Institution: Queen Mary University of London		
Unit of Assessment: 14 Geography and Environmental Studies		
Title of case study: Historic Coastal Landfill and Legacy Waste		
Period when the underpinning research was undertaken: 2000-2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Professor Kate Spencer James Brand	**Role(s) (e.g. job title)** Professor off Environmental Geochemistry PDRA	**Period(s) employed:** Feb 2003-Present Nov 2016-Feb 2017
Period when the impact occurred: 2015–2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

The Environment Agency identifies more than 20,000 'Historic Landfills' in England and Wales. These pre-date modern environmental regulation and waste management technologies. Research undertaken by Professor Spencer and colleagues into the extent and severity of legacy and future pollution risk of coastal historic landfills demonstrates that over 1200 sites are at risk of tidal flooding and/or coastal erosion. One in ten of these sites could erode by 2050 with significant deleterious effects to ecological health and environmentally sensitive areas. This research has (a) accelerated awareness of the issue from local to international level in government agencies and among the public, (b) directly informed changes to coastal and waste policy in the UK, Belgium and the Netherlands, and (c) contributed to the development of new best practice guidelines and recommendations for industry to manage the problem.

2. Underpinning research

The underpinning research into the pollution risks of coastal historic landfills (CHLs) builds on Spencer's work on marine pollution and the impact of disturbance events such as flooding, erosion and dredging on contaminant behaviour [3.1; 3.2]. It arises from stakeholder-driven research projects awarded to Spencer and conducted between 2011 and 2017 [EQR.3.3-3.5]. Spencer approached Arcadis (a global environmental engineering consultancy delivering sustainable management for natural and built assets) to develop a NERC CASE collaborative studentship on diffuse landfill pollution. The Environment Agency (EA) and Essex County Council (ECC) then approached Spencer to extend this work to investigate the potential for coastal realignment along the Essex coast where there are several CHLs dating from the 1930s, containing household, commercial and industrial waste. Coastal realignment involves the deliberate removal of current sea defences to allow the sea to realign landwards, in this case resulting in flooding and/or erosion of CHLs.

Two projects were devised which were academically rigorous whilst also responding to the needs of industry and government agencies for practical guidelines and evidence to inform policy making:
1) A NERC CASE award, partnered with Arcadis, [EQR.3.5] responded to a need from landfill managers and consulting engineers for evidence to assess the pollution risk from CHLs to adjacent rivers and estuaries associated with climate change (sea level rise (SLR), increased frequency/magnitude of extreme hydrological events and coastal erosion).
2) A research project funded by the EA, Southend Borough Council (SBC) and partnered by ECC [EQR.3.5] responded to the Essex and Suffolk Shoreline Management Plan, which was constrained by the unknown risk of coastal waste in several CHL sites. The project was partly delivered as a PhD (Brand, 2012–2016).

The main outcomes of these projects were as follows:
1) A national baseline dataset to indicate a) the numbers of CHL sites at risk of tidal flooding (more than 1200) and erosion (10% by 2050 if defences are not maintained to current standards) and b) the number of environmentally sensitive areas that are at risk (*c.* 30% of England's coastal Special Protection Areas, Marine Protection Areas, Ramsar sites and bathing water catchments) [3.3].

2) Evidence to demonstrate that CHLs are a source of legacy contamination in the coastal zone [3.4], and that both flooding through sea level rise and erosion would release soluble and solid waste materials to the marine environment with potential significant deleterious impacts on ecological health [3.5].

3) A new risk screening assessment method to support coastal managers and local government authorities to identify which CHLs pose the greatest pollution risk and hence where to focus remediation and management efforts [3.6].

4) The identification of key gaps in knowledge for a UK research agenda that requires new research and improved guidance for industry and stakeholders [5.1]. This has been achieved through close collaboration with the Construction Industry Research and Information Association (CIRIA), the Environment Agency, stakeholders and the University of Southampton (who carried out 'Coastal Landfill and Shoreline Management: implications for coastal adaptation infrastructure' [EQR.3.3]). The identified needs include a national risk assessment, development of new source-pathway-receptor models, knowledge on degradation and erosion of solid wastes and options for coastal landfill management within dynamic shoreline management plans (SMPs).

3. References to the research

[3.1] Spencer, K. L. (2002). Spatial variability of metals in the inter-tidal sediments of the Medway Estuary, Kent, UK. *Marine Pollution Bulletin 44*(9), 933-44. doi.org/ 10.1016/s0025-326x(02)00129-7

[3.2] Spencer, K. L., Dewhurst, R. E. and Penna, P. (2006). Potential impacts of water injection dredging on water quality and ecotoxicity in Limehouse Basin, River Thames, SE England, UK. *Chemosphere 63*(3), 509-521. doi.org/ 10.1016/j.chemosphere.2005.08.009

[3.3] Brand, J. H., Spencer, K. L., O'Shea, F. T. and Lindsay, J. E. (2018). Potential pollution risks of historic landfills on low-lying coasts and estuaries. *Wiley Interdisciplinary Reviews (WIRES): Water 5*(1), e1264. doi.org/10.1002/wat2.1264

[3.4] O'Shea, F. T., Cundy, A. B. and Spencer, K. L. (2018). The contaminant legacy from historic coastal landfills and their potential as sources of diffuse pollution. *Marine Pollution Bulletin*, *128*, 446–455. doi.org/10.1016/j.marpolbul.2017.12.047

[3.5] Brand, J. H. and Spencer, K. L. (2019). Potential contamination of the coastal zone by eroding historic landfills. *Marine Pollution Bulletin*, *146*, 282-291. doi.org/10.1016/j.marpolbul.2019.06.017

[3.6] Brand, J. H. and Spencer, K. L. (2018). Risk screening assessment for ranking historic coastal landfills by pollution risk. *Anthropocene Coasts, 1*(1), 44-61. doi.org/10.1139/anc-2018-0001

Evidence of the quality of the research

[EQR.3.3] Spencer [PI]. (2016). 3-Dimensional Floc Structure and Dynamics [NE/N011678/1]. *NERC*. GBP697,424.

[EQR3.4] Spencer [Co-I]. (2013). Measures for (non-Coal) Polluted Mine Waters [SBCH1F4R/GEGH1D6R]. *DEFRA*. GBP89,979.

[EQR3.5] Spencer [Co-I]. (2018). Saltmarsh Erosion [NE/R01082X/1]. *NERC*. RESIST. GBP328,927.

[EQR3.5] Spencer [Co-I]. (2020). Preventing Plastic Pollution [Project No: 188]. *European Commission*. GBP6,526.

4. Details of the impact

Raised awareness and understanding of coastal historic landfill pollution for national and international regulators and policy makers

Spencer's team have increased regulator and policy-maker awareness and understanding of coastal historic landfills (CHL) waste pollution at national and international levels. From 2015 to present, Spencer and Brand were invited to report findings to the United Nations, Environment Agency, Defra, TEAM 2100 (Thames Estuary Asset Management) and local government authorities. Spencer was invited to give evidence for the UN Special Rapporteur on Toxic Waste's visit to the UK (January 2017). The subsequent report was submitted to the UK Government in

September 2017 [5.2, p.12] and highlighted concerns regarding the large number of CHLs and the lack of national regulatory response and resources to assess and manage these pollution risks. Brand was invited to report to the National Local Authority Coastal Interest Group (March 2017) and East Anglia Regional Flood and Coastal Committee (Feb 2017), whilst Spencer was invited to present evidence to Defra ('Shaping the evidence for urban diffuse water pollution' 2016), the Public Policy Exchange (2016) and EU Enhanced Landfill Mining Symposium (2020).

This engagement has raised awareness locally, nationally and internationally. The East Anglia area manager of the Environment Agency stated:
> 'The new knowledge and evidence provided has raised the profile of the challenge to the most senior levels in the Environment Agency and Defra' [5.4]

and a key member of staff at the Belgian Public Waste Agency found that Spencer's 'research on historic landfills, climate change and environmental risk was an eye-opener to [the] team' [5.5]. In the Netherlands the executive agency of the Ministry of Infrastructure and Water Management found that:
> '[Spencer's] resource brought the risk of flooding's of former landfills and the potential release of pollution to our attention' [5.6].

Spencer's work has also raised the profile of CHLs at the EU Commission - 'the outputs from QMUL research were also the main driver of a (proposed) revision of the EU Landfill Directive 1999/31/EC' [5.5] – and now underpins a forthcoming EU policy brief on 'Climate Change, Flooding and Landfill Safety' (NewMine 2020) [5.11]. This new knowledge and understanding has provided the 'stimulus for [East Solent Coastal Partnership] to set up a national working group as part of the Local Government Authority Special Interest Group (LGA SIG) on landfill' [5.3] and provided local authorities with the evidence to lobby Defra for changes to policy and funding [5.3].

Informed public understanding of coastal historic landfill pollution

'The Secret Life of Landfill: A Rubbish History,' a BBC4 documentary based on this research, was broadcast twice (26th August 2018 and 1st October 2018), attracting over a million views 'The wider importance of the BBC4 documentary as a vehicle for introducing the public to new and challenging scientific issues […] has been evidenced by its critical success and public reach' [5.7]. The documentary won the 2019 Royal Television Society Scotland Award (Best Documentary and Specialist Factual: Science and Natural History) and was shortlisted for the 2019 Royal Television Society Awards (Science and Natural History) (RTS 2019) and the Grierson Awards Best Science Documentary (TernTV 2020).

The documentary received powerful reviews confirming its efficacy in bringing this topic to the public domain: 'The Secret Life of Landfill: A Rubbish History (BBC4, Thursday) was a genuine eye-opener' (Spectator 2018) [5.12]. As the presenter George McGavin says [5.7], the Queen Mary research 'provided a very convincing message and has significantly raised the profile of this problem in the national media' and led to significant traffic on social media and a very strong public response, e.g., 'What an eye opener' and 'Brilliant programme […] I think it should be shown in all schools, to children of all ages. It is their future, and they will have a huge influence on their parents to think about their own waste'.

Spencer was also invited to contribute to '800,000 tonnes: Waste Management and Recycling in Essex,' a National Lottery and Arts Council funded public programme of displays, site tours, and discussions run by Focal Point Gallery, Southend (1st – 29th February 2020). As the Deputy Director of the Focal Point Gallery stated: 'The subject matter […] Professor Spencer highlighted […] has enabled us to realise the strength of feeling on these matters across our audiences, and will influence our future exhibition programme, with discussions around a display in summer 2021' [5.8]. Furthermore, the Queen Mary 'Historic Landfill' project website has generated 19,000 views (as of October 2020).

At the national level, the profile and public understanding of the issue of CHL pollution has been raised by significant on-going media coverage generated by the research. Interviews with Spencer have formed the basis of six national news reports in The Independent: Landfill dumps across UK

'at risk of leaking hazardous chemicals' (21st February 2016); The Guardian: Pollution risk from over 1,000 old UK landfill sites due to coastal erosion (5th May 2016); The Times: Storm risk to coastal landfill sites (26th January 2018); ITV News Tyneside (23rd February 2019), BBC London News (2019), BBC Look North (November 2020), The New Statesman: Secrets of the shore: the landfill rubbish laid bare by the sea (30th October 2019); Daily Mail: Plastic rubbish from five decades of pollution flows into the Thames as old landfill site full of toxic waste is exposed to erosion (6th November 2019), Daily Mirror: Landfill site exposed by coastal erosion sees toxic chemicals leak into rivers (6th November 2019); and features on radio and TV: BBC Radio 4 File on Four: What Lies Beneath: The Legacy of Landfill (20th June 2017) and Countryfile BBC1 (9th December 2018) [5.12].

Changed practice and policy at local and national levels in the UK, Belgium and Netherlands

This research has directly informed local shoreline management practices in Essex and South Suffolk and the Thames Estuary, in areas where coastal waste is present, at risk from either tidal flooding and/or erosion and is currently constraining coastal asset management decisions. This management problem was identified in the Essex and South Suffolk Shoreline Management Plan (SMP) and the Thames Estuary 2100 Plan, and it was noted that 'to deliver the actions in the SMP the Environment Agency have commissioned a PhD with Queen Mary University of London to identify pilot areas of contaminated land at flood risk' [5.9, p.168]. One of the study sites Spencer and team investigated was Hadleigh Marshes, Thames Estuary that was identified in the SMP as a candidate for Managed Realignment. The research identified significant risks to the marine environment should the site be flooded or breached [3.5]. As the Environment Agency area manager noted:

> '[s]ince [the] QMUL research, a policy decision has been taken that Managed Realignment is no longer a viable option here because of the quantified rise of large-scale release of pollutants to the marine environment' [5.4].

Spencer and her team's proposed risk screening assessment [3.6] has also now been trialled at a national level on high risk sites by the Environment Agency [5.10] and has informed the work of the East Solent Coastal Partnership [5.3].

The presence of solid wastes in coastal, alluvial and fluvial settings is also a global problem. As the testimonials from the Rijkswaterstaat (RWS) and the Public Waste Agency of Flanders (OVAM) show [5.6, 5.5], Spencer's work led to both the Netherlands and Belgium carrying out national assessments of their landfill datasets to determine potential flood and erosion risk:

> '[i]nspired by QMUL's research and using approaches set out in Brand et al. (2017) [3.3], OVAM performed a GIS-analysis on its national landfill database to estimate the number of landfills vulnerable to coastal erosion and flooding' [5.5]; and
> '[s]ince engaging with Prof Spencer's research we [RWS] have now also carried out an assessment of our national datasets on landfills to explore and quantify which are at risk' [5.6].

The research has also provided the evidence to trial landfill mining (reclamation of buried waste) in Flanders: 'OVAM identified two pilot landfill sites in alluvial areas at flood risk to test the possibility of eliminating/mining landfills' [5.5]. The research has, therefore, changed national policy outside the UK. In Flanders:

> '[r]esearch and findings carried out by Prof Spencer's team at QMUL on historic landfills has had a significant impact on policy and policy makers in the Flemish region (and) led to the inclusion of historic landfills in the planning process for flood risk control and amendment of our national landfill management policy' [5.5].

Changed industrial understanding of coastal historical landfill pollution to inform guidelines

The research has also increased industry awareness and understanding through meetings and stakeholder engagement at a national level with invited talks at Environment Analyst Business Summit: Waste Management (May 2019), the Construction Industry Research and Innovation

Association (2015, 2019) and the Institute of Civil Engineers. In addition, Spencer and O'Shea delivered an international webinar to Arcadis (2015), as part of their professional development programme for their consultants and engineers. Findings have also been reported in national industry publications; The ENDS Report: Landfill: What lurks beneath (23rd September 2016) and The ENDS Report: One in ten historic landfills at risk of releasing waste (21st November 2017).

In 2013, the CIRIA – the independent, not for profit provider of good practice guidelines for the construction industry, local authorities and the EA – presented its 'Guidance on the management of landfill sites and land contamination on eroding or low-lying coastlines' [5.9]. This identified that outputs from Queen Mary's research would help develop evidence-based scenarios and guide national policy in future iterations of the guidance [5.9, p. 167-8]. A supplement to this guidance has been published [5.1] and is 'informed by an Environment Agency funded project (Brand, 2017) and other relevant research at Queen Mary University of London (Appendix 1), which focussed on diffuse pollution and potential contamination from eroded waste for coastal landfill sites in Essex'. The specific recommendations based on the Queen Mary research involve the need to develop methods to: 1) determine the magnitude, transport and impact of eroded solid waste and the response of leachate mobility to increasing salinity, 2) quantify transport mechanisms and harm to environmental receptors, and 3) assess risk of environmental pollution from erosion of coastal landfill sites.

5. Sources to corroborate the impact

[5.1] [Guidance] CIRIA (2019) Guidance on the management of landfill sites and contamination on eroding or low-lying sites. Supplementary Guide. SP169, RP963, ISBN 978-0-86017-932-0. (piv, p1).

[5.2] [Report] United Nations Human Rights Council (2017) Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes on his mission to the United Kingdom of Great Britain and Northern Ireland, Thirty-sixth session, 11-29 September 2017, Agenda item 3, A/HRC/36/41/Add.1, pp 22.

[5.3] [Testimonial] Coastal Policy, Strategy & Environment Team Manager, Eastern Solent Coastal Partnership, Havant Borough Council. [Corroborator 1]

[5.4] [Testimonial] Area Coastal Manager, Environment Agency, East Anglia. [Corroborator 2]

[5.5] [Testimonial] Senior Advisor, Openbare Vlaamse Afvalstoffenmaatschappij - Public Waste Agency of Flanders (OVAM) [Corroborator 3]

[5.6] [Testimonial] Head of Soil and Subsoil (Afdelingshoofd Bodem en Ondergrond), Rijkswaterstaat (executive agency of the Ministry of Infrastructure and Water Management), Netherlands.

[5.7] [Testimonial] Presenter and Broadcaster, Oxford University Museum of Natural History. [Corroborator 4]

[5.8] [Testimonial] Deputy Director, Focal Point Gallery, Southend. [Corroborator 5]

[5.9] [Guidance] [Testimonial] Guidance on the management of landfill sites and land contamination on eroding or low-lying coastlines, CIRIA, C718 (ISBN: 978-0-86017-721-0). London: www.ciria.org; 2013. 198 p.

[5.10] [Report] Environment Agency (2018) Identifying sites of high pollution risk using a novel risk screening assessment. Report commissioned by the Environment Agency's Research, Analysis and Evaluation Group.

[5.11] [Policy Brief] KU Leuven Institute for Sustainable Metals and Minerals. https://kuleuven.sim2.be/new-mine-policy-brief-climate-change-flooding-and-landfills/

[5.12] [Media] Portfolio