Institution: University of Glasgow

Unit of Assessment: B7 Earth Systems and Environmental Sciences

a. Context

a1. Beneficiaries of our work: The Earth Systems Research Group (**ESRG**) has created impact through a wide range of non-academic users in the UK and overseas. Beneficiaries include mineral and hydrocarbon exploration companies (e.g. Boliden Tara Mines; ENI exploration & production; Noventa; Shell; Tsodilo Resources), businesses that develop and market scientific equipment and software (e.g. Sarmap; Thermo Fisher Scientific), utility companies (e.g. British Nuclear Fuels; Cluff Geothermal; Forth Ports; Pacific Oil and Gas; Scottish Power), government agencies (e.g. China Earthquake Administration; DEFRA; English Heritage; Food Standards Agency; Historic Scotland; Scottish Natural Heritage; UK police forces & customs), trans-national bodies (International Atomic Energy Agency), charities (e.g. Oxfam), consumers, and the general public.

a2. Main types of impact: The ESRG integrates researchers from the School of Geographical and Earth Sciences (**GES**) and the Scottish Universities Environmental Research Centre (**SUERC**). The work of the 36 GES and SUERC staff returned to UoA7 is directed through 4 process-based themes: surface; shallow crust; Earth-life; extraterrestrial and mantle. Surface process research has had impact on: (i) the environment (development and application of policy, assessment of damage from fluvial and coastal erosion and construction, monitoring of accidental releases of radionuclides); (ii) health (setting of international standards for identification of irradiated food); (iii) businesses (evaluation of damage to infrastructure from natural hazards); and (iv) law enforcement (identification and dating of human and animal remains). Economic impacts of the shallow crust theme include providing specialist skills and training for resource exploration, and Earth-life research has had impact on the environment (development of policy). All 4 themes have benefitted society and culture by stimulating public interest in science, and enhancing teaching in schools.

b. Approach to impact

Research-derived impact is integral to the mission of the University of Glasgow (**UoG**), as stated in its strategic plan 'Glasgow 2020: a global vision'. The 20 years of research that underpins our impact case studies demonstrates how external user engagement is central to the culture of the ESRG. Throughout this time we have nurtured strong relationships with key partners, and evidence for how we have instigated and developed these associations during the assessment period is provided below with exemplar impact highlights.

b1. Strategic partnerships with industry: A successful pathway to impact has been via formal knowledge transfer (KT) partnerships whereby ESRG staff work with company personnel and train industry-funded PhD students and postdoctoral researchers. We currently have 2 key partnerships:

- The **FRACS** network was established in 2010 with €1M from the German Society for Petroleum and Coal Science. The network is led by ESRG (Koehn), and works with international oil companies to understand fluid flow in heterogeneous, fractured and resealed reservoirs.
- The **Volcanic Margins Research Consortium** is a venture between UK universities, research institutes and 6 international hydrocarbon companies. ESRG's Bell and D. Brown are consortium members, and via field courses and workshops they train industry partners to interpret volcanic sequences and so enhance the partners' ability to find resources in fields such as those to the west of Shetland.

Specific ESRG research strengths have also acted as a catalyst for industry collaborations. Areas of current work include: (i) Base metal exploration in Ireland (Boliden Tara Mines with Boyce and a fully funded ESRG PhD student); (ii) Development of multi-collector static vacuum mass spectrometers (Thermo Fisher Scientific with Mark and Stuart); (iii) Incorporation of vapour correction models into SARscape interferometry software (Sarmap with Li - the company currently has 400 active licences for this SARscape software, half of which have been sold outside Europe).

b2. UoG support for KT with industry: Support from the UoG **EPSRC KT account** (£2.5M; 2009-2012) has enabled industry to successfully work with ESRG researchers. In 2012 we received funds to employ a consultant to give our materials analysis centre (ISAAC) greater industry focus. Since its inception in 2012, ISAAC has had over 30 contracts with businesses including Fugro GEOS, Lombard Medical and Woodward Aircraft Engine Systems. Scottish SMEs

have also drawn on ESRG expertise via **First Step Awards**, which are innovation vouchers funded by the UoG-led £1.9M Encompass programme (supported by the Scottish Funding Council (SFC), Scottish Enterprise and the European Regional Development Fund). Encompass has £400k to support initiatives in 3 universities, and in 2012 four ESRG projects were supported:

- Development of the GeoloGIS geospatial database (*GeoloGIS* with Forrest),
- A new methodology for measuring flow velocity (*River Energy Systems* with Hoey),
- An assessment of the use of atomic dielectric resonance to monitor landslides (*Adrok* with Li),
- Evaluating kriging for interpolation of reservoir simulation models (*Sciencesoft* with R. Brown).

The last of these projects has developed into a joint research programme between *Sciencesoft*, R. Brown and the UoG School of Engineering funded by £100k from the Technology Strategy Board.

b3. Research Council supported partnerships: Mutually beneficial partnerships between research users and ESRG have been developed via the **NERC Knowledge Exchange fund**. The Carbon Landscapes and Drainage (CLAD) network was founded in 2009 by Waldron with £183k from the fund. This support enabled the establishment of a dialogue between academics and 29 partners from industry and government agencies who manage peatlands. Following its success in the UK the CLAD model has been adopted by the Malaysian government and industry. Waldron's research into the loss of carbon to wind farm drainage systems has also been integral to the revision of the Scottish Government's Carbon Calculator tool, introduced in 2011. More than 200 people working in renewable energy in Scotland and Malaysia have been trained to use the tool and so to understand carbon loss from peatlands during wind farm construction.

Government bodies and industry have developed beneficial and lasting relationships with the ESRG through **CASE studentships**, and KT has been maximized by student placements with the partners. Over the review period we have held 3 NERC studentships, which have been co-funded by Historic Scotland and Midland Valley (a Scottish SME), and an EPSRC studentship with Scottish Natural Heritage. Following successful completion of their CASE project, Historic Scotland fully funded a PhD student and postdoctoral researcher to help develop a strategy for protecting the built heritage from the impacts of climate change. Results are being communicated directly to Historic Scotland and stakeholders (e.g. architects) via a series of user workshops.

b4. Setting user agendas: Through membership of advisory boards we provide scientific evidence to underpin policy, and these roles have also given ESRG researchers the opportunity to explore new routes for KT. We currently advise the Centre for Ecology and Hydrology (Waldron is on the Science Development Group to advise on science strategy), Oxfam *(*Hansom is their coastal science and sustainability advisor*),* the Scottish Government (Stuart and Waldron are members of the Unconventional Oil and Gas panel) and Scottish Natural Heritage (Hansom is coastal processes and morphology consultant for the National Renewables Infrastructure Projects).

b5. Outreach: The ESRG is committed to using its research to inspire members of the public of all ages and socio-economic groups. The UoG media relations office is an effective pathway with an international reach; for example a 2013 *Nature Communications* paper published by Lee and Mark was featured by BBC News Online (receiving >150,000 hits in the first 2 weeks) and 14 other news outlets. Audiences worldwide have learned about Hansom's work on protecting coastal dunes in Aberdeenshire via the award winning movie 'You've Been Trumped'. ESRG has also stimulated public interest in science by talks to amateur groups throughout the UK. Our outreach programme includes the 'Solar System Rocks' workshop, which was established with a **STFC Science in Society** award. It has reached audiences of ~2000 at the Edinburgh, Glasgow and Orkney science festivals, and engaged people who do not normally attend such events via 'pop-up' workshops in shopping centres. Another pathway that is very important to us is enhancing geography teaching in schools. We hold an annual in-service day for ~100 teachers where they learn about the latest research, give an annual Christmas lecture that is attended by 300 high school students and teachers, and run a summer school for pupils from disadvantaged parts of Glasgow.

c. Strategy and plans

The ESRG's approach to increasing the volume, reach and significance of its impact activities is informed by and builds on the UoG's 'Impact and Knowledge Exchange Strategy 2013-2016'.

Specifically we have a three-fold plan to sustain and develop an environment that enables innovation, creativity and enterprise to flourish.

c1. Pooling skills: The ESRG is establishing 2 knowledge exchange nodes that will pool expertise to the benefit of research users. The *hazards and environmental change* node combines our world leading capability in determining the frequency and effects of natural hazards (e.g. earthquakes), measuring and mitigating the impact of environmental change (e.g. coastal erosion) and monitoring radionuclide contamination. The *energy* node will capitalise on our new research capability in hydrocarbon exploration and geothermal power coming from investment in staff (e.g. D. Brown; Koehn) and infrastructure, including the SUERC gas analysis facility. There are also many opportunities for impact from this node via a series of national oil and gas initiatives (see below).

c2. Exploiting knowledge exchange initiatives and facilities: The UoG College of Science and Engineering business development team provides guidance for industry, communities and policy makers who wish to work with us, and they organize a biennial industry open day (>500 participants) at which ESRG is well represented. The business development team also has access to 2 funds to support projects with ESRG researchers. The £1.3M **Impact Acceleration Account** is for engagement relevant to EPSRC research, and is a likely route for commercialization of microbial technologies for sealing radioactive waste vaults that are being developed by Phoenix within the EPSRC-funded BANDD consortium. The £1M **Glasgow KE Fund** extends the benefits of the Impact Acceleration Account to those ESRG members funded by non-EPSRC sources, and is an ideal route for developing impact from both of our nodes. The College has long-standing procedures for exploitation of intellectual property, and has also been the first to introduce a fast-track route to maximize the uptake of research by industry known as 'Easy Access IP'. This is a free licence designed to accelerate the innovation process by getting early stage technology into the hands of businesses that can develop and exploit it quickly. Our development of analytical instrumentation is one area of KT that is set to benefit from this new approach to licensing.

The innovation centres that are being established by the SFC will be a powerful pathway for ESRG to develop new industry partnerships. The £10M UoG-led **CENSIS Innovation Centre** was founded in 2013 and will support commercialization of our current research on environmental sensors. ESRG is also a co-applicant on a well received proposal to the SFC for an **Oil and Gas Innovation Centre** (outcome announced in December 2013). If funded it will help to generate impact for our energy node, and KT with oil companies will be supported further through our membership of a NERC Centre for Doctoral Training in Oil & Gas (led by Heriot-Watt). Our 2 NERC Doctoral Training Partnerships (E3 and IAPETUS) have strong links to research users and will be a valuable means for embedding an impact culture in our graduate school, and for exploring new opportunities for user engagement.

c3. Supporting an impact culture: GES and SUERC managers are leading a culture that recognises and rewards impact by incorporating time spent undertaking KT in workload models, and by enabling researchers to use impact generation to justify study leave. User engagement is also assessed in the annual development reviews of all staff, and strong performance is rewarded by salary increments and promotion. The ESRG Research and Knowledge Transfer Committee has ~£30k at its disposal annually to pump-prime impact activities (e.g. attending industry workshops) and group members with a track record of successful engagement share best practice via one-to-one mentoring. As part of this programme the Committee has obtained funding from the EPSRC Impact Acceleration Account for a KT workshop in December 2013 that will be delivered to ESRG researchers by consultants.

d. Relationship to case studies

Our current and future impact strategies draw on the track record of user engagement that is described in our 4 case studies. The radiocarbon, food irradiation and environmental radioactivity case studies highlight how ESRG research strengths (e.g. accelerator mass spectrometry) have led to sustained and meaningful relationships. They also show how user engagement has served as a catalyst for research and technology development to underpin further impact, e.g. design of photostimulated luminescence instruments and airborne gamma ray spectrometers. The coastal management case study exemplifies the success of our work with environmental agencies and charities, and our desire to maximise its impact by engagement with affected communities.