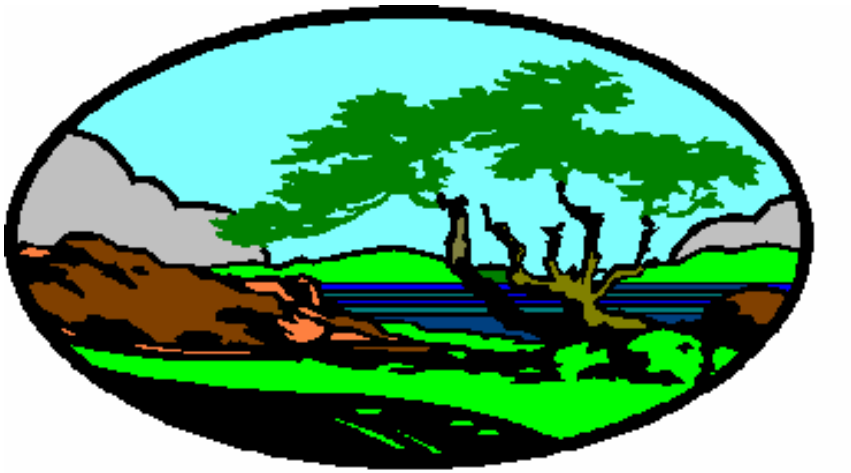
Key Solutions

Statistical Uncertainty
What, When, Why and How



2005 RETS/REMP Workshop

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What Do I Use and When

- CL
- MDA
- MDC
- LTL
- LLD

Detection Limits

- A Posteriori – “After the Fact”
  - Used in Decision Making and Reporting
- A Priori - “Before the Fact”
  - Used to Establish Minimum Level of Effort
  - In Vivo, In Vitro, Effluent and Environmental Sensitivities are Stated in Terms of A Priori Detection Limits

A Posteriori Detection Limits

- Decision Statistic
  - Critical Level (CL)
- Reporting Statistics
  - Minimum Detectable Level (MDL)
    - Minimum Detectable Activity (MDA)
    - Minimum Detectable Concentration (MDC)
  - Less-Than Level (LTL)

Critical Level - CL

- Decision Statistic - “Yes” or “No”
- Is the sample count rate statistically different from the background?
- Used to Accept or Reject a Measurement
- Defined as the Net Count Rate Which Must be Exceeded Before the Sample is Said to Have Activity Above Background

Critical Level

- For Example: Critical Level is Used to Accept or Reject Peaks in Gamma Spectroscopy Analysis.
- If Net Peak Area > CL Then Peak is Present
- If Net Peak Area < CL Then Peak is Absent

Critical Level

- Typically Defined With a 95% Confidence Level
- Only 5% Probability of Falsely Reporting Zero Activity as Real Activity

Critical Level

$$CL = 1.65\sqrt{2\frac{R_b}{T_c}}$$

Where

CL	=	Critical Level
1.65	=	5% Confidence Level Factor
R_b	=	Background Count Rate
T_c	=	Count Time

Statistics are defined for case where Sample Count and Background Count Times are Equal (e.g. Gamma Spec)

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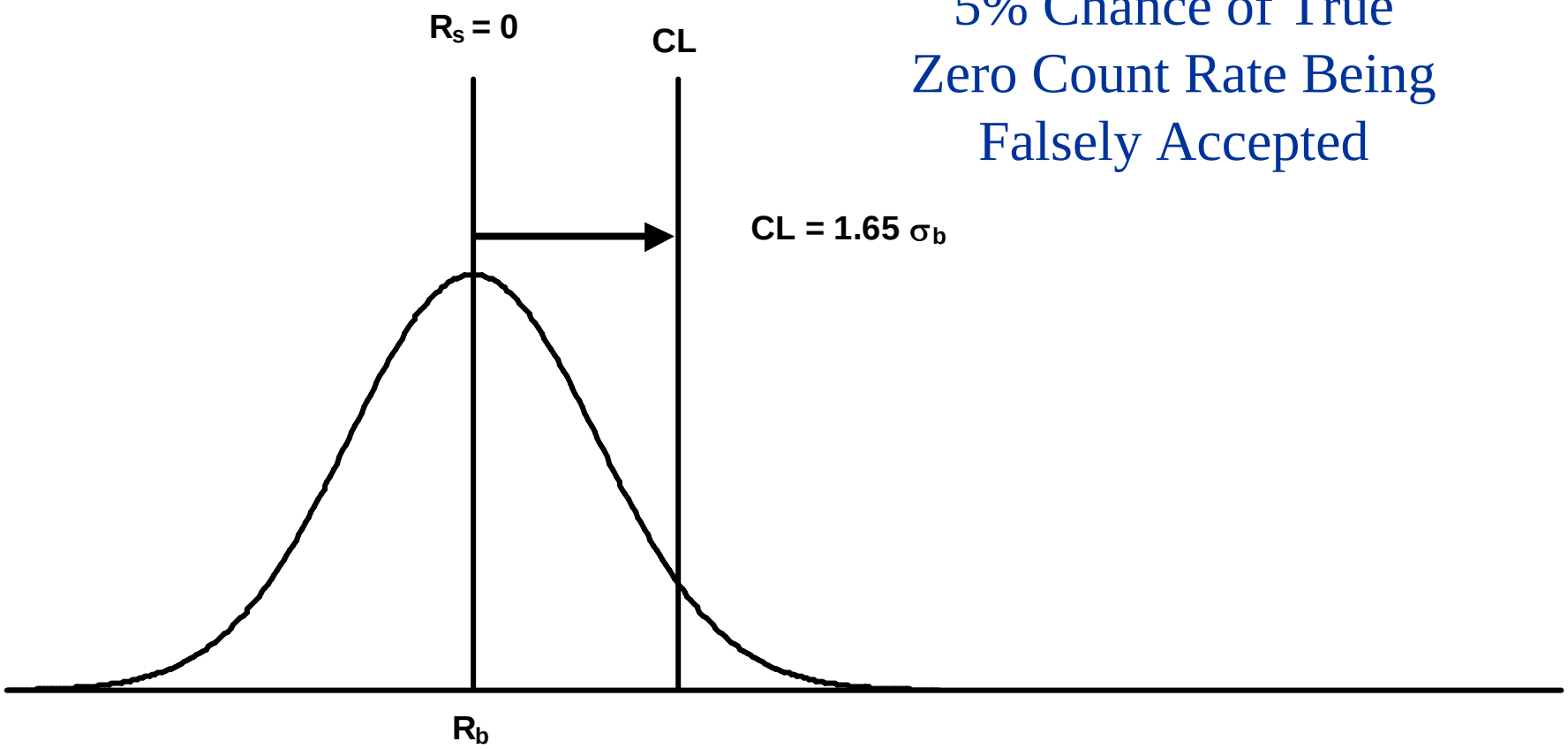
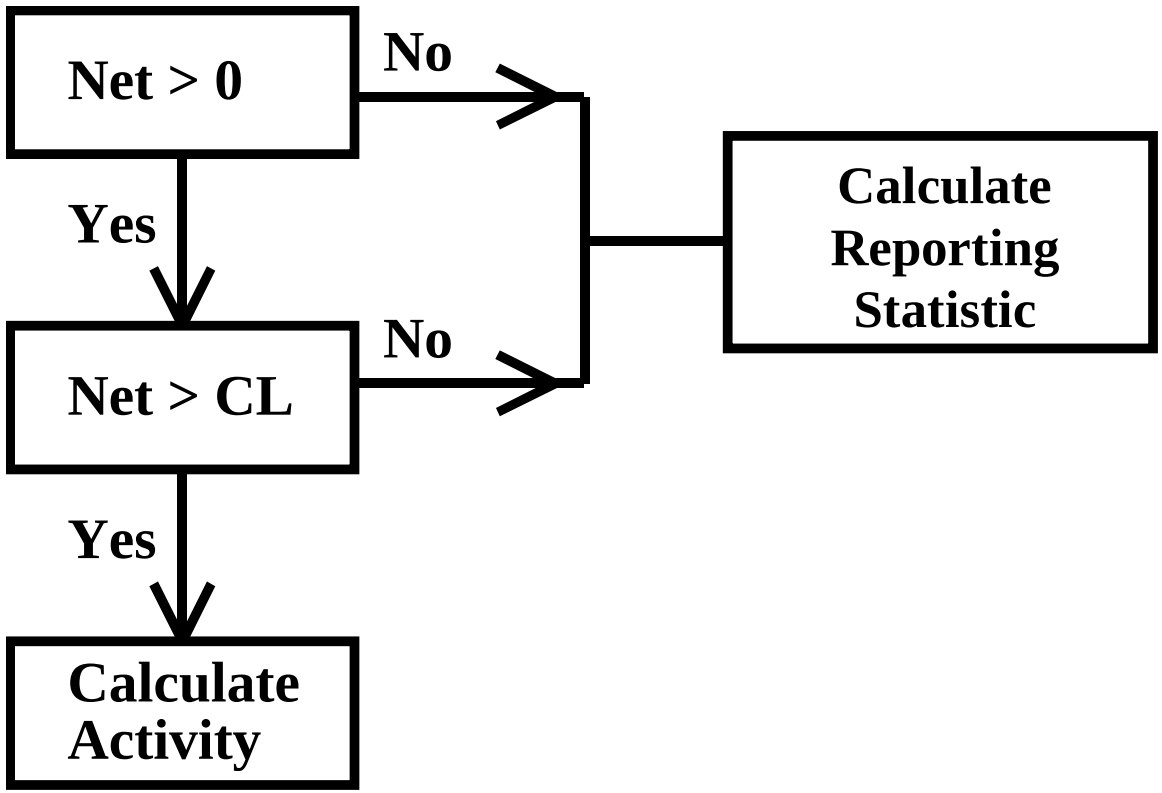
Critical Level



5% Chance of True Zero Count Rate Being Falsely Accepted

Use of Critical Level



Reporting Statistics

- Minimum Detectable Limit
  - Minimum Detectable Activity
  - Minimum Detectable Concentration
- Less-Than Level

Minimum Detection Limit

- What is the smallest quantity of activity which can be detected with 95% confidence?
- What level can be detected on a routine basis?
- Used as a Reporting Statistic.

Minimum Detectable Limit – MDL (MDA/MDC)

$$MDC = 4.66 \frac{\sqrt{R_b / T_c}}{\varepsilon \, Y_\gamma \, V \, e^{-\lambda t_h}}$$

Where

ε	=	Detection Efficiency
Y_γ	=	Gamma Yield
λ	=	Decay Constant
t_h	=	Sample Hold Time
V	=	Volume

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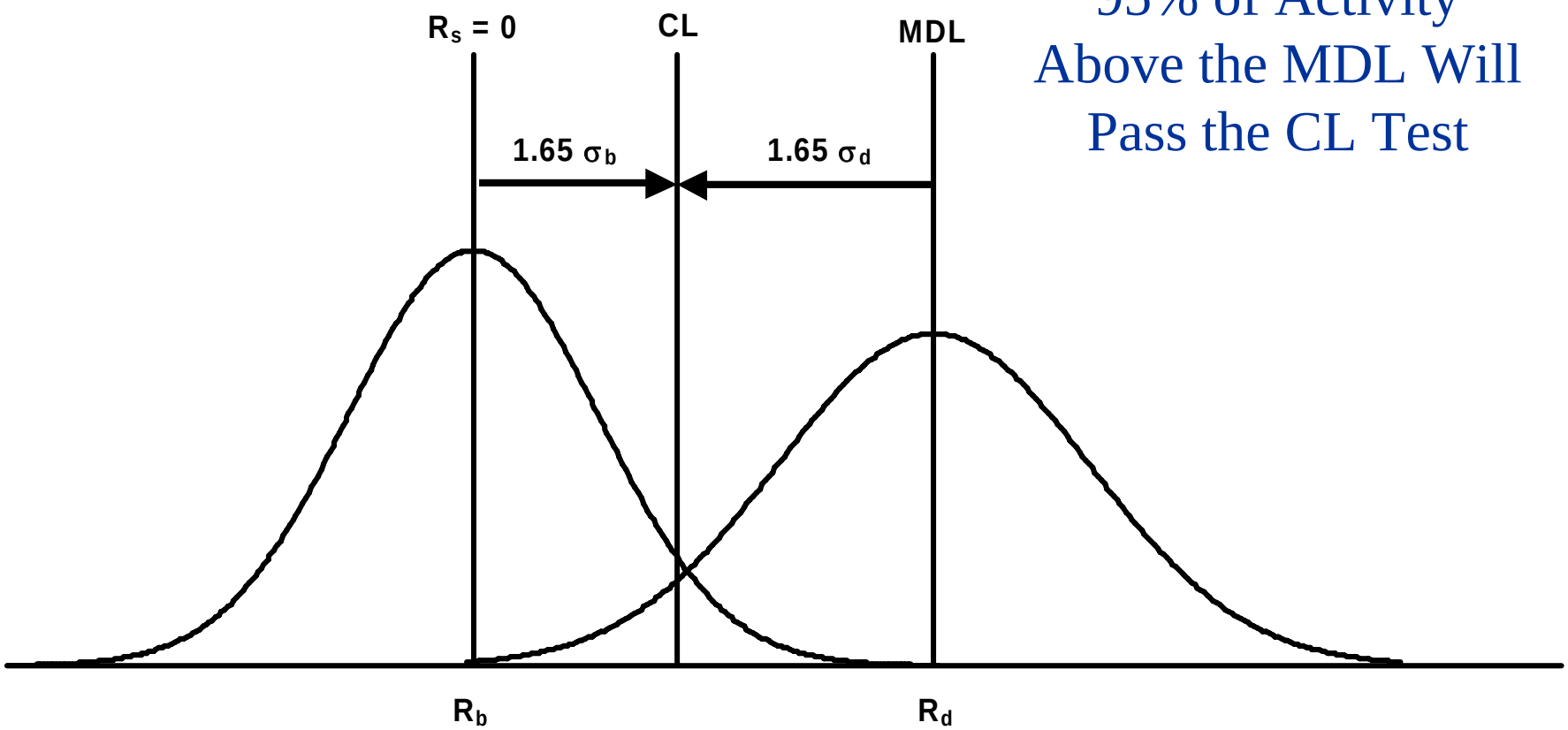
Minimum Detection Limit



95% of Activity Above the MDL Will Pass the CL Test

Less-Than Level

- What is the maximum true count rate a sample can have and still be less than the critical level (i.e. not detected)?
- Less-Than Level (LTL) sets an upper limit on the activity that could be present.
- Used as a Reporting Statistic.

Less-Than Level

- Only Has Meaning When Used in Conjunction With Critical Level Test.
  - Calculated LTL if Critical Level Test Fails.
- True activity could be any where from zero to the Less-Than Level.
- Less-Than Level (LTL) sets an upper limit on the activity that could be present but not detected.

Less-Than Level

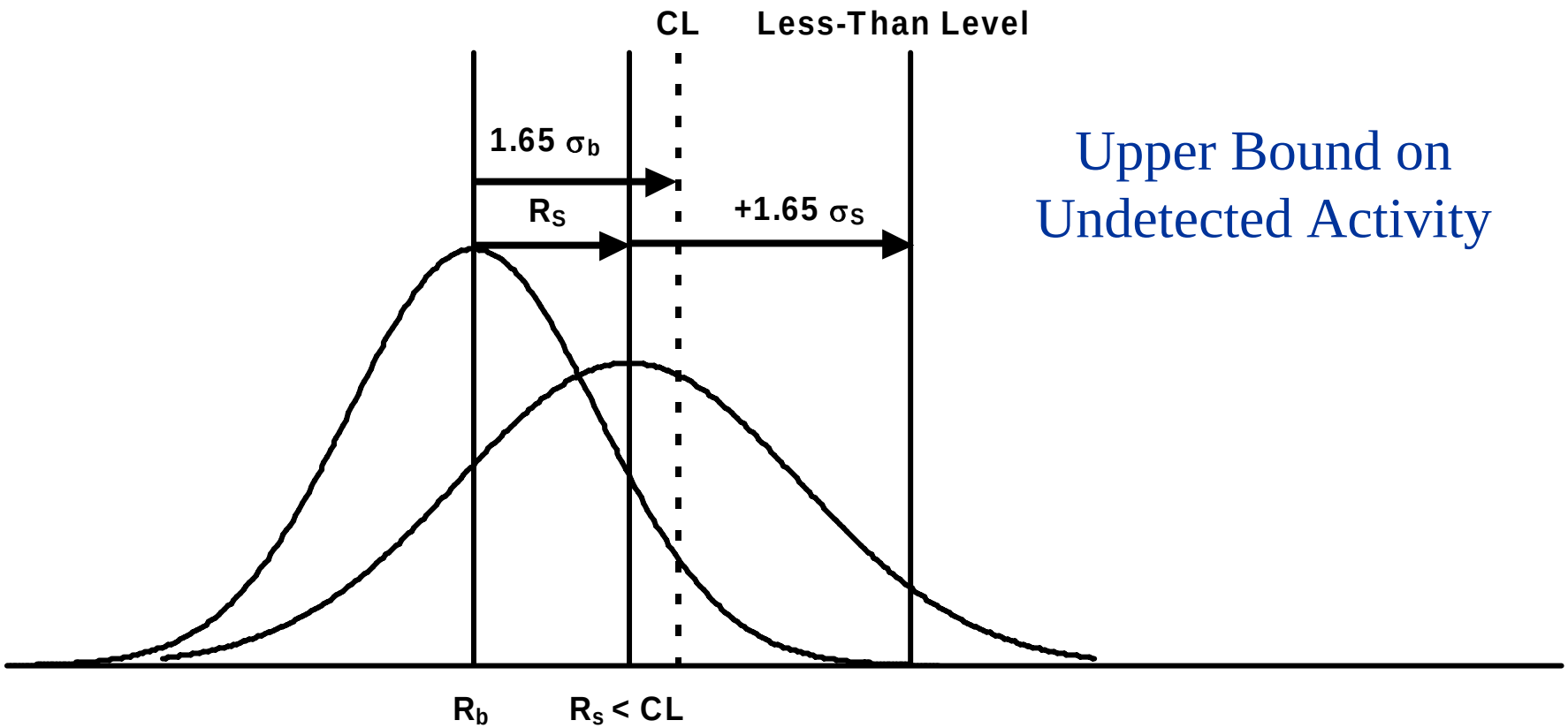
$$LTL = R_s + 1.65\sqrt{\frac{R_t + R_b}{T_c}}$$

Where

LTL	=	Less-Than Level
1.65	=	5% Confidence Level Factor
R_t	=	Total Count Rate
R_b	=	Background Count Rate
T_c	=	Count Time

Key Solutions

Less-Than Level



Upper Bound on Undetected Activity

Less-Than Level

- Note that Less-Than Level could possibly be zero or negative.
- For the case where the Net Count Rate is zero:

$$LTL = CL$$

A Priori Detection Limits

- Detection Limit Concept Subject to Most Confusion and Abuse.
- “Before the Fact” Statement of Potential Measurement Sensitivity.
- Asks the question: “What is the limit on the minimum activity that can be detected?”

Lower Limit of Detection - LLD

$$LLD = 2\left(1.65\right)\sqrt{2\frac{R_b}{T_c}} = 4.66\sqrt{\frac{R_b}{T_c}}$$

Where

1.65 = 5% Confidence Level Factor

R_b = Background Count Rate

T_c = Count Time

Regulatory Detection Limits

- Detection Limits for Effluent and Environmental Monitoring are Required by Tech Specs (NUREGs 0472, 0473, 1401 and 1402).
- Explicitly Stated as A Priori Detection Limits.
- NUREGs Use the Term “LLD” But Define an A Priori “MDC”.

Tech Spec LLDs

- Intent is to specify a minimum level of effort for detection of activity in effluent and environmental samples.
- The Tech Spec LLD dictates, in an A Priori fashion, the constraints of the measurement process.

NUREG - LLD

$$LLD = 4.66 \frac{\sqrt{R_b / T_c}}{\varepsilon \, 2.22 \times 10^6 \, Y \, V \, e^{-\lambda t_h}}$$

4.66	=	5% Confidence Level Factor
R_b	=	Background Count Rate
T_c	=	Count Time
ε	=	Detector Efficiency
2.22	=	dpm/pCi
Y	=	Radiochemical Yield
V	=	Sample Volume
λ	=	Decay Constant
t_h	=	Sample Hold Time

NUREG - LLD

LLD Met By Controlling:

- Background
- Counting Time
- Counting Efficiency
- Sample Volume
- Sample Hold Time

Key Solutions

LLD Compliance

Parameter to Control	Establish Min/Max Limit	How Controlled and Documented
Background	**Max**	**QC/Procedure**
Count Time	**Min**	**Procedure**
Count Eff.	**Min**	**QC/Procedure**
Volume	**Min**	**Procedure**
Collect Eff.	**Min**	**QC/Procedure**
Hold Time	**Max**	**Procedure**

Definition of Background Count Rate

- "Counting Rate of a Blank Sample As Appropriate"
- Blank – "Signal Resulting from a Sample Which is Identical … to the Sample of Interest, Except that the Substance Sought is Absent" (Currie – 1968)

What Is Appropriate Blank?

- Note Wording of LLD Definition In Guidance for Effluent LLDs

"Blank Sample as Appropriate"

What Is Appropriate Blank?

- Note Wording of LLD Definition In Guidance for Environmental LLDs

  "…background fluctuations, unavoidable small sample size or the presence of interfering nuclides…"

What Is Appropriate Blank?

- Environmental Samples Expected to Contain Background Peaks
- LLDs for Environmental Samples Need to be Established Based on Real Sampling Medium

What Is Appropriate Blank?

- NOT Empty Shield
- Background Should be Established for Each Sampling Medium
  - Air Sample = Filter and Charcoal Cart
  - Soil Sample = Clean Soil
  - Etc

LLD - Use

- Used to Establish Constraints on Entire Measurement Process
- Dictates a Minimum Level of Effort
- Allows One to State the POTENTIAL Measurement Sensitivity

LLD - Abuse

- Tech Spec LLD is **Not** an A Posteriori Detection Measurement
- Should **Not** Be Calculated for Each and Every Measurement
- Bad Practice to Rely On A Posteriori MDA as Proof Meeting LLD

LLD - Abuse

- **Not** Appropriate to Report “Less Than LLD”
- Should Report Calculate and Report LTL

Key Solutions

How Low Do We Go?

Where Did the LLD Number Come From?

- LLDs in Current Guidance Based On

  "What (we thought) the technology would be capable of by the time the RETS were in force."
- Based on 25+ Year Old Technology.

How Low Do We Go?

"…the detection capability of environmental measurements should be the most sensitive that is practicably achievable for measuring plant-contributed radionuclides in the environment."

Reg Guide 4.1

- Absence of Proof is not Proof of Absence.
- Could You Have Looked Lower If You Wanted To?
- How Much Activity Was Released and You Did Not See It?

Key Solutions

NUCLEAR INFORMATION RESOURCE SERVICE

ROUTINE RADIOACTIVE RELEASES FROM NUCLEAR REACTORS - IT DOESN'T TAKE AN ACCIDENT

What you are not supposed to know:

www.nirs.org/factsheets/routineradioactivereleases.htm

What you are not supposed to know:

"Radioactive releases from a nuclear power reactor's routine operation often are not fully detected or reported. Accidental releases may not be completely verified or documented."

What you are not supposed to know:

"Government regulations allow radioactive water to be released to the environment containing "permissible" levels of contamination. Permissible does not mean safe. Detectors at reactors are set to allow contaminated water to be released, unfiltered, if below "permissible" legal levels."

What you are not supposed to know:

"The Nuclear Regulatory Commission relies upon self-reporting and computer modeling from reactor operators to track radioactive releases and their projected dispersion. A significant portion of the environmental monitoring data is extrapolated – virtual, not real."

- Accidental Releases May Not Be Completely Verified Or Documented
- Permissible Does Not Mean Safe
- Absence of Proof is not Proof of Absence”

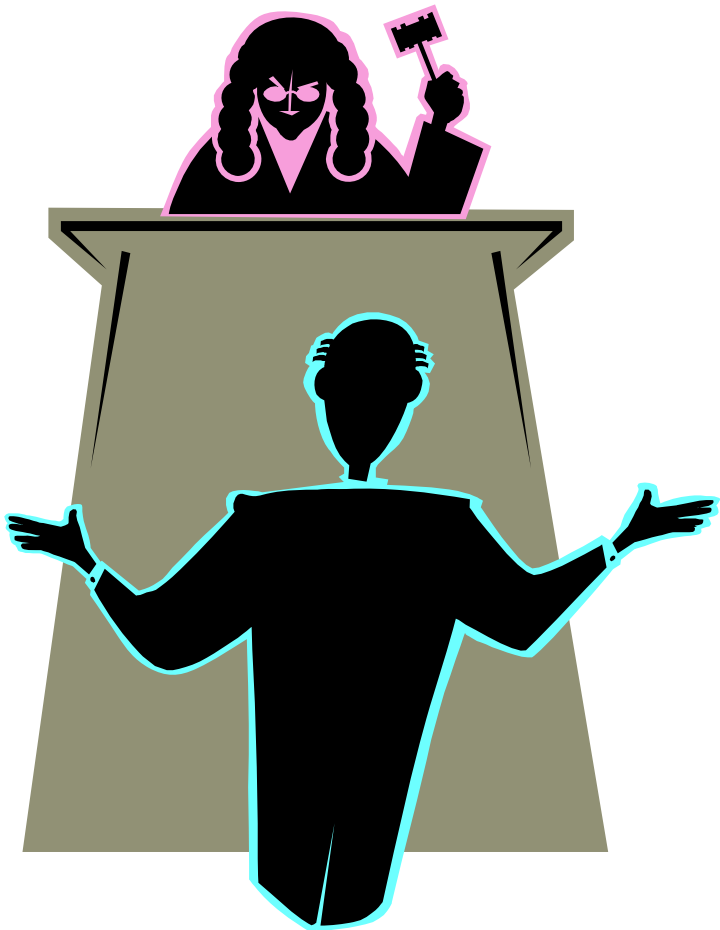
Key Solutions

“Missed Dose”

- D.O.E. Practice is to Calculate “Missed Dose” Assuming Activity Was Continually Present at the Critical Level
- Government Rad Worker Compensation Will Be Based on “Missed Dose” Thus Establishing Legal Precedent

Key Solutions

In Court…



"We Complied With Regulatory Requirements" – Poor Litigation Defense

Must Be Prepared to Demonstrate Due Diligence

Key Solutions

In Court…

"You Were Aware That the Technology Could Easily Look to Lower Levels. Why Didn't You Monitor at the Lower Levels"

"Afraid We Would See Something and Have to Start Reporting It."