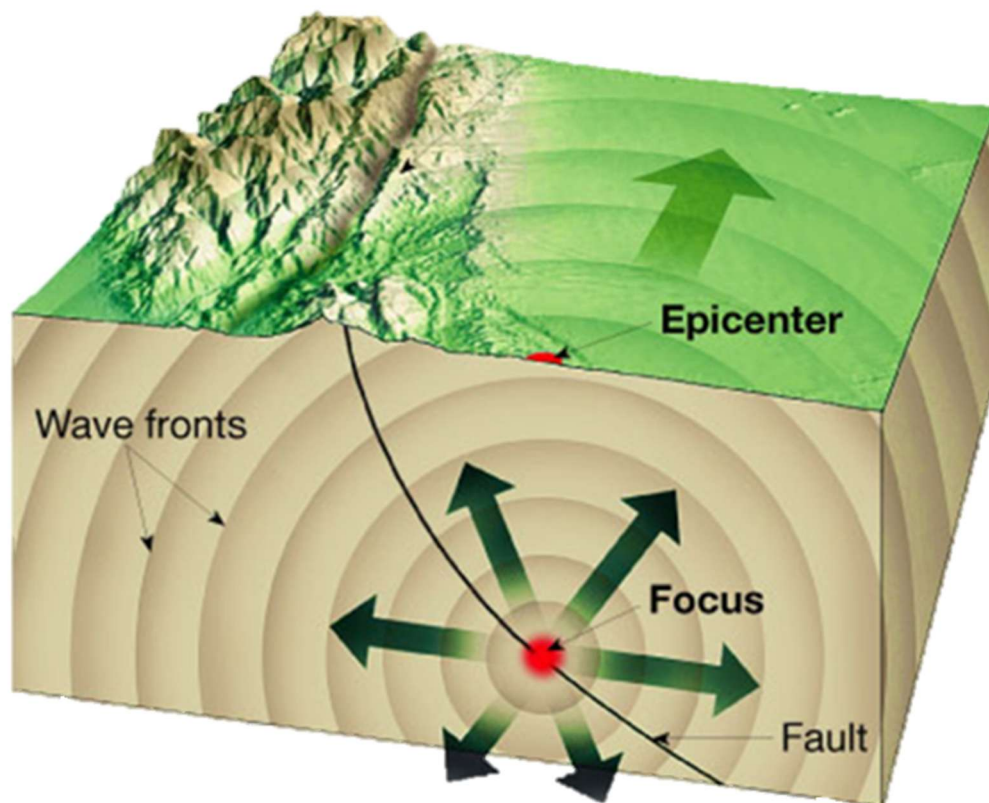


**Figure 1:** A Robinson global projection showing station locations of the Global Seismographic Network. Current active stations are shown in blue, inactive stations are shown in red (Davis, 2024). The UK's sole GSN station is located in Eskdalemuir, Scotland, linking UK national monitoring to global seismic observations.

## 2.2 Seismic Monitoring in the UK: A Low Seismicity Region

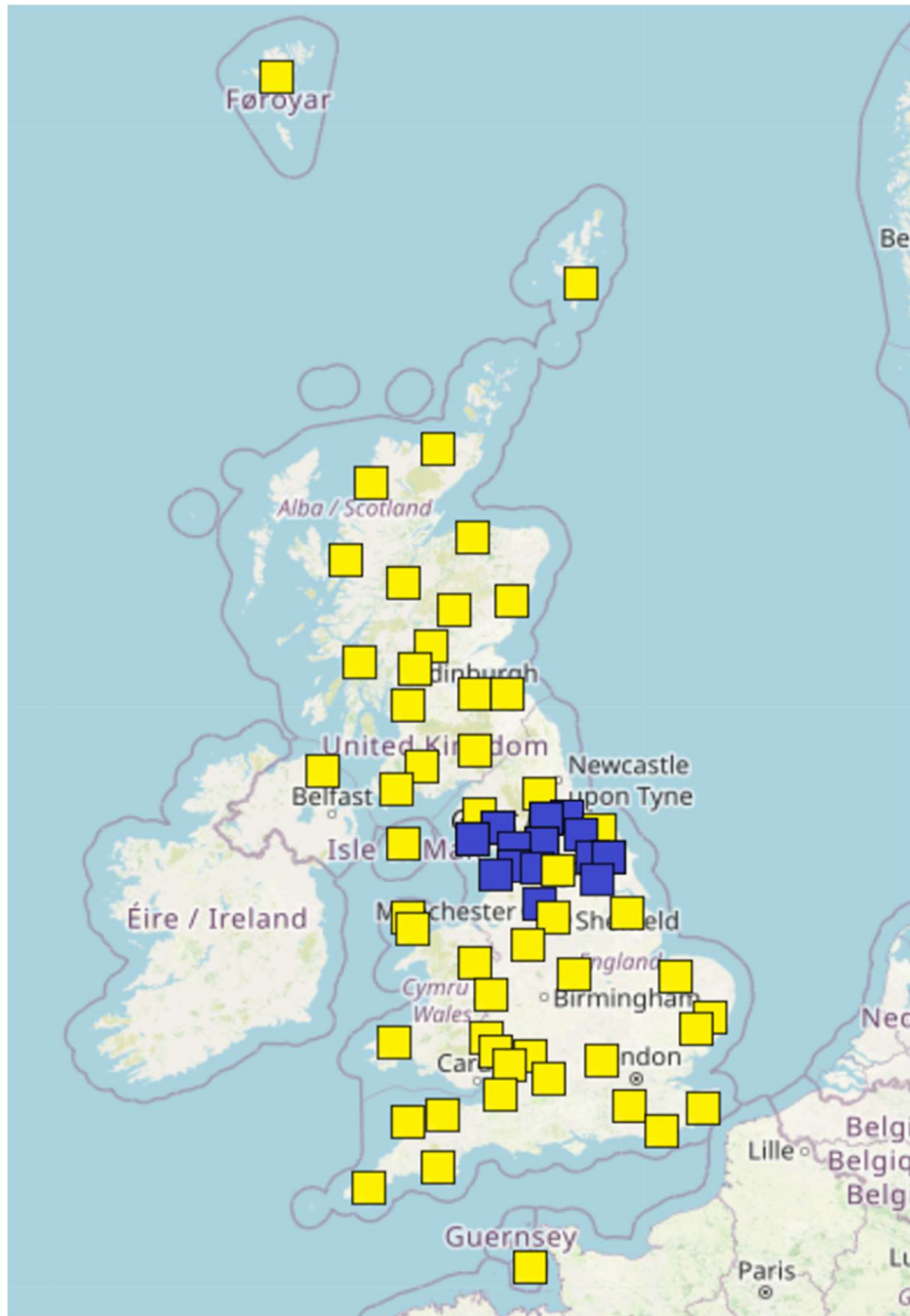
Seismic monitoring on a global scale has successfully been supported by sustained public and governmental interest, reinforced by frequent large earthquakes that attract attention (Ringler et al., 2022). By contrast, monitoring in low seismicity regions is often constrained by limited resources, lower academic interest and the absence of significant or destructive events (Ebel et al., 2020). In such contexts, using GIS-based tools for optimal site selection in small or low-seismicity countries offers a cost-effective way to improve EMS coverage without requiring large-scale infrastructure investment (Samela et al., 2018).

The UK's seismicity originates from intraplate faults (Figure 2) rather than plate boundaries (Woods & Lee, 2018; Goda et al., 2013), with generally weak seismic activity. Anthropogenic sources such as industrial activity, fracking, transport and reservoir operations further contribute to the seismic noise environment (Wilson et al., 2015).



**Figure 2:** A diagram of an intraplate fault. Intraplate faults are geological faults located within a tectonic plate, rather than on the boundary of a tectonic plate. In the UK, seismic activity often occurs from movement within ancient intraplate faults (Lehane, 2021).

While European hazard projects like the Global Seismic Hazard Assessment Program (GSHAP) have assessed broad regional seismic risk (Grünthal & Bosse, 1996), BGS oversees UK national monitoring. BGS operates the UK's EMS network, maintaining a national seismic database to inform hazard assessment, precautionary measures and research (Hawthorn et al., 2023; Baptie, 2012). From initial deployment in the 1970s, the network expanded to 146 stations by 2000, achieving 70 km average spacing to provide relatively uniform detection capability (Browitt & Walker, 2019). The current network geometry is displayed in Figure 3.

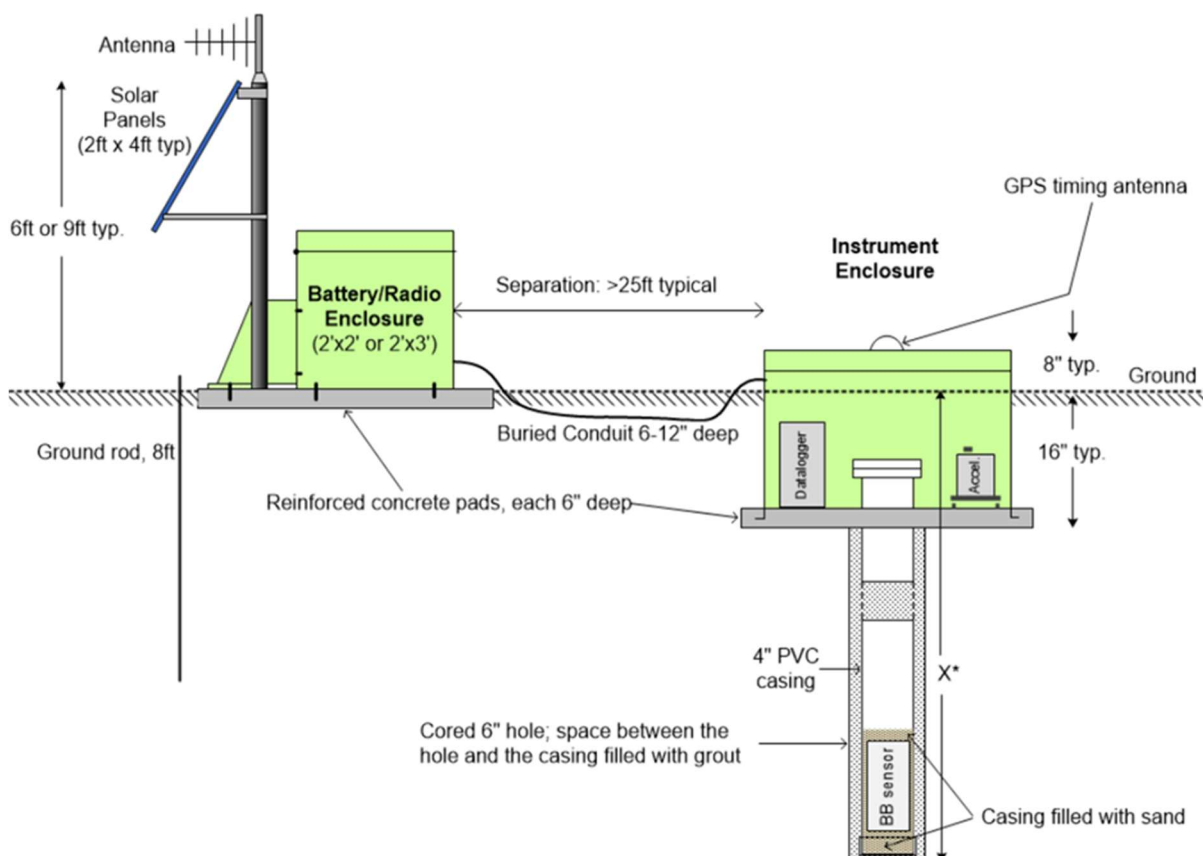


**Figure 3:** The current UK EMS network. Yellow squares are permanent stations connected to mains power. Blue squares are temporary stations connected to solar power and 4G telecom. These stations are mostly used for temporary scientific research, and are targeted to regions of interest over short-term periods (British Geological Survey, n.d.).

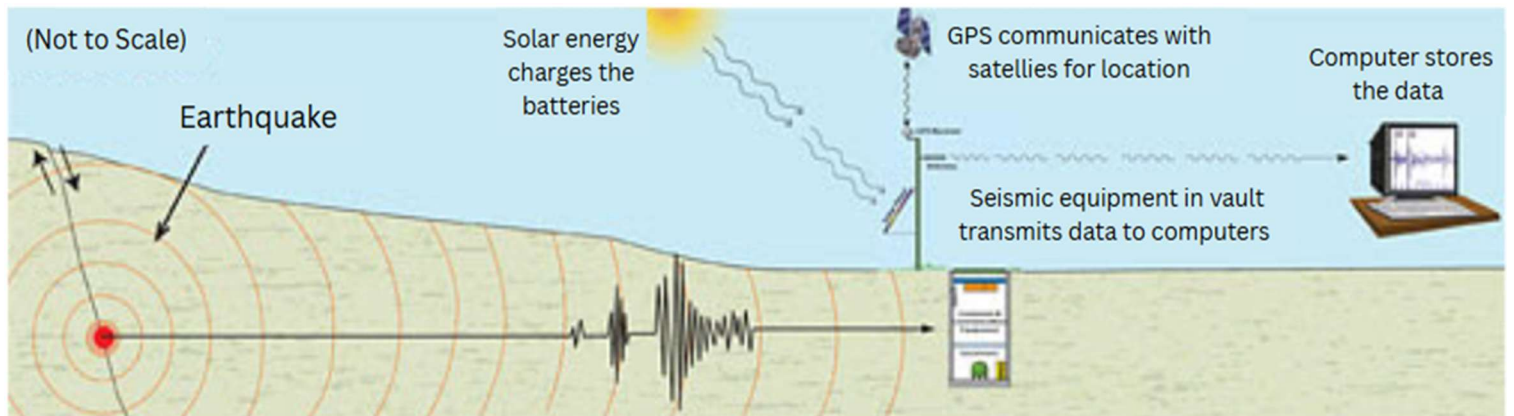
## 2.3 Considerations for Earthquake Monitoring Station Placement

Careful site selection ensures data quality and network performance (Fuggi et al., 2024). Though optimal network design is well documented in literature (Callahan et al., 2025; De Landro et al., 2020; Gao et al., 2013; Hallo, 2012), EMS site selection remains comparatively underexplored (Plenkens et al., 2015). A foundational reference on optimal site selection procedures is the New Manual of Seismological Observatory Practice (Trnkoczy, 2012), which outlines technical considerations such as geological conditions, local seismic noise environment and proximity to infrastructure.

These considerations are closely tied to the technical characteristics and operation of an EMS. An EMS comprises a seismometer, timing device and recording unit. It is typically installed below ground in a sealed, buried container to minimise external interference (Figure 4). Each station is equipped with a solar panel (and where available, mains power) to power batteries and a communications module for transmitting real-time data via satellite, cellular network or internet (See Appendix A for photographs illustrating BGS’s station installation process). Seismic movements are detected by the sensor and transmitted to a central computer system (Figure 5).



**Figure 4:** An example of a broadband digital seismic station. Sensors are encased in the ground, alongside a data logger and accelerometer. Power is supplied through mains power or solar panels constructed above ground (ZZ System Operations, 2025).



**Figure 5:** A diagram showing the process of how an EMS detects ground motion and transmits the data to a central processing system (IRIS, n.d.).

Instruments record earthquake signals and background seismic noise, including microseisms (<1 Hz) from environmental sources (e.g. ocean waves) and microtremors (>1 Hz) from human activities (e.g. traffic, industry) (Havskov & Alguacil, 2016; Wilson et al., 2015). Table 1 displays the average frequency of common sources of vibration.

**Table 1:** Common sources of ambient vibration encountered in every day environments and their typical frequency ranges. These ranges can contextualise the rationale for EMS placement (Malaji & Ali, 2015).

Source	Frequency range (Hz)	Acceleration range (g)
Trees	0.1–0.8	0.001–0.05
Civil Infrastructure	0.3–10	0.01–0.2
Cars	1–15	0.005–0.8
Buildings	9–40	0.001–0.22
Human motion	0.–10	0.05–10
Electric motor	50–80	0.001–5

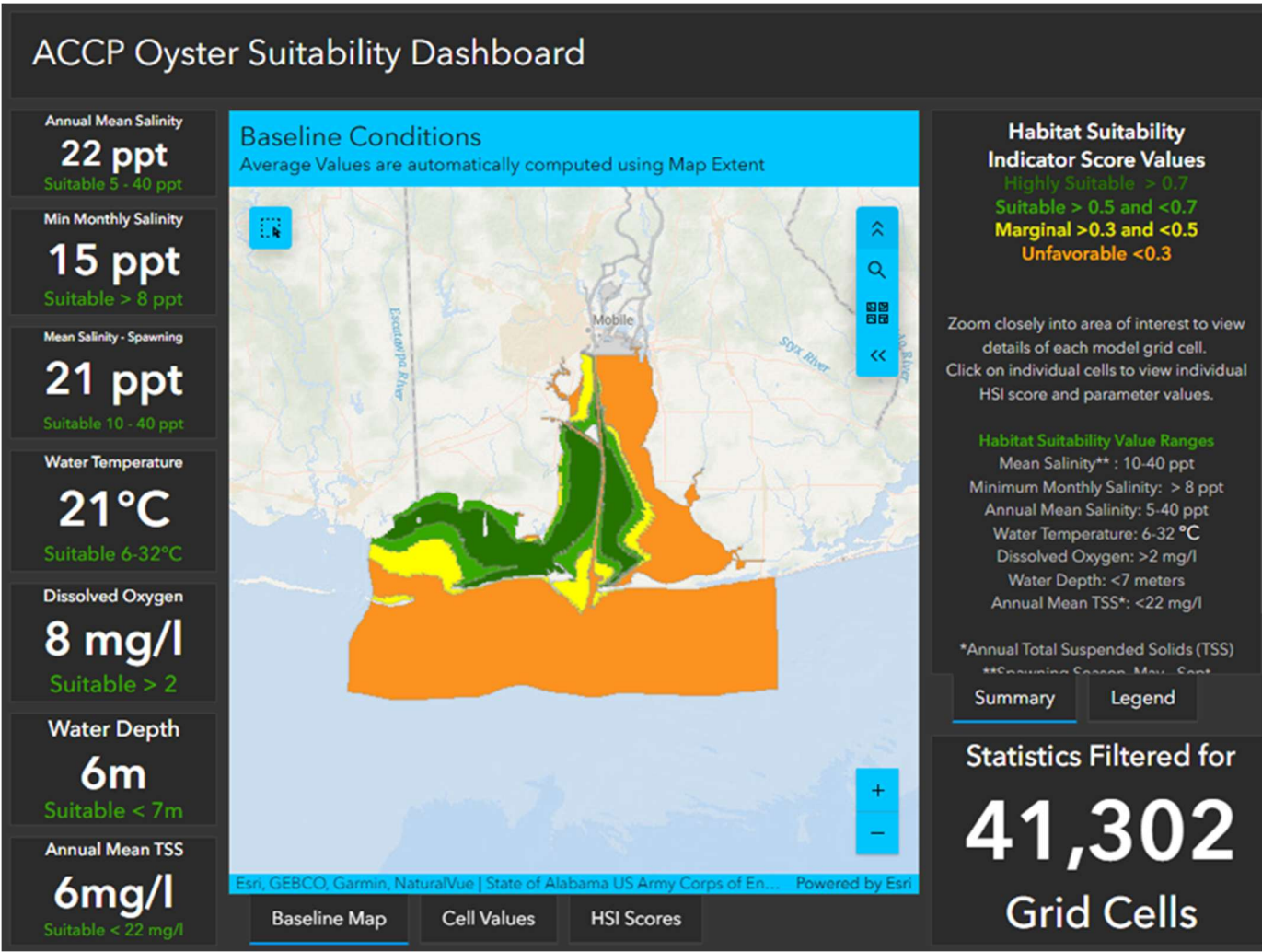
Excessive seismic noise can obscure the accuracy of recorded data. This is particularly problematic in low-magnitude environments like the UK. Poor site selection can lead to systematic location biases, reduced detection capability, and difficulty distinguishing natural from anthropogenic events. For example, Wilson et al. (2015) found that among 1,769 onshore UK seismic events between 1970-2012 with magnitudes (ml) <1.5, approximately 21% were anthropogenic, 40% natural and 39% undetermined.

As newer EMS systems become increasingly sensitive to background noise, site selection criteria have been periodically updated to position sensors further from anthropogenic noise sources (Rietbrock et al., 2013; Bormann & Bergman, 2000). These criteria continue to evolve as environmental, technological and societal conditions change. Given the UK's low-magnitude seismicity and complex noise conditions, ongoing refinement of network configuration and station placement remains important.

## **2.4 GIS and Web-Based tools for Suitability Mapping**

Geographical Information Science (GIS) have become essential for spatial decision-making and planning. GIS integrates geographic and attribute data to generate maps, analyses and visualisations that improve understanding and communication of complex spatial relationships (Maguire, 1991; O'Looney, 2000). In suitability mapping, GIS enables multiple datasets to be combined to evaluate land suitability for specific purposes (Qu et al., 2013), with applications across environmental management, forestry, urban planning and resource allocation (Petrov et al., 2020; Engelen et al., 2003; Chen et al., 2011).

The rise of web-based GIS applications has further expanded accessibility, interactivity and user-driven analysis (Boroushaki & Malczewski, 2010). These platforms enable users to adjust parameters and visualise customised outputs in real time, according to user-defined preferences. For instance, Rajappan et al. (2024) created a web GIS application to identify suitable flood shelter locations based on hazard and exposure data. Panda et al. (2024) developed a web dashboard integrating soil, fertility and climate data to help farmers select suitable sites for Chinese bushclover cultivation. Such tools (Figure 6) demonstrate the potential to support dynamic suitability mapping and interactive exploration of spatial datasets. Although widely adopted in other fields (Mekonnen & Gorsevski, 2015; Netek, 2024), web-based applications for seismic monitoring remain relatively underexplored, presenting an opportunity for advancement. In the UK context, their ability to integrate multiple datasets and support interactive decision-making makes web applications a potential solution to BGS's current, inefficient site selection process.

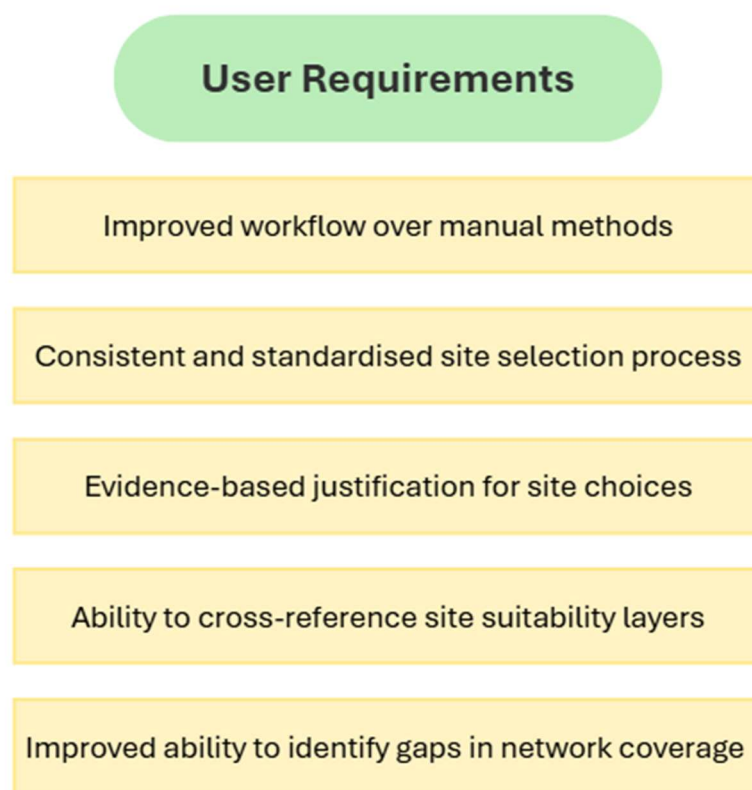


**Figure 6:** An example of a dashboard used as a suitability mapping tool. The Oyster Habitat Suitability Dashboard by the United States Geological Survey (USGS) displays the current conditions in the eastern Mississippi Sound and Mobile Bay. Areas are classified along a suitability spectrum based on multiple parameters such as salinity, temperature and oxygen levels (United States Geological Survey, 2023).

### 3 Developing a Suitability Mapping Tool

#### 3.1 User and Tool Requirements

Before creating the web application, user and tool requirements were defined to guide the process, shown in Figure 7 and 8. Success is measured by effectiveness in meeting these requirements and functions as a practical tool. BGS, as the end user, provided input to establish a list of essential and desirable requirements. While the overall objective was specified by BGS, the design and implementation decisions were determined independently.



**Figure 7:** User requirements identified by BGS to improve current EMS site selection methods. These requirements guided the development of a web application to support and streamline the site selection process.

## Tool Requirements

### Essential

Provide an accessible interactive tool for EMS placement.

Display sources of seismic vibration on a base map.

Implement interactive widgets for controlling map content.

Allow filtering by distance from key vibration sources through slider controls.

### Desirable

Create a simple design that non-speciality users can operate.

Ensure reasonably fast performance for a national-scale map with multiple layers.

Integrate multiple filter conditions into a combined suitability score (e.g., weighted overlay functionality)

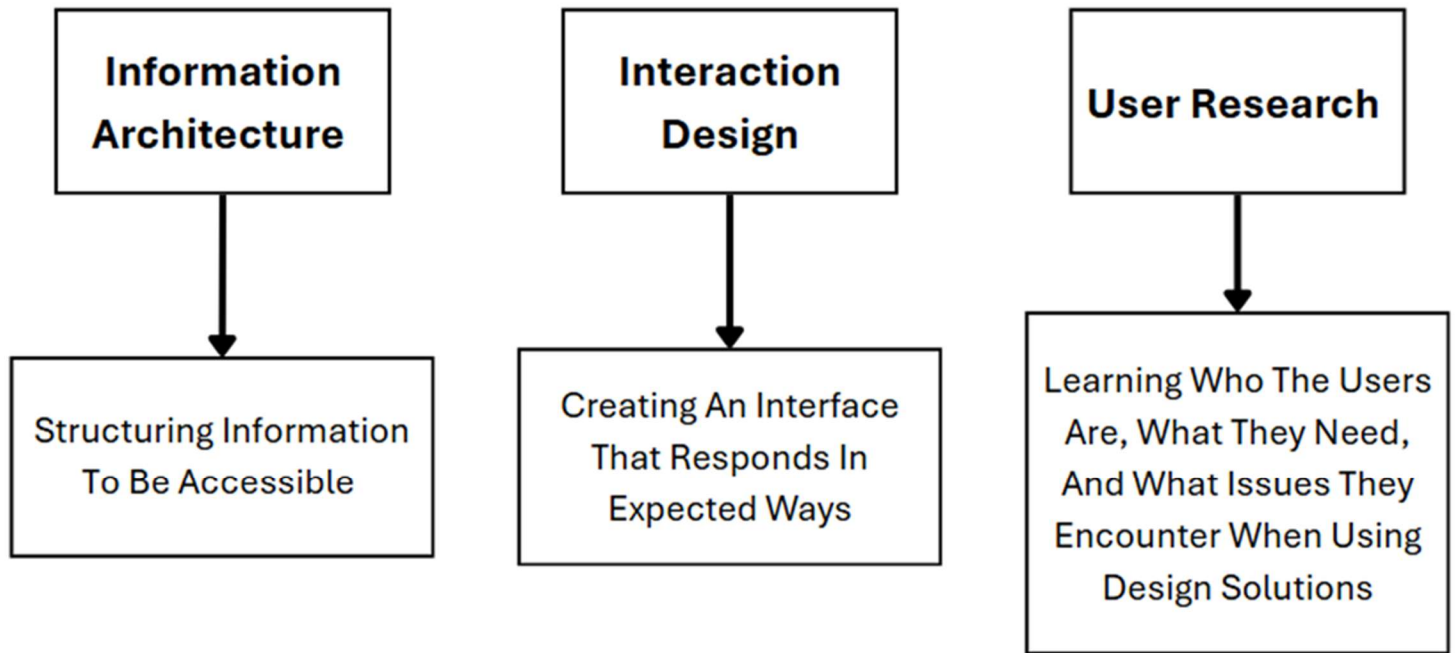
Provide a dynamic pop-up information panel showing minimum distance from a clicked point to all sources of vibration.

Display topographic information to identify areas likely to be suitable/not suitable for solar panels.

**Figure 8:** A list of both essential and desirable tool requirements. The requirements were identified following discussions with BGS to define the functionalities needed for a practical suitability assessment tool.

### 3.2 UI and UX Design Considerations

User interface (UI) and user experience (UX) are central to the effectiveness of a web application. The terms are associated with a wide variety of definitions across academic and industry settings (Tang & Herli, 2025). The most comprehensive definition within a GIS context is provided by Unger and Chandler (2023) in A Project Guide to UX Design (Figure 9).



**Figure 9:** Unger and Chandler’s three principles for effective user experience design. Throughout the development of the dashboard, these principles remained central to the design and implementation (Unger & Chandler, 2023).

UI/UX design directly influences user engagement. In parallel, application functionality determines how effectively information is communicated, highlighting usability as a key development priority (Hassenzahl & Tractinsky, 2006). A user-centred approach improves decision-making by facilitating access to information through well designed user flows, information architecture and usability testing (Hamidli, 2023). For a suitability tool, the interface must deliver a seamless user experience while meeting the specific needs of BGS professionals and GIS specialists. A clear conceptual model and minimalistic design further support complex spatial tasks, particularly when multidisciplinary teams use the tool (Johansson, 2024). These principles informed the dashboard’s design, resulting in a minimalistic, well-structured layout with grouped controls and clear icons to support BGS’s workflows and simplify decision-making.

### 3.3 Tool Rationale and Novel Approach to Site Suitability Mapping

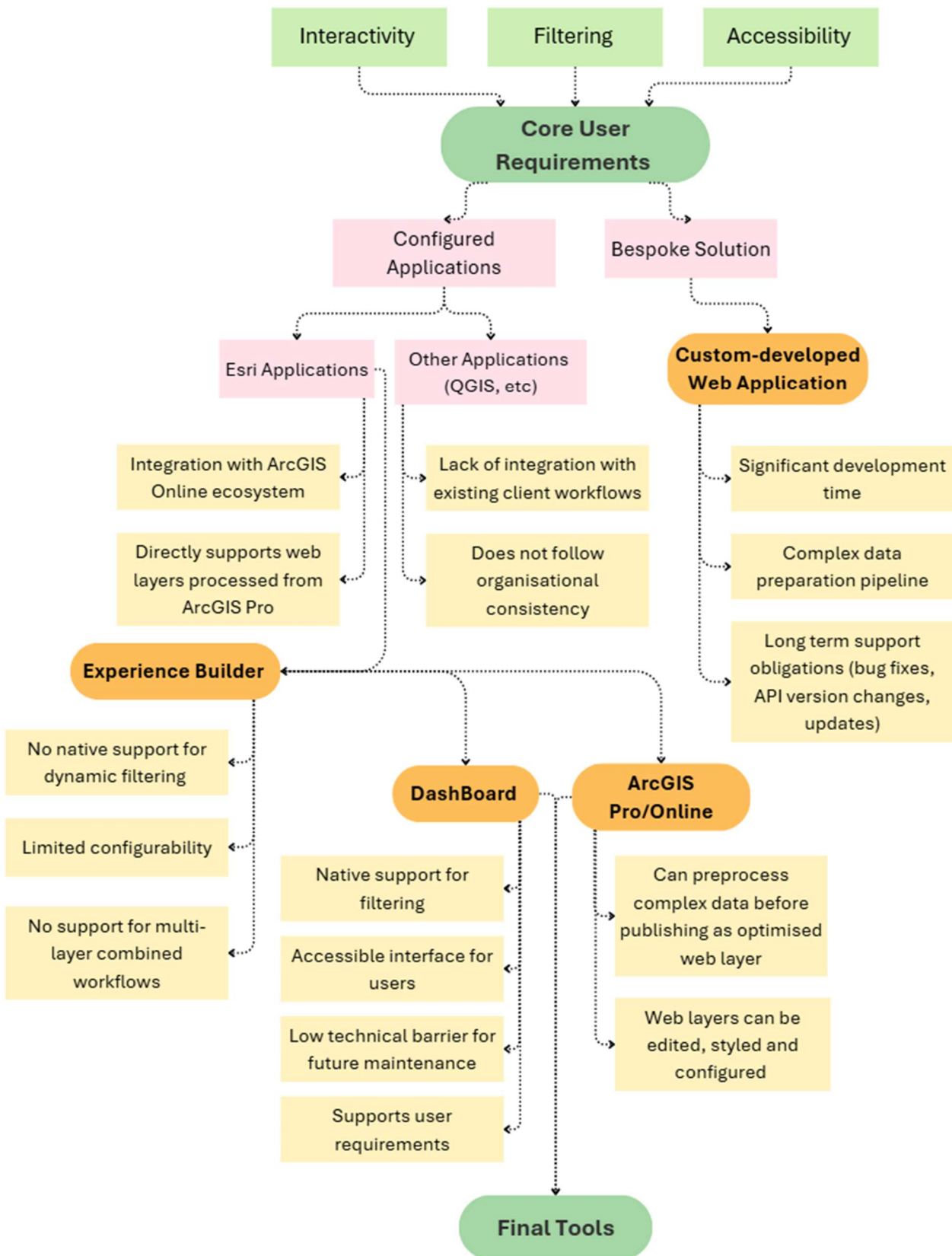
This project introduces a novel approach to suitability mapping for EMS site selection by providing a dynamic, interactive decision-support tool. Traditional suitability maps are static images, presenting fixed snapshots based on predefined criteria with no user interactivity. Adjustments to user requirements or geographic extent require producing an entirely new map. In contrast, incorporating interactive and dynamic features enables greater exploration and manipulation of spatial data (Vaníček et al., 2024).

While there are many GIS web applications related to earthquakes, these primarily focus on hazard alerts, earthquake notifications or disaster reporting. Examples include Disaster Alert from the Pacific Disaster Center in Hawaii (Pacific Disaster Center, n.d.) or the IRIS Earthquake Browser (Incorporated Research Institutions for Seismology [IRIS], n.d.), which allows users to explore global earthquake epicentres and seismic station data. There are fewer tools in publicly accessible formats to support researchers or agencies in identifying optimal sites for EMS. This project meets that need by providing a tool specifically designed to support EMS network expansion.

Several approaches were considered during development, outlined in Figure 10. A custom-built website using languages such as Python, JavaScript, HTML and CSS, combined with a Leaflet map interface (Das & Natarajan, 2024) was explored, but the complexity of managing large geospatial datasets and long development time rendered this impractical. Handling shapefiles in this format is challenging, as their structure is difficult to store in relational databases and makes advanced query tasks difficult (Ye & Mao, 2010). Given these constraints, specialist GIS software was chosen as it is purpose-built for geospatial data processing and readily accommodates formats such as shapefiles, rasters, TIFFs and CSV.

As BGS currently uses Esri software, it was logical to adopt a solution built within the ArcGIS ecosystem to ensure compatibility and ease of integration. The integration of ArcGIS products, including ArcGIS Pro, ArcGIS Online, and Dashboard, facilitates user-friendly interfaces and improves accessibility for users (Poslončec-Petrić et al., 2022).

Both ArcGIS Experience Builder and ArcGIS Dashboard were evaluated. Experience Builder lacked key functions required by BGS, while Dashboard provided built-in support for essential features such as widgets, sliders and filtering tools, meeting user requirements effectively (Esri, n.d.). ArcGIS Dashboard is a common platform for displaying dynamic geospatial data and has been used in earthquake-related applications such as spatio-temporal data displays in Indonesia (Susanta et al., 2019) and various monitoring dashboards globally (Adrianto et al., 2024; Tashi & Tshering, 2024; Visner et al., 2021). While Dashboard is less customisable than a bespoke application, it offers a robust, user-friendly interface that meets BGS's requirements for this project.



**Figure 10:** A flowchart outlining the decision-making process for selecting the most suitable platforms to develop the tool. Several software options were evaluated based on capabilities, limitations and alignment with the project’s needs. The final choice was based on the platform’s ability to meet technological requirements, user requirements and future usability.

### 3.4 Data Inputs and Origin

When planning to expand an EMS network, one must define unwanted seismic noise sources to guide site selection. Data for this project was compiled from open, accessible sources identified through a review of vibration-related literature and in consultation with BGS. To ensure compatibility with ArcGIS Pro, selected datasets were either already available in suitable formats (e.g., shapefiles, rasters) or could be transformed appropriately.

Each dataset was assigned a defined maximum slider distance, representing the threshold beyond which a given vibration source no longer significantly affects seismic monitoring. Recommended distances were provided by BGS and supplemented by guidance from the New Manual of Seismological Observatory Practice (Bormann, 2002; Trnkoczy et al., 2012) (Table 2), and the final values were adjusted for practical implementation. For example, although a 300 km exclusion distance from the ocean was suggested, this would encompass the entire landmass of the UK and was thus impractical. Furthermore, to manage performance and loading times across a national-scale dashboard, slider distances were capped at a maximum of 50 km, balancing detail and usability. The final seismic sources and buffer distances are shown in Table 3.

**Table 2:** A table of minimum recommended distances between EMS and sources of seismic noise from the New Manual of Seismological Observatory Practice. The “Actual Distance” column corresponds to the Loma Palo Bonito seismic station in the Dominican Republic, which is situated on hard granite rock. The shaded cells indicated criteria that do not meet the Class A standard for optimal station performance (Trnkoczy et al., 2012).

STATION SITE NAME: Loma Palo Bonito  COORDINATES: N 18°46' 58.4" W 70°13' 20.1"		SITE #7			DATE OF VISIT: 02/14/1998			ACTUAL DISTANCE  [km]
		HARD ROCK GRANITE, ETC.			HARDPAN HARD CLAY, ETC.			
		RECOMMENDED MINIMAL DISTANCES [KM]						
		A	B	C	A	B	C	
1. Oceans, coastal mountains systems		300	50	1	300	50	1	75
2. Large lakes		150	25	1	150	25	1	22
3. Large dams, waterfalls	a	40	10	1	150	25	5	22
	b	60	15	5	50	15	10	
4. Large oil pipelines	a	20	10	5	30	15	5	
	b	100	30	10	100	30	10	
5. Small lakes	a	20	10	1	20	10	1	20
	b	50	15	1	50	15	1	
6. Heavy machinery, reciprocating machinery	a	15	3	1	20	5	2	25
	b	25	5	2	40	15	3	
7. Low waterfalls, rapids of a large river, intermittent flow over large dams	a	5	2	0.1	15	5	1	
	b	15	3	1	25	8	2	6
8. Railway, frequent operation	a	6	3	1	10	5	1	40
	b	15	5	1	20	10	1	
9. Airport, air traffic		6	3	1	6	3	1	
10. Non-reciprocating machinery, balanced industrial machinery	a	2	0.5	0.1	10	4	1	25
	b	4	1	0.2	15	6	1	
11. Busy highway, large farms		1	0.3	0.1	6	1	0.5	2.3
12. Country roads, high buildings		0.3	0.2	0.05	2	1	0.5	2.0
13. Low buildings, high trees and masts		0.1	0.03	0.01	0.1	0.1	0.05	0.03
14. High fences, low trees, high bushes, large rocks		0.05	0.02	0.005	0.06	0.03	0.01	0.02

**Legend:**

- A Seismic station with a gain of 200,000 or more at 1 Hz
- B Seismic station with a gain from 50,000 to 150,000 at 1 Hz
- C Seismic station with a gain of approximately 25,000 at 1 Hz
- a Source and seismometer on widely different formations or that mountain ranges or valleys intervene
- b Source and seismometer on the same formation and with no intervening alluvial valley or mountain ranges

**Table 3:** A list of all included seismic noise sources and their corresponding features and data source. Final layers used in the dashboard are shown in yellow. Each layer has a maximum slider distance, indicating the furthest buffer threshold that was generated for the dashboard, and the feature type (e.g., polygon, line, point).

Source	Feature(s)	Sub-category	Slider Bar Max Distance	Data Type
OS Open Rivers	Rivers	Minor Inland Rivers	20 km	Shapefile (Line Features)
		Major Inland Rivers	50 km	
		Tidal Rivers	50 km	
		Canals	10 km	
OS Open Roads	Roads	A Roads	20 km	Shapefile (Line Features)
		B Roads	10 km	
		Motorways	30 km	
		Unclassified Roads	5 km	
National Grid Network Route Map	National Grid	Overhead Lines	15 km	Shapefile (Line Features)
British Geological Survey (BGS)	BGS Stations	N/A	50 km	CSV File
Renewable Energy Planning Database (REPD)	Renewable Electricity Projects	Onshore Operating Wind Turbines	25 km	CSV File
British Dam Register	Dams	N/A	30 km	CSV File
Open Street Map (OSM) Airports	Airports	N/A	25 km	Shapefile (Polygon Features)
Open Street Map (OSM) Sea Ports	Sea Ports	N/A	25 km	Shapefile (Polygon Features)
Environmental Information Data Centre (EIDC) Water Bodies	Lakes	Small Lakes	50 km	Shapefile (Polygon Features)
		Large Lakes	50 km	Shapefile (Polygon Features)
Global Administrative Areas (GADM)	GBR Administrative Areas	UK Coastline	50 km	Shapefile (Polygon Features)
Environmental Information Data Centre (EIDC) Gridded Population	UK Gridded Population at 1 km Resolution	UK Population Density	Density per km <sup>2</sup>	TIFF File (Raster)

## **4 Methodology** (Figure 11)

For further technical detail on the building process, including data selection, processing, workflow steps and tool configurations, refer to the Data Sourcing and Management and Dashboard Build Process documentation in the Technical Report.

### **4.1 Data Collection and Preparation**

Data was collected from openly available resources and datasets provided by BGS, including shapefiles, raster data and CSV files. These were organised into two main categories: anthropogenic seismic sources (e.g., roads, railways, population) and environmental/geological sources (e.g., rock type, water bodies).

Datasets were cleaned to ensure correct attribute structures, resolve missing or erroneous values and projected onto the British National Grid for spatial consistency. The data was further categorised into features and suitability-related datasets. Suitability datasets were processed in ArcGIS Pro using spatial analysis tools to calculate distance-based polygons from key vibration sources.

### **4.2 Web Layer Preparation**

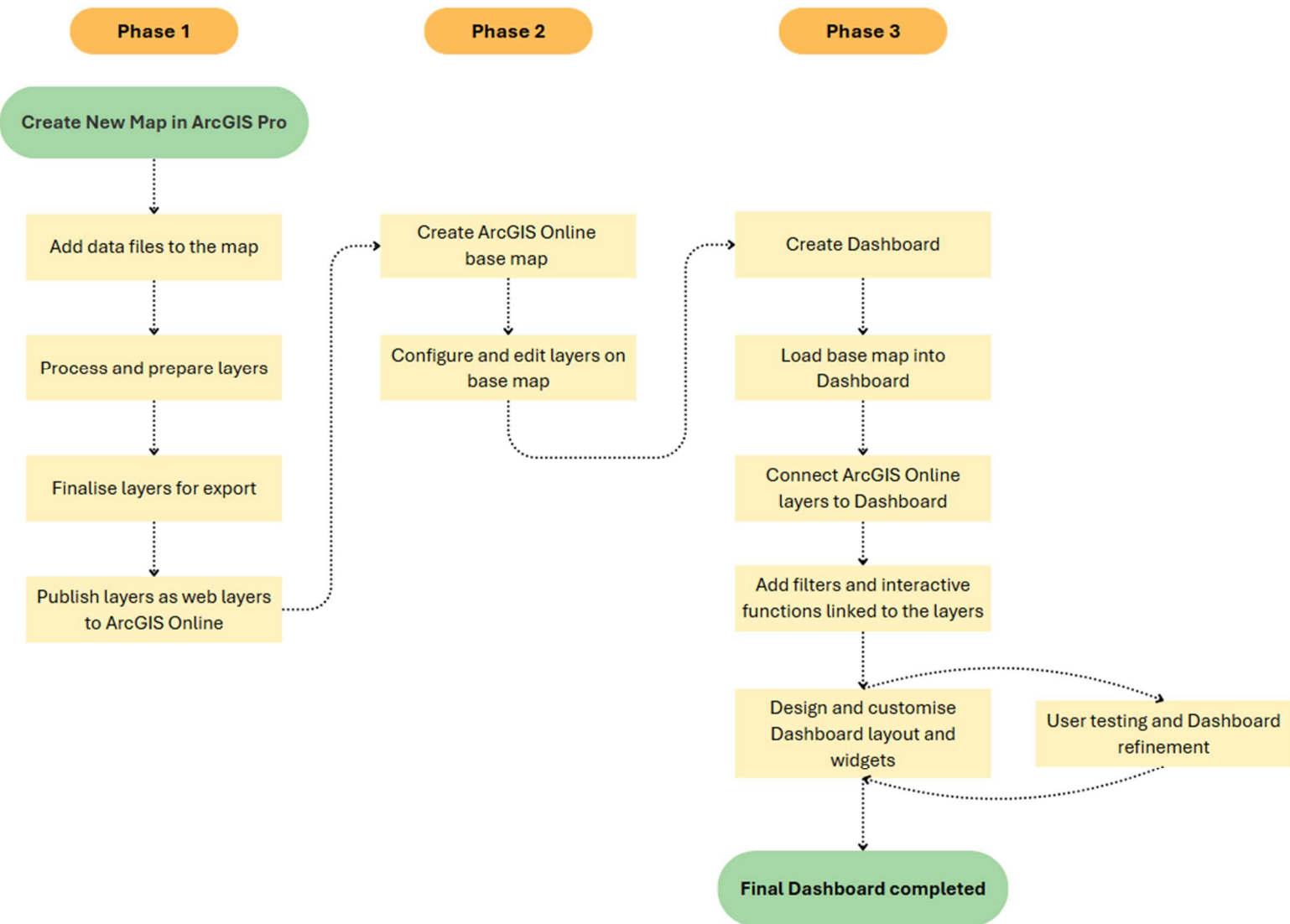
Processed layers were exported as hosted web layers to ArcGIS Online to facilitate integration into the dashboard. Additional edits, including attribute adjustments and symbology refinements, were completed in ArcGIS Online before loading onto a basemap.

### **4.3 Dashboard Development**

A new ArcGIS Dashboard was created, incorporating the prepared basemap and layers. Interactive widgets were configured to allow users to dynamically filter map content based on distance from various seismic noise sources. Layers were optimised to balance detail and performance, ensuring smooth interaction even at a national scale.

### **4.4 UI and UX Design, Testing and Refinement**

The dashboard was tested with multiple audiences, including BGS staff, GIS students and non-specialist users, to assess usability, performance and clarity. Initial tests identified performance limitations, which were addressed through polygon simplification and widget configuration adjustments. Design refinements improved responsiveness and cross-platform compatibility.



**Figure 11:** A simplified dashboard build process workflow. The dashboard was developed in three phases: (1) data processing and export in ArcGIS Pro, (2) web layer and symbology preparation and editing in ArcGIS Online, (3) integrating web layers into ArcGIS Dashboard, user testing and finalisation.

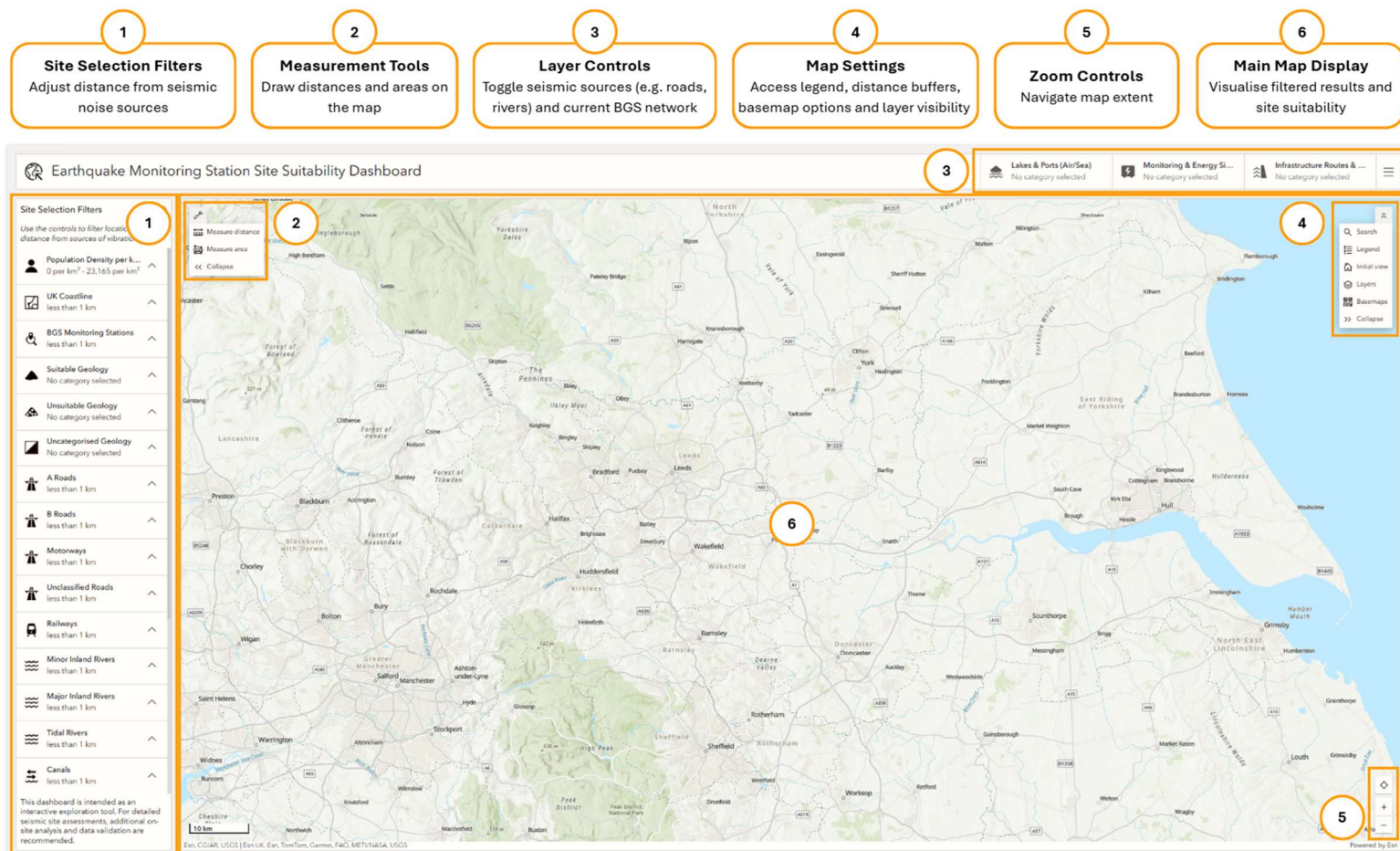
## 5 Results

The dashboard was evaluated on two main criteria: (1) how well the dashboard meets BGS's core user requirements; and (2) technical quality and usability of the build. The evaluation draws on user survey feedback, performance metrics and observations from testing to assess the dashboard's effectiveness and reliability as a decision-support tool.

### 5.1 Meeting BGS User Requirements

This section evaluates how effectively the dashboard meets the functional requirements defined by BGS for seismic monitoring network planning.

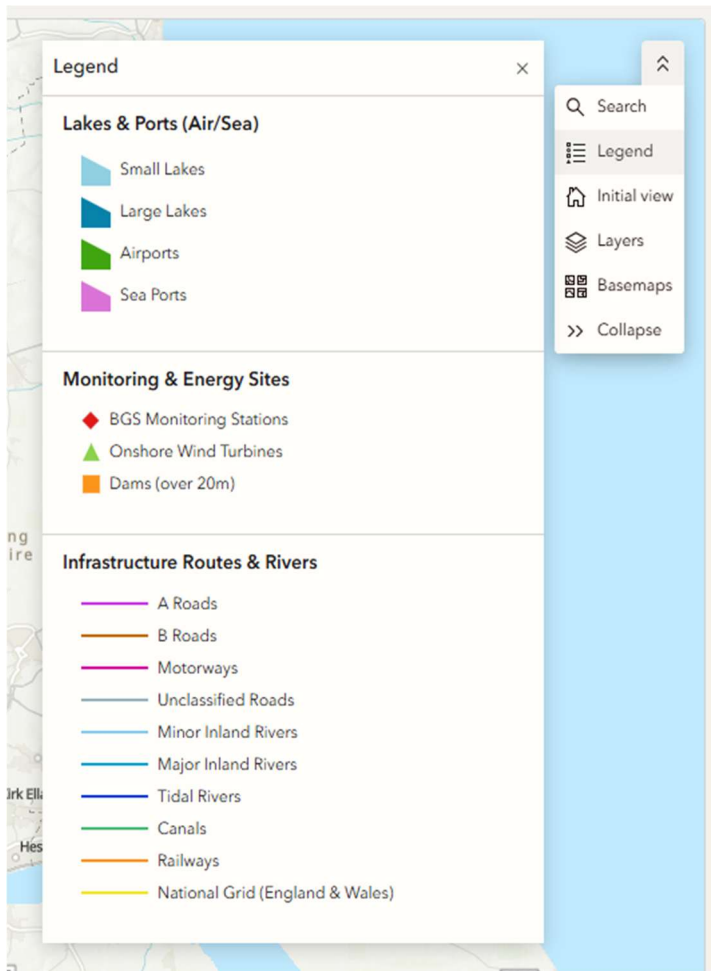
The initial dashboard view presents a clear, map-centric layout (Figure 12). The interactive map occupies the central portion of the screen, maximising spatial exploration. The main controls are on the left panel and top right corner, while additional smaller control buttons are located in each corner of the map to support quick access to key functions.



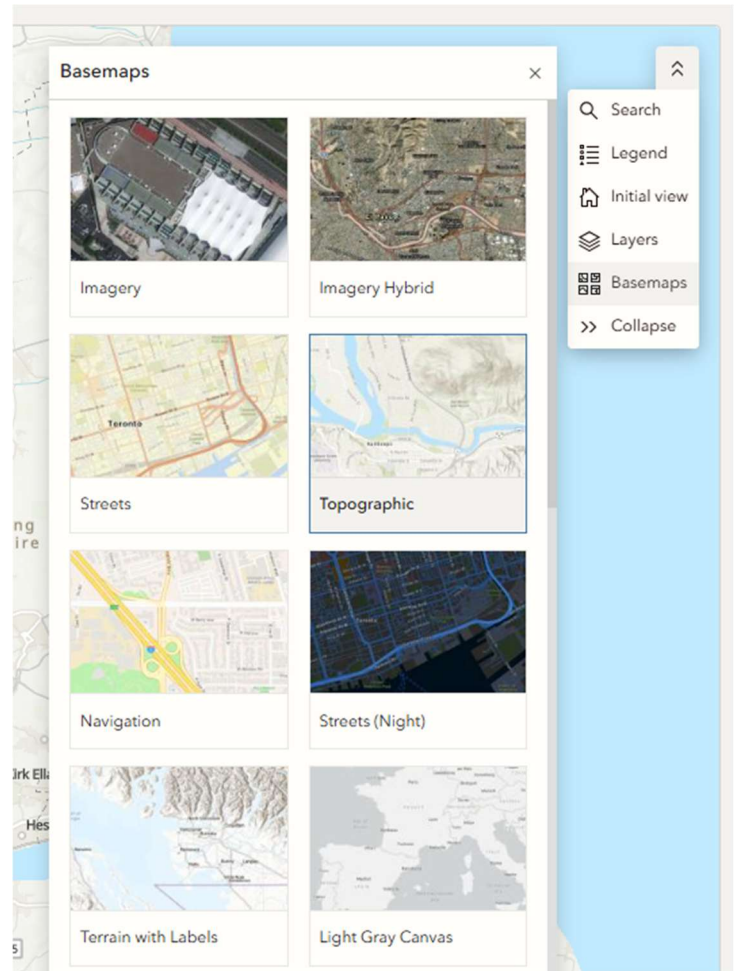
**Figure 12:** The initial dashboard view with labelled interface elements. The default map is centred on northeast England. The primary tools are labelled 1, 3 and 4. The supporting controls are labelled 2 and 5. Number 6 highlights the main map interface, where the filtered results are visualised.

Figures 13 and 14 show the expanded content panels of the dashboard.

The map settings section includes a legend that helps users interpret the colour schemes associated with each feature. Users can switch between multiple base maps, such as topographic, satellite imagery and night streets, to customise the map's appearance.

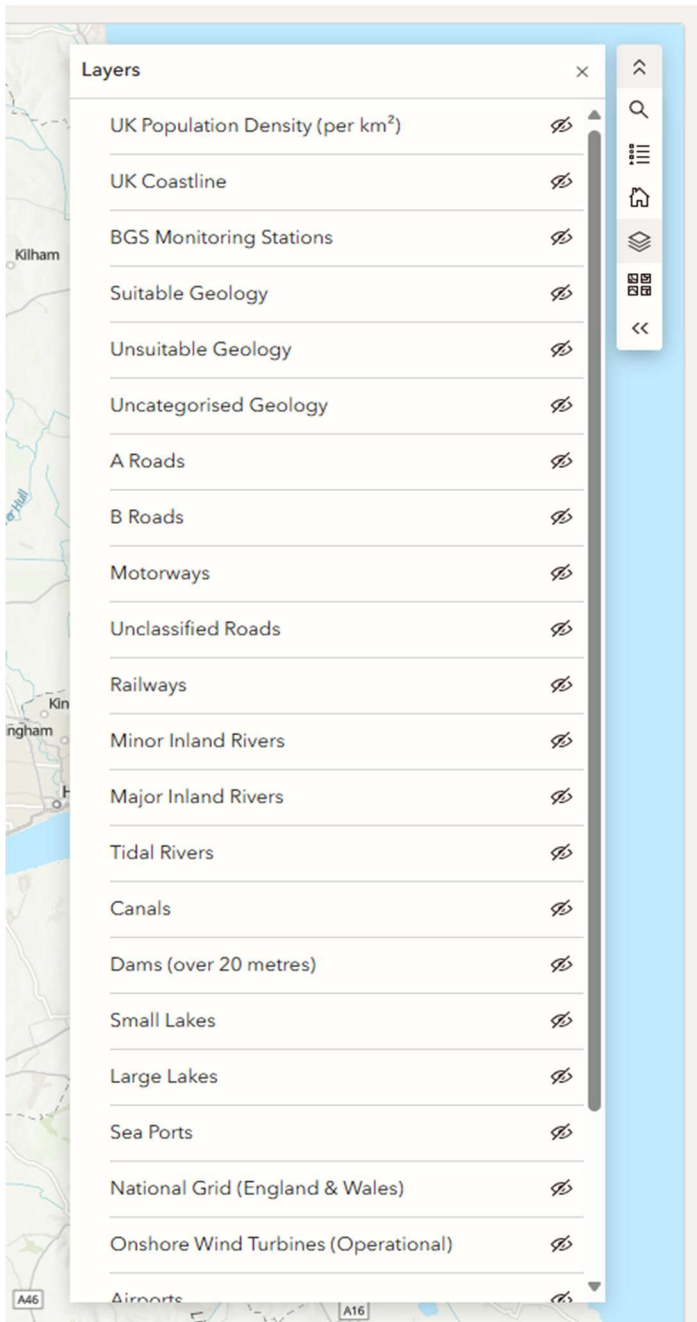


**Figure 13:** The legend is accessed via the side menu. It displays colours and shapes used to represent different features, helping users interpret and distinguish between features during visual analysis.

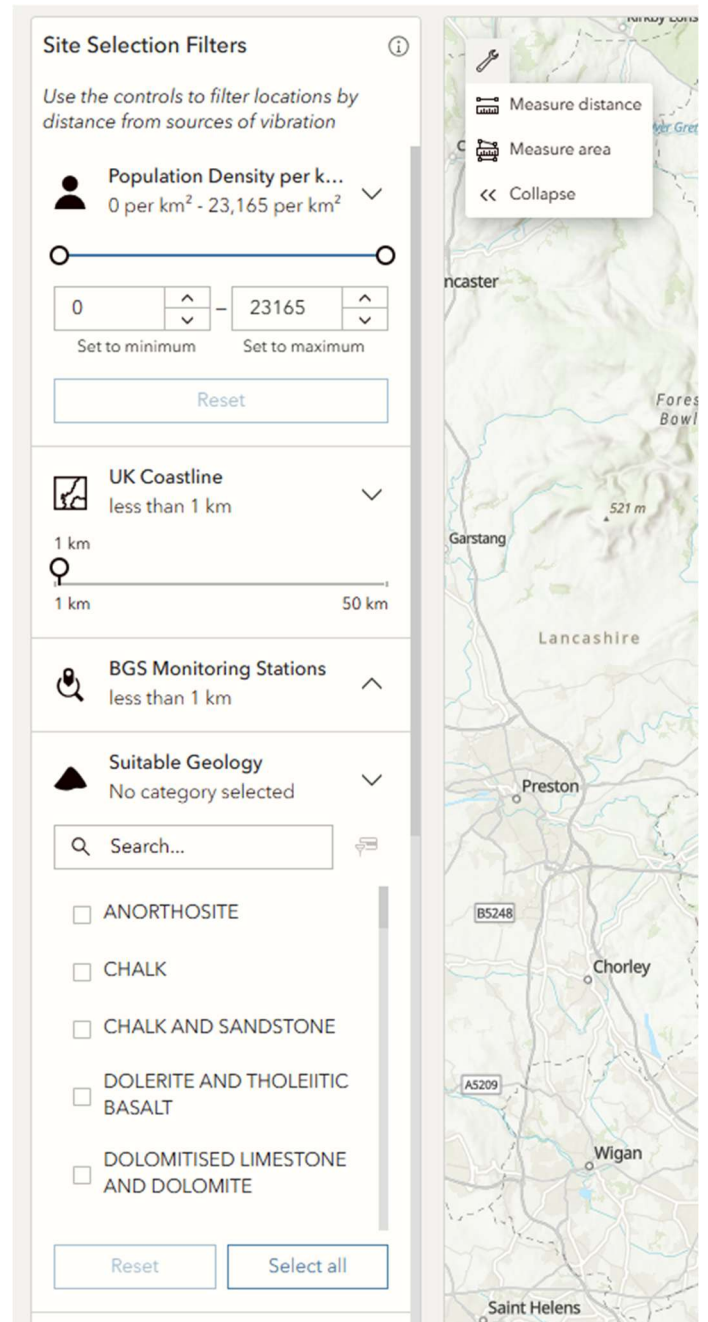


**Figure 14:** Basemap selection is also accessed via the side panel, in addition to a search function, initial view (return to home) and buffer layers. Users can switch between multiple basemap styles, including satellite imagery, hybrid view (satellite with place names), terrain, night mode, navigation and other stylistic options. This feature is useful for assessing land and terrain context during site selection.

Two controls activate the buffers from seismic noise. First, the relevant layers must be turned on from “Layers” to display buffer zones around seismic noise sources (Figure 15). Once active, users can then adjust the buffers using interactive sliders, buttons and density options (per km<sup>2</sup>) (Figure 16), allowing them to customise suitability criteria based on proximity to specific features.

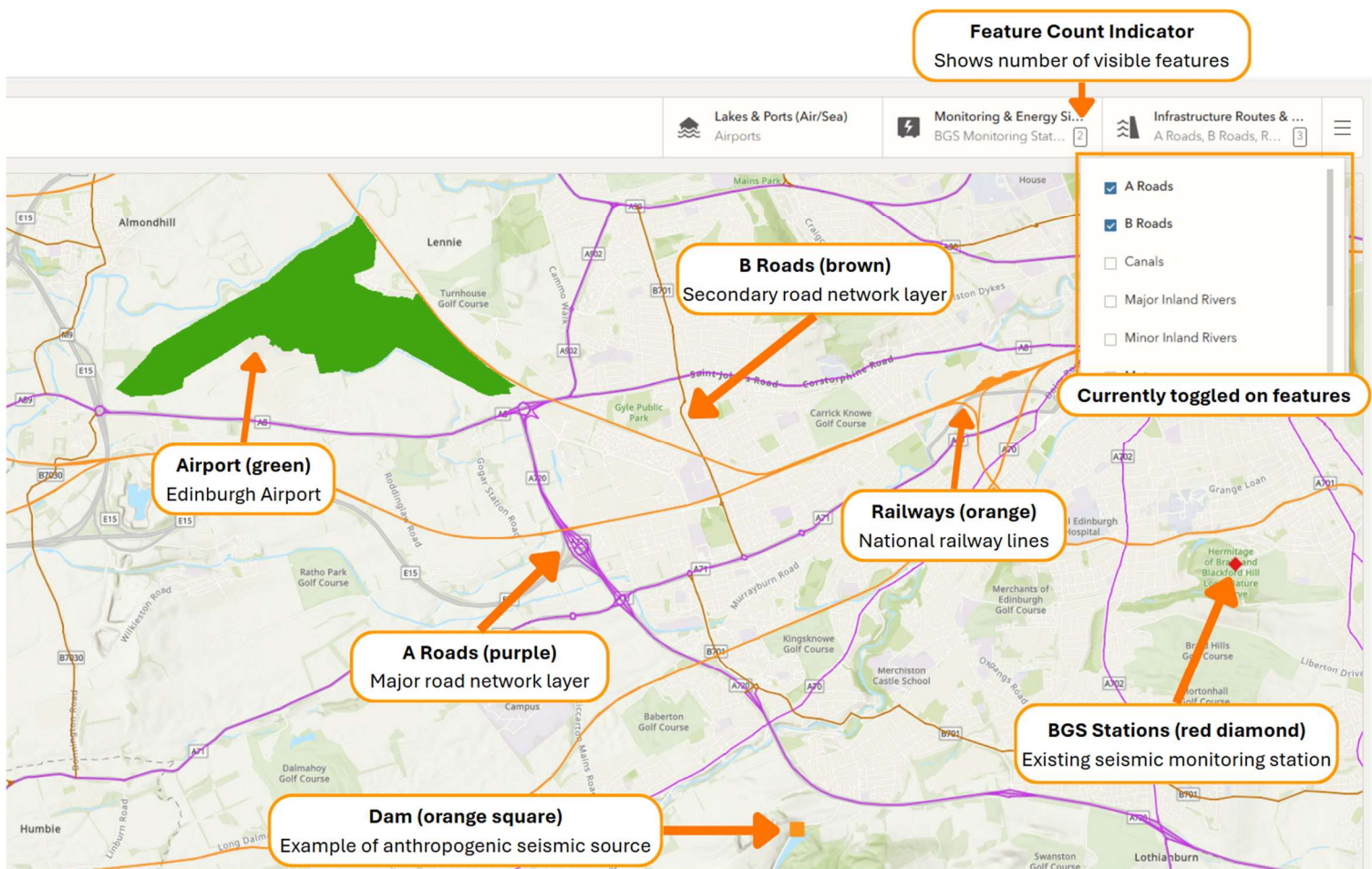


**Figure 15:** Buffer layers are accessed from the side menu. These layers represent proximity to seismic noise noises. They are toggled off by default to avoid visual clutter. Users can selectively turn on layers, each initially displaying a 1km buffer. Turning on and overlapping multiple buffers helps identify potential sites with minimal noise interference.



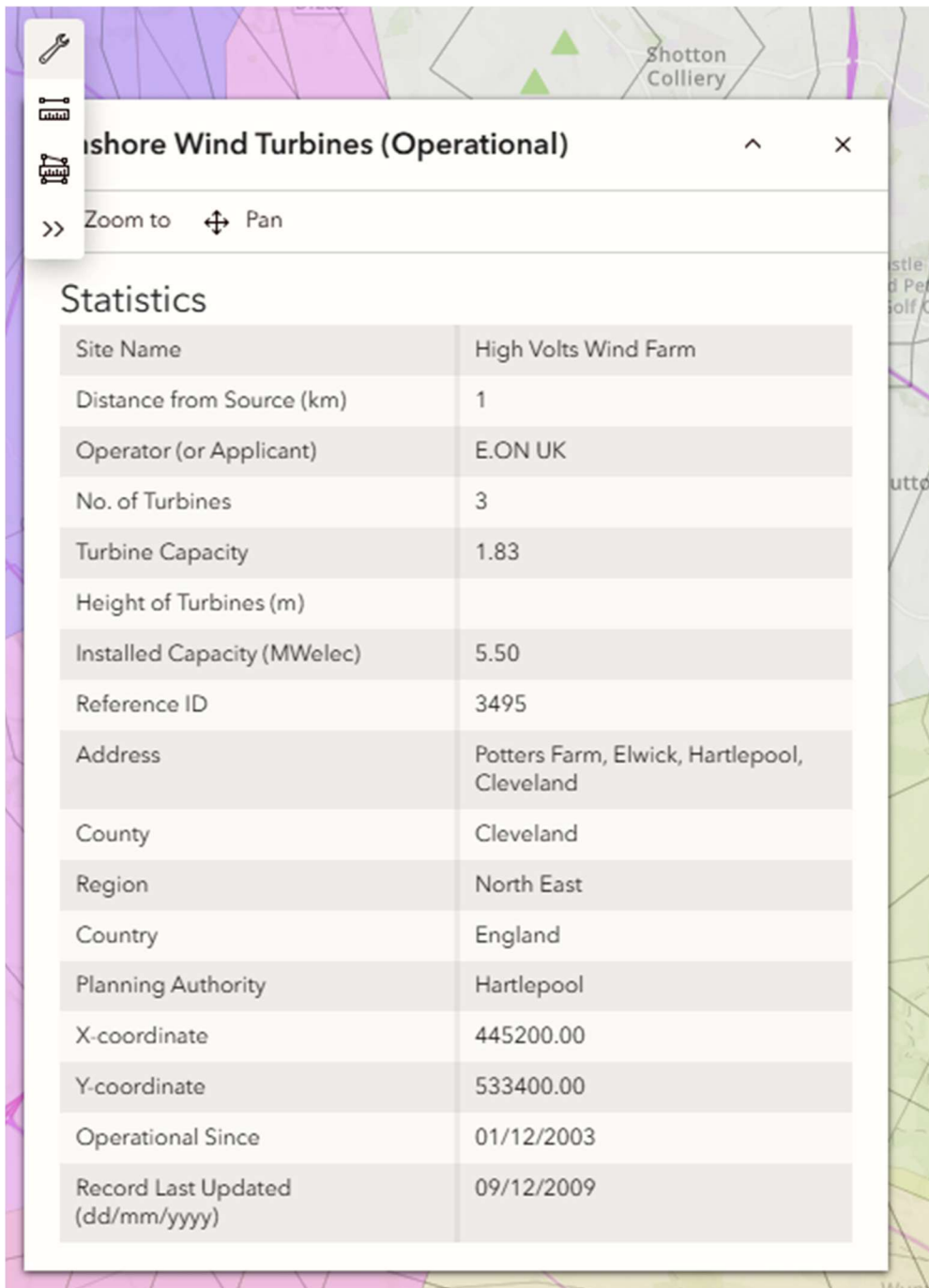
**Figure 16:** Site selection filters are located on the left sidebar. The interactive controls, including sliders, numeric inputs and category selectors, allow users to filter the buffer layers based on distance or type. Once a buffer layer is activated, the corresponding filter can be configured, and the results are dynamically visualised on the map.

The top-right controls display the features themselves, separately from the buffer layers, allowing users to visually inspect existing infrastructure, such as road networks, around potential sites (Figure 17). This is useful for assessing general site context and accessibility, important considerations when planning new station installations.



**Figure 17:** A screenshot of a portion of the map, displaying A roads, B roads, railways, dams over 20m, existing EMS stations and airports. These have been activated via the controls in the top-right. These are feature layers only (not buffer layers) and are colour coded for clarity.

Clicking on a feature opens an attribute window displaying its associated information (Figure 18). For buffer polygons, this includes the calculated distance from the corresponding seismic noise source in kilometres.

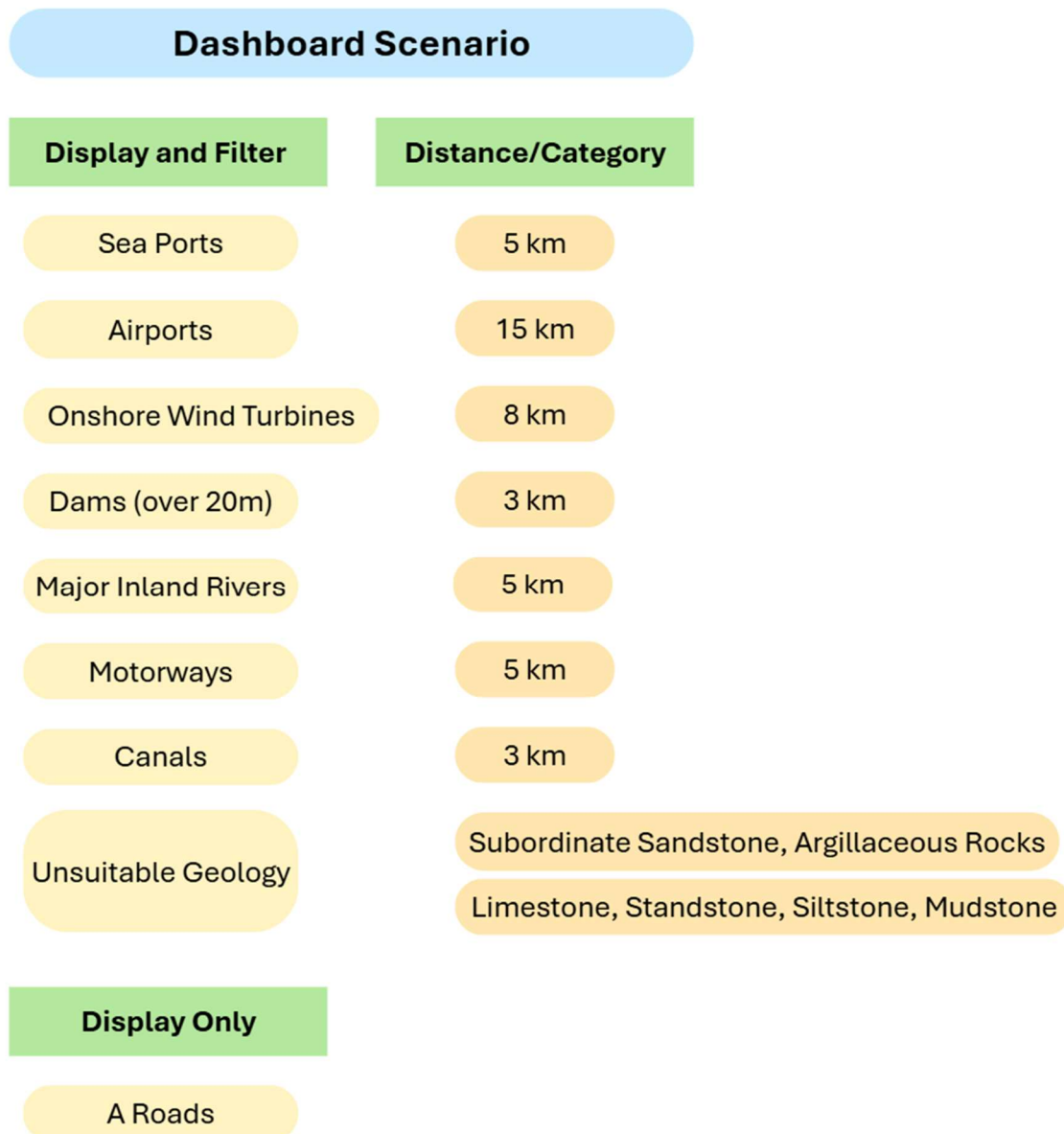


The screenshot shows a GIS interface with a map in the background. A pop-up attribute window is open, titled "Onshore Wind Turbines (Operational)". The window has a toolbar with icons for zooming and panning. Below the toolbar is a "Statistics" section containing a table with the following data:

Site Name	High Volts Wind Farm
Distance from Source (km)	1
Operator (or Applicant)	E.ON UK
No. of Turbines	3
Turbine Capacity	1.83
Height of Turbines (m)	
Installed Capacity (MWelec)	5.50
Reference ID	3495
Address	Potters Farm, Elwick, Hartlepool, Cleveland
County	Cleveland
Region	North East
Country	England
Planning Authority	Hartlepool
X-coordinate	445200.00
Y-coordinate	533400.00
Operational Since	01/12/2003
Record Last Updated (dd/mm/yyyy)	09/12/2009

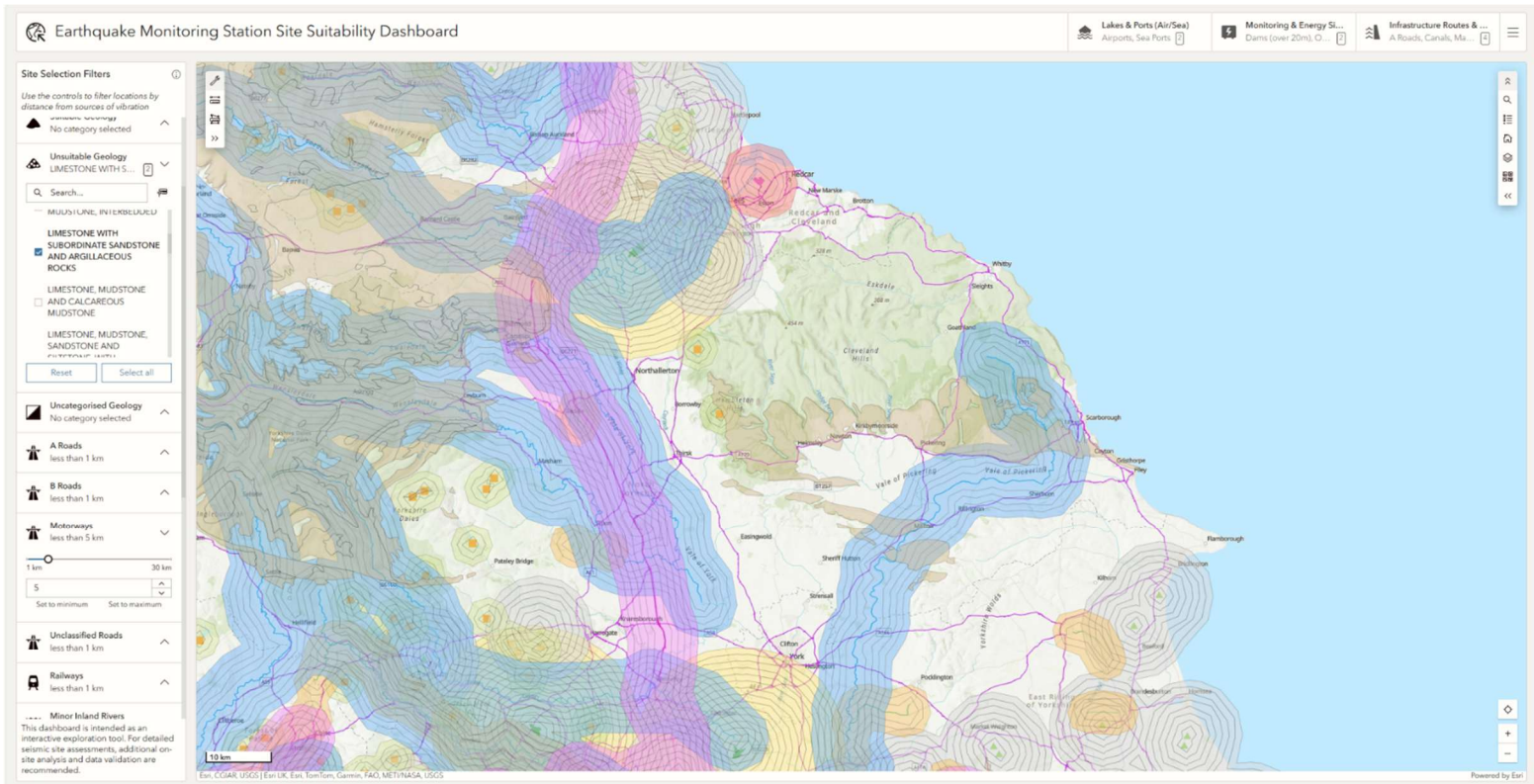
**Figure 18:** An example pop-up attribute table from clicking on a wind turbine point. Each feature has a unique set of attribute data. In this case, the table includes the site name, distance from source, operator and other relevant information. Attribute information varies between layers depending on the source and type of data.

To demonstrate dashboard functionality, a typical use case scenario is presented. Figure 19 below outlines a sample query for northeast England in which specific layers are turned on and filtered by set distance thresholds and categories.



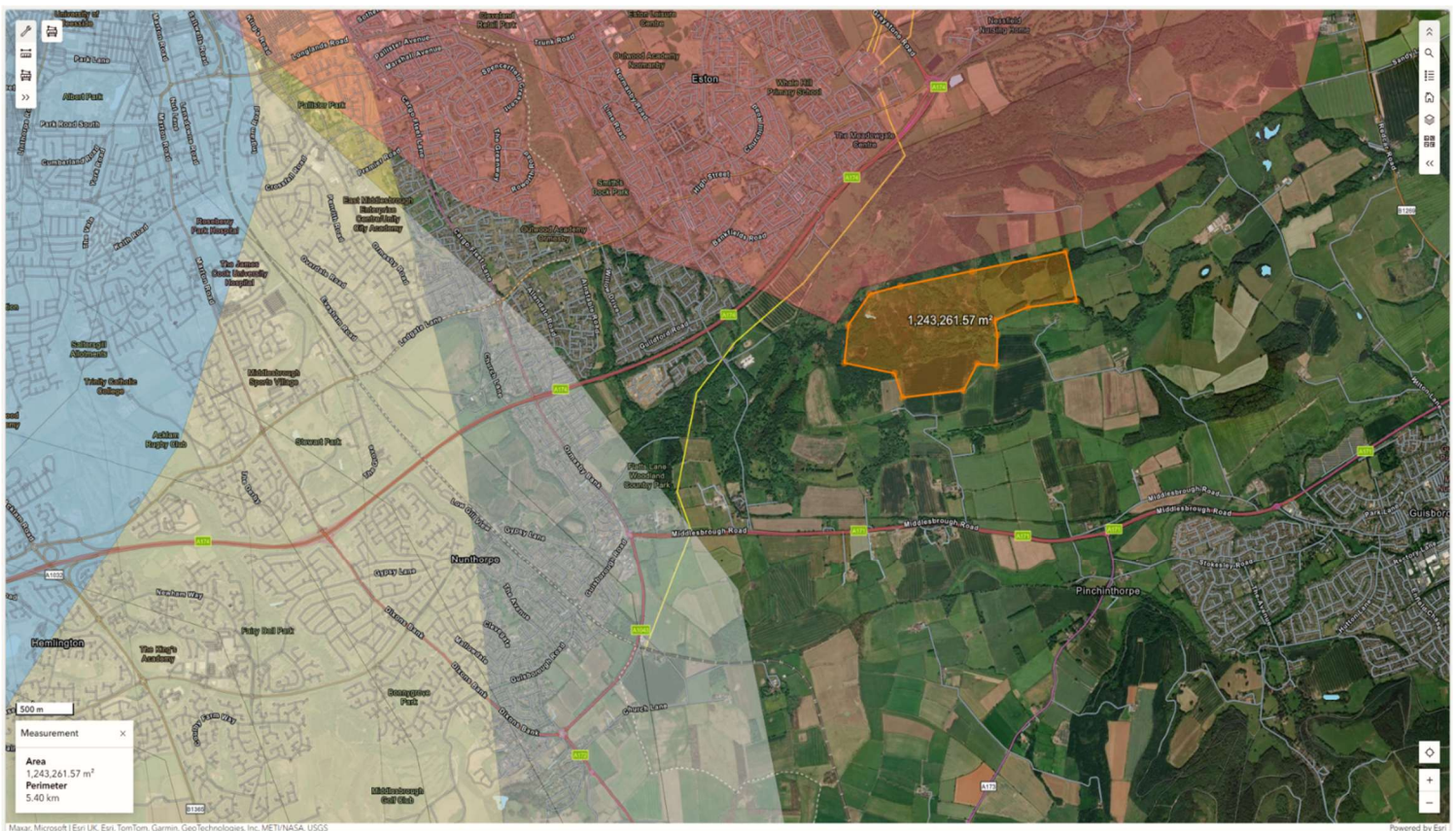
**Figure 19:** An example user input scenario for identifying a suitable EMS location in and around the North York Moors National Park. Eight buffer layers are activated and filtered using the site selection controls following set distances. The unsuitable geology layer is activated, with two rock types selected. A Roads are displayed as a feature only.

The map in Figure 20 reflects these inputs. The coloured regions represent buffer zones around selected noise sources. In this scenario, suitable locations for an EMS are the areas outside these buffers, where potential seismic interference is minimised.



**Figure 20:** The map view after activating and filtering seismic noise sources in the broader area surrounding North York Moors National Park. Each layer is translucent, with bands representing 1km intervals. The left side of the map shows significant overlap of seismic noise sources and unsuitable geology. The national park appears not to have much seismic noise (according to the inputs), with A roads providing potential access. Users can evaluate which factors are most critical when balancing proximity to different sources.

Figure 21 presents a zoomed-in view of the map with the satellite basemap enabled for more detailed site analysis. Unclassified roads are displayed to assess local access routes. The measure tool is used to calculate the dimensions of a selected location. The highlighted orange area represents a user-selected potential EMS site. It lies outside all buffer zones, indicating minimal seismic noise interference, while remaining accessible for installation and maintenance given its proximity to local roads. After identifying potential sites using the dashboard, professionals would then carry out on-site validation to confirm suitability for EMS installation.



**Figure 21:** A zoomed-in map view using a satellite basemap. Unclassified road features have been turned on to assess local access routes. An area away from the buffers has been identified as a potential EMS site. The area measurement tool (shown in orange) has been used to select a region of interest, displaying the area in square metres.

Table 4 summarises the essential and desirable tool requirements and how they were addressed in the dashboard implementation.

**Table 4:** A table outlining the essential and desirable user requirements identified in collaboration with BGS. The right column details the evaluation outcomes of the dashboard, indicating whether requirement was fulfilled and describing how it was addressed. Colour coding is used for clarity. Green indicates the requirement was fully met, yellow indicates it was met to a degree, and pink indicates it was not met.

BGS User Requirement	Evaluation Outcome
<b>Essential Requirements</b>	
Provide an accessible interactive tool for EMS placement	The dashboard delivers an accessible, web-based interface for exploring EMS site suitability interactively.
Display sources of seismic vibration on a base map	The map clearly displays major anthropogenic and environmental vibration sources overlaid on a national-scale basemap (number of sources limited by data availability)
Implement interactive widgets for controlling map content	The dashboard includes interactive widgets, allowing users to control visible layers and filter content dynamically.
Allow filtering by distance from key vibration sources through slider controls	Slider widgets enable users to filter map content based on user-defined distance thresholds.
<b>Desirable Requirements</b>	
Create a simple design that non-speciality users can operate	The interface is a minimal, user-friendly layout testing with specialist and non-specialist users for clarity and ease of use.
Ensure reasonably fast performance for a national-scale map with multiple layers	Performance optimisation (polygon simplification, scale-dependent rendering, cache control, etc.) improved load times, resulting in acceptable responsiveness at larger scales.
Integrate multiple filter conditions into a combined suitability score (e.g., weighted overlay functionality)	Not implemented. Filtering operates on individual criteria rather than an integrated weighted score.
Provide a dynamic pop-up information panel showing minimum distance from a clicked point to all sources of vibration.	Not implemented due to technical constraints. This feature is a potential future enhancement.
Display topographic information to identify areas likely to be suitable/not suitable for solar panels.	Not implemented, as no suitable solar radiation dataset was available for integration into the dashboard within the project scope.

Two user requirements could not be met due to constraints of the chosen platform. ArcGIS Dashboard does not support certain functions, such as weighted overlay, which limits filtering to individual layers rather than a combined suitability score. These limitations are discussed in detail in the technical report, along with potential future enhancements.

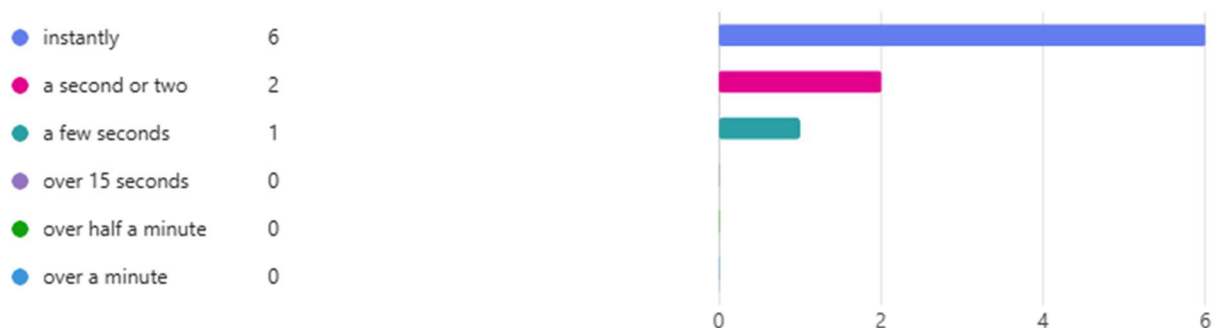
Overall, the dashboard successfully met all essential user requirements and addressed several desirable features, with certain advanced functionalities identified as potential future enhancements.

## 5.2 Build Quality and Usability Evaluation

This section evaluates the technical quality, responsiveness and usability of the dashboard, drawing on feedback from usability testing, user surveys and performance observations during development. The full user survey results are detailed in Appendix B.

### Widget Performance and Response Time

Survey participants were asked to click on several loaded features to test if attribute pop-ups loaded correctly. All nine participants were able to successfully load and view multiple attribute tables. Participants were also asked to toggle on features, such as airports and lakes, and record how long they took to load (Figure 22).



**Figure 22:** Results from nine participants loading the Airports feature-only layer. Six reported instant loading, two reported a delay of one to two seconds, and one reported a delay of a few seconds – a substantial improvement compared to pre-optimisation performance.

Widget responses times were tested to be consistently acceptable, with layers taking approximately 1-5 seconds on average to load in. Participants found that panning and zooming across geographic extents performed relatively smoothly following optimisation techniques, although some delay remained when rendering extensive polygons at large scales.

Participants were also asked to rate their overall experience using statements scored from “Not at all” to “Very much”, as shown in Figure 23. The majority of responses were highly positive, with rating predominantly in the “Quite a bit” and “Very much” range.



**Figure 23:** A bar graph showing responses from nine participants. All seven statements received majority positive ratings, with only two statements receiving “A little” from two participants, and no statements receiving “Not at all”.

Typed feedback from participants also helped refine the dashboard’s design. One participant suggested adding a “reset to factory defaults” option, which led to the addition of a dashboard reset button in the bottom-right corner. Another participant noted difficulty understanding some functions as a non-GIS user, resulting in the creation of a user manual.

## Key Optimisation Measures

Several optimisation techniques were implemented, based on iterative testing during development and user feedback, to improve loading speed, visual detail and overall performance (Table 5). Many of these strategies were informed by best practices outlined in an ArcGIS blog by Pisut (2024) on improving feature layer performance.

**Table 5:** A summary of the optimisation techniques applied throughout the dashboard development process. The function and impact of each technique is outlined. Each technique was implemented after iterative user feedback and personal testing, collectively contributing to a significant enhancement in dashboard performance.

Optimisation Technique	Function & Impact
Polygon Simplification	Increased the cell size of polygons from 25m to 500m, significantly improving loading speed while retaining sufficient detail for small-scale (zoomed in) views.
Scale-Dependent Rendering	Adjusts the level of detail displayed based on zoom level, prioritising performance by reducing rendering load at broader map extents.
Conversion to Integer Values	Rounded floating-point values to integer in datasets and attribute tables to avoid excessive decimal places. This ensured cleaner, more compact data and helped prevent service slowdowns caused by overly detailed numeric fields.
Optimise Layer Drawing	Utilised ArcGIS Online’s built-in settings to speed up rendering of complex line and polygon geometries.
Cache Control	Increased cache duration from 30 seconds to 1 hour, allowing repeated actions to reuse stored data and minimising the need for frequent reloads.
Slider Extent Limiting	Capped slider distance thresholds to constrain the spatial extent of layers, reducing data load and improving performance across the UK-wide map.

## **Browser and Device Compatibility Testing**

The dashboard was tested across several browsers, operating systems (macOS, Windows) and devices. Google Chrome suffered frequent crashes and prolonged loading times, possibly due to GPU memory limitations and caching issues, while Microsoft Edge, Firefox and Safari loaded the dashboard successfully. A splash screen was created to advise users to use browsers other than Google Chrome. A mobile version was also developed with the aim of supporting field use by BGS; however, processing demands of rendering large-scale geospatial data on current mobile devices rendered it non-viable. As a result, the mobile version remains a conceptual prototype, and the desktop version is the primary platform.

## **Usability Considerations**

To support effective use, a user manual was developed to accompany the dashboard (see the User Manual in the Technical Report). The guide provides step-by-step instructions on using the dashboard's features and to familiarise users with a typical use case. This documentation ensures the dashboard is accessible to both specialist and non-specialist users. The resulting dashboard is publicly accessible, user-friendly and demonstrates good build quality.

## 6 Discussion

This study aimed to address the absence of accessible tools to support seismic network expansion in the UK and to develop a practical solution tailored to the specific requirements of BGS. The resulting platform enables users to evaluate the suitability of potential monitoring sites by filtering proximity to seismic noise sources. It incorporates user-friendly controls such as sliders, checkboxes and dynamic pop-ups, to accommodate a broad range of users, from GIS experts to seismologists and field teams with limited technical training.

The iterative development process was informed by continuous user testing and refinement. A key design objective was to make spatial analysis accessible to users with varying technical expertise, without sacrificing functionality. The interface design was intentionally minimal, using intuitive widgets, consistent symbology and simplified attribute labels (e.g., renaming field headers for readability). Pop-ups and legends were structured for ease of interpretation, and visual hierarchy was maintained through careful colour coordination and thematic design (Barševska & Rakele, 2019). Graphs and summaries were omitted, as integrating them required extensive data manipulation and system changes which delivered little added value since key spatial relationships can be observed directly on the map.

### 6.1 Technological Limitations and Methodological Trade-Offs

The decision to build a national-scale dashboard posed several challenges. Methodological limitations emerged, including difficulties in sourcing suitable data and technical constraints inherent to the platform. Dashboards are typically designed for local or regional applications, but this project extended the approach to a national scale, requiring significant performance optimisation to deliver usability. Substantial data volume introduced bottlenecks, alongside server-side constraints in ArcGIS Online. Despite implementing optimisation strategies, performance issues remain, particularly when navigating across large extents or loading in several layers simultaneously. Feature loading is restricted to the visible extent to reduce processing load, which can cause delays when panning to new areas. However, once features have loaded, subsequent interactions within the same view are unaffected, as the data is cached and does not need to be reloaded. During development, it became evident that high levels of complexity can overwhelm the dashboard. This suggests that future iterations should further incorporate data and processing streamlining techniques.

Within the ArcGIS Dashboard environment, functionality such as multi-criteria analysis and weighted overlays cannot be implemented. Exporting results as a shapefile is also not possible within the platform constraints. Expanding functionality through a custom widget built with the ArcGIS API for JavaScript would allow advanced features like querying distance from user-defined points. However, this would require rebuilding the interface in Experience builder or similar, as the current architecture is not transferable across frameworks.

Mobile compatibility emerged as a key consideration, especially for potential fieldwork applications in dynamic remote environments. However, performance limitations, particularly with intensive geoprocessing at a national scale, caused the mobile version to exhibit inconsistent behaviour across devices, with frequent lag and crashes, rendering it currently unsuitable for reliable use. Addressing this limitation could be important in future iterations, especially as user demand for mobile-accessible GIS tools grows.

## **6.2 Alternative and Future Implications**

This dashboard proves the concept of an accessible, data-driven approach to infrastructure planning. The underlying workflow could be adapted for other domains, such as sensor placement for air quality monitoring, biodiversity tracking, or renewable energy planning. The web-based model reduces the needs for desktop GIS software and can support decentralised, collaborative decision-making processes (Sallwey et al., 2019). It incorporates transparent filtering, clear symbology and interactive pop-ups; standard features that enhance usability and are transferable to future GIS tools. Though the dashboard faced challenges with access to data, this limitation is less relevant where organisations have direct access to proprietary data.

Achieving a balance between functionality and accessibility remains crucial, especially when working with large datasets. While future versions can integrate predictive modelling or machine learning to improve decision support, these enhancements should avoid compromising performance.

Beyond technical use, the dashboard has potential as a policy engagement tool. Improved transparency around site selection strategies through a publicly accessible tool can support funding proposals and guide strategic planning for EMS network expansion. Local authorities and research institutions lacking technical resources could benefit from adopting or adapting this tool, saving development time and costs, as well as training costs for users. By enabling data sharing and interactive exploration, the dashboard also facilitates cross-sector collaboration and enhances communication between stakeholders. While it is not a substitute for field validation, such as on-site visits or taking local seismic measurements, it provides a structured pre-screening process that can significantly streamline early-stage planning.

## 7 Conclusion

This project aimed to develop a GIS-based web application tailored to support the British Geological Survey (BGS) identify suitable locations to expand the UK's EMS network. The resulting dashboard successfully integrates multiple layers of seismic noise source data and presents the output through an interactive, user-driven interface. In contrast to static suitability maps or BGS's previous manual assessments, the dashboard enables dynamic spatial filtering through an accessible interface. This approach to site selection facilitates structured decision-making and pre-screening of potential sites prior to field validation. Though the dashboard was tailored for BGS's needs, its core functionality is adaptable to other use cases and encourages critical evaluation of existing suitability methods.

Although the dashboard performed successfully on computers, the mobile version faced challenges with processing and display of information. Improving mobile functionality – especially with offline use for field-based users – should be a focus for future development. Most limitations stemmed from inherent constraints of the ArcGIS Dashboard platform, including the lack of advanced spatial querying and weighted overlays. Limited access to data also restricted the inclusion of relevant seismic noise sources (e.g., industrial zones).

Despite these limitations, the results demonstrate the value of web-based GIS tools in infrastructure planning, especially in resource constrained contexts. By making complex spatial data accessible and interactive, this project lays the groundwork for future scalable decision-support systems within geoscience and wider environmental planning projects.

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## **Part 2**

# **Technical Report**

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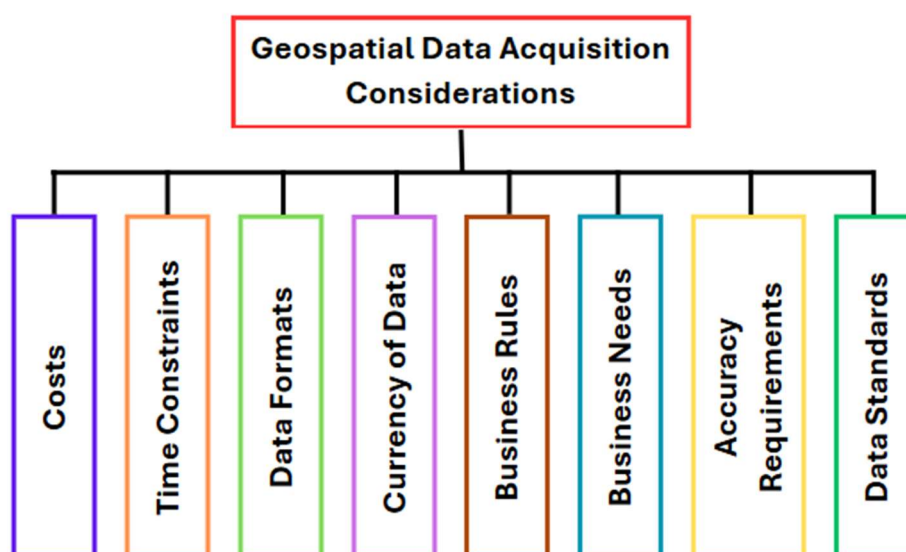
# 1 Data Sourcing and Management

## 1.1 Challenges with Data Acquisition

This project benefitted from the wide range of geospatial data publicly available online. However, careful consideration was required to select appropriate datasets based on factors, such as data quality, format and costs. Furthermore, consideration was given to issues relating to data licensing and sharing. As the dashboard operates as a decision-support tool for infrastructure planning, using accurate and reliable geospatial data was essential (Selmy et al., 2025). Datasets were sourced from reputable organisations with established data standards, like Ordnance Survey and the Environmental Information Data Centre (EIDC).

Near exclusive reliance on open datasets for the dashboard introduced several challenges during the data sourcing process. While BGS provided datasets on current monitoring station and dam locations, they were unable to provide additional datasets. Consequently, all remaining data had to be independently sourced. Although the UK has many open data resources like Ordnance Survey and UKRI (Jaakkola et al., 2014), some desired datasets were either unavailable, restricted by licensing agreements, or provided in incompatible formats.

Licensing restrictions were carefully considered, as the dashboard is intended for organisational use and benefits from free access to public datasets to avoid future complications. For instance, an enquiry for data access to the Scottish electricity network was submitted to SSEN (Scottish and Southern Electricity Networks) but they failed to respond. The lack of access meant that the dashboard only uses a publicly accessible electricity grid shapefile for England and Wales. In other cases, some datasets simply were not available (e.g., industrial zones), or were incompatible, such as a land cover dataset which was an RGB layer composed of pixel values rather than distinct features. All selected datasets had to meet criteria described in Figure 1.



**Figure 1:** The key considerations when acquiring geospatial data to ensure it is high-quality, reliable and suitable for the intended use (Selmy et al., 2025).

Despite several data acquisition constraints, the final dashboard includes 22 buffer layers, resulting in a substantial improvement over previous methods used by BGS. While the inclusion of additional seismic noise sources would have been beneficial, the current number of layers strikes a practical balance by providing meaningful functionality while avoiding overwhelming the user with excessive layers. It's important to note that this project was developed independently without institutional data access. If adopted by institutional or commercial organisations for future development, expanded access to datasets would almost certainly improve the dashboard's analytical scope and precision.

## 1.2 Data Sourcing

Geospatial data is generally classified into two types: primary data, which is gathered first hand through fieldwork; and secondary data, which consists of pre-existing data usually published by government agencies, non-government organisations and corporations (St Martin & Pavlovskaya, 2010). This project exclusively utilised secondary geospatial data, sourced from government agencies and academic open data platforms. The selection process for the datasets was guided by a review of seismic literature, consultation with the British Geological Survey (BGS) and overall ease of accessibility of the data. Development of the dashboard was informed and underpinned by a wide range of sources. Table 1 presents the final list of seismic sources considered. The sources highlighted in red indicate sources that were initially considered but ultimately excluded from the final selection, due to factors such as redundancy, lack of compatibility with the dashboard, or lack of availability.

All sources under consideration were grouped into two categories: anthropogenic and environmental seismic noise. This distinction reflects common classifications in seismic research and provides a logical structure for data organisation.

**Table 1:** This table presents a list of seismic noise sources considered for inclusion in the dashboard. The data is organised by seismic noise type and includes details on the data provider, dataset title, data format and access link to download the data. Sources coloured in red were excluded from the final selection.

Seismic Noise Type	Data Provider	Dataset Title	Data Format	Data Source URL
N/A	British Geological Survey	Current BGS Stations	CSV	Microsoft Excel Document Provided by BGS
Human	Ordnance Survey	Open Roads	Shapefile	<a href="https://osdatahub.os.uk/downloads/open/OpenRoads">https://osdatahub.os.uk/downloads/open/OpenRoads</a>
Human	Open Street Map	UK Railways	Shapefile/GeoJSON	<a href="https://data.humdata.org/dataset/hotom_gbr_railways">https://data.humdata.org/dataset/hotom_gbr_railways</a>
Human	Open Street Map	UK Airports	Shapefile	<a href="https://data.humdata.org/dataset/hotom_gbr_airports">https://data.humdata.org/dataset/hotom_gbr_airports</a>
Human	Environmental Information Data Centre	UK Gridded Population at 1km resolution for 2021 based on Census 2021/2022 and Land Cover Map 2021	Raster File (.tif)	<a href="https://catalogue.eh.ac.uk/documents/7beefde9-c520-4ddf-897a-0167e8918595">https://catalogue.eh.ac.uk/documents/7beefde9-c520-4ddf-897a-0167e8918595</a>

Human	Ordnance Survey	<b>Built Up Areas</b> *Excluded to avoid redundancy as its influence is already accounted for by the population density layer.	CSV / GeoPackage	<a href="https://osdatahub.os.uk/downloads/open/BuiltUpAreas">https://osdatahub.os.uk/downloads/open/BuiltUpAreas</a>
Human	Renewable Energy Planning Database (REPD)	<b>UK Renewable Electricity Projects (Onshore Wind Turbines)</b>	CSV	<a href="https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract">https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract</a>
Human and Environmental	Environmental Information Data Centre	<b>Land Cover Map 2023 (10m classified pixels, GB)</b> *Excluded due to its format (RGB pixel values) which could not be converted into vector features.	GeoTiff	<a href="https://catalogue.ceh.ac.uk/documents/7727ce7d-531e-4d77-b756-5cc59ff016bd">https://catalogue.ceh.ac.uk/documents/7727ce7d-531e-4d77-b756-5cc59ff016bd</a>
Human		<b>Industrial Zones</b> *Excluded due to lack of publicly available data.		
Human		<b>Power Stations</b> *Excluded due to lack of publicly available data.		
Human	Open Street Map	<b>UK Sea Ports</b>	Shapefile	<a href="https://data.humdata.org/dataset/hot-sm_gbr_sea_ports">https://data.humdata.org/dataset/hot-sm_gbr_sea_ports</a>
Human	British Dam Register	<b>British Dam Register</b>	CSV	Microsoft Excel Document Provided by BGS
Human	National Grid	<b>Transmission Network (Substation Site, Over Head Line, Cables, Towers)</b>	Shapefile	<a href="https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps">https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps</a>
Environmental	Ordnance Survey	<b>Open Rivers</b>	Shapefile	<a href="https://osdatahub.os.uk/downloads/open/OpenRivers">https://osdatahub.os.uk/downloads/open/OpenRivers</a>
Environmental	Environmental Information Data Centre	<b>UK Water Bodies</b>	Shapefile	<a href="https://catalogue.ceh.ac.uk/documents/b6b92ce3-dcd7-4f0b-8e43-e937ddf1d4eb">https://catalogue.ceh.ac.uk/documents/b6b92ce3-dcd7-4f0b-8e43-e937ddf1d4eb</a>

Environmental	Ordnance Survey	OS Terrain 50 *Excluded due to incompatibility with the dashboard's basemap configuration.	Shapefile / GeoPackage / Vector Tiles	<a href="https://osdatahub.os.uk/downloads/open/Terrain50?_gl=1*1curh3h*_gcl_au*NzcyNjk3MDcwLjE3NDY0NjI1ODA.*_ga*MTUwNzQzNzc4My4xNzQ2NDYyNTQ3*_ga_59ZBN7DVBG*cze3NDY0NjQ4NDQkbzlkZzEkdDE3NDY0NjQ4NjYkajM4JGwwJGgw*_ga_E5T3PCFCG7*cze3NDY0NjQ4NDQkbzlkZzEkdDE3NDY0NjQ4NjYkajAkBDaKaDA">https://osdatahub.os.uk/downloads/open/Terrain50?_gl=1*1curh3h*_gcl_au*NzcyNjk3MDcwLjE3NDY0NjI1ODA.*_ga*MTUwNzQzNzc4My4xNzQ2NDYyNTQ3*_ga_59ZBN7DVBG*cze3NDY0NjQ4NDQkbzlkZzEkdDE3NDY0NjQ4NjYkajM4JGwwJGgw*_ga_E5T3PCFCG7*cze3NDY0NjQ4NDQkbzlkZzEkdDE3NDY0NjQ4NjYkajAkBDaKaDA</a> .
Environmental		Wind Levels *Excluded due to lack of publicly available data.		
Environmental		Solar Radiation *Excluded due to lack of publicly available data.		
Environmental	Ordnance Survey	BGS Geology 625K	Shapefile	<a href="https://osdatahub.os.uk/downloads/open/BGS_Geology_625k">https://osdatahub.os.uk/downloads/open/BGS_Geology_625k</a>
Environmental	Database of Global Administrative Areas (GADM)	UK Administrative Areas (Coastline)	Shapefile	<a href="https://gadm.org/download_country.html">https://gadm.org/download_country.html</a>

### **1.3 Rationale for Source Selection**

Many of the sources were chosen based on recommendations and guidance provided from Bormann and Wielandt's *Seismic Signals and Noise* (2013), which serves as a foundational reference for understanding the influence of seismic noise from various features. Source selection is further supported by seismic studies from broader literature. A concise overview of the final sources and their associated seismic noise is provided below.

#### **Roads**

Roads are a major contributor to anthropogenic seismic noise, particularly along high-speed routes like motorways. Ground vibrations vary by vehicle type and speed, with heavy-duty vehicles generating the highest level of noise. Additionally, the seismic noise generated by traffic can span multiple kilometres away, with Dean and Hasani (2020) finding that heavily trafficked roads with more than 100,000 vehicles per 24 hours create a seismic noise corridor up to 4 kilometres wide.

#### **Railways**

Railways produce continuous ground vibrations generated by train movement, wheel and rail vibrations, and track maintenance. The vibrations create high amplitude waves that, combined with soft soil conditions, propagate over significant distances away from the track (Thompson, 2008).

#### **Airports**

Airports generate significant levels of seismic noise due to aircraft activity, ground transport, vehicle operations, transportation links and passenger movement (Ignaccolo, 2000). Alongside mechanical, electrical, traffic and wind seismic noise, aircrafts themselves often produce bursts of high amplitude noise up to 200 Hz frequency (Dean, 2018).

#### **Population**

Urban areas are a complex source of seismic noise, with vibrations resulting from a multitude of factors including industrial activity, vehicles and human-induced vibrations. Densely populated areas hinder the detection of micro-earthquakes due to the numerous levels of seismic noise (Groos & Ritter, 2010).

#### **Onshore Wind Turbines**

Seismic vibrations are propagated into the subsurface via the foundations of wind turbines. High wind speeds result in increased amplitudes and transference of vibration from the wind tower into the ground. Neuffer and Kremers (2017) found that wind turbines established in proximity to several monitoring stations in Germany had caused the stations' seismic recordings to deteriorate in quality, particularly the automatic detection of small seismic events.

## **Sea Ports**

Sea ports function as industrial and logistical hubs, generating substantial seismic noise through ship manoeuvring, mooring, cargo handling, mechanical activity and construction. Fredianelli et al. (2022) identified ports as serious contributors to noise pollution.

## **Dams**

Dams, especially larger dams (over 20 metres in height), cause seismic noise from mechanical operations (e.g., gate operations, turbines), hydraulic systems and maintenance activity. In addition, extraneous seismic noise is also generated from vehicles that travel across or near the dam, as well as associated human activity (Diaz et al., 2024).

## **Electricity Grid**

Although electrical transmission networks do not generate as high levels of seismic noise as other anthropogenic sources, electrical substations and high voltage lines emit low-frequency electromagnetic noise which can be detected by sensitive seismic equipment (Piana & Roozen, 2020). As a precautionary measure, it is still recommended to position monitoring stations at a safe distance from this source.

## **Rivers**

Flowing water produces seismic noise through erosion, turbulent flow and flooding. Ambient seismic noise from rivers varies spatially and temporally, with frequencies exceeding 1 Hz. This can be amplified by the interaction of flowing water with sediment and bedrock, in addition to periods of heavy rainfall (Burtin et al., 2008).

## **Lakes**

Lakes generate seismic activity through wave action, moving ice and wind-driven microseisms (Besedina et al., 2024). Mereu et al. (2002) suspects that seismicity in lakes may also result from subsurface water flow through fissures beneath the lake.

## **Geology**

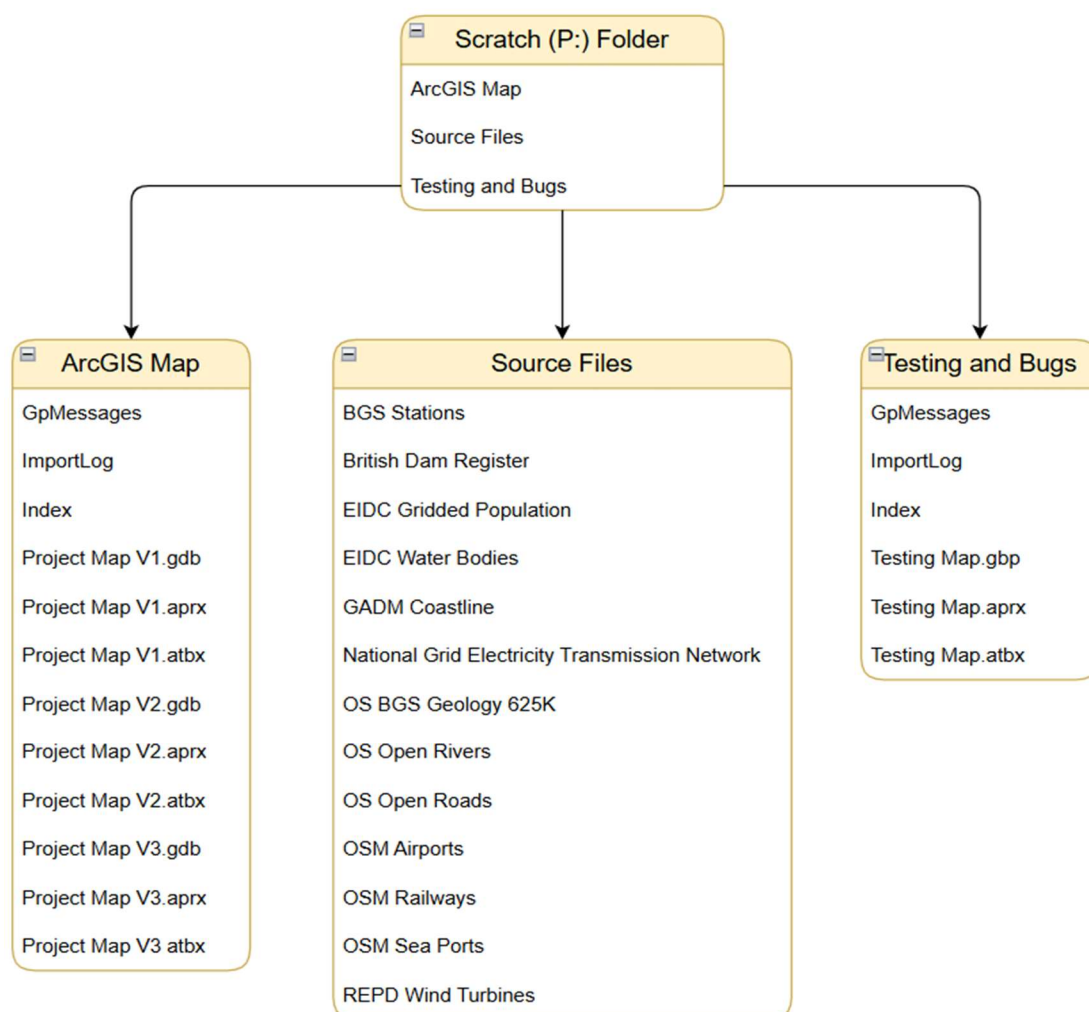
Rock type strongly affects the transmission of seismic vibrations, and how monitoring stations pick up those vibrations. Harder bedrock allows for more accurate vibration transmissions while softer rocks can amplify ambient noise and distort vibrations. A study of seismic background noise levels (Anthony et al., 2022) demonstrated that the quietest monitoring stations were sited on harder rocks found in deserts and mountain ranges, whereas the noisiest stations were sited in water-saturated or soft sediment environments.

## **Coastline**

A dominant source of environmental seismic noise is ocean activity. Ocean wave interactions generate pressure variations on the sea floor which radiate as seismic energy. Many microseisms originate when ocean waves reach shallower coastal waters and interact with the sloping seafloor (Stutzmann et al., 2012). As such, the coastline represents an important source of seismic noise, and needs to be accounted for in decisions related to EMS placement.

## 1.4 File Organisation

Project files were organised within a dedicated 50 GB scratch folder, which provided more storage space than the standard M: drive. This additional space was necessary to accommodate the large spatial datasets and ArcGIS Pro files created during the project. As scratch storage is temporary and unsuitable for long-term storage. After completion of the project, all files were reorganised, compressed and transferred to the permanent M: drive for secure archiving and future accessibility. The files were structured to streamline data processing and maintain organisation during development and testing. Three main subfolders were created: one for ArcGIS Pro map files, one for raw and processed source data, and one for testing outputs and identifying bugs (Figure 2).



**Figure 2:** A graphical representation of the structured directory system. Within the ArcGIS Map folder, multiple Project Maps were created to manage data processing workflows and avoid overloading a single file. The Source Files folder contained the raw downloaded datasets, each one stored in a subfolder corresponding to the data provider. A

Testing and Bugs folder contained a separate map file used for testing various tools and visualisations before integrating changes into the main project files. Files ending in “.aprx” are project files containing maps, “.atbx” are toolbox files containing tools and scripts, and “.gdb” are geodatabases used to store spatial and attribute data.

ArcGIS Pro also creates additional files such as Index and ImportLog to support background operations.

## 1.5 Data Subdivisions

After collating the main datasets into the Source Files folder, certain datasets were further subdivided according to feature type.

- **Dams:**

The original British Dam Register Excel file contained over 3000 dams across the UK and surrounding territories. A new “clean” file was created of dams located on the UK mainland and equal to/over 20 metres in height, aligning with BGS’s preferences. Coordinate fields were added and converted into a format compatible with ArcGIS.

- **Onshore Wind Turbines:**

REPD’s file contained all UK renewable electricity projects. The dataset was filtered to include only operating onshore wind turbines, removing decommissioned turbines or installations in the planning stage.

- **Roads:**

Roads were classified and separated into four categories: A Roads, B Roads, Motorways and Unclassified Roads. This separation allows users to filter seismic sources more accurately, as different road types produce varying magnitudes of vibrations.

- **Lakes:**

Lakes were divided into Small Lakes (<50 hectares) and Large Lakes ( $\geq$  50 hectares) following lake size classification criteria from the UKTAG Guidance on Typology for Lakes in the UK (2003).

- **Geology:**

The BGS Geology 625K shapefile contains bedrock geology, dykes and linear (faults) features spanning the UK. A new layer was created, containing bedrock geology only. BGS supplied a classification list identifying rock types as suitable, unsuitable or uncategorised for EMS placement. Based on the list, the bedrock geology layer was filtered and split into three layers.

For efficient processing in ArcGIS Pro, the subdivided data was then organised into three main feature type categories (Table 2).

**Table 2:** Layers grouped by vector data type (points, lines, polygons). Non-vector datasets (e.g., the gridded population raster dataset) were excluded from this categorisation. Grouping layers by geometry type allowed for more efficient batch processing within ArcGIS Pro.

Points	Lines	Polygons
Current BGS Stations Dams over 20m Onshore Wind Turbines	A Roads B Roads Motorways Unclassified Roads Railways Minor Inland Rivers Major Inland Rivers Tidal Rivers Canals National Grid Overhead Lines	Airports Sea Ports Small Lakes Large Lakes Suitable Geology Unsuitable Geology Uncategorised Geology

## 2 Dashboard Build Process

### 2.1 Data Importing in ArcGIS Pro

ArcGIS Pro was used to process the datasets and transform them into appropriately formatted layers suitable for publishing as hosted web layers on ArcGIS Online. A new ArcGIS Pro project was created, and the Source Files folder containing the datasets was connected to a newly created geodatabase. In instances where the dataset contained multiple layers, only relevant layers were imported.

The data consisted of three main types: vector features, rasters and CSV files. The CSV files were converted from coordinate-based tables into point feature layers using the XY Table to Point function. Several of the datasets came originally projected in WGS84, a global standard coordinate system used in many mapping applications. WGS84 is defined by latitude and longitude coordinates generated from GPS tracking stations located across the globe (Stanaway, 2007). For this project, all datasets were re-projected to the British National Grid (BNG) coordinate system, which uses Eastings and Northings (metres) to define locations on a projected grid specific to Great Britain. This ensured consistency across all layers and enabled spatial analysis using metric units.

Two types of layers were developed for the dashboard: buffer layers, which visualised distance from sources of seismic noise, and feature-only layers, which allow users to view features without the visual interference of buffer zones.

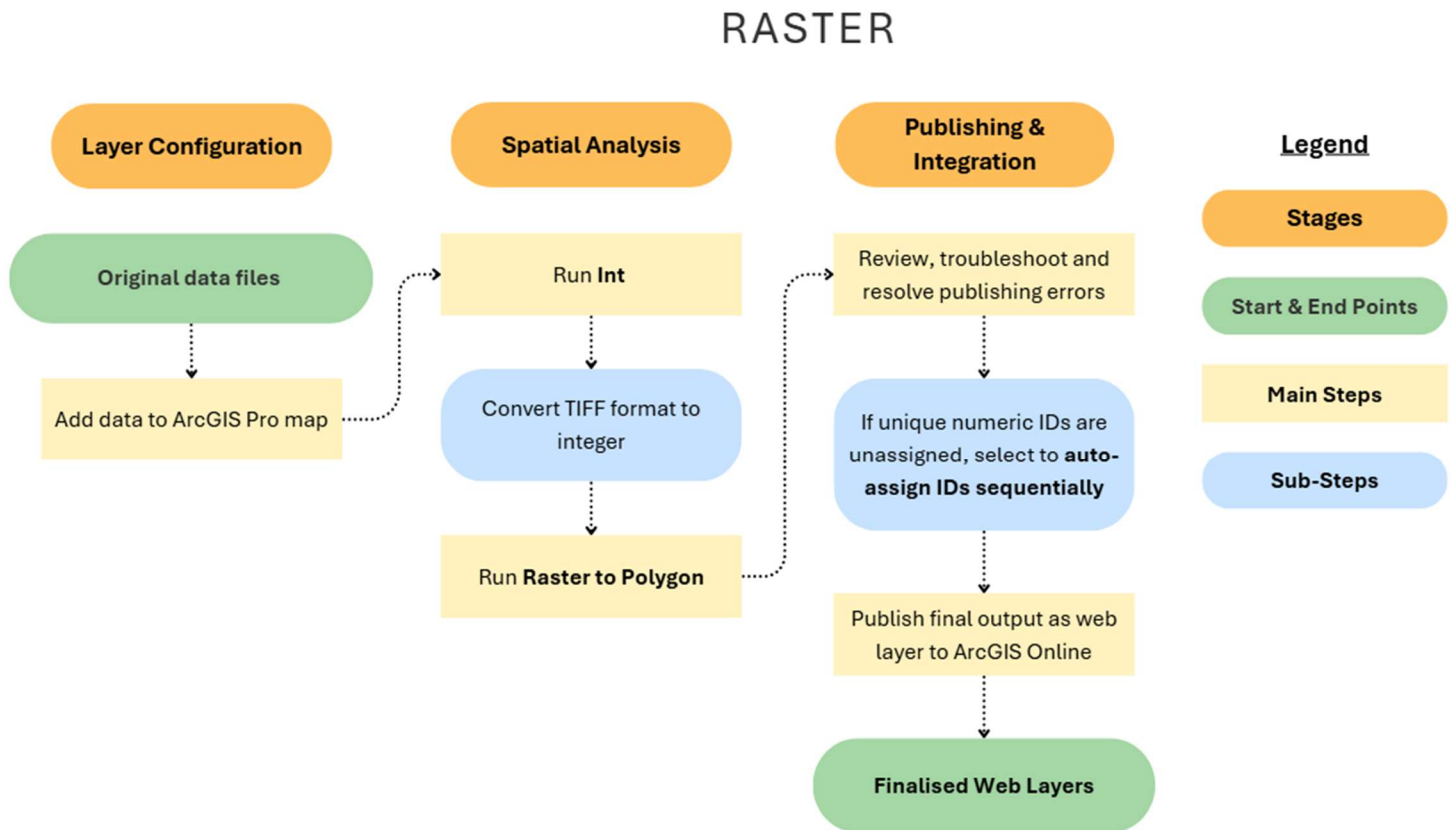
## 2.2 Creating Buffer Suitability Layers

To create the buffer layers, separate processing workflows were required based on the feature type. Spatial analysis was carried out using the Spatial Analyst and Geoprocessing tools within ArcGIS Pro. The tools used for analysis, along with their functions, are detailed Table 3 below.

**Table 3:** An overview of all the tools and their functions used in ArcGIS Pro to process raw datasets and shapefiles (Esri, n.d.).

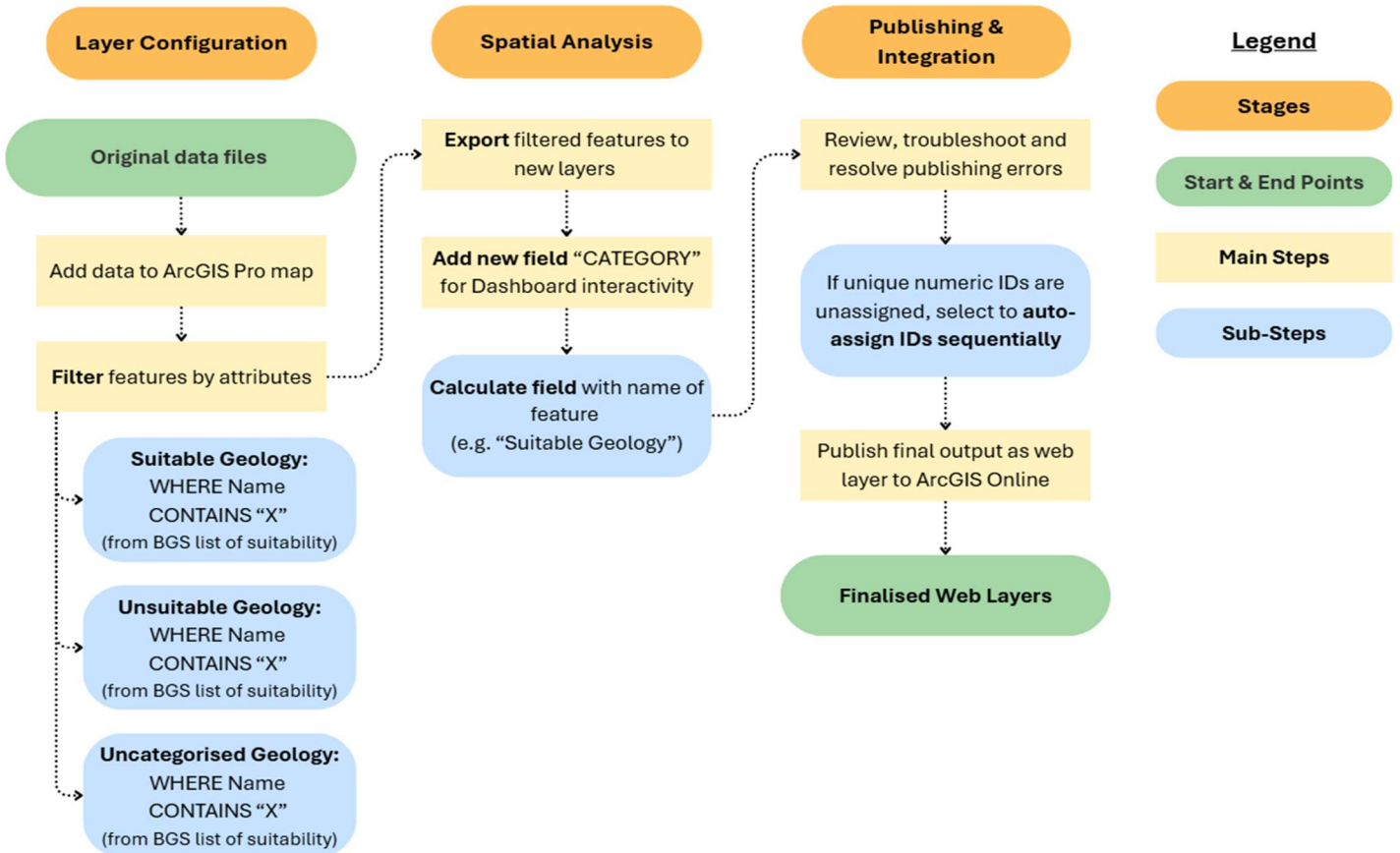
ArcGIS Pro Tools	Function
Reproject	Reprojects spatial data from one coordinate system to another.
XY Table to Point	Converts data from tables into point features based on X and Y coordinates.
Filter by Attribute	Filters features by attributes using queries. A new layer containing only the records that meet the condition of the query can be exported.
Polygon to Line	Converts polygon boundaries into a line feature class.
Euclidean Distance	Generates a raster showing the straight-line distance from each cell to the nearest source feature.
Reclassify	Classifies continuous raster values into defined categories. Used to split Euclidean Distance rasters into kilometre increments.
Raster to Polygon	Converts raster cells into polygon features, allowing the raster data to be visualised like vector data.
Spatial Join	Joins attribute data from one feature to another based on spatial relationship.
Int	Converts floating-point values to integers by truncating decimals.
Merge	Combines multiple layers or datasets of the same type into a single output layer.
Add Field/ Calculate Field	Add new field/information to an attribute table to support classification or visualisation.

Figures 3 to 7 illustrate the process of creating buffer layers for each corresponding feature type.



**Figure 3:** The workflow for processing raster layers (UK Population Density).

# GEOLOGY POLYGONS



**Figure 4:** The workflow for processing Geology layers (Suitable, Unsuitable, Uncategorised).

# POLYGONS

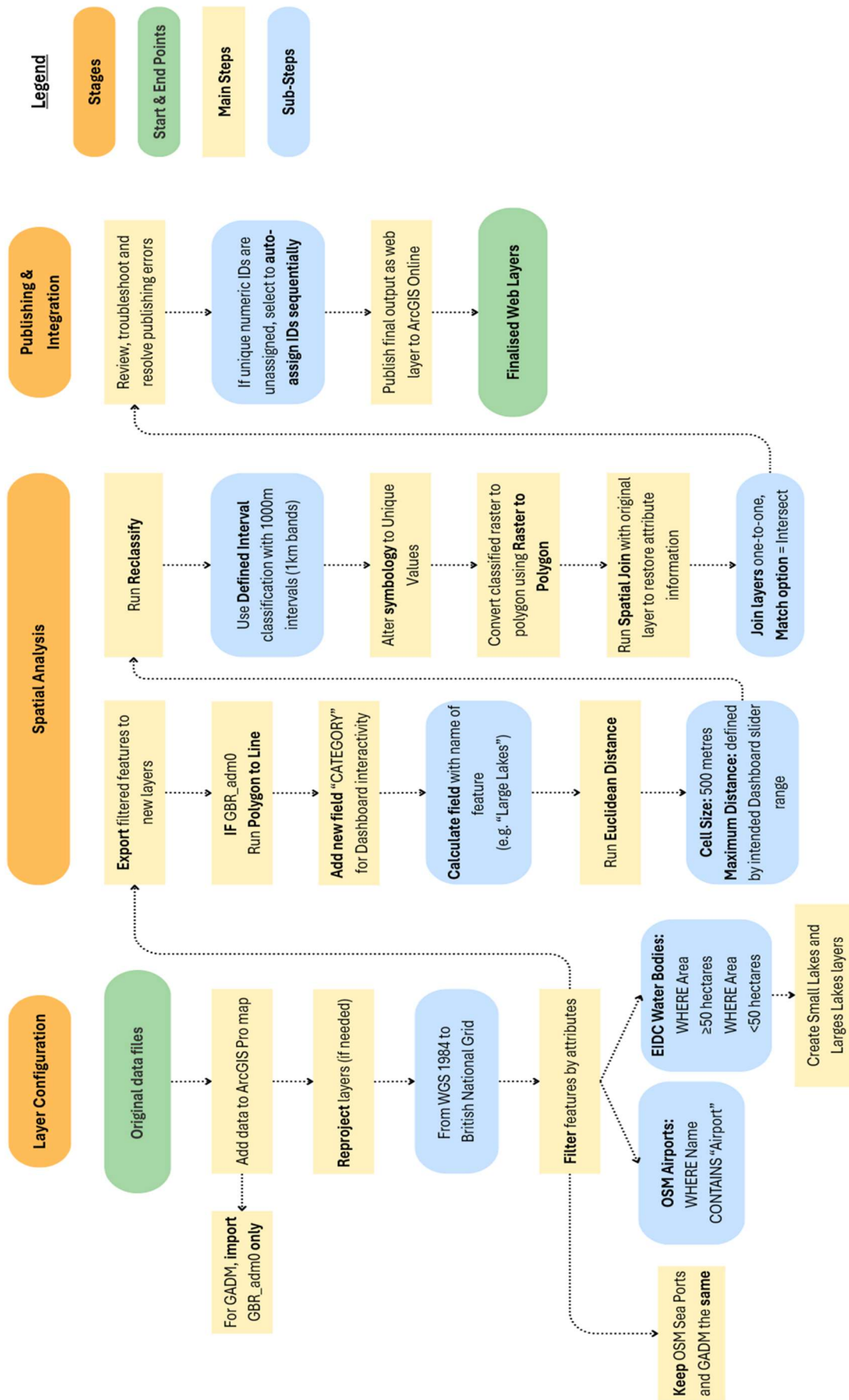


Figure 5: The workflow for processing polygon layers (Airports, Sea Ports, Lakes).

# POINTS

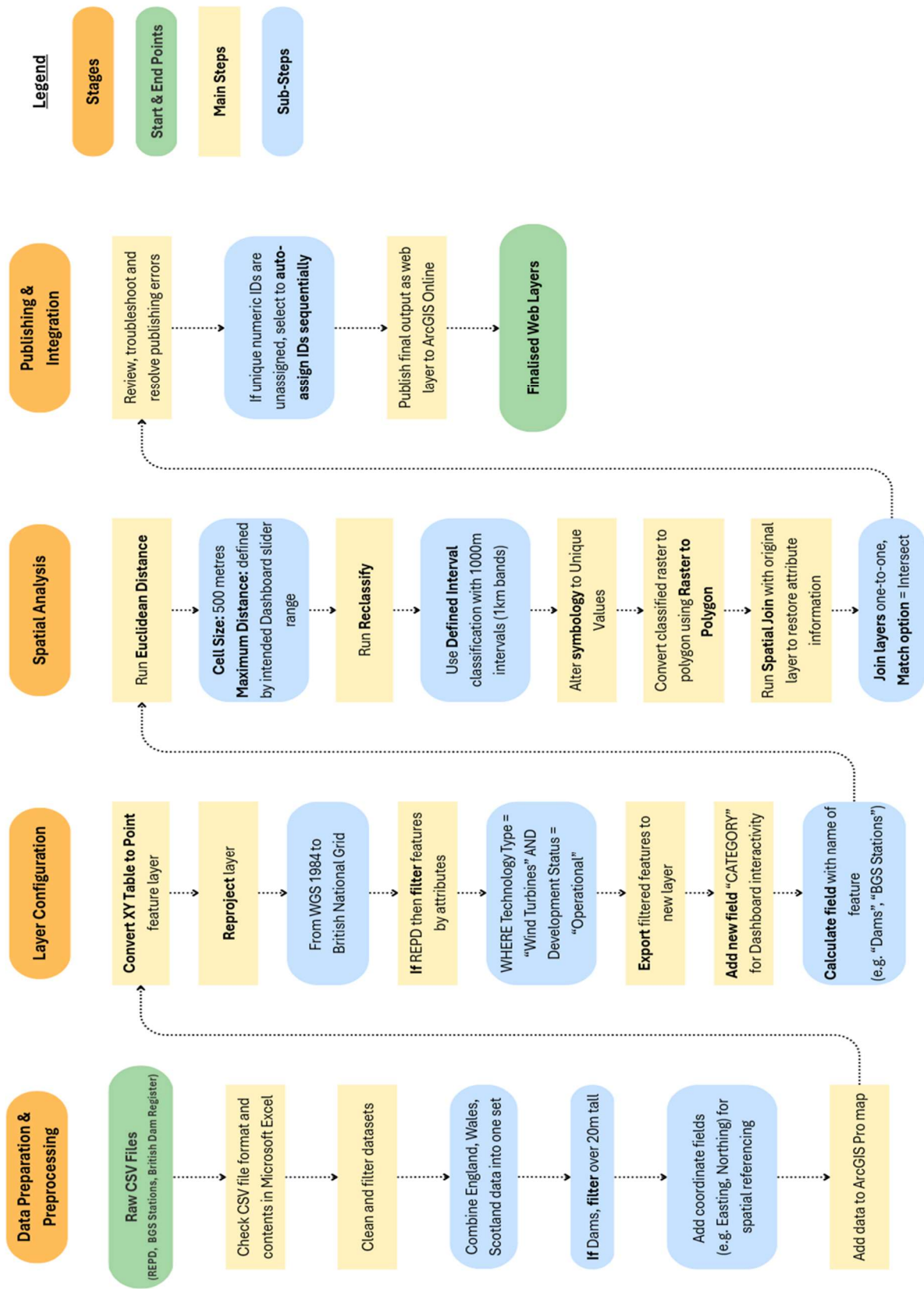


Figure 6: The workflow for processing point layers (BGS Stations, Wind Turbines, Dams).

# LINES

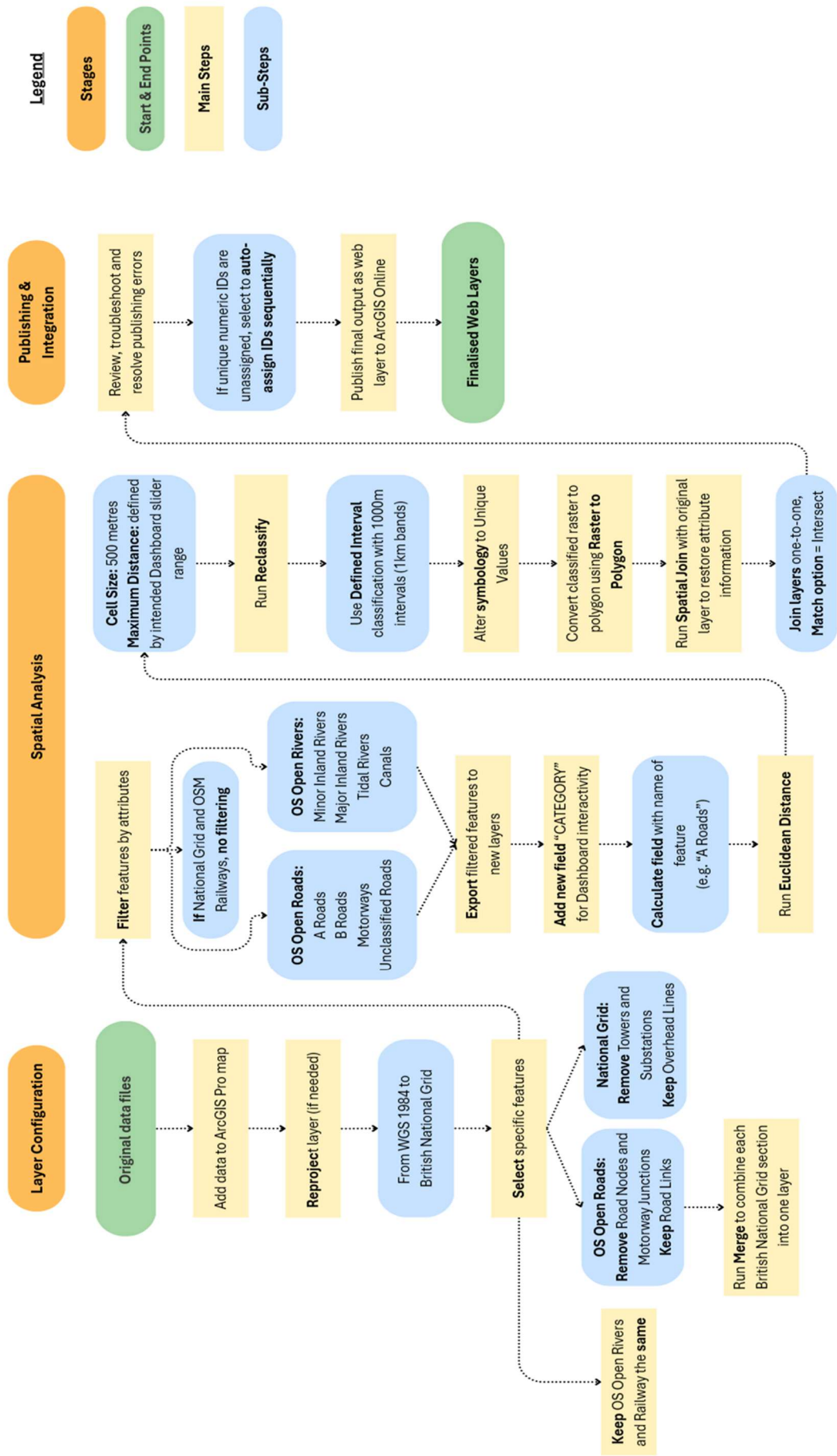


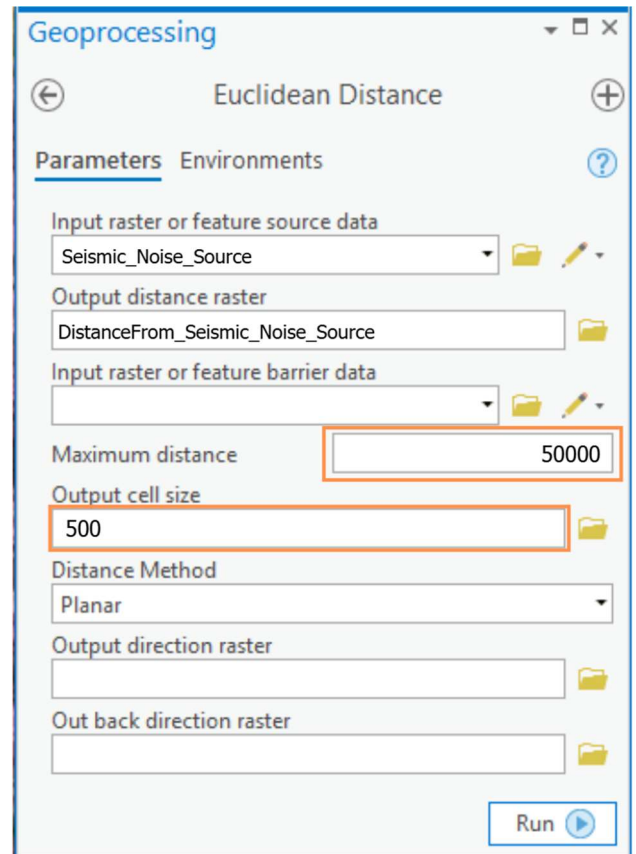
Figure 7: The workflow for processing line layers (National Grid, Roads, Rivers).

To create the feature-only layers, duplicates of the buffer layers were created after reprojection and filtering by attribute, but prior to any further spatial analysis. These layers were then exported separately to ArcGIS Online.

One of the main tools used to create the buffer layers was Euclidean Distance, which produced a raster representing distance away from each seismic noise source (Figure 8). Two key parameters - Maximum distance and Output cell size - significantly impacted the resulting layer. Maximum distance defines how far the raster extends from the source, and Output cell size sets the spatial resolution of the raster.

Each seismic noise source layer was assigned a predetermined maximum slider distance, which was used as the input value for the Maximum distance parameter. As all layers were reprojected to the BNG coordinate system, this value was specified in metres.

Determining the appropriate maximum distance requires balancing technical performance with spatial extent. Capping the maximum distance was necessary for several reasons. Limiting the extent of the distance raster reduces processing time and memory usage, which is crucial given the national scale of the dashboard. Smaller output rasters also result in smaller file size, which are faster and simpler to publish to ArcGIS Online. Furthermore, it is unlikely that areas extending hundreds of kilometres away from each source would be significantly affected by seismic noise. Restricting the extent keeps slider ranges at a logical scale reflecting realistic zones of influence.

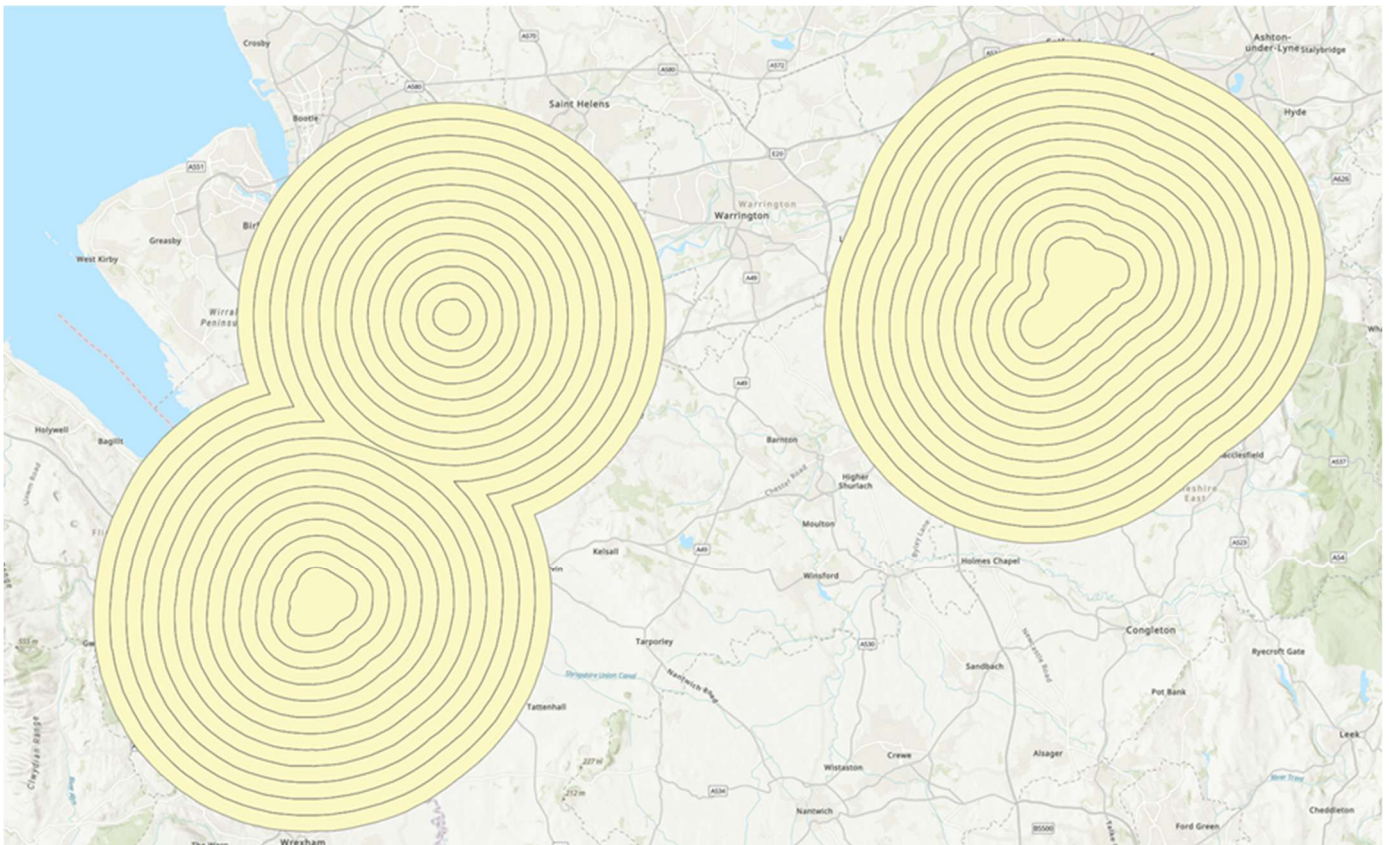


**Figure 8:** the Euclidean Distance tool interface, with the two key inputs highlighted in orange.

The influence of cell size on dashboard performance and visualisation was a major focus during the testing stage. Cell size defines the resolution of the raster, with smaller values (higher resolution) resulting in more accurate and detailed outputs. However, smaller cell sizes also result in significantly more complex geometries and larger file sizes. This leads to longer loading times, increased client-side processing demands and reduced performance, appearing as lagging or crashing, particularly when viewing at a national scale or toggling multiple buffer layers simultaneously. Conversely, while larger cell sizes improve performance and processing times, lower resolutions can oversimplify buffer zones and reduce spatial accuracy, which can undermine the dashboard's effectiveness.

A balance is required between visual performance and spatial accuracy to deliver usability without compromising the dashboard’s robustness. Since the dashboard functions as a visual tool which relies on dynamic updating and frequent user interaction through widgets, maintaining reasonable loading times was a priority during development.

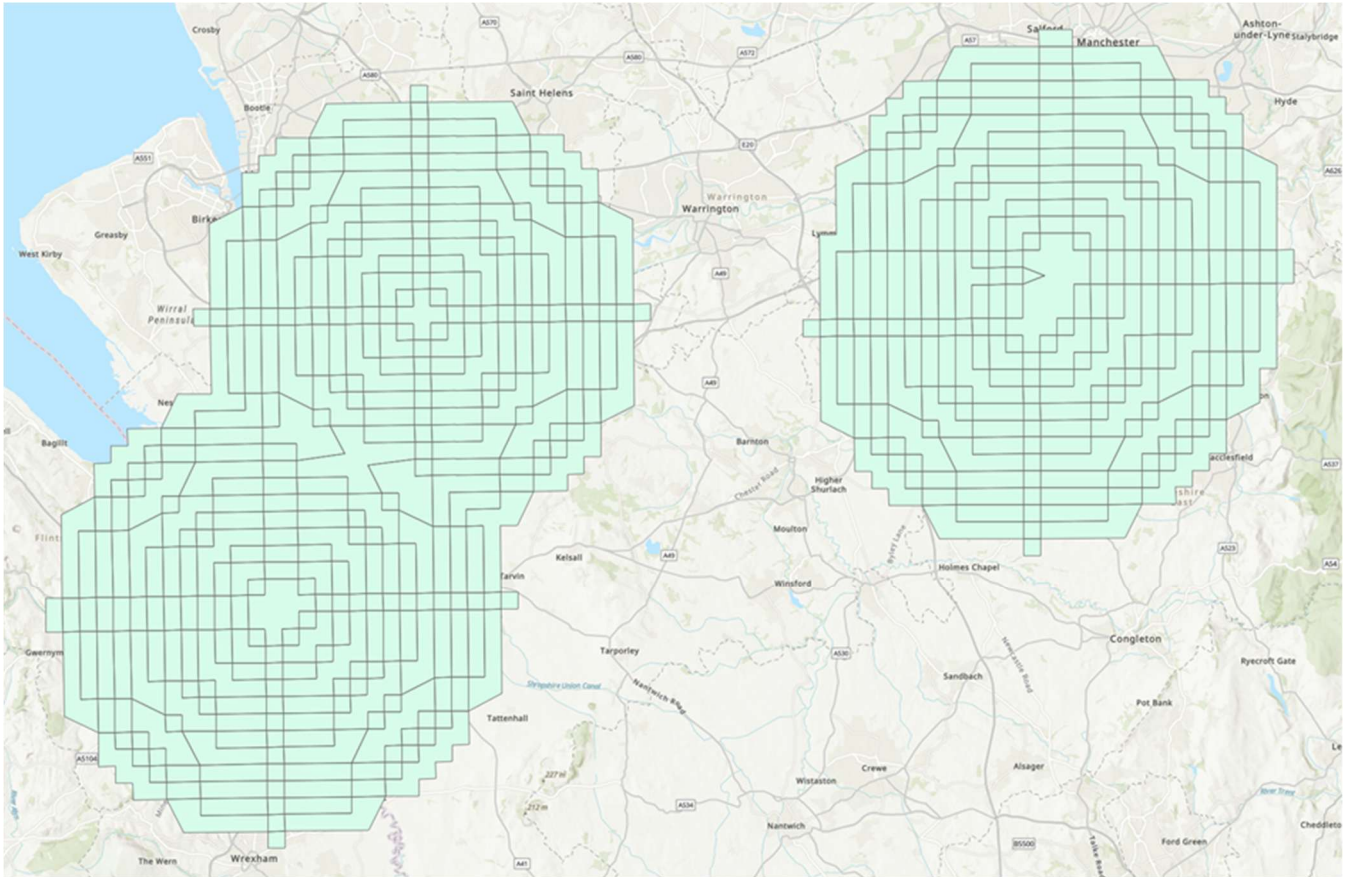
An initial cell size of 25 metres was tested with the Seaports layer, meaning the layer had a resolution of 25 metre pixels (Figure 9). Although this level of detail is unusually high for a national scale map, it was initially chosen for testing to enable BGS to examine the map at a fine spatial resolution and assess site suitability with greater precision.



**Figure 9:** Polygons created using a 25 m cell size input, with 1 km distance bands.

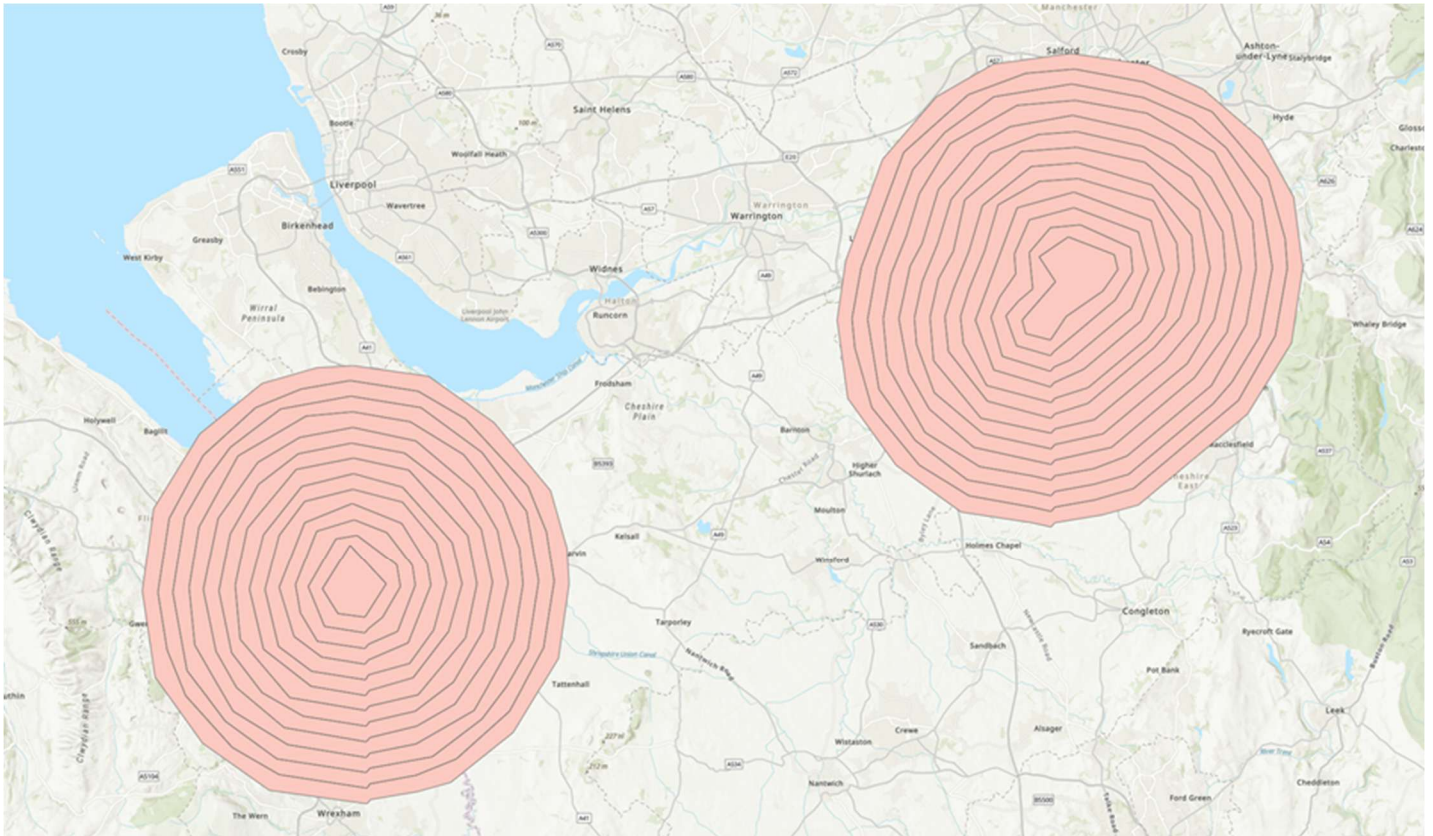
When simply inspecting the layer, the polygons appear smooth and detailed. However, when loading the layers into a test dashboard, significant loading delays occurred, especially when multiple layers were activated simultaneously. The long loading times negatively affected the dashboard’s responsiveness, dynamism and overall interactivity. It was determined that sacrificing performance for very high detail was unnecessary for a national-scale application, with such resolution unlikely to offer meaningful improvements in EMS placement, as 25 metre distances are not significant in the context of seismic noise.

To enhance performance, a significantly larger cell size of 1000 was tested (Figure 10). This delivered greatly improved loading speeds, confirming that the smaller cell size was the most important contributor to performance issues. However, the coarser resolution produced irregular, blocky polygons that hindered interpretation of the 1km distance bands. The crude and angular output also detracted from the dashboard’s visual appeal, underscoring the importance of balancing system performance with cartographic clarity.



**Figure 10:** Polygons created using a 1000 m cell size input, with 1 km distance bands.

To find a balance between visual clarity and dashboard performance, several additional cell sizes were tested. Ultimately, a 500-metre cell size was identified as the best balance between performance and detail (Figure 11). This resolution maintained the faster loading speeds observed with larger cell sizes, while producing polygons that were significantly smoother and more easily interpreted visually. Although the 500-metre output was not as detailed as the 25-metre output and appeared slightly angular, the level of detail was sufficient for the dashboard’s national scale and did not compromise overall functionality.



**Figure 11:** Polygons created using a 500 m cell size input, with 1 km distance bands.

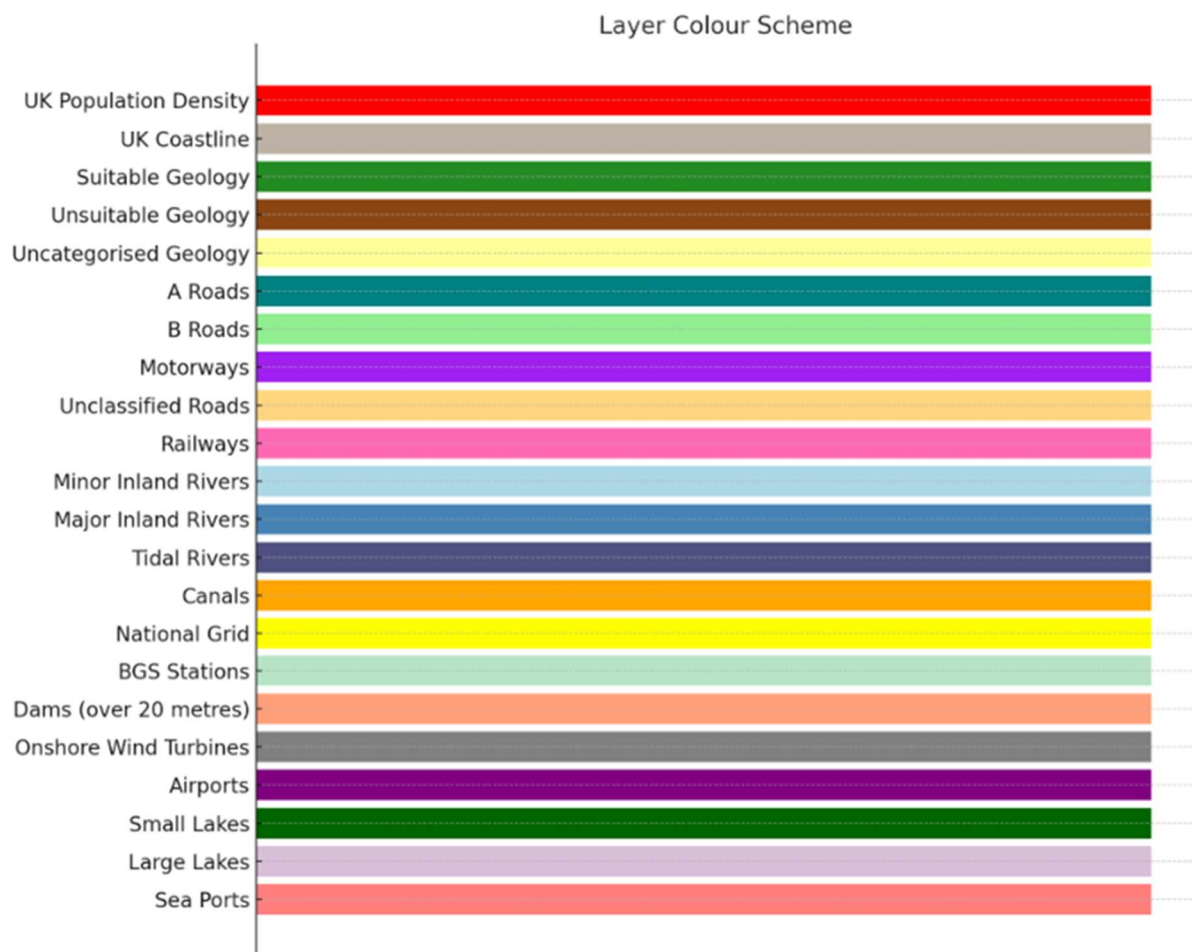
Alongside cell size testing, layers were also evaluated using the Reclassify tool, which converts continuous Euclidean Distance rasters into distinct bands, an essential step for enabling slider functionality in the dashboard. Several classification methods were considered, ultimately settling on Equal Interval classification, which divides the raster into equally spaced bands based on a specified interval. Given the raster's resolution of 500 metres and maximum distance values ranging from 5 km to 50 km (depending on the layer), 1000 metres (1 km) increments were chosen as the most practical option. Using 1km bands ensured consistency across all layers regardless of their extent and provided a clear, intuitive measurement unit for users. 1 km unit step sizes also reduced the total number of slider intervals, making the widgets more user-friendly while still maintaining sufficient precision for EMS site selection.

### 2.3 Publishing, Design and Attribute Pop-Up Windows

After the layer processing stage in ArcGIS Pro, each layer was exported as a hosted web layer to ArcGIS Online. These were stored as individual feature layers within a designated folder. A new blank web map was created to serve as the base map onto which the layers were added. Prior to integration into the dashboard, each layer underwent additional configuration, focusing primarily on symbology design and pop-up attribute tables.

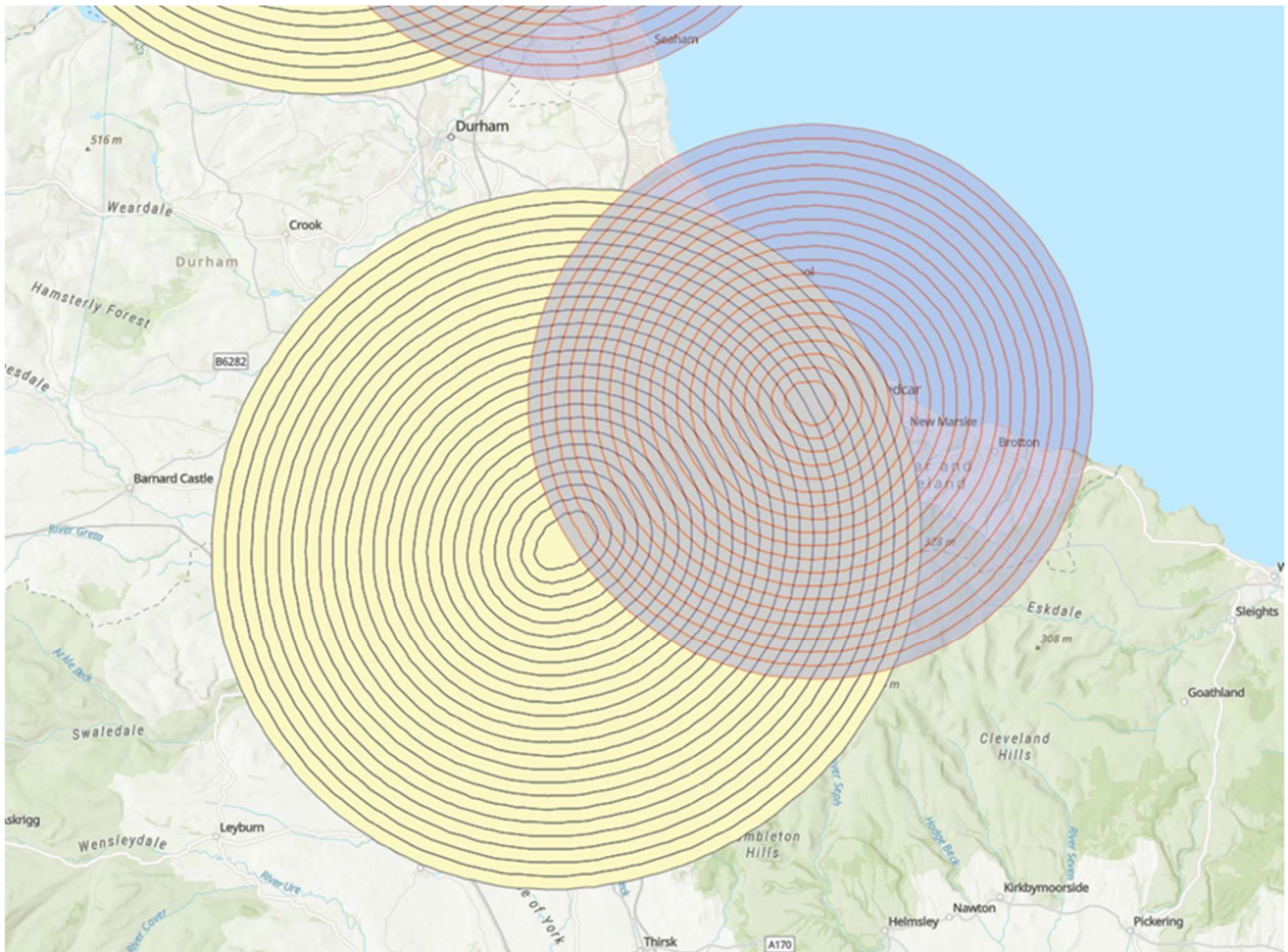
As the map contained 22 buffer layers, clear visual distinction between the layers was essential for effective interpretation. Visual clarity is particularly important as the dashboard’s primary functionality relies on users being able to interpret stacked layers to identify suitable areas. Therefore, considerable attention was given to the design of layer colours, transparency levels and overall presentation.

To maximise contrast and clarity, colours were systematically assigned. Certain layers were assigned colours based on intuitive association (e.g., blue for rivers, yellow for the electricity grid, green for suitable geology), with remaining layers were assigned colours that contrasted effectively with these, ensuring that each layer remained distinguishable even when multiple layers were active. The assigned colours are shown in Figure 12 below.



**Figure 12:** A chart displaying the assigned colours for each buffer layer. Distinct hex codes were used to ensure all colours were unique and provided clear visual contrast between layers.

After assigning colours, transparency levels were tested to optimise visual clarity. Transparency plays a key role in helping users distinguish between overlapping layers while retaining visibility of the underlying basemap for geographic context. Various levels of transparency were tested with different combinations of stacked layers (Figures 13 and 14). A range between 55% and 70% was found to offer the best balance between legibility of individual layers and the ability to interpret multiple overlapping layers simultaneously.



**Figure 13:** Comparison of two polygons with different levels of transparency. The yellow polygon on the left is at 0% transparency, the purple polygon on the right is at 50%

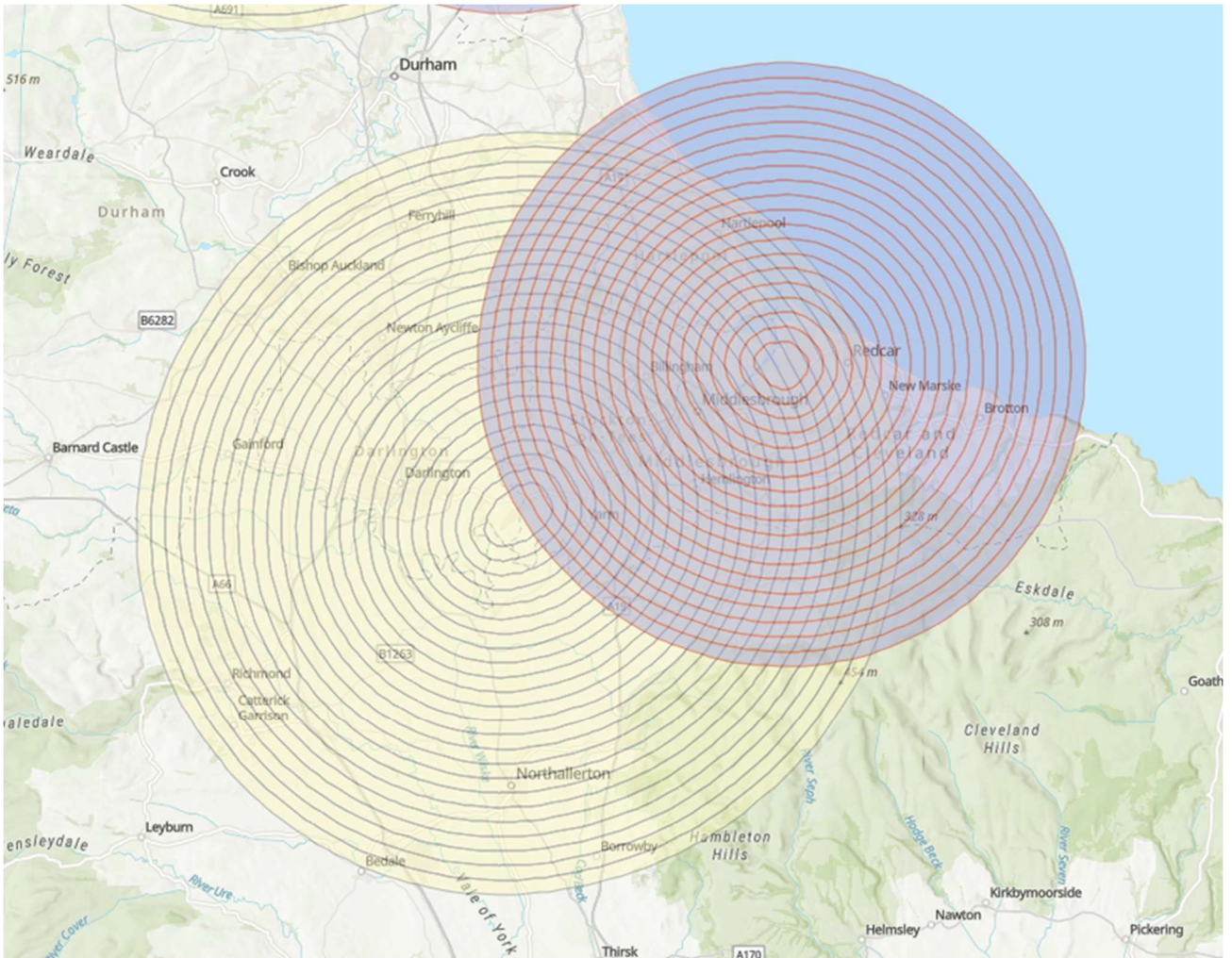
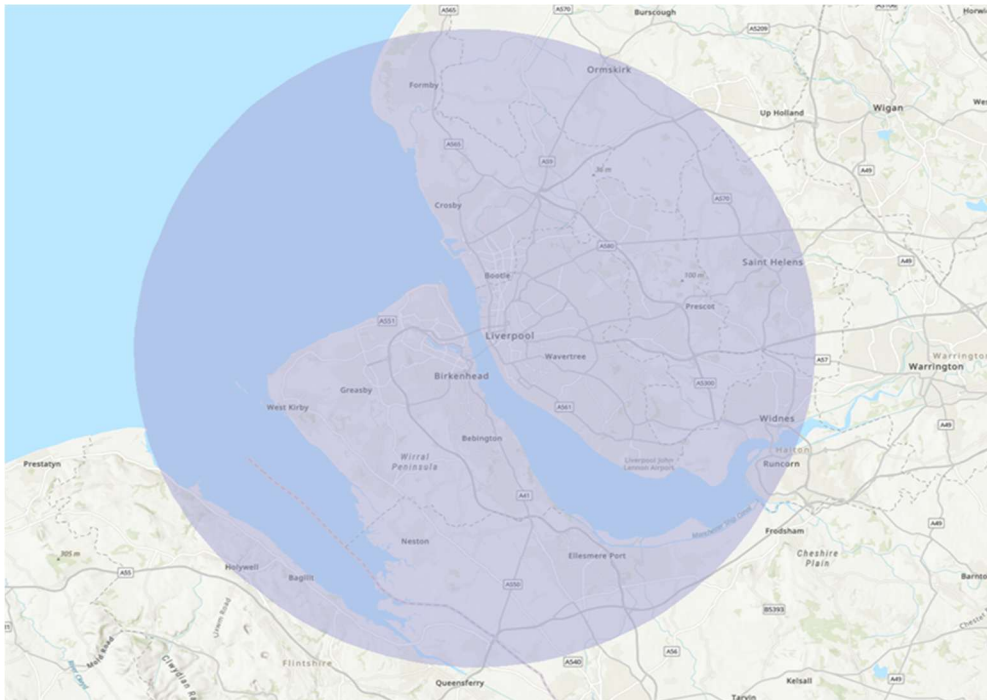
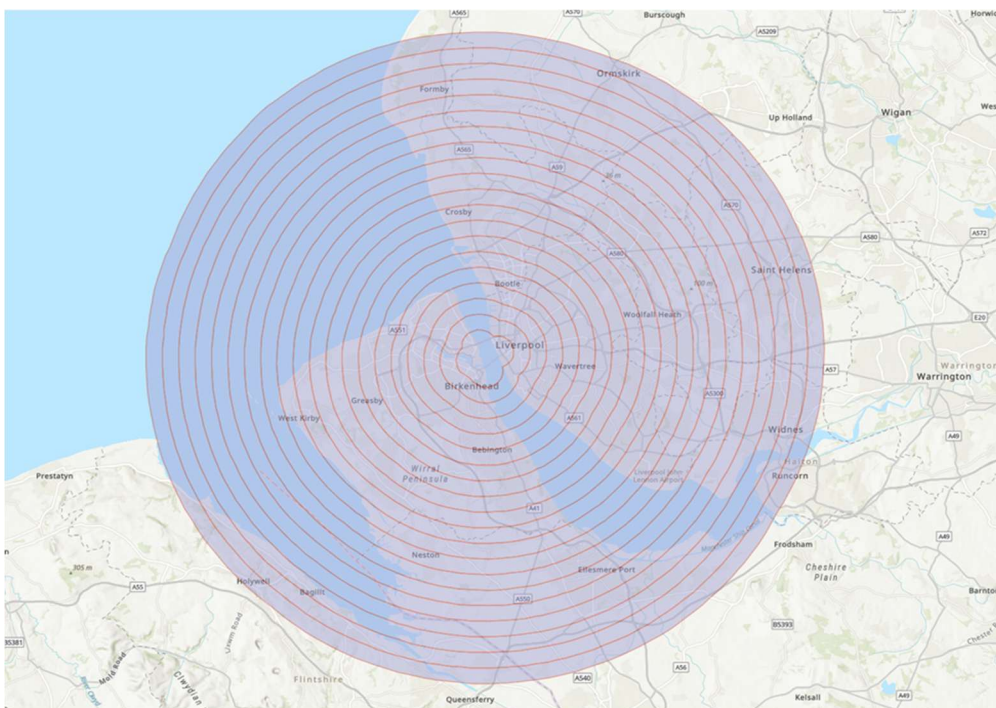


Figure 14: Both the yellow and purple polygons at 50% transparency.

Additionally, since the buffer layers were classified into 1 km bands, the visual representation of these bands was also considered. Options included removing the band outlines entirely (Figure 15), experimenting with different line types and adjusting colour and thickness. While removing the lines produced a cleaner looking “swath” of colour, this option made it difficult to see specific distance intervals. To support spatial interpretation, lines at a 0.5 width were added to delineate each 1 km band (Figure 16).



**Figure 15:** A polygon from the Sea Ports buffer layer displayed without visible 1 km delineating distance bands.



**Figure 16:** A polygon from the Sea Ports buffer layer displayed with visible 1 km delineating distance bands.

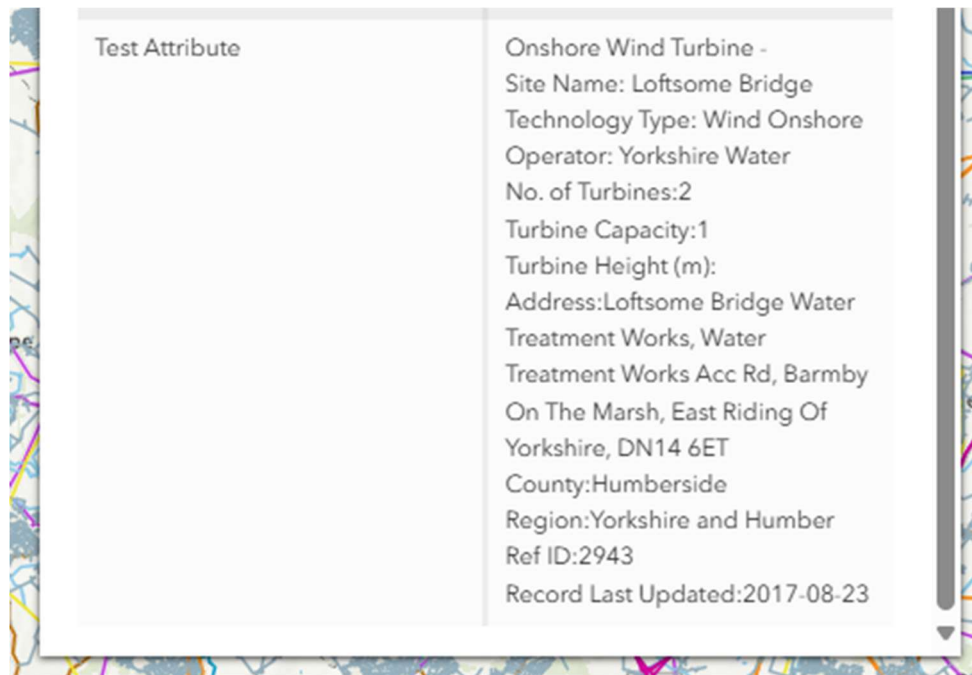
Pop-up attribute windows were configured for each layer to allow users to click on features and view corresponding information. These pop-ups were edited to determine which attributes would be displayed and how they would be presented. Many of the datasets contained extensive metadata and detailed technical fields that were unnecessary for dashboard users, so only relevant attributes were included. The attributes also had to be edited for readability. This involved renaming fields for user accessibility (e.g., changing “RIVER\_NAME\_EN” to “Tidal River Name”), reordering fields and formatting measurement units (like limiting decimal places).

For the buffer layers, each had a separate attribute table, so configuring individualised pop-ups was relatively straightforward. However, as the features-only layers were combined based on vector data type (e.g., lakes, ports and airports combined into one polygon layer), each layer's attributes were merged into one table. The goal was to ensure that when a polygon was selected, only its specific information would be shown, rather than bringing up a list of attributes of all the polygons in the layer. Two approaches were tested to manage this.

The first method was to use Arcade code expressions to query and display only the relevant attributes for the feature clicked (Figure 17). However, despite formatting the output with line breaks, all attribute values were displayed in a single row, resulting in a cluttered pop-up window (Figure 18). This issue arose from the structure of the merged tables, where rows are fixed and cannot be added post-processing.

```
Run
1  var category = $feature.Category;
2
3  if (category == 'BGS Monitoring Stations') {
4      return "BGS Monitoring Station - " +
5          "\nSite Code: " + $feature.SITE_CODE +
6          "\nEasting: " + $feature.GRID_EAST +
7          "\nNorthing: " + $feature.GRID_NORTH;
8  } else if (category == 'Dams (over 20m)') {
9      return "Dam - " +
10         "\nDate Built: " + $feature.Date_Built +
11         "\nReservoir Type: " + $feature.Reservoir_Type +
12         "\nFlood Category: " + $feature.Flood_Category;
13 } else if (category == 'Onshore Wind Turbines') {
14     return "Onshore Wind Turbine - " +
15         "\nSite Name: " + $feature.Site_Name +
16         "\nTechnology Type: " + $feature.Technology_Type +
17         "\nOperator: " + $feature.Operator_or_Applicant_ +
18         "\nNo. of Turbines:" + $feature.No_of_Turbines +
19         "\nTurbine Capacity:" + $feature.Turbine_Capacity +
20         "\nTurbine Height (m): " + $feature.Height_of_Turbines_m_ +
21         "\nAddress:" + $feature.Address +
22         "\nCounty:" + $feature.County +
23         "\nRegion:" + $feature.Region +
24         "\nRef ID:" + $feature.Ref_ID +
25         "\n Record Last Updated:" + $feature.Record_Last_Updated__dd_mm_yyyy;
26 } else {
27     return "Category: " + category;
28 }
```

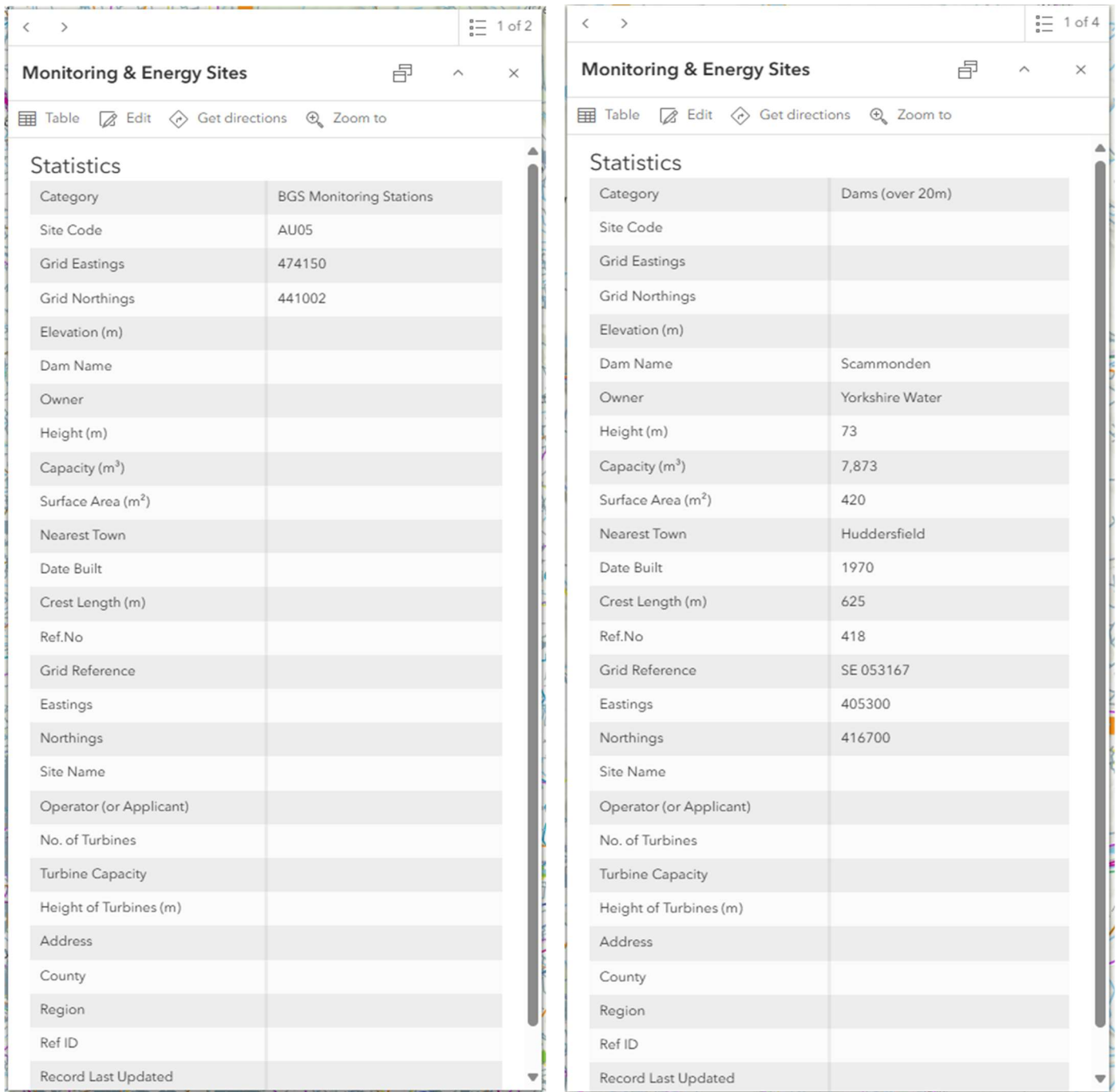
**Figure 17:** Test Arcade expression used to generate custom attribute pop-up windows for each feature type.



**Figure 18:** The resulting pop-up window displaying attributes data for a selected wind turbine.

This layout wasn't ideal, as longer attribute values (such as addresses) did not fit neatly into a single line, making them feel continuous and harder to read. Additionally, because each attribute was stacked closely together with no spacing or visual separation, it was difficult to quickly distinguish where one attribute ended and another began.

As a result, a second method was tested and then adopted. This involved the use of existing attribute columns from the merged features. These columns included all fields from the combined datasets (for example, those related to BGS stations, wind turbines and dams), structured so the top row displays the feature name, followed by only the relevant attribute fields populated with information (Figure 19). Rows not applicable to the selected feature were left blank. This method allows users still to view separate structured feature-specific information without compressing all the information into a single row. Although the blank fields may appear unbalanced, displaying relevant attribute data in clearly separated rows and columns significantly improved readability and comprehension.



**Figure 19:** The resulting pop-up windows using the second method. The left window shows attribute data for a selected BGS monitoring station, with the category “BGS Monitoring Stations” displayed at the top, and relevant details listed below. Rows for unrelated features (e.g., dam name, turbine capacity) are blank. The right window shows a selected dam feature with the relevant attribute data displayed in the corresponding rows.

## 2.4 Dashboard Construction

During the ArcGIS Online basemap configuration stage, a testing version of the dashboard was developed. This version was used to load in layers and evaluate key performance aspects such as layer loading times, slider responsiveness and colour schemes and symbology. The layers could be edited in real time within ArcGIS Online and immediately reviewed on the dashboard. Once testing was completed, a final version of the dashboard was created.

A user-centred approach was implemented when designing the dashboard layout. The map was positioned as the central focal point, with site selection filters placed as a left-hand sidebar and feature controls placed in the top-right corner. This layout aligns with common user reading patterns that follow a left-to-right, top-to-bottom flow (McKay, 2013). Additional tools, like the measurement tool, location search, basemap selector and legend, were added directly to the map interface corners to facilitate easy access to key functions.

When configuring the site selection filters in the sidebar, selector types were matched to the data type of each layer. Distance-based buffer layers were given slider selectors, categorical datasets were given category button selectors and density-based datasets were given range selectors to allow users to define a specific density range.

To connect each selector with its corresponding layer, the selector settings were adjusted by adding the data under “statistic” and selecting the matching layer from ArcGIS Online (Figure 20). For the measurement field, “gridcode” was selected, corresponding to the attribute table column that stored kilometre distance bands. Further slider settings were adjusted in line with BGS requirements. Within the Actions section, the slider was configured to filter the active target layer. The “render only when filtered” option was also selected for the category buttons, ensuring that polygons are only displayed after a user interacts with the widget to prevent the map automatically displaying all the polygons.

## Number selector

The image displays the configuration interface for a 'Number selector' widget. The interface is split into two main sections: 'Selector options' on the left and a preview on the right.

**Selector options:**

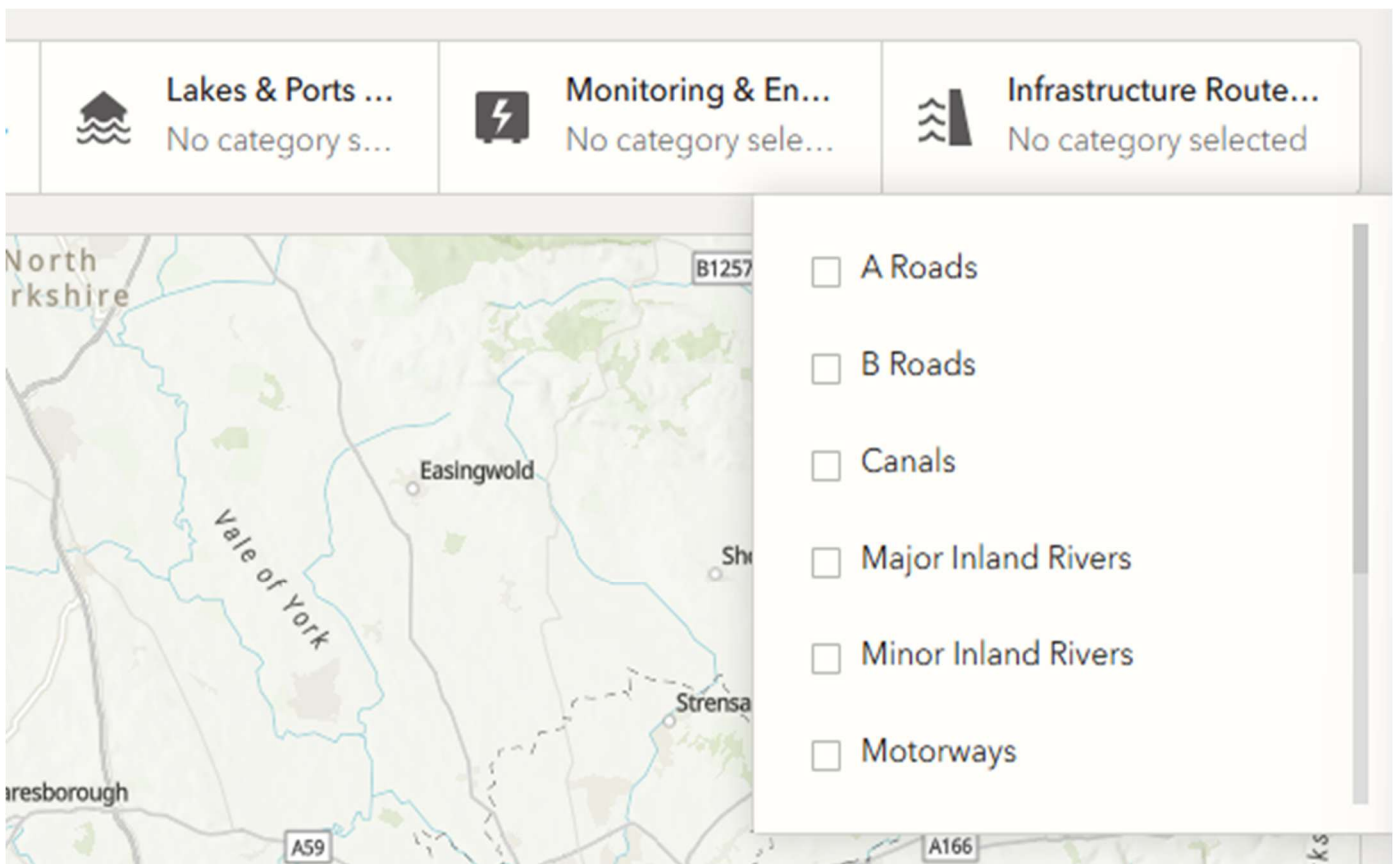
- Label:** B Roads
- Icon:** Add icon
- Presentation mode:** Inline, **Accordion**, Dropdown
- Display type:** Spinner, **Slider**, Combination
- Input type:** **Single**, Range
- Operator:** less than or equal
- Show reset:** Disabled
- Value formatting:**
  - Style:** **Decimal**, Percent
  - Digit grouping:** Enabled
  - Minimum decimal places:** Default
  - Maximum decimal places:** Default
- Value prefix/suffix:** km
- Unit prefix:** Disabled
- Limits from:** Defined values, **Statistic**

**Preview:** Shows the 'B Roads' selector with the label 'less than 1 km' and a slider range from 1 to 10.

**Data table:** Located at the bottom right of the preview area.

**Figure 20:** A portion of the selector configurator options, where selector type, functions, data and additional controls can be configured. These settings were used to connect and customise each layer with a corresponding widget.

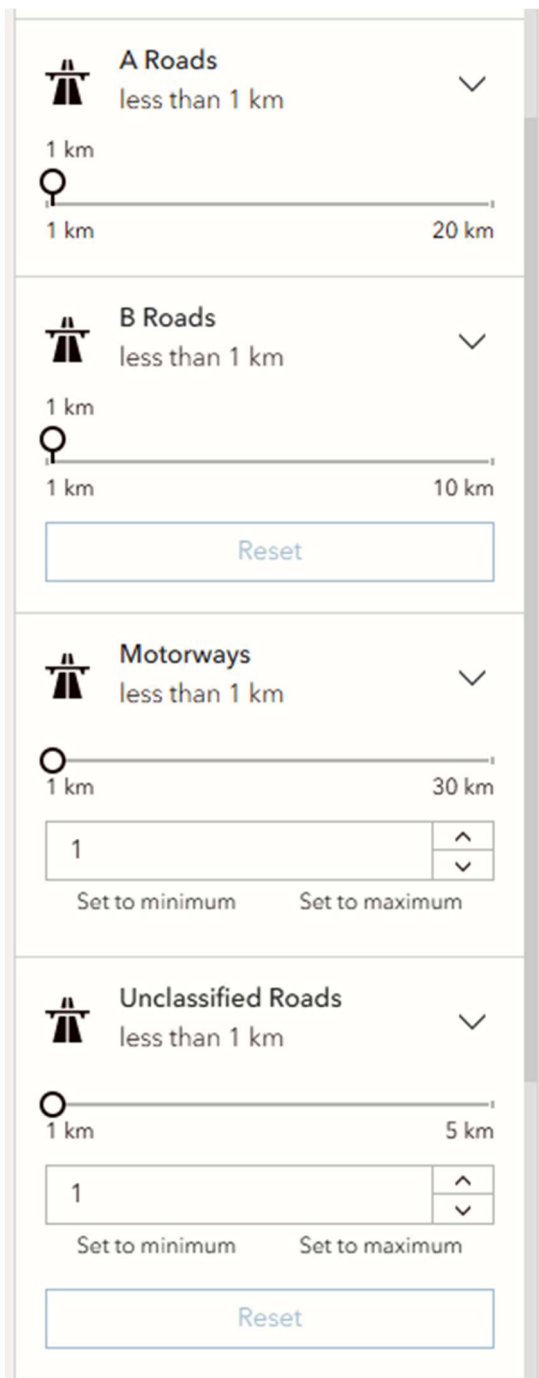
As mentioned earlier, features-only layers were merged into single layers depending on geometry type (points, polygons, lines). However, these three layers could not be merged into another single layer as data structures require that all features within a single layer share the same geometry type. Mixing geometry types (e.g., points with lines) would lead to compatibility issues and errors in the dashboard. Consequently, they were retained as separate layers requiring three individual drop-down selectors for displaying the features (Figure 21). While having three different drop downs is less optimal for UI design (a single drop-down would be more streamlined and efficient), merging them would have introduced unnecessary complexity. To maintain clarity for users, each category was clearly labelled according to the features it contained, with icons added for visuals.



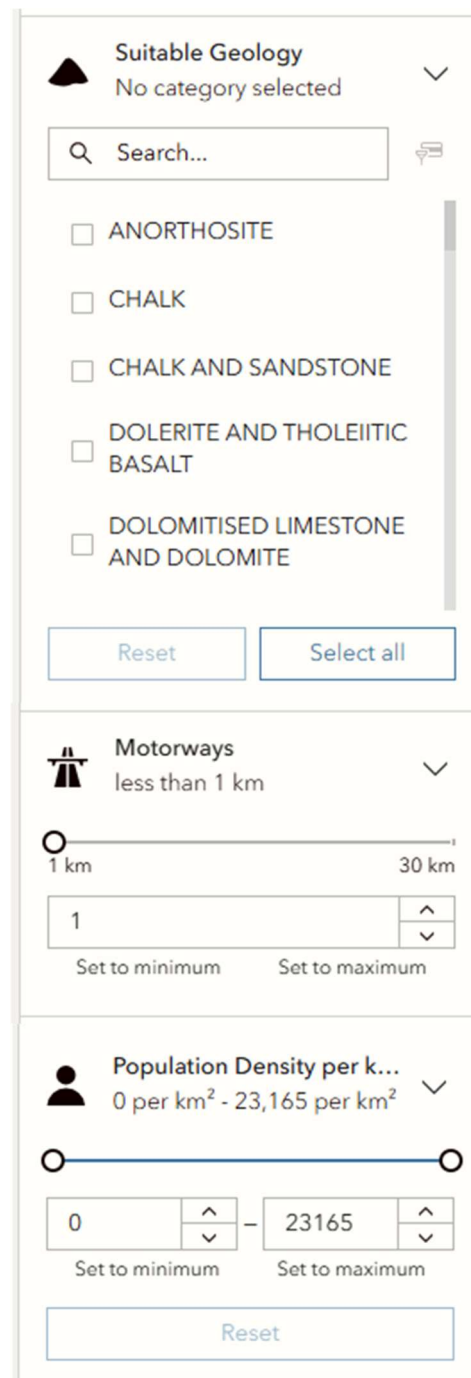
**Figure 21:** A view of the three drop-down selectors for the individual features-only layers. From left to right: “Lakes & Ports (Air/Sea)”, “Monitoring & Energy Sites”, “Infrastructure Routes & Rivers”.

## 2.5 Usability and Interface Refinement

When creating the dashboard, the build process began with the default design and the most basic controls. As progress developed, subsequent versions were progressively redefined and built upon, with updates sent to BGS for feedback on design, functionality and additional requirements. As an example, based on this feedback, the slider design was updated from a simple slider to a dropdown style widget, with a slider, numeric input and min/max button, allowing BGS to input precise values more quickly (Figures 22 and 23).



**Figure 22:** Four different selector designs considered for distance-based buffer layers. From top to bottom: (1) a simple slider only, (2) a slider with a rest button, (3) a slider with numeric input and min/max buttons, (4) a slider with numeric input, min/max buttons and a reset button.



**Figure 23:** The final selector designs for each layer type. The top selector is used for categorical data, the middle selector for distance-based buffers, and the bottom selector for density range inputs.

Finally, theme settings were adjusted to modify the dashboard’s colours, widget placement, text size, font, and other design elements (Figures 24 to 26). Consideration was given to adopting a dark colour scheme, as “dark mode” has become increasingly popular in modern interface design (Eisfield & Kristallovich, 2020). However, feedback from multiple users indicated that a lighter colour scheme provided better clarity and was easier on the eyes.

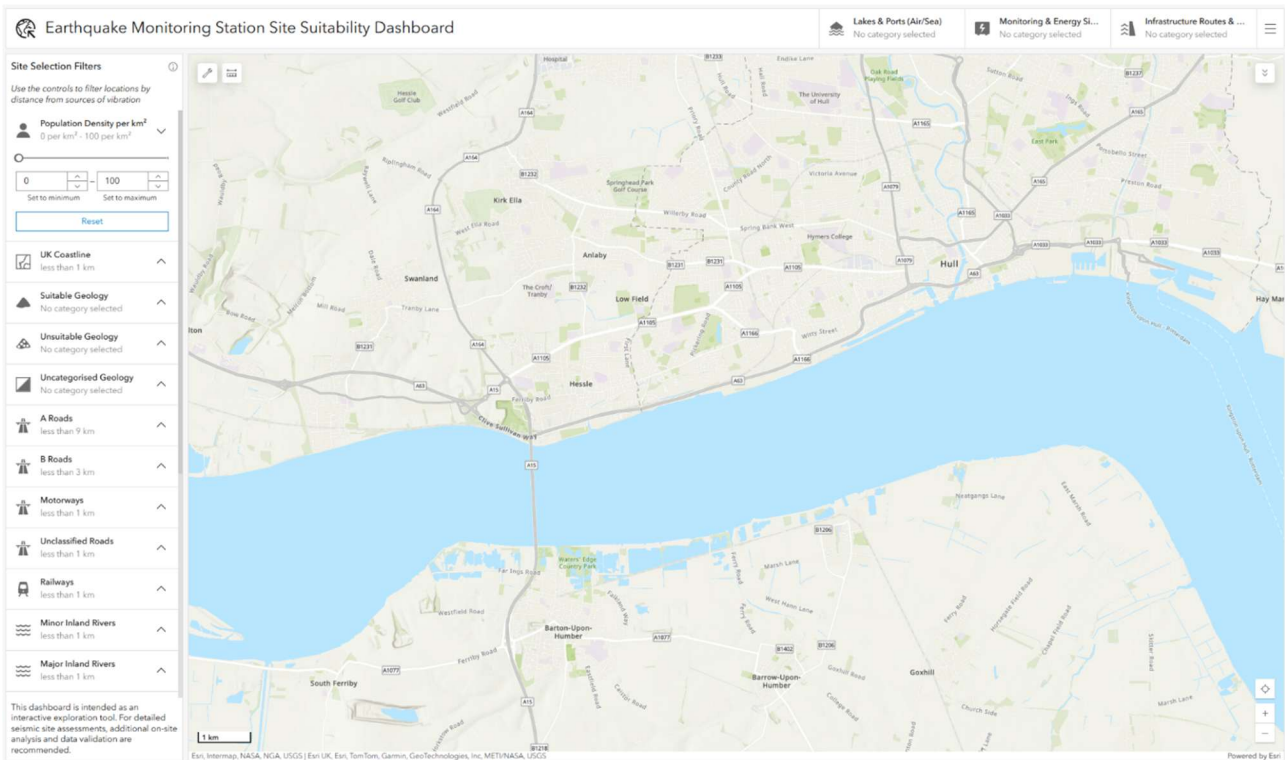


Figure 24: The default ArcGIS Dashboard theme.

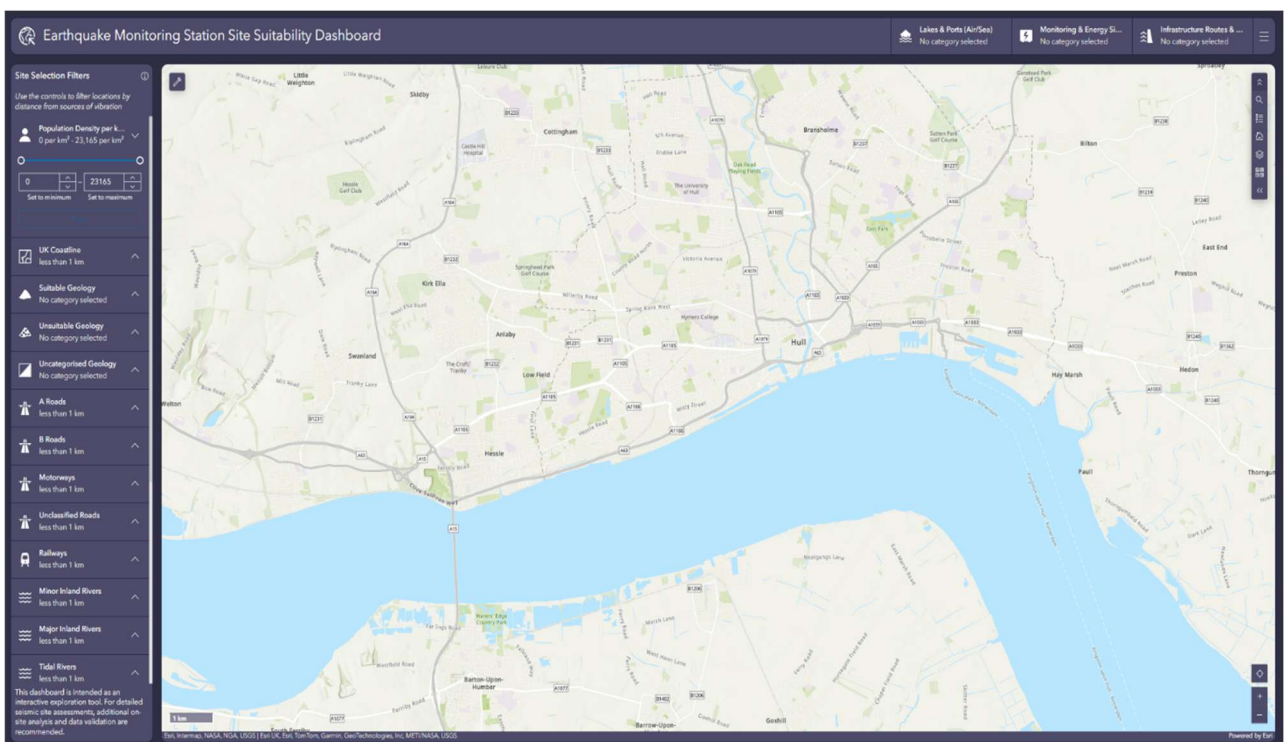
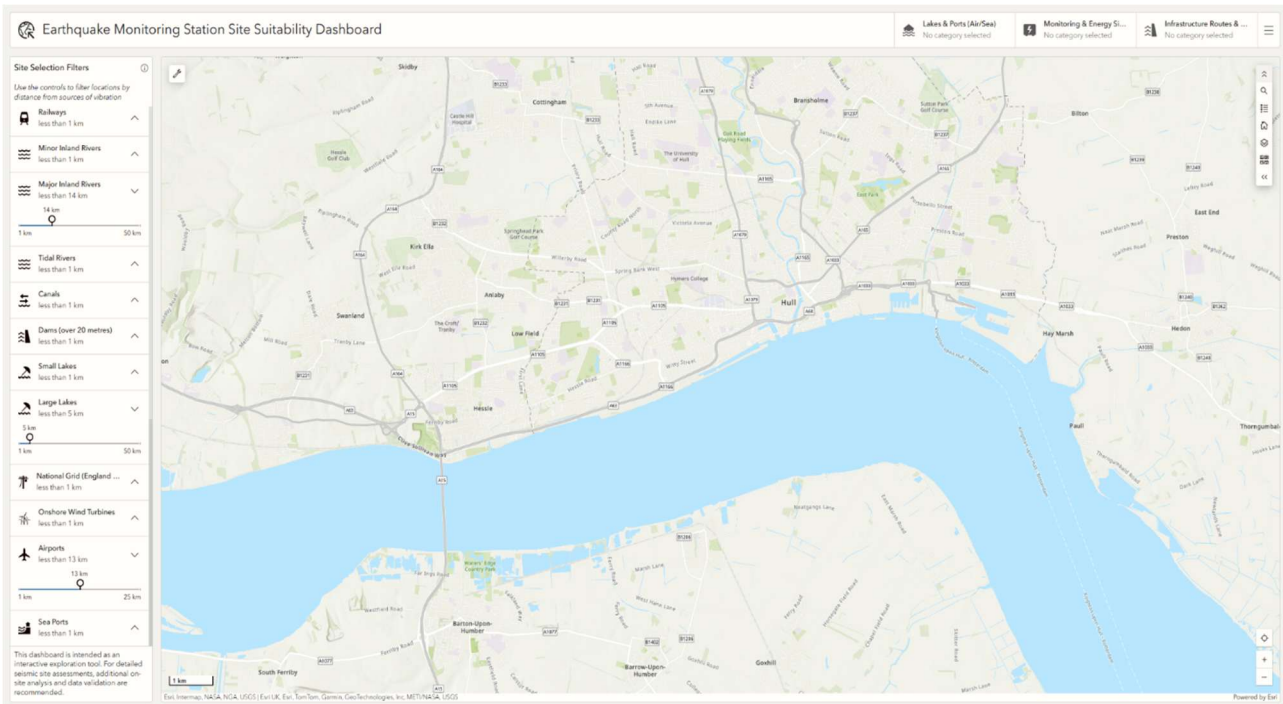
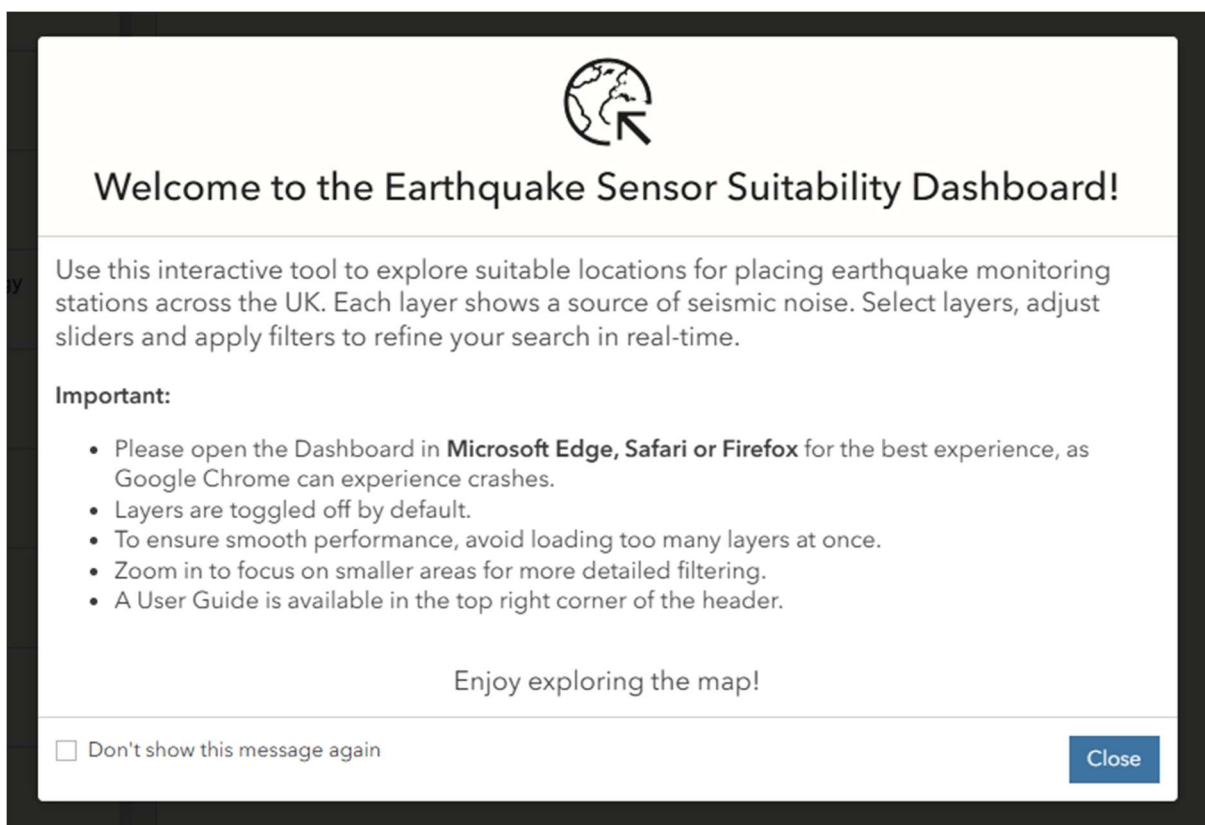


Figure 25: A customised “dark mode” version of the dashboard.



**Figure 26:** The final customised theme with adjusted colours, font sizes, accent highlights, widget and element sizes.

In addition, a splash screen was added to assist users when opening the dashboard for the first time, providing instructions and tips for optimal use (Figure 27). This was particularly important as performance issues were encountered in Google Chrome, so a warning was included to advise users to access the dashboard through alternative browsers. The splash screen also directs users to an accompanying user manual linked within the dashboard.



**Figure 27:** A splash screen that is displayed upon first opening the dashboard, featuring a welcome message and important tips for use.

## 2.6 Performance Optimisation

During the development process, extensive testing was carried out using a test version dashboard before implementing features into the final dashboard. Several optimisation measures were applied, including simplifying symbology, using scale-dependent rendering and optimising feature layers to improve performance. In addition, stress testing was carried out to determine how many layers could be simultaneously activated before performance suffered. Layers were added one by one to measure loading speeds. Load times reduced from approximately 30 seconds to almost instant/a few seconds (depending on computer model) after implementing various optimisation techniques.

Coupled with this, a cross-platform testing matrix was conducted to evaluate functionality and performance across different browsers and devices (Table 3). The following platforms were tested:

**Table 3:** A list of the browser and laptop models used to test dashboard performance.

Browsers	Laptop Models (year)
Google Chrome Microsoft Edge Safari Firefox Opera	Macbook (2020) Macbook Pro (2020) Macbook Pro (2020) Dell XPS 13 Dell Inspiron 15 (2024) HP Elitebook (2023)

The dashboard functioned successfully on all tested browsers except Google Chrome, and performed well on all tested laptop models when using compatible browsers. In Google Chrome, however, the dashboard frequently lagged, and activating more than four buffer layers often caused the map to render as a blank screen or for the browser to crash entirely (Figure 28).



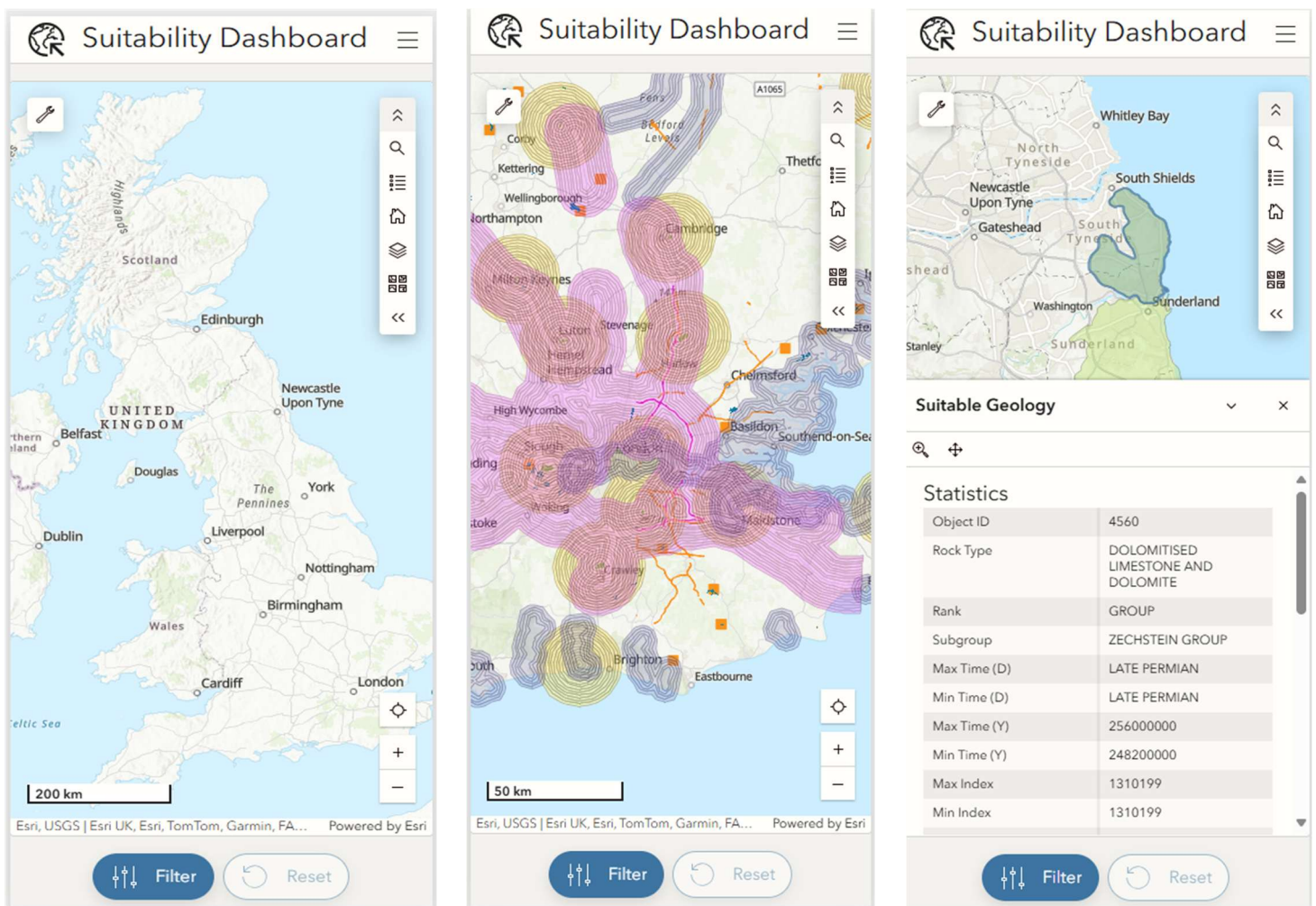
**Figure 28:** A screenshot of the dashboard failing to render in Google Chrome, showing a blank map view generated after trying to load multiple layers.

This performance issue was attributed to Google Chrome's stricter GPU memory limits, which can reduce the capacity to render large polygon datasets with multiple layers. Handling numerous web requests at once (such as loading multiple feature layers with complex geometries) can overwhelm the browser, resulting in the failure of the map to display. Other browsers did not have this problem, likely due to more efficient GPU memory management and more effective caching.

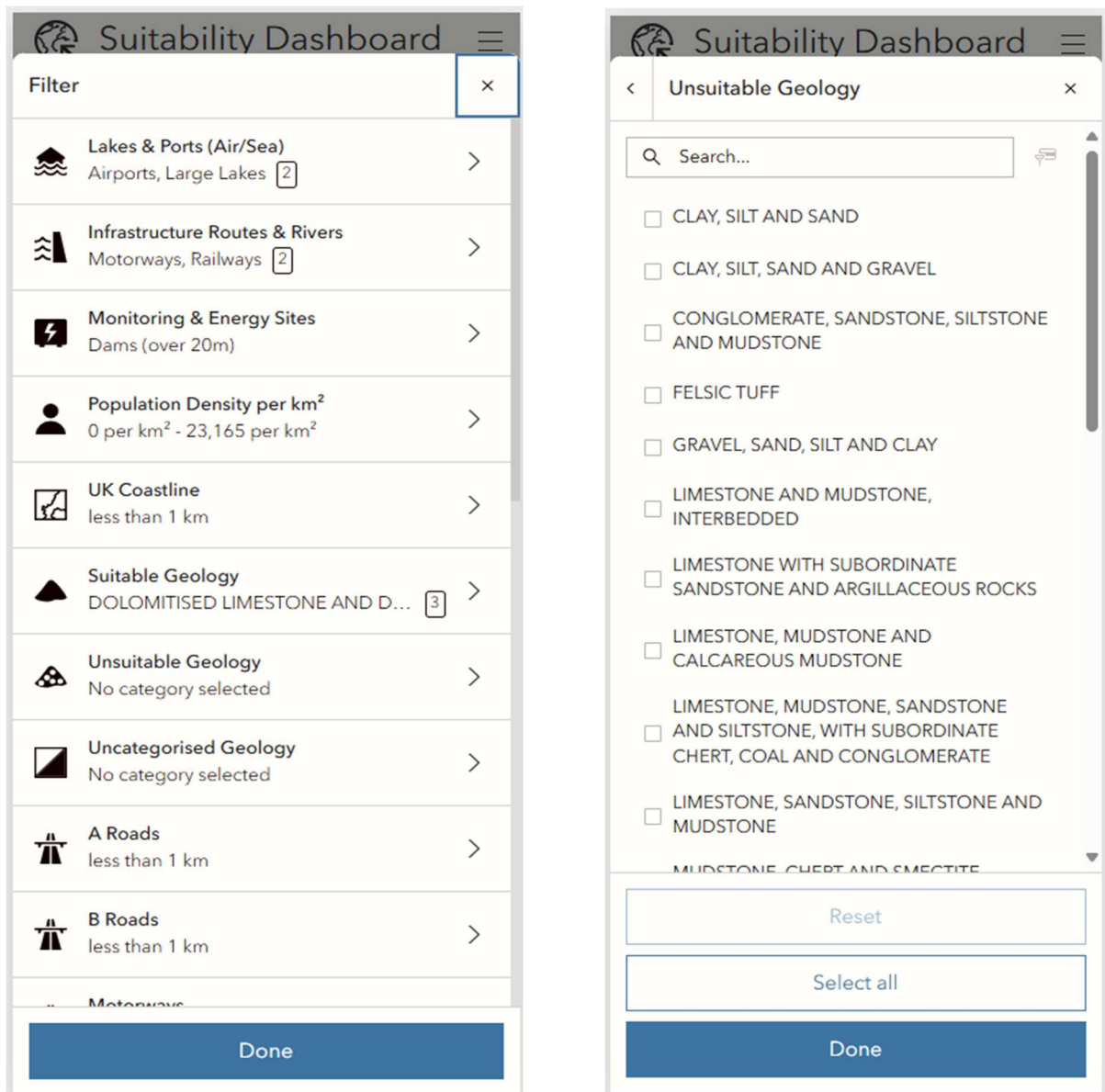
## 2.7 Development of a Mobile Version

In addition to the main computer-based dashboard, a mobile version was developed to provide a portable mobile accessible version for BGS workers in the field. The intention was to allow quick access to data without the need for a full computer setup. A version capable of offline use would further allow users to assess potential sites when in remote areas without cellular coverage, upgrading the dashboard’s practicality for on-site decision making.

The mobile version retains the same functionality and widgets as the desktop version, but with a layout adapted for a vertical screen (Figure 29). The sidebar was shifted to the bottom to maximise map visibility and ensure the map remained the primary focus of the interface (Figure 30).



**Figure 29:** Screenshots of the mobile dashboard design. From the left to right: (1) the default mobile view, (2) the map after applying several buffer filters, (3) the attribute table view. Here, the attribute table is displaying information for a geology feature. The mobile version was tested on the Safari, Google and Microsoft Edge app on an iPhone 11, iPhone SE (2020), Samsung Galaxy A15, and Motorola Edge 5G UW.



**Figure 30:** The site suitability filters and feature-only layer toggles relocated to the bottom of the interface in the mobile version, within a maximisable/minimisable panel.

The mobile version was developed on a computer, and functioned well during desktop testing. However, when tested on mobile devices (both iOS and Android), it experienced significant performance issues, including issues with loading layers, incomplete map rendering, crashes and browser auto-refreshing. These issues most likely stem from limited processing power and memory constraints on mobile devices, especially when handling large datasets. As a result, the mobile version was deemed non-functional in its current state. As the project was focused on developing a desktop web application, the mobile version remains a conceptual model. Nonetheless, the mobile concept represents a valuable direction for future development, and it would be a key area for prioritisation for future iterations of the dashboard.

## 2.8 Functional Limitations and Future Enhancements

The decision to develop the web application in ArcGIS Dashboard was guided by BGS's preferences for accessibility, ease of use and suitability for a range of user types. The platform's browser-based access and interactive widgets make it highly approachable for audiences (De Miguel González et al., 2025). The interface also enables spatial data exploration without requiring prior GIS experience. Hosting the layers on ArcGIS Online allows them to be edited easily and updated for evolving user needs, while maintaining a low maintenance overhead.

The benefits of ArcGIS Dashboard also introduce inherent limitations. As the platform relies on pre-processed datasets and fixed layers, it lacks the capability for dynamic spatial analysis beyond filtering and selection. Key limitations include the inability to:

- Register clicks on the basemap to retrieve coordinates or calculate distances to nearby features.
- Aggregate statistics across multiple datasets.
- Perform custom calculations.

These limitations stem from the way ArcGIS Dashboard is designed, which focuses on displaying and interacting with precomputed layers rather than generating dynamic outputs from user driven inputs. As a result, the platform constrains the tool's ability to deliver more advanced analytical functionality.

Addressing these limitations would require migrating the interface to ArcGIS Experience Builder Developer Edition, creating custom widgets with the ArcGIS API for JavaScript (Esri, n.d.) or building a bespoke GIS web application. These approaches would allow for more advanced capabilities, such as querying distances from user-selected points and performing multi-criteria analysis, allowing users to assign weights to different noise sources and generate tailored suitability maps. Although implementing these features require significantly greater development time, coding expertise and hosting resources than the current dashboard configuration, such developments would substantially enhance the tool's analytical functionality by transforming it from a filtering-based system into a dynamic decision support environment, as demonstrated in other GIS applications (Rao et al., 2007).

## **3 User Manual**

### **Preface to User Manual Section**

The following section presents the user manual as it appears in the dashboard. As it is designed for practical user guidance rather than academic presentation, the formatting differs from the rest of the technical report. Images are not formally captioned as figures and are not included in the Table of Figures. This is intentional, as the manual was developed to be intuitive and visually accessible in a web-based environment rather than formatted for print or academic referencing.

# Earthquake Monitoring Station Site Suitability Dashboard

# User Manual

## Part 1: Dashboard Controls Overview

*An overview of the tools, filters and functions.*

## Part 2: Walkthrough - Finding a Suitable Site

*A step-by-step guide to finding a suitable site.*

## Welcome to the Dashboard

This user manual will guide you through the features and functions of the dashboard.

## Purpose of the Dashboard

This dashboard was developed to support the British Geological Survey in selecting suitable locations for new earthquake monitoring stations. To select the optimal location, monitoring stations should be positioned as far as possible from external sources of vibration. This dashboard enables you to:

- Visualise sources of vibration.
- Apply buffer filters to display distance zones around seismic noise sources.
- Explore potential sites with the dashboard's tools.

## Recommendations for a Smoother User Experience

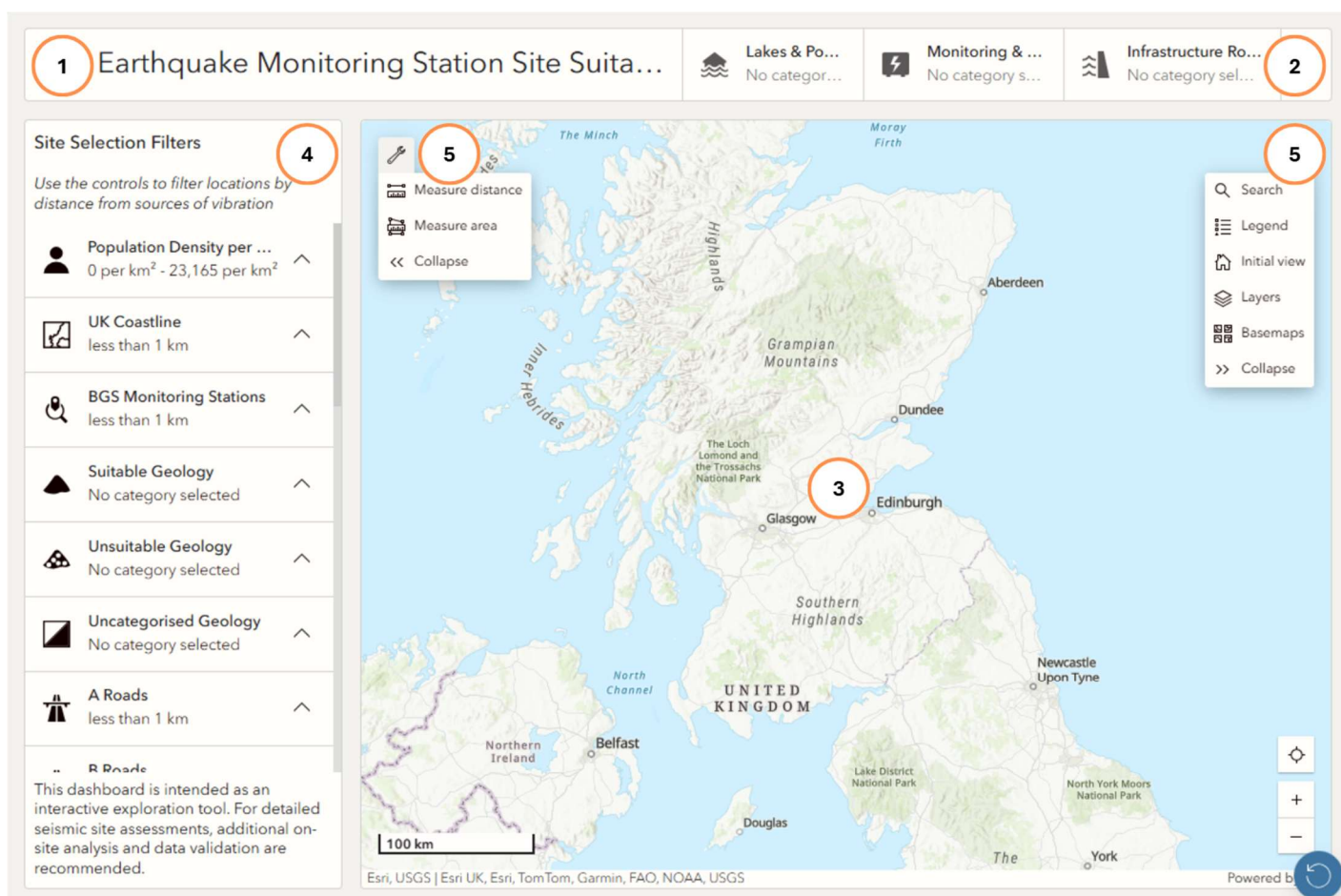
- Allow a few seconds for layers to load after turning them on.
- Close-up views of the map load faster than national-scale views.
- Refresh the dashboard if it becomes unresponsive.

# Part 1: Dashboard Controls Overview

After opening the dashboard, you will see the main interface.

The layout includes:

- (1) Header
- (2) Feature toggles
- (3) Central map view
- (4) Site selection filters
- (5) Additional controls



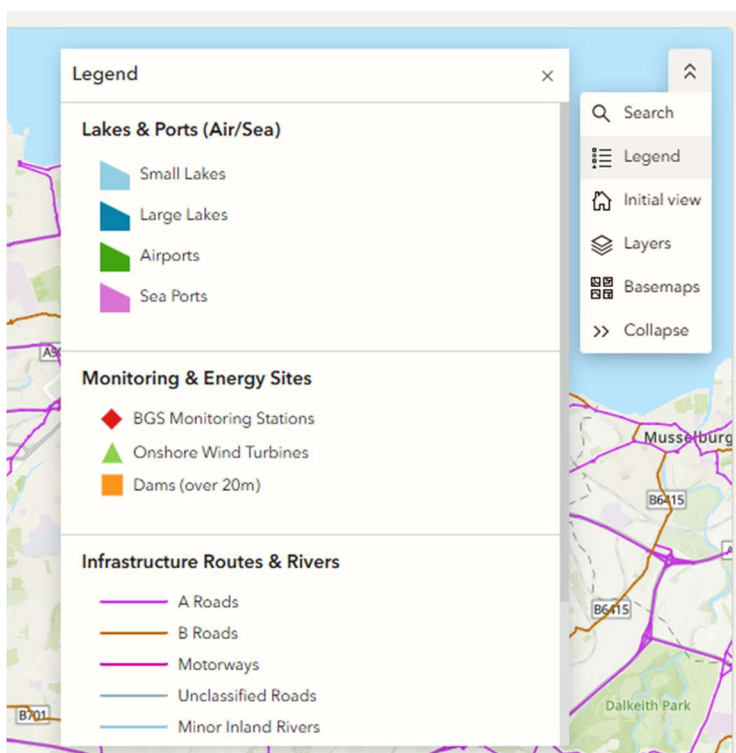
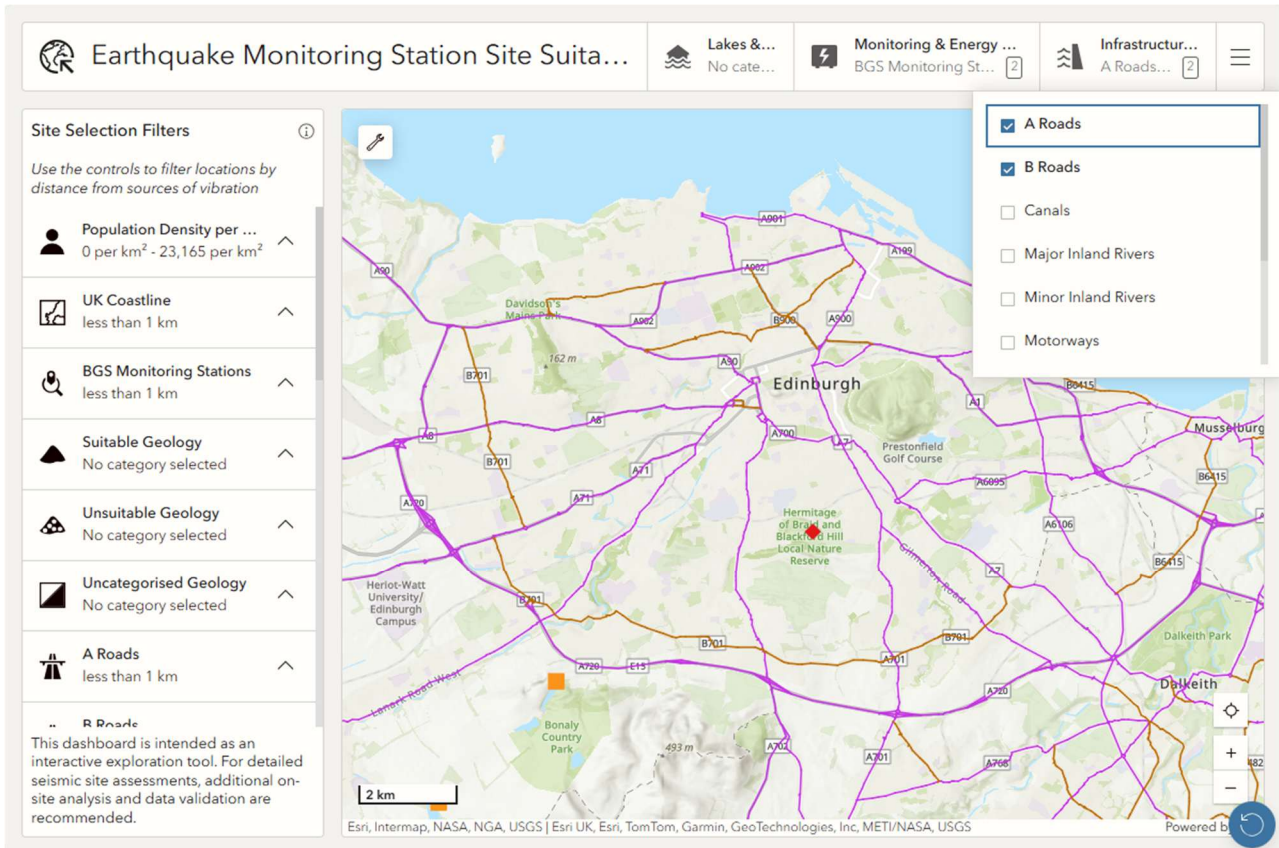
## (2) Feature Toggles

Use these to toggle features on/off in the map view. The features are sources of seismic noise, such as airports, road networks and wind turbines.

## (4) Site Selection Filters

Use these to adjust the buffer layers that visualise distances from seismic noise sources. Turn on buffer layers in the control panel (5), then adjust the layer using the site selection filters.

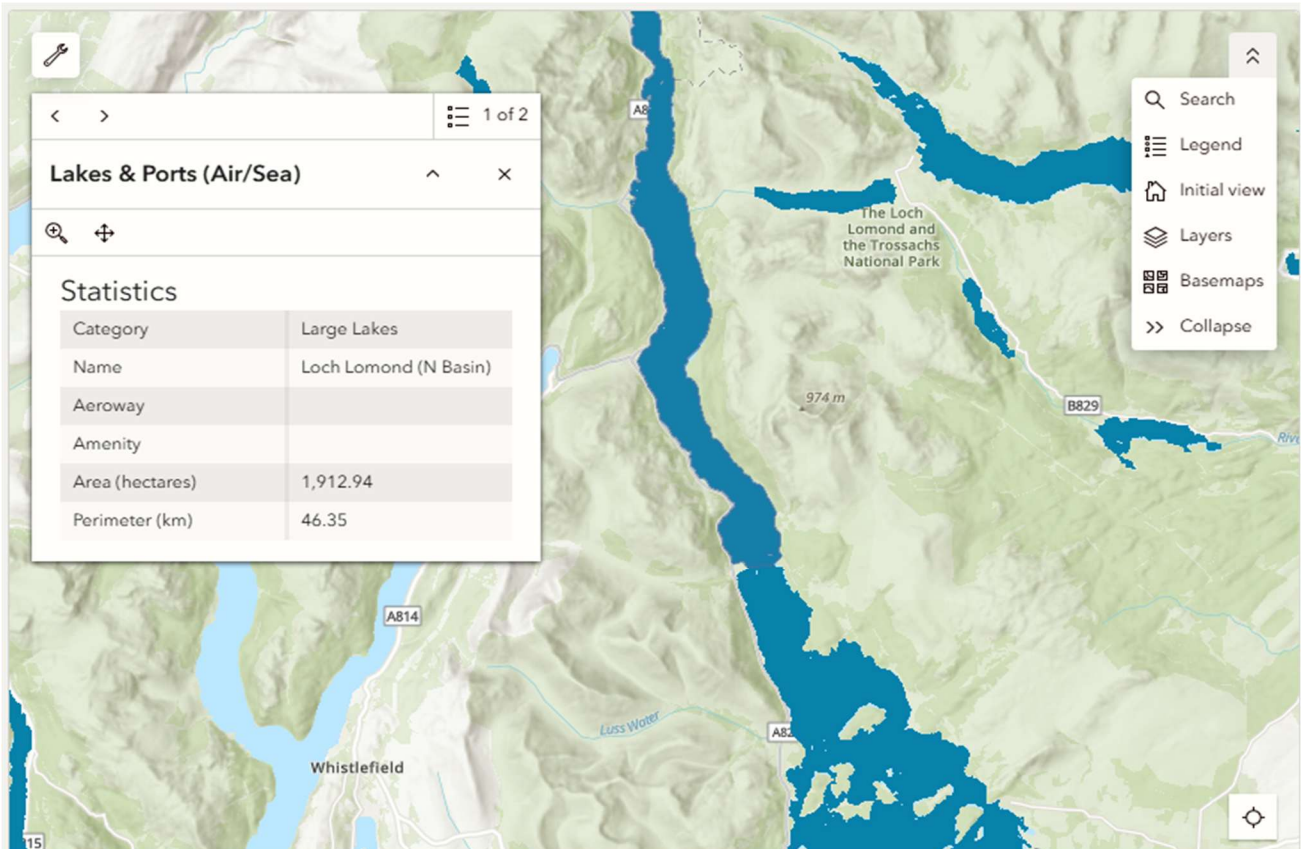
The feature toggles include “Lakes & Ports (Air/Sea)”, “Monitoring & Energy Sites”, “Infrastructure Routes & Rivers”. Toggle a feature to view it on the map. In the example below, A Roads, B Roads, Dams and BGS Monitoring Sites are turned on.



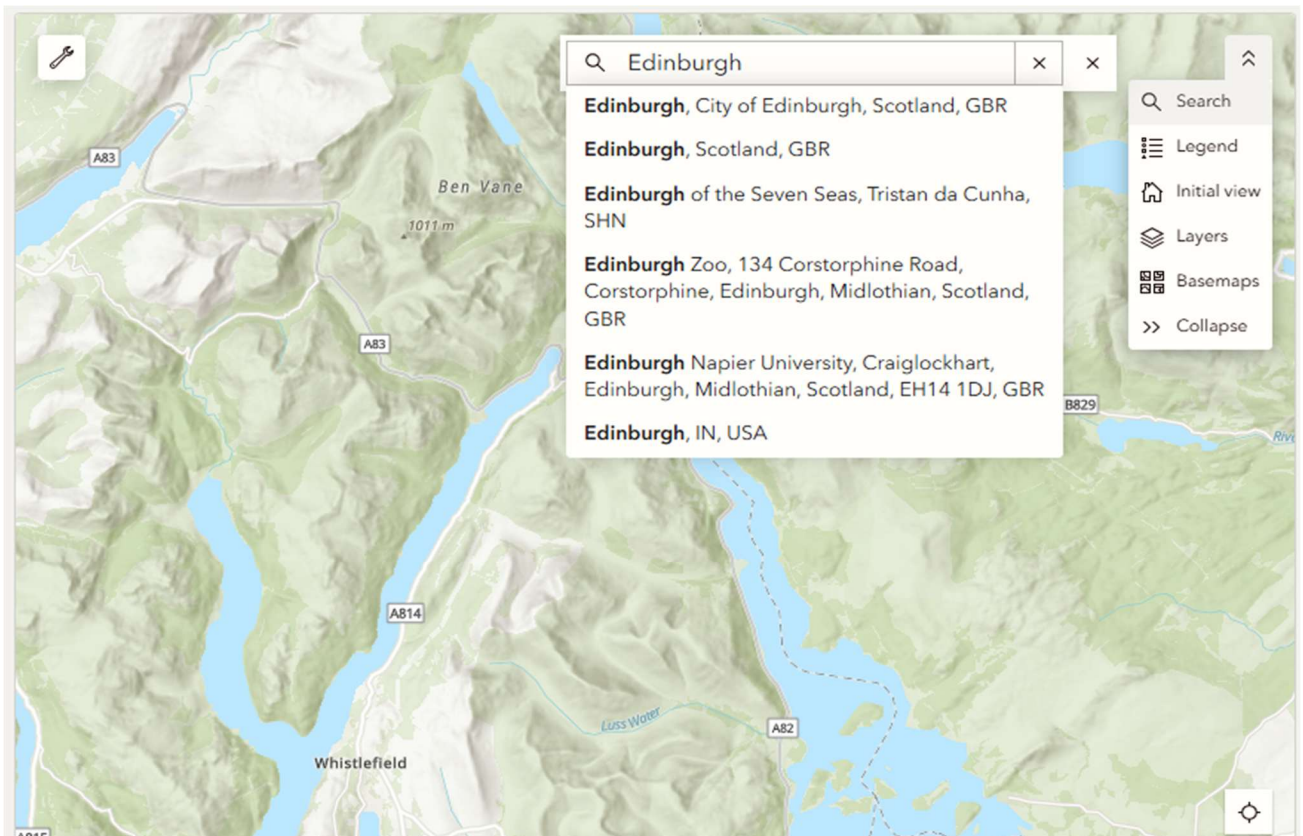
The legend can be accessed from the controls on the right.

It explains the colours and symbols on the map for ease of interpretation.

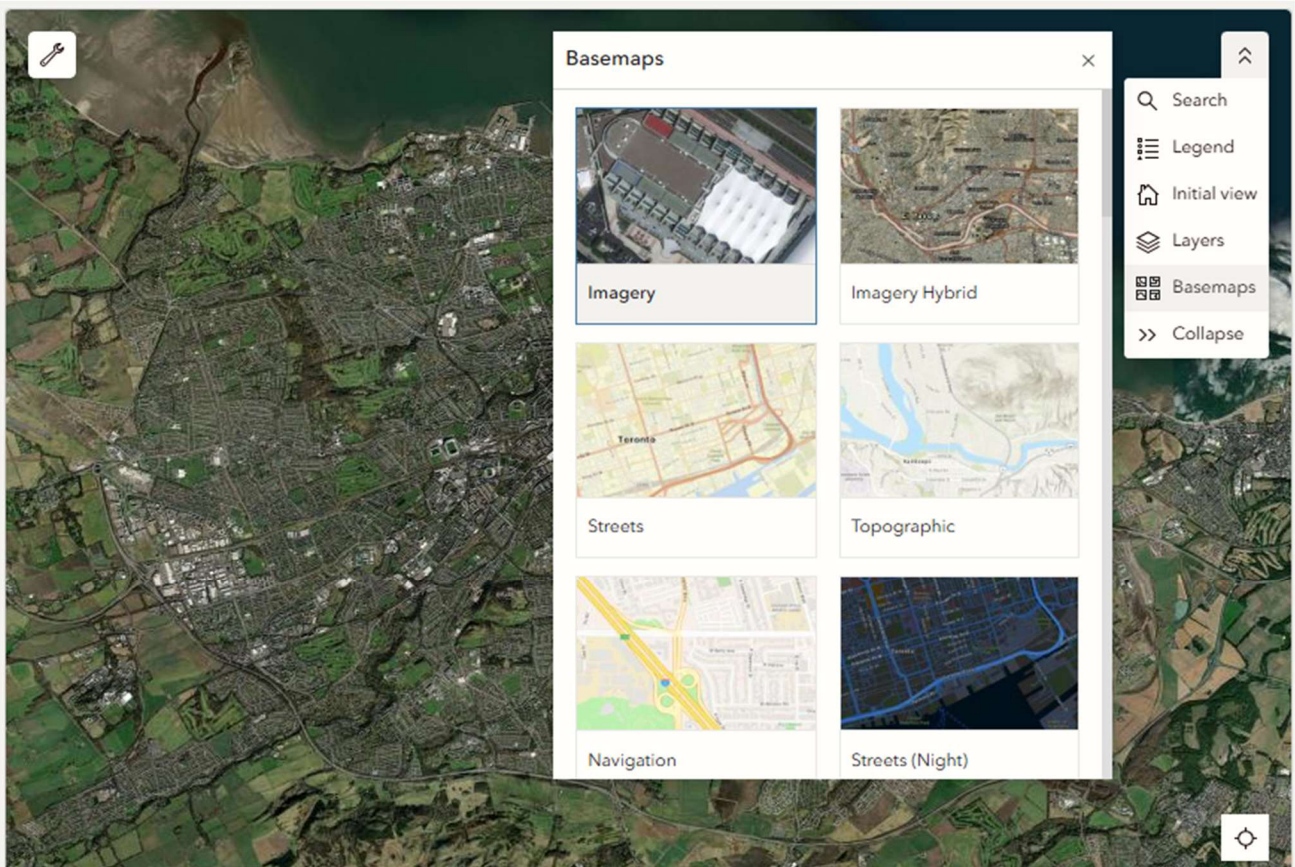
Click on a feature to view its information.



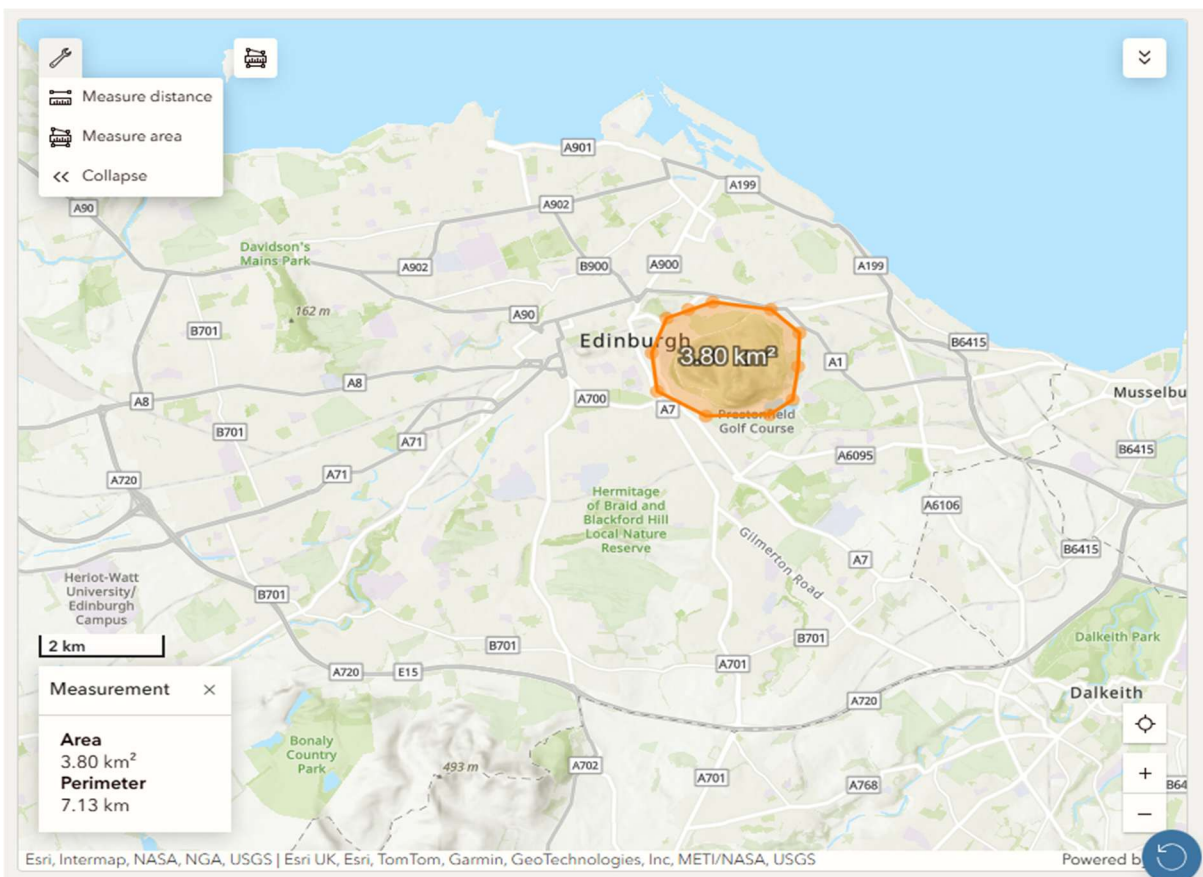
Use the search function to find and zoom to a location.



Select from various basemap styles, such as satellite imagery or night view.



Use the measuring tools on the left to measure distances and areas on the map.



## Using the Site Selection Filters

First, turn on the buffer layers using the controls on the right. Then, use the site selection filters on the left to adjust the buffer layers.

In the example below, “Suitable Geology” is activated, with the rock types selected in the site selection filter displayed on the map.

The screenshot shows the 'Earthquake Monitoring Station Site Suitability' tool interface. The top navigation bar includes sections for 'Lakes & Po...', 'Monitoring & ...', and 'Infrastructure Ro...'. The main interface is divided into three main areas: a left sidebar for 'Site Selection Filters', a central map, and a right sidebar for 'Layers'.

**Site Selection Filters (Left Sidebar):**

- Section: **Suitable Geology** (ANORTHOSITE, CH... 38)
- Search: Search...
- Selected categories:
  - ANORTHOSITE
  - CHALK
  - CHALK AND SANDSTONE
  - DOLERITE AND THOLEIITIC BASALT
  - DOLOMITISED LIMESTONE AND DOLOMITE
- Buttons: Reset, Deselect all
- Section: **Unsuitable Geology** (No category selected)
- Footer: This dashboard is intended as an interactive exploration tool. For detailed seismic site assessments, additional on-site analysis and data validation are recommended.

**Layers (Right Sidebar):**

- UK Population Density (per km<sup>2</sup>)
- UK Coastline
- BGS Monitoring Stations
- Suitable Geology** (Turn on the layer)
- Unsuitable Geology
- Uncategorised Geology
- A Roads
- B Roads
- Motorways
- Unclassified Roads
- Railways
- Minor Inland Rivers

**Map (Center):**

- Geographical features: The Minch, Moray Firth, Grampian Mountains, Southern Highlands, Glasgow, Edinburgh, Dundee, Newcastle Upon Tyne, North Channel.
- Scale bar: 100 km
- Map data: Esri, USGS | Esri UK, Esri, TomTom, Garmin, FAO, NOAA, USGS

**Annotations:**

- A circled '2' points to the 'Filter the layer' button in the Site Selection Filters sidebar.
- A circled '1' points to the 'Turn on the layer' button in the Layers sidebar.

In the example below, several buffer layers are turned on, and their distances have been set by the site selection filters.

**Earthquake Monitoring Station Site Suitability**

**Site Selection Filters**

Use the controls to filter locations by distance from sources of vibration

- National Grid (England & Wales)**  
less than 2 km
- Onshore Wind Turbines**  
less than 13 km
- Airports**  
less than 14 km

This dashboard is intended as an interactive exploration tool. For detailed seismic site assessments, additional on-site analysis and data validation are recommended.

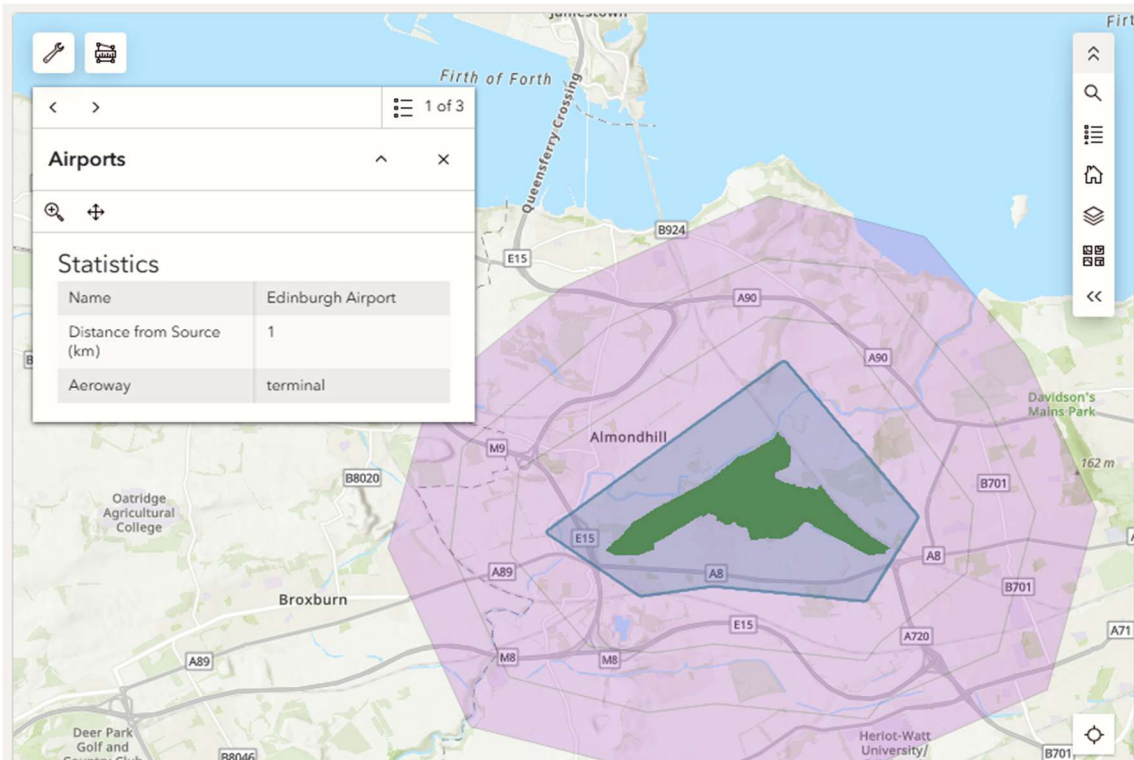
**Layers**

- Railways
- Minor Inland Rivers
- Major Inland Rivers
- Tidal Rivers
- Canals
- Dams (over 20 metres)
- Small Lakes
- Large Lakes
- Sea Ports
- National Grid (England & Wales)
- Onshore Wind Turbines (Operational)

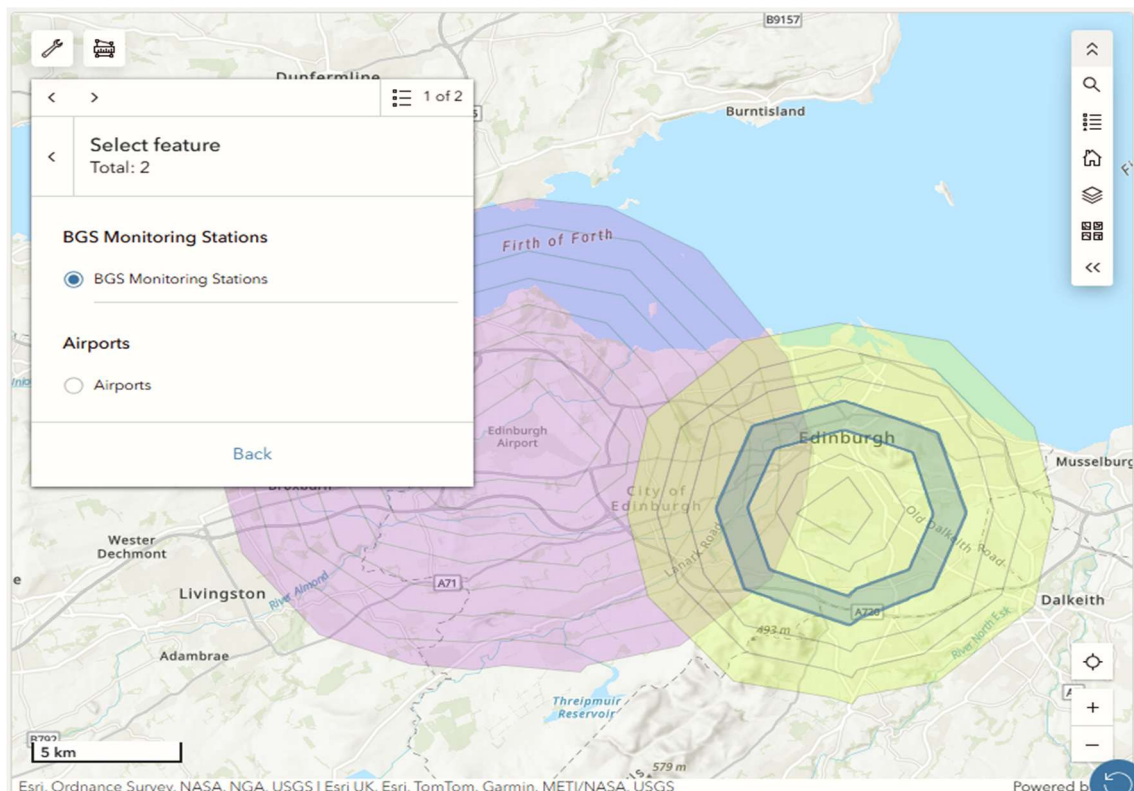
Esri, CGIAR, USGS | Esri UK, Esri, TomTom, Garmin, FAO, METI/NASA, USGS

Powered by

The buffer layers and features can be activated simultaneously. In this example, “Airports” is turned on from the “Lakes & Ports (Air/Sea)” feature toggle, and the Airports buffer layer is activated from the right-hand layer controls.

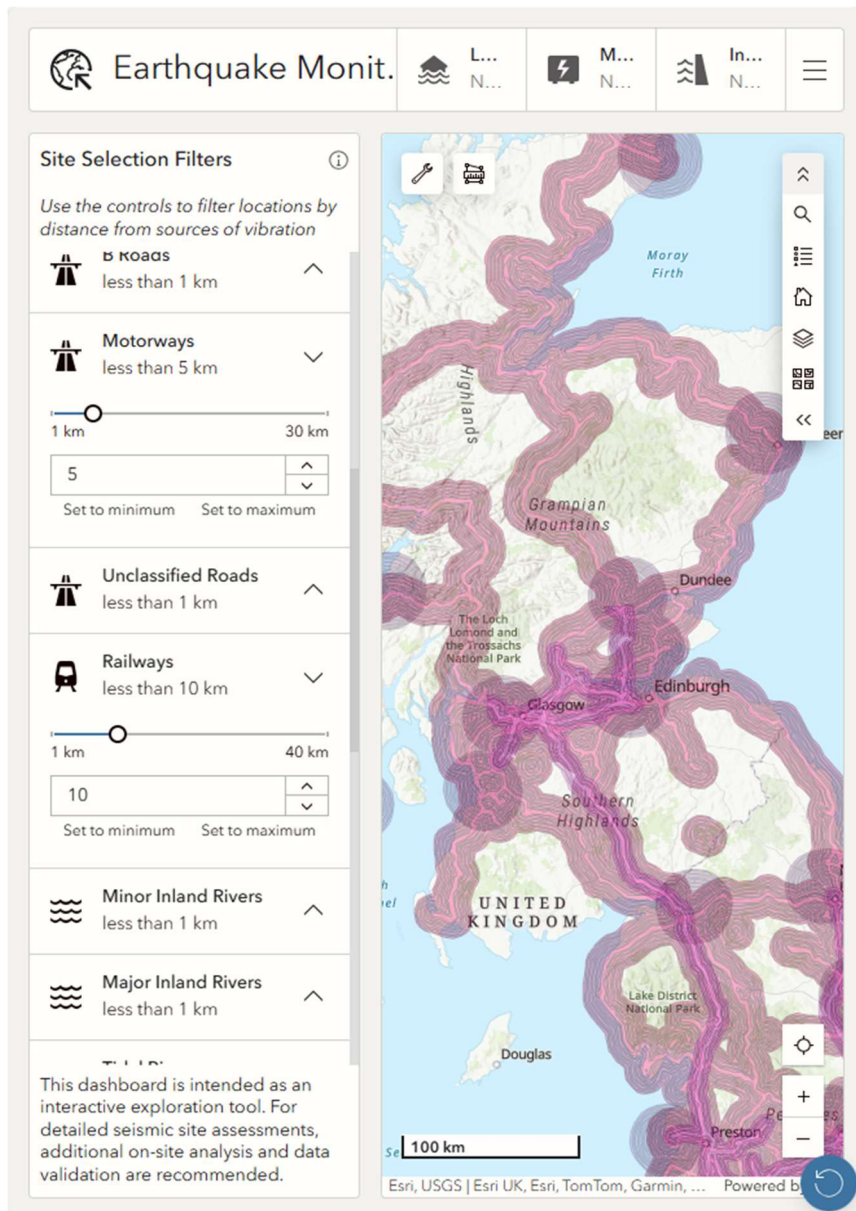


When two buffer layers overlap, you can click on the area and use the list button (top right of the information window) to highlight a selected layer.



## Part 2: Walkthrough - Finding a Suitable Site

Walk through the steps to explore suitable sites for a monitoring station.



### Step 1:

Move the map to Scotland.

In the right-hand controls turn on Motorways, Railways and Airports buffer layers.

### Step 2:

In the site selection filters on the left, set the layers to these distances:

Motorways – 5 km

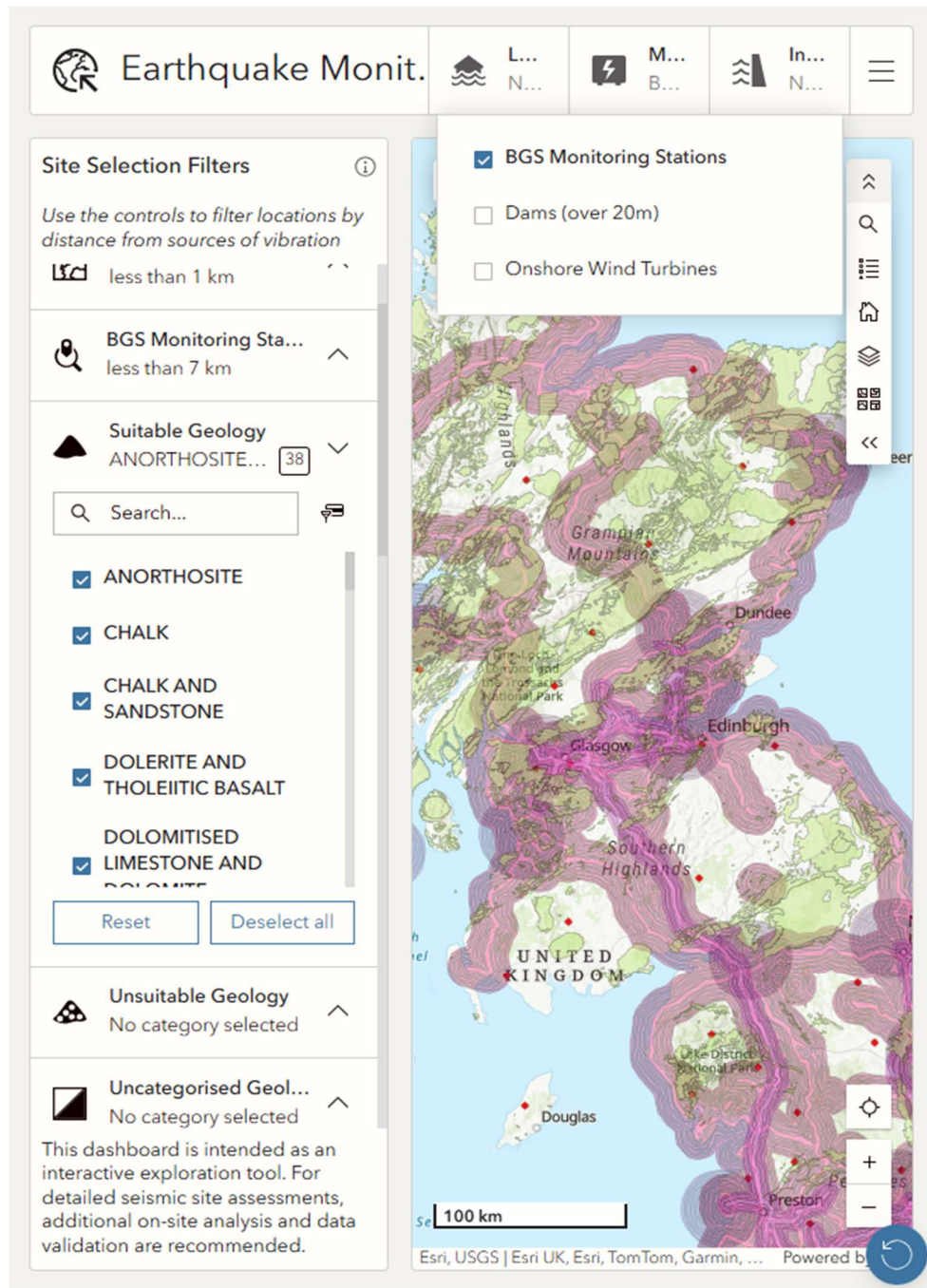
Railways – 20 km

Airports – 20 km

### Step 3:

Turn on the Suitable Geology buffer layer. In the Suitable Geology site selection filter, click “Select All”.

In the Monitoring & Energy Sites feature toggle, turn on BGS Monitoring Stations.



## Step 4:

Zoom to Inverness in the north of Scotland (use the search function if needed). There are a few locations away from seismic noise sources.

Next, find a location outside the buffer layers, but on suitable geology. An example is the triangular shaped felsic rock shown below.

Earthquake Monitoring Station Selection

Site Selection Filters

Use the controls to filter locations by distance from sources of vibration

less than 1 km

BGS Monitoring Stations less than 7 km

Suitable Geology ANORTHOSITE... 38

Search...

ANORTHOSITE

CHALK

CHALK AND

This dashboard is intended as an interactive exploration tool. For detailed seismic site assessments, additional on-site analysis and data validation are recommended.

Suitable Geology

Statistics

Object ID	4214
Rock Type	FELSIC-ROCK
Rank	INTRUSION
Subgroup	No Parent
Max Time (D)	ORDOVICIAN
Min Time (D)	SILURIAN
Max Time (Y)	495000000
Min Time (Y)	417000000

20 km

Esri, CGIAR, N Robinson, NCEAS, USGS | Esri UK, Esri, TomTom, Garmin, FAO, METI/NASA, USGS Powered by

## Step 5:

To view the area more clearly, open the measurement tools on the top left of the map and select the Measure Area tool. Click several points to outline the area, then press Enter to confirm the measurement.

Turn off all the buffer layers. Then, in the right-hand controls, open Basemaps and select “Imagery”.

To assess site accessibility, open the Infrastructure Routes & Rivers feature toggle and turn on A Roads, B Roads and Unclassified Roads.

The screenshot displays the Earthquake Monitoring Station dashboard. The top navigation bar includes the title "Earthquake Monitoring Station..." and several icons for "Lak...", "Moni...", and "Infrastructur...". The left sidebar contains "Site Selection Filters" with a search bar and checkboxes for "ANORTHOSITE", "CHALK", and "CHALK AND". The main map area shows a brown-shaded polygon with a measurement of 66.72 km². A "Measurement" popup window displays the area and perimeter. The right sidebar shows a list of infrastructure features with checkboxes for "A Roads", "B Roads", "Canals", "Major Inland Rivers", "Minor Inland Rivers", and "Motorways". The map includes a 5 km scale bar and a "Powered by" logo.

**Site Selection Filters**

Use the controls to filter locations by distance from sources of vibration

less than 1 km

BGS Monitoring Sta... less than 7 km

Suitable Geology ANORTHOSITE... 38

Search...

ANORTHOSITE

CHALK

CHALK AND

This dashboard is intended as an interactive exploration tool. For detailed seismic site assessments, additional on-site analysis and data validation are recommended.

**Measurement**

Area 66.72 km<sup>2</sup>

Perimeter 32.67 km

**Infrastructure Routes & Rivers**

A Roads

B Roads

Canals

Major Inland Rivers

Minor Inland Rivers

Motorways

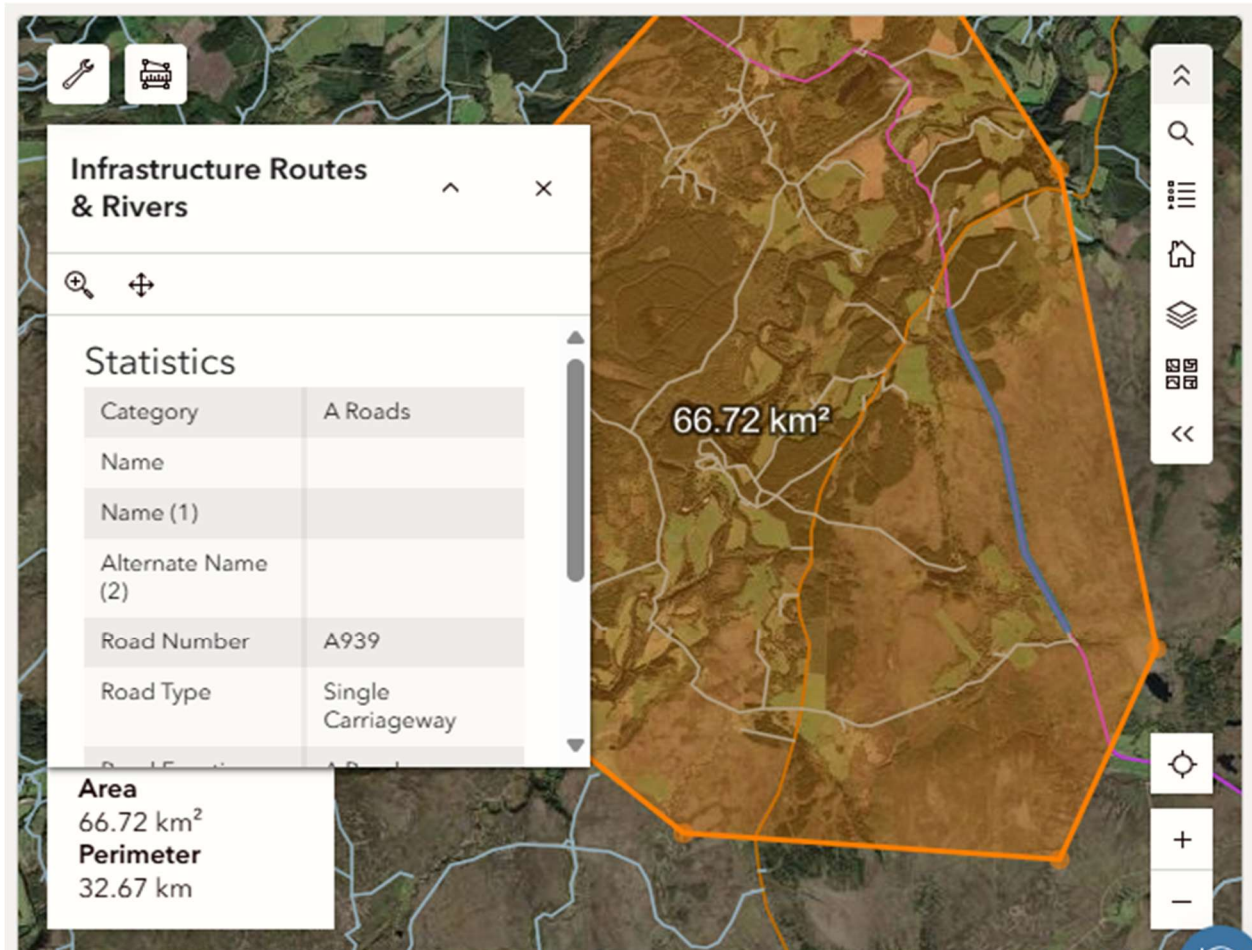
5 km

Earthstar Geographics

Powered by

## Step 6:

Zoom into the area. By clicking on the roads, we can see the A939 (A Road) and B9007 (B Road) within the area. The grey roads are smaller unclassified roads that extend further into the site.



Congratulations! This location appears to be a suitable candidate site\* based on the defined selection criteria.

\*As this is a preliminary tool, a site visit is recommended to gather additional information such as elevation, wind conditions and accessibility.

**Thank you for reviewing the user manual.**

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## **Appendices**

### **Appendix A**

Photographs of the British Geological Survey's earthquake monitoring station installation process.

### **Appendix B**

Microsoft Forms Dashboard Testing User Survey.

### **Appendix C**

Format and Description of Data.

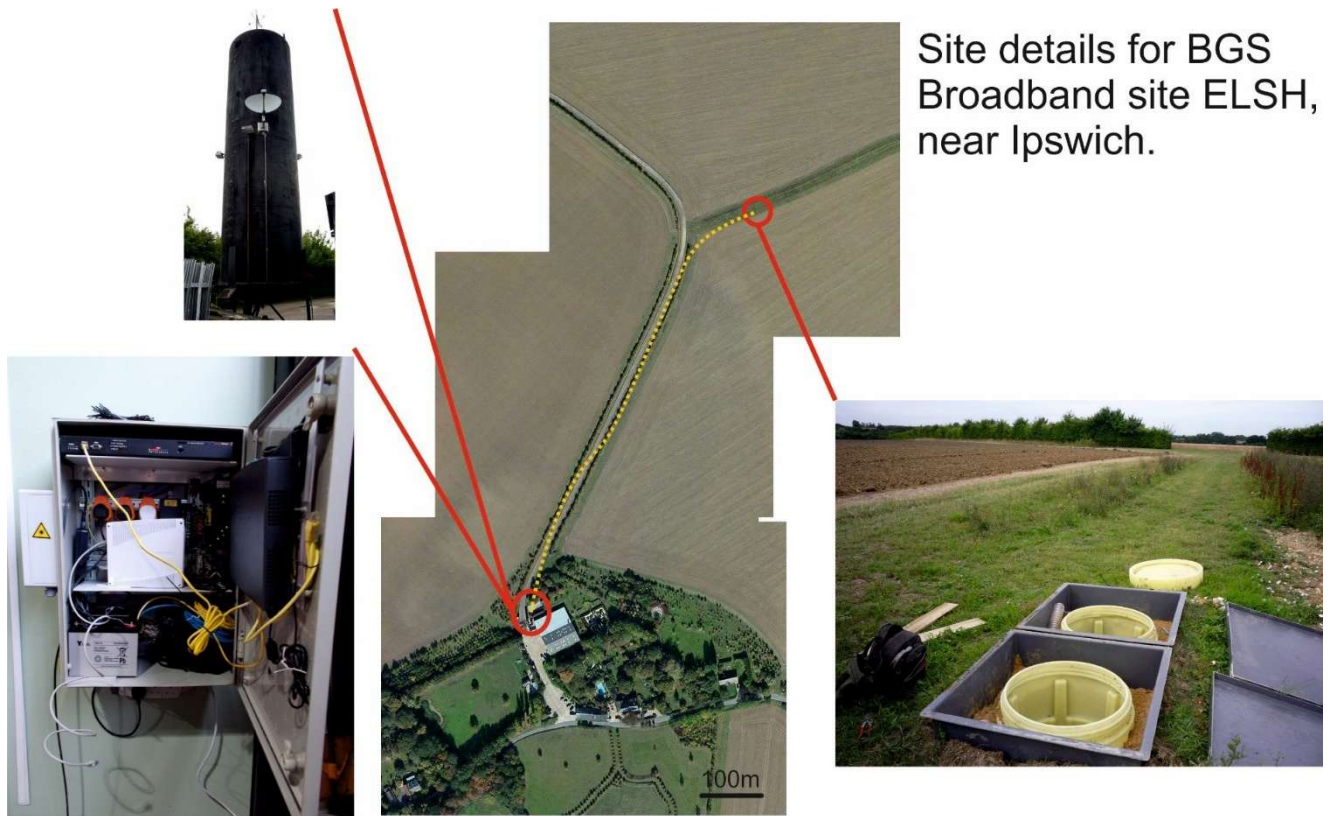
## Appendix A

Photographs of the British Geological Survey's earthquake monitoring station installation process.

A photograph showing concrete being poured to prepare the foundation for installing a BGS monitoring station.



The site of a monitoring station, including images of the power supply and network signal cone.



A BGS staff member reviewing seismic data collected from a monitoring station.



An earthquake monitoring station setup, including the solar panel and surrounding equipment.



## Appendix B

Microsoft Forms survey used to gather user feedback on dashboard design during testing.

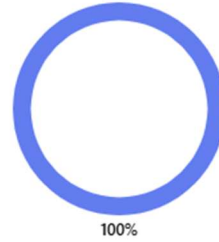


4. Step 4: Click on the different Large Lakes.

[More details](#)

Question: Do they each give different information in their pop up window? (0 point)

- Yes 9
- No 0

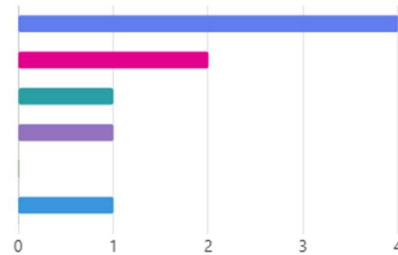


5. Step 5: Turn off Airports and Large Lakes. Move the map back to central London. Go to Infrastructure Routes & Rivers in the top right. Click on Tidal Rivers.

[More details](#)

Question: How long did Tidal Rivers take to load in? (0 point)

- instantly 4
- a second or two 2
- a few seconds 1
- over 15 seconds 1
- over half a minute 0
- over a minute 1

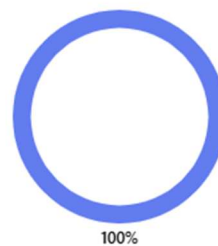


6. Step 6: Turn off Tidal Rivers. Turn on A Roads. Zoom in and click around on parts of the roads.

[More details](#)

Question: Does clicking on different parts of the road show different names, road numbers, road types and functions? (0 point)

- Yes 8
- No 0

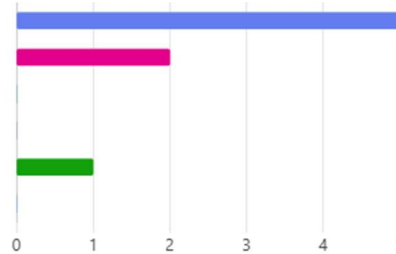


7. Step 7: Zoom out and move to Aberdeen. Zoom to a 5km scale. Go to the Layers button on the right side controls (picture of three stacked squares). Turn on the A Roads layer. **These layers visualise distance from vibrations coming from the source.**

[More details](#)

Question: How long did A Roads take to load? (0 point)

- instantly 5
- a second or two 2
- a few seconds 0
- over 15 seconds 0
- over half a minute 1
- over a minute 0



8. Step 8: Go to the filters on the left side. Find A Roads. Adjust the slider to 3km. This now shows 3km away from A Road vibrations.

Go to the Railways layer (within the layers button on the right side controls) and turn it on. Go to the Railways filter on the left and also adjust it to 3km.

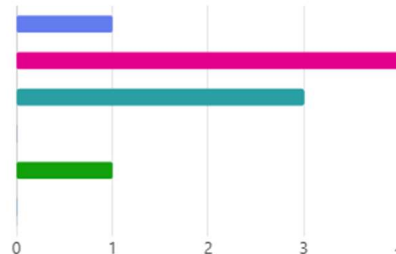
[More details](#)

Go to the Unsuitable Geology layer and turn it on. Go to the Unsuitable Geology filter. Open in and click "Select all".

You should now have a map with 3 active layers.

Question: How intuitive/easy to grasp was this process? (0 point)

- very intuitive 1
- intuitive after trying it out once 4
- intuitive only after following the instructions specifically 3
- not particularly intuitive 0
- hard to follow 1
- very difficult to understand 0



9. Please expand a bit more on the intuitiveness of the above step. (one or two sentences about how you have found the experience so far!) (0 point)

[More details](#)

5  
Responses

Latest Responses

"Straightforward and easy to follow."

"the thing I always manage to forget is its a three stage process, I consisten..."

...

10. Step 9: So far, these layers show vibrations. So we should look for areas AWAY from the coloured spots. However, let's now look at Suitable Geology. Go to the Suitable Geology layer and turn it on. Now go to the Suitable Geology filter and select FELSIC-ROCK.

Suitable Geology shows up in green. We want our monitoring station to be on good geology. Move the map to the large central Felsic Rock section at around a 2km zoom (town name shown as Tillybirloch). Go to the feature dropdowns (top right) and select Onshore Wind Turbines from Monitoring & Energy Sites.

[More details](#)

Ah! There's a wind turbine here (green triangle as shown in the legend). We should check its details. Go to the Suitable Geology layer (don't touch the filter) and turn it off. Now click on the wind turbine. We can see the site is called "Easter Tolmauds".

Now turn on the Suitable Geology layer again. Our Felsic Rock selection remains active.

Question: How intuitive was this section? (0 point)



11. Please expand a bit more on the intuitiveness of the above step.  
(one or two sentences about how you have found the experience so far!) (0 point)

[More details](#)

2  
Responses

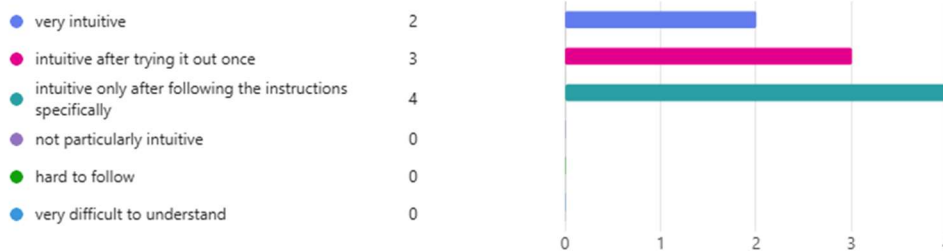
Latest Responses  
...

12. Step 10: Let's find a suitable area to put your monitoring sensor. It should be within the Felsic Rock area, away from the other sources of vibration and away from the wind turbine. Go to the measuring tools in the top left of the map (small wrench symbol), click on Measure Area (the second option). Now use the tool to decide a suitable area by clicking and placing points. Once you've created a shape, press Enter on your keyboard to lock it.

We can examine this chosen area in more detail. Go to the layers on the right side and turn all of them off (not the bottom three - they always stay on). Zoom into your area. We need to know how to get to this area. Go to Infrastructure Routes & Rivers and select B Roads and Unclassified Roads. Now we can see access options. [More details](#)

Now go to basemaps (right hand side, symbol of four squares) and click on Imagery. We can now see what the area is in real life with the roads highlighted!

Question: How intuitive was this section? (0 point)



13. Please expand a bit more on the intuitiveness of the above step. (one or two sentences about how you have found the experience so far!) (0 point) [More details](#)

2  
Responses

Latest Responses  
...

14. Step 11: To reset everything, go to basemaps and change it to Topographic. Turn off Onshore Wind Turbines, B Roads and Unclassified Roads. Click the small Measure Area button in the top left to turn off your area drawing.

Next, I want to gather your opinion on filter slider designs. I have four designs. They are implemented in A Roads, B Roads, Motorways and Unclassified Roads.

Now that you know how the dashboard works, move to Edinburgh. Zoom into a 1km view. Try turning on the Roads layers and testing out the sliders to see which is the most intuitive. (Unclassified roads won't show any changes as it's too dense, however, you can still try out the feel of the slider). [More details](#)

Question: which slider design do you like the best? (0 point)

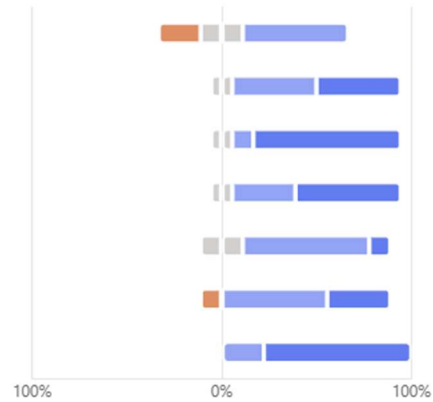


15. Thank you for participating in the main testing. The final section will be asking about your overall user experience. Please select an option for the statements below: (0 point)

[More details](#)

● Not at all ● A little ● Somewhat ● Quite a bit ● Very much

- The dashboard was easy to use
- The sliders and filters worked as expected
- The map loaded quickly enough for comfortable use
- The colours and symbols made it easy to interpret the map
- The overall design of the dashboard was clear and user-friendly
- The dashboard effectively communicated areas of suitability
- I would prefer this interactive dashboard to a static map



16. Finally, in one or two sentences, please describe

- 1) What you liked most about the dashboard.
- 2) Anything that made the dashboard difficult to use/potential improvements? (0 point)

[More details](#)

5  
Responses

Latest Responses

"1)It saves me lots of time. 2) possibly a reset to factory defaults option?"

...

17. Thank you so much! You have now finished the testing survey. Your responses are very valuable, as I will be using the m to directly evaluate my dashboard in my dissertation results section.

Before submitting the survey, please write below what model and date (if possible) of computer you used to test the dashboard (e.g. Macbook Air, 2023) [More details](#)

Thank you! (0 point)

7  
Responses

Latest Responses

"Dell latitude laptop"

...

## Appendix C

### Format and Description of Data.

The table below provides a list of content of the data and files used in the project, located on the University of Edinburgh's Geosciences server (M: Drive). All folders and files can be accessed at:

**\\students.geos.ed.ac.uk\s2748693\diassfinal**

#### Contents of the M: Drive

<b>Title</b>	<b>Description of Data</b>	<b>Format</b>
ArcGIS Map	Folder containing the ArcGIS Pro project files used for data processing and exporting web layers for online use.	ArcGIS Pro File .aprx .gdb .lyrx .xml
Source Files	Folder containing subfolders of downloaded spatial datasets used in generating buffer and feature layers for the dashboard.	CSV Files Shapefiles GeoTIFFs
Testing and Bugs	Folder containing ArcGIS Pro project files created during the testing and iterative development phase.	ArcGIS Pro File .aprx .gdb .lyrx .xml