

The Sellafield Contaminated Land and Groundwater Management Project: Characterisation of a Complex Nuclear Facility

Julian Cruickshank

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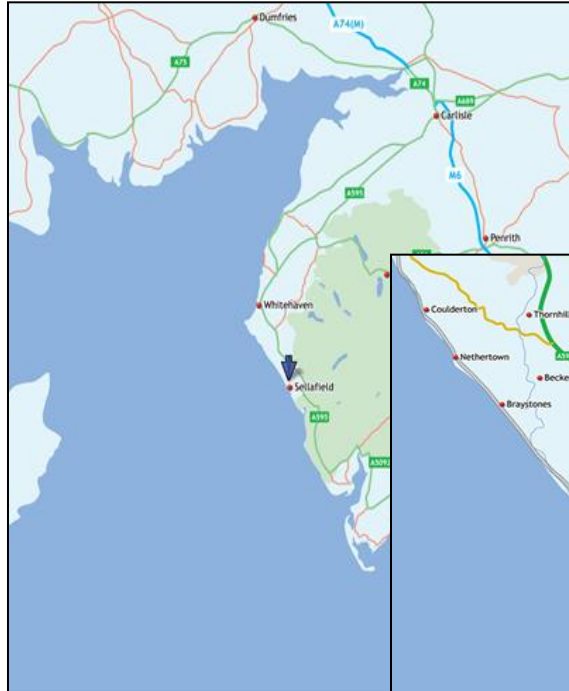
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Presentation Outline

- Background to Sellafield Land Quality Management
- Design of Site Investigation Strategy and Techniques
- Site Investigation Performance and Findings
- Summary of How Results will be Used in Future Management

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Sellafield Site



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Land Quality

Sellafield Today



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Introduction

- During the industrial history of the Sellafield site there have been a number of leaks, spills and burials which have resulted in the contamination of soil and groundwater
- Sellafield Ltd is committed to a programme to manage this historical contamination. This is to ensure protection of the Sellafield work force, the public and the environment.
- The overall goal is to ensure that contaminated ground and groundwater on site are controlled such that the risks associated with them are acceptable and commensurate with the agreed use of the land

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History of Sellafield Operations

- 1941 – 1946: WWII Royal Ordnance Factory for production of TNT
- 1947: Site adopted to support production of atomic weapons materials
- Early 1950's: Development of world's first power generation reactors (Calder Hall)
- Two further generation of plants have followed for the reprocessing of commercial reactor Magnox and Oxide fuels
- Current Status
 - Reprocessing Operations
 - Waste management
 - Decommissioning
 - Potential nuclear new-build site

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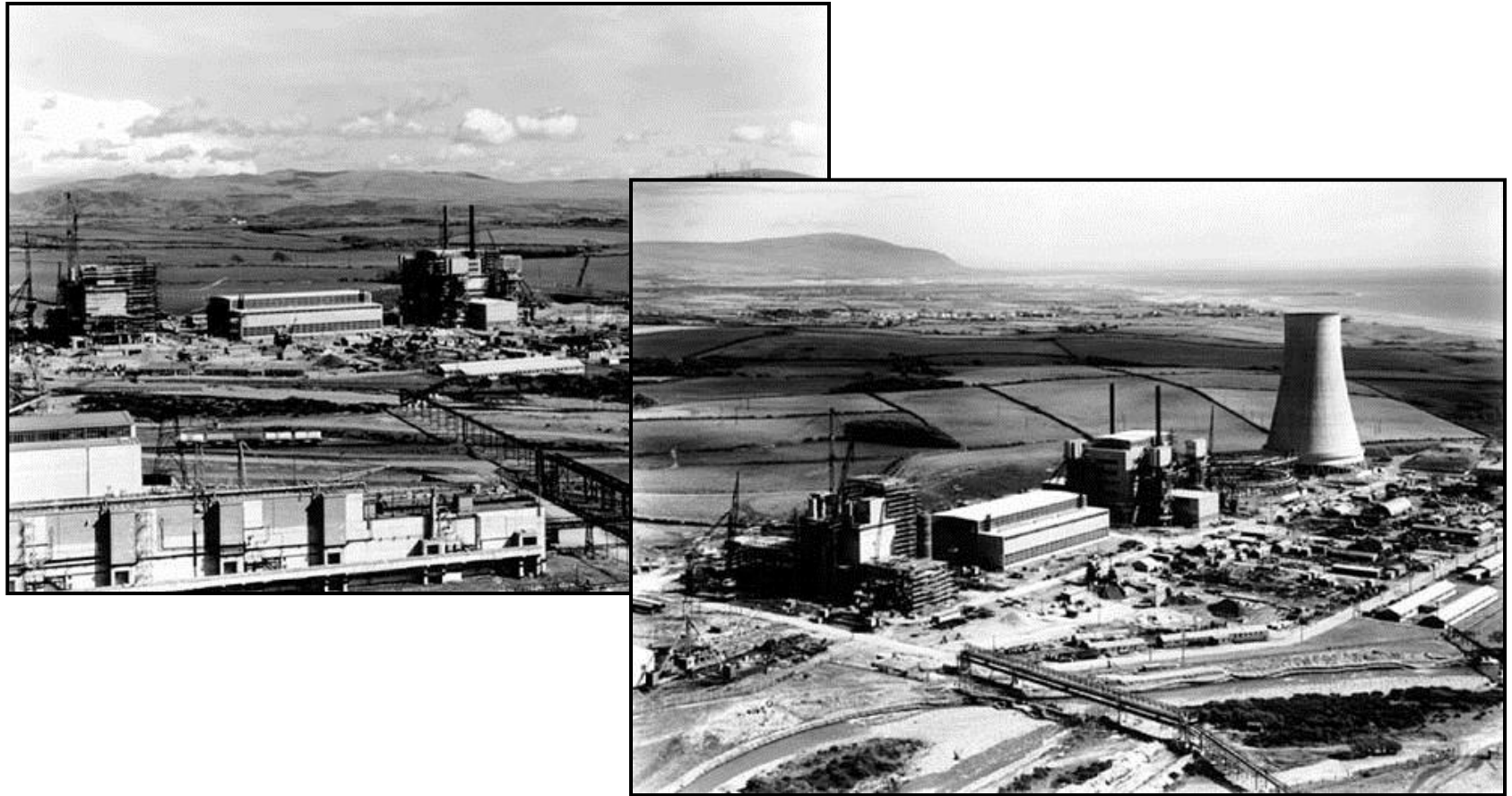
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Sellafield - an Ammunition Factory in 1940



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Construction of Calder Hall Magnox Reactors 1953



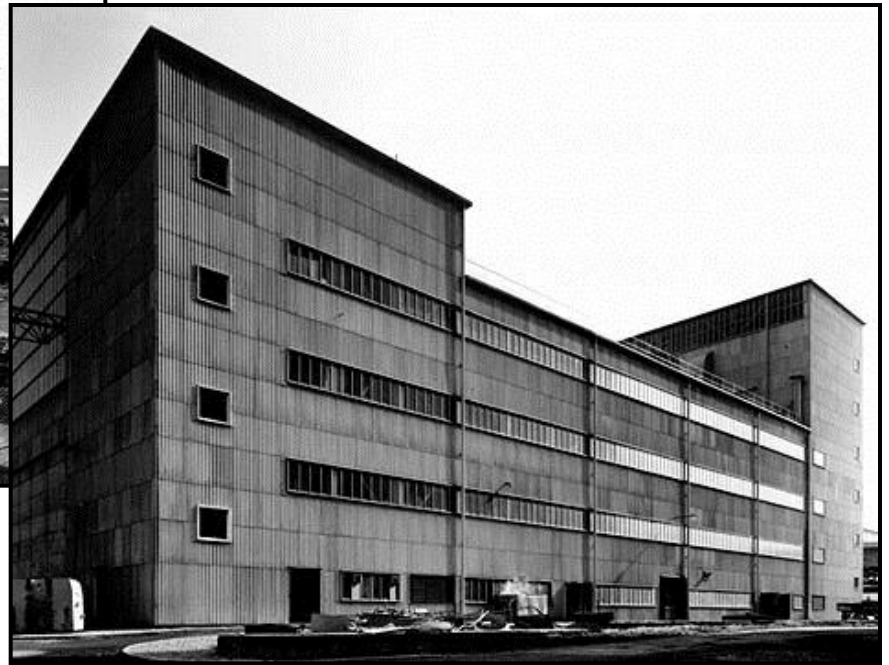
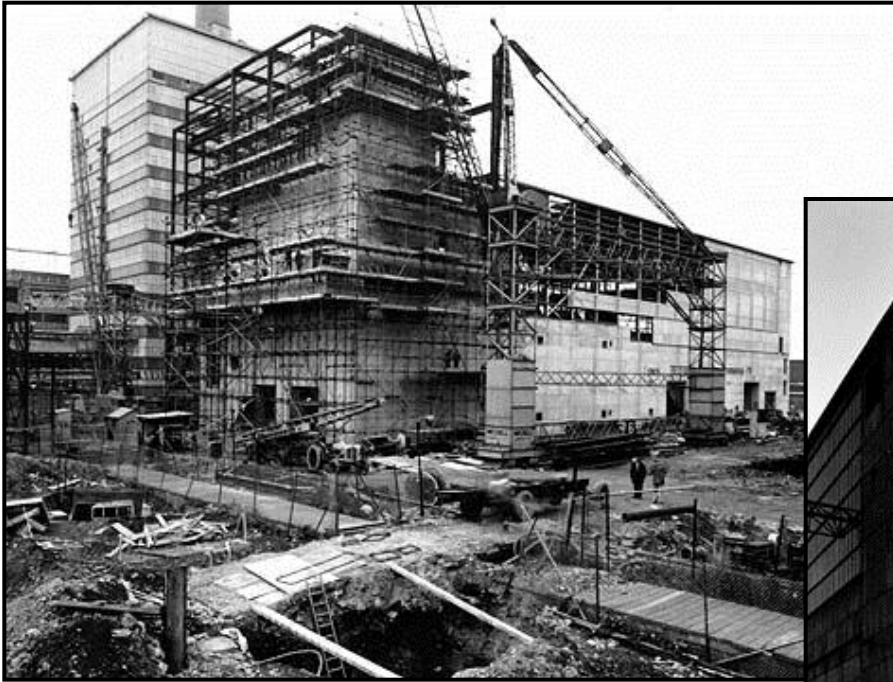
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Construction of the Prototype Gas Cooled Reactor 1958-63



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Magnox Reprocessing Plant Construction 1964



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Legacy Ponds



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Contaminated Land at Sellafield

- Legacy of 70 years of Industrial activity
- Lifetime Plan estimates of £3 Billion for dealing with the soil and groundwater contamination
- Major contaminants include Caesium-137, Strontium-90, Tritium, Technetium-99 and Plutonium-239.
- Potentially over 13 Million m³ of soil classed as radioactive waste
- Timescales for remediation run to 2120

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Previous Contaminated Land Investigations

- 1970s – 2000 Focussed investigations on leaks and reconnaissance scale overview of ground conditions
- 2001 -2004 Systematic characterisation of ground and groundwater outside Main Process (Separation) Area
- Conceptual models of geology, hydrogeology and contaminant transport developed
- Network of groundwater monitoring boreholes installed
- Concluded that few sources of ground or groundwater contamination located outside Separation Area
- Groundwater plumes observed extending towards site boundary

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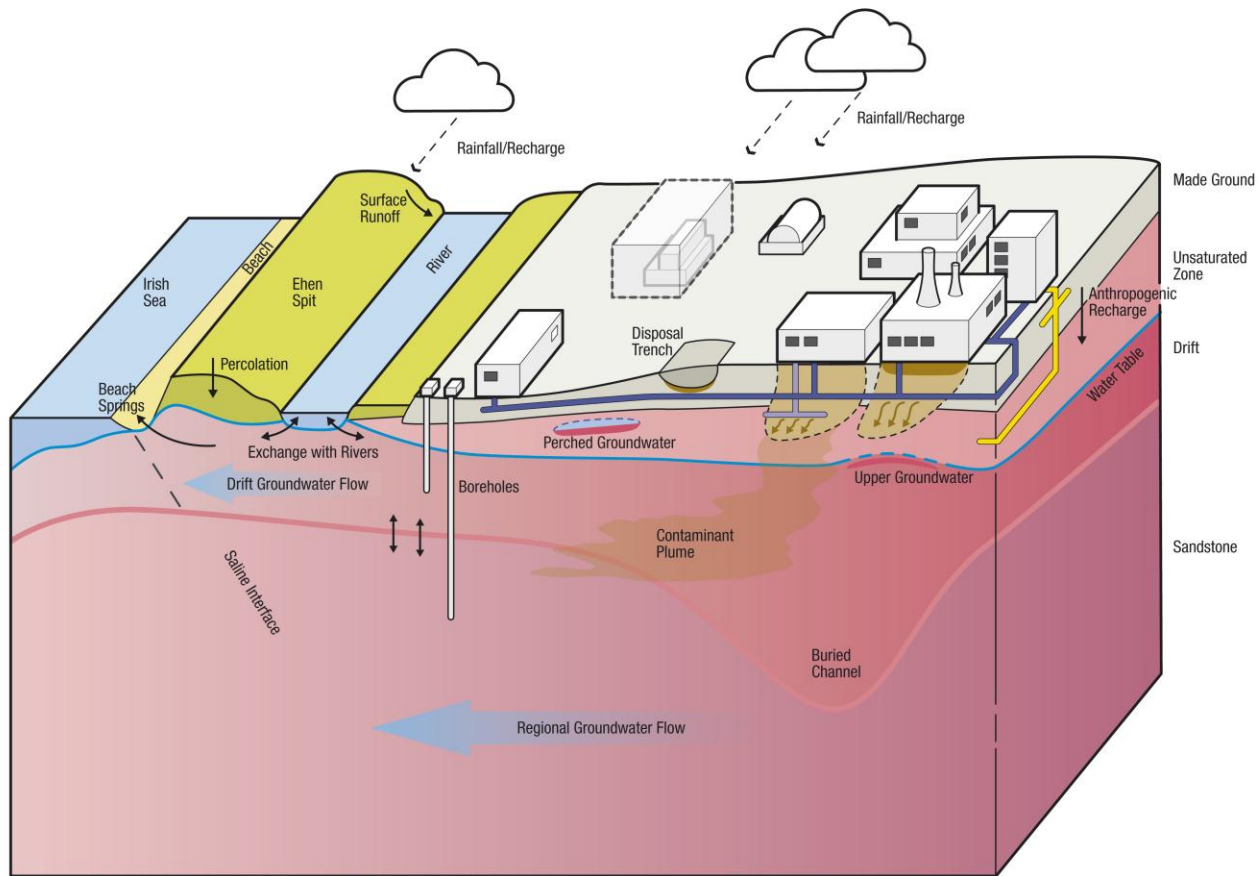
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Challenges to Investigation at Sellafield

- Congested operational site with many restrictions on where drilling is possible
- Presence of structures with vibration constraints
- Need to manage dose and contamination spread in radiologically controlled areas
- High standard of health and safety requirements
- Long timescale to obtain approval for work
- Highly variable Quaternary near surface geology
- Complex combination of contamination types and sources from intensive history of industrial activity

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Schematic of Ground Conditions at Sellafield



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Characterisation Strategy

- Boreholes located to:
 - investigate most significant leaks
 - address data gaps and conceptual model uncertainties
- Non-targeted sampling strategy for potential non-radioactive contaminants
- Characterise groundwater pathways in superficial deposits and upper part of bedrock
- Focus on investigating source terms with large estimated inventories and relatively small uncertainties in location

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SCL&GMP Characterisation Activities

- Geophysical surveys
 - surface and down-hole geophysics
- Borehole drilling
 - fully cored boreholes
 - analysis of soil/rock samples for radioactive/non-radioactive contaminants
- Groundwater monitoring

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Sonic Drilling



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Performance of Sonic Drilling Technology

- Reliability. No refusals in any boreholes (drilled through clays, running sands, granite boulders)
- Speed. Rapid drilling (relevant to programme and dose considerations)
- Waste minimisation (ability to drill dry to moderate depth)
- Health and Safety. Advanced features on drilling rig: interlocks on cage, remote operation
- Quality. High quality core recovered and fewer fines in groundwater monitoring installations

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Geophysics

- Surface Geophysics to improve understanding of nature of the made ground and near-surface geology
 - EM31 Ground conductivity
 - EM61 Metal detection
 - Ground Penetrating Radar
 - Electrical resistivity imaging
- Cone Penetrometry to improve understanding of disposal trench contents
- Downhole Geophysics to improve understanding of bedrock formation and flow
 - temperature, conductivity, caliper, natural and spectral gamma and induction logging

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Performance of Geophysics

- Surface techniques gave generally poor results – too many interferences in complex industrial environment
- Probing techniques had generally poor results – ground conditions too tough for instrumentation
- Down Hole techniques limited success – generic radiometric equipment needs development to be effective on complex nuclear sites

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Analytical Schedule for Soil Samples

- Tiered approach taken to analysis of soils
 - Tier 1 (100% of soil samples)
 - Gross Alpha Activity
 - Gross Beta Activity
 - Gamma Spectrometry: manmade / natural radionuclides
 - Toxic Metals: Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc
 - Total Hydrocarbons
 - pH, Conductivity, Sulphate, Chloride, Nitrate
 - Tier 2 (by trigger or proportion)
 - Sr-90, U/Pu isotopes, H-3 (focused on unsaturated zone), Tc-99, C-14
 - Speciated TPH, VOC/SVOC, PAH, PCB, Phenols, dioxins, asbestos, explosives residues

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Radionuclides in soils: summary

- Lateral migration of contamination in unsaturated zone is limited: generally tens of metres
- As a consequence, much of the unsaturated zone beneath Separation Area contains low activities of man-made radionuclides or is uncontaminated
- Some radionuclides fully or largely contained in unsaturated zone (e.g. Cs-137, Pu isotopes)
- Other radionuclides are more mobile, and enter groundwater. Principal radionuclides are:
 - H-3, Tc-99. Both appear to be unretarded
 - Sr-90, C-14. Weakly to moderately sorbing
- Few detectable soil plumes in saturated zone

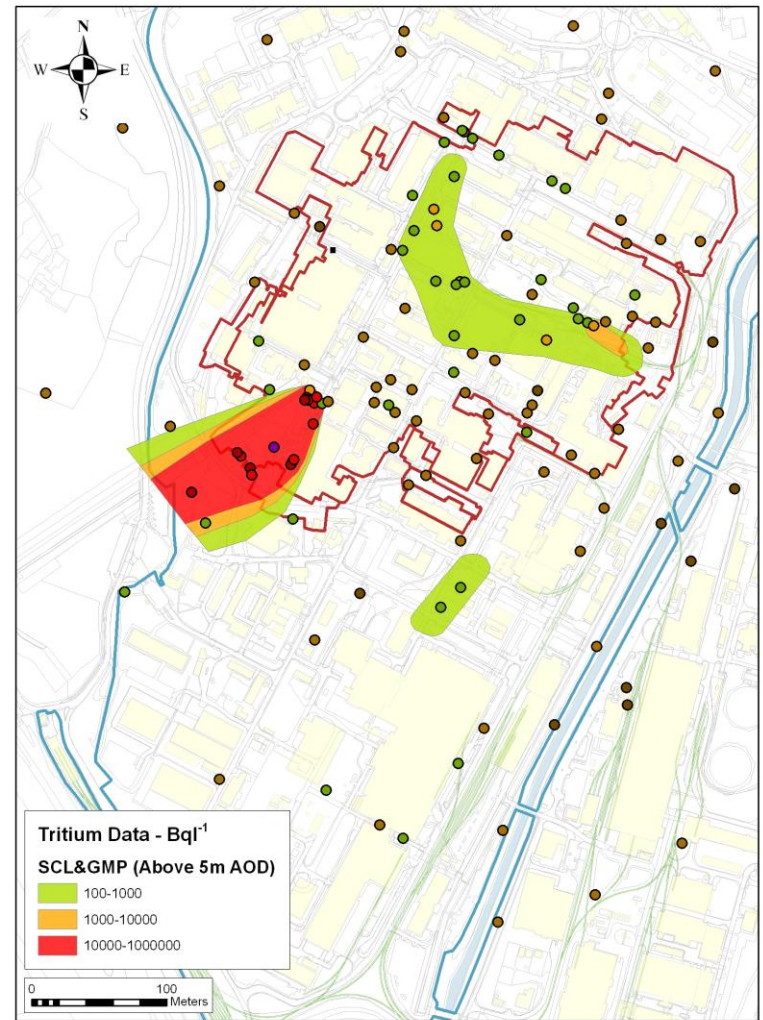
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H-3 in groundwater

- July – November 2009
- Tritium in shallower groundwater (>+5m AOD)
- Ground elevation falls to SW. Near coast, GW table is <+5m AOD
- In SW Sep, groundwater flow towards coast
- In central Sep, some degree of radial flow



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Summary of How Results Will be Used in Future Management

- Optimising the groundwater monitoring strategy based on Data Quality Objectives
- Developing and maintaining the Safety Case
- Undertaking Best Available Technique assessments for contamination sources and groundwater plumes
- Supporting the site leak management and detection programme
- Designing the remediation programme

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Learning From Experience at Sellafield

- Characterisation on Nuclear sites can be difficult, requiring commitment and a realistic approach
- Maximising use of existing knowledge is key
- Use of less intrusive investigation techniques would be preferred but results to date have been disappointing
- Innovative techniques are needed to investigate sources but will have to meet stringent safety standards

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Further Info - www.sellafieldsites.com/land/



Review of Contaminated Land at Sellafield Site



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Geology and Hydrogeology

The Sellafield site sits on sediments (known as superficial deposits or drift) deposited by a variety of glacial, river (alluvial), lake (lacustrine) and marine processes that have been altered and added to in the near-surface by activities at the site.

The underlying bedrock is Triassic Sandstone, a red fine to medium grained rock with bedding planes dipping south west towards the coast and with occasional bands of finer grained mudstones. The depth to bedrock beneath the superficial deposits varies from 3m to 60m due to the presence of "channels" in the buried bedrock surface, probably representing pre-glacial valleys that were infilled with sediments during the Ice Age. The main buried channel or valley lies to the north west of the site, roughly associated with the route of the River Ehen. A side buried channel from this extends east to run under the Separation Area in the middle of the site. These channel features are possibly partially aligned with faults or zones of weakness in the bedrock, and the top of the sandstone generally can be weathered and in places broken up. ([Link to SCLSGeologicalreport](#))



Boreholes drilled into the sediments typically encounter groundwater at 5 to 15 meters

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