Sampling Aspects of BS10175:2010

The central role of uncertainty to judge fitness-for-purpose of SI

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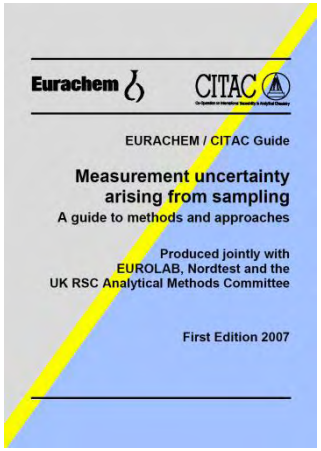

BS 10175 "Investigation of Potentially Contaminated Sites – Code of Practice" *SCI, London 14th July 2010 11.25-11.40 (15 min)*

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Overview

- Traditional view of Sampling & Analysis - *separately*
- Benefits of integrated view of measurement process
- What is Uncertainty of Measurement (U)?
- Benefits of knowing U on every measurement
  - e.g. judging Fitness For Purpose (FFP)
- Case studies – show cost savings
- What needs to go into BSI 10175
- Conclusions

Traditional view of sampling & analysis

Sampling: – assume representative if you stick to the protocol

- **3.12 sampling**

  methods and techniques used to obtain a representative sample of the material under investigation

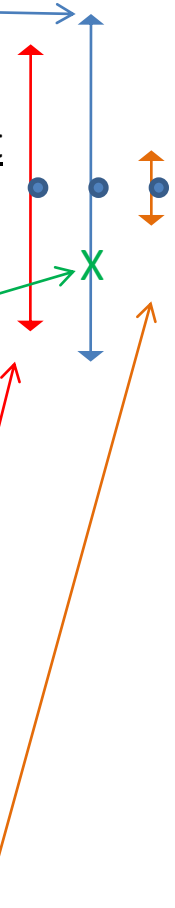
- Better definition - *Process of drawing or constituting a sample.* ISO 11074-2 (1998)
- Estimate the uncertainty to see how representative sampling was

Analysis: assume measurements ≈ true values if accredited

- Ignore the fact that all measurements are wrong
  - to some extent
- measurements all have uncertainty

What is Uncertainty of Measurement?

3.7 Measurement uncertainty



- parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurement
- Misquoted, should be 'attributed to the measurand'
  - = *'quantity intended to be measured'*(JCGM 200, 2008)*.
  - ~ true value of contaminant concentration
- Older definition clearer:-
- An estimate attached to a test result which characterises the range of values within which the true value is asserted to lie (ISO 3534-1: 3.25, 1993)
- Sampling uncertainty: The part of the total measurement uncertainty attributable to sampling. IUPAC (2005)
- Analytical uncertainty: The part of the total measurement uncertainty attributable to chemical analysis.

* JCGM 200 (2008) International Vocabulary of Metrology – Basic and General Concepts and Associated Terms. (VIM, 3rd edition). Joint Committee for Guides in Metrology.

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Case Studies - 6 routine Site Investigations

Site	Area ha	Main type of contamination	Suspected source	Site end-use	Sampling method	Primary contaminant
1	8	Heavy metal	Tin mining	Housing	Trial pits	Arsenic
2	1.5	Organic	Infill waste from gas works	Recreational land	Trial pits	Indeno(123) pyrene
3	0.08	Heavy metal	Infill after WWII bombing	Garden and allotment	Window sampling	Lead
4	12	Organic	Gas works	Hazard assessment	Trial pits	Total PAH
5	45	Heavy metal	Railway sidings and colliery spoil	Nature reserve	Trial pits	Arsenic
6	1	Heavy metal	Ex-firing range	Housing	Hand auger	Lead

Wide range of different: - sites (size, history & value),

- contaminants, sampling methods

Taylor P.D., Ramsey M.H. and Boon K.A. (2007) Estimating and optimising measurement uncertainty in environmental monitoring: an example using six contrasting contaminated land investigations. Geostandards and Geoanalytical Research, 31, 237-249

Taylor P.D., Boon K.A. and Ramsey M.H. (2007) *Cost-effective investigation of contaminated land*, CL:AIRE report RP4, CLAIRE, London. ISBN 978-1-905046-01-0.

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Estimation of uncertainty in a routine site investigation

Site 4 - Gas Works, East London

Site	Area ha	Main type of contamination	Suspected source	Site end-use	Sampling method	Primary contaminant
4	12	Organic	Gas works	Hazard assessment	Trial pits	Total PAH

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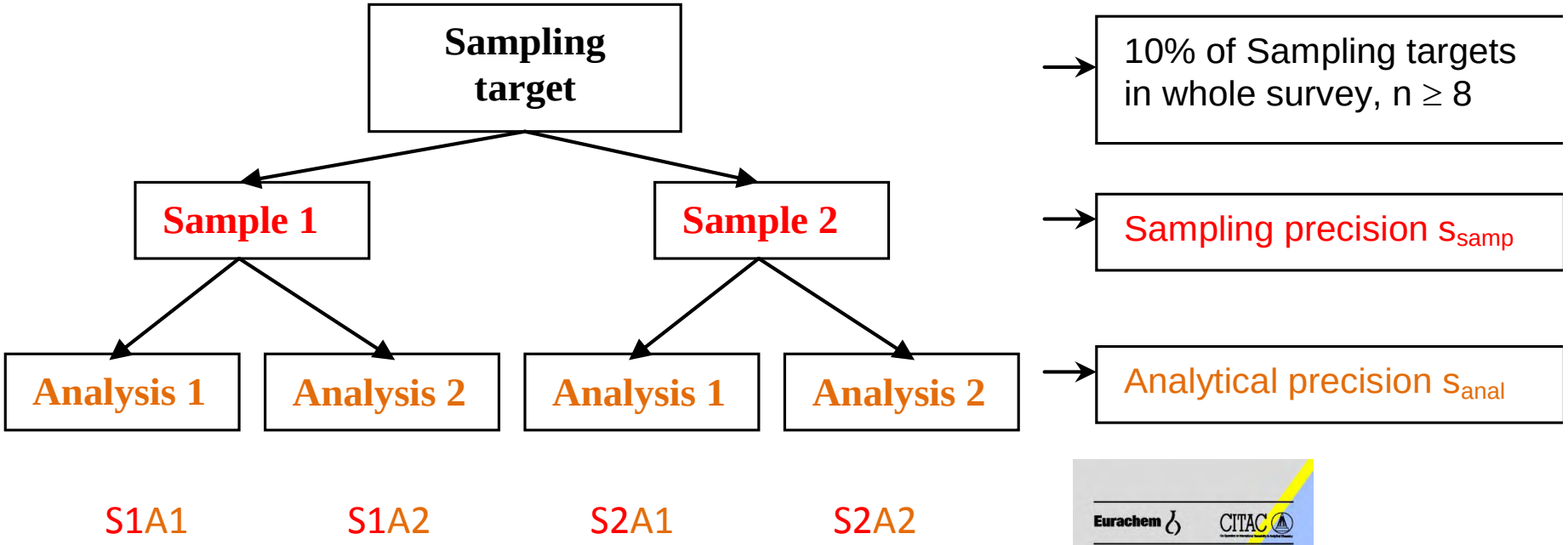
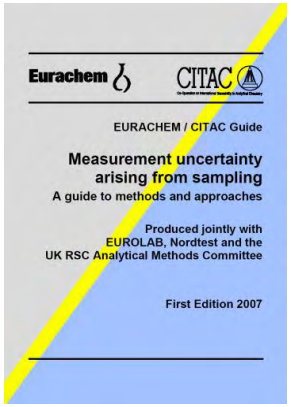
Estimating U

using the Duplicate Method

(BS10175:2010 Annex D)





Eurachem Guide – *better ref than older CLAIRE TB7*

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Duplicate Results at Gasworks Site

	S1A1	S1A2	S2A1	S2A2
1	6.4	6.5	13.6	14.2
2	52.3	55.2	70.2	79.4
3	99.0	96.5	36.1	59.6
4	8.1	6.0	3.7	31.6
5	247.4	368.4	133.7	146.3
6	148.8	109.3	187.9	233.2
7	50.1	85.5	112.2	42.6
8	15.2	33.9	17.6	18.5

PAH (mean conc 76 mg/kg)	Standard Uncertainty (1s) mg/kg	Relative Expanded Uncertainty (2s) %
Sampling (inc prep)	27	71%
Analysis	20	53%
Measurement	34	89%

Much higher than quoted by lab - MCERTS 30%(2s) Precision

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Estimates of Uncertainty

in 6 Case studies

Site number	Key contaminant	U'random (%)	U'meas (%)	% of measurement variance	
				Sampling	Analysis
1	Arsenic	63.7	66.7	85.6	14.4
2	Indeno(123-cd)pyrene	50.8	54.6	80.3	19.7
3	Lead	25.3	32.2	58.9	41.1
4	Total PAH	89.3	91.5	60.5	39.5
5	Arsenic	157.6	158.9	-	-
6	Lead	75.1	77.8	86.6	13.4

U' meas (including analytical bias) ranges from 32 – 159% (at 95% confidence)

Main source of U is in the sampling (60-90% of total U)

- is this level of U acceptable – are measurement fit-for-purpose?

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Judging Fitness-For-Purpose (FFP)

using OCLI method.

- Estimates the Fitness-for-purpose (FFP) of measurements overall,
  - corresponds to minimum cost (expectation of lost)
  - sub-divide to estimate FFP of analytical and sampling components separately.
- Considers
  - all costs of measurement,
  - potential cost of misclassification
    - e.g. end-use, unnecessary remediation, potential litigation.

- Details in Ramsey M.H., Taylor P. D. and Lee J.C. (2002) **Optimized Contaminated Land Investigation (OCLI)** at minimum overall cost to achieve fitness-for-purpose, Journal of Environmental Monitoring, 4, 5, 809 - 814

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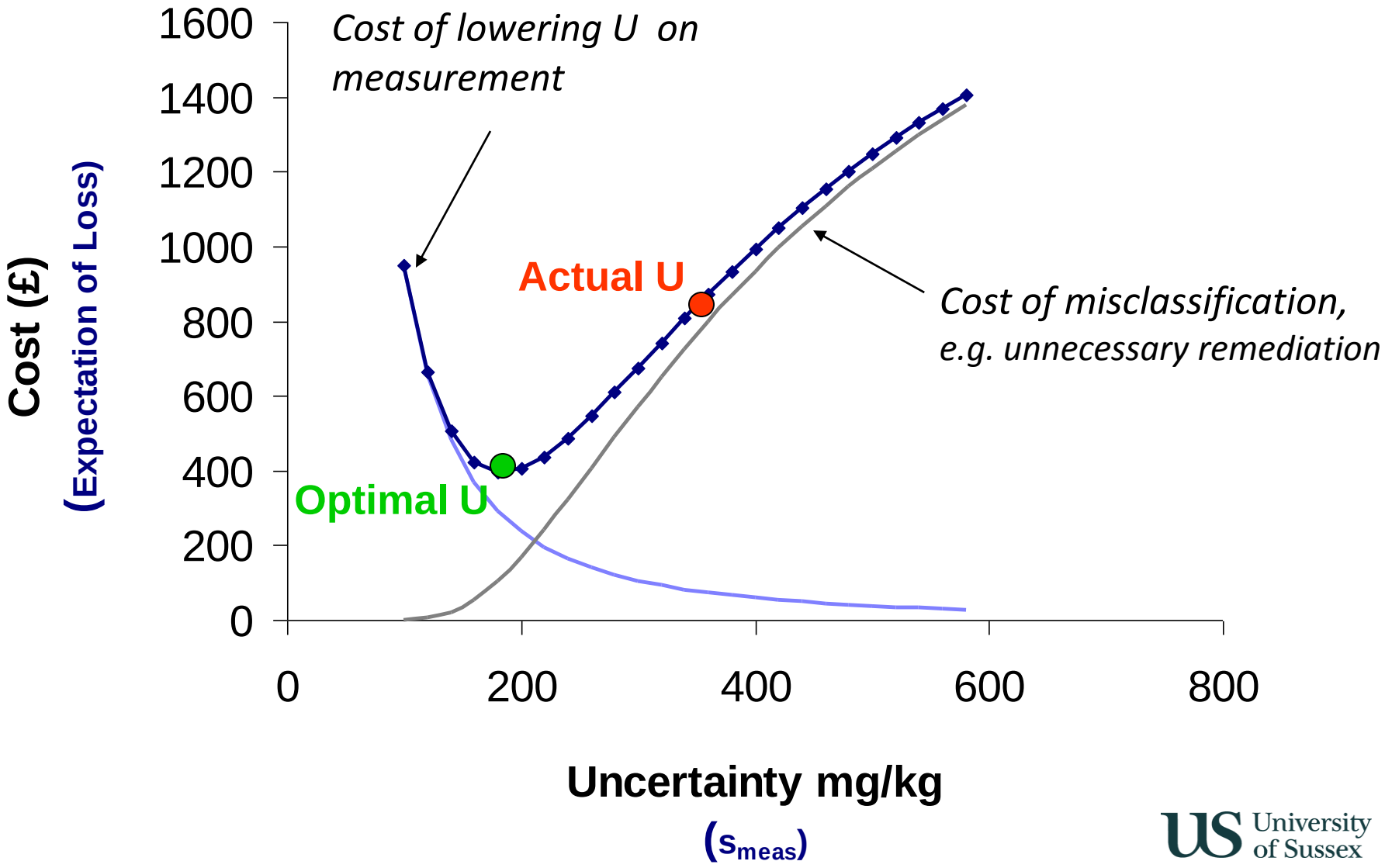
Acceptable level of Uncertainty?



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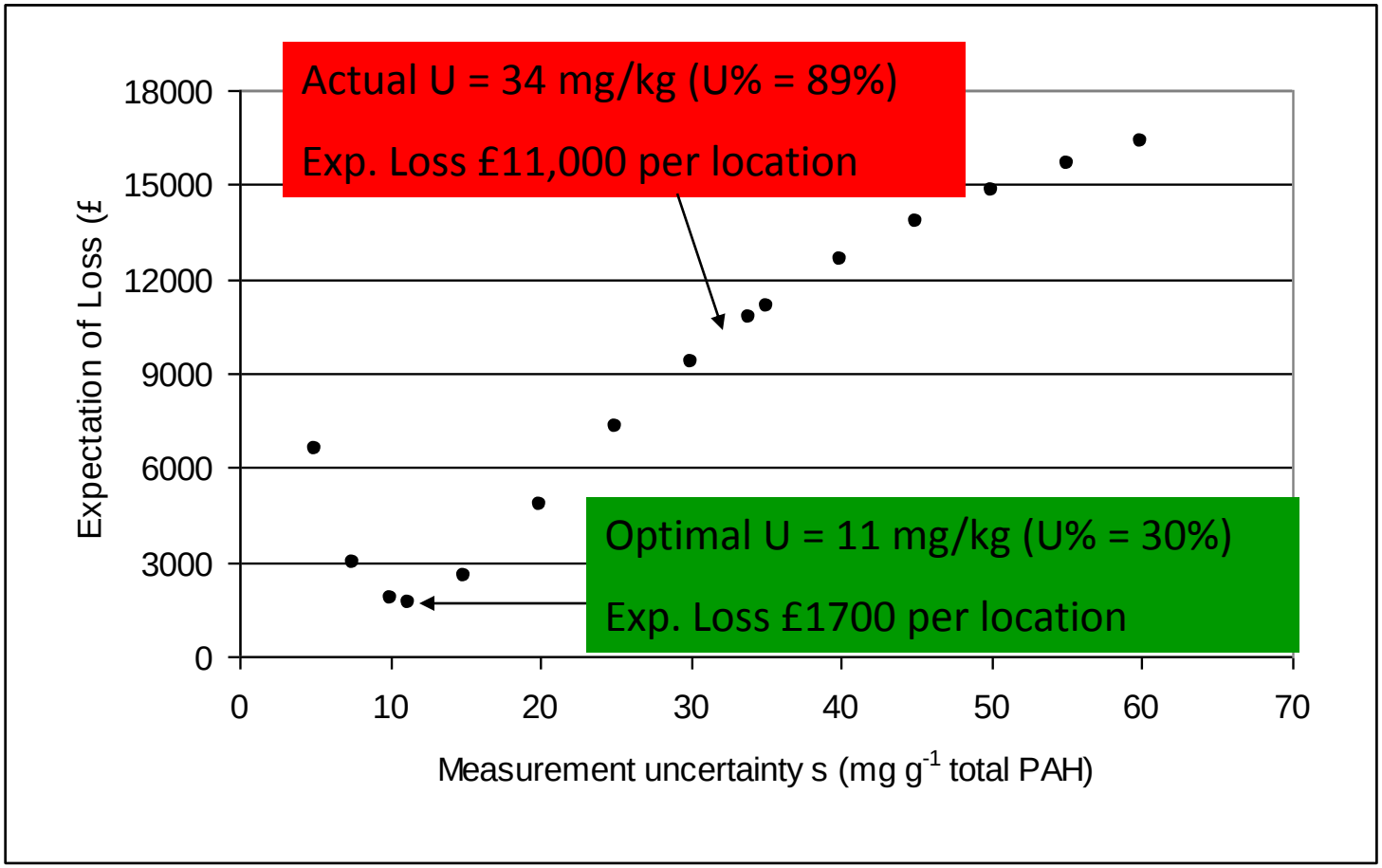
Actual v Optimal U for Gasworks Site



Overall saving of £74,400 on whole development

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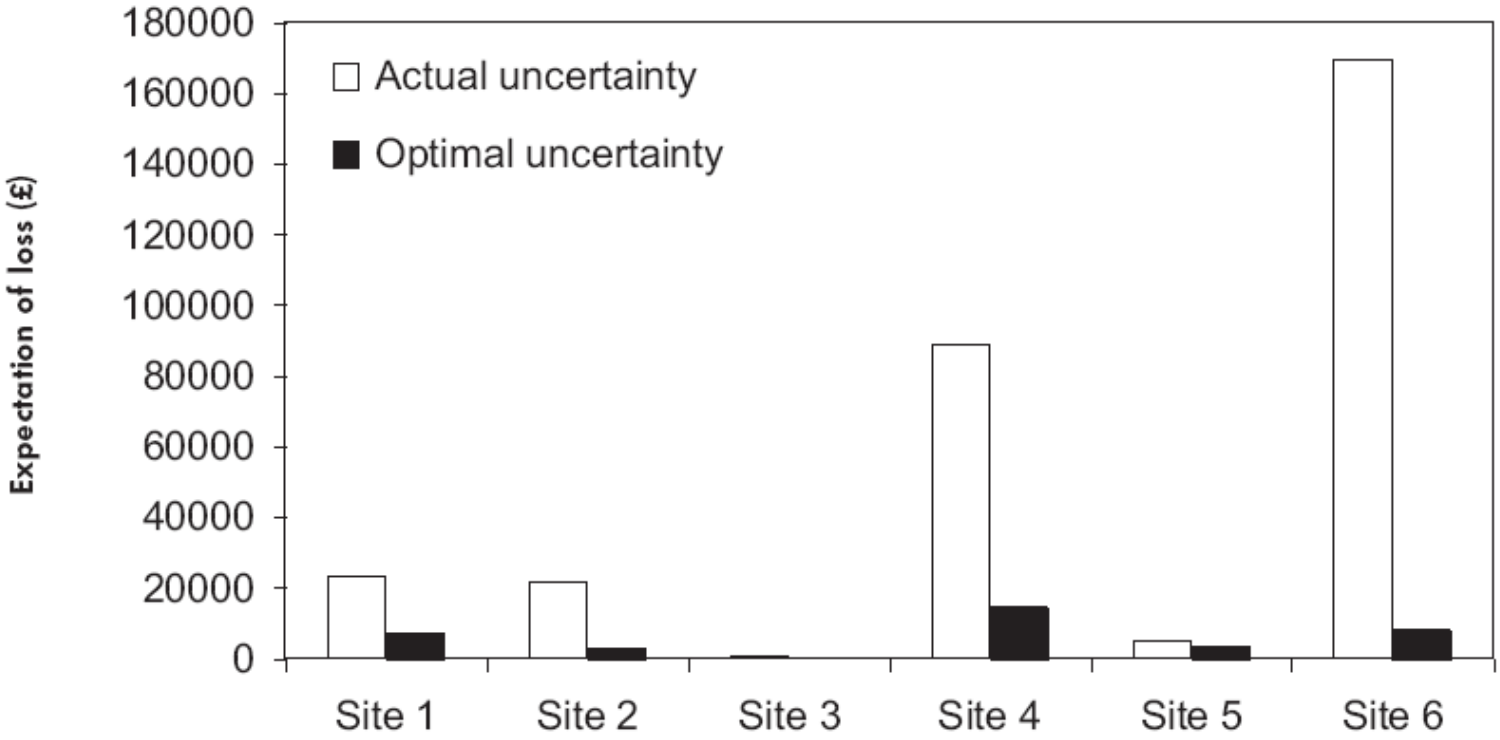
Financial Saving from optimal U



Expectation of financial loss estimated for whole sites for 6 routine site investigations.

Cost are calculated at either:- uncertainty actually found (clear bars), or optimal value (black bars)

Site 6 has largest potential saving of £160,000

Reduce sampling uncertainty by taking composite samples (e.g. BS10175:2001)

e.g. 9-fold composite ('cluster') reduces U from Sampling by factor of ~ √9 = 3

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What needs to go into BSI 10175?

- Integrated view of measurement process
  - Sampling + Analysis
- Importance of realising all measurements are uncertain
- Need to report U value for all measurements (S&A)
- Enables:-
  - judgement of whether measurements are FFP
    - by investigator, user & regulator
  - Shows how to make measurements FFP (e.g. comp. samples)
  - Probabilistic interpretation of the site (e.g. EA, 2009)

- So:- 'Strongly recommend estimation of Uncertainty from sampling' (Sections: 5.7.1 Decision 4)

Estimating Uncertainty – Annex D

- Applies to field sampling (Sec 7.8 as QC?) sample prep & anal (Sec 9.3)
- When to 'Estimating sampling uncertainty using the duplicate method *might be* (is generally recommended but ?) particularly appropriate when':

  a) the confidence and robustness required of decisions to be based on the information from the site investigation is high; - ALWAYS?

  b) an investigation involves a large number of sampling locations

  - NO – just need 8 duplicates – so a minimum of 8 samples (i.e >10% of locations) - DELETE

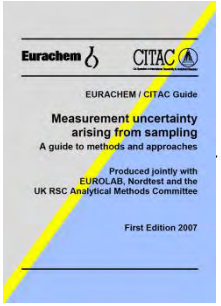
  c) the analytical results are close to the site assessment criteria;

  - if away from T – show higher U (lower cost) justified

  d) the ground is expected to be highly heterogeneous.

  Common on contaminated site - don't know otherwise without duplicate samples!

Explain practicality & utility - saving money on development overall, - judging and demonstrating fitness-for-purpose (FFP) (add to list)



Accepted in European Guidance – with contaminated land example*

- *better to cite than earlier CLAIRE TB7*
- *also give design needed to quantify the contribution from sample preparation (Appendix D)*

* Eurachem/EUROLAB/CITAC/Nordtest/AMC Guide: *Measurement uncertainty arising from sampling: a guide to methods and approaches Eurachem* Ramsey M.H., and Ellison S. L. R.,(eds.) (2007) ISBN 978 0 948926 26 6. (http://www.eurachem.org/guides/UfS_2007.pdf)

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What needs to go into BSI 10175?(2)

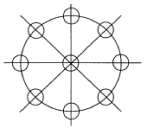
- Don't just consider UfS as part of QC = pass/fail – give values of Uncertainty to user
- **Composite samples – Importance for reducing U**.
  - Currently not recommended (7.6.2.6 Composite sampling and Table 9),
  - however 'cluster samples' = closely spaced incremental samples(8.3.2) 'may' be taken (e.g. for trial pits) – to make samples 'representative'.
  - composite sample in international terminology – just with increments taken over a smaller scale than envisaged for the not recommended 'composite' samples.
- Reasons for not taking composite samples (sec 7.6.2.6) - can all be refuted if U known:-

  a) difficulty of comparing resultant data with guideline concentrations that relate to spot samples;

  – *- just lower measurement uncertainty*

  b) possibility of disguising isolated locations of high concentration by mixing with samples of lower concentration;

  - not a problem with small-scale composites (~ 'cluster samples' over <1m^2) - **Are** suitable for undisturbed sam

  c) possibility of loss of volatile compounds during the compositing processes;

  – *also applies to spot/grab samples – needs separate treatment*

  d) difficulty of achieving an adequately mixed and representative sample;

  - *no sample is entirely representative (has uncertainty) but composite samples are more representative if properly prepared*

  e) difficulty in undertaking statistical analysis of composited data.

  – OK is uncertainty known (lower for composite sample – if sampling target properly defined (e.g. small area, or one trial pit)
- 4.2 Setting investigation objectives- need to make sure measurements ~ FFP – need Uncertainty values
- Approach also applicable to on site and *in situ* measurements (8.4 On-site testing)
  - – make ref to EA (2009)* gives worked example

*ENVIRONMENT AGENCY (2009) Framework for the use of rapid measurement techniques (RMT) in the risk management of land contamination ISBN 978-1-84432-982-3

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Conclusions

1. Clearer definitions of sampling, measurement uncertainty, sampling uncertainty (section 3)
2. Broader introduction to the importance of estimation and reporting of uncertainty, rather than assumption of 'representative' sampling (Sections 7.8 & 10.3)
3. 'Strongly recommend estimation of U from sampling' (Sections: 5.7.2 Decision 4)
4. Revised wording in Annex D – to explain broader applicability and usefulness of duplicate method, e.g. for judging fitness-for-purpose
   - cite Eurachem Guide, rather than CLAIRE TB7, in Annex D
5. Recommend taking composite samples (over small area *= cluster sample*) if sampling uncertainty needs to be reduced (Sections 7.6.2.6 & 8.3.2)
6. State U approach also applicable to on site and *in situ* measurements - making reference to EA (2009) - (8.4.1 On-site testing)

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    - for application to on site measurements

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