Application Form for World Centre of Excellence on Landslide Risk Reduction 2023-2026

1. **Name of Organization**
   British Geological Survey

2. **Name of Leader**
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Core members of the activities, Names/Affiliations:
Paul Wilkinson, Principal Geophysicist, BGS
Oliver Kuras, Head of Environmental & Engineering Geophysics, BGS
Luke Bateson, Head of Geodesy & Remote Sensing, BGS
Marcus Dobbs, Head of Engineering Geology, BGS

3. **Date of Submission of Application**
   28 March 2023

4. **Activity scale and targeted region.**
   1) Global, 2) Intercontinental, 3) Continental, 4) Regional, 5) National
   Global relevance – developing geophysical tools and technologies for international deployment.

5. **Short Title characterizing past and planned activities (10 words maximum)**
   Integrated geophysical-geotechnical monitoring technologies for local scale landslide early warning

6. **Objectives for 3 years: (5 lines maximum; what you expect to accomplish?)**
   The objectives of this project are to explore and improve the resolution and reliability of geophysically-derived slope condition information to inform: (1) monitoring installation design; (2) sampling strategy; (3) geomechanical models of slope stability; and (4) early warning and decision support. We will use geophysical infrastructure and data from an international network of landslide observatories, coupled with laboratory testing, to relate geophysical and geomechanical parameters.

7. **Background Justification: (10 lines maximum)**

Geophysical imaging technologies are emerging as a means of spatially characterizing and monitoring subsurface precursors to landslide events (e.g. Uhlemann et al., 2017). They can complement geodetic and geotechnical approaches by 'seeing-inside' unstable slopes to identify the hydraulic drivers of failure. Although proof-of-concept has been established for several key techniques (e.g. geoelectrics, seismics – see references for examples), further work is required to translate geophysical observations into quantitative geomechanical information (e.g. moisture-content, pore-pressure, shear-strength) that can be used directly in the management of landslide hazard. Our hypothesis is that suitably calibrated geophysical models can enable quantitative assessments of slope condition at the spatial scales required for landslide early-warning. Our overarching aim is to shift the geophysical monitoring of landslides from the research sphere towards providing quantitative decision-support information for practical hazard management.

8. **Resources available for WCoE activities**

Personnel, Facilities, Budgets, and Affiliation and Contribution to ICL/IPL andKLC2020.

The British Geological Survey (BGS) is the UK's principal supplier of objective, impartial and up-to-date geological expertise and information for decision making for governmental, commercial and individual users. The BGS carries out research and innovation in strategically important areas including in geohazards and earth system science, often in collaboration with the national and international scientific academic community. Activities for the WCoE will be coordinated through the BGS Shallow Geohazards & Earth Observation (SGEO) Capability (which includes the Engineering Geology, Geodesy & Remote Sensing, and Environmental & Engineering Geophysics teams). The SGEO capability has the following research infrastructures available for the WCoE:

- State-of-the-art laboratories for geophysical and geomechanical property characterization, instrumentation development, and landslide processes simulation.
- High Performance Computing cluster and access to range of geophysical, groundwater, remote sensing and slope stability modelling codes.
- Geophysical (electromagnetic, radar, electrical seismic, gravity), geodetic (UAVs, LiDAR, GNSS etc.) and ground investigation equipment (drill rig, penetrometers etc.) pool for sampling, surveys and monitoring activities.
- Landslide observatory network comprising instrumented research sites on unstable slopes, the primary example being the Hollin Hill Landslide Observatory, which has been continuously monitored for the last 15 years (e.g. Kelevitz et al., 2022; Uhlemann et al., 2017).

In addition, BGS is enthusiastic to host visiting researchers affiliated to ICL/IPL.

9. **Description of your past activities related to risk reduction of landslides and other related earth**

system disasters (30 lines maximum)

The BGS Shallow Geohazards & Earth Observation (SGEO) section has a long-term program of research to enhance societal resilience to ground instability hazards including landslides, coastal erosion, karst and shrink-swell (https://www.bgs.ac.uk/geology-projects/landslides/). This encompasses UK and international landslide hazard and susceptibility mapping (inland and coastal), trigger threshold values determination, the development of novel geophysical, geodetic and geotechnical techniques, natural landslide field laboratories (or observatories), and slope stability modelling. Specific research topics of particular relevance to this application include:

Natural field laboratories (observatories) on landslides. We have developed a network of inland and coastal landslide observations extending across the UK and internationally. The observatories enable long-term landslide research allowing measurements across multiple seasonal cycles. Crucially these observatories serve as a test bed for the development of a range of novel characterization, monitoring and early warning technologies and methodologies. They have also served to facilitate collaborations with international researchers at Amrita University, India (Ramesh, M.V., Thirugnanam, H.), Canadian Geological Survey (Bobrowsky, P, Huntley, D), Lawrence Berkeley National Laboratory, US (Uhlemann, S), and many others – enabling a wider range of geomorphological and climatological settings to be considered, extending from lowland landslides in temperate UK conditions (Uhlemann et al., 2017) to mountainous and monsoonal regions in southern India (Watlet,… & Ramesh, 2022). Funding/resources: UK National Capability, Natural Environment Research Council (NERC) PhD studentships.

Geophysical imaging of landslide processes. A core focus of BGS research is the development of electrical geophysical technologies for subsurface imaging and monitoring. The key advantage of electrical methods for landslide monitoring is their sensitivity to moisture driven processes. We have driven developments in geoelectrical monitoring instrumentation (Chambers et al., 2022), integrated geophysical and geodetic sensing (Kelevitz et al., 2022), process understanding and linked geophysical-geomechanical modelling for slope stability assessment (Uhlemann et al., 2017). Funding/resources: UK National Capability, UK Research & Innovation (UKRI) research grants, Natural Environment Research Council (NERC) PhD studentships.

Landslide early warning systems (LEWS). We have developed a scheme for incorporating geoelectrical observations into slope scale LEWS (Whiteley et al., 2021). This scheme has been developed and validated using our landslide observatory network, and in particular the Hollin Hill Landslide Observatory. Funding/resources: Natural Environment Research Council (NERC) PhD studentship.

10. Planned future activities /Expected Results: (20 lines maximum; work phases and milestones)

Activity 1 – Petrophysical transfer functions (PTFs): We will seek to relate geophysical properties (e.g. resistivity, shear wave velocity) to geomechanical properties (e.g. moisture content, pore pressure, shear

strength) – thereby developing new PTFs with which to translate field-scale geophysical observations into geomechanical property distributions (see Activity 2). This will involve laboratory measurements of samples from a range of field sites and developing and extending existing testing schemes. Results: New PTFs for key lithology types. Publication: Peer-reviewed article (target publication – P-LRT) on PTFs in the context of landslide monitoring (2024).

Activity 2 - Field-scale sampling, measurement and monitoring: We will utilize data sets from our landslide observatory network to validate PTFs at the field scale and produce new geophysically-derived models of geomechanical property distributions. These will be used as inputs into near-real-time models of slope stability (see Activity 3). Results: Dynamic field scale geophysical-geomechanical models for input into slope stability models. Publication: Peer-reviewed article (target publication - Landslides) on dynamic geophysical-geomechanical monitoring of landslides (2025).

Activity 3 – Geophysically-informed models of slope stability: We will use geophysical models calibrated with laboratory-derived PTFs (see Activities 1 & 2) to inform geomechanical models of slope stability – which will be validated against slope failure events observed at the test sites using a suite of geodetic and geotechnical observing approaches. Results: Validation of linked geophysical-geomechanical modelling workflow at slope scale. Publication: Peer-reviewed paper (target journal - Landslides) on geophysically-informed slope stability modelling (2025).

Activity 4 - Visualization and decision support: We will explore and develop web-based visualization and decision support tools for use by stakeholders and end-users (e.g. consultants, engineers, decision makers). In particular, we will focus on the development of web-dashboards for near-real-time information delivery and decision support – in a form that is intelligible and accessible to decision makers. Publication: Peer-reviewed article (target publication – P-LRT) on geophysical decision-support tools for local LEW (2026).

11. Beneficiaries of WCoE: (5 lines maximum; who directly benefits from the work?)

Government/public sector: National & local government departments and agencies. Industry: Geotechnical asset owners, consultants and contractors responsible for the management of unstable slopes; insurance industry. Academic: Including research groups, societies and students able to access novel landslide research infrastructure. Wider society: Communities and businesses impacted by landslides who will benefit from improved early warning.

12. References: 10 lines maximum, i.e., relevant publications, international/regional/national recognition supporting items 9-10.

Chambers, J. et al. [2022] Long-term geoelectrical monitoring of landslides in natural and engineered slopes. *The Leading Edge* 41, 768-776.

Huntley, D. et al. [2019] Application of multi-dimensional electrical resistivity tomography datasets to investigate a very slow-moving landslide near Ashcroft, Canada. *Landslides* 16(5), 1033-1042.

Kelevitz, K, et al. [2022] Ground and Satellite-Based Methods of Measuring Deformation at a UK Landslide Observatory: Comparison and Integration. *Remote Sensing* 14(12).

Uhlemann, S., Chambers, J. et al. [2017] Four-dimensional imaging of moisture dynamics during landslide reactivation. *Journal of Geophysical Research: Earth Surface* 122(1), 398-418.

Watlet, A., … & Ramesh, M.V.. [2023] 4D electrical resistivity to monitor unstable slopes in mountainous tropical regions: an example from Munnar, India. *Landslides* (in press).

Whiteley, J. S. et al. [2021] Brief communication: The role of geophysical imaging in local landslide early warning systems. *Natural Hazards and Earth System Sciences* 21(12), 3863-3871.

13. If your organization is an ongoing WCoE 2020-2023, please attach the articles as pdf files reporting activities of WCoE, IPL project and ICL network published/contributed or a list of planned reports of WCOE 2020-2023 to either journal "Landslides" or/and "P-LRT books."

(Those organizations with no activity report/no achievement in WCOE 2020-2023 will not be accepted as the candidate of WCOE 2023-2026 to be submitted to the Independent Panel of Experts for WCOEs.)

This is a new application (and is not associated with an ongoing WCoE).

Note: Please fill and submit this form by 30 March 2023 to **KLC2020 secretariat** <klc2020@iclhq.org>