Colliery Spoil

Geochemistry and use of Colliery Spoil in Materials Management Plans

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Origins of Colliery Spoil ("discards")

- Rock waste from mine development and coal face cutting
    - Coarse discards separated from the raw coal during screening and raising material to the surface
    - Fine discards, of which two types
        - Slurry, high coal content, from coal washing taken from suspension
        - Tailings: fine mudstone reject from froth floatation used in cleaning the coal, typically slurried in disposal
- Coarse discards disposed of in tips
- Fine discards also commonly disposed in tips where the coarse discard was used in forming bunds to the slurry lagoons; can be quite deep, >15m

Lithology of discards

Coarse Discard

- Dominant rock types: mudstone / shale, siltstone, mostly minor sandstone content (roof rocks over the coal seams worked)
- Other minor constituents: fireclays, ganisters, argillaceous limestones
- Coal content variable: the older tips may contain higher content due to inefficient processing

Fine Discard

- Tailings fines, typically particles of silt –sand size, from the same suite of rocks found in coarse discard. Has variable and often high coal content
- Slurry fines, typically silt – sand size, high coal content
- The slurry-deposition process can produce a sedimentological pattern including lamination /layering, and features mimicking fluvial deposition such as fining upwards / outwards away from the input pipe

Mineralogy of discards

– Base mineralogy dominated by quartz and clay minerals

– The trace minerals, and the trace elements in the “fresh” discard, are what interests us most!
  - Sulphide minerals
  - sulphates
  - Metal oxides
  - Carbonate minerals

– Note the significant difference between the make-up of coarse versus fine discards

– Note: the key aspect of interest for us is the consequences of discard weathering

TABLE 2.1 AVERAGE (PROXIMATE) MINERALOGY OF DISCARDS (WEIGHT PERCENTAGE)

		Coarse Discards 74 samples	Fine Discards 47 samples (72 determinations)
Quartz		17.5	6.0
Illite	clay minerals	31.5	34.0 (Illite + Mixed-layer clay)
Mixed-layer clay	clay minerals	26.0	
Kaolinite	clay minerals	10.5	8.5
Chlorite	clay minerals	0.5	– (b)
Carbonates(a)		1.0	2.0
Pyrite		– (b)	2.0
Organic carbon (dom.coal)		13.0	47.5
Total		100.0	100.0

(a) Dominantly siderite and some ankerite in tips, whereas ferroan dolomite (ankerite) in fine discards.

(b) Small quantities in some samples.

NOTE: In coarse and fine discards, trace amounts of sulphates, feldspar, rutile and phosphate total less than 2%.

Coarse Discards			Fine Discards		
Area	Tip	Number of samples	Area	Lagoon	Number of samples

Elemental geochemistry of discards

– Dominated by quartz (silicate) and clays (alumino-silicates)

– Minor constituents of major importance to us:
  - Sulphide - derived sulphates metals and metalloids
  - Oxides of iron, magnesium, manganese
  - Aluminium oxides
  - Carbonates
  - Coal and other carbonaceous matter

– Production of sulphates and oxides from weathering of fresh discard is the key aspect addressed in environmental risk assessment

TABLE 2.2 AVERAGE MAJOR ELEMENT GEOCHEMISTRY OF DISCARDS (WEIGHT PERCENTAGE)

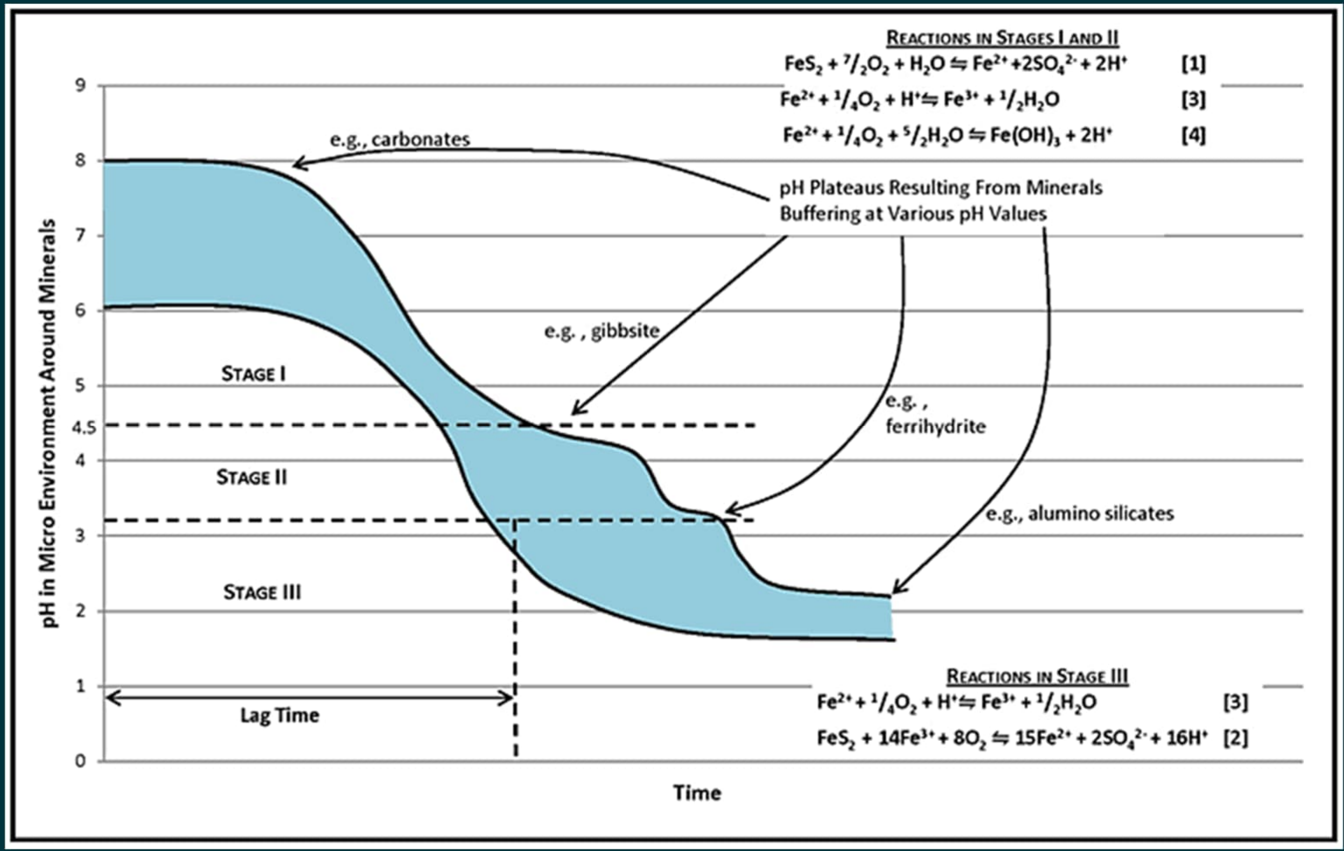
	Coarse Discards (74 samples)				Fine Discards (54 samples)			
	Mean	Standard Dev.	Max.	Min.	Mean	Standard Dev.	Max.	Min.
SiO_2	46.23	7.77	61.42	23.86	32.68	8.90	46.19	10.74
Al_2O_3	19.74	2.74	26.24	13.92	16.42	5.49	29.91	5.45
Fe_2O_3	5.39	2.69	19.30	2.57	4.86	1.80	8.70	2.14
MnO	0.10	0.01	0.89	0.01	ND	ND	ND	ND
MgO	1.01	0.32	0.30	1.70	0.99	0.38	2.38	0.05
CaO	0.74	0.71	4.53	0.17	2.05	1.59	7.21	0.19
Na_2O	0.41	0.19	3.50	0.01	0.31	0.13	0.82	0.10
K_2O	3.40	0.55	4.56	1.76	2.83	0.88	4.40	0.74
TiO_2	0.88	0.10	1.11	0.56	0.78	0.13	1.06	0.46
S	0.96	0.72	3.67	0.05	2.89	1.54	7.85	0.44
P_2O_5	0.18	0.07	2.10	0.05	0.10	0.03	0.18	0.03
CO_2	1.81	1.60	9.00	0.00	ND	ND	ND	ND
C_{org}	13.30	8.16	40.48	0.01	ND	ND	ND	ND
H_2O^+	5.04	1.77	10.29	1.86	ND	ND	ND	ND
H_2O^-	1.15	0.27	1.83	0.74	ND	ND	ND	ND
	100.34				63.91			

ND = Not Determined

Coarse Discards

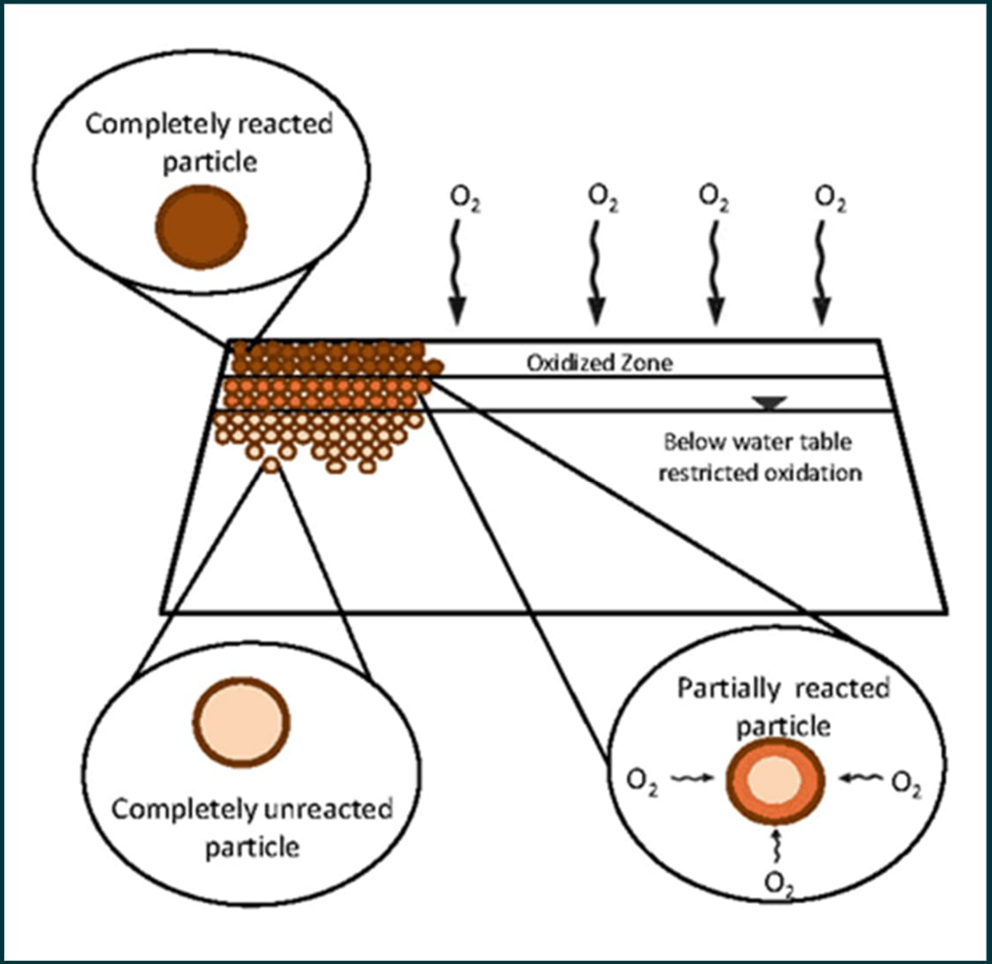
Weathering of coarse discard with time

- Fresh material exposed to atmosphere
- Sulphide minerals become unstable
- Sulphide to sulphate conversion, accompanied by release of protons
- Release of metals and metalloids
- Acidification
- Buffering capacity depends on carbonate content, and the buffering provided by other weathering products in the sequence

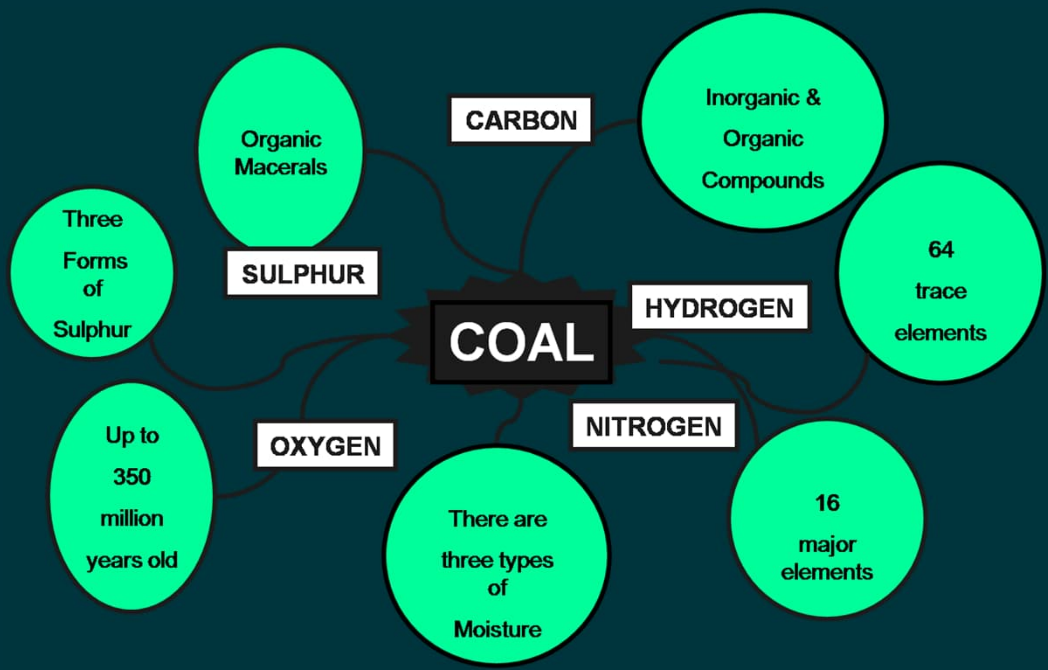


Influence of exposure on weathering

- Duration and degree of exposure in the original tip
- Material deep in the tip may have escaped weathering………….
- Until we excavate and reintroduce exposure!
- Compared with this diagram, many old tips sit above the natural water table, but receive downwards infiltration unless protected or sealed



Coal fractions in colliery discards reflect the source seams mined



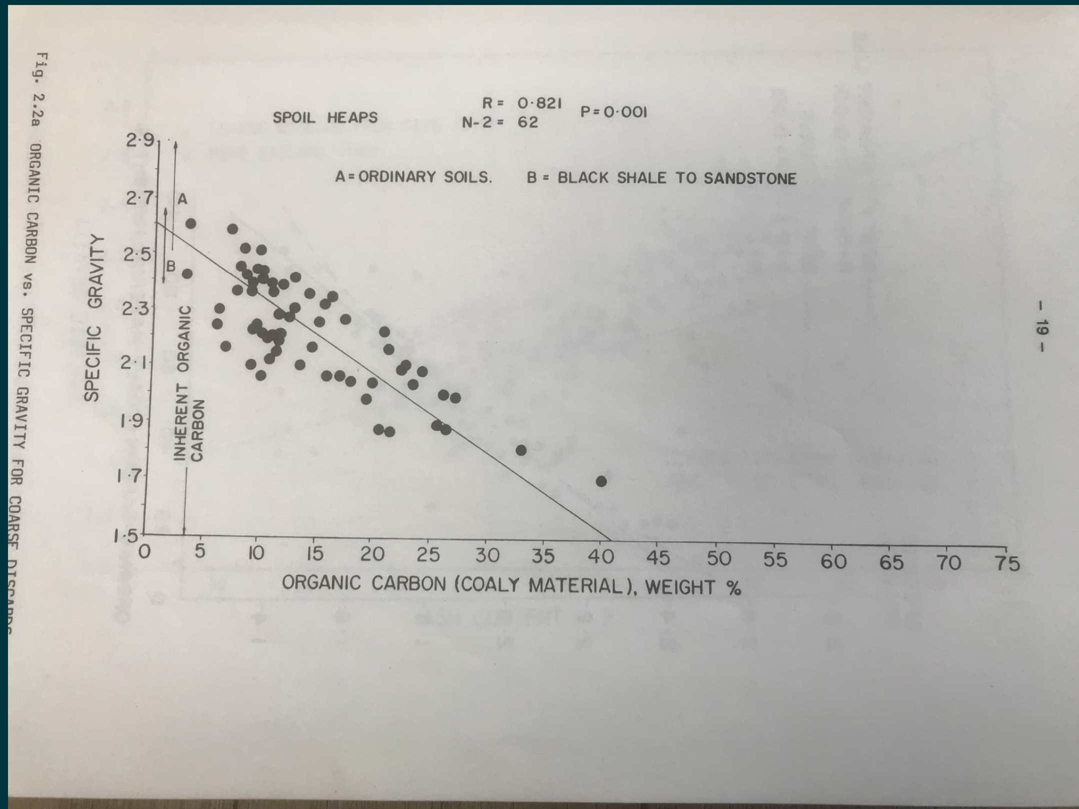
COALIFICATION

Coal	% C	C	H	O	Heating value (MJ/kg)
Cellulose	45	100	14	111	-
Wood (Dry)	50	100	12	88	10-11
Peat	60	100	10	57	10-12
Lignite	62	100	8	54	16-24
Bituminous coal	79	100	6	21	26-30
Anthracite	91	100	5	5.2	32-34
Graphite	100	100	0	0	34

Time

Ground gas in colliery spoil: related to inherent organic content

- As part of the deposition and diagenesis the coal seams in situ would have contained adsorbed methane and some carbon dioxide and other volatiles
- Argillaceous rock strata, with variable carbonaceous content, would also have contained these adsorbed gases and volatiles
- Mining process and surface disposal of colliery spoil in tips leads to oxidation and biogenic breakdown of methane and carbonaceous matter in spoil. Main product is carbon dioxide.
- Other gases potentially present: hydrogen sulphide, carbon monoxide

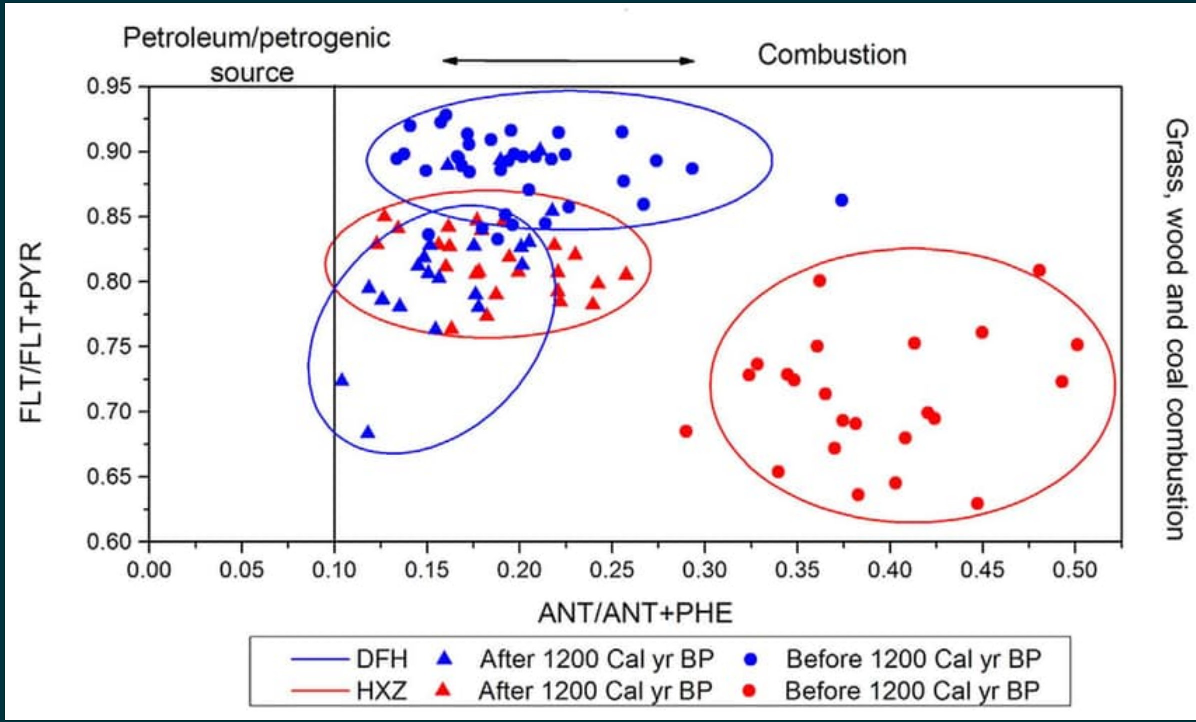


Mature organics in colliery spoil subject to weathering

- Coal fragments and carbonaceous matter contain aromatic compounds

- As coalification progressed geologically the degree of “aromaticity” in the coal and the surrounding mudstones would have increased and weight percent of oxygen and hydrogen would have decreased

- Lab analysis of colliery spoil samples will thus record PAHs
- can characterise PAH content as originally “petrogenic” but in process of weathering they are oxidised (combusted) so ratios in the spoil will be different
- Again, product of aerobic PAH weathering is mainly carbon dioxide



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Substances and parameters in colliery spoil typically requiring assessment of contaminant hazard and risk

- Metals released from sulphides: most tend to be at low concentrations but iron and aluminium will be in higher concentrations

- Arsenic released from iron sulphides: can be present at up to150 – 200mg/kg

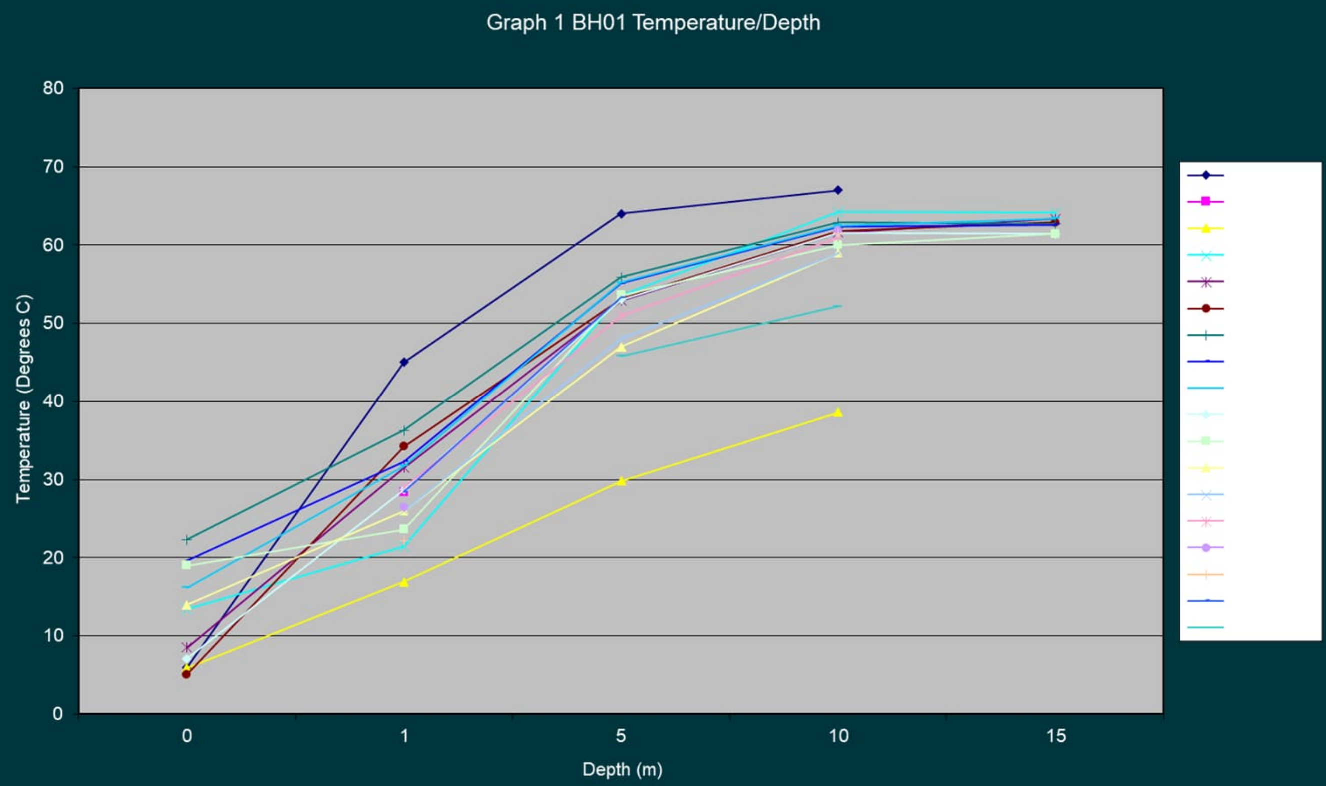
- Acidity/alkalinity: due to the weathering process low pH is more common

- Sulphates: present in coal and the mudstone fragments as a result of sulphide weathering, concentrations can be 20,000mg/kg or greater

- Organic sources: PAH

Self-heating combustion of colliery spoil in tips

- Tips with significant coal content and subject to oxidation (combustion)
- Sulphide to sulphate conversion is exothermic
- Presence of organic source, oxygen and moisture may lead to self-heating
- High temperatures can be “held in” over many decades
- Removal of oxygen by compaction can arrest self heating



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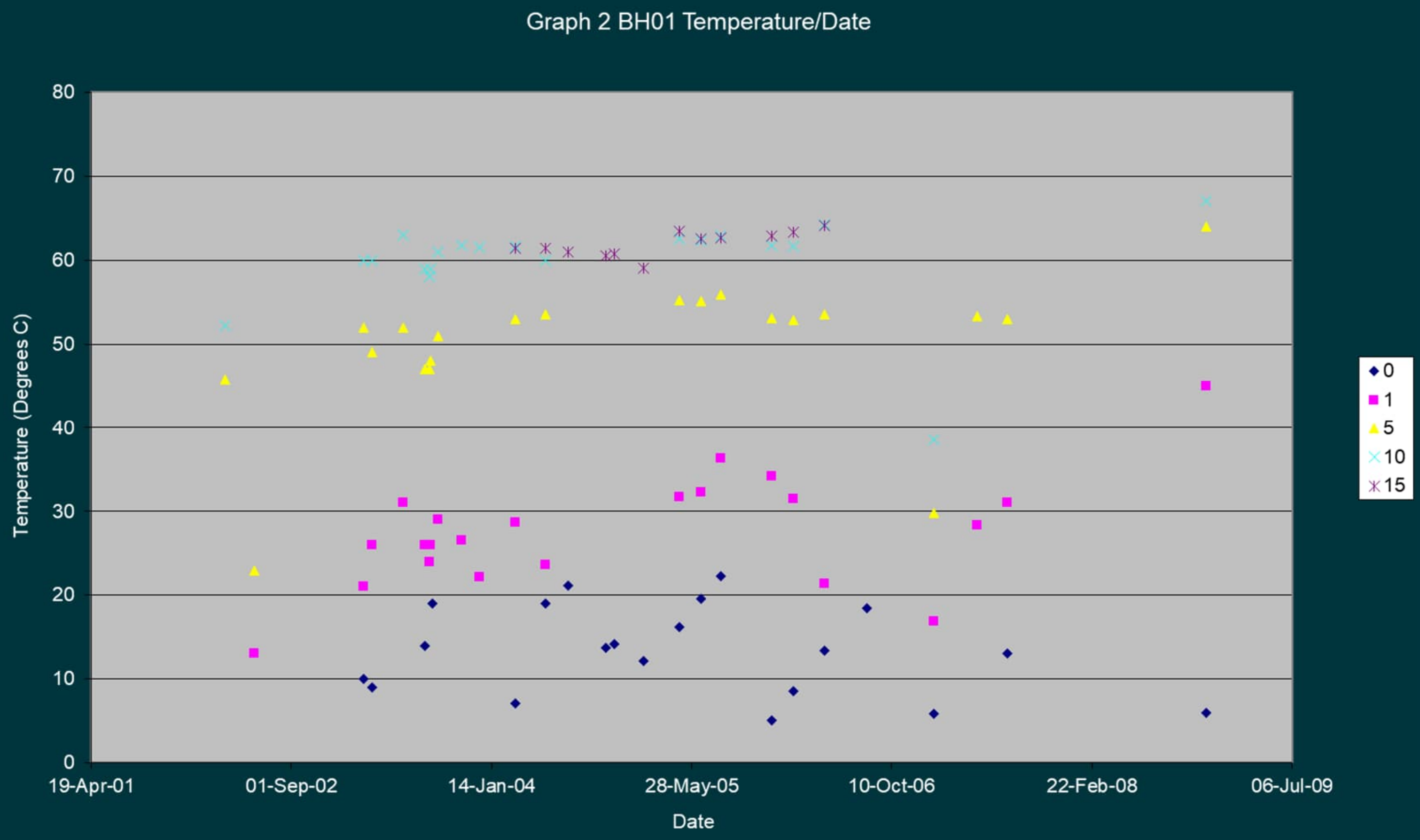
Self-heating in colliery tip: monitoring

– Galvanised steel standpipes

– Down-hole temperature probe

– Repeat measurement

– Fluctuations and trends



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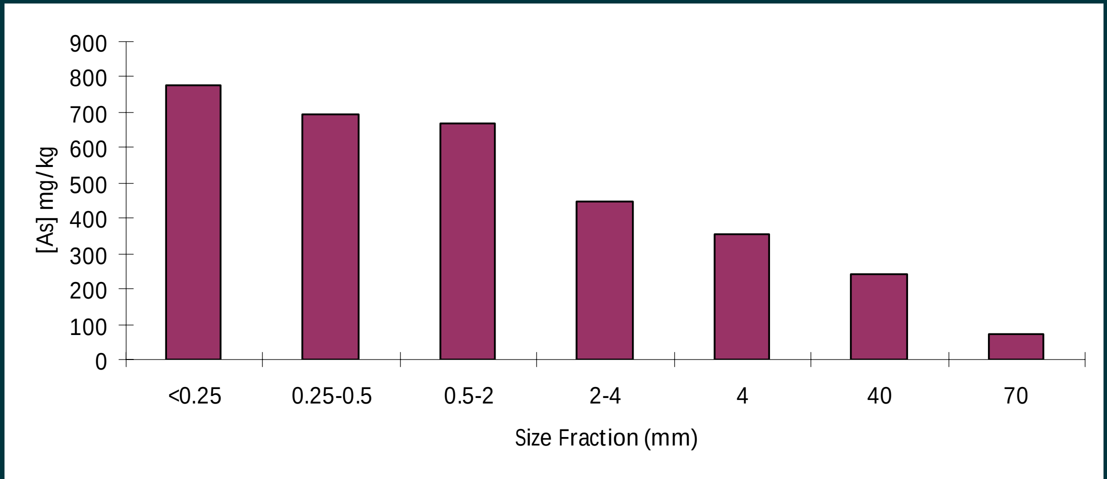
Burnt colliery spoil: what are the consequences and effects

- High temperature combustion due to self-heating, can be >150 deg C and of long duration
- Causes loss of free moisture and dehydration of clays
- Accelerates conversion of sulphides to sulphates
- May result in higher bulk concentrations of sulphates, some metals and metalloids
- Size fractionation of metals and metalloids (this is an extreme example!)



Colliery Spoil: understand the material and mitigate risks in re-use

- Colliery spoil has been used successfully in many land remediation and reclamation schemes

- Hazards and risks should be assessed with background knowledge of the tip history, mineral content, coal content, weathering effects and variability

- Obtain site-specific information from site investigation

- Devise a strategy for appropriate re-use

- Mitigate risks to an appropriate level

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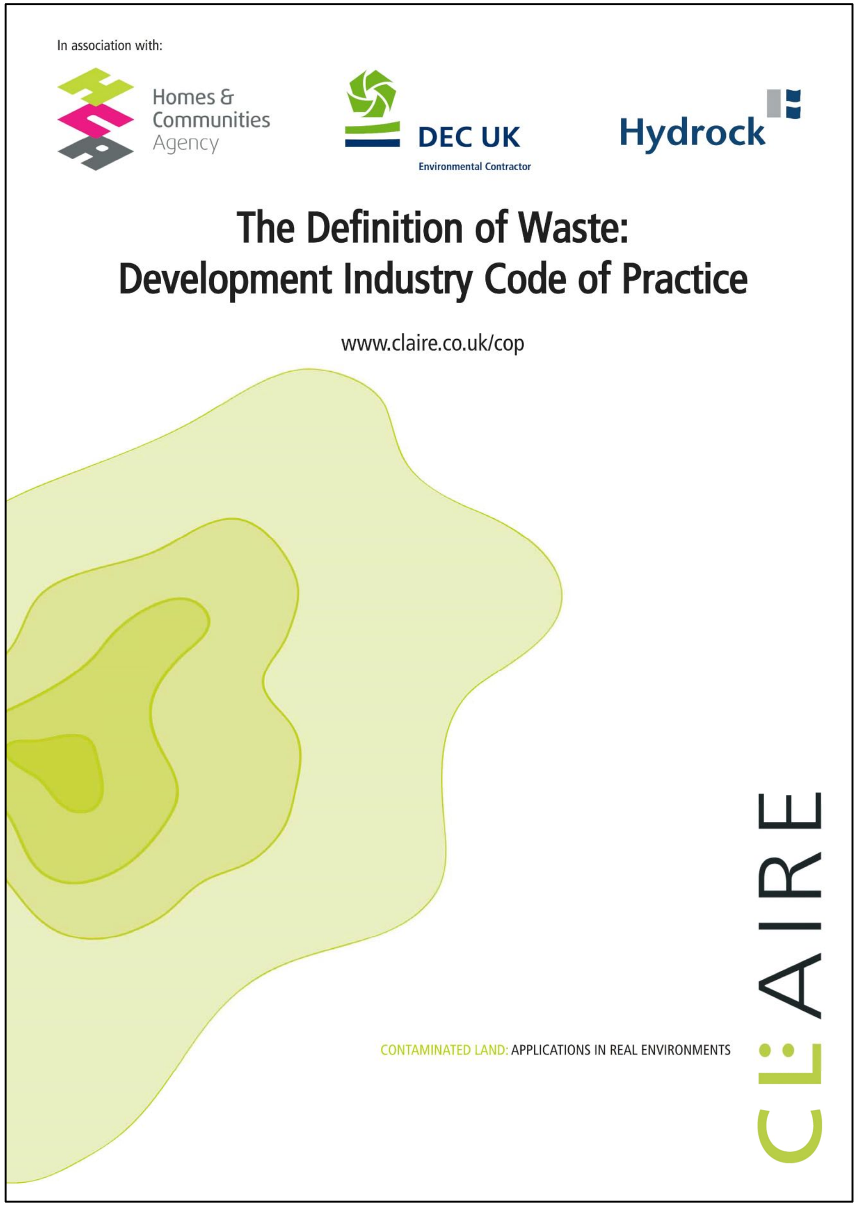
CL:AIRE

Definition of Waste: Development Industry Code of Practice (DoWCoP) – Colliery Spoil as an Earthworks Material

Introduction

CL:AIRE Definition of Waste Development Industry Code of Practice

- Provides a clear, consistent, auditable process which facilities the re-use of excavated materials or movement of materials between sites.
- Supports the sustainable and economic redevelopment of land.
- Requires self regulation and high level of professional integrity.



Introduction to DoWCoP

- Excavated material generated by land redevelopment may be waste and subject to waste regulatory controls.
- Initially released in 2008 the Code of Practice is a voluntary scheme (England & Wales only) serving the following key purposes:
  - ➢ Sets out good practice for the development industry to use when:
    - I. Assessing whether excavated materials are classified as waste or not; and
    - II. Determining when treated excavated materials can cease to be waste for a particular use.
  - ➢ Describes an auditable system to demonstrate that the CoP has been adhered to.
- The Code of Practice is <u>Site Specific</u>

Other Options

Dig & Dump

- Quick
- Sustainable?
- Costly

Exemption

- Very Limited (types / quantity)

Environmental Permit

- Wide range of scenarios
- Cost / Timescale
- Surrender

WRAP Protocol

- Aggregates only

BEST PRACTICE

1) Ensure adequate MMP is in place

2) Ensure MMP is based on appropriate risk assessment

3) Ensure that the materials are treated and used as proposed – Verification Plan

THE 4 KEY FACTORS TO DEMONSTRATE

1. Protection of human health & the environment

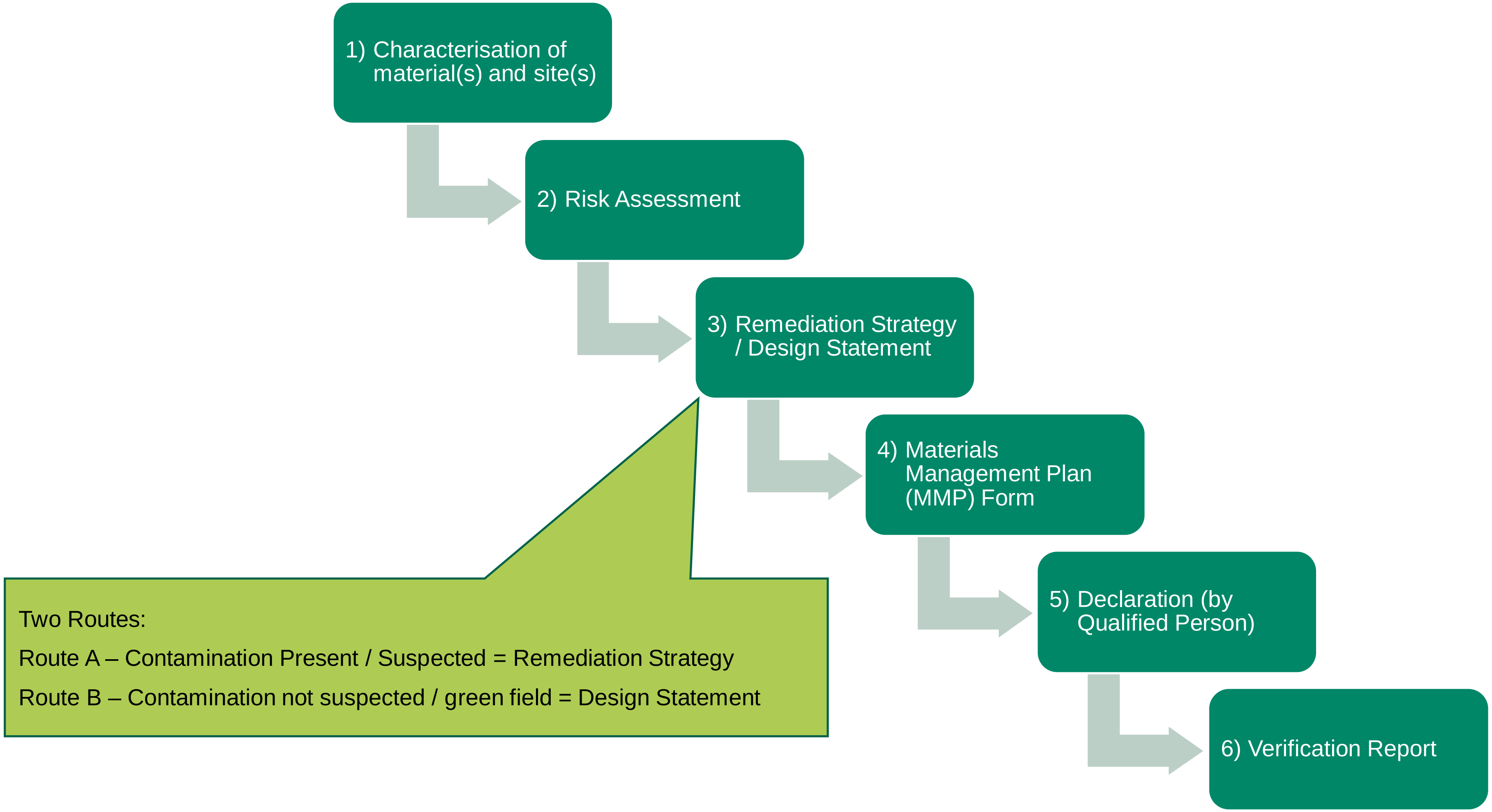
2. Suitability for use

ALL SITES

3. Certainty of use

4. Quantity of use

The DoWCoP Process



Scope

What materials are covered by DoWCoP?

Materials WITHIN the scope of DoWCoP

Soil (top soil and sub-soil), parent material and underlying geology

Soil and mineral based dredgings

Ground based infrastructure (e.g road base, concrete floors)

Made Ground

Segregated aggregate material from demolition activities (e.g. crushed brick and concrete)

Stockpiled excavated material that include the above

Materials EXCLUDED from scope of DoWCoP

- Soil contaminated with invasive weeds (e.g. Japanese Knotweed)
- Excavated infrastructure (e.g. pipework, storage tanks)
- General Construction Waste (e.g plasterboard, glass, wood etc.)
- Other demolition wastes not detailed previously (e.g. crushed brick and concrete)
- Extractive wastes (within the scope of the Mining Waste Directive)

Mining Waste Directive & Colliery Spoil

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Mining Waste Directive (2006/21/EC)

- Covers ‘extractive waste’: the management of waste resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries.
- Inert waste and unpolluted soil <u>not</u> subject to requirement for:
    - Environmental Permit; and
    - Closure and after-closure procedures.
- Article 24 – Transitional Provision
    - 24(1) Waste facilities closed by 1st May 2008 not required to comply with provisions of the MWD
    - 24(3) Notwithstanding closure before 1st May 2008 extractive waste managed so as not to prejudice Article 4(1)
    - 24(4) Facilities stopped accepting waste before 1st May 2006, and will be closed by 2010: <u>no</u> requirement for Waste Management Plan, Environmental Permit, Closure and after-closure procedures.

EPR 6.14 – How to comply with your Environmental Permit. Additional Guidance for Mining Waste Operations, Environment Agency

- Covers colliery spoil tips and the MWD and states the following in relation to Old Tips closed before 1st May 2008 (Section 3.3.3);

Is the material Extractive Waste?	YES
Is an Environmental Permit required for existing situation?	NO
Is a Mining Waste Operation Environmental Permit required for re-profiling leading to footprint increase?	YES
Is a Mining Waste Operation Environmental Permit required for mineral extraction from the spoil heap?	YES

- However, does MWD apply? Article 24(1)

- Notes state that spoil is taken off site to a site that is not a mining waste facility, it becomes subject to regulation as Waste Framework Directive Waste.

CL:AIRE Guidance / FAQs

- Colliery tips operational / not closed from 2006 and covered by the MWD are outside of DoWCoP;
- Historical Tips are not covered by MWD and may also not be covered by DoWCoP
  - However, reasons for potential exclusion from DoWCoP unclear

Colliery Spoil Reclamation Projects

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Glasshoughton, West Yorkshire

- Former Glasshoughton Colliery and Coking Works
- Reclamation work began in the 1990's
- Mixed end-use development

Glasshoughton, West Yorkshire contd.

- Crib Wall construction for large residential plot

Shipley Lakeside, Derbyshire

- Former Opencast Coal site, including some mineshafts
- Former Theme Park (American Adventure)
- Mixed end-use development

In Conclusion

- Colliery Spoil is an important engineering material
- Re-use under DoWCoP has resulted in numerous successful large mixed-use developments
- Ultimately re-use should be discussed and agreed with relevant regulators
- Clear and Consistent approach required for continued re-use

Thank you.

Any Questions?