Paula Wilson

From: Michael Backe <mBacke@OlyTech.com>
Sent: Tuesday, July 26, 2011 5:14 PM
To: Paula Wilson; Orville Green; Bruce Wicherski
Cc: Hugh O'Riordan; Michael Brush
Subject: PQL comments
Attachments: Appendix A-11 and Appendix A-11 Table esc.pdf; Appendix A-11 PQL_7-8-11 ots.doc; Appendix A-11 Table PQL_7-8-11 ots.doc; Sampling error hdr.pdf

Paula,

Attached are our comments for Appendix A-11 of the Draft Petro REM Guidance. Also attached are discussions on PQL provided by ESL Lab Sciences for Appendix A-11, and from Mike Murray (HDR) related to Appendix section A-9.4.4.1.

Thanks again for your help.

Mike Backe

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Table A-11-1

MDL and PQL Soil, Water, and Vapor Concentrations for Petroleum Chemicals of Interest Using Selected Analytical Methods

	SOIL			WATER			VAPOR		
CHEMICALS	Method	MDL (mg/kg)	PQL (mg/kg)	Method	MDL (mg/L)	PQL (mg/L)	Method	MDL (ug/m3)	PQL (ug/m3)
Acenaphthene	8270(SIM)	0.0087 (0.0016)	0.036 (0.006)	8270(SIM)	0.0004 (0.000013)	0.001 (0.00005)	NA		
Anthracene	8270(SIM)	0.0074 (0.0008)	0.036 (0.006)	8270(SIM)	0.00036 (0.000012)	0.001 (0.00005)	NA		
Benzo(a)anthracene	8270(SIM)	0.0093 (0.0011)	0.036 (0.006)	8270(SIM)	0.0004 (0.000023)	0.001 (0.00005)	NA		
Benzo(a)pyrene	8270(SIM)	0.0098 (0.0008)	0.036 (0.006)	8270(SIM)	0.00053 (0.000013)	0.001 (0.00005)	NA		
Benzo(b)fluoranthene	8270(SIM)	0.0098 (0.0011)	0.036 (0.006)	8270(SIM)	0.00046 (0.000024)	0.001 (0.00005)	NA		
Benzo(k)fluoranthene	8270(SIM)	0.0089 (0.0005)	0.036 (0.006)	8270(SIM)	0.00036 (0.000020)	0.001 (0.00005)	NA		
Chrysene	8270(SIM)	0.013 (0.0006)	0.036 (0.006)	8270(SIM)	0.00028 (0.000018)	0.001 (0.00005)	NA		
Fluoranthene	8270(SIM)	0.011 (0.0008)	0.036 (0.006)	8270(SIM)	0.0004 (0.000020)	0.001 (0.00005)	NA		
Fluorene	8270(SIM)	0.0078 (0.0018)	0.036 (0.006)	8270(SIM)	0.00042 (0.000012)	0.001 (0.00005)	NA		
Pyrene	8270(SIM)	0.010 (0.0006)	0.036 (0.006)	8270(SIM)	0.00035 (0.000022)	0.001 (0.00005)	NA		
1,2-Dichloroethane	8260	0.00053	0.001	8260	0.00027	0.001	TO-17	--	0.4
Ethylene Dibromide	8011	0.000007	0.00001	8011	0.0000057	0.00001	TO-15 SIM	--	0.8
Benzene	8260	0.00033	0.001	8260	0.00029	0.001	TO-17	--	0.32
Ethylbenzene	8260	0.00023	0.001	8260	0.00022	0.001	TO-17	--	0.43
Toluene	8260	0.0012	0.005	8260	0.00027	0.005	TO-17	--	0.38
Total Xylenes	8260	0.00046	0.003	8260	0.00086	0.003	TO-17	--	0.43
MTBE	8260	0.00028	0.001	8260	0.00019	0.001	TO-15 SIM	--	0.5
Naphthalene	8260	0.0004	0.005	8260	0.00017	0.005	TO-17	--	0.05

Appendix A-11: Practical Quantitation Limits

INTRODUCTION

During the risk evaluation process when collecting media-specific chemical concentration data and establishing remediation standards situations may arise where practical quantitation limits (PQL) for specific chemicals and samples may exceed screening levels or site-specific, risk based concentrations. Section 500 of IDAPA 58.01.24, Application of Risk Based Corrective Action at Petroleum Release Sites delineates factors which may be used to allow the use of PQLs as remediation standards, as follows:

- Analytical Method
- Method Detection Limit
- Sampling Procedures
- Estimated Risk Levels
- Other

This appendix provides guidance on how to apply these factors when making this determination.

PRACTICAL QUANTITATION LIMITS AND METHOD DETECTION LIMITS

A PQL is defined in part in 58.01.24.010 as "The lowest concentration of a chemical that can be reliably quantified among laboratories within specified limits of precision and accuracy for a specific laboratory analytical method during routine laboratory operating conditions". The Method Detection Limit (MDL) is defined as "The minimum concentration of a substance that can be reported with 99% confidence is greater than zero".

PQL values are derived in a number of ways and there is no consensus as to the process used to develop them. In some cases they are derived as a fixed multiplier applied to the MDL value or the standard deviation of samples used to develop the MDL. The multiplier commonly ranges from 3 to 5 and may be as great as 10. In other cases PQL may be derived by analysis of data from actual laboratory performance studies. In these cases, PQL values are a function of analytical methods, a given laboratory's equipment, operating protocols, operating conditions, QA/QC procedures, and sampling and media considerations. Values are sometimes reported by laboratories at levels between the MDL and the PQL and are commonly qualified as estimated quantities. The closer the estimated value is to the PQL the more confidence in the estimated value.

For the petroleum chemicals of interest (COI) listed in the rule the common analytical methods employed at petroleum release sites are established by the U.S. Environmental Protection Agency (EPA) in SW-846 (EPA, 2011). Table A-11-1 lists methods commonly employed in the analysis of the petroleum COI along with typically achieved detection and quantitation limits.

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These values were obtained from sample laboratory reports for site investigations done for DEQ at a number of sites where petroleum COI were suspected. In their method descriptions EPA lists examples of lower limits of quantitation for individual analytes but indicates that they are instrument dependent and influenced by sample preparation/introduction technique (EPA, 2006) or highly matrix-dependent and are provided for guidance only (EPA, 2007).

Comment [MAB1]: This type of approach may lead to false expectations. The laboratory QA/QC may vary between laboratories. On laboratory may achieve lower limits, but at the expense of QA/QC. A different approach would be to survey a sample of laboratories that do business in Idaho to determine what the typical limits are, then use a 95% UCL of their limits (standard PQL).

A process could be established to modify the standard PQL as technology improves.

For a given media, sampling considerations may have an impact on achievable detection limits. For example, when sampling soil vapor or ambient air with certain methods, the achievable quantitation limit can be a function of the amount of vapor or air sampled. Quantitation limits are commonly reduced as the amount of air sampled increases.

Specialized analytical techniques can sometimes provide lower MDL and PQL values. Table A-11-1 illustrates this with a comparison of values between the use of standard method 8270 for semivolatile compounds vs. employing 8270 using selective ion monitoring (SIM). PQL values are 6X lower for soils and 20X lower for water samples.

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Depending on the petroleum product released, the levels of contamination, chemicals present and the media in question (soil, water, and vapor) interferences to analytical detection and quantitation may be present. This may require procedures such as sample dilution in order to quantify COI concentrations in a sample but that result in elevated detection and quantitation limits.

REMEDIATION STANDARD

A remediation standard is defined in IDAPA 58.01.24 as a "media specific concentration which, when attained, is considered to provide adequate protection of human health and the environment".

Remediation standards are established at petroleum release sites where corrective action has been determined to be required. The need for corrective action is commonly determined after completion of a risk evaluation. Remediation standards are commonly established as part of a risk evaluation or an approved corrective action plan (CAP).

The magnitude of a remediation standard that is established for a given chemical and the potential that it may be exceeded by a PQL is dependent on a number of factors. These factors include, but are not limited to:

- assumptions regarding current and future site land use, both on and off site,
- what petroleum products were released and the relative distribution of chemicals detected,
- the magnitude and distribution of contamination (which media are impacted), and
- the routes of exposure determined to pose the greatest threats.

The two risk evaluation scenarios where elevated PQL values may require the reevaluation of initially selected remediation standards include:

1) Screening Level Evaluation
The screening level evaluation described in IDAPA 58.01.24 employs the simplest and most straightforward use of remediation standards, in the form of the residential use screening levels. The screening levels are conservative, calculated, risk-based concentrations determined to be protective of unrestricted use exposures. These media-specific chemical concentrations are established without consideration of the ability of standard laboratory methods to detect and quantify these values.

Comment [MAB2]: Any screening level should be set such that the required PQL can be achieved (on an undiluted sample); otherwise, a screening level is useless.

In the screening level evaluation, the user must compare maximum media-specific concentrations measured during site assessment activities to the screening levels. If the measured concentrations do not exceed the screening levels, the site may be eligible for site closure. If the measured concentrations do exceed screening levels, the user may select screening levels as the remediation standards upon which corrective action is based. Measured concentrations may exceed the screening levels either as a result of detected and quantified concentrations or by elevated PQLs. In the latter case, an unacceptable risk would be indicated and would require either additional investigation/evaluation or development of a cleanup plan.

Comment [MAB3]: There should be a mechanism to use standard PQLs (as discussed above) rather than requiring additional evaluation on non-detect samples that have standard PQLs

2) Site-Specific Risk Evaluation
During the site-specific risk evaluation process media-specific chemical concentration data is collected and used, along with assumptions regarding exposure pathways and receptors, to calculate risk to expected receptors. If the calculated risk is unacceptable, media-specific risk-based chemical concentrations are established. These risk-based concentrations become the remediation standards for site corrective action. Samples are then taken during and after corrective action to demonstrate the standards have been attained.

PQLs for selected analytes in a given media sample may exceed one or more of the calculated risk based remediation standards, making the demonstration that the standard has been attained problematic. It is also problematic when samples with results below a PQL are included in the calculation of exposure point concentrations and risk.

Remediation standards are oftentimes the lowest at sites where:

- screening levels have been selected as the standards,
- unrestricted use is the desired corrective action land use goal,
- contamination has migrated offsite in ground water,
- onsite vapor intrusion risk is determined to exist, or
- diesel fuel contamination (and polynuclear aromatic hydrocarbon chemicals) are present in surface soil or in close proximity to surface water.

Accordingly, PQL-related issues often arise at such sites.

PROCESS FOR THE CONSIDERATION OF PQLs AS REMEDIATION STANDARDS

When a REM user proposes the use of PQLs as remediation standards, the user must develop and provide to DEQ as part of a proposed CAP a ~~a~~ proposal of PQLs as the remediation standards. . The proposal should include the results of any risk evaluation, the remediation standards developed from that process and the proposed PQL. The proposal should be completed so as to answer the questions below. The proposal should identify and discuss the site-specific issues, with supporting information, that justify the use of the proposed PQL(s) as a remediation standard(s).

Risk Evaluation

- What are the chemicals, media and pathway or route of exposure for which the issue exists?
- Is the PQL issue related to a Screening Evaluation and screening levels or a Site Specific Evaluation and risk based concentrations?
- If a Screening Level Evaluation, would performing a site specific evaluation address the PQL issue?
- If a Site Specific Evaluation, what is the impact on the estimated risk of assuming the specific COI at the proposed PQL? Is the risk still acceptable? If the risk was calculated for a residential receptor would the risk be acceptable for non-residential receptors? Does the chemical(s) with PQL issues contribute a significant portion of the cumulative risk?
- ~~Would the implementation of activity and use limitations through an environmental covenant mitigate the risk presented by the chemical(s) at the PQL.~~
- If risk based concentrations (RATLs) are calculated for multiple chemicals can the risk be allocated in a different manner such that the allowable concentrations for chemical(s) without PQL issues be reduced to meet the cumulative risk criteria while maintaining the chemicals at issue at their respective PQL?

Comment [MAB4]: It should not be necessary to establish an EC for a site is the standard PQL (discussed above) is used

Analytical Methods

- What are the analytical methods being employed that are the basis of the PQL?
- Are there other analytical methods available with lower reporting limits?
- Are there special analytical techniques (such as Selective Ion Monitoring or SIM) which may be employed to achieve lower detection and quantitation limits?
- Are there other laboratories available which can achieve lower quantitation limits?
- Are there QA/QC issues that impact the stated PQL? Supporting lab QA information should be provided.

Comment [MAB5]: These should be based on standard, readily available EPA-approved methods

Method Detection Limit

- What is the stated method detection limit and what is the magnitude of the difference between it and the PQL?
- Is the method detection limit at or below the risk based remediation standard?

Sampling

- What sampling procedures are used for the media and chemical of interest?
- Are there alternative sampling procedures (such as increasing sample air volumes for soil vapor samples) which may result in lower detection and quantitation limits?
- Are there matrix interference issues with the samples being used in the proposal that prevent adequate quantitation limits from being attained? What is the supporting laboratory evidence that matrix interference issues exist? Are there specialized sample preparation methods which might reduce these interferences?
- Has resampling taken place to confirm the PQL issue?

DEQ will review the proposal for use of a specific PQL as a remediation standard as part of the overall CAP and approve or deny the request along with specifying any conditions of approval or reasons for denial.

Comment [MAB6]: IDEQ should present a pathway on how it will address PQL issues; this statement is too vague.

REFERENCES

EPA, 2006. Method 8260C. Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), Revision 3, August 2006 in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. United States Environmental Protection Agency. SW-846.

EPA, 2007. Method 8270D. Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS).), Revision 4, February 2007 in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. United States Environmental Protection Agency. SW-846.

EPA, 2011. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. United States Environmental Protection Agency. SW-846. Update IV of the Third Edition. Can be accessed at: http://www.epa.gov/epawaste/hazard/testmethods/index.htm

From: Judy Morgan
To: mBacke@OlyTech.com
Subject: RE: REM for Petroleum Releases - Appendix A-11 and Appendix A-11 Table attached
Date: Tuesday, July 26, 2011 5:02:38 PM

Hi Mike,

My comments are as follows:

General

We have multiple instruments. When we establish MDLs, we see a wide range of performance based on the instruments being evaluated. Many times, depending on the everyday use of a given instrument, the sensitivity may not be as good as one that is newer or equipped with newer technology. Soil samples are much more difficult to recover accurately and consistently at low levels. We have LOD verifications that give assurance to the accuracy of the reporting limit and indicate a higher accuracy for the MDL since the value is set at 2-3 times the MDL. MDL's that fall lower than this value are questionable.

The MDL procedure that laboratories use is a statistical calculation based on reproducibility and most labs don't set a recovery criteria, since it is not required. ESC sets the recovery criteria to 50-150% and still must provide reproducibility at an acceptable level. There are several ratio tests that an MDL must pass in order to be valid. Therefore unless all laboratories involved in the data calculations performed the MDL procedure the same way, then the results could be biased. NELAC and DOD laboratories are required to verify the LOD thus giving more credibility to the MDL being reported.

The ratio comparisons are as follows:

- The concentration used to establish the MDL can be no more than 10 times higher than that of the final calculated MDL. (If it is, then the study must be repeated)
- The final calculated MDL cannot exceed that of the established PQL.
- The PQL should be at least 3 times that of the final calculated MDL.

PQL Table

Ethylene Dibromide in Soil by 8011: - Method 8011 gives no provision to analyze anything other than water. The alternative is 8260 which in effect gives an MDL of 0.000372 and a PQL of 0.001, therefore the limits are substantially lower than readily achievable by available methods and technology.

Volatiles in soil:

We are only able to meet the stated MDL on 1,2-Dichloroethene and Toluene. The remaining compounds range anywhere from 1.25X to 2X above the stated MDL.

All PQLs are achievable.

In water we have a similar problem with the MDLs and can only meet Toluene and Total Xylenes.

Air:

We would be running all compounds by TO15 and TO15SIM.

5 compounds (1,2-Dichloroethane, Toluene, Total Xylenes, MTBE, Naphthalene) are not currently

calibrated by SIM and have PQLs that are multiples higher. We can add most of them to SIM, but prefer not to add Naphthalene.

Compound	PQL TO15 ug/m3	TO15 SIM
1,2-Dichloroethane	0.81	NA
Benzene	0.81	0.064
Ethylbenzene	0.87	0.13
Toluene	0.75	NA
Total Xylenes	2.57	NA
MTBE	1.1	NA
Naphthalene	3.3	NA

8270 Soil:

Most compounds are achievable except for:

Anthracene ESC 0.00875 vs ID 0.0074
Benzo(b)fluoranthene ESC 0.0115 vs ID 0.0098

8270 Soil SIM

Benzo(b)fluoranthene ESC 0.000825 vs ID 0.0011
Benzo(k)fluoranthene ESC 0.00134 vs ID 0.0005
Chrysene ESC 0.0011 vs ID 0.0006
Fluoranthene ESC 0.00104 vs ID 0.0008

8270 Water:

Most compounds are achievable except for:

Anthracene ESC 0.000373 vs ID 0.00036

8270 Water SIM

Anthracene ESC 0.0000131 vs ID 0.000012
Benzo(a)pyrene ESC 0.0000158 vs ID 0.00013
Benzo(k)fluoranthene ESC 0.0000255 vs ID 0.000020

In the overall evaluation of the MDL criteria for water and soil, it appears as though many of the values are lower than what is achievable on a consistent basis. It is important that the MDL process be followed, recovery criteria set, and that the ratio criteria be passed in order to achieve solid scientific and defensible data. It is my recommendation that a single method, such as TO-15/TO-15 SIM be chosen to monitor the vapor conpounds. Both TO-17 and TO-15 have different advantages and should be evaluated closely to determine which method meets the data quality objectives of the program.

If you have any questions or need additional information, please contact me.

Thanks!

Judy

Judy Morgan, MS, REM
VP, Director of Technical & Regulatory Affairs
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"It is the province of knowledge to speak, and it is the privilege of wisdom to listen" -- Oliver Wendell Holmes

---

From: Michael Backe [mailto:mBacke@OlyTech.com]
Sent: Monday, July 25, 2011 4:09 PM
To: Judy Morgan
Cc: Michael Brush; Hugh O'Riordan
Subject: RE: REM for Petroleum Releases - Appendix A-11 and Appendix A-11 Table attached

Judy,

Do you have any comments? I will need to respond to the IDEQ by tomorrow.

Thanks,

Mike Backe

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From: Michael Backe [mailto:mBacke@OlyTech.com]
Sent: Thursday, July 14, 2011 3:14 PM
To: Judy Morgan (jmorgan@esclabsciences.com)
Cc: Michael Brush (mike.brush@idahosif.org); Hugh O'Riordan (who@givenspursley.com)
Subject: FW: REM for Petroleum Releases - Appendix A-11 and Appendix A-11 Table attached

Judy,

Attached is the IDEQ draft guidance regarding PQLs. As we spoke on the telephone, we would appreciate your comments on the document. We need to have our comments to the IDEQ no later than July 26th.

Since I will be out of the office traveling next week, E-mails is the best way to contact me. If you need, you can try me on my cell phone, 208-859-2294.

Thanks,

Mike Backe

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From: Paula.Wilson@deq.idaho.gov [mailto:Paula.Wilson@deq.idaho.gov]
Sent: Monday, July 11, 2011 10:02 AM
To: Aaron.Scheff@deq.idaho.gov; alabeau@iaci.org; Bill.Allred@deq.idaho.gov; wholder@stratageotech.com; Bruce.Olenick@deq.idaho.gov; Bruce.Wicherski@deq.idaho.gov; burl.ackerman@simplot.com; christian.norman@pacelabs.com; clarice.garcia@avistacorp.com; Curt.Fransen@deq.idaho.gov; dkerner@brwncald.com; ddjo@chevron.com; Daniel.Redline@deq.idaho.gov; daryl.peterson@pacelabs.com; dpeterson@pacelabs.com; Douglas.Tanner@deq.idaho.gov; elizabeth.romano@wgint.com; Erick.Neher@deq.idaho.gov; sirs.erik@epa.gov; Gayle.Osburn@deq.idaho.gov; Geoff.Harvey@deq.idaho.gov; who@givenspursley.com; barracloughjt@yahoo.com; jpotts@brwncald.com; jronk@iaci.org; Jeffrey.Fromm@deq.idaho.gov; jon.munkers@terragraphics.com; jhayes@idahoconservation.org; Keith.Donahue@deq.idaho.gov; kevin.freeman@lfr.com; kryan@stratageotech.com; Kristi.Lowder@deq.idaho.gov; lhenry@brwncald.com; ecody@cityofboise.org; lgerbert@brwncald.com; mark.christensen@pacificorp.com; mtorf@torf.us; mary.sitko@pacelabs.com; Michael.McCurdy@deq.idaho.gov; mbacke@olytech.com; mike.brush@idahosif.org; mike.murray@hdrinc.com; mike.procsal@terragraphics.com; neil.colwell@avistacorp.com; Orville.Green@deq.idaho.gov; patbarclay@icie.org; pclark@stakerparson.com; pkhunter@mse-env.com; paul.spillers@tetratech.com; paula.lyon@lfr.com; Paula.Wilson@deq.idaho.gov; Pete.Wagner@deq.idaho.gov; rachel.damewood@inl.gov; Rick.Jarvis@deq.idaho.gov; robin.nimmer@terragraphics.com; ron.phillips@tetratech.com; updates@mytitan.net; greatsam@usfds.com; scohn@idahoconservation.org; sarah.weppner@terragraphics.com; shawkins@iaci.org; srt@moffatt.com; Steven.Heaton@deq.idaho.gov; Susan.Hamlin@deq.idaho.gov; susan.spalinger@terragraphics.com; sbs@sbsidaho.com; Teri.Gregory@deq.idaho.gov; tglindeman@brwncald.com
Subject: REM for Petroleum Releases - Appendix A-11 and Appendix A-11 Table attached

Attached is a copy of Appendix A-11: Practical Quantitation Limits and the Appendix A-11 Table. The written comment deadline for Appendix A-11 and the table is 7/22/11. Written comments may be submitted to me by e-mail or fax to (208)373-0481.

These documents will also be posted at http://www.deq.idaho.gov/risk-evaluation-manual.

Paula Wilson
(208)373-0418

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Memo

To: Mike Backe	
From: Mike Murray, HDR	Project: IDEQ Petroleum REM Draft Guidelines
CC:	
Date: July 15, 2011	Job No:

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Subject: Comments on Statistics for Additional Samples

This memo is a follow up to my April 2011 comments made to Appendix A-9 Exposure Point Concentrations. Specifically, in Section *A9.4.4.1- Exposure point compliance well concentration for protection of ground water*, the draft guidelines had described the need for two years of groundwater monitoring data or a minimum of 8 measurements. While generally it is desirable to have eight data points, the comment I had made was that if you do not have a secular trend in the data, then you could run statistics with as little as 3 points and determined if you need to collect more samples or can stop collecting samples. The rationale is presented below and is exerted from work that I have been doing at Mountain Home Air Force Base for soil sampling that IDEQ has had involvement with the study and has approved our work plans (Jeff Fromm and Michael McCurdy).

Decision Logic for determining need for more samples

Sampling error (measured as the relative standard error) is asymptotically related to the inverse of the sample size (**Figure 1**) for normal and log-normal distributed data. As the sample size increases, the variance decreases until it becomes asymptotic. To illustrate this, a simulation of relative error versus samples size was run for a normal distribution (Figure 1). For example, for a population with a coefficient of variation (CV) of 5 percent, the number of samples beyond approximately 8 does not reduce the sampling error very much; therefore, there is little justification to collect more than 8 samples. That is, the 8 samples are near or within the asymptotic region, collecting additional samples does not reduce the sampling error value, so there is no justification for more samples. However, as also illustrated in **Figure 1**, collecting additional samples prior to reaching the asymptotic condition (along the steep portion of the plot) reduces the sampling error (reduced the variance) and there are benefits in collecting additional samples.

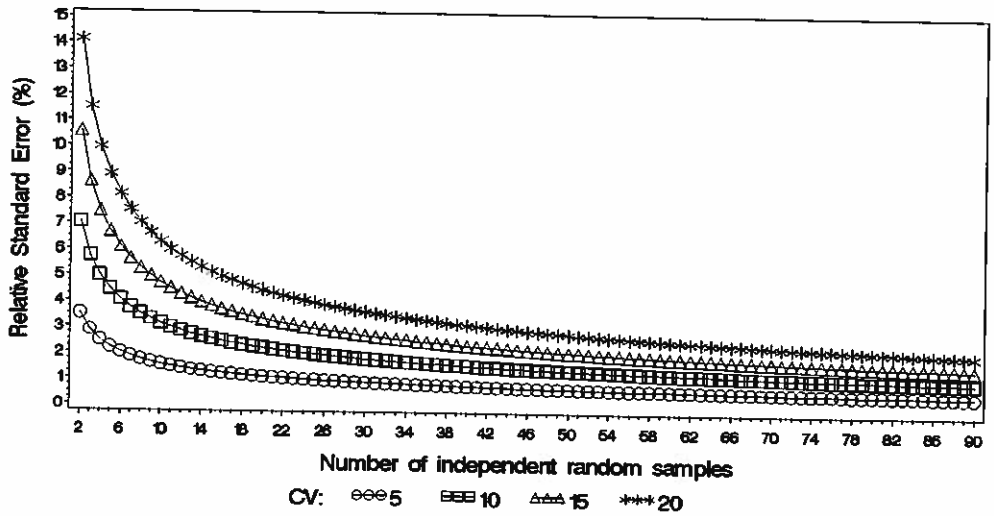

Figure 1. Relative Standard Error as a Function of Sample Size

Based on this relationship, the rationale for the decision logic for deciding if more samples are needed is further explained using the normal distribution for illustration purposes (same logic can be applied to log-normal or non-parametric conditions). This discussion assumes that there is no trend in the data and that samples collected from a groundwater well or series of wells are independent.

- *If the mean and the 95% UCL are equal to or greater than the action level, then site is dirty.* This is illustrated in **Figure 2** (Plot A), where both the mean and the 95 percent UCL are above the action level. Collecting more samples could result in a decrease in sampling error or no change in error (**see Figure 1**) while the estimate mean would remain about the same. Thus, while a reduction in the variance could result in a lower UCL value, additional sampling would likely not change the conclusion that the site is dirty. Therefore, remedial action is warranted and long term monitoring would continue.
- *If the mean and 95% UCL are both less than the action level, then no further action is required (site is considered clean).* This is illustrated in **Figure 2** (Plot B), where both the mean and the 95 percent UCL are below the action level. Collecting more samples would result in a decrease in sampling error or no change in error (**see Figure 1**) while the estimate mean would remain about the same. Thus, while a reduction in the variance could result in a lower UCL, additional sampling would likely not change the conclusion that the site is clean. Therefore, for this condition, no further sampling is recommended. In this situation, if, for example, 4 samples were collected, and there was not observable trend, and both the mean and 95% UCL were below the action level, collecting additional samples provides little value in terms of statistical inference.
- *If the mean is less than the action level but the 95% UCL is greater than or equal the action level, then additional sampling is recommended.* This is illustrated in **Figure 2** (Plot C), where the mean is less than the action level but the UCL is greater than or equal to the action level. Collecting more samples could result in a decrease in sampling error or no change in error (**see Figure 1**) while the estimate mean would remain about the

same. Thus, a reduction in the variance could result in a lower UCL, additional samples could be beneficial for increased statistical power to prevent a false positive. If there is no seasonality or secular trends, these samples could be taken at shorter time intervals (for example weekly rather than quarterly) to shorten the monitoring period and have sufficient samples for statistical inference.

In summary, the point I was trying to make is that requiring a minimum of 8 groundwater samples on a quarterly basis may not always be necessary. Under Plot B in Figure 2, you could use as little as three or four samples and conclude that site is clean. Furthermore, as long as there is no seasonality or secular trends, a shorter sampling interval should be allowed so that the monitoring period is shorten. The key to shorter sampling intervals is that the decision should be based on groundwater velocity and ensuring that samples are independent (see IDEQ's *Statistical Guidance for Determining Background Quality and Degradation* for discussion of sample independence).

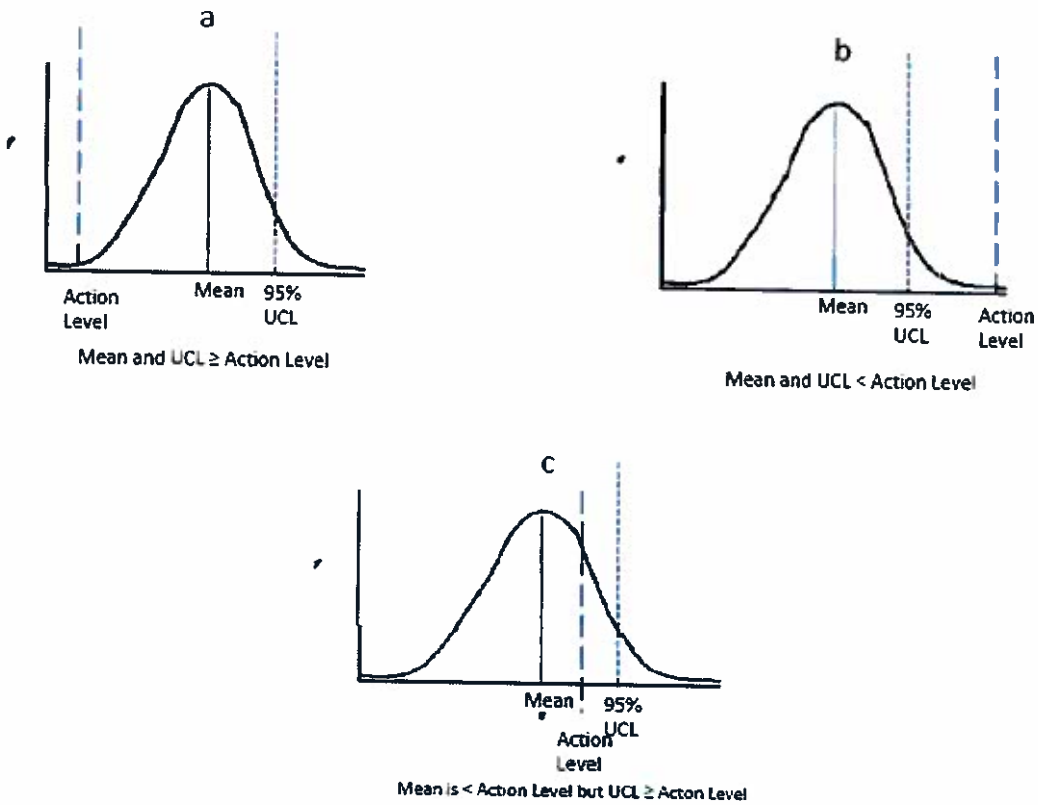

Figure 2 **Decision Logic Based on Mean, UCL, and Action Level Relationships**