SECTION III – TECHNICAL AND PROCEDURAL GUIDANCE III-3

SECTION III. TECHNICAL AND PROCEDURAL GUIDANCE

~~A. GENERAL GUIDANCE~~

~~B.~~A. Fate and Transport Analysis

Fate and transport analyses required under Act 2 may involve a wide spectrum of predictive assumptions, calculations and simulations, from the simple to the complex, depending on the hydrogeologic characteristics of a site, future use scenarios, and the selection/applicability of a particular cleanup standard.

Fate and transport analysis or modeling is a necessary part of site characterization and demonstrating attainment of an Act 2 standard. However, the regulations governing Act 2 use the term "fate and transport analysis" as opposed to "fate and transport model." This particular distinction was made because it will not always be necessary to run an analytical or numerical quantitative "fate and transport model" to achieve a standard.

Whether simple or complex, any fate and transport analysis must rely on having and/or obtaining valid data. Reliable field data will be critical in supporting the professional conclusions regarding any predictions of contaminant fate and transport and needs to be considered during the site characterization.

Fate and transport analysis will be used in the Act 2 process to predict contaminant concentrations migrating through the unsaturated zone and the saturated zone, including the impact of soil contamination on groundwater. It will also include an analysis of diffuse groundwater flow into surface water (*e.g.*, a stream) for purposes of determining compliance with surface water quality standards.

Comment [B1]: The next 3 paragraphs have been moved up from later in the section.

Generally, fate and transport analyses under Act 2 may be used for the following purposes:

- To predict the concentrations of one or more contaminants at one or more locations in the future, often at a specific time (*e.g.*, ~~10~~ 30 years).
- To assess potential remediation alternatives.
- To evaluate natural attenuation remedies and associated monitoring requirements.
- To assure continued attainment of the relevant standard.
- To estimate groundwater chemical flux used in mass balance calculations for attainment of surface water standards.
- To assess postremediation care requirements and termination.

Furthermore, fate and transport analysis is used in specific ways under the three standards.

BACKGROUND STANDARD

- To justify reduced duration for monitoring of upgradient release.
- To combine the background groundwater standard with non-background soil standards.
- To assess the impact of transformations in the upgradient plume.

STATEWIDE HEALTH STANDARD

- To justify reduced duration of attainment monitoring at the point of compliance.
- To complete the equivalency demonstration for soil-to-groundwater attainment.
- To predict the extent of contamination above the standard in off-property nonuse aquifers.
- To demonstrate attainment of the used aquifer standard at a point 1,000 feet downgradient from the point of compliance for the nonuse aquifer standard.
- To demonstrate compliance with surface water standards where there is diffuse groundwater flow to surface water.

SITE-SPECIFIC STANDARD

- To identify current completed pathways and related exposures.
- To predict future completed pathways and related exposures.
- To demonstrate pathway elimination.
- To establish numerical site-specific risk-based standards.
- To demonstrate compliance with surface water standards where there is diffuse groundwater flow to surface water.

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Comment [B2]: 3 paragraphs moved up to top of section.

~~a stream) for purposes of determining compliance with surface water quality standards.~~

When applicable, the fate and transport analysis should also consider the degradation of (a) particular chemical compound(s) into one or several "breakdown" compounds. This can occur in the unsaturated or saturated zone at or below the point of release of a particular compound of concern, or downgradient in the chemical plume. An example may include a scenario involving a release of trichloroethylene ~~(TCE)~~ from an upgradient source which has entered the saturated zone and migrated downgradient under a site seeking a release under the background standard. The site in question may exhibit dichloroethylene ~~(DCE)~~ and vinyl chloride ~~(VC)~~ in wells on its property but also may have never used chlorinated compounds. In this case, the remediator may be able to demonstrate that there was no release of the regulated substance on the property and use fate and transport analysis to demonstrate that the constituents result from breakdown of compounds from the upgradient release.

1. Fate and Transport Analysis in the Unsaturated Zone

a) General

In lieu of using the soil-to-groundwater medium-specific concentrations (MSCs) from Tables 3 and 4 in Appendix A of the Act 2 regulations as the Statewide health standards, a person may also perform a site-specific demonstration. The site-specific demonstration can be used to show that contaminant levels in soil exceeding the Statewide health standard for one or more contaminants at that site are protective of groundwater. Such a demonstration requires the use of fate and transport models, equations, algorithms, or methods (hereafter "analytical tools") applied to contaminants in the soil of the unsaturated zone and may also include the use of groundwater fate and transport analytical tools (*e.g.*, using the results of an unsaturated zone transport demonstration as input into a groundwater fate and transport analysis).

The unsaturated zone fate and transport analytical tools may be very simple equations requiring minimal input or may be more complex models requiring much more detailed input. The choice of the analytical tool or tools used in making site-specific demonstrations for contaminants in unsaturated zone soil should be appropriate to the circumstances of the site. At a minimum, the analytical tools used in making demonstrations in the unsaturated zone should include certain contaminant-specific and site-specific parameters. Other parameters may also be necessary depending on the analytical tools being used and the overall goal of the demonstration. In addition, the analytical tools and parameter input values themselves are subject to certain conditions.

b) Minimum Contaminant-specific and Site-specific Requirements

With very few exceptions, the analytical tools currently available for unsaturated zone contaminant fate and transport demonstrations are based on equilibrium partitioning equations. The equations that have been used in estimating the soil-to-groundwater MSCs and the soil buffer distances in Tables 3 and 4 in

Appendix A of the Act 2 regulations are equilibrium partitioning equations. These equations can be used in a variety of different types of analytical tools. Depending on the analytical tool being used, other parameter input values may be necessary. At a minimum, input values are needed for each of the following parameters for any unsaturated zone analytical tool:

i) Contaminant-specific requirements for all analytical tools

- **K_{oc}** in L/kg or mL/g (for organic compounds only): ~~-~~[~~T~~]his is the organic carbon partition coefficient. Values for this parameter for listed organic regulated substances can be found in Table 5A~~a~~ in Appendix A of the Act 2 regulations or in ~~the~~ scientific literature. For organic compounds not listed in Appendix A of the Act 2 regulations, values can be found in ~~the~~ literature. K_{oc} estimation methods (based on other parameters such as aqueous solubility, octanol-water partition coefficient, bioconcentration factor, and molecular structure) are also available in ~~the~~ literature.
- **K_d** in L/kg or mL/g (primarily for inorganic contaminants and, in some instances, organic compounds): ~~-~~[~~T~~]his is the soil to water partition coefficient. Values for this parameter for listed inorganic regulated substances can be found in Table 5B~~b~~ in Appendix A of the Act 2 regulations. Some K_d values for inorganic contaminants can also be found in ~~the~~ scientific literature. In many instances, it may be necessary to estimate K_d values based on soil analytical data at a particular site. This can be done by using total contaminant concentrations in soil in conjunction with leachable concentrations. Generally, the K_d values for organic compounds are estimated from K_{oc} values and the fraction of organic carbon in soil (f_{oc} - which is discussed later). ~~It is also possible to estimate K_d values for organics~~ or by using total contaminant concentrations in soil in conjunction with leachable concentrations. If K_d values are estimated in this manner, it is not necessary to include or use a K_{oc} value for the organic compound.
- **C_{soil}** in mg/kg: ~~-~~This is the dry weight concentration of a regulated substance or contaminant in soil which is determined through use of the site characterization data (if the demonstration is being done to show that groundwater is protected under current site conditions) or which is used as input (on a trial and error basis) to estimate a concentration in soil that would be protective of groundwater.

ii) Site-specific requirements for all analytical tools

- **θ_w** (dimensionless): ~~-~~This is the water-filled porosity of the unsaturated zone soil. Appropriate values for this parameter generally range from 0.05 to 0.15 for sandy soils to 0.26 to 0.45 for clays. A default value of 0.2 has been used in the estimation of the soil to groundwater MSCs in Tables 3 and 4 in Appendix A of the Act 2 regulations.
- **ρ_b** in kg/L or g/mL: ~~-~~This is dry bulk density of unsaturated zone soil. Appropriate values for this parameter generally range from 1.3 to 2.0 for silts

and clays to 1.6 to 2.2 for sandy soils to 1.8 to 2.3 for gravelly soils. A default value of 1.8 has been used in the estimation of the soil to groundwater MSCs in Tables 3 and 4 in Appendix A of the Act 2 regulations.

- **f_{oc}** (dimensionless)-This is the fraction of organic carbon in unsaturated zone soil. This parameter applies only to demonstrations being done for organic compounds where the K_{oc} values for the compounds are being used. For demonstrations for organic compounds where K_d is being estimated or determined by a means other than use of K_{oc}, this parameter is not needed. Typical values for this parameter range from 0.001 to 0.006 for subsurface soils to 0.01 to 0.03 for topsoil~~s~~. A default value of 0.0025 has been used in the estimation of the soil to groundwater MSCs in Table 3b in Appendix A of the Act 2 regulations. A value of 0.005 has been used in estimation of the soil to groundwater buffer distances in Table 3b in Appendix A of the Act 2 regulations.

iii) Additional requirements ~~Depending on type of analytical tool~~

The simplest unsaturated zone analytical tools are those that estimate contaminant concentrations in unsaturated zone soil pore water from equilibrium partitioning equations and ~~then use~~utilize the~~os~~e aqueous concentrations as source input into a groundwater fate and transport analysis. Actual transport through the unsaturated zone is not estimated with this type of analytical tool. This type of unsaturated zone analytical tool would require input data for only those parameters discussed above.

Another type of unsaturated zone analytical tool that is commonly used and which is more complex is one that estimates the migration of contaminants through the unsaturated zone. These are generally either infinite source or finite source analytical tools. Both are more complicated than the one previously discussed and, as such, require additional parameter input values. Both of these analytical tools require a water recharge rate so that ~~a~~ pore water velocity can be estimated and the vertical depth to groundwater or bedrock from the contaminated soil. An unsaturated zone finite source analytical tool is particularly useful in demonstrating how long it will take a contaminant to migrate from unsaturated zone soils to groundwater (if at all) and what the contaminant concentration (including the maximum concentration) will be in soil or soil pore water at various depths and at various times as migration occurs. Finite source models generally require input values for additional parameters such as values for C_{soil} at different depths from the surface of the unsaturated zone. This can ensure that mass balance constraints are met, *i.e.*, the analytical tool will not estimate migration of a greater mass of contaminant than the amount that was originally in the source soil. The **BUFFER1.XLS** spreadsheet model is available on the DEP website to assist in performing this modeling.

In addition, more complex unsaturated zone analytical tools can take into account other mechanisms that would affect the vertical migration of contaminants toward groundwater. These mechanisms are generally ones that

result in loss of the contaminant through time meaning that additional input values are required. Two loss mechanisms are biodegradation and volatilization. Analytical tools that consider biodegradation require either a degradation rate constant (in units of reciprocal time) or a half-life value (in units of time). Rarely, an analytical tool may consider loss from volatilization. This would require a volatilization rate constant which can be calculated from several other parameters (such as Henry's constant, vapor pressure, aqueous solubility, other partition coefficients as well as soil property data) or can be estimated using onsite analytical data.

c) Conditions for Use of Analytical Tools and Parameter Input Values

Dozens of unsaturated zone analytical tools exist in the public domain, most of which are based on equilibrium partitioning between the solid soil matrix and the soil pore water. As such, most of these analytical tools are very similar with respect to the parameters that require input values. In order to ensure validity of the results of all unsaturated zone demonstrations submitted to the department, the following conditions should be met:

- Analytical tools used for unsaturated zone transport demonstrations should be based on equilibrium partitioning concepts when possible. Although analytical tools based on other concepts (such as metal speciation and non-equilibrium desorption) exist and may be technically valid, their use could cause significant delays in department review time.
- The source of all values for all required input parameters (K_{oc}, K_d, C_{soil}, θ_w, ρ_b, f_{oc}) should be provided. All data used as input for C_{soil} should be representative of the area for which the demonstration is being made and should meet all site characterization requirements.
- If analytical tools require input values for water recharge rate and vertical depth to groundwater, the sources of those values should be provided.
- Any degradation rate constant or half-life used in any unsaturated zone analytical tool should be based on site-specific data. Well-documented degradation constants and half-life values may be used from the literature or other studies only when it can be shown that the conditions at the site are clearly similar to those from which the degradation rate constant or half-life came. In addition, degradation products which may be toxic (such as those from chlorinated alkenes) should be considered in the demonstration. If these conditions are not met, the degradation rate constant should be assumed to be zero.
- Any unsaturated zone analytical tool that incorporates loss of contaminant from volatilization processes should base the volatilization rate constant on volatilization data for soils existing at the site. Otherwise, loss due to volatilization should be assumed to be zero.
- Any unsaturated zone analytical tool should be used only for soils in the unsaturated zone and should not be used for saturated zone soils or bedrock.

- For any unsaturated zone analytical tool that links to groundwater by means of dilution directly under the area of contaminated soil, the entire aquifer depth directly under the soil should not be used in dilution calculations, *i.e.*, as a mixing zone. The mixing zone should be calculated based on specific site parameters such as pore water velocity, groundwater velocity and direction, depth of the entire aquifer under the site, and areal extent of soil contamination.

d) Conclusion

This guidance is being provided to aid any person who is submitting results of a fate and transport analysis for the unsaturated zone to do so in a manner that will ensure validity of the analysis as well as timely and efficient review by the Department. There are many unsaturated zone analytical tools available in the public and private domains. Some of these are extremely complex, difficult to use, and not readily available to Department staff while others are fairly simple, easy to use and are readily available to the Department. For unsaturated zone fate and transport analysis submissions that rely on concepts other than equilibrium partitioning (such as metal speciation and non-equilibrium desorption), adequate supporting documentation must be submitted to the Department.

2. Fate and Transport Analysis in the Saturated Zone

This section provides guidelines for the application of fate and transport analysis in the saturated zone. As stated above, a "fate and transport analysis" is not necessarily a highly complex computer simulation. It can be a range of analyses, based on physical, structural, chemical and hydraulic factors. It is based on professional judgment, and may need to include the use of simulations.

Elements of Fate and Transport Analysis include:

GROUNDWATER FLOW

- Direction
- Velocity
- Boundaries

CHEMICAL FATE AND TRANSPORT MECHANISIMS

- Leaching/dissolving
- Adsorption/desorption
- Matrix diffusion
- Degradation/transformations/reactions
- Volatilization
- Precipitation
- Phase behavior

Depending of the characteristics of the site and the type of standard/remediation selected, the fate and transport analysis can range from the simple to the complex, which can span from qualitative "empirical" or simple conceptual models, up to quantitative simulation (analytical and numerical) models.

Simple descriptive or conceptual models may be either qualitative or quantitative. A particular example under this scenario might be a facility seeking a release under the background standard. This facility (facility "A") is downgradient from facility "B," which has caused a release of a contaminant to groundwater. The fate and transport analysis required under ~~Section 250.204(f)(5)~~Section 250.204(f)(5) could conceivably be a simple qualitative demonstration of a site conceptual model which employs the use of monitoring well data/measurements to establish that facility "A" is clearly hydraulically downgradient of facility "B." Data requirements would include water level measurements from a sufficient number of properly located monitoring wells and establishing the hydraulic gradient. Note, however, that simple scenarios such as this can easily become more complicated by other factors including water level fluctuations, pumping influences of wells, etc., which could require a more detailed quantitative fate and transport analysis.

Another scenario could involve the use of simple extrapolation in predicting groundwater plume movement or ~~it's~~its relative stability over time. If groundwater monitoring samples have been collected over a sufficiently long period of time, and the information consists of good, valid data, then certain predictions can be made using professional judgment as to aspects of plume behavior. For example, monitoring over a number of years may indicate that the contaminant plume has exhibited no movement over that time. In this case, the use of professional judgment involving simple extrapolation of the data may be a sufficient fate and transport analysis. The conclusion could be made, based on the above merits, that the plume has reached a steady state condition and would not migrate further downgradient. In this case it may also be possible to determine that downgradient surface water quality criteria may be met even though the concentrations in the groundwater plume exceed the MSCs.

Quantitative fate and transport analysis may be needed in more complex situations, where a demonstration of attainment would require additional data and calculations. One example might be a facility seeking to demonstrate that very low groundwater velocities in bedrock would preclude contaminated groundwater from the facility from reaching the property boundary/POC. Data requirements in this case would need to include calculation of hydraulic gradient, determination of hydraulic conductivity, estimation/measurement of effective porosity, and calculation of groundwater velocity. Note that this somewhat simple example could evolve into a more detailed quantitative or simulated model given a variety of complicating factors, such as saturated flow in soil, preferential fracture flow, etc. Another example of this type may be a demonstration of groundwater discharge into a natural flow boundary, as in the case of a facility located adjacent to a large river sustained by regional groundwater discharge. While in some cases this might be a qualitative analysis,

in other cases there would be a need to determine both vertical and horizontal gradients to demonstrate the stream is in fact a discharge feature and not losing flow to the surrounding terrain.

Quantitative analysis may involve the use of more complicated fate and transport tools involving various analytical equations up to the more complex numerical simulations of groundwater flow, which collectively can help determine the spread of contamination in a plume and predict its fate and concentration at specific future times and locations. The simpler analytical equations often do not require the use of a computer and are more appropriate where more uniform aquifer conditions exist and there are no complex boundary conditions. An example might be a facility seeking a release under Act 2 which is underlain by alluvium near a stream. Analytical fate and transport equations can be used to help determine the concentration of a groundwater contaminant at a downgradient location. In many cases the simple empirical examples mentioned above may need to employ analytical equations as conditions warrant, to account for dilution, attenuation, degradation, and other physical and chemical factors in contaminant fate and transport.

Numerical simulations are the most complex models used under the provisions of fate and transport analysis under Act 2. They generally require use of a ~~digital~~ computer software model due to the number of simultaneous equations to be solved. They are most applicable where predictions of groundwater contamination need to be made at certain locations in the future (*e.g.,* property boundary, 1,000 feet downgradient from property boundary, etc.), at sites which exhibit more heterogeneous geologic/hydrogeologic characteristics and more complex boundary conditions (which are common in Pennsylvania). As such, they will be useful tools for a variety of sites where such predictions are required to demonstrate attainment of an Act 2 standard. Additional discussion on numerical models is provided below.

a) Groundwater Solute Fate and Transport Modeling (General)

The Department recommends that those with appropriate academic training and practical experience in the field conduct fate and transport analysis, especially if it involves more complex numerical models.

Except in cases where it is unnecessary to project or predict contaminant concentrations in groundwater at various locations into the future, some sort of quantitative fate and transport analysis such as groundwater modeling will very likely be needed.

All models rely on input parameters that vary because of inherent heterogeneity and anisotropy of the aquifer.

Some of the required input parameters such as dispersivity are not measured and need to be determined by model calibration to accurate isoconcentration contour maps.

Some important information such as the date of the release and mass involved is often difficult to pin down.

All of the above creates uncertainty that needs to be considered in how the results of any model are used and their reliability.

The uncertainty associated with models can and should be reduced by collecting site-specific data for certain input parameters that are representative of subsurface conditions.

Accurate isoconcentration contour maps of each parameter of concern, which are constructed from data collected during the site characterization phase of the remedial action, are especially important. –These maps are the calibration targets of the model. -Adequate data to determine if a plume exhibits a centerline, and, if so, its location and associated concentrations is fundamental to a fate and transport analysis. –Several transects (lines of wells) should be installed downgradient from the source and perpendicular to the direction of ground water flow to accurately find and define any plume centerline and the spread of contamination away from the centerline.

The following data are the minimum input requirements of many models, both analytical and numerical. The following data should be derived from measurements made at the site:

- Source Geometry and Concentration
- Hydraulic conductivity
- Hydraulic gradient
- Natural fraction of organic carbon in the aquifer
- Porosity

The following additional parameters are also often involved:

- Time source active – this is a very important parameter in calibrating any model if transient plume conditions are suspected or involved, and can be one of the hardest to pin down unless good historical records are available.
- K_{oc} – this value can be derived from Appendix A Table 5 of Chapter 250.
- Lambda – this measure of biodegradation (as first order decay) varies from site to site for each compound and is usually determined by model calibration or sometimes calculated from plume centerline data. Published values such those in Appendix A, Table 5 of Chapter 250 should not be relied on as default values for site-specific modeling.-
- Soil Bulk Density – often estimated as (2.65)*(1-porosity).
- Dispersion – this parameter is used to simulate the spread of contaminants in one, two or three dimensions. Values are often initially derived using several published "rules of thumb" and then adjusted during model calibration to fit plume isoconcentration contours.

After selection of the best values for input parameters, the model is run and compared to the plume geometry portrayed by isoconcentration maps of each

parameter of concern. Adjustments may be needed for certain parameters such as lambda, dispersion or others within reasonable ranges to obtain a better match to site data. Modeling efforts associated with a post-remediation care plan under an Act 2 standard should include a test of the predictive accuracy of the model by comparing predictions to a future data set sometimes referred to as a "post audit", followed by recalibration and retesting, if needed.

Readers are referred to ASTM Standard Guide D 5447-~~93~~ 04 (2010) for an overview of the basic elements involved in groundwater flow modeling effort. The same general principles apply to fate and transport modeling. Since the ASTM Standard Guide 5447-~~93~~ 04 (2010) is intended as a general guide, covering both analytical and numerical models, all elements discussed may not be applicable to every modeling situation.

b) Define Study Objectives

In all cases the site characterization should be conducted with the objective of providing the data necessary to demonstrate attainment of an Act 2 standard. Prior to any computer modeling, an initial conceptual model of local hydrogeologic conditions should be developed. The results of the site characterization/initial conceptual model will influence what kind of fate and transport model, if any, should be used, as well as many of the values for the input parameters to that model. Some models require certain kinds or quantities of data which is good to know ahead of time. To some extent this will be an iterative process. As data are collected and evaluated, the selected Act 2 remediation standard may change, and areas where additional data are needed may be identified.

The acceptable tolerances for model calibration should also be defined in the study objectives.

c) Data Collection

The data used for groundwater fate and transport modeling will come from the site characterization and, in some cases, values published in scientific literature or Table 5 in Appendix A to the Act 2 regulations. Examples of data that may need to be obtained from published values include first-order decay coefficients and equilibrium partitioning coefficients. Once obtained, these values may need to be adjusted within reasonable ranges to calibrate a model to site conditions. Examples of data which should be obtained from the site characterization, to name a few, include hydraulic conductivity, gradients, porosity, organic carbon content and chemical concentrations. Some parameters such as dispersion coefficients, which are not available from the literature or site characterization work, initially need to be estimated according to basic assumptions and then adjusted during model calibration to match actual plume shape and concentration data.

d) Conceptual Model

As stated in ASTM D 5447, "the purpose of the conceptual model is to consolidate site and regional hydrogeologic and hydrologic data into a set of

assumptions and concepts that can be evaluated quantitatively." The conceptual model of the site will emerge from the data collected during the site characterization. The site characterization work should be designed to assure that the quantity and kind of data collected will, in the end, be sufficient for justifying and completing the fate and transport analysis. Elements important to developing the conceptual model of the site for any fate and transport analysis include geologic, hydrologic, hydraulic and contaminant data (note that these are common elements of some of the non-numerical conceptual models discussed above). Data collection should be concentrated on the site, but offsite features that influence contaminant fate and transport on the site should not be overlooked.

i) Geologic data

- thickness, continuity, lithology and structural features of consolidated geologic formations underlying the site;
- thickness, texture, density and organic carbon content of soil and unconsolidated units;
- information from review of published reports on the geology and soils of the site and nearby areas, or previous work at the site;
- information from any additional investigation needed to confirm or refine existing data such as wells, borings and backhoe pits, and possibly geophysical methods.

ii) Hydrologic data

- water levels, hydraulic gradients and groundwater flow directions, including seasonal variations; determining seasonal variations in hydrologic data are extremely important for conceptual site model development. These variations should likewise be reflected in the fate and transport analysis conducted on the aquifer;
- the presence and magnitude of vertical gradients at the site;
- recharge and discharge boundaries relevant to the site including groundwater divides, streams, and drains;
- sources and sinks, *e.g.*, characteristics of any pumping or injection wells, artificial recharge, ponds, etc.;
- the presence of any confining units;
- for bedrock aquifers, the degree to which the aquifer system departs from assumptions regarding flow in porous media;
- data from review of available information as well as drilling of wells, borings and piezometers, and water level measurements over regular intervals.

iii) Hydraulic data

- hydraulic conductivity and transmissivity data for consolidated and unconsolidated deposits;
- porosity, effective porosity estimates, and storativity;
- the degree to which the aquifer(s) depart from assumptions of isotropy or homogeneity;
- the degree of interconnection between different aquifer units and leakage characteristics between different water-bearing units;
- hydraulic data often is not available at the level of detail necessary and may require pumping tests on wells to determine aquifer anisotropy of bedrock systems and values for other hydraulic parameters such as transmissivity. Slug tests may suffice in bedrock wells where anisotropy is not a factor requiring consideration.

iv) Chemical and contaminant data

- location, age and current status of source areas to the extent knowable;
- types of contaminants and their chemical properties such as viscosity, solubility, biodegradability, density, toxicity, K_{oc} value, decay rate, etc.;
- the magnitude and vertical and horizontal extent of contamination in soil and/or groundwater;
- dissolved oxygen content and other electron acceptors in groundwater, if required by the model;
- historical plume configuration based on existing monitoring data;
- determination if the contaminant plume is at steady state conditions or is continuing to migrate. This is a critical piece of information. Is the mass of contamination increasing, decreasing or relatively constant? This should be determined by monitoring the vertical and horizontal extent of groundwater contamination for a period of time sufficient to reveal the trend. These data will be useful in calibrating the model and making predictive simulations. In some cases, the monitoring data alone may be all that is needed to complete the fate and transport analysis, provided the monitoring record is sufficiently long.
- review of chemicals used at the facility, which will help identify the chemicals of concern. Sampling soil, soil vapors and groundwater from appropriately constructed monitoring wells, borings or excavations and checking for any free product will need to be performed. Geophysical methods may be useful to delineate areas needing further investigation or identifying sources.

e) ~~Code~~ Model Selection

When the site characterization is completed and the conceptual model has been developed, selection of an appropriate ~~computer code~~model can be made. At sites where there is little variation in conditions over the model domain, with a simple plume geometry or conceptual model, relatively simple analytical models should be employed. At sites where the site characterization has determined significant variation in important parameters, or where more complex questions are being asked, a more sophisticated numerical solution may be needed.

The Department has prepared ~~three~~ two spreadsheets that may be useful in completing a fate and transport analysis. All spreadsheets are based on the following equation:

$$C(x,y,z,t) = \left(\frac{C_o}{8}\right)\exp\left\{x/2\alpha_x\left[1-\left(1+4\lambda\alpha_x/v\right)^{\frac{1}{2}}\right]\right\}erfc\left\{\left[x-vt\left(\sqrt{1+4\lambda\alpha_x/v}\right)\right]/2\sqrt{\alpha_x vt}\right\}$$
$$\left\{erf\left[(y+Y/2)/2\sqrt{\alpha_y x}\right]-erf\left[(y-Y/2)/2\sqrt{\alpha_y x}\right]\right\}\left\{erf\left[(z+Z/2)2\sqrt{\alpha_z x}\right]-erf\left[(z-Z/2)/2\sqrt{\alpha_z x}\right]\right\}$$

Field Code Changed

Reference: An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species, P.A. Domenico, 1987, Journal of Hydrology, 91, 49-58.

The ~~three~~ two spreadsheets are:

QUICK_DOMENICO.XLS

This spreadsheet calculates the concentration anywhere in a plume of contamination at any time after a continuous, finite source becomes active. A "User's Manual for the Quick Domenico Groundwater Fate-and-Transport Model" accompanies the spreadsheet model on the PA DEP website.

~~**FATBACK.XLS**~~

~~This spreadsheet calculates the steady-state source concentration given the desired or target receptor concentration and location of the receptor. Given a source concentration calculated by Fatback, Quick_Domenico could be used to establish a site-specific standard for a property line compliance point.~~

SWLOAD.XLS

This spreadsheet uses a rearrangement of the Domenico equation to calculate concentrations at different points in the cross section of a plume at any distance from a continuous finite source at any time. The concentrations are then added and multiplied by the groundwater flux and can be used to estimate the mass loading of a particular contaminant from diffuse groundwater flow to a stream or surface water body.

As mentioned above, ~~These~~ these spreadsheets and documentation can be downloaded from the PA DEP web site under "Standards, Guidance and

Procedures",“Guidance and Technical Tools-," "Fate and Transport Analysis Tools." These spreadsheets will not be applicable to every situation involving modeling. The remediator should review the help documents for the spreadsheet programs thoroughly to determine if the modeling spreadsheets are suitable for the situation.

f) Calibration and Sensitivity

As stated in ASTM D 5447, calibration is the process of adjusting hydraulic parameters, boundary conditions and initial conditions within reasonable ranges to obtain a match between observed and simulated potentials, flow rates or other calibration targets. In working with sites under Act 2, an obvious calibration target is matching the model output to existing, and, if known, historical geometry and concentration of plume contaminants. The Act 2 final report should include a discussion of calibration targets, and an analysis and significance of residuals (differences between modeled and actual contaminant concentrations).

Sensitivity analysis is an evaluation of which model parameters have the most influence on model results. The parameters to which the model is most sensitive should be identified. Those parameters which have the most influence on model results are those which should be given the most attention in the data collection phase.

g) Predictive Simulations

Fate and Transport models may be used in the Land Recycling Program to make predictions of future contaminant concentrations. Uses may include:

- Predicting the maximum concentrations that will occur at downgradient compliance points (usually property boundaries) for the Statewide health Standard in the case of both used and nonuse aquifers;
- Predicting whether groundwater contamination above an MSC will extend beyond 1000 feet in the case of nonuse aquifers, and if it will be at or below the MSC for groundwater in these areas within the next 30 years;
- In cases where the fate and transport analysis indicates that a standard may not be maintained at some time in the future, a postremediation care plan will be needed.
- If postremediation care is required, a "post audit" of the fate and transport model should be performed. In a post audit, the fate and transport model's predictions are compared to continued monitoring data collected during the postremediation care period to check the validity and accuracy of previous model predictions. Monitoring wells for the post-audit must be located at points where they would be sensitive to auditing the model. This may not coincide with the property line compliance point if the plume would not be expected to migrate to the compliance point by the time of the post-audit.

- Post audits should be performed on the model during the attainment monitoring phase (usually a minimum of two years) as a check on model predictions.

h) Fate and Transport Model Report

With the exception of those projects which do not require submission of a fate and transport model, the following general report format should be used to the extent applicable to adequately document the modeling effort.

~~The following format is modified after that in ASTM D 5447:~~

1.0 Introduction

1.1 General Setting

1.2 Study Objectives- which Act 2 standard is being demonstrated and what is the purpose of the modeling

2.0 Conceptual Model

2.1 Aquifer System Framework

2.2 Groundwater Flow Model

2.3 Hydrologic Boundaries

2.4 Hydraulic Boundaries

2.5 Sources and Sinks

3.0 ~~Computer Code~~Analytical Model

3.1 Model~~Code~~ Selection-justification for use of analytical, numerical or other analysis

3.2 ~~Code~~ Model Description- name and version of analysis, model assumptions and limitations, name of organization or person which has developed the analysis

4.0 Groundwater Flow Model Construction

4.1 Model Grid- state if fixed by model

4.2 Hydraulic Parameters- state source such as field determined or literature. Cite relevant section of Site Characterization report or literature reference.

4.3 Boundary Conditions- state if fixed by model

4.4 Selection of Calibration Targets

5.0 Calibration

5.1 Residual Analysis

5.2 Sensitivity Analysis

5.3 Model Verification, if applicable

6.0 Predictive Simulations- Indicate relation to applicable Act 2 standard

7.0 Summary and Conclusions

7.1 Model Assumptions/Limitations

7.2 Model Predictions

7.3 Recommendations- including planned post-audit activities during postremediation care plan if required

8.0 Figures and Tables-

8.1 Model grid or axes oriented on the site map

8.2 Input and output files

3. Impacts to Surface Water from Diffuse Flow of Contaminated Groundwater

Sections ~~250.309~~ 250.309 and ~~250.406~~250.406 of the Act 2 regulations provide for determining compliance with surface water quality standards from a diffuse surface or groundwater discharge. For some sites selecting the Statewide health groundwater standard for used aquifers with a total dissolved solids (TDS) concentration of 2500 mg/L or less, and all sites selecting the Statewide health nonuse aquifer groundwater standard, Statewide health standard in used aquifers with a TDS greater than 2500 mg/L ~~TDS~~ or, the site-specific standard for groundwater, this will involve analyzing the impact of a diffuse flow of a dissolved groundwater plume into a stream incorporating the methods and models of the Office of Water Management. All discharges involved with a remediation must be in compliance with the provisions of Chapter 93 to demonstrate attainment of the Statewide health and site-specific standards.

a) Conceptual Framework

In order to understand how to evaluate the impact of diffuse groundwater plumes on surface water quality, several important concepts must be understood. These concepts apply to evaluating impacts of groundwater plumes on surface water regardless of the standard selected.

The first is the concept of "maximum average concentration". Surface water impacts must be evaluated for the time that the "maximum average concentration" in the groundwater plume is discharging into the stream. As a plume in groundwater begins to encroach onto a stream, the average concentration entering the stream will rise, and remain steady-, or then fall depending on the nature of the source (continuous or pulse). For a constant source with a decaying contaminant, the maximum average concentration to the stream occurs when the plume has reached a steady-state condition. For a

constant source and non-decaying contaminant, the maximum average concentration to the stream occurs when the mass discharging into the stream equals the mass emanating from the source. For a pulse or slug source, the maximum average concentration will occur at the time the peak concentrations in the pulse (or slug) pass into the stream. The Department has prepared a spreadsheet, SWLOAD5, which will calculate the "maximum average concentration" for decaying and non-decaying plumes emanating from a constant source.

A second concept to understand concerns what is termed the plume "edge criterion". The "edge criterion" is simply the concentration above which the maximum average concentration and associated flow will be determined for the plume in question. An "edge criterion" is needed to assure that concentrations below the criterion will not be used and serve to dilute the average concentration and or increase the flow in the plume to a point where any and all discharges to surface water become acceptable. The "edge criterion" is contaminant specific. The following rules should be used in establishing the "edge criterion": These rules apply to selection of the "edge criterion" regardless of the standard selected:

- For those compounds on ~~Table IV-1~~Table III-1 of the TGM which have established surface water criteria, the "edge criterion" equals the Act 2 non-residential groundwater MSC for used aquifers <2500 mg/L TDS.
- For compounds on ~~Table IV-2~~Table III -2 of the TGM, the "edge criterion" equals the SW-846 PQL.
- For compounds on ~~Table IV-3~~Table III-3, if the Act 2 SW-846 PQL is below both the Act 2 MSC and the lowest surface water compliance value (LSWC), the "edge criterion" equals the LSWC. If both the LSWC and the Act 2 MSC are below the SW-846 PQL, the "edge criterion" equals 3.18 times the lowest Chapter 16 method detection limit or the lowest surface water criterion, whichever is higher.

Maximum average concentrations and flow for input into Pennsylvania's PENTOXSD surface water mixing model should only be calculated for portions of a groundwater plume that exceed the "edge criterion" for the compound being evaluated. The Department has prepared a spreadsheet, SWLOAD5, which incorporates the "edge criterion" for calculating inputs to PENTOXSD for decaying and non-decaying plumes emanating from a constant source. If no portion of a plume entering a stream at the time of maximum average concentration exceeds the "edge criterion", no further demonstration of surface water attainment is needed.

A third concept to understand is that of -"maximum modeled or measured concentration" as this phrase is used in connection with ~~Tables IV-1~~Tables III-1, ~~IV-2~~III-2 and ~~IV-3~~III-3 below. These tables provide for a waiver of a PENTOXSD analysis in cases where the Statewide Health Standard for groundwater is attained if the "maximum modeled or measured concentration" is below certain criteria. It is important to understand that the maximum concentration being

referred to by this phrase is the maximum concentration in the plume at the time and place that the maximum average concentration is discharging into the stream. Therefore, a measured concentration is inappropriate, and a modeled concentration should be used in cases where:

- the plume has not yet reached the stream
- the plume is entering the stream, but has not yet reached its maximum average concentration, or
- the number and/or location of wells is insufficient to assure the Department that the maximum concentration has been found.

A fourth concept to understand that is particularly important in using ~~Tables IV-1~~Tables III-1, ~~IV-2~~III-2 and ~~IV-3~~III-3 is where the concentrations should be measured with respect to the Act 2 property line POC and the meaning of the phrase " …at the POC or groundwater/surface water interface, as appropriate…". If a plume discharges off the property being remediated before discharging into a stream, then the criteria for waiving a PENTOXSD analysis on each table can be measured at the POC. If the plume discharges into a stream before leaving the property, criteria must be demonstrated along the groundwater/surface water interface where the plume is discharging.

The spreadsheet SWLOAD5 is constructed so that the "maximum modeled concentration" is compared to the "edge criterion" for each compound and a determination is automatically made if a PENTOXSD analysis is needed. By convention, the "edge criterion" in SWLOAD5 is defined as the threshold for waiving a PENTOXSD analysis in each table.

Two final comments need to be made regarding the demonstration of surface water quality attainment. First, worst-case source concentration and flow associated with the source can be input directly into PENTOXSD. Doing this will avoid groundwater modeling or measuring concentrations at the POC or groundwater/surface water interface in many situations.

Secondly, anytime it can be demonstrated conclusively that the maximum concentration in a plume is less than the lowest surface water quality criteria, attainment of surface water quality can be assumed.

b) Mathematical Framework

The basic mass balance equation to determine the concentration of a contaminant in surface water downstream of a diffuse groundwater contaminant discharge at design flow conditions with background contaminant levels included is:

$$C_{sw} = \frac{(Q_{gw} * C_{gw}) + (Q_{sw} * Y_c * C_{bsw})}{(Q_{sw} * Y_c) + Q_{gw}}$$

where:

C_{sw} = the concentration in surface water of a contaminant of concern downstream of ~~a~~ the nonpoint source discharge into the surface water.

Q_{sw} = the quantity of stream flow above the nonpoint source discharge into surface water.

Q_{gw} = the quantity of flow in the groundwater plume discharging into the surface water.

C_{gw} = the maximum average concentration of a contaminant in the groundwater discharging into surface water.

Y_c = the partial mix factor (decimal per cent), ~~-~~derived from using the PENTOXSD model.

C_{bsw} = the background concentration in surface water of a contaminant of concern above the nonpoint source discharge.

The equation for determining the allowable groundwater concentration in a plume discharging to surface water is:

$$C_{gw} = C_x + \frac{Y_c * Q_{sw} * (C_x - C_{bsw})}{Q_{gw}}$$

where:

C_x = the water quality objective (criteria value most of the time, can be site-specific).

Other variables are as listed above at design flow conditions

(e.g. $Q_{7\text{-}10}$ or Q_{hm}).

c) Application

The general procedure for applying the mathematical framework above to applicable compounds requires estimating the flow and maximum average concentration of the contaminated groundwater plume for each parameter of concern at the groundwater/surface water boundary. These values, in turn, are the discharge flow and discharge concentration values to be evaluated using the Office of Water Management's PENTOXSD model to determine if the groundwater discharge to the stream meets the applicable surface water quality criteria. Users are referred to Technical Guide 391-2000-011 and ~~User's Guide 391-2000-012~~PENTOXSD for Windows (Version 2.0D) Supplemental Information for information on using the PENTOXSD model.

The analysis will involve incorporating background concentrations in surface water for certain contaminants. Users are referred to 391-2000-022 (Implementation Guidance for the Determination and Use of Background/Ambient Water Quality in the Determination of Wasteload Allocations and NPDES Effluent Limitations for Toxic Substances) for information on how and when to apply background water quality data. Table ~~IV-3~~III-3 also identifies compounds where background water quality concentration is a factor in the analysis.

For steady state plumes which have compliance points at or very near a stream, the groundwater flow and concentrations (mass load) within the plume can and should be determined from direct measurements. The mass loading of groundwater plumes which have not yet reached the stream boundary, which are not at steady state at the stream boundary, or for which data at the stream boundary are not available, must be estimated in some way (e.g. using groundwater solute transport models, or by assuming, conservatively, that the highest concentrations measured in the plume are representative of those at the stream boundary).

The general guidelines and example problems presented below in this guidance apply to single source discharge analysis. If there is more than one source of a pollutant in a stream reach, it may be necessary to evaluate the cumulative impact of these sources. The stream reach is determined by the site-specific travel times, stream flow, discharge flow dilution and potency of the pollutant as it moves downstream. The term that describes this process is "multiple source discharge." The Office of Water Management recommends that the Equal Marginal Percent Reduction (EMPR) method of allocation be used for these situations.

EMPR is a two-step process:

- Baseline Analysis: this step evaluates each contributor individually to determine if it would exceed the water quality objective by itself. This step evaluates the contributor's currently modeled load and compares it to the water quality objective. If the modeled load is greater than the water quality objective, the modeled load is reduced to the water quality objective. A baseline value is determined for every contributor. This baseline value is either the currently modeled load or the water quality objective. This step assures that no contributor would cause an exceedance of the water quality objective by itself.
- Multiple Analysis: this step evaluates the cumulative impact of multiple sources on the stream. The analysis is carried out by systematically moving downstream, adding the baseline pollutant loads, and determining if the water quality objective is met at all locations. Through this process the critical reach of the stream can be found and any further necessary reductions from the baseline values can be made to meet the water quality objective at all points in the stream. Any further reductions from the baseline are made on an equal percentage basis.

At this time the Office of Water Management addresses the impact of multiple sources on a stream on a site-specific case-by-case basis. Sites which have more than one plume on a single property seeking the site-specific standard for the same contaminants, or adjacent properties on the same stream reach with the same contaminants are examples of sites which should be referred to The Office of Water Management for multiple source discharge analysis.

d) Statewide health Standard in Aquifers with 2500 mg/L TDS or less

For ~~65~~ compounds that have Statewide health standards established in Chapter 250, simply demonstrating attainment of the residential or nonresidential Statewide health standard ~~ medium-specific concentration (~~MSC~~)~~ for groundwater in used aquifers with ~~total dissolved solids (~~TDS~~)~~ less than or equal to 2500 mg/L at the point of compliance, or at the groundwater/surface water interface when the plume discharges to surface water prior to or instead of passing through the property line POC, will satisfy the surface water criteria attainment demonstration. This is because either the MSC is equal to or below the lowest surface water quality criterion (LSWC) or the compound in question does not have any corresponding surface water criteria at this time. These ~~65~~ compounds are listed in ~~Table IV-1~~Table III-1 ~~along with the nonresidential MSC~~.

The Department has identified ~~89~~ 80 compounds that require a more detailed analysis. These compounds are listed in Tables ~~IV-2~~III-2 and ~~IV-3~~III-3.

~~Table IV-2~~Table III-2 identifies ~~24~~ 22 compounds where the Act 2 MSC is above both the PQL and the LSWC, but the LSWC is below the PQL. Surface water quality attainment will be deemed to be attained when the maximum modeled or measured compliance well concentration of these compounds at the point of compliance and any groundwater/surface water interface, whether prior to or downgradient of the property line POC, is below the PQL. If the maximum

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
ACENAPHTHYLENE	208-96-8
ACEPHATE	30560-19-1
ACETALDEHYDE	75-07-0
ACETONITRILE	75-05-8
ACETOPHENONE	98-86-2
ACETYLAMINOFLUORENE, 2-(2AAF)	53-96-3
ACROLEIN	107-02-8
ACRYLIC ACID	79-10-7
ALACHLOR	15972-60-8
ALDICARB	116-06-3
ALLYL ALCOHOL	107-18-6
ALUMINUM	7429-90-5
AMINOBIPHENYL, 4-	92-67-1
AMITROLE	61-82-5
AMMONIA	7664-41-7
AMMONIUM SULFAMATE	7773-06-0
ANILINE	62-53-3
ANTHRACENE	120-12-7
ANTIMONY	7440-36-0
ARSENIC	7440-38-2
ASBESTOS	12001-29-5
ATRAZINE	1912-24-9
BARIUM AND COMPOUNDS	7440-39-3
BAYGON (PROPOXUR)	114-26-1
BENOMYL	17804-35-2

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
BENTAZON	25057-89-0
~~BENZENE~~	~~71-43-2~~
BENZO(G,H,I)PERYLENE	191-24-2
BENZOIC ACID	65-85-0
BENZOTRICHLORIDE	98-07-7
BENZYL ALCOHOL	100-51-6
BERYLLIUM	7440-41-7
~~BHC, DELTA~~	~~319-86-8~~
~~BHC, GAMMA (LINDANE)~~	~~58-89-9~~
BIPHENYL, 1,1-	92-52-4
BIS(2-CHLOROETHOXY)METHANE	111-91-1
BIS(2-CHLOROISOPROPYL)ETHER	39638-32-9
BIS(CHLOROMETHYL)ETHER	542-88-1
BISPHENOL A	80-05-7
~~BORON AND COMPOUNDS~~	~~7440-42-8~~
BROMACIL	314-40-9
BROMOCHLOROMETHANE	74-97-5
BROMOMETHANE ~~(METHYL BROMIDE)~~	74-83-9
BROMOPHENYL PHENYL ETHER, 4-	101-55-3
BROMOXYNIL	1689-84-5
BROMOXYNIL OCTANOATE	1689-99-2
BUTADIENE, 1,3-	106-99-0
BUTYL ALCOHOL, N-	71-36-3
BUTYLATE	2008-41-5
BUTYLBENZENE, N-	104-51-8

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
BUTYLBENZENE, SEC-	135-98-8
BUTYLBENZENE, TERT-	98-06-6
CADMIUM	7440-43-9
CAPTAN	133-06-2
CARBARYL	63-25-2
CARBAZOLE	86-74-8
CARBOFURAN	1563-66-2
CARBON DISULFIDE	75-15-0
CARBOXIN	5234-68-4
CHLORAMBEN	133-90-4
~~CARBON TETRACHLORIDE~~	~~56-23-5~~
CHLORIDE	
CHLORO-1, 1-DIFLUOROETHANE, 1-	75-68-3
CHLORO-1-PROPENE, 3- (ALLYL CHLORIDE)	107-05-1
CHLOROACETALDEHYDE	107-20-0
CHLOROACETOPHENONE, 2-	532-27-4
CHLOROANILINE, P-	106-47-8
CHLOROBENZENE	108-90-7
CHLOROBENZILATE	510-15-6
CHLOROBUTANE, 1-	109-69-3
CHLORODIFLUOROMETHANE	75-45-6
CHLOROETHANE	75-00-3
CHLOROETHYL VINYL ETHER, 2-	110-75-8
CHLORONITROBENZENE, P-	100-00-5
CHLOROPHENOL, 2-	95-57-8

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
CHLOROPHENYL PHENYL ETHER, 4-	7005-72-3
CHLOROPRENE	126-99-8
CHLOROPROPANE, 2-	75-29-6
CHLOROTHALONIL	1897-45-6
CHLOROTOLUENE, O-	95-49-8
CHLORPYRIFOS	2921-88-2
CHLORSULFURON	64902-72-3
CHLOROTHAL-DIMETHYL (DACTHAL) (DCPA)	1861-32-1
CHROMIUM, TOTAL	7440-47-3
CHROMIUM VI	18540-29-9
COBALT	7440-48-4
COPPER	7440-50-8
CRESOL(S)	1319-77-3
CRESOL, 0-(METHYLPHENOL, 2-)	95-48-7
CRESOL, M (METHYLPHENOL, 3-)	108-39-4
CROTONALDEHYDE	4170-30-3
CROTONALDEHYDE, TRANS-	123-73-9
CUMENE	98-82-8
CYCLOHEXANE	110-82-7
CYCLOHEXANONE	108-94-1
CYFLUTHRIN	68359-37-5
CYROMAZINE	66215-27-8
DECABORANE	17702-41-9
DI(2-ETHYLHEXYL)ADIPATE	103-23-1
DIALLATE	2303-16-4

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
DIAMINOTOLUENE, 2-4-	95-80-7
DIBENZOFURAN	132-64-9
DIBROMO-3-CHLOROPROPANE, 1,2-	96-12-8
DIBROMOBENZENE, 1,4-	106-37-6
DIBROMOETHANE, 1,2- (ETHYLENE DIBROMIDE)	106-93-4
DIBROMOMETHANE	74-95-3
DICHLORO-2-BUTENE, 1,4-	764-41-0
DICHLORO-2-BUTENE, TRANS-1, 4-	110-57-6
DICHLOROBENZENE, P	106-46-7
DICHLORODIFLUOROMETHANE (FREON 12)	75-71-8
DICHLOROETHANE, 1,1-	75-34-3
~~DICHLOROETHANE, 1,2-~~	~~107-06-2~~
~~DICHLOROETHYLENE, CIS 1,2-~~	~~156-59-2~~
~~DICHLOROETHYLENE, TRANS 1,2-~~	~~156-60-5~~
~~DICHLOROMETHANE (METHYLENE CHLORIDE)~~	~~75-09-2~~
DICHLOROPHENOL, 2,4-	120-83-2
DICHLOROPHENOXYACETIC ACID, 2,4- (2,4-D)	94-75-7
DICHLOROPROPANE, 1,2-	78-87-5
DICHLOROPROPIONIC ACID, 2,2- (DALAPON)	75-99-0
DICHLORVOS	62-73-7
DICYCLOPENTADIENE	77-73-6
DIETHANOLAMINE	111-42-2

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
DIFLUBENZURON	35367-38-5
DIGLYCIDYL ETHER (DGE)	2238-07-5
DIMETHOATE	60-51-5
DIMETHOXYBENZIDINE, 3,3-	119-90-4
DIMETHYL PHTHALATE	131-11-3
DIMETHYL SULFATE	77-78-1
DIMETHYLAMINOAZOBENZENE, P-	60-11-7
DIMETHYLANILINE, N,N-	121-69-7
DIMETHYLBENZIDINE, 3,3-	119-93-7
DIMETHYLHYDRAZINE, 1,1-	57-14-7
DIMETHYLPHENETHYLAMINE, ALPHA, ALPHA-	122-09-8
DINITROPHENOL, 2,4-	105-67-9~~51-28-5~~
DINITROBENZENE, 1,3-	99-65-0
DINITRO-O-CRESOL, 4,6-	534-52-1
DINITROTOLUENE, 2,4-	121-14-2
DINITROTOLUENE, 2,6- (2,6-DNT)	606-20-2
DINOSEB	88-85-7
DIOXANE, 1,4-	123-91-1
DIOXATHION	78-34-2
DIPHENAMID	957-51-7
DIPHENYLAMINE	122-39-4
DIQUAT	85-00-7
DISULFOTON	298-04-4
DIURON	330-54-1

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
ENDOSULFAN	115-29-7
ENDOSULFAN SULFATE	1031-07-8
ENDOTHALL	145-73-3
EPICHLOROHYDRIN	106-89-8
ETHEPHON	16672-87-0
ETHION	563-12-2
ETHOXYETHANOL, 2- (EGEE)	110-80-5
ETHYL ACETATE	141-78-6
ETHYL ACRYLATE	140-88-5
ETHYL DIPROPYLTHIOCARBAMATE, S- (EPTC)	759-94-4
ETHYL ETHER	60-29-7
ETHYL METHACRYLATE	97-63-2
ETHYL METHANESULFONATE	62-50-0
ETHYLENE GLYCOL	107-21-1
ETHYLENE THIOUREA (ETA)	96-45-7
ETHYLP-NITROPHENYL PHENYLPHOSPHOROTHIOATE	2104-64-5
FAMPHUR	52-85-7
FENAMIPHOS	22224-92-6
FENSULFOTHION	115-90-2
FENVALERATE (PYDRIN)	51630-58-1
FLUOMETURON	2164-17-2
FLUORIDE	
FLUOROTRICHLOROMETHANE (FREON 11)	75-69-4

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
FONOFOS	944-22-9
FORMIC ACID	64-18-6
FOSETYL-AL	39148-24-8
FURAN	110-00-9
FURFURAL	98-01-1
GLYPHOSATE	1071-83-6
~~HEPTACHLOR EPOXIDE~~	~~1024-57-3~~
~~HEXACHLOROBUTADIENE~~	~~87-68-3~~
HEXACHLOROETHANE	67-72-1
HEXACHLOROPROPENE	1888-71-7
HEXANE	110-54-3
HEXANONE, 2- (METHYL N-BUTYL KETONE)	591-78-6
HEXYTHIAZOX (SAVEY)	78587-05-0
HYDRAZINE/HYDRAZINE SULFATE	302-01-2
HYDROQUINONE	123-31-9
IODOMETHANE	74-88-4
IPRODIONE	36734-19-7
IRON	7439-89-6
ISOBUTYL ALCOHOL	78-83-1
ISODRIN	465-73-6
ISOPHORONE DIISOCYANATE	4098-71-9
ISOSAFROLE	120-58-1
KEPONE	143-50-0
LEAD	7439-92-1
MALATHION	121-75-5

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
MALEIC HYDRAZIDE	123-33-1
MANEB	12427-38-2
MANGANESE	7439-96-5
MERCURY	7439-97-6
MERPHOS OXIDE	78-48-8
METHACRYLONITRILE	126-98-7
METHAMIDOPHOS	10265-92-6
METHANOL	67-56-1
METHOMYL	16752-77-5
METHOXYCHLOR	72-43-5
METHOXYETHANOL, 2-	109-86-4
METHYL ACETATE	79-20-9
METHYL ACRYLATE	96-33-3
METHYL CHLORIDE	74-87-3
METHYL ETHYL KETONE	78-93-3
METHYL HYDRAZINE	60-34-4
METHYL ISOAMYL KETONE	110-12-2
METHYL ISOBUTYL KETONE	108-10-1
METHYL ISOCYANATE	624-83-9
METHYL METHACRYLATE	80-62-6
METHYL METHANESULFONATE	66-27-3
METHYL PARATHION	298-00-0
METHYL STYRENE (MIXED ISOMERS)	25013-15-4
METHYL TERT-BUTYL ETHER (MTBE)	1634-04-4
METHYLAMINE	74-89-5

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
METHYLCHLOROPHENOXYACETIC ACID (MCPA)	94-74-9
METHYLENE BIS(2-CHLOROANILINE), 4,4′-	101-14-4
METHYLNAPHTHALENE, 2-	91-57-6
METHYLSTYRENE, ALPHA	98-83-9
MEVINPHOS	7786-34-7
MONOCROTOPHOS	6923-22-4
NAPHTHOQUINONE, 1,4-	130-15-4
NAPHTHYLAMINE, 1-	134-32-7
NAPHTHYLAMINE, 2-	91-59-8
NAPROPAMIDE	15299-99-7
NICKEL	7440-02-0
NITRATE-NITROGEN (TOTAL)	14797-55-8
NITRITE-NITROGEN (TOTAL)	14797-65-0
NITROANILINE, M-	99-09-2
NITROANILINE, O-	88-74-4
NITROANILINE, P-	100-01-6
NITROPHENOL, 2-	88-75-5
NITROPHENOL, 4-	100-02-7
NITROPROPANE, 2-	79-46-9
NITROQUINOLINE-1-OXIDE, 4-	56-57-5
NITROSODIETHYLAMINE, N-	55-18-5
NITROSO-DI-N-BUTYLAMINE, N-	924-16-3
NITROSODIPHENYLAMINE, N-	86-30-6
NITROSO-N-ETHYLUREA, N-	759-73-9

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
OCTYL PHTHALATE, DI-N-	117-84-0
OXAMYL (VYDATE)	23135-22-0
PARATHION	56-38-2
PCB-1221 (AROCLOR)	11104-28-2
PCB-1232 (AROCLOR)	11141-16-5
PCB-1242 (AROCLOR)	53469-21-9
PCB-1248 (AROCLOR)	12672-29-6
PCB-1254 (AROCLOR)	11097-69-1
PCB-1260 (AROCLOR)	11096-82-5
PEBULATE	1114-71-2
PENTABORANE	19624-22-7
PENTACHLOROBENZENE	608-93-5
PENTACHLOROETHANE	76-01-7
PENTACHLORONITROBENZENE	82-68-8
PHENACETIN	62-44-2
PHENOL	108-95-2
PHENYL MERCAPTAN	108-98-5
PHENYLENEDIAMINE, M-	108-45-2
PHENYLPHENOL, 2-	90-43-7
PHORATE	298-02-2
PHTHALIC ANHYDRIDE	85-44-9
PICLORAM	1918-02-1
PICOLINE, 2-	109-06-8
PRONAMIDE	23950-58-5
PROPANIL	709-98-8

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
PROPANOL, 1-	71-23-8
PROPANOL, 2- (ISOPROPYL ALCOHOL)	67-63-0
PROPHAM	122-42-9
PROPIOLACTONE, BETA	57-57-8
PROPIONIC ACID	79-09-4
PROPIONITRILE (ETHYL CYANIDE)	107-12-0
PROPYLBENZENE, N-	103-65-1
PROPYLENE IMINE	75-55-8
PROPYLENE OXIDE	75-56-9
PYRENE	129-00-0
PYRETHRUM	8003-34-7
PYRIDINE	110-86-1
QUINOLINE	91-22-5
QUINONE (p-BENZOQUINONE)	106-51-4
QUIZALOFOP (ASSURE)	76578-14-8
RONNEL	299-84-3
SELENIUM	7782-49-2
SILVER	7440-22-4
SIMAZINE	122-34-9
STRONTIUM	7440-24-6
STRYCHNINE	57-24-9
STYRENE	100-42-5
SULFIDE	18496-25-8
SULFUR MONOCHLORIDE	10025-67-9
TEBUTHIURON	34014-18-1

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
TEPP	107-49-3
TERBACIL	5902-51-2
TERBUFOS	13071-79-9
TETRACHLOROBENZENE, 1,2,4,5-	95-94-3
TCDD, 2,3,7,8-	1746-01-6
TETRACHLOROETHANE, 1,1,2,2	79-34-5
~~TETRACHLOROETHYLENE (PCE)~~	~~127-18-4~~
TETRACHLOROPHENOL, 2,3,4,6-	58-90-2
TETRAETHYL LEAD	78-00-2
TETRAETHYLDITHIOPYROPHOSPHATE	3689-24-5
TETRAHYDROFURAN	109-99-9
TETRANITROMETHANE	
~~THALLIUM~~	~~7440-28-0~~
THIOFANOX	39196-18-4
THIONAZIN	297-97-2
THIRAM	137-26-8
TIN	7440-31-5
TOLUDINE, M-	108-44-1
TOLUDINE, O-	95-53-4
TOLUDINE, P-	106-49-0
TRIALLATE	2303-17-5
TRIBROMOMETHANE (BROMOFORM)	75-25-2
TRICHLORO-1,2,2-TRIFLUOROETHANE, 1,1,2-	76-13-1
TRICHLOROBENZENE, 1,3,5-	180-70-3
TRICHLOROETHANE, 1,1,1-	71-55-6

Table ~~IV~~III-1

Compounds Excluded from Further Surface Water Evaluation on Attainment of SHS for GW ≤ 2500 TDS

SUBSTANCE	CAS Number
~~TRICHLOROETHANE, 1,1,2-~~	~~79-00-5~~
~~TRICHLOROETHYLENE (TCE)~~	~~79-01-6~~
TRICHLOROPHENOL, 2,4,5-	95-95-4
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	93-76-5
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	93-72-1
TRICHLOROPROPANE, 1,1,2-	598-77-6
TRICHLOROPROPANE, 1,2,3-	96-18-4
TRICHLOROPROPENE, 1,2,3-	96-19-5
TRIETHYLAMINE	121-44-8
TRIETHYLPHOSPHOROTHIOATE, O,O,O-	126-68-1
TRIFLURALIN	1582-09-8
TRIMETHYLBENZENE, 1,3,4- (TRIMETHYLBENZENE, 1,2,4-)	95-63-6
TRINITROGLYCEROL (NITROGLYCERIN)	55-63-0
TRINITROTOLUENE, 2,4,6-	118-96-7
VANADIUM	7440-62-2
VINYL ACETATE	108-05-4
VINYL BROMIDE (BROMOETHENE)	593-60-2
~~VINYL CHLORIDE~~	~~75-01-4~~
WARFARIN	81-81-2
ZINC	7440-66-6
ZINEB	12122-67-7

Table ~~IV~~III-2

Compounds Requiring Additional Evaluation for Surface Water Compliance if PQL Exceeded*

SUBSTANCE	CAS Number	PQL	LSWC lowest ug/l	MSC highest ug/l
~~BENZO[A]PYRENE~~	~~50-32-8~~	~~0.07~~	~~0.0044~~	~~0.2~~
BHC, ALPHA-	319-84-6	0.05	0.0026	0.12
BHC, BETA	319-85-7	~~0.2~~0.05	~~0.014~~0.0091	~~1.4~~0.41
BIS[2-ETHYLHEXYL] PHTHALATE	117-81-7	5	1.2	6
~~BROMODICHLOROMETHANE (DICHLOROBROMOETHANE)~~	~~75-27-4~~	~~5~~	~~0.56~~	~~100~~
CARBON TETRACHLORIDE	56-23-5	0.5	0.23	5
CHLORDANE	57-74-9	0.14	0.0008	2
CHLORODIBROMOMETHANE	124-48-1	~~5~~0.5	0.4~~1~~	~~100~~80
~~CYANIDE, FREE~~	~~57-12-5~~	~~100~~	~~5.2~~	~~200~~
DDD, 4,4-	72-54-8	0.05	0.00031	3
DDE, 4,4-	72-55-9	0.05	0.00022	2.1
DDT 4,4-	50-29-3	0.05	0.00022	2.1
DICHLOROETHANE, 1,2-	107-06-2	0.5	0.38	5
~~ENDOSULFAN, ALPHA~~	~~959-98-8~~	~~0.3~~	~~0.056~~	~~500~~
~~ENDOSULFAN, BETA~~	~~33213-65-9~~	~~0.4~~	~~0.056~~	~~450~~
ENDRIN	72-20-8	~~0.9~~0.29	0.036	2
HEPTACHLOR	76-44-8	0.05	0.000079	0.4
HEPTACHLOR EPOXIDE	1024-57-3	0.05	0.000039	0.2
~~HEXACHLOROBENZENE~~	~~118-74-1~~	~~0.2~~	~~0.00075~~	~~1~~
HEXACHLOROBUTADIENE	87-68-3	10	0.44	9.4
HEXACHLOROCYCLOPENTADIENE	77-47-4	10	1	50
~~MERCURY~~	~~7439-97-6~~	~~0.2~~	~~0.05~~	~~2~~
~~NITROSO-DIPHENYLAMINE, N-~~	~~86-30-6~~	~~10~~	~~5~~	~~530~~
PCB-1016 (AROCLOR)	12674-11-2	~~0.2~~0.05	~~0.0000440~~0.014	~~7.2~~0.37
~~PCB-1221~~	~~11104-28-2~~	~~0.2~~	~~0.000044~~	~~5.2~~
~~PCB-1232~~	~~11141-16-5~~	~~0.2~~	~~0.000044~~	~~5.2~~
~~PCB-1242~~	~~53469-21-9~~	~~0.2~~	~~0.000044~~	~~5.2~~

Table ~~IV~~III-2

Compounds Requiring Additional Evaluation for Surface Water Compliance if PQL Exceeded*

SUBSTANCE	CAS Number	PQL	LSWC lowest ug/l	MSC highest ug/l
~~PCB 1248~~	~~12672-29-6~~	~~0.2~~	~~0.000044~~	~~1.4~~
~~PCB 1254~~	~~11097-69-1~~	~~0.2~~	~~0.000044~~	~~1.4~~
~~PCB 1260 (AROCLOR)~~	~~11096-82-5~~	~~0.2~~	~~0.000044~~	~~4.3~~
PENTACHLOROPHENOL	87-86-5	2	0.27	1
PHENANTHRENE	85-01-8	10	1	1,100
~~POLYCHLORINATED BIPHENYLS~~	~~-~~	~~0.2~~	~~0.000044~~	~~0.5~~
~~SILVER~~	~~7440-22-4~~	~~7~~	~~3.5~~	~~100~~
TETRACHLOROETHANE, 1,1,1,2-	630-20-6	0.5	0.17	70
TOXAPHENE	8001-35-2	0.5	0.0002	3
~~TRIBROMOMETHANE (BROMOFORM)~~	~~75-25-2~~	~~5~~	~~4.3~~	~~100~~
TRICHLOROPHENOL, 2,4,6-	88-06-2	10	~~2.1~~1.4	~~240~~42
VINYL CHLORIDE	75-01-4	0.5	0.025	2

* Any time the highest groundwater concentration in a plume at the POC or the groundwater/surface water interface, as appropriate, is below the LSWC, a PENTOXSD analysis is not required.

Table ~~IV~~III-3

Compounds Requiring Surface Water Compliance Analysis*

SUBSTANCE	CAS Number	PQL	LSWC lowest µg/l	MSC highest µg/l	APPLY BACK-GROUND DATA
ACENAPHTHENE	83-32-9	10	17	3800	
ACETONE	67-64-1	~~5~~2.5	3500	~~10000~~92,000	
ACRYLAMIDE	79-06-1	0.032	0.1	2.5	
*ACRYLONITRILE	107-13-1	5	0.059	~~2.7~~3.7	
*ALDRIN	309-00-2	~~4~~0.005	0.00013	~~0.037~~0.15	
BENZENE	71-43-2	0.5	1.2	5	
BENZIDINE	92-87-5		~~0.00012~~0.000086	0.011	
*BENZO[A]ANTHRACENE	56-55-3	10	0.003~~844~~	~~3.6~~3.7	
BENZO[A]PYRENE	50-32-8	10	0.0038	0.2	
*BENZO[B]FLUORANTHENE	205-99-2	10	0.~~0044~~0038	1.2	
*BENZO[K]FLUORANTHENE	207-08-9	10	0.~~0044~~0038	0.55	
BENZYL CHLORIDE	100-44-7		0.2	5.1	
~~*BHC, ALPHA~~	~~319-84-6~~	~~0.4~~	~~0.0039~~	~~0.41~~	
BHC, GAMMA (LINDANE)	58-89-9	0.05	0.098	0.2	
*BIS(2-CHLOROETHYL)ETHER	111-44-4	10	0.03~~1~~	~~0.55~~0.76	
~~BIS[2-ETHYLHEXYL] PHTHALATE~~	~~117-81-7~~	~~1~~	~~1.8~~	~~6~~	~~-~~
BORON AND COMPOUNDS	7440-42-8	4	1,600	6,000	
BROMODICHLOROMETHANE	75-27-4	0.5	0.55	80	
BUTYLBENZYL PHTHALATE	85-68-7	10	35	~~2700~~1,400	
~~CADMIUM~~	~~7440-43-9~~	~~0.1~~	~~2.2~~	~~5~~	~~-~~
~~*CHLORDANE~~	~~57-74-9~~	~~0.4~~	~~0.0021~~	~~2~~	
CHLOROFORM	67-66-3	~~5~~0.5	5.7	~~100~~80	
CHLORONAPHTHALENE, 2-	91-58-7	10	~~1700~~1,000	8,200	
~~CHROMIUM III~~	~~16065-83-1~~	~~1~~	~~74~~	~~-~~	~~-~~
~~CHROMIUM VI~~	~~18540-29-9~~	~~1~~	~~10~~	~~-~~	~~-~~
*CHRYSENE	218-01-9	10	0.~~0044~~0038	1.9	
~~COBALT~~	~~7440-48-4~~	~~7~~	~~19~~	~~6100~~	~~-~~
~~COPPER~~	~~7440-50-8~~	~~6~~	~~9~~	~~1000~~	~~yes~~

Table ~~IV~~III-3

Compounds Requiring Surface Water Compliance Analysis*

SUBSTANCE	CAS Number	PQL	LSWC lowest µg/l	MSC highest µg/l	APPLY BACK-GROUND DATA
CRESOL, P (METHYLPHENOL, 4-)-	106-44-5	10	160	510	
CRESOL, P-CHLORO-M-	59-50-7		30	~~510~~10,000	
CYANIDE, FREE	57-12-5	1	5.2	200	
~~*DDD,4,4'-~~	~~72-54-8~~	~~0.2~~	~~0.00083~~	~~2.7~~	
~~*DDE, 4,4'-~~	~~72-55-9~~	~~0.2~~	~~0.00059~~	~~7.6~~	
~~*DDT, 4,4'-~~	~~50-29-3~~	~~0.3~~	~~0.00059~~	~~5.5~~	
DIAZINON	333-41-5	0.11	0.17	1	
*DIBENZO(A,H)ANTHRACENE	53-70-3	10	0.~~00~~440038	0.36	
DIBUTYL PHTHALATE, N-	84-74-2	10	21	10,000	
DICHLOROBENZENE, 1,2-	95-50-1	10	160	600	
DICHLOROBENZENE, 1,3-	541-73-1	10	69	600	
*DICHLOROBENZIDINE, 3,3'-	91-94-1	20	0.~~04~~.021	5.8	
~~*DICHLOROETHYLENE, 1,1-~~	~~75-35-4~~	~~5~~	~~0.057~~	~~7~~	
DICHLOROETHYLENE, CIS-1,2-	156-59-2	0.5	12	70	
DICHLOROMETHANE (METHYLENE CHLORIDE	75-09-2	0.5	4.6	5	
DICHLOROPROPYLENE, 1,3-	542-75-6		~~10~~0.34	26	
*DIELDRIN	60-57-1	~~1~~0.05	0.~~00014~~000052	0.16	
DIETHYL PHTHALATE	84-66-2	10	800	~~5000~~82,000	
~~DIMETHYLPHENOL, 2,4-~~	~~105-67-9~~	~~10~~	~~130~~	~~2000~~	-
~~*DINITRO-O-CRESOL, 4,6-~~	~~534-52-1~~	~~50~~	~~13.4~~	~~5~~	
~~*DINITROTOLUENE, 2,4-~~	~~121-14-2~~	~~10~~	~~0.05~~	~~100~~	
~~*DINITROTOLUENE, 2,6-~~	~~606-20-2~~	~~10~~	~~0.05~~	~~100~~	
DINITROPHENOL, 2,4-	51-28-5	50	69	200	
DIPHENYLHYDRAZINE, 1,2-	122-66-7		0.~~04~~036	3.3	
ENDOSULFAN (ALPHA)	959-98-8	0.05	0.056	500	
ENDOSULFAN (BETA)	33213-65-9	0.05	0.056	450	
ETHYL BENZENE	100-41-4	0.~~5~~5	~~580~~530	700	

Table ~~IV~~III-3

Compounds Requiring Surface Water Compliance Analysis*

SUBSTANCE	CAS Number	PQL	LSWC lowest µg/l	MSC highest µg/l	APPLY BACK-GROUND DATA
FLUORANTHENE	206-44-0	10	40	260	
FLUORENE	86-73-7	10	~~1300~~1,100	1,900	
FORMALDEHYDE	50-00-0	~~20~~6.2	440	1,000	
~~*HEPTACHLOR~~	~~76-44-8~~	~~0.4~~	~~0.00021~~	~~0.4~~	
HEXACHLOROBENZENE	118-74-1	10	0.00028	1	
~~*~~INDENO(1,2,3-CD)PYRENE	193-39-5	10	~~.0.0044~~0.0038	3.6	
ISOPHORONE	78-59-1	10	~~36~~35	100	
~~LEAD~~	~~7439-92-1~~	~~1~~	~~1.46~~	~~5~~	~~yes~~
NAPHTHALENE	91-20-3	10	43	100	
~~NICKEL~~	~~7440-02-0~~	~~15~~	~~52~~	~~100~~	~~yes~~
~~NITRATE NITROGEN~~	~~14797-55-8~~	~~-~~	~~-~~	~~10000~~	~~yes~~
~~NITRITE NITROGEN~~	~~14797-65-0~~	~~-~~	~~-~~	~~1000~~	~~yes~~
~~NITRATE/NITRITE NITROGEN~~	~~-~~	~~-~~	~~10000~~	~~-~~	~~yes~~
NITROBENZENE	98-95-3	10	17	~~51~~200	
~~*~~NITROSO-DIMETHYLAMINE, N-	62-75-9	~~20~~	0.00069	~~0.013~~0.018	
NITROSODI-N-PROPYLAMINE, N-	621-64-7	10	0.005	0.37	
~~PENTACHLOROPHENOL~~	~~87-86-5~~	~~0.1~~	~~0.28~~	~~1~~	~~-~~
RESORCINOL	108-46-3	100	2,700	200,000	
~~SELENIUM~~	~~7782-49-2~~	~~2~~	~~4.6~~	~~50~~	~~yes~~
~~SULFATE~~	~~-~~	~~-~~	~~250000~~	~~500000~~	~~-~~
~~TETRACHLOROETHANE, 1,1,2,2-~~	~~79-34-5~~	~~0.1272~~	~~0.17~~	~~0.3~~	~~-~~
TETRACHLOROETHYLENE (PCE)	127-18-4	0.5	0.69	5	
THALLIUM	7440-28-0	27	0.24	2	
TOLUENE	108-88-3	~~5~~0.5	330	1,000	
~~*TOXAPHENE~~	~~8001-35-2~~	~~0.8~~	~~0.00073~~	~~3~~	
TRICHLOROBENZENE, 1,2,4-	120-82-1	~~5~~0.5	26	70	
TRICHLOROETHANE, 1, 1, 2-	79-00-5	0.5	0.59	5	
TRICHLOROETHYLENE (TCE)	79-01-6	0.5	2.5	5	

Table ~~IV~~III-3

Compounds Requiring Surface Water Compliance Analysis*

SUBSTANCE	CAS Number	PQL	LSWC lowest µg/l	MSC highest µg/l	APPLY BACK-GROUND DATA
TRIMETHYLBENZENE, 1, 3, 5-	108-67-8	0.5	72	1,000	
~~VANADIUM~~	~~7440-62-2~~	~~2.5~~	~~100~~	~~720~~	~~-~~
XYLENES (TOTAL)	1330-20-7	~~5~~1	210	10,000	
~~ZINC~~	~~7440-66-6~~	~~2~~	~~120~~	~~2000~~	~~yes~~

* Any time the highest groundwater concentration in a plume at the POC or the groundwater/surface water interface, as appropriate, is below the LSWC, a PENTOXSD analysis is not required.

concentration in groundwater exceeds the PQL, these compounds must be evaluated as those in Table ~~IV~~III-3, described below.

~~Table IV-3~~Table III-3 identifies ~~65~~ 58 compounds for which surface water compliance analysis is required. These are compounds where either the MSC exceeds the LSWC and both the MSC and LSWC exceed the PQL, or the LSWC is so much lower than the PQL that the Office of Water Management cannot be assured that the LWSC is met if attainment is demonstrated at the level of the PQL.

Regardless of the standard selected, whenever the maximum concentration of a regulated substance in groundwater discharging to a stream at the time of maximum mass loading to the stream is quantified at a level lower than the LSWC, further demonstration of compliance with surface water criteria is not required. For this reason a remediator may want to consider using other valid analytical methods which have lower PQLs.

It is also important to note that if the fate and transport modeling, or actual in-stream sampling show that surface water quality are exceeded, the remediator may be able to demonstrate that the Site Specific standard can be attained by addressing the exposure pathways applicable to that standard.

e) Examples

i) Example 1: ~~.~~ Groundwater Source Very Near or Adjacent to Surface Water Discharge

A site with an accumulation of gasoline as a separate phase liquid lies immediately adjacent to a small stream. Separate phase liquid is being collected by an interceptor/skimmer system that prevents its discharge to the stream. However, a dissolved phase hydrocarbon plume with maximum concentrations of certain compounds ~~at or~~ near their effective solubility is entering the stream. The remediator has selected the site-specific standard for these contaminants and must determine if surface water criteria are met without any treatment or removal of the dissolved phase plume. Because the site-specific standard has been selected and groundwater concentrations exceed the lowest surface water quality criteria, a PENTOXSD analysis is required.

Because the site is located very near the surface water discharge point, no opportunity for dispersion or decay of the groundwater plume prior to its discharge is expected. Data from the site characterization and attainment monitoring wells is assumed here to allow an accurate estimate of the quantity and concentration of the groundwater plume entering the stream, without any need for fate and transport modeling of groundwater. The following characteristics of the groundwater plume have been determined:

Plume (source) width – 100 feet

Plume depth – 10 feet

Permeability – ~~2.83~~1.92 ft/day

Gradient .01 ft/ft

Groundwater flow represented by plume: ~~28.3~~1,920 ft³/day = ~~212~~14,361 gallons/day

Average concentrations in groundwater at surface water interface (µg/L):

Benzene: ~~15,000~~ 12,000

Toluene 52,000

Ethylbenzene 1,500

Total xylenes 9,000

MTBE 6,900,000

Using benzene for this example, the maximum average groundwater concentration is ~~15,000~~12,000 µg/L and the plume flow is ~~212~~ 14,361 gallons/day or ~~0.00033 cfs (0.00021~~0.01436 MGD~~)~~.

Assuming all groundwater discharges to the stream, an evaluation of the plume discharge to the stream can now be made with the above data using PENTOXSD for each of the contaminants. The approach is described and shown below for benzene:

Figures ~~IV-1~~ III-1 and ~~IV-2~~III-2 are printouts from the PENTOXSD model for Example 1. PENTOXSD shows that the recommended effluent limit for benzene in this case is ~~12,323~~181 µg/L, which is less than the ~~15,000~~12,000 µg/L maximum average groundwater concentration for benzene calculated for this example. Therefore, a release of liability cannot be granted in this case until the maximum average groundwater concentration is reduced to at least ~~12,323~~181 µg/L and other parameters in the example are shown to be at acceptable levels.

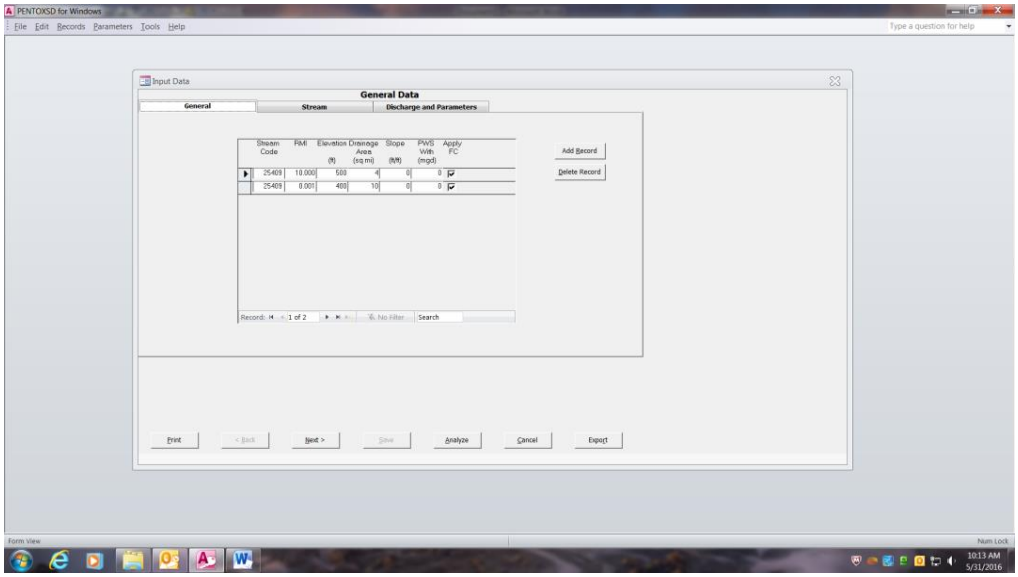
ii) Example 2~~:~~. Groundwater Source at Distance from Surface Water Discharge – Steady State Conditions

In this example, all conditions are the same as for Example 1 except the source is 100 feet from the stream. Additionally, one well is located 40 feet from the source in a downgradient direction toward the stream containing benzene at a concentration of 6,500 µg/L. Assume that wells cannot be drilled at the groundwater/surface water interface because of existing buildings and other obstacles. However, enough onsite and offsite data have been collected to reasonably calibrate a model and establish that the plume is at or near steady-state conditions. A groundwater solute transport model is chosen by the remediator to estimate the flow and concentration of the contaminants into the river. For purposes of this example, the Department's Quick Domenico (QD) and SWLOAD5 (SWL5) spreadsheet applications will be used. A plan view model such as Q~~uick~~ D~~omenico~~ is being used because it is difficult or impossible to calibrate a cross-sectional model such as SWL~~OAD~~5 using isoconcentration map data. Isoconcentration contours are usually developed and drawn in the

plan-view or horizontal dimension. Once the model input parameters are finalized using the plan view model, they are easily transferred for use into the cross-sectional model. The Department does not require the use of these particular models; however, if another surface water loading model is used, the rules incorporated into selection of SWL~~OAD~~5's "edge criterion" for establishing the portion of the plume flow and average concentration must be used.

Figure ~~IV~~III-1

Example 1 –PENTOXSD Model Inputs



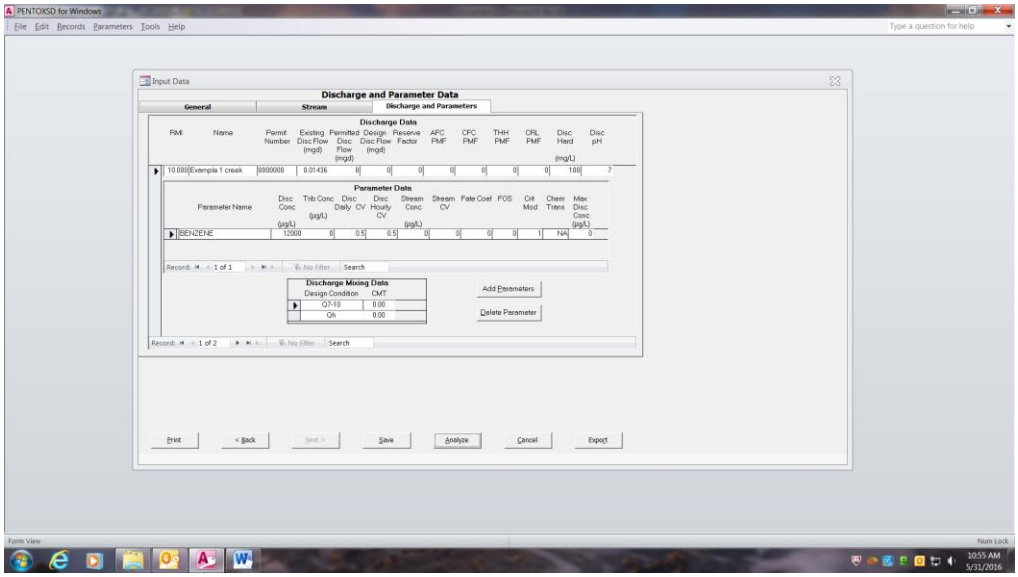
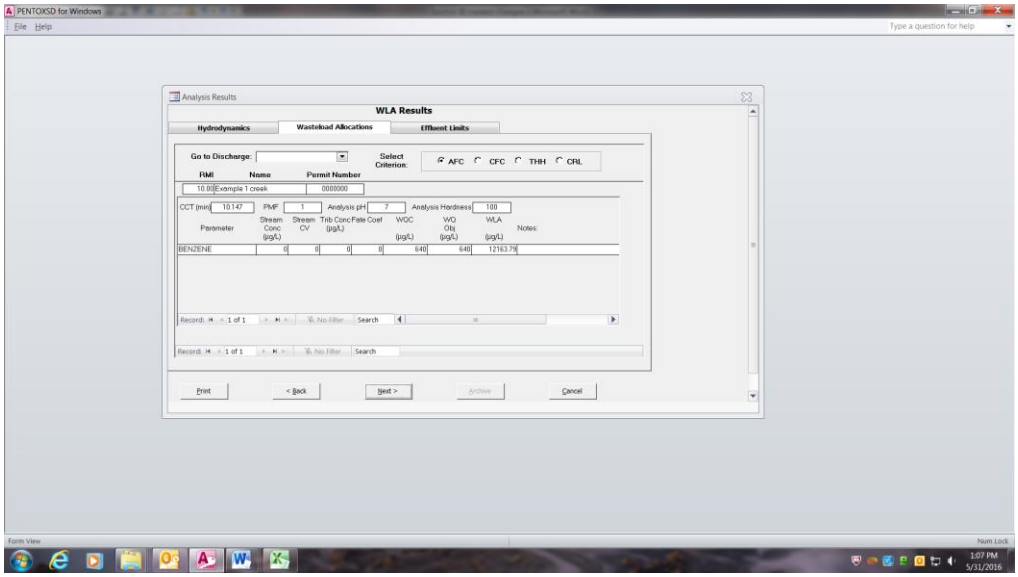
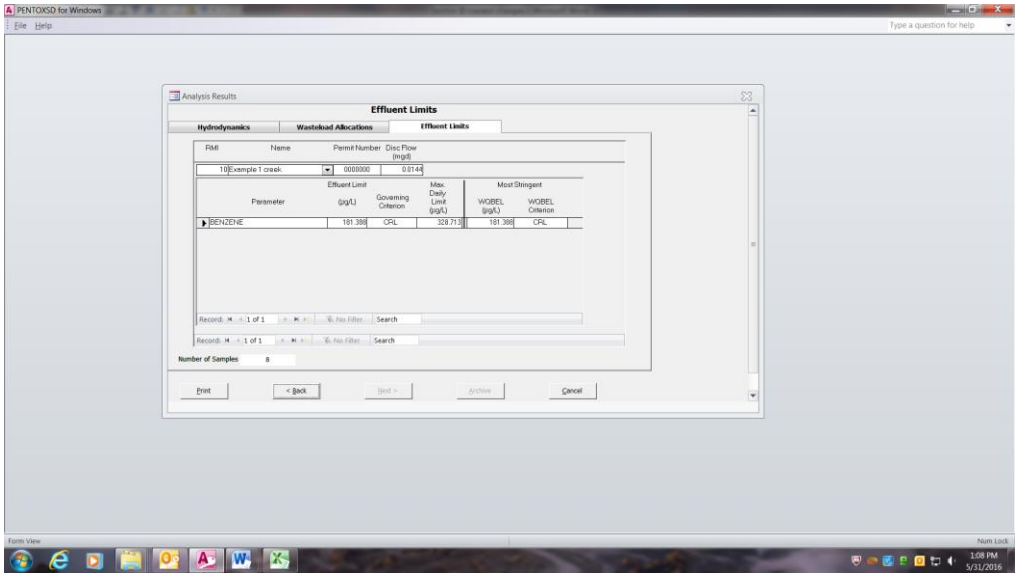


Figure ~~IV~~III-2

Example 1 –PENTOXSD Model Output





~~groundwater solute transport model is chosen by the remediator to estimate the flow and concentration of the contaminants into the river. For purposes of this example, the Department's Quick Domenico (QD) and SWLOAD5 (SWL5) spreadsheet applications will be used. A plan view model such as Quick Domenico is being used because it is difficult or impossible to calibrate a cross-sectional model such as SWLOAD5 using isoconcentration map data. Isoconcentration contours are usually developed and drawn in the plan view or horizontal dimension. Once the model input parameters are finalized using the plan view model, they are easily transferred for use into the cross-sectional model. The Department does not require the use of these particular models; however, if another surface water loading model is used, the rules incorporated into selection of SWLOAD5's "edge criterion" for establishing the portion of the plume flow and average concentration must be used.~~

In order to complete the analysis, input values for the following additional parameters required by the model were developed during the site characterization phase. Those parameters and how they were determined for this example are as follows (See ~~Figure IV-3~~Figure III-3 for the actual values):

Longitudinal and transverse dispersion – fitted to plume data (isoconcentration map) using QD

Vertical Dispersion – set to 0.0001 because the entire plume is assumed to discharge into the stream and any vertically dispersed contamination would reenter the stream.

Lambda – determined using methods of Buscheck and Alcantar (1995) for steady state plumes. Starting values may be found from Appendix A, Table 5A, Chapter 250 (and converted to the correct units).

Time – 11 years-established from historical records. Note that this is fixed at 1×10^{99} days in SWLOAD5 to assure that output is at steady state conditions. This assures that SWLOAD5 will yield the maximum average concentration for plumes emanating from a constant source.

Porosity – determined by laboratory analysis of undisturbed samples.

Dry bulk density – estimated at 2.65 * (1-porosity)

Koc – from Appendix A, Table 5, Chapter 250

Fraction organic carbon – Can be estimated from ASTM D2974-00

Once a satisfactory output matching the overall plume geometry at 11 years was achieved using QD, the flow and transport terms of QD, except for time, were input into SWLOAD5. The output from QD and SWLOAD5 is shown in Figures ~~IV-3~~III-3 and ~~IV-4~~III-4.

The model indicates that the maximum average concentration in groundwater is ~~2.35~~ 1.28 mg/L and the total flow through the plume is ~~0.0004~~0.00026 MGD. These values (after any necessary conversion) then become the input values for existing discharge flow and discharge concentration of benzene in PENTOXSD.

Note that the average concentration in the benzene plume is lower than in the first example because of first order decay and dispersion. However, note also that, because the plume has dispersed, the cross-sectional flow is somewhat greater.

Figure ~~IV~~III-3

Example 2 – Quick Domenico Model Output

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: TGM Example 2
Date: Prepared by: BECB
Contaminant: Benzene

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

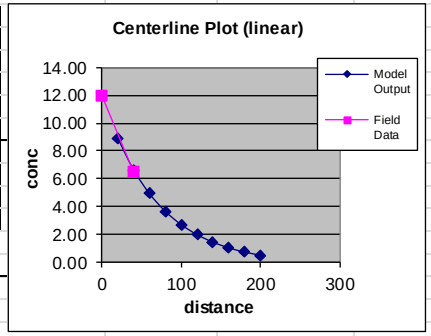
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
12	2.00E+01	1.00E+00	1.00E-04	0.0008	100	10	4015

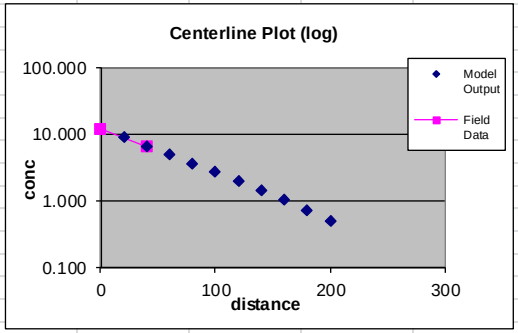
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^{3})	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
1.92E+00	0.01	0.358	1.7	58	1.00E-03	1.275418994	0.042049934

Point Concentration

x(ft)	y(ft)	z(ft)
100	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	100	0	0
at	4015	days =	2.701 mg/l





AREAL MODEL	CALCULATION DOMAIN
Length (ft)	200
Width (ft)	100

	20	40	60	80	100	120	140	160	180	200
100	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.003
50	4.466	3.323	2.469	1.830	1.351	0.991	0.720	0.517	0.365	0.253
0	8.932	6.646	4.939	3.660	2.701	1.980	1.437	1.029	0.724	0.499
-50	4.466	3.323	2.469	1.830	1.351	0.991	0.720	0.517	0.365	0.253
-100	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.003

Field Data:	Centerline C Concentration	12	6.5						
	Distance from Source	0	40						

Figure ~~IV~~III-4

Example 2 – SWLOAD Model Output

METHOD FOR ESTIMATNG FLOW, AVERAGE CONCENTRATION AND MASS LOADING TO SURFACE WATER FROM GROUNDWATER

Project: TGM Example 2
Date:
Contaminant: Benzene
Prepared by: BECB

PA DEPARTMENT
OF ENVIRONMENTAL PROTECTION
SWLOAD5B.XLS
A METHOD FOR ESTIMATING
COMTAMINANT LOADING TO SURFACE WATER
based on
P.A. Domenico (1987)
Modified to Include Retardation

SOURCE CONC (units)	Ax (ft)	Ay (ft)	Az (ft)	LAMBDA	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days)
mg/l	>.0001	>.0001	>=.0001	day-1			
12	20	1	1.00E-04	0.0008	100	10	1.00E+99

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
1.92E+00	0.01	0.358	1.7	58	1.00E-03	1.275419	0.04204993

		-93.875	-75.1	-56.325	-37.55	-18.775	0	18.775	37.55	56.325	75.1	93.875
Edge Criterion (mg/l)	0.005	0	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
Higest modeled conc.	2.75743	-1.0438	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
		-2.0876	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
SURFACE WATER LOADING GRID		-3.1314	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
Distance to Stream (ft)	100	-4.1752	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
Plume View Width (ft)	187.75	-5.219	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
Plume View Depth (ft)	10.438	-6.2628	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
		-7.3066	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
		-8.3504	0.0026474	0.1047209	0.9030088	2.23625869	2.72096528	2.7574273	2.7209653	2.2362587	0.9030088	0.1047209	0.002647
PENTOX NEEDED		-9.3942	0.0026473	0.10472	0.9030005	2.23623813	2.72094027	2.75740196	2.7209403	2.2362381	0.9030005	0.10472	0.002647
		-10.438	2.587E-06	0.0001023	0.0008823	0.00218489	0.00265846	0.00269408	0.0026585	0.0021849	0.0008823	0.0001023	2.59E-06

Average Groundwater Concentration 1.27773 mg/l

Plume Flow 0.00041 cfs 0.00026 MGD

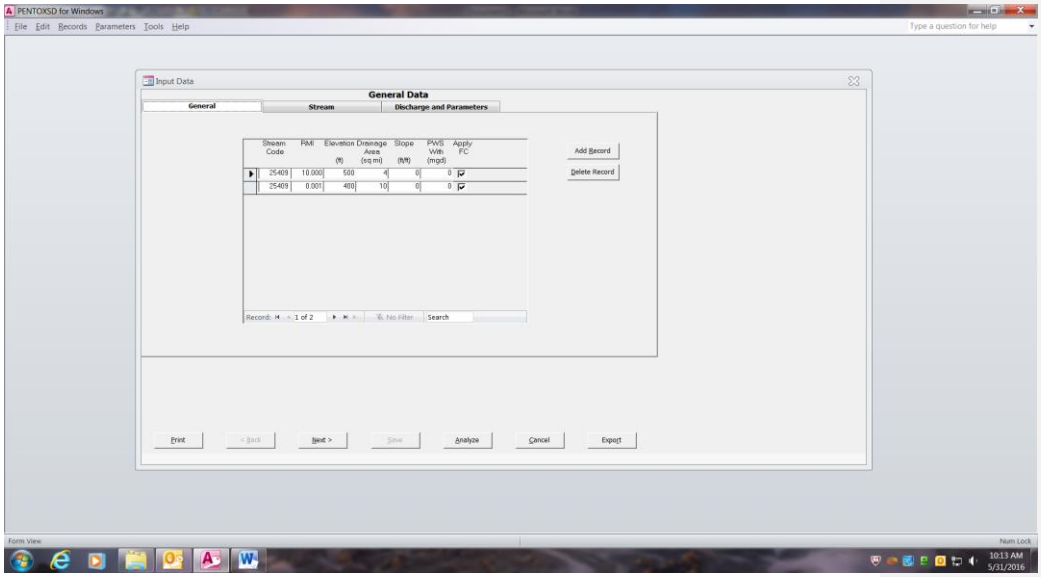
Mass Loading to Stream 1279.85 mg/day

Documentation for using SWLOAD5 to estimate plume flow, concentrations and mass loading is provided on the Land Recycling Program web page under "Guidance and Technical Tools."

Figures ~~IV-5~~ III-5 and ~~IV-6~~III-6 are printouts from the PENTOXSD model run for Example 2. In this case, the recommended effluent limit for benzene is ~~6,469.9~~ 1,994 µg/L, which is greater than the maximum average benzene concentration of ~~2,353~~1,278 µg/L calculated with SWLOAD5. Therefore, attainment of surface water criteria for benzene has been demonstrated. If attainment of the other parameters in the example with surface water criteria were also demonstrated, a release of liability would convey.

Figure ~~IV~~III-5

Example 2 – PENTOXSD Model Inputs



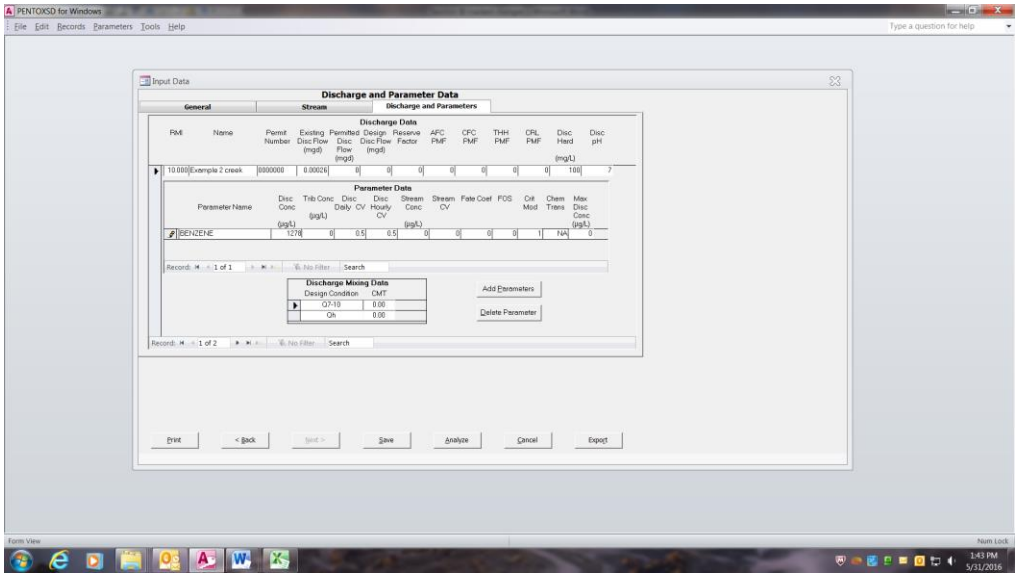
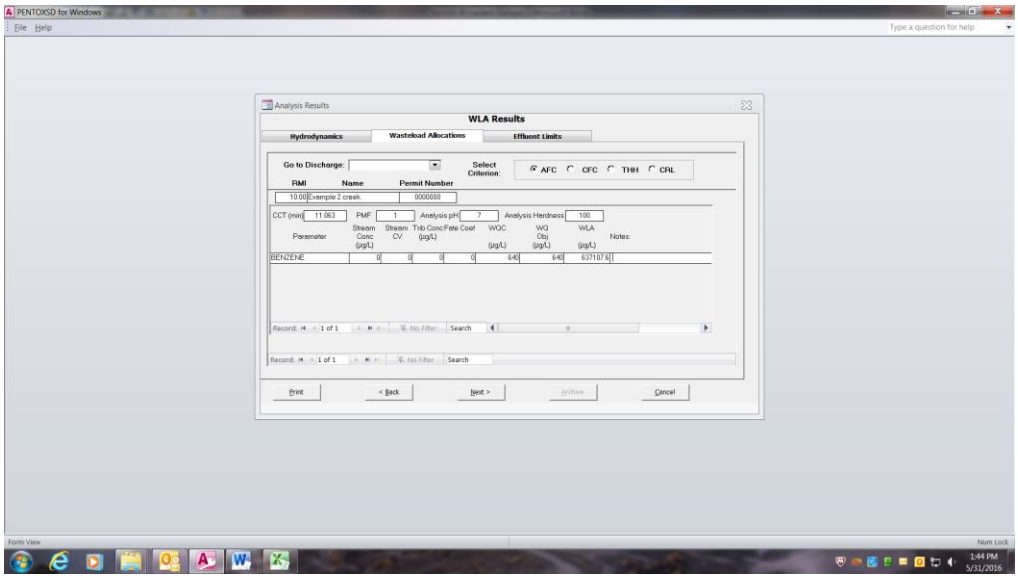
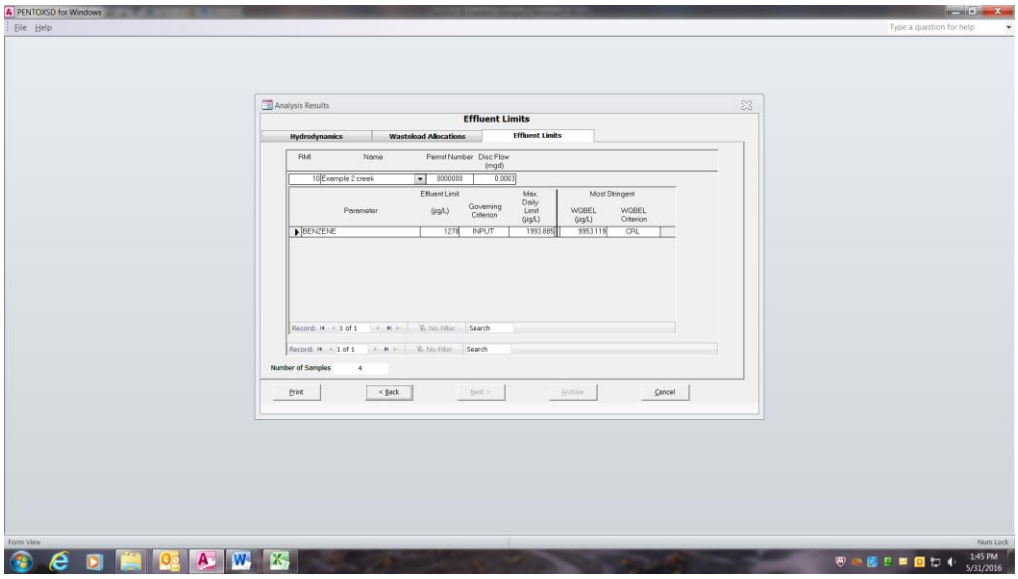


Figure ~~IV~~III-6

Example 2 – PENTOXSD Model Output





~~C.~~B. Guidance for Attainment Demonstration with Statistical Methods

1. Introduction

The requirement to apply statistical methods to verify the cleanup of a site is emphasized in Act 2. Sections 302, 303 and 304 of Act 2 require that attainment of a standard be demonstrated by the collection and analysis of samples from affected media (such as surface water, soil, groundwater in aquifers at the point of compliance) through the application of statistical tests set forth in regulation. The Act also requires the Department to recognize those methods of attainment demonstration generally recognized as appropriate for that particular remediation.

Statistical methods are emphasized because there is a practical need to make decisions regarding whether a site meets a cleanup standard in spite of uncertainty. The uncertainty arises because we are able to sample and analyze only a small portion of the soil and groundwater at a site, yet we have to make a decision regarding the entire site.

The purpose of this section is to provide guidance for the use of statistics to demonstrate that a site has attained a cleanup standard under Act 2. It is intended to address certain key issues pertinent to the sampling and statistical analysis under Act 2, to provide references for proper statistical analysis and, if necessary, to provide examples of applying statistical procedures in detail. It is not intended to address every statistical issue.

For statistical attainment issues not addressed directly in this manual or the Act 2 regulations, a person may consult the latest ITRC and EPA documents for additional guidance. The ITRC document '*Groundwater Statistics and Monitoring Compliance*' and EPA guidance documents (EPA ~~1989b,~~ 1992b, 1992c, 1996, 2002b, 2009) are particularly helpful. They provide detailed statistical procedures for demonstration of attainment and data analysis.

For groundwater characterization, ~~persons~~ remediators should consult the current DEP guidance document "Groundwater Monitoring Guidance Manual" ~~(Section V.F)~~, which provides general information on groundwater monitoring and sampling issues, such as monitoring well construction, locations and depths of monitoring wells, and well abandonment procedures. The DEP Groundwater Monitoring Guidance Manual provides a good summary of various statistical methods used for groundwater characterization.

For conducting statistical analys~~e~~is, remediators may wish to utilize EPA's ProUCL Statistical Software for Environmental Applications. This free program is available on EPA's website and accompanied with a Technical Guide. ProUCL will be able to run most of the statistical applications summarized in this section of the TGM.

Other ~~references cited in this document and~~ standard statistics-related texts may be used to perform the procedures to demonstrate attainment as appropriate. If necessary, professional services should be obtained.

When we consider applying statistical methods to demonstrate the attainment of a risk-based cleanup standard, it is important to realize that three components may influence the overall stringency of this cleanup standard:

- The first component is the magnitude, level, or concentration that is deemed protective of human health and the environment. The development of risk-based cleanup standards is addressed in the Act 2 regulations and Department's risk assessment guidances.
- The second component of the standard is the sampling that is done to evaluate whether a site is above or below the standard.
- The final component is how the resulting data are compared with the standard to decide whether the remedial action was successful (a statistical analysis).

Persons overseeing cleanup must look beyond the cleanup level and explore the sampling and statistical analysis that will allow evaluation of the site relative to the cleanup level. This guidance is intended to address statistical analysis and sampling components that may affect the stringency of cleanup standards.

~~**2. Data Quality Objectives Process, Sampling, and Data Quality Assessment Process**~~

Comment [B3]: Moved to Section III.F

~~An important issue regarding sampling and statistical analysis is the quality assurance (QA) management considerations associated with these activities. Steps for the QA management process, in general, can be divided into three phases: planning, implementation and assessment. During the planning phase, a sampling and analysis plan is developed based on Data Quality Objectives (DQO). The implementation phase includes sampling execution and sample analysis. The assessment phase includes Data Quality Assessment (DQA) (See Section 250.702(a) of the regulations).~~

~~To help a person design a scientific and resource-effective sampling program, EPA has provided guidance on developing Data Quality Objectives (EPA 1993). The DQO process allows a person to define the data requirements and acceptable levels of decision errors, before any data are collected. The DQO process should be considered in developing the sampling and analysis plan, including the quality assurance plan.~~

~~As stated in the EPA guidance (EPA 1993), the DQO process includes the following seven steps:~~

- ~~State the problem.~~
- ~~Identify the decision.~~
- ~~Identify inputs to the decision.~~
- ~~Define the spatial and temporal boundaries of the decision.~~
- ~~Develop a decision rule.~~
- ~~Specify limits on decision errors.~~

- Optimize the design for obtaining data.

Step 4 of the DQO process, defining the spatial and temporal boundaries of the decision, is particularly important, because it prevents pooling and averaging data in a way that could mask potentially useful information. Activities in this step include:

- Define the domain or geographic area within which all decisions must apply. Some examples are property boundaries, operable units, and exposure areas.
- Specify the characteristics that define the population of interest. Identification of multiple areas of concern - each with its own set of samples and descriptive statistics - will help to reduce the total variability if the areas of concern are defined so that they are very different in their contaminant concentration profiles. For example, the top 2 feet of soil are defined as surface soil. Another example is to define contaminated soil that has been impacted by separate-phase liquid (SPL) as SPL-impacted soil.
- When appropriate, divide the population into strata that have relatively homogeneous characteristics. This helps to reduce the variability in each data set.
- Define the scale of decision making. The scale of decision making is the smallest area, volume, or time frame of the media in which decision errors are to be controlled. This is also the unit that will be assumed to generate a "statistical unit" of possible measurements which allows the assessment and control of decision errors. Examples are remediation units, exposure units, and hot spots.
- Determine the time frame to which the study data apply. It may not be possible to collect data over the full time period to which the decision will apply. Therefore a decision should be made regarding the most appropriate time frame that the data should reflect.
- Determine when to collect samples. Conditions at the site may vary due to seasons, weather or other factors. Therefore a decision should be made regarding the most appropriate time period to collect data that will reflect the conditions that are of interest.
- Identify any practical constraints on data collection, such as seasonal or meteorological conditions, unavailability of personnel, time, or equipment.

At the completion of the DQO process, information obtained from the DQO process can be used to develop a sampling and analysis plan, including a quality assurance/quality control plan.

Unless otherwise specified or approved by the Department, systematic sampling (grid sampling) designs should be used in developing the sampling and analysis plan for demonstrating attainment of soil cleanup standards (See Section 250.703(c) of the regulations). Systematic random sampling is a grid sampling design with a random starting point. Systematic random sampling provides better coverage of the soil study area than simple random sampling. Limitations

~~and procedures to implement systematic sampling can be found in Sections 5.3 and 6.5 of EPA guidance (EPA, 1989b). A square grid and a triangular grid are two common patterns used in systematic sampling. To avoid grid pattern corresponding to patterns of contamination, EPA (EPA 1992c) recommended the use of unaligned grid sampling design (Gilbert, 1987, p.94). Unaligned grid sampling design maintains the advantage of uniform coverage while incorporating an element of randomness in the choice of sampling locations. To obtain an unbiased estimate of the variance of the mean, the multiple systematic sampling approach (Gilbert, 1987, p.97) may be needed.~~

~~To generate a grid sampling design, a computer random number generator or a random number table may be used, such as~~ Table IV-4~~.~~

~~After the environmental data have been collected and validated in accordance with the sampling and analysis plan (including the QA/QC plan), data must be assessed to determined whether the DQOs are met. This is the Data Quality Assessment (DQA) process. EPA has developed guidance on DQA (EPA, 1996).~~

~~The DQA process involves the following five steps(EPA, 1996):~~

- ~~Review the DQOs and sampling design.~~
- ~~Conduct a preliminary data review.~~
- ~~Select the statistical test.~~
- ~~Verify the underlying assumptions of the statistical test.~~
- ~~Perform the statistical hypothesis test and draw conclusions that address the data user's objectives.~~

~~A properly implemented DQA process can help to determine if planning objectives were achieved. The following discussions will address key statistical issues that are pertinent to Act 2 and are encountered during these DQO and DQA processes.~~

2. ~~Preliminary~~ Data Review for Statistical Methods

Preliminary data review for statistical analysis (also known as exploratory data analysis in the DEP Groundwater Monitoring Guidance Manual; PA ~~a~~DEP, ~~1999~~2001) includes the use of graphical techniques and calculation of summary statistics. ~~Preliminary data review should be performed whenever data are used.~~ By reviewing the data both numerically and graphically, one can learn the "structure" of the data and identify limitations for using the data. Graphical methods include histograms, probability plots, box charts, and time-series plots to visually review the data for trends or patterns. EPA and most statistical texts recommend that time-series data should be graphed. This visual approach allows for a quick assessment of the statistical features of the data. Calculations of summary statistics are typically done to characterize the data and make judgments on the central tendencies, symmetry, presence of outliers, etc. Preliminary data review is critical in selecting additional appropriate mathematical procedures.

Graphical and parametric statistical procedures discussed here are included in many introductory statistics textbooks (*e.g.*, Iman and Conover, 1983 and Ott, 1988) and are available in many computer statistics packages~~, such as SAS and DataQUEST (EPA QA/G-9D)~~.

a) Summary statistics

Basic summary statistics can be used to characterize groundwater monitoring data. Summary statistics include median, interquartile range (IQR), mean, standard deviation, and range. Median and IQR are determined from percentiles. Median is the 50th percentile and IQR is the 25th to 75th percentile. Median indicates the "center" of data values. The mean is another measure of center but only if data are normally or symmetrically distributed. Mean and standard deviation are required values with parametric procedures. Range is the minimum to maximum values. Procedures for such summary statistics are found in introductory statistics texts.

b) Graphical procedures

Refer to ~~Cleveland (1993) or EPA QA/G-9 (EPA, 1996)~~ITRC (2013) for a general reference on graphical procedures.~~ The use of boxplots is also described in the EPA Addendum (EPA, 1992a).~~

Histogram - A histogram is a graphic display of frequency distribution. The area within the bar represents the relative density of the data.

Boxplots - A boxplot summarizes a data set by presenting the percentile distribution of the data. The "box" portion indicates the median and interquartile range (IQR). IQR is the middle 50 percent of data. Difference in the size of box halves represents data skewness.

Normal and symmetrical distributions will have equal size box halves. Extreme outliers are displayed as individual points that are recognized easily. Boxplots can be constructed by hand; however, many computer statistical packages will do them.

The boxplot of a lognormal distribution will have noticeably different-sized box halves. Lack of IQR overlap for different data sets will indicate a probable significant difference. Boxplots of seasonally grouped data can be used to detect data seasonality.

Time Series Plots - A time series plot displays individual data points on a time scale. A monthly scale can help to identify seasonal variation. A yearly scale also can identify possible trends. Superimposing data from multiple sampling locations may provide additional information. Improved trend information is often available with data smoothing. ~~One smoothing procedure showing movement of the "center" of data over time is LOWESS. This procedure is most helpful with data having substantial variability and a long period of record. LOWESS requires computer software.~~

Control Charts - Control charts are used to define limits for an analyte that has been monitored at an uncontaminated well over time. This procedure is a graphical alternative to prediction limits.

A common technique is the Shewhart-CUSUM control chart that plots the data on a time scale. Obvious features such as trends or sudden changes in concentration levels could then be observed. With this method, if any compliance well has a value or a sequence of values that lie outside the control limits for that analyte, it may indicate statistically significant evidence of contamination.

The control chart approach is recommended only for uncontaminated wells, a normal or lognormal data distribution with few nondetects, and for a dataset that has at least eight independent samples over a one year period. This baseline is then used to judge the future samples. See the EPA ~~Interim Final~~ Guidance (EPA, ~~1989a~~2009, ~~Section~~ Chapter 20 ~~7~~) ~~and the EPA Addendum (EPA, 1992a, Section 6.1) for procedures~~.

3. Statistical Inference and Hypothesis Statements

A statistical procedure that is designed to allow the extrapolation from the results of a few samples to a statement regarding the entire site is known as statistical inference. Statistical inference allows decision making under uncertainty and valid extrapolation of information that can be defended and used with confidence to determine whether the site meets the cleanup standard.

The goal of statistical inference, the process of extrapolating results from a sample to a larger population, is to decide which of two complementary hypotheses, null hypothesis and alternative hypothesis, is likely to be true.

In general, statistical inference procedures include the following steps:

(1) A null hypothesis and its alternative hypothesis are drawn up. The null hypothesis is developed in such a way that the probability of Type I error can be determined. The Type I error is an error that we falsely reject the null hypothesis, when the null hypothesis is true. Type I error is also known as false positive error.

(2) Decide the level of significance, α. This controls the risk of committing a Type I error.

(3) Establish a decision rule for each scale of decision making that is derived from step 4 of the DQO process (See Section III.F.2 for more information on the DQO process).

(4) Determine the sample size, n. This is the number of environmental samples needed to make decision. Obtain data through the implementation of sampling and analysis plan.

(5) Apply the decision rule to the data. The null hypothesis is rejected or not rejected. Rejection of the null hypothesis implies acceptance of the alternative hypothesis.

~~Section 250.707(d)(1)~~Section 250.707(d)(1) of the regulations has specified the ground rules of hypothesis statements under Act 2. For demonstration of attainment of Statewide health or site-specific standards, the null hypothesis (H_o) is that the true site arithmetic average concentration is at or above the cleanup standard, and the alternative hypothesis (H_a) is that the true site arithmetic average concentration is below the cleanup standard. When statistical methods are to be used to determine that the background standard is exceeded, the null hypothesis (H_o) is that the background standard is achieved and the alternative hypothesis (H_a) is that the background standard is not achieved.

To understand the rationale of hypothesis testing, let us consider a nonstatistical hypothesis testing example - the process in which an accused individual is judged to be innocent or guilty in a criminal court. Under our legal system, we feel that it is a more grievous mistake to convict an innocent man than to let a guilty man go free. Therefore, the accused person is presumed to be innocent under our legal system. The burden of proof of his guilt rests upon the prosecution. The prosecutor must present sufficient evidence to the jury in order to convict the defendant while the defendant's lawyer would want to throw any reasonable doubt into the evidence presented by the prosecutor in order to get acquittal verdict for the defendant. Using the language of hypothesis testing, we want to test a null hypothesis (H_o) that the accused man is innocent. That means that an alternative hypothesis (H_a) exists, that the defendant is guilty. The jury will examine the evidence and decide whether the prosecution has demonstrated sufficiently that the evidence is inconsistent with the null hypothesis (H_o) of innocent. If the jurors decide that the evidence is inconsistent with H_o, they reject that hypothesis and therefore accept the alternative hypothesis (H_a) that the defendant is guilty.

Similar to the above legal process example, because we feel that it is a more serious mistake to declare a ~~dirty~~ contaminated site to be ~~clean~~ uncontaminated than to declare ~~a clean~~an uncontaminated site to be ~~dirty~~ contaminated under the Statewide health and site-specific standards, we choose the following null hypothesis statement: the true site arithmetic average concentration is at or above the cleanup standard. The null hypothesis is assumed to be true unless substantial evidence shows that it is false. The demonstration of attainment must be presented with sufficient evidence in order to show that the postremediation condition at the site is not consistent with the null hypothesis. We use "true site arithmetic average concentration" here because arithmetic average concentration is representative of the concentration that would be contacted at a site over time and toxicity criteria that are used to develop cleanup standards are based on long-term average exposure. The arithmetic average is appropriate regardless of the type of statistical distribution that might best describe the sampling data. We do not use geometric average concentration because the geometric mean of a set of sampling data bears no logical connection to the cumulative intake that would result from long-term contact with site contaminants.

It should be noted that the above hypothesis statements referring to the arithmetic average concentration does not force everyone to use 95% upper

confidence limit (UCL) to infer the true site arithmetic average concentration. Methods other than the 95%UCL, such as tests for percentiles or proportions, also may be used provided that a person can document that high coverage of the true population mean occurs, (*i.e.*, the value used in a method equals or exceeds the true site arithmetic average concentration with high probability).

For the background standard, the null hypothesis (H_o) is that the background standard is achieved and the alternative hypothesis (H_a) is that the background standard is not achieved. The background standard is not risk-based. These hypothesis statements will allow some site concentrations to be higher than some background reference-area measurements without rejecting the null hypothesis. These hypothesis statements are consistent with EPA guidance documents (EPA, ~~1992c~~2009). If we reverse the hypothesis statements and presume that the background standard is not achieved, we would require most site concentrations to be less than the reference measurements in order to declare a site to be clean. In considering the cost of remediation, both the Department and EPA believe that this requirement is unreasonable.

4. Selection of Statistical Methods

a) Factors Affecting the Selection of Statistical Methods

The selection of statistical methods for use in assessing the attainment of cleanup standards depends on the characteristics of the environmental media. In soils, concentrations of contaminants change relatively slowly, with little variation from season to season. In groundwater, the number of measurements available for spatial characterization is limited and seasonal patterns may exist in the data. As a result of these differences, separate procedures are recommended for the differing problems associated with soils and groundwater.

The selection of statistical methods also depends on remediation standards. There are three types of remediation standards under Act 2: background standards, Statewide health standards, and site-specific standards. Background standards are developed using background data. Statewide health standards and many site-specific standards are risk-based standards that are concentration limits based on risk assessment methodologies. At some sites, a site-specific standard could be a technology-based standard, such as capping a site to eliminate pathways. The cap must be designed to meet certain engineering specifications prescribed in numerical levels. A background standard is not a single number but rather a range of numbers. A statistical method used to demonstrate the attainment of the background standard is used to compare the distribution of data for a background reference area to the distribution of data for the impacted area. Different statistical methods are used to demonstrate the attainment of a risk-based concentration limit ~~(a bright line standard)~~.

As a result of the above factors, recommended statistical approaches are addressed separately based on environment media and remediation standards. The flowchart in ~~Figure IV-7~~ Figure III-7 provides a summary of recommended statistical methods described in Act 2 regulations. Since Act 2 also requires the Department to recognize those methods of attainment demonstration generally

recognized as appropriate for a particular remediation, the Department will also accept other appropriate statistical methods that meet the performance standards described in ~~250.707(d)(2)~~250.707(d)(2) of the Act 2 regulations.

Statistical methods generally can be classified into two categories: parametric procedures, and nonparametric procedures. The selection of a parametric or a nonparametric procedure depends on the distribution of the data, the percentage of nondetects, and the database size. However, both procedures have assumptions that must be met to be considered valid analyses.

Parametric Procedure - Assumptions of parametric procedures include a specific data distribution such as normal (also known as Gaussian or the bell-shaped curve) or lognormal (normality achieved by log-transforming the data), and data variances that are similar. In addition, the data are assumed to be independent.

Nonparametric Procedure - Assumptions for nonparametric tests also are important. Nonparametric procedures assume equal variances and that the type (shape) of distribution of the population is the same. In other words, nonparametric methods do not require a specific type of data distribution, which is different from assuming a normal distribution when using parametric statistics.

Nonparametric procedures may be preferred because they:

- are free from normal distribution assumptions thereby eliminating the need for normality tests and data transformations;
- are resistant to effects of outliers; and
- are usable when censored (*i.e.,* less than detection values) data are present.

b) Recommended Statistical Procedures

In consideration of the factors described above, ~~Section 250.707~~Section 250.707 of the Act 2 regulations provides recommended statistical procedures that can be used to demonstrate attainment of cleanup standards. The following discussions provide background information of these recommended methods.

i) Soil risk-based standards

For risk-based standards, the selection of statistical parameters, such as mean, median or an upper percentile, to use in the statistical assessment decision depends on the toxicity criteria. Mean and median are useful for cleanup standards based on carcinogenic or chronic health effects and long-term average exposure. Upper proportion or percentile should be used if the health effects of the contaminant are acute or worst-case effects. Because the Statewide health standards are based on the evaluation of carcinogenic or chronic health effects and long-term average exposure, the Cleanup Standards Scientific Advisory Board (CSSAB) has recommended that mean or median should be the statistical parameter of choice. The Act 2 regulations allow the remediator to use the 75%/10X rule or the 95% upper confidence limit (UCL) of arithmetic mean to demonstrate attainment of the Statewide health standard in soils. For UST

release sites that have only localized (soil) contamination as defined in the storage tank program's Closure Guidance, and where the confirmatory samples taken in accordance with this technical guidance document result in fewer samples being taken than otherwise required [including the sampling procedure for petroleum contaminated soils outlined in Section 250.707(b)(1)(iii)(B)], all sample results must meet the Statewide health standard. For the site-specific standard, the regulations recommend the use of the 95% upper confidence limit (UCL) of the arithmetic mean to demonstrate attainment in soils. ~~Sections 250.707(b) and (c)~~Sections 250.707(b) and (c) of the regulations discuss statistical tests appropriate to demonstrating compliance of surface soils with the Statewide health and site-specific standards.

(a) 75%/10X rule

The 75%/10X rule is a statistical *ad hoc* rule that tests whether the true site median concentration is below the cleanup standard. This rule requires that 75% of the samples collected for demonstration attainment be equal to or below the risk-based cleanup standard and that no single sample result exceeds the risk-based standard by more than ten times (~~See Section 250.707(b)(1)(i)~~ See Section 250.707(b)(1)(i) of the regulations).

For the 75%/10X rule~~-~~, the number of sample points required for each distinct area of contamination is specified in Section ~~250.703(d)~~250.703(d) of the Act 2 regulations and is as follows:

- For soil volumes equal to or less than 125 cubic yards, at least eight (8) samples.
- For soil volumes up to 3,000 cubic yards, at least twelve (12) sample points.
- For each additional volume of up to 3,000 cubic yards, an additional twelve (12) sample points.
- Additional sampling points may be required based on site-specific conditions.

This recommendation of 8 to 12 samples at minimum is based on a simulation study using lognormal distributions (CSSAB 1996). Because the heterogeneity of a volume of soil increases as the volume increases, the number of samples required to accurately demonstrate attainment would also increase.

In a situation where compliance with two different statewide health standard MSCs are required, such as an MSC for surface soil and another MSC for subsurface soil, two separate attainment tests, each applying the 75%/10x rule would be required (0-2 feet and 2-15 feet).

It should be noted that the 75%/10X rule should not be used to demonstrate attainment of site-specific standard. The site-specific standard is based on site-specific risk assessment methodology, including the assumption that a receptor's long-term exposure is related to the true site arithmetic average concentration of

a contaminant. Therefore, the 75%/10X rule is not appropriate for the site-specific standard.

(b) The 95% upper confidence limit (UCL) of arithmetic mean

Using 95%UCL of the arithmetic mean as described in ~~Section 250.707(b)(1)(ii)~~Section 250.707(b)(1)(ii) and ~~250.707(c)~~250.707(c) of the regulations is well documented in various EPA risk assessment or statistical guidances (EPA, ~~1989b,~~ 1989~~c~~, 1992c, 1996, 2002a). The following formula can be used for calculating sample size (number of discrete soil samples) needed to estimate the mean :

$$n_d = \sigma^2\{ (Z_{1-\beta} + Z_{1-\alpha})/(C_s - \mu_1)\}^2$$

where α is the false positive rate; β is the false negative rate; $Z_{1-\alpha}$ and $Z_{1-\beta}$ are the critical values for the normal distribution with probabilities of $1-\alpha$ and $1-\beta$; C_s is the cleanup standard; μ_1 is the value of population mean under the alternative hypothesis for which the specific false negative rate (β) is to be controlled; σ is an estimate of true standard deviation of the population.

Please note that the above equation may generate exceedingly large sample size numbers (*e.g.*, >>50). When some adjustments of the sample size are necessary based on practical and cost considerations, a person may use the equation to generate a smaller sample size by increasing the false negative rate or the detection difference C_s-μ_1. Professional judgment should be used in calculating sample size versus the reliability of the statistical test. The false positive rate must not be greater than 0.20 for a nonresidential site and 0.05 for a residential site [~~Section 250.707(d)(2)(vii)~~Section 250.707(d)(2)(vii)].

Procedures to calculate 95%UCL of arithmetic mean are provided in Sections III~~V~~.B.6~~7~~ and III~~V~~.B.7~~8~~.

The following decision rule is used to determine if a site meets the cleanup standard:

- If 95%UCL of arithmetic mean is greater than or equal to C_s, conclude that the area is ~~dirty~~contaminated.
- If 95%UCL of arithmetic mean is less than C_s, conclude that the area is ~~clean~~uncontaminated.

Note that this rule uses the 95%UCL of the arithmetic mean to estimate the limit of the population mean. The decision rule is consistent with the hypothesis statements.

The primary assumptions of this method are independence of the data, and sample mean is approximately normally distributed or data are lognormally distributed. Examples of normal and lognormal distributions are shown in ~~Figure IV-8~~Figure III-8. When the population is normally distributed, the sample mean is normally distributed, no matter the sample size. However, if the population distribution is unknown, Central Limit Theorem states that the distribution of sample means of random samples with fixed sample size (n) from

a population with an unknown distribution will be approximately normally distributed provided the sample size (n) is large. This means that moderate violation of the assumption of normality for the population is acceptable when sample size is large.

For sample sizes up to 50, EPA recommends to use Shapiro Wilk ~~W~~ test for testing normality (EPA, 2009~~1996~~). Other tests for normality, such as ~~chi-square tes~~Shapiro-Francia test and other goodness-of-fit tests are discussed in ~~Section 4.2 of.~~ EPA's Unified Guidance ~~QA-G9~~ (EPA, 2009~~1996~~). To test the independence of data, ordinary-runs test (Gibbons, 1990) can be used.

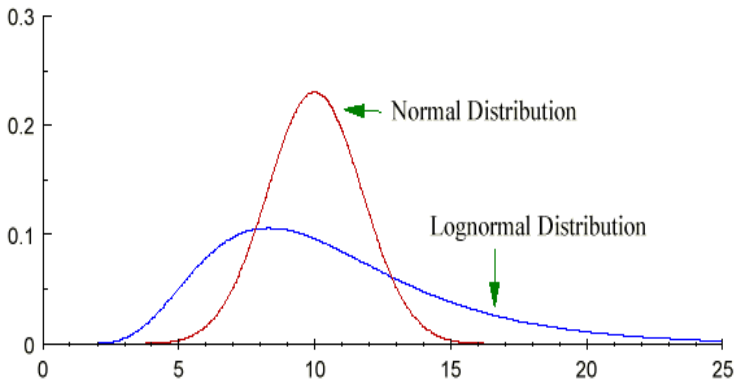


Figure ~~IV~~III-8. Examples of Normal Distribution and Lognormal Distribution

An important consideration regarding the 95%UCL of arithmetic mean is the use of composite sampling approach. Unless composite sampling is considered inappropriate (such as for volatile organic compounds), data from composite sampling can be more cost-efficient to estimate population mean and population variance than from discrete sampling (Edland et al., 1994; Patil et al., 1994). Composite sampling can reduce the laboratory analysis cost. Composite sampling may be considered, if appropriate, to obtain the 95%UCL of arithmetic mean. Equations to calculate the 95%UCL of arithmetic mean for composite sampling are available (Edland et al., 1994; Patil et al., 1994).

(c) no exceedance rule

For cleanup of releases of petroleum products where full site characterization has not been conducted and remediation is guided by visual observation and/or field screening, the no exceedance rule must be used as described in ~~Section 250.707(b)(1)(iii)~~Section 250.707(b)(1)(iii) of the regulations as follows:

For sites where there is localized contamination as defined in the document "Closure Requirements for Underground Storage Tank Systems" (DEP technical

document No. ~~2530-BK-DEP2008~~263-4500-601), samples shall be taken in accordance with that document.

For sites with contamination that does not qualify as localized under that document, samples shall be taken from the bottom and sidewalls of the excavation in a biased fashion that concentrates on areas where any remaining contamination above the Statewide health standard would most likely be found. The samples shall be taken from these suspect areas based on visual observation and the use of field instruments. If a sufficient number of samples has been collected from all suspect locations and the minimum number of samples has not been collected, or if there are no suspect areas, the locations to meet the minimum number of samples shall be based on a random procedure. The number of sample points required shall be determined in the following way:

- For 250 cubic yards or less of excavated contaminated soil, five samples shall be collected.
- For each additional 100 cubic years of excavated contaminated soil, one sample shall be collected.
- For excavation involving more than 1,000 cubic yards of contaminated soil, the Department will approve the confirmatory sampling plan.
- Where water is encountered in the excavation and no obvious contamination is observed or indicated, a minimum of two of the soil samples identified above shall be collected just above the soil/water interface. These samples shall meet the MSC determined by using the saturated soil component of the soil-to-groundwater numeric value.
- Where water is encountered in the excavation and no obvious contamination is observed or indicated, a minimum of two water samples shall also be collected from the water surface in the excavation.

All sample results shall meet the Statewide health standard.

For sites where there is a release to surface soils resulting in excavation of 50 cubic yards or less of contaminated soil, samples shall be collected as described above, except that two samples shall be collected.

ii) Groundwater risk-based standards

Statistical tests appropriate to demonstrating compliance with groundwater standards are presented in ~~Section 250.707(b)(2)~~Section 250.707(b)(2) of the regulations. Groundwater cleanup activities generally include site investigation, groundwater remediation, a post-treatment period allowing the groundwater to stabilize, sampling and analysis to assess attainment, and possible post-cleanup monitoring. Different statistical procedures are applicable at different stages in this cleanup process. The statistical procedures used must account for the changes in the groundwater system over time due to natural or man-induced causes. The specific statistical procedures used depend on the goals and quality of the monitoring data. The methods selected should be consistent with the goals

of the monitoring. For example, a ~~person~~ remediator may want to use regression analysis to decide when to stop treatment of groundwater. Regression analysis can be used to detect trends in contaminant concentration levels over time, to determine variables that influence concentration levels, and to predict chemical concentrations at future points in time. After terminating groundwater treatment, a ~~person~~ remediator may want to use time trend analysis or plotted~~s of~~ data to find if the groundwater has stabilized. After the groundwater has reached a steady state, the ~~person~~ remediator may compare monitoring well concentrations to background reference well concentrations to determine whether the post-cleanup contamination concentrations are acceptable compared to the cleanup standards and may perform trend analysis or use plotted~~s of~~ data to determine whether the post-cleanup contamination concentrations are likely to remain acceptable.

Once the groundwater has stabilized, it is recommended to use the 95% upper confidence limit of the mean (EPA, ~~1992b~~2002a) or the following CSSAB ad hoc rule to compare with groundwater risk-based standards: In monitoring wells beyond the property boundary, the attainment criteria would be 75% of the sampling results from any given well ~~being~~ below the standard with no individual value being more than 2 times the standard (75%/2X rule). This rule would have to be met in each individual monitoring well.

To use the CSSAB ad hoc rule, 8 samples from each compliance well must be obtained during 8 consecutive quarters. Shorter sampling period requires the use of the no exceedance rule (~~Section 250.704(d)(3)~~Section 250.704(d)(3) of the Act 2 regulations) with written approval of the Department.

iii) Soil background standards

The determination of attainment of soil background standards is ~~be~~ based on a comparison of the distributions of the background concentrations of a regulated substance with the concentrations in an impacted area. Section ~~250.707(a)(1)~~250.707(a)(1) of the regulations allows a person to use highest measurement comparison, combination of Wilcoxon Rank Sum test and Quantile test, or other appropriate methods to demonstrate attainment of background standards. No matter which method is used, Act 2 regulations require that the minimum number of samples to be collected is ten from the background reference area and ten from each cleanup unit. This requirement of ten samples is to ensure that any selected statistical test has sufficient power to detect contamination. The regulations do not specify the false negative rate because it is more appropriate to determine the false negative rate on a site-specific basis. For the background standard, the false negative rate is the probability of mistakenly concluding that the site is clean when it is contaminated. It is the probability of making a Type II error.

Background soil sampling locations must be representative of background conditions for the site, including soil type and depth below ground surface. Randomization of sampling at background reference and onsite locations must be comparable. EPA (EPA, 1992c) recommends that samples be collected from

background reference areas and cleanup units based on a random-start equilateral triangular grid. When a triangular grid may miss the pattern of contamination, EPA recommends the use of an unaligned grid (Gilbert, 1987, p.94) to determine the sampling locations.

(a) Wilcoxon rank sum test

This procedure (also known as Mann-Whitney U test) is a nonparametric test for differences between two independent groups. See ~~Chapter 6 of the~~ EPA, 2009 ~~Attainment, Volume 3 (EPA, 1992c)~~, ITRC (2013) and Section ~~250.707(a)(1)(ii)~~250.707(a)(1)(ii) of the regulations.

For the Wilcoxon Rank Sum (WRS) test, the EPA states that Noether's formula may be used for computing the approximate total number of samples to collect from the background reference area and in the cleanup unit (EPA 1992c).

$$N = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{12c(1-c)(Pr-0.5)^2(1-R)} \qquad \text{(Noether's formula)}$$

= total number of required samples.

where

α = specified Type I error rate

β = specified Type II error rate

$Z_{1-\alpha}$ = the value that cuts off (100α)% of the upper tail of the standard normal distribution

$Z_{1-\beta}$ = the value that cuts off (100β)% of the upper tail of the standard normal distribution

c = specified proportion of the total number of required samples, N, that will be collected in the reference area

m = number of samples required in the reference area = c x N

Pr = specified probability greater than 1/2 and less than 1.0 that a measurement of a sample collected at a random location in the cleanup unit is greater than a measurement of a sample collected at a random location in the reference area. This value is specified by the user. See Section 6.2.2 of EPA, 1992c for methods to determine Pr.)

R = expected rate of missing or unusable data

n = number of samples required in the cleanup unit = N - m

The underlying assumptions for Wilcoxon Rank Sum test are random sampling, independence assumption of selecting sampling points, and that the distributions of the two populations are identical in shape and dispersion. The distributions need not to be symmetric. When applied with the Quantile test, the combined tests are most powerful for detecting true differences between two population distributions. When using the combined test, caution should be

exercise to ensure that the underlying assumption of equal variance is met. An appropriate test for dispersion, such as Levene's test can be used. Unequal dispersion of data due to higher concentration of contaminant at the site should be properly addressed.

Procedures and an example of using the Wilcoxon Rank Sum test are in ~~Section IV.B.9~~Section III.B.8.

(b) ~~quantile~~ Quantile test

The Quantile test (Johnson et al. 1987), described in ~~Section 250.707(a)(1)(ii)~~Section 250.707(a)(1)(ii) of the regulations, is performed by first listing the combined reference-area and cleanup-unit measurements from smallest to largest as was done for the Wilcoxon Rank Sum (WRS) test. Then, among the largest r measurements (*i.e.,* r is the number of measurements) of the combined data sets, a count is made of the number of measurements, k, that are from the cleanup unit. If k is sufficiently large, then we conclude that the cleanup unit has not attained the reference-area cleanup standard. The Quantile test is more powerful than the WRS test for detecting when only one or a few small portions of the cleanup unit have concentrations larger than those in the reference area. Also, the Quantile test can be used when a large proportion of the data is below the limit of detection. See Chapter 7 of the EPA attainment guidance (EPA, 1992c). See ProUCL Version 4.0 (2007) for further details.

For Quantile test, EPA recommends to use look-up tables to determine the number of measurements that are needed from the background reference area and the cleanup unit (Section 7.2 of EPA, 1992c).

Procedures and an example of using the Quantile test are in ~~Section IV.B.10~~Section III.B.9. The null hypothesis (H_o) and alternative hypothesis (H_a) statements for the Quantile test are:

H_o: $\varepsilon = 0$, $\Delta/\sigma = 0$

H_a: $\varepsilon > 0$, $\Delta/\sigma > 0$

where

ε = the proportion of the soil in the cleanup unit that has not been remediated to background reference levels

Δ/σ = amount (in units of standard deviation, σ) that the distribution of 100ε% of the measurements in the remediated cleanup unit is shifted to the right (to higher measurements) of the distribution in the background reference area

The underlying assumptions for Quantile test are random sampling, independence assumption of selecting sampling points, and that the distributions of the two populations have the same dispersion (variance). ~~See Chapter 4 of EPA QA/G-9 (EPA, 1996) for methods and examples to verify underlying assumptions.~~

iv) Groundwater background standards

There are two general categories of background conditions. The first is naturally occurring background or area wide contamination, neither of which is expected to exhibit seasonal patterns or trends. The second is background associated with a release of regulated substances at a location upgradient from the site that may be subject to such patterns and trends.

For naturally occurring background or area wide contamination, it is recommended that a minimum of 12 samples be collected from any combination of upgradient monitoring wells, provided that all data collected are used in determination of background concentrations. This same number of samples must then be collected from monitoring wells impacted by a release on the site during the same sampling event. In both cases, this sampling may be accelerated such that all samples ~~be~~are collected as quickly as possible so long as the frequency does not result in serial correlation in the data. The resulting values may be compared using nonparametric or parametric methods to compare the two populations, such as using the combination of Wilcoxon Rank Sum test and Quantile test described previously. When comparing with the background results, the sampling results in the onsite plume should not exceed the sum of the arithmetic average and three times standard deviation calculated for the background reference area [~~Section 250.707(a)(3)(vii)~~Section 250.707(a)(3)(vii)].

For background associated with a release of regulated substances at a location upgradient from a property, the background groundwater concentrations will be determined at the hydrogeological upgradient property line of the property, or a point hydrogeologically upgradient from the upgradient property line that is unaffected by the release.

Attainment of the background standard must be demonstrated wherever the contamination occurs. There may be some mass of a particular contaminant added to groundwater on the property. However, that additional mass cannot result in concentrations which exceed the concentration measured at the property line, nor can it be used to allow releases on the property. Background concentrations are not related to a release at the site (Section 103 of Act 2).

In the event contamination migrates off the property, concentrations at the downgradient property boundary must be equal to or less than the background concentrations measured where groundwater enters the property. If there has been a release on-property, the plume migrating beyond the property boundary must also meet the background standard.

For background associated with an upgradient release of regulated substances, ~~Section 250.707(a)(2)~~Section 250.707(a)(2) of the Act 2 regulations allows the use of the nonparametric tolerance limit procedure. The nonparametric tolerance limit procedure requires at least 8 samples from each well over 8 quarters to have sufficient power to detect contamination. Once the nonparametric upper tolerance limit is established for upgradient data, data from downgradient compliance wells can be compared to the limit. A resampling strategy can be used when an analyte exceeds the nonparametric upper tolerance limit. The well

is retested for the analyte of concern and the value is compared to the nonparametric upper prediction limit. These two-phase testing strategies can be very effective tools for controlling the facility-wide false positive rate while maintaining a high power of detecting contamination. ~~See Sections 5.2.2 and 5.2.3 of the EPA Addendum (EPA, 1992a) which describes the procedures to use along with recommended coverage and confidence levels.~~

5. Additional Information on Statistical Procedures

This section provides an overview regarding various other statistical methods available to use to determine if a cleanup activity is successful. The EPA ~~Interim Final Guidance (EPA, 1989a), EPA~~ Addendum (EPA, 1992a) , ~~EPA Soil Attainment (EPA, 1989b),~~ EPA Groundwater Attainment (EPA, 1992b), EPA Soil Reference-Based Standards Attainment (EPA, 1992c), ~~and~~ EPA QA/G-9 (EPA, 1996), and EPA Unified Guidance (2009) describe and provide examples for both the parametric and nonparametric methods. See additional discussions in Helsel and Hirsch (1992), Conover (1980), Gilbert (1987), and Davis and McNichols (1994, Parts I and II), and ITRC's Groundwater Statistics and Monitoring Compliance (2013).

a) Interval tests

Statistical Intervals - Statistical interval tests can be used independently for comparing with a numerical value or in combination with other tests for comparing populations. Statistical intervals include three main types: tolerance intervals, prediction intervals, and confidence intervals. Which ones are used depend on the goals of the data analysis ~~(see EPA (1992a) Section 4 or Chapters 6 and 7 of EPA (1989b) for procedures)~~.

Tolerance Intervals - Tolerance intervals will typically be the most useful interval test. They are used to determine the extent of data that is within a standard (like an MCL) or ambient level. Parametric tolerance intervals can be computed by assuming a lognormal distribution.

Prediction Intervals - Prediction intervals are used to determine if the next one or more samples are within the existing data distribution at a certain confidence level. The prediction interval contains 100 * (1- α value) percent of the distribution. A smaller α value will include a larger range of data. Prediction intervals are used for intrawell (single well) comparisons, and with comparison of a compliance well with a background well.

Confidence Intervals - Confidence intervals contain a specified parameter of the distribution (such as the mean of the data) at a specified confidence level. Confidence intervals do not address extreme values. The step-by-step procedures to calculate the upper confidence of mean are provided in Sections ~~IV.B.7~~III.B.6 and ~~IV.B.8~~III.B.7.

b) Tests for comparing populations

~~The following tests are outlined in the EPA Interim Final Guidance (EPA, 1989a) and the EPA Addendum (EPA, 1992a).~~ The~~se~~ following tests are some of the

EPA's recommended tests for analysis of groundwater data between upgradient and downgradient well groups, downgradient wells and a health-based standard, or of intrawell (single well) comparisons. This does not include all potentially satisfactory statistical tests.

Analysis of Variance (ANOVA) - ANOVA includes a group of procedures used for comparing the means of multiple (3 or more) independent groups such as upgradient wells and downgradient wells. The ANOVA methods are used to determine if there is statistically significant evidence of contamination at downgradient wells compared to an upgradient well, or groups of wells.

The one-way ANOVA method is described with examples in Section ~~5.2~~17 of the EPA ~~Interim Final~~Unified Guidance (EPA, ~~1989a~~2009). This is the EPA recommended procedure for comparing data that do not violate the assumptions of normal distribution and approximately equal variances.

However, as the number of wells (or groups) increases at a site, the power of ANOVA to detect individual instances of contamination decreases. For this reason, tolerance and prediction intervals with retesting provisions are often much better procedures to use.

Kruskal-Wallis Test - If assumptions of the one-way ANOVA test are "grossly" violated, the nonparametric Kruskal-Wallis test is used for more than 2 independent groups of data. It can be used for comparison of upgradient water quality to water quality from many downgradient wells in one procedure. Alternatively, if the wells are grouped by some characteristic (*e.g.*, depth, geology, location, season), comparisons among other groups can be made.

If the null hypothesis (no change) is rejected by Kruskal-Wallis (*i.e.,* the test statistic exceeds the tabulated critical value), then pairwise comparisons should be made to determine what wells are contaminated (see Gilbert (1987), Section 18.2.2; the EPA Addendum (1992a), Section 3.1; and the EPA ~~Interim Final~~Unified Guidance (~~1989a~~2009), Section ~~5.2~~17.1.2). The underlying assumptions are the distributions of the independent populations are identical in shape (variance), but the distributions need not to be symmetric.

t-test - The t-test is a parametric, ANOVA type of test used to assess differences in means of two independent groups. This test assumes normal distributions and equal variances for both groups. The t-test is best limited to situations where the data sets are too small to use nonparametric procedures. For example, if background water quality is limited to two or three samples, the t-test can be used to test for differences between background and compliance data.

c) Trend tests

Considerations - When monitoring data have been collected over several years or more, trend tests allow the determination of the change in distribution of data over time. In addition to water quality trends, a time series of monitoring data may contain characteristics of seasonality and serial correlation. Other complicating factors include changes in laboratories or procedures involving the sampling and analysis of the analyte.

Seasonality and serial correlation interfere with trend tests either by reducing the power to detect trends or giving erroneous probabilities. Correction for seasonality is available for tests presented here. Serial correlation exists if a data point value is at least partially dependent on nearby data point values. For a given data set, serial correlation decreases with increasing temporal distance between samples. Harris, *et al*. (1987) reported difficulty detecting serial correlation in 10 years or less of quarterly groundwater data. Therefore, correction is not recommended for quarterly data. Serial correlation correction is available for the Seasonal Kendall trend test (Hirsch and Slack, 1984), but has reduced power with small data sets and is not recommended for a monthly time series that is less than 5 years.

Parametric Trend Tests - Parametric trend tests are based on regression methods and allow compensation for exogenous effects (outside influences). Regression analysis between two variables can be used to calculate the correlation coefficient (r). The closer r is to one, the closer the relationship is between the two variables. A t-test of correlation can be done on r to see if it is significant (see Davis, 1987, Chapter 2 ; ~~EPA, 1992a, Chapter 6;~~ EPA, 1996, Section 4.3.2; EPA, 2009).

Mixed (*i.e.*, parametric and nonparametric methods) methods also are available when removing the effects of exogenous variables. Helsel and Hirsch (1992) present a thorough review of trend analysis. Methods for detecting trends also are presented in Chapter 16 of Gilbert (1987).

Because regression techniques are based on the assumption of a normal distribution of the data, a nonparametric approach may have to be used.

Nonparametric Trend Tests - The Mann-Kendall trend test is a nonparametric test for monotonic (steadily upward or downward) trend. (Gilbert, 1987; Section 4.3.4 of EPA, 1996; Section 17.3.2 of EPA, 2009).

This test requires constant variance in data. Non-constant variance may be changed to constant variance with a power transformation. Logarithm transformation is usually most appropriate. This transformation does not affect the test statistic. Decision rules, exact test tables, normal approximation formulas, and correction for ties can be found in Helsel and Hirsch (1992); Gilbert (1987) and many introductory statistics texts. When a trend is present, the slope of fitted line can be estimated using Sen's estimator (see Gilbert, 1987; Section 4.3.3 of EPA, 1996; Section 17.3.3 of EPA, 2009).

The Seasonal Kendall trend test is a seasonally corrected Mann-Kendall trend test. This should be applied when time series graphs or boxplots of data indicate the presence of seasonal variation. See Chapter 17 of Gilbert (1987).

The following sections present the methodology of several statistical tests which may be utilized in the course of demonstrating attainment of an Act 2 standard. Again, it is worthwhile to note that statistical computer software, such as EPA's ProUCL, has been developed to perform these tests.

6. Calculation of UCL of Mean When the Distribution of the Sampling Mean is Normal

The following is a step-by-step description of the approach used to calculate confidence limits of an arithmetic mean when the distribution of the sampling mean is normal. For data sets of lognormal distribution, the approach in ~~Section IV.B.8~~Section III.B.7 should be used instead.

1. Calculate the sample mean by dividing the sum of the total readings by the total number of readings:

$$\overline{X} = (X_1 + X_2 + ...Xn)/n$$

2. Calculate the sample variance (Sb^2) by taking the sum of the squares of each reading minus the mean and dividing by the degrees of freedom (df, the total number of samples minus one):

$$Sb^2 = [(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + ...+(Xn-\overline{X})^2]/(n-1)$$

3. Calculate the standard deviation (Sb) by taking the square root of the variance (Sb^2):

$$Sb = \sqrt{(Sb^2)}$$

4. Calculate the standard error of the mean (Sx). Standard error is inversely proportional to the square root of the number of samples (increasing n from 4 to 16 reduces Sx by 50%) where Sx equals $Sb/\sqrt{n}$. [Note: The above procedure is for simple random samples. For systematic sampling, the calculation of standard error should follow instructions in Section 6.5 of EPA soil attainment guidance (EPA, 1989b). For multiple systematic sampling, the equation to calculate unbiased estimate of variance is also available (Gilbert, 1987, p. 97).]

5. Since the concern is only whether the upper limit of a confidence interval is below or above the Act 2 regulatory threshold (RT), the lower confidence limit (LCL) need not be considered. The upper confidence limit (UCL) can be calculated using the one-tailed (one-sided) t values with n-1 degrees of freedom (df) derived from a table of the student's t distribution, $t_{1-\alpha,n-1}$ (~~Table IV -5~~Table III -5).

6. The 95% UCL (α=0.05; one-sided) is calculated by using the following formula and substituting the values determined above plus the appropriate t value obtained from the student's t table where UCL equals $\overline{X} + t_{1-\alpha,n-1} * Sx$.

The UCL number resulting from this formula will indicate with a 95% probability that it is either above or below the Act 2 regulatory threshold (RT) developed for the regulated substance subjected to the test.

7. Calculation of UCL of Mean of a Lognormal Distribution

Following is a step-by-step description of the approach used to calculate confidence limits of an arithmetic mean when the distribution of the data set is lognormal. This method is used in risk assessment by EPA (EPA, 1992d).

1. Transform all sample data Xi to Yi (i = 1,2,….n) using the natural logarithm function:

$$Yi = \ln Xi$$

2. Calculate the arithmetic mean of transformed data by dividing the sum of the transformed data by the total number of data:

$$\overline{Y} = (Y_1 + Y_2 + ...Yn)/n$$

3. Calculate the variance (Sy^2) of transformed data by taking the sum of the squares of each data minus the mean and dividing by the degrees of freedom (df, the total number of samples minus one):

$$Sy^2 = [(Y_1 - \overline{Y})^2 + (Y_2 - \overline{Y})^2 + ...+(Yn-\overline{Y})^2]/(n-1)$$

4. Calculate the standard deviation (Sy) by taking the square root of the variance (Sy^2):

$$Sy = \sqrt{(Sy^2)}$$

5. Since the concern is only whether the upper limit of a confidence interval is below or above the Act 2 regulatory threshold (RT), the lower confidence limit (LCL) need not be considered. The upper confidence limit (UCL) can be calculated using the one-tailed (one-sided) $H_{1-\alpha}$ values associated with sample size n from the table of $H_{1-\alpha}$ for computing a one-sided upper 95% confidence limit on a lognormal mean.

6. The 95% UCL (α=0.05; one-sided) is calculated by using the following formula and substituting the values determined above plus the appropriate $H_{1-\alpha}$ value obtained from the table of $H_{1-\alpha}$ where UCL equals

$$\exp\left(\overline{Y} + 0.5*Sy^2 + Sy*H_{1-\alpha}/\sqrt{n-1}\right).$$

The UCL number resulting from this formula will indicate with a 95% probability that it is either above or below the Act 2 regulatory threshold (RT) developed for the regulated substance subjected to the test.

Note: The $H_{1-\alpha}$ tables can be found in "Selected Tables in Mathematical Statistics, Volume III, American Mathematical Society," pp. 385-419, C. E. Land, 1975. A subset of Land's tables also can be found in "Statistical Methods for Environmental Pollution Monitoring," Tables A10-A13, R. O. Gilbert, 1987. The value of $H_{1-\alpha}$ depends on Sy, n, and the confidence level α. If $H_{1-\alpha}$ is required for values of Sy and n not given in the tables, Land (1975) indicated that four-point Lagrangian interpolation appeared to be adequate with these tables.

The equation used in four-point Lagrangian interpolation is:

$$y = f(x) = \frac{y_1(x-x_2)(x-x_3)(x-x_4)}{(x_1-x_2)(x_1-x_3)(x_1-x_4)} + \frac{(x-x_1)y_2(x-x_3)(x-x_4)}{(x_2-x_1)(x_2-x_3)(x_2-x_4)}$$
$$+ \frac{(x-x_1)(x-x_2)y_3(x-x_4)}{(x_3-x_1)(x_3-x_2)(x_3-x_4)} + \frac{(x-x_1)(x-x_2)(x-x_3)y_4}{(x_4-x_1)(x_4-x_2)(x_4-x_3)}$$

where $y_1 = f(x_1)$

$y_2 = f(x_2)$

$y_3 = f(x_3)$

$y_4 = f(x_4)$

The interpolation procedure may include four interpolation steps which are performed along the columns of the table and one interpolation step performed along the rows of the table. The following example illustrates the procedure to apply the four-point Lagrangian interpolation:

$H_{1-\alpha}$	Sample Size, n			
Table	3	5	7	10
0.1	2.750	2.035	1.886	1.802
0.2	3.295	2.198	1.992	1.881
Sy 0.3	4.109	2.402	2.125	1.977
0.4	5.220	2.651	2.282	2.089

The above table only provides values for sample sizes of 3, 5, 7, and 10, and Sy values of 0.1, 0.2, 0.3 and 0.4. To interpolate a value for a sample size of 6 and an Sy value of 0.25, the first step is to interpolate a value corresponding to an Sy of 0.25 and a sample size of 3 using the four-point Lagrangian interpolation equation, where

$x = 0.25$

$x_1 = 0.10 \quad y_1 = 2.750$

$x_2 = 0.20 \quad y_2 = 3.295$

$x_3 = 0.30 \quad y_3 = 4.109$

$x_4 = 0.40 \quad y_4 = 5.220$

The result of this interpolation step is $y = f(0.25) = 3.667$.

The second step is to interpolate a value corresponding to Sy of 0.25 and a sample size of 5 using the four-point Lagrangian interpolation equation, where

$x = 0.25$

$x_1 = 0.10 \quad y_1 = 2.035$

$x_2 = 0.20 \quad y_2 = 2.198$

$x_3 = 0.30 \quad y_3 = 2.402$

$x_4 = 0.40 \quad y_4 = 2.651$

The result of this interpolation step is $y = f(0.25) = 2.295$.

The third step is to interpolate a value corresponding to an Sy of 0.25 and a sample size of 7 using the four-point Lagrangian interpolation equation, where

$x = 0.25$

$x_1 = 0.10 \quad y_1 = 1.886$

$x_2 = 0.20 \quad y_2 = 1.992$

$x_3 = 0.30 \quad y_3 = 2.125$

$x_4 = 0.40 \quad y_4 = 2.282$

The result of this interpolation step is $y = f(0.25) = 2.055$.

The fourth step is to interpolate a value corresponding to an Sy of 0.25 and a sample size of 10 using the four-point Lagrangian interpolation equation, where

$x = 0.25$

$x_1 = 0.10 \quad y_1 = 1.802$

$x_2 = 0.20 \quad y_2 = 1.881$

$x_3 = 0.30 \quad y_3 = 1.977$

$x_4 = 0.40 \quad y_4 = 2.089$

The result of this interpolation step is $y = f(0.25) = 1.927$.

The last step is using the results obtained from steps 1 - 4 to perform another four-point Lagrangian interpolation to generate a value corresponding to an Sy of 0.25 and a sample size of 6, where

$x = 6$

$x_1 = 3 \quad y_1 = 3.667$

$x_2 = 5 \quad y_2 = 2.295$

$x_3 = 7 \quad y_3 = 2.055$

$x_4 = 10 \quad y_4 = 1.927$

The resulted interpolation value is 2.087.

8. Procedure and Example for Conducting the Wilcoxon Rank Sum Test

Procedure

For each cleanup unit and pollution parameter, use the following procedure to compute the WRS test statistic and to determine on the basis of that statistic if the cleanup unit being compared with the background reference area has attained the background standard.

1. Collect the m samples in the reference area and the n samples in the cleanup unit (m + n = N).

2. Measure each of the N samples for the pollution parameter of interest.

3. Consider all N data as one data set. Rank the N data from 1 to N; that is, assign the rank 1 to the smallest datum, the rank 2 to the next smallest datum,..., and the rank N to the largest datum.

4. If several data are tied, *i.e.*, have the same value, assign them the midrank, that is, the average of the ranks that would otherwise be assigned to those data.

5. If some of the reference-area and/or cleanup-unit data are less-than data (*i.e.*, data less than the limit of detection) consider these less-than data to be tied at a value less than the smallest measured (detected) value in the combined data set. Assign the midrank for the group of less-than data to each less-than datum. For example, if there were 10 less-than data among the background reference and cleanup-unit measurements, they would each receive the rank 5.5, which is the average of the ranks from 1 to 10. The assumption that all less-than measurements are less than the smallest detected measurement should not be made lightly because it may not be true for some pollution parameters, as pointed out by Lambert et al. (1991). However, the development of statistical testing procedures to handle this situation are beyond the scope of this document.

The above procedure is applicable when all measurements have the same limit of detection. When there are multiple limits of detection, the adjustments given in Millard and Deveral (1988) may be used.

Do not compute the WRS test if more than 40% of either the reference-area or cleanup unit measurements are less-than values. However, still conduct the Quantile test.

6. Sum the ranks of the n samples from the cleanup unit. Denote this sum by Wrs.

7. If both m and n are less than or equal to 10 and no ties are present, conduct the test of H_o (cleanup standard attained, Pr = 1/2) versus H_a (cleanup standard not attained, Pr > 1/2) by comparing Wrs to the appropriate critical value in Table A.5 in Hollander and Wolfe (1973). Then go to Step 12 below.

8. If both m and n are greater than 10, go to Step 9. If m is less than 10 and n is greater than 10, or if n is less than 10 and m is greater than 10, or if both m and n are less than or equal to 10 and ties are present, then consult a statistician to generate the required tables.

9. If both m and n are greater than 10 and ties are not present, compute Equation A3-1 and go to Step 11.

$$Zrs = \frac{Wrs - n(N+1)/2}{\sqrt{mn(N+1)/12}} \quad \text{(A3-1)}$$

10. If both m and n are greater than 10 and ties are present, compute

$$Zrs = \frac{Wrs - n(N+1)/2}{\sqrt{(nm/12)\left[N+1-\sum_{j=1}^{g} t_j\left(t_j^{\,2}-1\right)/\left(N(N-1)\right)\right]}} \quad \text{(A3-2)}$$

where g is the number of tied groups and t_j is the number of tied measurements in the jth group.

11. Reject H_o (cleanup standard attained) and accept H_a (cleanup standard not attained) if Zrs (from Equation A3-1 or A3-2, whichever was used) is greater than or equal to $Z_{1-\alpha}$, where $Z_{1-\alpha}$ is the value that cuts off $100\alpha\%$ of the upper tail of the standard normal distribution.

12. If H_o is not rejected, conduct the Quantile test.

EXAMPLE

TESTING PROCEDURE FOR THE WILCOXON RANK SUM TEST

1. Suppose that the number of samples was determined using the following specification:

β = specified Type II error rate = 0.30

α = specified Type I error rate = 0.05

c = specified proportion of the total number of required samples, N, that will be collected in the reference area = 0.50

Pr = specified probability greater than 1/2 and less than 1.0 that a measurement of a sample collected at a random location in the cleanup unit is greater than a measurement of a sample collected at a random location in the reference area = 0.75

R = expected rate of missing or unusable data = 0.10
For these specifications we found that m = n = 14 based on Noether's formula.

2. Rank the reference-area and cleanup-unit measurements from 1 to 28, arranging the data and their ranks as illustrated. Measurements below the limit of detection are denoted by ND and assumed to be less than the smallest value reported for the combined data sets. The data are lead measurements (mg/kg).

3. The sum of the ranks of the cleanup unit is

$$Wrs = 3 + 7 + \ldots + 27 + 28 = 272.$$

4. Compute Zrs using Equation A3-2 because ties are present. There are t = 5 tied values for the g = 1 group of ties (ND values). We obtained:

$$Zrs = \frac{272 - 14(28+1)/2}{\sqrt{(14*14/12)\left[28+1-5(5*5-1)/(28(28-1))\right]}}$$

$$= \frac{69}{21.704} = 3.18$$

5. From the table of z (~~Table IV-6~~Table III-6) we find that $Z_{1-\alpha} = 1.645$ for α = 0.05 (α = 0.05, the Type I error rate for the test, was specified in Step 1 above). Since 3.18 > 1.645, we reject the null hypothesis H_o: Pr = 1/2 and accept the alternative hypothesis Ha: Pr > 1/2.

6. Conclusion:
The cleanup unit does not attain the cleanup standard of Pr = 1/2. This test result occurred because most of the small ranks were for the reference area and most of the large ranks were for the cleanup unit. Hence, Wrs was large enough for H_o to be rejected.

Example - Wilcoxon Rank Sum Test

Reference Area		Cleanup Unit	
Data	**Rank**	**Data**	**Rank**
ND	3		
ND	3	ND	3
ND	3		
ND	3		
39	6		
		48	7
49	8		
		51	9
53	10		
59	11		
61	12		
65	13		
67	14		
70	15		
72	16		
75	17		
		80	18
		82	19
		89	20
		100	21
		150	22
		164	23
		193	24
		208	25
		257	26
		265	27
		705	28
		Wrs = 272	

9. Procedure and Example for Conducting the Quantile Test

Table Look-Up Procedure

A simple table look-up procedure for conducting the Quantile test when m and n are specified *a priori* is given in this section. It is assumed that m and n representative measurements have been obtained from the reference area and the cleanup unit, respectively. The procedure in this section is approximate because the Type I error rate, α, of the test may not be exactly what is required. However, the difference between the actual and required levels will usually be small. Moreover, the exact α level may be computed.

The testing procedure is as follows:

1. Specify the required Type I error rate, α. The available options in this document are α equal to 0.01, 0.025, 0.05 and 0.10.
2. Turn to Table A.6, A.7, A.8, or A.9 in Appendix A of EPA 1992 guidance document (EPA, 1992c) if α is 0.01, 0.025, 0.05, or 0.10, respectively.
3. Enter the selected table with m and n (the number of reference-area and cleanup-unit measurements, respectively) to find
   - values of r and k needed for the Quantile test.
   - actual α level for the test for these values of r and k (the actual α may differ slightly from the required α level in Step 1)
4. If the table has no values of r and k for the values of m and n, enter the table at the closest tabled values of m and n. In that case, the α level in the table will apply to the tabled values of m and n, not the actual values of m and n. However, the α level for the actual m and n can be computed using the following equations:

$$\alpha = \frac{\sum_{i=k}^{r}\left(\frac{m+n-r}{n-i}\right)\left(\frac{r}{i}\right)}{\left(\frac{m+n}{n}\right)} \qquad \text{(A4-1)}$$

where $\left(\frac{a}{b}\right) \equiv \frac{a!}{b!(a-b)!}$

and $a! = a*(a-1)*(a-2)*.....*3*2*1$

5. Order from smallest to largest the combined m + n = N reference-area and cleanup-unit measurements for the pollution parameter. If measurements less than the limit of detection are present in either data set, assume that their values are less than the rth largest measured value in the combined data set of N measurements (counting down from the maximum measurement). If fewer than r measurements are greater than the limit of detection, then the Quantile test cannot be performed.
6. If the rth largest measurement (counting down from the maximum measurement) is among a group of tied (equal-in-value) measurements, then increase r to include that entire set of tied measurements. Also increase k by the same amount. For example, suppose from Step 3 we have r = 6 and k = 6. Suppose the 5th through 8th largest measurements (counting down from the maximum measurement) have the same value. Then we would increase both r and k from 6 to 8.
7. Count the number, k, of measurements from the cleanup unit that are among the r largest measurements of the ordered N measurements, where r and k were determined in Step 3 (or Step 6 if the rth largest measurement is among a group of tied measurements).

8. If the observed k (from Step 7) is greater than or equal to the tabled value of k, then reject H_o and conclude that the cleanup unit has not attained the reference area cleanup standard ($\varepsilon = 0$ and $\Delta/\sigma = 0$).
9. If H_o is not rejected, then do the WRS test. If the WRS test indicates the H_o should be rejected, then additional remedial action may be necessary.

EXAMPLE

TABLE LOOK-UP TESTING PROCEDURE FOR THE QUANTILE TEST

1. We illustrate the Quantile test using the measurements listed in the example of ~~Section IV.B.9~~Section III.B.8. There are 14 measurements in both the reference area and the cleanup unit. Suppose we specify $\alpha = 0.05$ for this Quantile test.
2. Turn to Table A.8 in EPA 1992 guidance (EPA, 1992c; because the table is for $\alpha = 0.05$). We see that there are no entries in that table for m = n = 14. Hence, we enter the table with n = m = 15, the values closest to 14. For n = m = 15 we find r = 4 and k = 4. Hence, the test consists of rejecting the H_o if all 4 of the 4 largest measurements among the 28 measurements are from the cleanup unit.
3. The N = 28 largest measurements are ordered from smallest to largest in the Example of Section ~~IV.B.9~~III.B.8.
4. From the Example of Section ~~IV.B.9~~III.B.8, we see that all 4 of the r = 4 largest measurements are from the cleanup unit. That is, k = 4.
5. Conclusion:

   Because k = 4, we reject the H_o and conclude that the cleanup unit has not attained the cleanup standard of $\varepsilon = 0$ and $\Delta/\sigma = 0$. The Type I error level of this test is approximately 0.05.

Note: The exact Type I error level, α, for this test is not given in Table A.8 in EPA 1992 guidance (EPA, 1992c) because the table does not provide r, k, and α for m = n = 14. However, the exact α level can be computed using Equation (A4-1).

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Table ~~IV~~III-4. Random Number Table

67	35	39	82	14	21	81	21	96	81	65	41	49	04	80	38	34	13	03	15	96	42	55	62	54
43	25	59	81	92	29	54	98	87	58	77	38	02	09	27	06	83	23	00	90	63	39	04	52	72
93	16	47	22	58	33	01	43	61	70	10	55	75	64	68	40	17	24	98	10	53	93	00	31	43
76	77	01	14	64	62	38	18	48	04	77	42	32	38	34	34	34	91	42	14	98	51	98	29	05
69	46	32	94	85	32	27	87	78	37	73	39	25	48	92	91	57	68	52	55	11	08	99	13	55
79	92	47	00	30	13	95	52	30	16	41	45	60	80	42	90	05	38	89	84	04	33	13	21	72
84	35	41	19	11	63	65	09	06	44	43	71	87	58	78	95	27	91	41	54	10	42	38	55	83
18	57	74	64	75	42	79	88	46	32	90	31	29	09	90	07	59	89	22	74	50	05	90	43	37
14	18	29	77	76	54	35	67	41	92	09	28	91	97	68	05	60	09	22	47	04	96	99	06	24
49	02	18	20	81	94	15	81	23	52	28	84	83	75	19	13	55	96	13	70	49	79	66	85	27
49	44	95	16	39	39	13	83	99	97	38	48	63	01	40	03	95	68	71	39	36	99	24	29	55
62	07	74	32	26	41	64	83	37	57	55	37	51	98	24	99	16	02	88	85	13	65	61	81	59
75	35	06	72	07	45	22	98	59	25	90	22	41	03	96	33	89	33	58	78	01	32	36	92	82
12	50	08	09	64	33	54	62	98	24	41	72	97	33	34	11	73	67	33	79	95	62	31	23	87
16	95	18	38	50	33	78	48	00	83	01	43	77	97	26	74	84	53	05	49	29	75	77	02	32
76	23	56	61	20	15	68	82	18	28	35	82	40	18	40	31	78	53	98	45	21	87	21	31	95
74	26	53	14	97	14	09	11	22	65	74	81	52	44	80	03	86	84	78	02	55	45	90	71	49
93	69	54	96	15	66	92	23	22	51	38	42	26	71	37	01	70	87	82	47	97	83	49	24	10
85	99	75	39	81	83	56	56	87	09	32	47	40	14	72	95	74	21	08	69	47	94	65	84	88
86	43	28	23	92	54	05	55	03	89	12	57	75	16	83	36	93	99	23	59	67	24	69	74	30
22	91	19	64	96	84	66	44	09	48	80	12	65	25	43	76	36	68	27	47	52	35	61	03	33
65	82	01	56	34	08	22	38	56	21	68	55	13	18	97	45	90	91	27	25	92	06	69	84	31
51	41	63	38	07	27	96	11	21	06	24	45	33	45	37	44	40	67	80	81	39	80	77	98	43
97	80	96	04	25	30	36	44	40	25	84	23	42	79	14	41	11	64	23	14	38	29	48	18	65
89	63	32	14	59	33	78	24	52	88	02	79	97	35	74	67	96	31	61	18	00	44	59	88	88
54	14	28	53	79	48	05	74	00	98	15	74	72	91	47	45	90	66	55	38	99	60	85	09	01
77	14	06	84	47	46	88	91	03	36	75	64	77	72	11	96	46	87	33	07	29	48	37	86	66
67	33	09	75	00	76	85	28	80	71	36	29	40	32	52	52	72	89	43	05	89	50	25	84	26
75	48	93	50	88	27	76	21	90	66	48	55	88	37	76	57	00	14	83	60	67	20	35	37	18
75	86	22	20	23	27	17	67	16	38	16	33	28	72	13	47	84	57	36	12	75	86	75	23	51
40	41	19	44	32	22	13	31	25	77	28	93	89	37	04	52	71	49	87	72	32	30	69	94	36
70	94	88	25	57	99	94	82	56	91	38	22	09	52	01	84	00	60	04	91	53	10	10	51	94
42	06	41	49	47	44	71	23	61	25	64	16	16	04	48	20	65	84	89	71	43	89	73	79	80
90	55	23	36	61	93	34	69	43	83	38	03	93	00	03	13	04	77	54	90	61	26	88	01	26
22	71	21	14	59	41	29	51	06	96	62	92	63	96	16	62	48	56	86	21	16	58	33	07	41
65	63	59	60	55	36	77	10	63	48	11	60	55	27	52	73	11	95	03	79	46	12	07	26	52
74	20	65	77	78	83	37	34	09	07	47	57	86	13	47	91	17	32	50	29	72	25	87	96	71
12	16	90	59	89	14	66	72	99	45	88	86	45	48	35	26	30	34	73	46	78	29	91	46	44
52	14	41	65	84	73	55	53	00	76	43	83	09	28	13	82	07	62	72	74	60	34	43	69	26
19	87	80	56	89	83	28	45	99	87	37	02	53	39	74	08	91	23	30	13	59	59	10	57	10
29	13	62	89	16	81	78	54	60	92	31	01	04	83	60	16	42	66	81	37	42	39	74	64	40
37	30	72	00	39	53	83	30	75	48	44	30	38	98	76	94	55	60	35	12	22	82	36	18	48
66	17	13	28	82	64	10	76	67	69	53	39	05	71	22	35	13	39	97	27	48	26	94	74	53
86	41	73	49	70	03	41	05	77	28	37	71	01	30	86	36	42	65	97	78	09	34	36	56	01
56	52	43	82	45	20	20	45	49	83	52	73	63	70	47	89	93	77	32	26	73	70	50	75	10
17	89	69	72	84	80	48	78	32	51	66	12	29	79	90	25	11	33	37	44	25	47	18	40	74
11	29	91	99	26	43	90	15	09	64	20	54	89	91	59	01	93	40	33	04	46	91	86	33	90
96	68	63	61	19	29	71	05	42	14	05	84	10	36	27	60	49	40	84	92	29	23	10	45	05
29	12	44	07	75	41	74	25	36	05	49	36	50	27	64	37	51	92	47	32	05	02	21	20	71
79	00	54	24	24	32	03	96	86	98	90	65	41	87	39	29	39	75	07	20	14	94	28	87	23

EXAMPLE

USING THE RANDOM NUMBER TABLE (~~TABLE IV-4~~TABLE III-4)

Say, we need to select 10 random numbers with four digits between 0000 and 6000. We need to select a starting point on the table and a path to be followed. The common way to locate a starting point is to look away and arbitrarily point to a starting point. Suppose the number we located this way was 3848. (It is located in the upper left corner of the block that is in the third large block from the left and the third large block down.) From here we will proceed down the column, then go to the top of the next set of columns, if necessary. The first selected number is 3848. Proceeding down the column, we find 5537 next. This is the second selected number. The number 9022 is next. This number is discarded. Continue down this column, the selected 10 random numbers will be 3848, 5537, 4172, 0143, 3582, 3842, 3247, 1257, 2445, and 0279. (The numbers 9022, 7481, 8012, 6855 and 8423 were discarded because they are greater than 6000.)

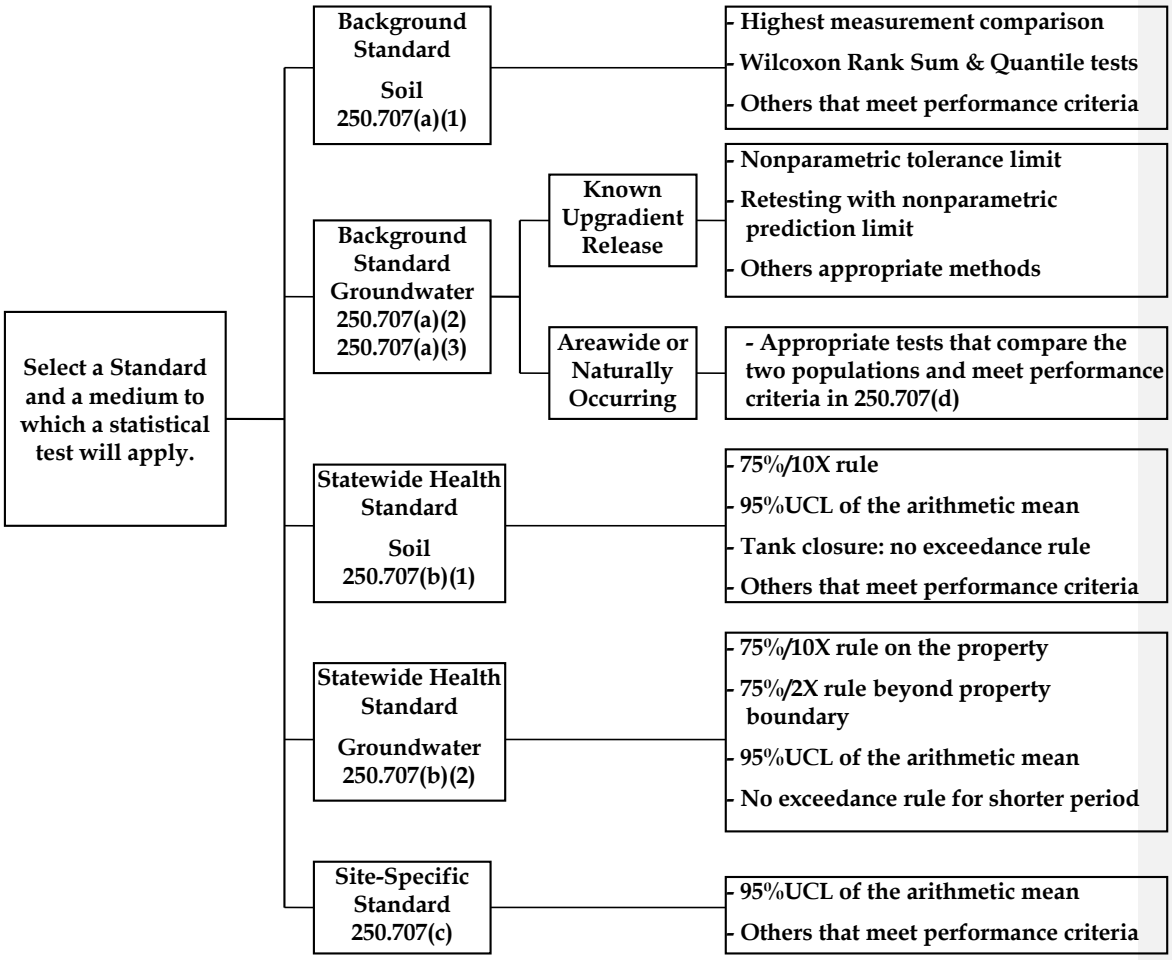
Table ~~IV~~III-5. Student's t-Distribution for Selected Alpha and Degrees of Freedom

	α for determining $t_{1-a,n-1}$							
one-tailed	0.450	0.250	0.200	0.100	0.050	0.025	0.010	0.005
	α for determining $t_{1-a/2,n-1}$							
two-tailed	0.900	0.500	0.400	0.200	0.100	0.050	0.020	0.010
1	0.158	1.000	1.376	3.078	6.314	12.706	31.821	63.657
2	0.142	0.816	1.061	1.886	2.920	4.303	6.925	9.925
3	0.137	0.765	0.978	1.638	2.353	3.182	4.541	5.841
4	0.134	0.741	0.941	1.533	2.132	2.776	3.747	4.604
5	0.132	0.727	0.920	1.476	2.015	2.571	3.365	4.032
6	0.131	0.718	0.906	1.440	1.943	2.447	3.143	3.707
7	0.130	0.711	0.896	1.415	1.895	2.365	2.998	3.499
8	0.130	0.706	0.889	1.397	1.860	2.306	2.896	3.355
9	0.129	0.703	0.883	1.383	1.833	2.262	2.821	3.250
10	0.129	0.700	0.879	1.372	1.812	2.228	2.764	3.169
11	0.129	0.697	0.876	1.363	1.796	2.201	2.718	3.106
12	0.128	0.695	0.873	1.356	1.782	2.179	2.681	3.055
13	0.128	0.694	0.870	1.350	1.771	2.160	2.650	3.012
14	0.128	0.692	0.868	1.345	1.761	2.145	2.624	2.977
15	0.128	0.691	0.866	1.341	1.753	2.131	2.602	2.947
16	0.128	0.690	0.865	1.337	1.746	2.120	2.583	2.921
17	0.128	0.689	0.863	1.333	1.740	2.110	2.567	2.898
18	0.127	0.688	0.862	1.330	1.734	2.101	2.552	2.878
df 19	0.127	0.688	0.861	1.328	1.729	2.093	2.539	2.861
20	0.127	0.687	0.860	1.325	1.725	2.0S6	2.528	2.845
21	0.127	0.686	0.859	1.323	1.721	2.080	2.518	2.831
22	0.127	0.686	0.858	1.321	1.717	2.074	2.508	2.819
23	0.127	0.685	0.858	1.319	1.714	2.069	2.500	2.807
24	0.127	0.685	0.857	1.318	1.711	2.064	2.492	2.797
25	0.127	0.684	0.856	1.316	1.708	2.060	2.485	2.787
26	0.127	0.684	0.856	1.315	1.706	2.056	2.479	2.779
27	0.127	0.684	0.855	1.314	1.703	2.052	2.473	2.771
28	0.127	0.683	0.855	1.313	1.701	2.048	2.467	2.763
29	0.127	0.683	0.854	1.311	1.699	2.045	2.462	2.756
30	0.127	0.683	0.854	1.310	1.697	2.042	2.457	2.750
40	0.126	0.681	0.851	1.303	1.684	2.021	2.423	2.704
60	0.126	0.679	0.848	1.296	1.671	2.000	2.390	2.660
120	0.126	0.677	0.845	1.289	1.658	1.980	2.358	2.617
∞	0.126	0.674	0.842	1.282	1.645	1.960	2.326	2.576

Table ~~IV~~III-6 Table of z for Selected Alpha

α	$Z_{1-\alpha}$
0.450	0.124
0.400	0.253
0.350	0.385
0.300	0.524
0.250	0.674
0.200	0.842
0.100	1.282
0.050	1.645
0.025	1.960
0.010	2.326
0.0050	2.576
0.0025	2.807
0.0010	3.090

Figure ~~IV~~III-7. Flow Chart of Recommended Statistical Methods



C. Mass Calculations

The following sections demonstrate methods to calculate groundwater and soil mass utilizing site specific measurements of contaminants and volume of the specific soil or liquid plumes.

1. Groundwater Mass Calculation

Calculate Water Volume (WV)

Water Volume(WV-ft^3) = Length of plume(L) x Average Thickness of plume(H) x Average Width of plume(W) x porosity(n)

Calculate Water Mass (WM)

Water Mass(WM-lb.) = Water Volume(WV-ft^3) x 62.5 lb./ft^3

Calculate Mass of Contaminant

Water Mass(WM-lb.) x Contaminant Concentration(C-ppm)/ 10^6 = Contaminant Mass(lb.)

2. Soil Mass Calculation

These soil mass calculations provide a way of quantifying contaminants in soil that under an Act 2 remediation would track the estimations of the mass of contaminants removed from public exposure as a measure of program success. Contaminants removed from public exposure can be any one or a combination of excavation & disposal, treatment or pathway elimination measures. The mass calculations would not include areas of the site where site characterization found concentrations to be at or below the applicable standard. This area remains unchanged and thus there is no reduction in exposure as part of the remediation.

$M(x) = D_{(soil)} \times V_{(total)} \times C_{ave.}(x)$

Where:

M(x) = The mass of a specific contaminant in soil (lb)

$D_{(soil)}$ = Density of soil, assume to be a default value of 110 lb/ft^3

$V_{(total)}$ = Volume based on the soil site characterization data with respect to the horizontal and vertical depth of the soil samples collected in areas above the applicable standard. The -volume sum of the each plot would equate to the total volume.

$C_{ave.}$ (x) = The soil contaminant concentration would be the arithmetic mean concentration of the contaminant throughout the soil column. This is the free and absorbed phase of the soil contaminant in areas above the applicable standard and expressed in $lb_{comtaminant}/lb_{soil}$ (ppmw = ppm/10^6).

D. Long Term Stewardship

1. Introduction

Long-Term Stewardship is generally accepted as the establishment and maintenance of physical and non-physical controls that are necessary to maintain the effectiveness of an approved remedy at cleanup sites where remaining regulated substances do not allow for the unrestricted use of the property. It also includes any lifetime responsibilities (e.g., sampling, operation and maintenance, etc.) that ensure the effectiveness of the remedy after completion of the response action.

This section provides general guidelines on the methodology of ~~postremediation care and the~~long term stewardship which includes the use of a postremediation care plan. The plan shall be submitted as part of the final report and approved by the Department. The approved postremediation care plan will become a condition of attainment of the chosen standard(s) under Act 2. The plan shall identify the activities that will be conducted after closure and the frequency of those activities.

Answer the questions from the matrix in ~~Table IV-7~~Table III-7, relative to your chosen standard(s), to determine when a postremediation care plan is required. The proposed postremediation care requirements shall be included in the cleanup plan for Department approval, as specified in ~~Section 250.410(b)(5)~~Section 250.410(b)(5).

If any of the ~~above~~ answers in the following matrix are yes, relative to the selected standard(s), a postremediation care plan shall be included as part of the final report.

2. Uniform Environmental Covenants Act

On Dec. 18, 2007, Act 68, the Uniform Environmental Covenants Act (UECA), was signed into law. ~~Act 68~~UECA provides a standardized process for creating, documenting and assuring the enforceability of activity and use limitations (AULs) on contaminated sites. Under UECA an environmental covenant will be required whenever an engineering or institutional control is used to demonstrate the attainment of an Act 2 remediation standard. Environmental covenants are legal documents affecting property rights so remediators are encouraged to seek legal counsel with respect to the contents of the environmental covenant.

For the purposes of Act 2, ~~UECA~~environmental covenants will take the place of deed notices in relation to any ~~activity and use limitations (AUKL~~restrictions required to attain or maintain the standard. ~~These covenants will replace the deed notices previously required.~~

A model environmental covenant is provided on the LRP website. The model is provided as an example of what type of information should be provided in an environmental covenant. However, it is important to note that each site is unique so the content of each covenant will vary from site to site.

~~It is important to note that~~At some sites there may be additional AUL's that are put in place ~~and~~but are not included in the environmental covenant.~~; o~~Only those AULs that are necessary to attain and/or maintain the selected standard are required for inclusion

within the environmental covenant. In addition, the property owner's ~~concent~~consent and signature are required to implement an environmental covenant.

~~1.~~3. Institutional versus Engineering Controls

An institutional control, by definition of Act 2, is a measure taken to limit or prohibit certain activities that may interfere with the integrity of a remedial action or result in exposure to regulated substances at a site. These include, but are not limited to, fencing or restrictions on the future use of the site.

An engineering control, by definition of Act 2, is a remedial action directed exclusively toward containing or controlling the migration of regulated substances through the environment. These include, but are not limited to, slurry walls, liner systems, caps, leachate collection systems, ~~and~~ groundwater recovery trenches, and vapor mitigation systems.~~.~~

Example: An environmental covenant~~ deed restriction~~ prohibiting use of the property in some way is an institutional control. An impermeable cap that prevents volatilization to the atmosphere, controls contaminant migration by run-on and run-off, and limits dermal contact (hydraulic conductivity less than 1 x 10^{-7} cm/sec) is an engineering control.

Institutional and engineering controls ~~are also known as activity and use limitations~~serve as AULs because they restrict the use of a property. Institutional controls cannot be used to attain the background or Statewide health standards. ~~Institutional controls alone cannot be used to attain the site-specific standard.~~ Engineering and/or institutional controls may be used to maintain all three standards.

~~2.~~4. Postremediation Care Plan

The postremediation care plan should include the following:

- The reason(s) that the postremediation care plan is necessary (See Sections ~~250.204(g)~~250.204(g), ~~250.311~~250.311, ~~250.312~~250.312, ~~250.411(d)~~250.411(d), and ~~250.708~~250.708).
- A schedule of operation and maintenance of the controls. Include a description of the planned maintenance activities and frequencies at which they will be performed and future plans for submission of proposed changes.
- Information regarding the submission of quarterly monitoring results and analysis, or as otherwise approved by the Department, that demonstrates the effectiveness of the remedy. Include a description of the planned monitoring activities and frequencies at which they will be performed.
- The proposed method for reporting any instances of nonattainment of the selected standard(s).
- The proposed measures to be taken to correct nonattainment conditions as they occur. This includes ~~any necessary~~ soil management plans~~. These soil~~

~~management plans~~ that ~~detail~~provide ~~any~~ special handling instructions for contaminated soil in the event of future activity. Include a description of the corrective measures that may be required for all possible nonattainment scenarios.

- Information regarding the maintenance of records at the property where the remediation is being conducted for monitoring, sampling and analysis. Include the name, address and telephone number of the person or office to contact about the site during the postremediation care period. This person or office shall keep an updated postremediation plan during the postremediation care period.
- Documentation of a plan to maintain the mitigated ecological resource, report of success or failure of the mitigation measure, and demonstration of sustaining the measures up to five years from final report approval.
- If requested by the Department, documentation of financial ability to implement the remedy and the postremediation care plan.

~~3.~~5. Postremediation Monitoring

In some situations, postremediation monitoring may be required as part of the postremediation care ~~program~~plan. For example, postremediation monitoring is conducted to determine any changes in groundwater quality after attainment of a standard(s). Unless otherwise instructed by the Department, analytes to be included are those which were monitored during assessment and remediation monitoring. All monitoring activities should incorporate quality control and quality assurance provisions consistent with Act 2 regulations and policies.

Well locations for postremediation monitoring are generally selected from existing monitoring wells used in the ~~assessment~~ characterization and remediation phases. Where a source of contamination is removed prior to impacting groundwater, postremediation monitoring should continue at locations that will detect any residual contamination in the unsaturated zone that might migrate to the groundwater.

a) Duration

In most cases, postremediation monitoring requirements will be developed on a case-by-case basis. The factors determining the duration of postremediation monitoring are the same factors that determine whether a postremediation care plan is necessary.

b) Frequency

As stated in ~~Section 250.204(g)~~Section 250.204(g) of the regulations , postremediation monitoring will take place on a quarterly basis unless otherwise approved by the Department. The interval between sampling events should be short enough to allow for response and correction of any problems that may cause nonattainment at the point of compliance.

Factors that could influence the need for an alternative postremediation monitoring schedule include site size, groundwater velocity, contaminant characteristics and

the vulnerability of a site to pulses of contaminant migration during precipitation events.

c) Cessation of Postremediation Monitoring

Postremediation monitoring may be terminated when monitoring provisions set forth in the postremediation care plan are met, the engineering controls are no longer needed, and it can be documented by fate and transport analysis that the standard will not be exceeded in the future.

~~4.~~6. Postremediation Care Attainment

A person may terminate postremediation care as approved in the final report if he can demonstrate attainment of the standard(s) without the engineering controls in place, and document by a fate and transport analysis that the standard will not be exceeded in the future. An amendment to the postremediation care plan shall be submitted for approval by the Department. The postremediation care plan shall be amended whenever changes in operating plans or facility design, or events that occur during postremediation care, affect the currently approved postremediation care plan.

TABLE ~~IV~~III-7

Postremediation Care Decision Matrix

Background

		Yes	No
1.)	Is an ENGINEERING CONTROL(s) needed to attain and/or maintain the background standard?		
2.)	Is an INSTITUTIONAL CONTROL(s) needed to maintain the background standard?		
3.)	Does the FATE & TRANSPORT analysis indicate that the background standard may be exceeded at the point of compliance in the future?		
4.)	Does the remediation rely on NATURAL ATTENUATION?		

Statewide Health

1.)	Is an ENGINEERING CONTROL(s) needed to attain and/or maintain the Statewide health standard?		
2.)	Is an INSTITUTIONAL CONTROL(s) needed to maintain the Statewide health standard?		
3.)	Does the FATE & TRANSPORT analysis indicate that the Statewide health standard, including the solubility limitation in section 250.304(b), may be exceeded at the point of compliance in the future?		
4.)	Does the remediation rely on NATURAL ATTENUATION?		
5.)	If there are ECOLOGICAL IMPACTS identified in the evaluation of ecological receptors that must be addressed, will a post-remedy use be relied on to eliminate complete exposure pathways, as set forth in Section 250.311(e)(2)?		

6.)	If there are ECOLOGICAL IMPACTS identified in the evaluation of ecological receptors that must be addressed, will mitigation measures be implemented, as set forth in section 250.311(f)(v)? [If yes, follow guidelines in section 250.312(b)(1-3) for reporting requirements.]		

Site-Specific

1.)	Is an ENGINEERING CONTROL(s) needed to maintain the Site-specific Standard?		
2.)	Is an INSTITUTIONAL CONTROL(s) needed to maintain the Site-specific Standard?		
3.)	Does the FATE & TRANSPORT analysis indicate that the Site-specific Standard may be exceeded at the point of compliance in the future?		
4.)	Does the remediation rely on NATURAL ATTENUATION?		
5.)	If there are ECOLOGICAL IMPACTS identified in the evaluation of ecological receptors that must be addressed, will a post-remedy use be relied on to eliminate complete exposure pathways, as set forth in section 250.311(e)(2)?		
6.)	If there are ECOLOGICAL IMPACTS identified in the evaluation of ecological receptors that must be addressed, will mitigation measures be implemented, as set forth in section 250.311(f)? [If yes, follow guidelines in section 250.411(f)(1-3) for reporting requirements.]		

E. One Cleanup Program

In March 2004, PA DEP and Region 3 of the U.S. Environmental Protection Agency (USEPA) entered into a Memorandum of Agreement (MOA) that outlines a procedure where sites remediated according to the LRP may also satisfy requirements of several federal laws: the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response Compensation Liability Act (CERCLA), and the Toxic Substances Control Act (TSCA).

1. Purpose

PA DEP and USEPA sought to promote the One Cleanup Program initiative by working together to achieve cleanups that protect human health and the environment by making greater use of all available ~~authorites~~authorities, and selecting the optimum programmatic tools to increase the pace, effectiveness, efficiency, and quality of cleanups. In effect, entering into the One Cleanup Program can provide a remediator with a "one-stop shop" for state and federal standards guiding the cleanup of brownfield sites.

2. Provisions and Applicability

USEPA has reviewed and evaluated the LRP and has determined that the LRP, as implemented under the MOA, includes each of the four elements of a state response program listed in CERCLA Section 128(a)(2):

- timely survey and inventory of brownfield properties;
- oversight and enforcement authorities adequate to ensure that a response action will protect human health and the environment;
- mechanisms and resources to provide meaningful opportunities for public participation; and
- mechanisms for approval and a requirement for verification and certification that the response activity is complete.

The One Cleanup Program applies only to remediation of properties conducted pursuant to Act 2 provisions in effect as of the date of the executed MOA (as of March 2004). As determined by PA DEP and USEPA, the following properties are not eligible to enter in the ~~the~~ program:

- permitted hazardous waste management units,
- properties proposed in the Federal Register to be placed on the National Priorities List,
- properties that have been placed on the National Priorities List, and
- properties that have been permitted under the PA Solid Waste Management Act and the PA Clean Streams Law for which cleanup standards are ~~dfifferent~~different than those of the LRP ~~are applicable~~.

3. Implementation

Under the MOA, PA DEP and USEPA have agreed to work in a coordinated manner to avoid possible duplication of efforts at properties, while ensuring that remediation of properties continues in a timely fashion. PA DEP will notify USEPA when properties are being addressed under the LRP and will provide written documentation for properties in Comprehensive Environmental R~~r~~esponse, Compensation and Liability Information System (CERCLIS) that are being addressed under the LRP.

For all RCRA Corrective Action Facilities being remediated under the LRP, PA DEP will provide US EPA with copies of reports. PA DEP and USEPA will work in ~~joint work~~teams to accomplish cleanup goals in an appropriate and efficient use of both Agencies' resources. USEPA will review reports submitted to PA DEP under the LRP to determine if the site data meets RCRA Corrective Action obligations.

RCRA facilities enrolled in the One Cleanup Program may be subject to UECA requirements (Section III.D). As such, a model covenant for any activity and use limitations which may be in effect for these facilities is located on the PA DEP website on the 'One Cleanup Program' webpage.

4. Benefits

In summary, by entering into the One Cleanup Program, site owners or operators may be able to satisfy federal RCRA obligations **and** obtain liability relief under the Act 2 program. Interested parties can review the historic MOA, RCRA Corrective Action Baseline Facilities that have entered the One Cleanup Program, and other useful information on the PA DEP website on the One Cleanup Program tab.

Any owner, ~~/~~operator, ~~/~~or remediator interested in entering the One Cleanup Program should consult with their assigned DEP Project Officer about opportunities and eligibility requirements.

F. Data Quality and Practical Quantitation Limits

1. Data Quality Objectives Process, Sampling, and Data Quality Assessment Process

Comment [B4]: DQO language moved from statistical methods section

An important issue regarding sampling and statistical analysis is the quality assurance (QA) management considerations associated with these activities. Steps for the QA management process, in general, can be divided into three phases: planning, implementation and assessment. During the planning phase, a sampling and analysis plan is developed based on Data Quality Objectives (DQO). The implementation phase includes sampling execution and sample analysis. The assessment phase includes Data Quality Assessment (DQA) (See Section 250.702(a) of the regulations).

To help ~~a person~~remediators design ~~a~~ scientific and resource-effective sampling programs, EPA ~~has~~ provide~~d~~s guidance on developing Data Quality Objectives (EPA 1993). The DQO process allows a person to define the data requirements and acceptable levels of decision errors, before any data are collected. The DQO process

should be considered in developing the sampling and analysis plan, including the quality assurance plan.

As stated in the EPA guidance (EPA 1993), the DQO process includes the following seven steps:

- State the problem.
- Identify the decision.
- Identify inputs to the decision.
- Define the spatial and temporal boundaries of the decision.
- Develop a decision rule.
- Specify limits on decision errors.
- Optimize the design for obtaining data.

Step 4 of the DQO process, defining the spatial and temporal boundaries of the decision, is particularly important, because it prevents pooling and averaging data in a way that could mask potentially useful information. Activities in this step include:

- Define the domain or geographic area within which all decisions must apply. Some examples are property boundaries, operable units, and exposure areas.
- Specify the characteristics that define the population of interest. Identification of multiple areas of concern - each with its own set of samples and descriptive statistics - will help to reduce the total variability if the areas of concern are defined so that they are very different in their contaminant concentration profiles. For example, the top 2 feet of soil are defined as surface soil. Another example is to define contaminated soil that has been impacted by separate-phase liquid (SPL) as SPL-impacted soil.
- When appropriate, divide the population into strata that have relatively homogeneous characteristics. This helps to reduce the variability in each data set.
- Define the scale of decision making. The scale of decision making is the smallest area, volume, or time frame of the media in which decision errors are to be controlled. This is also the unit that will be assumed to generate a "statistical unit" of possible measurements which allows the assessment and control of decision errors. Examples are remediation units, exposure units, and hot spots.
- Determine the time frame to which the study data apply. It may not be possible to collect data over the full time period to which the decision will apply. Therefore a decision should be made regarding the most appropriate time frame that the data should reflect.
- Determine when to collect samples. Conditions at the site may vary due to seasons, weather or other factors. Therefore a decision should be made

regarding the most appropriate time period to collect data that will reflect the conditions that are of interest.

- Identify any practical constraints on data collection, such as seasonal or meteorological conditions, unavailability of personnel, time, or equipment.

At the completion of the DQO process, information obtained from the DQO process can be used to develop a sampling and analysis plan, including a quality assurance/quality control plan.

Unless otherwise specified or approved by the Department, systematic sampling (grid sampling) designs should be used in developing the sampling and analysis plan for demonstrating attainment of soil cleanup standards (See Section 250.703(c) of the regulations). Systematic random sampling is a grid sampling design with a random starting point. Systematic random sampling provides better coverage of the soil study area than simple random sampling. Limitations and procedures to implement systematic sampling can be found in Sections 5.3 and 6.5 of EPA guidance (EPA, 1989b). A square grid and a triangular grid are two common patterns used in systematic sampling. To avoid grid pattern corresponding to patterns of contamination, EPA (EPA 1992c) recommended the use of unaligned grid sampling design (Gilbert, 1987, p.94). Unaligned grid sampling design maintains the advantage of uniform coverage while incorporating an element of randomness in the choice of sampling locations. To obtain an unbiased estimate of the variance of the mean, the multiple systematic sampling approach (Gilbert, 1987, p.97) may be needed.

To generate a grid sampling design, a computer random number generator or a random number table may be used.

After the environmental data have been collected and validated in accordance with the sampling and analysis plan (including the QA/QC plan), data must be assessed to ~~determined~~determine whether the DQOs are met. This is the Data Quality Assessment (DQA) process. EPA has developed guidance on DQA (EPA, 1996).

The DQA process involves the following five steps(EPA, 1996):

- Review the DQOs and sampling design.
- Conduct a preliminary data review.
- Select the statistical test.
- Verify the underlying assumptions of the statistical test.
- Perform the statistical hypothesis test and draw conclusions that address the data user's objectives.

A properly implemented DQA process can help to determine if planning objectives were achieved. The discussions in the statistics section (III.B) will address key statistical issues that are pertinent to Act 2 and are encountered during these DQO and DQA processes.

2. Preliminary Data Review

Preliminary data review should be performed whenever data are used. By reviewing the data both numerically and graphically, one can learn the "structure" of the data and identify limitations for using the data. Graphical methods include histograms, probability plots, box charts, and time-series plots to visually review the data for trends or patterns. Calculations of summary statistics are typically done to characterize the data and make judgments on the central tendencies, symmetry, presence of outliers, etc. These statistical methods are defined and explained in more detail in the statistical section of this guidance. (Section III.B)

Chemical concentrations should initially be compared to laboratory blank concentrations. If the blank samples contain detectable levels of common laboratory contaminants, then the sample results should be considered as positive results only if the concentrations in the sample exceed ten times the maximum amount detected in the blank. If the concentration is less than ten times the blank contaminant level, it is concluded that the chemical was not detected in the sample and the blank-related chemical concentration is considered to be the quantitation limit for the chemical in that sample. If all samples contain levels of a common laboratory contaminant that are less than ten times the level of contamination noted in the blank, then completely eliminate that chemical from the set of sample results. Some common laboratory contaminants include acetone, 2-butanone (methyl ethyl ketone), methylene chloride, toluene, and phthalate esters. This evaluation is typically done during the laboratory data review process and anything that meets the criteria to be included in data evaluation will typically be marked with a "B" qualifier.

If the blank samples contain constituents other than common laboratory contaminants, then the sample results should be considered as positive results only if the concentrations in the sample exceed five times the maximum amount detected in any laboratory blank. As with the common laboratory contaminants, if the concentration is less than five times the blank constituent level, it is concluded that the constituent was not detected in the sample and the blank-related chemical concentration is considered to be the quantitation limit for the chemical in that sample. Again, if all samples contain levels of a constituent other than common laboratory contaminants that are less than five times the level of contamination noted in the blank, then completely eliminate that chemical from the set of sample results. As with common laboratory contaminants, this evaluation is typically done during the laboratory data review process and anything that meets the criteria to be included in data evaluation will typically be marked with a "B" qualifier.

3. Practical quantitation Limit

Practical quantitation limit (PQL) is the lowest limit that can be reliably achieved under normal laboratory conditions. For the purposes of Act 2, the PQL's are either defined in the EPA method typically performed to quantitate the compound or they are set as the reporting limit of the compound as analyzed at the Department's Bureau of Laboratories.

The methods and instrumentation listed in the following tables are for reference only. These are the methods that are used in developing these values. There may be other methods that may be used for the same analysis.

The PQLs are given in Tables III-8 and III-9 and

~~PQLs~~ ~~were~~are determined via the following process:

1. If a PQL or Estimated quantitation limit (EQL) ~~was~~is cited in the method given in tables III-8 and III-9, that value ~~was~~is set as the PQL.~~.~~
2. If no PQL or EQL ~~was~~is listed in the method but a Method detection limit (MDL) with a determining factor is ~~as~~ defined in the method, then the MDL is ~~to~~ set ~~a~~ as the PQL. ~~or EQL~~
3. If no PQL, EQL or MDL ~~was~~is listed in the method, the PQL ~~was~~is defined as the PA DEP Bureau of Laboratories Reporting Limit (BOL RL).
4. If there is no determining factor to set a PQL accompanying the MDL and No BOL RL, the MDL was set as the PQL.
5. If none of the above rules apply, the PQL was either left blank or remained the PQL previously listed.

Table IV-10
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
ACENAPHTHENE	83-32-9	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS	EQL	0.66	10	0.66
ACENAPHTHYLENE	208-96-8	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS	EQL	0.66	10	0.66
ACEPHATE	30560-19-1												
ACETALDEHYDE	75-07-0	EMSLC	554	HPLC	MDL	44		8315A		MDL	43.7	100	140
ACETONE	67-64-1	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
ACETONITRILE	75-05-8	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
ACETOPHENONE	98-86-2	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS			10	
ACETYLAMINOFLUORENE, 2- (2AAF)	53-96-3	OSW	8270C	GCGMS	EQL	20	OSW	8270C	GCGMS			20	
ACROLEIN	107-02-8	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
ACRYLAMIDE	79-06-1	OSW	8032	GCECD	MDL	0.032						0.1	
ACRYLIC ACID	79-10-7												
ACRYLONITRILE	107-13-1	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
ALACHLOR	15972-60-8	EMSLC	505	GCGECD	MDL	0.23	–					0.7	
ALDICARB	116-06-3	OSW	8321A		MDL	1.4	OSW	8321A		MDL	0.017	4	0.054
ALDRIN	309-00-2	OSW	8081A	GCGECD	MDL	1.4	OSW	8081A	GCECD	MDL	0.00022	4	0.007
ALLYL ALCOHOL	107-18-6	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
AMINOBIPHENYL, 4-	92-67-1	OSW	8270C	GCGMS	EQL	20	OSW	8270C	GCGMS			20	
AMITROLE	61-82-5												
AMMONIA	7664-41-7												
AMMONIUM SULFAMATE	7773-06-0												
ANILINE	62-53-3	OSW	8131		EQL	23	OSW	8131		MDL	2.3	20	7.3
ANTHRACENE	120-12-7	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS	EQL	0.66	10	0.66
ATRAZINE	1912-24-9	EMSLC	505	GCGECD	MDL	2.4	OSW	8141	GCGFPD			8	
BAYGON (PROPOXUR)	114-26-1		531.1		MDL	1		8318		MDL	17	3	54
BENOMYL	17804-35-2		8321A		MDL	0.4		8321A		MDL	0.025	1	0.08
BENTAZON	25057-89-0		8151A		MDL	0.2		8151A				0.6	

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Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
BENZENE	71-43-2	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
BENZIDINE	92-87-5		8270C					8270C					
BENZO[A]ANTHRACENE	56-55-3	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
BENZO[A]PYRENE	50-32-8		610	HPLC	MDL	0.023	OSW	8270C	CGCMS	EQL	0.66	0.07	0.66
BENZO[B]FLUORANTHENE	205-99-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
BENZO[GHI]PERYLENE	191-24-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
BENZO[K]FLUORANTHENE	207-08-9	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
BENZOIC ACID	65-85-0	OSW	8270C	CGCMS	EQL	50	OSW	8270C	CGCMS	EQL	3.3	50	3.3
BENZOTRICHLORIDE	98-07-7		8121		EQL	0.06		8121		MDL	0.006	0.06	0.019
BENZYL ALCOHOL	100-51-6	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS	EQL	1.3	20	1.3
BENZYL CHLORIDE	100-44-7	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
BHC, ALPHA-	319-84-6	OSW	8081A	GCECD	EQL	0.35	OSW	8081A	GCECD	EQL	1.3	0.4	1.3
BHC, BETA-	319-85-7	OSW	8081A	GCECD	EQL	0.23	OSW	8081A	GCECD	EQL	2.2	0.2	2.2
BHC, DELTA-	319-86-8	OSW	8081A	GCECD	EQL	0.24	OSW	8081A	GCECD	EQL	0.74	0.2	0.74
BHC, GAMMA (LINDANE)	58-89-9		608	GC/ECD	MDL	0.004	OSW	8081A	GCECD	EQL	0.002	0.01	0.002
BIPHENYL, 1,1-	92-52-4												
BIS(2-CHLOROETHOXY)METHANE	111-91-1	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	660
BIS(2-CHLOROETHYL)ETHER	111-44-4	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
BIS(2-CHLORO-ISOPROPYL)ETHER	39638-32-9	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
BIS(CHLOROMETHYL)ETHER	542-88-1												
BIS[2-ETHYLHEXYL] PHTHALATE	117-81-7		525.2		MDL	0.46	OSW	8270C	CGCMS	EQL	0.66	1	0.66
BISPHENOL A	80-05-7												
BROMACIL	314-40-9		8321A		MDL	0.4		8321A		MDL	0.021	1	0.067
BROMOCHLOROMETHANE	74-97-5	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
BROMODICHLOROMETHANE	75-27-4	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
BROMOMETHANE	74-83-9	OSW	8260	CGCMS	EQ	5	OS	8260	CGCMS	EQ	0.00	5	0.005

Table IV-10
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
			B		L		W	B		L	5		
BROMOPHENYL PHENYL ETHER, 4-	101-55-3	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
BROMOXYNIL	1689-84-5		8270C					8270C					
BROMOXYNIL OCTANOATE	1689-99-2												
BUTADIENE, 1,3-	106-99-0												
BUTYL ACETATE, N-	123-86-4												
BUTYL ACETATE, SEC-	105-46-4												
BUTYL ACETATE, TERT-	540-88-5												
BUTYL ALCOHOL, N-	71-36-3	OSW	8015B	GCFID	MDL	8	OSW	8015B		MDL	0.23	30	0.73
BUTYLAMINE, N-	109-73-9												
BUTYLATE	2008-41-5		525.2		MDL	0.064						0.2	
BUTYLBENZENE, N-	104-51-8		8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
BUTYLBENZENE, SEC-	135-98-8		8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
BUTYLBENZENE, TERT-	98-06-6		8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
BUTYLBENZYL PHTHALATE	85-68-7	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
CAPTAN	133-06-2	OSW	8270C	CGCMS	EQL	50	OSW	8270C	CGCMS			50	
CARBARYL	63-25-2	OSW	8318	HPLC	MDL	1.7	OSW	8318	HPLC	MDL	0.031	5	0.099
CARBAZOLE	86-74-8												
CARBOFURAN	1563-66-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL		10	
CARBON DISULFIDE	75-15-0	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CARBON TETRACHLORIDE	56-23-5	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CARBOXIN	5234-68-4		525.2		MDL	0.4						1	
CATECHOL	120-80-9												
CHLORAMBEN	133-90-4	OSW	8151A		MDL	0.093						0.3	
CHLORDANE	57-74-9		505		MDL	0.14	OSW	8081A	GCECD	EQL		0.4	
CHLORO 1,1-DIFLUOROETHANE, 1-	75-68-3												

Table IV-10
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
CHLORO-1-PROPENE, 3- (ALLYL CHLORIDE)	107-05-1	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLOROACETALDEHYDE	107-20-0												
CHLOROACETOPHENONE, 2-	532-27-4												
CHLOROANILINE, P-	106-47-8	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS	EQL	1.3	20	1.3
CHLOROBENZENE	108-90-7	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLOROBENZILATE	510-15-6	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
CHLOROBUTANE, 1-	109-69-3	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLORODIBROMOMETHANE	124-48-1	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLORODIFLUOROMETHANE	75-45-6												
CHLOROETHANE	75-00-3	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLOROETHYL VINYL ETHER, 2-	110-75-8	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLOROFORM	67-66-3	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLORONAPHTHALENE, 2-	91-58-7	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
CHLORONITROBENZENE, P-	100-00-5												
CHLOROPHENOL, 2-	95-57-8	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
CHLOROPHENYL PHENYL ETHER, 4-	7005-72-3	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
CHLOROPRENE	126-99-8	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CHLOROPROPANE, 2-	75-29-6												
CHLOROTHALONIL	1897-45-6		8081A					8081A					
CHLOROTOLUENE, O-	95-49-8												
CHLORPYRIFOS	2921-88-2	OSW	8141A		MDL	0.07	OSW	8141A		MDL	5	0.2	16
CHLORSULFURON	64902-72-3												
CHLORTHAL-DIMETHYL (DACTHAL) - (DCPA)	1861-32-1		8081A					8081A					
CHRYSENE	218-01-9	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
CRESOL(S)	1319-77-3	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
CRESOL, O- (METHYLPHENOL, 2-)	95-48-7	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66

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Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
CRESOL, M (METHYLPHENOL, 3-)	108-39-4	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
CRESOL, P (METHYLPHENOL, 4-)	106-44-5	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
CRESOL, P-CHLORO-M-	59-50-7												
CROTONALDEHYDE	4170-30-3	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CROTONALDEHYDE, TRANS-	123-73-9	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CUMENE	98-82-8	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
CYCLOHEXANE	110-82-7												
CYCLOHEXANONE	108-94-1	OSW	8315	HPLC	MDL	6.9						20	
CYFLUTHRIN	68359-37-5												
CYROMAZINE	66215-27-8												
DDD, 4,4'-	72-54-8	OSW	8081AA	GCECD	MDL	0.05	OSW	8081AA	GCECD	MDL	0.0042	0.2	0.013
DDE, 4,4'-	72-55-9	OSW	8081AA	GCECD	MDL	0.058	OSW	8081AA	GCECD	MDL	0.0025	0.2	0.008
DDT, 4,4'-	50-29-3	OSW	8081AA	GCECD	MDL	0.081	OSW	8081AA	GCECD	MDL	0.0036	0.3	0.011
DECABORANE	17702-41-9												
DI(2-ETHYLHEXYL)ADIPATE	103-23-1		525.2		MDL	0.09						0.3	
DIALLATE	2303-16-4	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
DIAMINOTOLUENE, 2,4-	95-80-7	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
DIAZINON	333-41-5		525.2		MDL	0.11	OSW	8141A	CGCFPD	EQL	0.1	0.3	0.1
DIBENZO[A,H]ANTHRACENE	53-70-3	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
DIBENZOFURAN	132-64-9	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
DIBROMO-3-CHLOROPROPANE, 1,2-	96-12-8	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
DIBROMOBENZENE, 1,4-	106-37-6												
DIBROMOETHANE, 1,2- (ETHYLENE DIBROMIDE)	106-93-4		524.2		MDL	0.06	OSW	8260B	CGCMS	EQL	0.005	0.2	0.005
DIBROMOMETHANE	74-95-3	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
DIBUTYL PHTHALATE, N-	84-74-2	OSW	8270C	CGCMS	EQL	10						10	

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Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
DICHLORO-2-BUTENE, 1,4-	764-41-0	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLORO-2-BUTENE, TRANS-1,4-	110-57-6	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
DICHLOROBENZENE, 1,2-	95-50-1	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
DICHLOROBENZENE, 1,3-	541-73-1	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
DICHLOROBENZENE, P-	106-46-7	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
DICHLOROBENZIDINE, 3,3'-	91-94-1	OSW	8270C	GCGCMS	EQL	20	OSW	8270C	GCGCMS	EQL	1.3	20	1.3
DICHLORODIFLUOROMETHANE (FREON 12)	75-71-8	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROETHANE, 1,1-	75-34-3	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROETHANE, 1,2-	107-06-2	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROETHYLENE, 1,1-	75-35-4	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROETHYLENE, CIS 1,2-	156-59-2	EMSLC	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROETHYLENE, TRANS-1,2-	156-60-5	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROMETHANE (METHYLENE CHLORIDE)	75-09-2	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROPHENOL, 2,4-	120-83-2	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
DICHLOROPHENOXYACETIC ACID, 2,4- (2,4-D)	94-75-7	OSW	8151A	GCGCECD	MDL	0.2	OSW	8151A	GCGCECD	MDL	0.00011	0.6	0.00035
DICHLOROPROPANE, 1,2-	78-87-5	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
DICHLOROPROPENE, 1,3-	542-75-6												
DICHLOROPROPIONIC ACID, 2,2- (DALAPON)	75-99-0	OSW	8151A	GCGCECD	MDL	1.3	OSW	8151A	GCGCECD	MDL	0.12	4	0.38
DICHLORVOS	62-73-7	OSW	8141A	GCGCFPD	EQL	8	OSW	8141	GCGCFPD	EQL	0.4	8	0.4
DICYCLOPENTADIENE	77-73-6												
DIELDRIN	60-57-1	OSW	8081A	GC	MDL	0.44						1	
DIETHANOLAMINE	111-42-2												
DIETHYL PHTHALATE	84-66-2	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
DIETHYLAMINE	109-89-7												
DIFLUBENZURON	35367-38-5												

Table IV-10
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
DIGLYCIDYL ETHER (DGE)	2238-07-5												
DIMETHOATE	60-51-5	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
DIMETHOXYBENZIDINE, 3,3-	119-90-4	OSW	8270C	CGCMS	EQL	100	OSW	8270C	CGCMS			100	
DIMETHYL PHTHALATE	131-11-3	OSW	8270C	CGCMS	EQL	40	OSW	8270C	CGCMS	EQL	0.66	40	0.66
DIMETHYL SULFATE	77-78-1									EQL	1.66		1.7
DIMETHYLAMINOAZOBENZENE, P-	60-11-7	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
DIMETHYLANILINE, N,N-	121-69-7												
DIMETHYLBENZIDINE, 3,3-	119-93-7												
DIMETHYLHYDRAZINE, 1,1-	57-14-7												
DIMETHYLPHENETHYLAMINE, ALPHA, ALPHA-	122-09-8	OSW	8270C	CGCMS				8270C	CGCMS				
DIMETHYLPHENOL, 2,4-	105-67-9	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
DINITROBENZENE, 1,3-	99-65-0	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
DINITRO-O-CRESOL, 4,6-	534-52-1	OSW	8270C	CGCMS	EQL	50	OSW	8270C	CGCMS	EQL	3.3	50	3.3
DINITROPHENOL, 2,4-	51-28-5	OSW	8270C	CGCMS	EQL	50	OSW	8270C	CGCMS	EQL	3.3	50	3.3
DINITROTOLUENE, 2,4-	121-14-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
DINITROTOLUENE, 2,6- (2,6-DNT)	606-20-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
DINOSEB	88-85-7		515.1		MDL	0.33	OSW	8270b	CGCMS			1	
DIOXANE, 1,4-	123-91-1	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
DIOXATHION	78-34-2												
DIPHENAMID	957-51-7		525.2		MDL	0.041						0.1	
DIPHENYLAMINE	122-39-4	OSW	8270C	CGCMS			OSW	8270C	CGCMS				
DIPHENYLHYDRAZINE, 1,2-	122-66-7	OSW	8270C	CGCMS			OSW	8270C	CGCMS				
DIQUAT	85-00-7	EMSLC	549.1	HPLCUV	MDL	0.51	–					2	
DISULFOTON	298-04-4	OSW	8141A	CGFPD	EQL	0.7	OSW	8141A	CGCFPD	EQL	0.035	0.7	0.035
DIURON	330-54-1	OSW	8321A	HPLCMS	MDL	0.4	OSW	8321A	HPLCMS	MDL	0.018	1	0.057
ENDOSULFAN	115-29-												

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REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
	7												
ENDOSULFAN I (ALPHA)	959-98-8	OSW	8081A	CGCECD	EQL	0.3	OSW	8081A	CGCECD	EQL	1.4	0.3	1.4
ENDOSULFAN II (BETA)	33213-65-9	OSW	8081A	CGCECD	EQL	0.4	OSW	8081A	CGCECD	EQL	1.6	0.4	1.6
ENDOSULFAN SULFATE	1031-07-8	OSW	8081A	CGCECD	EQL	0.35	OSW	8081A	CGCECD	EQL	2.4	0.4	2.4
ENDOTHALL	145-73-3	EMSLC	548.1	CGCECD	MDL	1.8						6	
ENDRIN	72-20-8		525.2		MDL	0.29	OSW	8081A	CGCECD	EQL	2.4	0.9	2.4
EPICHLOROHYDRIN	106-89-8	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
ETHEPHON	16672-87-0												
ETHION	563-12-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
ETHOXYETHANOL, 2- (EGEE)	110-80-5	--					--						
ETHYL ACETATE	141-78-6	ASTM	D3695	GCFID	MDL	1000	--					3000	
ETHYL ACRYLATE	140-88-5	ASTM	D3695	GCFID	MDL	1000	--					3000	
ETHYL BENZENE	100-41-4	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
ETHYL DIPROPYLTHIOCARBAMATE, S- (EPTC)	759-94-4		525.2		MDL	0.056						0.2	
ETHYL ETHER	60-29-7	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
ETHYL METHACRYLATE	97-63-2	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
ETHYL METHANESULFONATE	62-50-0	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
ETHYLAMINE	75-04-7												
ETHYLENE CHLORHYDRIN	107-07-3												
ETHYLENE GLYCOL	107-21-1		8015B					8015B					
ETHYLENE THIOUREA (ETU)	96-45-7		509		MDL	2.7						9	
ETHYLP-NITROPHENYL PHENYLPHOSPHOROTHIOATE	2104-64-5	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
FAMPHUR	52-85-7	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
FENAMIPHOS	22224-92-6	EMSLC	525.2		MDL	0.95						3	
FENSULFOTHION	115-90-2	OSW	8270C	CGCMS	EQL	40	OSW	8270C	CGCMS			40	

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REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
FENVALERATE (PYDRIN)	51630-58-1												
FLUOMETURON	2164-17-2		8321A		MDL	0.6		8321A		MDL	0.011	2	0.035
FLUORANTHENE	206-44-0	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
FLUORENE	86-73-7	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
FLUOROTRICHLOROMETHANE (FREON 11)	75-69-4	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
FONOFOS	944-22-9		8141A					8141A					
FORMALDEHYDE	50-00-0	OSW	8315A	HPLC	MDL	6.2	OSW	8315A	HPLC	MDL	6.2	20	20
FORMIC ACID	64-18-6	--					--						
FOSETYL AL	39148-24-8												
FURAN	110-00-9												
FURFURAL	98-01-1	--					--						
GLYPHOSATE	1071-83-6	EMSLC	547	HPLCFL	MDL	6						20	
HEPTACHLOR	76-44-8	OSW	8081A	GCECD	EQL	0.4	OSW	8081A	GCECD			0.4	
HEPTACHLOR EPOXIDE	1024-57-3	OSW	8081A	GCECD	EQL	0.32	OSW	8081A	GCECD	EQL	1.4	0.3	1.4
HEXACHLOROBENZENE	118-74-1		612	GCECD	MDL	0.05	OSW	8270C	CGCMS	EQL	0.66	0.2	0.66
HEXACHLOROBUTADIENE	87-68-3		612	GCECD	MDL	0.34	OSW	8270C	CGCMS	EQL	0.66	1	0.66
HEXACHLOROCYCLOPENTADIENE	77-47-4	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
HEXACHLOROETHANE	67-72-1		524.2		MDL	0.057	OSW	8270C	CGCMS	EQL	0.66	0.2	0.66
HEXACHLOROPROPENE	1888-71-7	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
HEXANE	110-54-3	ASTM	D3695	GCFID	MDL	1000	--					3000	
HEXANONE, 2-(METHYL N-BUTYL KETONE)	591-78-6	OSW	8260B	CGCMS	EQL	1	OSW	8260B	CGCMS	EQL	0.005	1	0.005
HEXYTHIAZOX (SAVEY)	78587-05-0												
HYDRAZINE/HYDRAZINE SULFATE	302-01-2												
HYDROQUINONE	123-31-9												
INDENO[1,2,3-CD]PYRENE	193-39-5	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
IODOMETHANE	74-88-4	OSW	8260	CGCMS	EQ	1	OS	8260	CGCMS	EQ	0.00	1	0.005

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REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
			B		L		W	B		L	5		
IPRODIONE	36734-19-7												
ISOAMYL ACETATE	123-92-2												
ISOBUTYL ACETATE	110-19-0												
ISOBUTYL ALCOHOL	78-83-1	OSW	8260B	GCMS	EQL	5	OSW	8260B	GCMS	EQL	0.005	5	0.005
ISODRIN	465-73-6	OSW	8270C	GCGMS	EQL	20	OSW	8270C				20	
ISOPHORONE	78-59-1	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS	EQL	0.66	10	0.66
ISOPHORONE DIISOCYANATE	4098-71-9												
ISOSAFROLE	120-58-1	OSW	8270C	GCGMS	EQL	10	OSW	8270C				10	
KEPONE	143-50-0	OSW	8270C	GCGMS	EQL	20	OSW	8270C	GCGMS			20	
MALATHION	121-75-5	OSW	8270C	GCGMS	EQL	50	OSW	8141				50	
MALEIC HYDRAZIDE	123-33-1												
MANEB	12427-38-2												
MERPHOS OXIDE	78-48-8												
METHACRYLONITRILE	126-98-7	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
METHAMIDOPHOS	10265-92-6												
METHANOL	67-56-1	OSW	8015B	GCFID	MDL	21	OSW	8015B	GCFID	MDL	0.46	70	1.5
METHOMYL	16752-77-5	OSW	8321A		MDL	1.5	OSW	8321A		MDL	0.015	5	0.048
METHOXYCHLOR	72-43-5	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS			10	
METHOXYETHANOL, 2-	109-86-4												
METHYL ACETATE	79-20-9												
METHYL ACRYLATE	96-33-3	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
METHYL CHLORIDE	74-87-3		524.2		MDL	0.13	OSW	8260B	GCGMS	EQL	0.005	0.4	0.005
METHYL ETHYL KETONE	78-93-3	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
METHYL HYDRAZINE	60-34-4												
METHYL ISOAMYL KETONE	110-12-3												
METHYL ISOBUTYL KETONE	108-10-1	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005

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Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
METHYL ISOCYANATE	624-83-9												
METHYL MERCAPTAN	74-93-1												
METHYL METHACRYLATE	80-62-6	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
METHYL METHANESULFONATE	66-27-3	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS			10	
METHYL PARATHION	298-00-0	OSW	8141A	GCGCFPD	MDL	0.12	OSW	8141A	GCGCFPD	MDL	0.06	0.4	0.19
METHYL STYRENE (MIXED ISOMERS)	25013-15-4												
METHYL TERT BUTYL ETHER (MTBE)	1634-04-4	OSW	8260B	GCGCMS	EQL	5	OSW	8260B	GCGCMS	EQL	0.005	5	0.005
METHYLAMINE	74-89-5												
METHYLCHLOROPHENOXYACETIC ACID (MCPA)	94-74-9	OSW	8151A	GCECD	MDL	0.056	OSW	8151A	GCECD	EDL	0.043	0.2	0.14
METHYLENE BIS(2-CHLOROANILINE), 4,4'-	101-14-4	OSW	8270C	GCGCMS			OSW	8270C	GCGCMS				
METHYLNAPHTHALENE, 2-	91-57-6	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
METHYLSTYRENE, ALPHA	98-83-9												
MEVINPHOS	7786-34-7	OSW	8270C	GCGCMS	EQL	10	OSW	8141A	GCFPD	MDL	0.025	10	0.08
MONOCROTOPHOS	6923-22-4	OSW	8270C	GCGCMS	EQL	40	OSW	8270C	GCGCMS			40	
NAPHTHALENE	91-20-3	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
NAPHTHOQUINONE, 1,4-	130-15-4	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS			10	
NAPHTHYLAMINE, 1-	134-32-7	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS			10	
NAPHTHYLAMINE, 2-	91-59-8	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS			10	
NAPROPAMIDE	15299-99-7		525.2		MDL	0.06						0.2	
NITROANILINE, M-	99-09-2	OSW	8270C	GCGCMS	EQL	50	OSW	8270C	GCGCMS	EQL	3.3	50	3.3
NITROANILINE, O-	88-74-4	OSW	8270C	GCGCMS	EQL	50	OSW	8270C	GCGCMS	EQL	3.3	50	3.3
NITROANILINE, P-	100-01-6	OSW	8270C	GCGCMS	EQL	20	OSW	8270C	GCGCMS	EQL		20	
NITROBENZENE	98-95-3	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
NITROPHENOL, 2-	88-75-5	OSW	8270C	GCGCMS	EQL	10	OSW	8270C	GCGCMS	EQL	0.66	10	0.66
NITROPHENOL, 4-	100-02-7	OSW	8270C	GCGCMS	EQL	50	OSW	8270C	GCGCMS	EQL	3.3	50	3.3
NITROPROPANE, 2-	79-46-9	OSW	8260	GCMS	EQ	5	OS	8260	GCMS	EQ	0.00	5	0.005

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REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
			B		L		W	B		L	5		
NITROQUINOLINE-1-OXIDE, 4-	56-57-5	OSW	8270C	CGCMS	EQL	40	OSW	8270C	CGCMS			40	
NITROSODIETHYLAMINE, N-	55-18-5	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
NITROSODIMETHYLAMINE, N-	62-75-9	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
NITROSO-DI-N-BUTYLAMINE, N-	924-16-3	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
NITROSODI-N-PROPYLAMINE, N-	621-64-7	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
NITROSODIPHENYLAMINE, N-	86-30-6	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
NITROSO-N-ETHYLUREA, N-	759-73-9												
OCTYL PHTHALATE, DI-N-	117-84-0	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
OXAMYL (VYDATE)	23135-22-0	OSW	8321A		MDL	0.3	OSW	8321A		MDL	0.015	1	0.048
PARATHION	56-38-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCFPD			10	
PCB-1016 (AROCLOR)	12674-11-2	OSW	8082	CGCECD	MDL	0.054	OSW	8082	CGCECD	MDL	0.057	0.2	0.18
PCB-1221 (AROCLOR)	11104-28-2	OSW	8082	CGCECD	MDL	0.054	OSW	8082	CGCECD	MDL	0.057	0.2	0.18
PCB-1232 (AROCLOR)	11141-16-5	OSW	8082	CGCECD	MDL	0.054	OSW	8082	CGCECD	MDL	0.057	0.2	0.18
PCB-1242 (AROCLOR)	53469-21-9	OSW	8082	CGCECD	MDL	0.054	OSW	8082	CGCECD	MDL	0.057	0.2	0.18
PCB-1248 (AROCLOR)	12672-29-6	OSW	8082	CGCECD	MDL	0.054	OSW	8082	CGCECD	MDL	0.057	0.2	0.18
PCB-1254 (AROCLOR)	11097-69-1	OSW	8082	CGCECD	MDL	0.054	OSW	8082	CGCECD	MDL	0.057	0.2	0.18
PCB-1260 (AROCLOR)	11096-82-5	OSW	8082	CGCECD	MDL	0.054	OSW	8082	CGCECD	MDL	0.057	0.2	0.18
PEBULATE	1114-71-2		525.2		MDL	0.08						0.3	
PENTABORANE	19624-22-7												
PENTACHLOROBENZENE	608-93-5	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
PENTACHLOROETHANE	76-01-7	OSW	8260B	GCMS	EQL	5	OSW	8260B	GCMS	EQL	0.005	5	0.005
PENTACHLORONITROBENZENE	82-68-8	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
PENTACHLOROPHENOL	87-86-5		525.2		MDL	0.034	OSW	8270C	CGCMS	EQL	3.3	0.1	3.3
PERCHLOROMETHYL MERCAPTAN	594-42-3												
PHENACETIN	62-44-2	OSW	8270	CGCMS	EQ	20	OS	8270	CGCMS			20	

Table IV-10
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
			C		L		W	C					
PHENANTHRENE	85-01-8	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
PHENOL	108-95-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
PHENYL MERCAPTAN	108-98-5	OSW	8270C	CGCMS	EQL	20	OSW	8270C	CGCMS			20	
PHENYLENEDIAMINE, M-	108-45-2	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
PHENYLPHENOL, 2-	90-43-7												
PHORATE	298-02-2	OSW	8270C	CGCMS	EQL	10	OSW	8141A	CGFPD	EQL	0.02	10	0.02
PHTHALIC ANHYDRIDE	85-44-9	OSW	8270C	CGCMS	EQL	100	OSW	8270C	CGCMS			100	
PICLORAM	1918-02-1	OSW	8151A		MDL	0.14	OSW	8151A				0.4	
PICOLINE, 2-	109-06-8	OSW	8270C	CGCMS			OSW	8270C	CGCMS				
POLYCHLORINATED BIPHENYLS (AROCLORS) (PCBS)	1336-36-3		8082					8082					
PRONAMIDE	23950-58-5	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	
PROPANIL	709-98-8												
PROPANOL, 1-	71-23-8	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
PROPANOL, 2- (ISOPROPYL ALCOHOL)	67-63-0	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
PROPHAM	122-42-9		8321A		MDL	0.4		8321A		MDL	0.012	1	0.038
PROPIOLACTONE, BETA	57-57-8	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
PROPIONIC ACID	79-09-4												
PROPIONITRILE (ETHYL CYANIDE)	107-12-0	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
PROPYLBENZENE, N-	103-65-1	OSW	8260B	CGCMS	EQL	5	OSW	8260B	CGCMS	EQL	0.005	5	0.005
PROPYLENE IMINE	75-55-8												
PROPYLENE OXIDE	75-56-9	ASTM	D3695	GCFID	MDL	1000						3000	
PYRENE	129-00-0	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS	EQL	0.66	10	0.66
PYRETHRUM	8003-34-7												
PYRIDINE	110-86-1	OSW	8270C	CGCMS			OSW	8270C	CGCMS				
QUINOLINE	91-22-5												
QUINONE (p-BENZOQUINONE)	106-51-4	OSW	8270C	CGCMS	EQL	10	OSW	8270C	CGCMS			10	

~~Table IV-10~~
~~Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils~~
~~Organics~~

~~REGULATED SUBSTANCE~~	~~CASRN~~	~~AQUEOUS METHODS (µg/L)~~					~~SOILS METHODS (mg/kg)~~					~~PQL~~	
		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
~~QUIZALOFOP (ASSURE)~~	~~76578-14-8~~												
~~RESORCINOL~~	~~108-46-3~~	~~OSW~~	~~8270C~~	~~GCGMS~~	~~EQL~~	~~100~~	~~OSW~~	~~8270C~~	~~GCGMS~~			~~100~~	
~~RONNEL~~	~~299-84-3~~	~~OSW~~	~~8141A~~	~~GCFPD~~	~~EQL~~	~~0.7~~	~~OSW~~	~~8141A~~	~~GCFPD~~	~~EQL~~	~~0.035~~	~~0.7~~	~~0.035~~
~~SIMAZINE~~	~~122-34-9~~	~~EMSLC~~	~~525.2~~		~~MDL~~	~~0.045~~	~~OSW~~	~~8141~~	~~CGCFPD~~			~~0.1~~	
~~STRYCHNINE~~	~~57-24-9~~	~~OSW~~	~~8270C~~	~~GCGMS~~	~~EQL~~	~~40~~	~~OSW~~	~~8270C~~	~~GCGMS~~			~~40~~	
~~STYRENE~~	~~100-42-5~~	~~OSW~~	~~8260B~~	~~GCGMS~~	~~EQL~~	~~5~~	~~OSW~~	~~8260B~~	~~GCGMS~~	~~EQL~~	~~0.005~~	~~5~~	~~0.005~~
~~SULFIDE~~	~~18496-25-8~~												
~~SULFUR MONOCHLORIDE~~	~~10025-67-9~~												
~~TEBUTHIURON~~	~~34014-18-1~~		~~8321A~~		~~MDL~~	~~0.5~~		~~8321A~~		~~MDL~~	~~0.021~~	~~2~~	~~0.067~~
~~TEPP~~	~~107-49-3~~	~~OSW~~	~~8141A~~	~~GCFPD~~	~~EQL~~	~~8~~	~~OSW~~	~~8141A~~	~~GCFPD~~	~~EQL~~	~~0.4~~	~~8~~	~~0.4~~
~~TERBACIL~~	~~5902-51-2~~		~~525.2~~	~~CGCMS~~	~~MDL~~	~~0.22~~						~~0.7~~	
~~TERBUFOS~~	~~13071-79-9~~	~~EMSLC~~	~~525.2~~	~~CGCMS~~	~~MDL~~	~~0.096~~	~~OSW~~	~~8270C~~	~~CGCMS~~			~~0.3~~	
~~TETRACHLOROBENZENE, 1,2,4,5-~~	~~95-94-3~~	~~OSW~~	~~8270C~~	~~CGCMS~~	~~EQL~~	~~20~~	~~OSW~~	~~8270C~~	~~CGCMS~~			~~20~~	
~~TETRACHLORODIBENZO-P-DIOXIN, 2,3,7,8-(TCDD Equivalents))~~	~~1746-01-6~~	~~OSW~~	~~8280A~~	~~CGCMS~~	~~EQL~~	~~0.01~~	~~OSW~~	~~8280A~~	~~CGCMS~~	~~EQL~~	~~0.001~~	~~0.01~~	~~0.001~~
~~TETRACHLOROETHANE, 1,1,1,2-~~	~~630-20-6~~	~~OSW~~	~~8260B~~	~~GCGMS~~	~~EQL~~	~~5~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~0.005~~	~~5~~	~~0.005~~
~~TETRACHLOROETHANE, 1,1,2,2-~~	~~79-34-5~~		~~524.2~~		~~MDL~~	~~0.04~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~0.005~~	~~0.1~~	~~0.005~~
~~TETRACHLOROETHYLENE (PCE)~~	~~127-18-4~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~5~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~0.005~~	~~5~~	~~0.005~~
~~TETRACHLOROPHENOL, 2,3,4,6-~~	~~58-90-2~~	~~OSW~~	~~8270C~~	~~CGCMS~~	~~EQL~~	~~10~~	~~OSW~~	~~8270C~~	~~CGCMS~~			~~10~~	
~~TETRAETHYL LEAD~~	~~78-00-2~~												
~~TETRAETHYLDITHIOPYROPHOSPHATE~~	~~3689-24-5~~	~~OSW~~	~~8270C~~	~~CGCMS~~	~~EQL~~	~~20~~	~~OSW~~	~~8270C~~	~~CGCMS~~			~~20~~	
~~TETRAHYDROFURAN~~	~~109-99-9~~												
~~TETRANITROMETHANE~~	~~509-14-8~~												
~~THIOFANOX~~	~~39196-18-4~~		~~8321A~~					~~8321A~~					
~~THIONAZIN~~	~~297-97-2~~	~~OSW~~	~~8270C~~	~~CGCMS~~	~~EQL~~	~~20~~	~~OSW~~	~~8270C~~	~~CGCMS~~			~~20~~	
~~THIRAM~~	~~137-26-8~~												

Table IV-10
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
TOLUENE	108-88-3	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
TOLUIDINE, M-	108-44-1												
TOLUIDINE, O	95-53-4	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS			10	
TOLUIDINE, P-	106-49-0												
TOXAPHENE	8001-35-2	OSW	8081A	GCGMS	EQL	0.81	OSW	8081A	GCGMS			0.8	
TRIALLATE	2303-17-5												
TRIBROMOMETHANE (BROMOFORM)	75-25-2	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
TRICHLORO-1,2,2-TRIFLUOROETHANE, 1,1,2-	76-13-1												
TRICHLOROBENZENE, 1,2,4-	120-82-1	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
TRICHLOROBENZENE, 1,3,5-	180-70-3	OSW	8121		EQL	120	OSW	8121		EQL	8040	100	8000
TRICHLOROETHANE, 1,1,1-	71-55-6	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
TRICHLOROETHANE, 1,1,2-	79-00-5	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
TRICHLOROETHYLENE (TCE)	79-01-6	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
TRICHLOROPHENOL, 2,4,5-	95-95-4	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS	EQL	0.66	10	0.66
TRICHLOROPHENOL, 2,4,6-	88-06-2	OSW	8270C	GCGMS	EQL	10	OSW	8270C	GCGMS	EQL	0.66	10	0.66
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	93-76-5	OSW	8151A	GCECD	EDL	0.08	OSW	8151A	GCMS			0.3	
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	93-72-1	OSW	8151A	GCECD	EDL	0.08	OSW	8151A	GCMS	EQL	0.000028	0.3	0.00028
TRICHLOROPROPANE, 1,1,2-	598-77-6												
TRICHLOROPROPANE, 1,2,3-	96-18-4	OSW	8260B	GCGMS	EQL	5	OSW	8260B	GCGMS	EQL	0.005	5	0.005
TRICHLOROPROPENE, 1,2,3-	96-19-5												
TRIETHYLAMINE	121-44-8												
TRIETHYLPHOSPHOROTHIOATE, O,O,O-	126-68-1	OSW	8270C	GCGMS			OSW	8270C	GCGMS				
TRIFLURALIN	1582-09-8		525.2		MDL	0.048	OSW	8270C	GCGMS			0.2	
TRIMETHYLBENZENE,	95-63-6	OSW	8260	GCGMS	EQ	5	OS	8260	GCGMS	EQ	0.00	5	0.005

~~Table IV-10~~
~~Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils~~
~~Organics~~

~~REGULATED SUBSTANCE~~	~~CASRN~~	~~AQUEOUS METHODS (µg/L)~~					~~SOILS METHODS (mg/kg)~~					~~PQL~~	
		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER (µg/L)~~	~~SOIL (mg/kg)~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~		
~~1,3,4-(TRIMETHYLBENZENE, 1,2,4-)~~			~~B~~		~~L~~		~~W~~	~~B~~		~~L~~	~~5~~		
~~TRIMETHYLBENZENE, 1,3,5-~~	~~108-67-8~~		~~524.2~~		~~MDL~~	~~0.05~~						~~0.2~~	
~~TRINITROGLYCEROL (NITROGLYCERIN)~~	~~55-63-0~~												
~~TRINITROTOLUENE, 2,4,6-~~	~~118-96-7~~												
~~VINYL ACETATE~~	~~108-05-4~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~5~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~0.005~~	~~5~~	~~0.005~~
~~VINYL BROMIDE (BROMOETHENE)~~	~~593-60-2~~												
~~VINYL CHLORIDE~~	~~75-01-4~~		~~524.2~~		~~MDL~~	~~0.17~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~0.005~~	~~0.5~~	~~0.005~~
~~WARFARIN~~	~~81-81-2~~												
~~XYLENES (TOTAL)~~	~~1330-20-7~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~5~~	~~OSW~~	~~8260B~~	~~CGCMS~~	~~EQL~~	~~0.005~~	~~5~~	~~0.005~~
~~ZINEB~~	~~12122-67-7~~												

Table III-8
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHOD	SOIL METHOD	AQUEOUS PQL (µg/L)	SOIL PQL (mg/kg)
ACENAPHTHENE	83-32-9	8270D	8270D	10	0.66
ACENAPHTHYLENE	208-96-8	8270D	8270D	10	0.66
ACEPHATE	30560-19-1	-	-	-	-
ACETALDEHYDE	75-07-0	554	8315A	44	0.11
ACETONE	67-64-1	8260C	8260C	2.5	0.003
ACETONITRILE	75-05-8	8260C	8260C	5	0.005
ACETOPHENONE	98-86-2	8270D	8270D	10	-
ACETYLAMINOFLUORENE, 2- (2AAF)	53-96-3	8270D	8270D	20	-
ACROLEIN	107-02-8	8260C	8260C	5	0.005
ACRYLAMIDE	79-06-1	8032	-	0.032	-
ACRYLIC ACID	79-10-7	-	-	-	-
ACRYLONITRILE	107-13-1	8260C	8260C	5	0.005
ALACHLOR	15972-60-8	8081B	8081B	0.05	0.01
ALDICARB	116-06-3	8321A	8321A	1.4	0.017
ALDRIN	309-00-2	8081B	8081B	0.05	0.01
ALLYL ALCOHOL	107-18-6	8260C	8260C	5	0.005
AMINOBIPHENYL, 4-	92-67-1	8270D	8270D	20	-
AMITROLE	61-82-5	-	-	-	-
AMMONIA	7664-41-7	-	-	-	-
AMMONIUM SULFAMATE	7773-06-0	-	-	-	-
ANILINE	62-53-3	8131	8131A	23	2.3

~~Table IV-10~~
~~Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils~~
~~Organics~~

~~REGULATED SUBSTANCE~~	~~CASRN~~	~~AQUEOUS METHODS (µg/L)~~					~~SOILS METHODS (mg/kg)~~					~~PQL~~	
		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
ANTHRACENE	120-12-7				8270D			8270D		10		0.66	
ATRAZINE	1912-24-9				505			8270D		2.4			
BAYGON (PROPOXUR)	114-26-1				531.1			8318		1		54	
BENOMYL	17804-35-2				8321A			8321A		0.4		0.025	
BENTAZON	25057-89-0				8151A			8151A		2			
BENZENE	71-43-2				8260C			8260C		0.5		0.05	
BENZIDINE	92-87-5				8270D			8270D					
BENZO[A]ANTHRACENE	56-55-3				8270D			8270D		10		0.66	
BENZO[A]PYRENE	50-32-8				8270D			8270D		10		0.66	
BENZO[B]FLUORANTHENE	205-99-2				8270D			8270D		10		0.66	
BENZO[GHI]PERYLENE	191-24-2				8270D			8270D		10		0.66	
BENZO[K]FLUORANTHENE	207-08-9				8270D			8270D		10		0.66	
BENZOIC ACID	65-85-0				8270D			8270D		50		3.3	
BENZOTRICHLORIDE	98-07-7				8121			8121		0.06		0.006	
BENZYL ALCOHOL	100-51-6				8270D			8270D		20		1.3	
BENZYL CHLORIDE	100-44-7				8260C			8260C		5		0.005	
BHC, ALPHA-	319-84-6				8081B			8081B		0.05		0.01	
BHC, BETA-	319-85-7				8081B			8081B		0.05		0.01	
BHC, DELTA-	319-86-8				8081B			8081B		0.05		0.01	
BHC, GAMMA (LINDANE)	58-89-9				8081B			8081B		0.05		0.01	
BIPHENYL, 1,1-	92-52-4												
BIS(2-CHLOROETHOXY)METHANE	111-91-1				8270D			8270D		10		0.66	
BIS(2-CHLOROETHYL)ETHER	111-44-4				8270D			8270D		10		0.66	
BIS(2-CHLORO-ISOPROPYL)ETHER	39638-32-9				8270D			8270D		10		0.66	
BIS(CHLOROMETHYL)ETHER	542-88-1												
BIS[2-ETHYLHEXYL] PHTHALATE	117-81-7				8270D			8270D		5		1	
BISPHENOL A	80-05-7												
BROMACIL	314-40-9				8321A			8321A		0.4		0.021	
BROMOCHLOROMETHANE	74-97-5				8260C			8260C		0.5		0.05	
BROMODICHLOROMETHANE	75-27-4				8260C			8260C		0.5		0.05	
BROMOMETHANE	74-83-9				8260C			8260C		0.5		0.05	
BROMOPHENYL PHENYL ETHER, 4-	101-55-3				8270D			8270D		10		0.66	
BROMOXYNIL	1689-84-5				8270D			8270D		10			
BROMOXYNIL OCTANOATE	1689-99-2												
BUTADIENE, 1,3-	106-99-0												
BUTYL ACETATE, N-	123-86-4												
BUTYL ACETATE, SEC-	105-46-4												
BUTYL ACETATE, TERT-	540-88-5												
BUTYL ALCOHOL, N-	71-36-3				8015D			8015D		8		0.23	
BUTYLAMINE, N-	109-73-9												
BUTYLATE	2008-41-5				525.2			8270D		0.064			
BUTYLBENZENE, N-	104-51-8				8260C			8260C		0.5		0.05	
BUTYLBENZENE, SEC-	135-98-8				8260C			8260C		0.5		0.05	
BUTYLBENZENE, TERT-	98-06-6				8260C			8260C		0.5		0.05	
BUTYLBENZYL PHTHALATE	85-68-7				8270D			8270D		10		0.66	
CAPTAN	133-06-2				8270D			8270D		50			
CARBARYL	63-25-2				8318			8318		2		0.031	
CARBAZOLE	86-74-8												

~~Table IV-10~~
~~Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils~~
~~Organics~~

~~REGULATED SUBSTANCE~~	~~CASRN~~	~~AQUEOUS METHODS (µg/L)~~					~~SOILS METHODS (mg/kg)~~					~~PQL~~	
		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
CARBOFURAN	1563-66-2				8270D			8270D		10			
CARBON DISULFIDE	75-15-0				8260C			8260C		0.5			0.05
CARBON TETRACHLORIDE	56-23-5				8260C			8260C		0.5			0.05
CARBOXIN	5234-68-4				525.2			8270D		1.4			
CATECHOL	120-80-9												
CHLORAMBEN	133-90-4				8151A			8151A		0.93			0.04
CHLORDANE	57-74-9				505			8270D		0.14			
CHLORO-1,1-DIFLUOROETHANE, 1-	75-68-3												
CHLORO-1-PROPENE, 3- (ALLYL CHLORIDE)	107-05-1				8260C			8260C		5			0.005
CHLOROACETALDEHYDE	107-20-0												
CHLOROACETOPHENONE, 2-	532-27-4												
CHLOROANILINE, P-	106-47-8				8270D			8270D		20			1.3
CHLOROBENZENE	108-90-7				8260C			8260C		0.5			0.05
CHLOROBENZILATE	510-15-6				8270D			8270D		10			
CHLOROBUTANE, 1-	109-69-3				8260C			8260C		5			0.005
CHLORODIBROMOMETHANE	124-48-1				8260C			8260C		0.5			0.05
CHLORODIFLUOROMETHANE	75-45-6												
CHLOROETHANE	75-00-3				8260C			8260C		0.5			0.05
CHLOROETHYL VINYL ETHER, 2-	110-75-8				8260C			8260C		5			0.005
CHLOROFORM	67-66-3				8260C			8260C		0.5			0.05
CHLORONAPHTHALENE, 2-	91-58-7				8270D			8270D		10			0.66
CHLORONITROBENZENE, P-	100-00-5												
CHLOROPHENOL, 2-	95-57-8				8270D			8270D		10			0.66
CHLOROPHENYL PHENYL ETHER, 4-	7005-72-3				8270D			8270D		10			0.66
CHLOROPRENE	126-99-8				8260C			8260C		5			0.005
CHLOROPROPANE, 2-	75-29-6												
CHLOROTHALONIL	1897-45-6				8081B			8081B					
CHLOROTOLUENE, O-	95-49-8												
CHLORPYRIFOS	2921-88-2				8141A			8141A		0.7			0.035
CHLORSULFURON	64902-72-3												
CHLORTHAL-DIMETHYL (DACTHAL) (DCPA)	1861-32-1				8081B			8081B		0.05			0.01
CHRYSENE	218-01-9				8270D			8270D		10			0.66
CRESOL(S)	1319-77-3				8270D			8270D		10			0.66
CRESOL, 0- (METHYLPHENOL, 2-)	95-48-7				8270D			8270D		10			0.66
CRESOL, M (METHYLPHENOL, 3-)	108-39-4				8270D			8270D		10			
CRESOL, P (METHYLPHENOL, 4-)	106-44-5				8270D			8270D		10			0.66
CRESOL, P-CHLORO-M-	59-50-7												
CROTONALDEHYDE	4170-30-3				8260C			8260C		5			0.005
CROTONALDEHYDE, TRANS-	123-73-9				8260C			8260C		5			0.005
CUMENE	98-82-8				8260C			8260C		0.5			0.05
CYCLOHEXANE	110-82-7												
CYCLOHEXANONE	108-94-1				8315			8315		6.9			0.007
CYFLUTHRIN	68359-37-5												
CYROMAZINE	66215-27-8												
DDD, 4,4'-	72-54-8				8081B			8081B		0.05			0.01
DDE, 4,4'-	72-55-9				8081B			8081B		0.05			0.01

~~Table IV-10~~
~~Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils~~
~~Organics~~

~~REGULATED SUBSTANCE~~	~~CASRN~~	~~AQUEOUS METHODS (µg/L)~~					~~SOILS METHODS (mg/kg)~~					~~PQL~~	
		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
DDT, 4,4'-	50-29-3			8081B				8081B		0.05			0.01
DECABORANE	17702-41-9												
DI(2-ETHYLHEXYL)ADIPATE	103-23-1			525.2				8270D		0.09			
DIALLATE	2303-16-4			8270D				8270D		10			
DIAMINOTOLUENE, 2,4-	95-80-7			8270D				8270D		20			
DIAZINON	333-41-5			525.2				8270D		0.11			0.1
DIBENZO[A,H]ANTHRACENE	53-70-3			8270D				8270D		10			0.66
DIBENZOFURAN	132-64-9			8270D				8270D		10			0.66
DIBROMO-3-CHLOROPROPANE, 1,2-	96-12-8			8260C				8260C		0.5			0.05
DIBROMOBENZENE, 1,4-	106-37-6												
DIBROMOETHANE, 1,2- (ETHYLENE DIBROMIDE)	106-93-4			524.2				8260C		0.25			0.05
DIBROMOMETHANE	74-95-3			8260C				8260C		0.5			0.05
DIBUTYL PHTHALATE, N-	84-74-2			8270D				8270D		10			
DICHLORO-2-BUTENE, 1,4-	764-41-0			8260C				8260C		5			0.005
DICHLORO-2-BUTENE, TRANS-1,4-	110-57-6			8260C				8260C		10			0.66
DICHLOROBENZENE, 1,2-	95-50-1			8270D				8270D		10			0.66
DICHLOROBENZENE, 1,3-	541-73-1			8270D				8270D		10			0.66
DICHLOROBENZENE, P-	106-46-7			8270D				8270D		10			0.66
DICHLOROBENZIDINE, 3,3'-	91-94-1			8270D				8270D		20			1.3
DICHLORODIFLUOROMETHANE (FREON 12)	75-71-8			8260C				8260C		0.5			0.05
DICHLOROETHANE, 1,1-	75-34-3			8260C				8260C		0.5			0.05
DICHLOROETHANE, 1,2-	107-06-2			8260C				8260C		0.5			0.05
DICHLOROETHYLENE, 1,1-	75-35-4			8260C				8260C		0.5			0.05
DICHLOROETHYLENE, CIS-1,2-	156-59-2			8260C				8260C		0.5			0.05
DICHLOROETHYLENE, TRANS-1,2-	156-60-5			8260C				8260C		0.5			0.05
DICHLOROMETHANE (METHYLENE CHLORIDE)	75-09-2			8260C				8260C		0.5			0.05
DICHLOROPHENOL, 2,4-	120-83-2			8270D				8270D		10			0.66
DICHLOROPHENOXYACETIC ACID, 2,4-(2,4-D)	94-75-7			8151A				8151A		2			0.001
DICHLOROPROPANE, 1,2-	78-87-5			8260C				8260C		0.5			0.05
DICHLOROPROPENE, 1,3-	542-75-6												
DICHLOROPROPIONIC ACID, 2,2-(DALAPON)	75-99-0			8151A				8151A		13			0.001
DICHLORVOS	62-73-7			8141A				8141A		8			0.4
DICYCLOPENTADIENE	77-73-6												
DIELDRIN	60-57-1			8081B				8081B		0.05			0.01
DIETHANOLAMINE	111-42-2												
DIETHYL PHTHALATE	84-66-2			8270D				8270D		10			0.66
DIETHYLAMINE	109-89-7												
DIFLUBENZURON	35367-38-5												
DIGLYCIDYL ETHER (DGE)	2238-07-5												
DIMETHOATE	60-51-5			8270D				8270D		20			
DIMETHOXYBENZIDINE, 3,3-	119-90-4			8270D				8270D		100			
DIMETHYL PHTHALATE	131-11-3			8270D				8270D		40			0.66
DIMETHYL SULFATE	77-78-1												1.7

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~~REGULATED SUBSTANCE~~	~~CASRN~~	~~AQUEOUS METHODS (µg/L)~~					~~SOILS METHODS (mg/kg)~~					~~PQL~~	
		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
DIMETHYLAMINOAZOBENZENE, P-	60-11-7				8270D			8270D		10		-	
DIMETHYLANILINE, N,N-	121-69-7				-			-		-		-	
DIMETHYLBENZIDINE, 3,3-	119-93-7				-			-		-		-	
DIMETHYLHYDRAZINE, 1,1-	57-14-7				-			-		-		-	
DIMETHYLPHENETHYLAMINE, ALPHA, ALPHA-	122-09-8				8270D			8270D		-		-	
DIMETHYLPHENOL, 2,4-	105-67-9				8270D			8270D		10		0.66	
DINITROBENZENE, 1,3-	99-65-0				8270D			8270D		20		-	
DINITRO-O-CRESOL, 4,6-	534-52-1				8270D			8270D		50		3.3	
DINITROPHENOL, 2,4-	51-28-5				8270D			8270D		50		3.3	
DINITROTOLUENE, 2,4-	121-14-2				8270D			8270D		10		0.66	
DINITROTOLUENE, 2,6- (2,6-DNT)	606-20-2				8270D			8270D		10		0.66	
DINOSEB	88-85-7				515.1			8270D		0.4		-	
DIOXANE, 1,4-	123-91-1				8260C			8260C		5		0.005	
DIOXATHION	78-34-2				-			-		-		-	
DIPHENAMID	957-51-7				525.2			8270D		0.041		-	
DIPHENYLAMINE	122-39-4				8270D			8270D		-		-	
DIPHENYLHYDRAZINE, 1,2-	122-66-7				8270D			8270D		-		-	
DIQUAT	85-00-7				549.2			-		0.72		-	
DISULFOTON	298-04-4				8141A			8141A		0.7		0.035	
DIURON	330-54-1				8321A			8321A		0.4		0.057	
ENDOSULFAN	115-29-7				-			-		-		-	
ENDOSULFAN I (ALPHA)	959-98-8				8081B			8081B		0.05		0.01	
ENDOSULFAN II (BETA)	33213-65-9				8081B			8081B		0.05		0.01	
ENDOSULFAN SULFATE	1031-07-8				8081B			8081B		0.05		0.01	
ENDOTHALL	145-73-3				548.1			-		0.7		-	
ENDRIN	72-20-8				525.2			8270D		0.29		2.4	
EPICHLOROHYDRIN	106-89-8				8260C			8260C		5		0.005	
ETHEPHON	16672-87-0				-			-		-		-	
ETHION	563-12-2				8270D			8270D		10		-	
ETHOXYETHANOL, 2- (EGEE)	110-80-5				-			-		-		-	
ETHYL ACETATE	141-78-6				D3695			-		1000		-	
ETHYL ACRYLATE	140-88-5				D3695			-		1000		-	
ETHYL BENZENE	100-41-4				8260C			8260C		0.5		0.05	
ETHYL DIPROPYLTHIOCARBAMATE, S- (EPTC)	759-94-4				525.2			8270D		0.11		-	
ETHYL ETHER	60-29-7				8260C			8260C		5		0.005	
ETHYL METHACRYLATE	97-63-2				8260C			8260C		5		0.005	
ETHYL METHANESULFONATE	62-50-0				8270D			8270D		20		-	
ETHYLAMINE	75-04-7				-			-		-		-	
ETHYLENE CHLORHYDRIN	107-07-3				-			-		-		-	
ETHYLENE GLYCOL	107-21-1				8015D			8015D		1		-	
ETHYLENE THIOUREA (ETU)	96-45-7				509			-		2.7		-	
ETHYLP-NITROPHENYL PHENYLPHOSPHOROTHIOATE	2104-64-5				8270D			8270D		10		-	
FAMPHUR	52-85-7				8270D			8270D		20		-	
FENAMIPHOS	22224-92-6				525.2			-		0.95		-	
FENSULFOTHION	115-90-2				8270D			8270D		40		-	

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		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
FENVALERATE (PYDRIN)	51630-58-1												
FLUOMETURON	2164-17-2				8321A			8321A		0.6		0.011	
FLUORANTHENE	206-44-0				8270D			8270D		10		0.66	
FLUORENE	86-73-7				8270D			8270D		10		0.66	
FLUOROTRICHLOROMETHANE (FREON 11)	75-69-4				8260C			8260C		0.5		0.05	
FONOFOS	944-22-9				8141A			8141A					
FORMALDEHYDE	50-00-0				8315A			8315A		6.2		6.2	
FORMIC ACID	64-18-6												
FOSETYL-AL	39148-24-8												
FURAN	110-00-9												
FURFURAL	98-01-1												
GLYPHOSATE	1071-83-6				547					8.99			
HEPTACHLOR	76-44-8				8081B			8081B		0.05		0.01	
HEPTACHLOR EPOXIDE	1024-57-3				8081B			8081B		0.05		0.01	
HEXACHLOROBENZENE	118-74-1				8270D			8270D		10		0.66	
HEXACHLOROBUTADIENE	87-68-3				8270D			8270D		10		0.66	
HEXACHLOROCYCLOPENTADIENE	77-47-4				8270D			8270D		10		0.66	
HEXACHLOROETHANE	67-72-1				524.2			8270D		0.057		0.66	
HEXACHLOROPROPENE	1888-71-7				8270D			8270D		10			
HEXANE	110-54-3				D3695					1000			
HEXANONE, 2- (METHYL N-BUTYL KETONE)	591-78-6				8260C			8260C		2.5		0.25	
HEXYTHIAZOX (SAVEY)	78587-05-0												
HYDRAZINE/HYDRAZINE SULFATE	302-01-2												
HYDROQUINONE	123-31-9												
INDENO[1,2,3-CD]PYRENE	193-39-5				8270D			8270D		10		0.66	
IODOMETHANE	74-88-4				8260C			8260C		1		0.005	
IPRODIONE	36734-19-7												
ISOAMYL ACETATE	123-92-2												
ISOBUTYL ACETATE	110-19-0												
ISOBUTYL ALCOHOL	78-83-1				8260C			8260C		5		0.005	
ISODRIN	465-73-6				8270D			8270D		20			
ISOPHORONE	78-59-1				8270D			8270D		10		0.66	
ISOPHORONE DIISOCYANATE	4098-71-9												
ISOSAFROLE	120-58-1				8270D			8270D		10			
KEPONE	143-50-0				8270D			8270D		20			
MALATHION	121-75-5				8270D			8270D		50			
MALEIC HYDRAZIDE	123-33-1												
MANEB	12427-38-2												
MERPHOS OXIDE	78-48-8												
METHACRYLONITRILE	126-98-7				8260C			8260C		5		0.005	
METHAMIDOPHOS	10265-92-6												
METHANOL	67-56-1				8015D			8015D		1		1.5	
METHOMYL	16752-77-5				8321A			8321A		1.5		0.015	
METHOXYCHLOR	72-43-5				8270D			8270D		10			
METHOXYETHANOL, 2-	109-86-4												
METHYL ACETATE	79-20-9												

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		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
METHYL ACRYLATE	96-33-3				8260C			8260C		5		0.005	
METHYL CHLORIDE	74-87-3				8260C			8260C		0.5		0.05	
METHYL ETHYL KETONE	78-93-3				8260C			8260C		2.5		0.25	
METHYL HYDRAZINE	60-34-4				-			-		-		-	
METHYL ISOAMYL KETONE	110-12-3				-			-		-		-	
METHYL ISOBUTYL KETONE	108-10-1				8260C			8260C		2.5		0.25	
METHYL ISOCYANATE	624-83-9				-			-		-		-	
METHYL MERCAPTAN	74-93-1				-			-		-		-	
METHYL METHACRYLATE	80-62-6				8260C			8260C		2.5		0.25	
METHYL METHANESULFONATE	66-27-3				8270D			8270D		10		-	
METHYL PARATHION	298-00-0				8141A			8141A		1.2		0.06	
METHYL STYRENE (MIXED ISOMERS)	25013-15-4				-			-		-		-	
METHYL TERT-BUTYL ETHER (MTBE)	1634-04-4				8260C			8260C		0.5		0.05	
METHYLAMINE	74-89-5				-			-		-		-	
METHYLCHLOROPHENOXYACETIC ACID (MCPA)	94-74-9				8151A			8151A		0.56		0.003	
METHYLENE BIS(2-CHLOROANILINE), 4,4'-	101-14-4				8270D			8270D		-		-	
METHYLNAPHTHALENE, 2-	91-57-6				8270D			8270D		10		0.66	
METHYLSTYRENE, ALPHA	98-83-9				-			-		-		-	
MEVINPHOS	7786-34-7				8270D			8270D		10		0.08	
MONOCROTOPHOS	6923-22-4				8270D			8270D		40		-	
NAPHTHALENE	91-20-3				8270D			8270D		10		0.66	
NAPHTHOQUINONE, 1,4-	130-15-4				8270D			8270D		10		-	
NAPHTHYLAMINE, 1-	134-32-7				8270D			8270D		10		-	
NAPHTHYLAMINE, 2-	91-59-8				8270D			8270D		10		-	
NAPROPAMIDE	15299-99-7				525.2			8270D		0.06		-	
NITROANILINE, M-	99-09-2				8270D			8270D		50		3.3	
NITROANILINE, O-	88-74-4				8270D			8270D		50		3.3	
NITROANILINE, P-	100-01-6				8270D			8270D		20		-	
NITROBENZENE	98-95-3				8270D			8270D		10		0.66	
NITROPHENOL, 2-	88-75-5				8270D			8270D		10		0.66	
NITROPHENOL, 4-	100-02-7				8270D			8270D		50		3.3	
NITROPROPANE, 2-	79-46-9				8260C			8260C		5		0.005	
NITROQUINOLINE-1-OXIDE, 4-	56-57-5				8270D			8270D		40		-	
NITROSODIETHYLAMINE, N-	55-18-5				8270D			8270D		20		-	
NITROSODIMETHYLAMINE, N-	62-75-9				8270D			8270D		20		-	
NITROSO-DI-N-BUTYLAMINE, N-	924-16-3				8270D			8270D		10		-	
NITROSODI-N-PROPYLAMINE, N-	621-64-7				8270D			8270D		10		0.66	
NITROSODIPHENYLAMINE, N-	86-30-6				8270D			8270D		10		0.66	
NITROSO-N-ETHYLUREA, N-	759-73-9				-			-		-		-	
OCTYL PHTHALATE, DI-N-	117-84-0				8270D			8270D		10		0.66	
OXAMYL (VYDATE)	23135-22-0				8321A			8321A		0.3		0.015	
PARATHION	56-38-2				8270D			8270D		10		-	
PCB-1016 (AROCLOR)	12674-11-2				8082			8082		0.05		0.05	
PCB-1221 (AROCLOR)	11104-28-2				8082			8082		0.05		0.05	
PCB-1232 (AROCLOR)	11141-16-5				8082			8082		0.05		0.05	
PCB-1242 (AROCLOR)	53469-21-9				8082			8082		0.05		0.05	

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REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER	SOIL
					TYPE	VALUE				TYPE	VALUE	(µg/L)	(mg/kg)
PCB-1248 (AROCLOR)	12672-29-6		8082		8082				0.05		0.05		
PCB-1254 (AROCLOR)	11097-69-1		8082		8082				0.05		0.05		
PCB-1260 (AROCLOR)	11096-82-5		8082		8082				0.05		0.05		
PEBULATE	1114-71-2		525.2		8270D				0.08				
PENTABORANE	19624-22-7												
PENTACHLOROBENZENE	608-93-5		8270D		8270D				10				
PENTACHLOROETHANE	76-01-7		8270D		8270D				5		0.001		
PENTACHLORONITROBENZENE	82-68-8		8270D		8270D				20				
PENTACHLOROPHENOL	87-86-5		525.2		8270D				2		3.3		
PERCHLOROMETHYL MERCAPTAN	594-42-3												
PHENACETIN	62-44-2		8270D		8270D				20				
PHENANTHRENE	85-01-8		8270D		8270D				10		0.66		
PHENOL	108-95-2		8270D		8270D				10		0.66		
PHENYL MERCAPTAN	108-98-5		8270D		8270D				20				
PHENYLENEDIAMINE, M-	108-45-2		8270D		8270D				10				
PHENYLPHENOL, 2-	90-43-7												
PHORATE	298-02-2		8270D		8270D				10		0.02		
PHTHALIC ANHYDRIDE	85-44-9		8270D		8270D				100				
PICLORAM	1918-02-1		8151A		8151A				1.4				
PICOLINE, 2-	109-06-8		8270D		8270D								
POLYCHLORINATED BIPHENYLS (AROCLORS) (PCBS)	1336-36-3		8082		8082								
PRONAMIDE	23950-58-5		8270D		8270D				10				
PROPANIL	709-98-8												
PROPANOL, 1-	71-23-8		8260C		8260C				5		0.005		
PROPANOL, 2- (ISOPROPYL ALCOHOL)	67-63-0		8260C		8260C				5		0.005		
PROPHAM	122-42-9		8321A		8321A				0.4		0.012		
PROPIOLACTONE, BETA	57-57-8		8260C		8260C				5		0.005		
PROPIONIC ACID	79-09-4												
PROPIONITRILE (ETHYL CYANIDE)	107-12-0		8260C		8260C				5		0.05		
PROPYLBENZENE, N-	103-65-1		8260C		8260C				0.5		0.005		
PROPYLENE IMINE	75-55-8												
PROPYLENE OXIDE	75-56-9		D3695						1000				
PYRENE	129-00-0		8270D		8270D				10		0.66		
PYRETHRUM	8003-34-7												
PYRIDINE	110-86-1		8270D		8270D								
QUINOLINE	91-22-5												
QUINONE (p-BENZOQUINONE)	106-51-4		8270D		8270D				10				
QUIZALOFOP (ASSURE)	76578-14-8												
RESORCINOL	108-46-3		8270D		8270D				100				
RONNEL	299-84-3		8141A		8141A				0.7		0.035		
SIMAZINE	122-34-9		525.2		8270D				0.15				
STRYCHNINE	57-24-9		8270D		8270D				40				
STYRENE	100-42-5		8260C		8260C				0.5		0.05		
SULFIDE	18496-25-8												
SULFUR MONOCHLORIDE	10025-67-9												
TEBUTHIURON	34014-18-1		8321A		8321A				0.5		0.021		
TEPP	107-49-3		8141A		8141A				8		0.4		

Table IV-10
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Organics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHODS (µg/L)					SOILS METHODS (mg/kg)					PQL	
		ORG	METHOD	APPARATUS	DETECTION LIMIT		ORG	METHOD	APPARATUS	DETECTION LIMIT		GROUNDWATER (µg/L)	SOIL (mg/kg)
					TYPE	VALUE				TYPE	VALUE		
TERBACIL	5902-51-2				525.2			8270D		2.1			
TERBUFOS	13071-79-9				525.2			8270D		0.096			
TETRACHLOROBENZENE, 1,2,4,5-	95-94-3				8270D			8270D		20			
TETRACHLORODIBENZO-P-DIOXIN, 2,3,7,8- (TCDD Equivalents))	1746-01-6				8280A			8280A		0.01		0.001	
TETRACHLOROETHANE, 1,1,1,2-	630-20-6				8260C			8260C		0.5		0.05	
TETRACHLOROETHANE, 1,1,2,2-	79-34-5				8260C			8260C		0.5		0.05	
TETRACHLOROETHYLENE (PCE)	127-18-4				8260C			8260C		0.5		0.05	
TETRACHLOROPHENOL, 2,3,4,6-	58-90-2				8270D			8270D		10			
TETRAETHYL LEAD	78-00-2												
TETRAETHYLDITHIOPYROPHOSPHATE	3689-24-5				8270D			8270D		20			
TETRAHYDROFURAN	109-99-9												
TETRANITROMETHANE	509-14-8												
THIOFANOX	39196-18-4				8321A			8321A					
THIONAZIN	297-97-2				8270D			8270D		20			
THIRAM	137-26-8												
TOLUENE	108-88-3				8260C			8260C		0.5		0.05	
TOLUIDINE, M-	108-44-1												
TOLUIDINE, O	95-53-4				8270D			8270D		10			
TOLUIDINE, P-	106-49-0												
TOXAPHENE	8001-35-2				8081B			8081B		0.5		0.1	
TRIALLATE	2303-17-5												
TRIBROMOMETHANE (BROMOFORM)	75-25-2				8260C			8260C		0.5		0.05	
TRICHLORO-1,2,2-TRIFLUOROETHANE, 1,1,2-	76-13-1												
TRICHLOROBENZENE, 1,2,4-	120-82-1				8260C			8260C		0.5		0.05	
TRICHLOROBENZENE, 1,3,5-	180-70-3				8121			8121		120		8040	
TRICHLOROETHANE, 1,1,1-	71-55-6				8260C			8260C		0.5		0.05	
TRICHLOROETHANE, 1,1,2-	79-00-5				8260C			8260C		0.5		0.05	
TRICHLOROETHYLENE (TCE)	79-01-6				8260C			8260C		0.5		0.05	
TRICHLOROPHENOL, 2,4,5-	95-95-4				8270D			8270D		10		0.66	
TRICHLOROPHENOL, 2,4,6-	88-06-2				8270D			8270D		10		0.66	
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	93-76-5				8151A			8151A		0.8			
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	93-72-1				8151A			8151A		0.75		0.0028	
TRICHLOROPROPANE, 1,1,2-	598-77-6												
TRICHLOROPROPANE, 1,2,3-	96-18-4				8260C			8260C		0.5		0.05	
TRICHLOROPROPENE, 1,2,3-	96-19-5												
TRIETHYLAMINE	121-44-8												
TRIETHYLPHOSPHOROTHIOATE, O,O,O-	126-68-1				8270D			8270D					
TRIFLURALIN	1582-09-8				525.2			8270D		0.096			
TRIMETHYLBENZENE, 1,3,4- (TRIMETHYLBENZENE, 1,2,4-)	95-63-6				8260C			8260C		0.5		0.05	
TRIMETHYLBENZENE, 1,3,5-	108-67-8				8260C					0.5		0.05	
TRINITROGLYCEROL (NITROGLYCERIN)	55-63-0												

~~Table IV-10~~
~~Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils~~
~~Organics~~

~~REGULATED SUBSTANCE~~	~~CASRN~~	~~AQUEOUS METHODS (µg/L)~~					~~SOILS METHODS (mg/kg)~~					~~PQL~~	
		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~ORG~~	~~METHOD~~	~~APPARATUS~~	~~DETECTION LIMIT~~		~~GROUNDWATER~~	~~SOIL~~
					~~TYPE~~	~~VALUE~~				~~TYPE~~	~~VALUE~~	~~(µg/L)~~	~~(mg/kg)~~
TRINITROTOLUENE, 2,4,6-	118-96-7				-	-		-	-	-	-	-	-
VINYL ACETATE	108-05-4				8260C	0.5		8260C		8260C	0.5	0.5	0.05
VINYL BROMIDE (BROMOETHENE)	593-60-2				-	-		-	-	-	-	-	-
VINYL CHLORIDE	75-01-4				8260C	0.5		8260C		8260C	0.5	0.5	0.05
WARFARIN	81-81-2				-	-		-	-	-	-	-	-
XYLENES (TOTAL)	1330-20-7				8260C	1		8260C		8260C	1	1	0.1
ZINEB	12122-67-7				-	-		-	-	-	-	-	-

Table III-9
Analytical Methodologies for Establishing Quantitation Limits in Groundwater and Soils
Inorganics

REGULATED SUBSTANCE	CASRN	AQUEOUS METHOD	SOIL METHOD	AQUEOUS PQL (µg/L)	SOIL PQL (mg/kg)
ALUMINUM	7429-90-5	6010C	-	30	-
AMMONIA	7664-41-7	-	-	-	-
ANTIMONY	7440-36-0	6010C	-	32	-
ARSENIC	7440-38-2	200.8	-	0.1	-
ASBESTOS	12001-29-5	-	-	-	-
BARIUM AND COMPOUNDS	7440-39-3	6010C	-	1	-
BERYLLIUM	7440-41-7	6010C	-	0.2	-
BORON AND COMPOUNDS	7440-42-8	6010C	-	4	-
CADMIUM	7440-43-9	200.8	-	0.03	-
CHROMIUM(Total)	7440-47-3	200.8	-	0.08	-
CHROMIUM VI	18540-29-9	200.8	-	1	-
COBALT	7440-48-4	6010	-	5	-
COPPER	7440-50-8	6010C	-	4	-
CYANIDE, FREE	57-12-5	1310A	-	1	-
FLUORIDE	16984-48-8	9056A	-	5	-
IRON	7439-89-6	6010C	-	4	-
LEAD	7439-92-1	200.8	-	0.02	-
LITHIUM	7439-93-2	6010C	-	2.8	-
MANGANESE	7439-96-5	6010C	-	1	-
MERCURY	7439-97-6	7470A	7471A	0.2	0.2
MOLYBDENUM	7439-98-7	6010C	-	5.3	-
NICKEL	7440-02-0	6010C	-	10	-
NITRATE-NITROGEN (TOTAL)	14797-55-8	-	-	-	-
NITRITE-NITROGEN (TOTAL)	14797-65-0	-	-	-	-
PERCHLORATE	7790-98-9	314	-	0.53	-
SELENIUM	7782-49-2	200.8	-	0.5	-
SILVER	7440-22-4	6010C	-	5	-
STRONTIUM	7440-24-6	6010C	-	0.28	-
THALLIUM	7440-28-0	6010C	-	27	-
TIN	7440-31-5	6010C	-	17	-
VANADIUM	7440-62-2	6010C	-	8	-
ZINC	7440-66-6	6010C	-	1	-

~~F.~~G. Site-Specific Human Health Risk Assessment Guidance

1. Introduction~~Introduction~~

This Section provides general guidelines on the methodology of risk assessment and the risk assessment report for human health evaluation under Act 2. Regulations regarding risk assessment are in Chapter 250, Subchapter F. This section of the guidance document does not address issues related to ecological risk assessment. Ecological risk assessment is addressed in Section III.H.

Prior to performing a risk assessment, it is important to clearly define the problem that is to be addressed, the objectives of the study and how the results will be used to meet these objectives. This initial step is critical to ensure a successful outcome (accurate, protective, timely, cost-effective evaluation) and that the level of effort is commensurate with the scope of the problem.

Risk assessment procedures have been well defined in various Environmental Protection Agency (EPA) guidance documents. The process does not need to be reiterated in this document. Instead certain key issues pertinent to site-specific evaluations under Act 2 are discussed subsequently.

For risk assessment issues not directly addressed in this document, remediators may consult the most recent EPA and ASTM guidelines, such as those listed on Table III-10, for additional guidance. For petroleum release sites, the risk assessment methodology in ASTM E 1739 (Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites) may be consulted for further guidance.

A suggested outline for the risk assessment report is provided in Section II.C.7.b of the manual. The outline is intended to provide guidance on minimum requirements for the report.

2. When to Perform a Risk Assessment

~~This Section provides general guidelines on the methodology of risk assessment and risk assessment report for human health evaluation under Act 2. Regulations regarding risk assessment are in Chapter 250, Subchapter F~~Subchapter F. ~~This guidance document does not address issues related to ecological risk assessment. Ecological risk assessment is addressed in Section IV.H~~Section III.H.

Remediators selecting the site-specific standard established by Section 304 of Act 2 should submit a risk assessment report to the Department for review and approval unless no present or future complete exposure pathways exist as demonstrated in the fate and transport analysis in the site-specific remedial investigation. The exposure scenarios (*e.g.*, residential, industrial, recreational), which will define the exposure pathways, must be based on site-specific land use considerations. The pathways, which describe the mechanism by which receptors may be exposed to a source, are also site-specific. Detailed guidance on land use determination and identification of exposure scenarios and pathways are addressed in Section IV.G.2.b.i of this document and references cited therein. A risk assessment only needs to be performed if complete exposure pathways for human receptors exist under current or potential future conditions. If engineering or institutional controls that are to be

implemented will eliminate all exposure pathways, a risk assessment report is not required.

~~Any person selecting the site-specific standard established by Section 304 of Act 2 should submit a risk assessment report to the Department for review and approval unless no present or future complete exposure pathways exist as demonstrated by a fate and transport analysis. If no complete exposure pathways exist, a risk assessment report and cleanup plan are not required and no remedy is required to be proposed or completed. If complete exposure pathways exist, the fate and transport analysis, which is a part of the exposure assessment, should be documented in the risk assessment report.~~

~~Under Act 2, a risk assessment report may include the following:~~

- ~~a baseline risk assessment report that describes the potential adverse effects to both human and ecological receptors under both current and planned probable future conditions caused by the presence of regulated substances in the absence of any further control, remediation or mitigation measures;~~
- ~~a risk assessment report that documents which exposure pathways will be eliminated excluded by a pathway elimination measure so thatto prevent any substantial present or probable future risk to human health or the environment is eliminated;~~
- ~~a risk assessment to develop a site-specific standards report that describes the methods used to develop site-specific concentration levels at which human health and the environment are protected; and~~
- ~~the comments obtained as a result of a public involvement plan, if any, and the responses to those public comments.~~

A baseline risk assessment report is not required if the Department, in its remedial investigation report or cleanup plan approval, determines that a specific remediation measure that eliminates all pathways, other than a no-action remedial alternative, can be implemented to attain the site-specific standard. ~~[Section 250.405(c)~~[Section 250.405(c)]. A baseline risk assessment is an evaluation of risk prior to, or in the absence of, a remedial measure. When the remedial measure has been completed a residual risk assessment that evaluates risks posed by post-remediation contamination, if present, is required in order to demonstrate attainment of the site-specific standard.~~All current or probable future exposure pathways as identified in the fate and transport analysis should be addressed in the risk assessment to develop the site-specific standards report.~~

~~4. Introduction~~

~~To determine if a site-specific risk assessment for human health evaluation is necessary, a site conceptual model should be developed that defines potential exposure scenarios and pathways. The exposure scenario (*e.g.*, residential, industrial, recreational) which will define the exposure pathways must be based on site-specific land use considerations. The pathways, which describe the mechanism by which receptors may be exposed to a source are also site-specific. Detailed guidance on land use determination and identification of exposure scenarios and pathways are~~

~~addressed in Section IV.G.2.b.i~~Section IV.G.2.b.i ~~of this document and references cited therein. A risk assessment only needs to be performed if complete exposure pathways for human receptors exist under current or future planned~~ possible ~~conditions. If engineering or institutional controls that are to be implemented will eliminate all exposure pathways, the risk assessment report does not need to include information regarding quantification of exposure, toxicity assessment, risk algorithm and risk calculation as identified in Section II.C.7.b~~Section II.C.7.b ~~of this manual.~~

~~However, before getting into the mechanics of performing the assessment, it is important to clearly define the problem that is to be addressed, the objectives of the study and how the results will be used to meet these objectives. This initial step is critical to ensure a successful outcome (accurate, protective, timely, cost-effective evaluation) and that the level of effort is commensurate with the scope of the problem.~~

~~Risk assessment procedures have been well-defined in various Environmental Protection Agency (EPA) guidance documents. The process will not be reiterated in this document. Instead certain key issues pertinent to site-specific evaluations under Act 2 are discussed subsequently.~~

~~For risk assessment issues not directly addressed in this document, a person may consult the most recent EPA and ASTM guidelines, such as those listed on Table IV-12~~Table III-10~~, for additional guidance. For petroleum release sites, the risk assessment methodology in ASTM E 1739 (Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites) may be consulted for further guidance.~~

~~A suggested outline for the risk assessment report is provided in Section II.C.7.b of the manual. The outline is intended to provided guidance on minimum requirements for the report.~~

~~5.~~3. Risk Assessment for Human Health [~~Section 250.602(c)~~Section 250.602(c)]

A risk assessment for human exposure from contaminated sites consists of the following four steps:

(1) ~~site~~Site characterization~~;~~

(2) ~~exposure~~Exposure assessment~~;~~

(3) ~~toxicity~~Toxicity assessment~~; and~~

(4) ~~risk~~Risk characterization that evaluates if the risks meet the human health protection goals specified in subsections 304(b) and (c) of Act 2.

The following discussions address key issues pertinent to these four steps of risk assessment for human exposure:

a) Site Characterization [~~Section 250.602(c)(1)~~Section 250.602(c)(1)]

i) Chemicals of concern

The initial steps of the site characterization are to review the analytical data and to select the chemicals of concern that are identified in distinct areas of contamination at the site. Under Act 2 there are two possible situations in determining the chemicals of concern in a baseline risk assessment under the site-specific standard: (1) strictly using the site-specific standard, or (2) a combination of standards using site-specific and Statewide health, site-specific and background, or all three standards. These situations are discussed separately below.

In the first situation of using only the site-specific standard, the chemicals of concern can be screened using the EPA Regional Screening Level~~Region III Risk Based Concentration~~ (~~RBC~~RSL) screening procedures. The purpose of this screening procedure is only for potential reduction of the number of chemicals carried through the risk assessment. Those chemicals on the site whose maximum concentration exceeds the ~~RBC~~ RSL values for carcinogenic effects or $1/10^{th}$ of the ~~RBC~~ RSL values (HQ=0.1) for noncarcinogenic effects should be retained in the risk assessment. Chemicals on the site at maximum concentration below the ~~RBC~~ RSL values for carcinogenic effects or $1/10^{th}$ of the ~~RBC~~ RSL values for noncarcinogenic effects may be dropped from the risk assessment unless other contaminant-specific or site-specific considerations suggest that the inclusion of these constituents in the risk assessment is more appropriate to determine the total risk of the site. Chemicals that are not retained in the risk assessment may be considered having minimal influence on total risk.

T~~In t~~he second situation ~~of~~ uses~~using~~ a combination of the site-specific standard with one or both of the other two standards~~,~~ ~~t~~The ~~list of~~ chemicals of concern to be addressed in the ~~site-specific~~ risk assessment should include those ~~onsite~~ chemicals that ~~comply~~ cannot be addressed ~~with neither~~using either the Statewide health standard ~~nor~~ or the background standard. The chemicals of concern identified for evaluation in the risk assessment may then be screened using the same RSL screening procedures mentioned above.

As described in Section II.2.C, soil MSCs are selected by comparing the soil to groundwater and direct contact numeric values and choosing the higher of the two. ~~In the special circumstance when~~If ~~an EC is being used to eliminate~~pathway elimination is being used to address groundwater exposure under the SSS, direct contact is the only pathway of concern for soil. As a result, in this situation the contaminants to be evaluated in the risk assessment can ~~the soil concentrations that do not meet~~be determined by a comparison to the direct contact numeric values. ~~need to be evaluated in a risk assessment. The soil concentrations that do meet the direct contact values should then be taken through the SHS process.~~ This is only applicable under a combination of standards because groundwater exposure ~~pathways are being~~is being eliminated using ~~an EC~~pathway elimination which is only applicable to the SSS. ~~The chemicals of concern may be further screened or re-included using the same RBC RSL screening procedures mentioned above.~~

~~Chemical concentrations should also be compared to blank concentrations. If the blank samples contain detectable levels of common laboratory contaminants, then~~

Comment [B5]: Moved to data review section

~~the sample results should be considered as positive results only if the concentrations in the sample exceed ten times the maximum amount detected in the blank. If the concentration is less than ten times the blank contaminant level, it is concluded that the chemical was not detected in the sample and the blank-related chemical concentration is considered to be the quantitation limit for the chemical in that sample. If all samples contain levels of a common laboratory contaminant that are less than ten times the level of contamination noted in the blank, then completely eliminate that chemical from the set of sample results. Common laboratory contaminants include acetone, 2-butanone (methyl ethyl ketone), methylene chloride, toluene, and phthalate esters.~~

~~If the blank samples contain constituents other than common laboratory contaminants, then the sample results should be considered as positive results only if the concentrations in the sample exceed five times the maximum amount detected in a any blank. As with the common laboratory contaminants, if the concentration is less than five times the blank constituent level, it is concluded that the constituent was not detected in the sample and the blank-related chemical concentration is considered to be the quantitation limit for the chemical in that sample. Again, if all samples contain levels of a constituent other than common laboratory contaminants that are less than five times the level of contamination noted in the blank, then completely eliminate that chemical from the set of sample results.~~

Three other factors should be considered when deciding to retain constituents for the risk assessment. Specifically, these factors include the constituent's toxicity, mobility and persistence. Toxicity is obviously a driving force when determining if exposure to a site poses any adverse impact to human health or the environment. Some constituents may be frequently detected at a site, but may be considered relatively innocuous or toxicologically inert. These constituents should not be retained for the risk assessment. In contrast, some constituents may be infrequently detected, but may be relatively more toxic than most constituents. Regardless of the constituent's frequency of detection, its presence (assuming it is not anomalous) may deem it necessary to be retained as a constituent of concern.

The mobility of a constituent dictates what receptors on and off site may be potentially affected and consequently whether the constituent should be retained in the assessment. Physical and chemical properties of a compound control its transport and fate in the environment. For example, these attributes determine whether a constituent will readily volatilize into the air or be transported via advection or diffusion through the soil, groundwater and surface water. These characteristics also describe a chemical s tendency to adsorb onto soil/sediment particles, in turn reducing its mobility through the environment.

Finally, the persistence of a chemical in the environment determines whether further receptors would be impacted. The persistence of a chemical in the environment depends on factors such as microbial content of soil and water and the ability of these organisms to degrade the chemical. In addition, chemical and photochemical degradation may contribute to the elimination of a particular compound. Although the parent compound may be eliminated, the byproducts of the degradation of that compound must also be considered and evaluated. These chemical-specific factors

will also be used to determine whether a constituent and its byproducts are retained for the risk assessment.

~~To document attainment in order to obtain liability protection under Act 2, frequency of detection should not be used as a means for determining whether a constituent is retained for the risk assessment. However, infrequently detected constituents that are anomalies due to sampling, analytical or other problems would not be retained in the risk assessment.~~

Comment [B6]: Removed because stated in above paragraph

In general, liability protection is not afforded under the site-specific standard for those chemicals that are not identified as contamination at a site and for which attainment has not been demonstrated.

ii) ~~Site conceptual~~Conceptual site model

Development of a ~~site~~ conceptual site model is an important step in identifying additional data needs in site characterization and in defining exposure. A ~~site~~ conceptual site model identifies all potential or suspected sources of contamination, types and concentrations of contaminants detected at the site, potentially contaminated media, potential exposure pathways and receptors. Many components of exposure (such as the source, receptors, migration pathways and routes of exposure) are determined on a site-specific basis. The ~~site~~ conceptual site model provides a systematic way to identify and summarize this information to ensure that potential exposures at the site are accounted for accurately.

The conceptual site model may be graphical, tabular or narrative but should provide an accurate understanding of complete exposure pathways for the site. Examples of ~~site~~ conceptual site models may be found in EPA or ASTM guidance documents, including Section 4.2 of RAGS Part A (EPA, 1989a) and the ASTM RBCA Tier 2 guidance manual (ASTM, 1995). It is suggested that the development of the ~~site~~ conceptual site model be coordinated with the regulatory risk manager to ensure that potential pathways and receptors are adequately and appropriately addressed prior to performing the assessment.

b) Exposure Assessment [Sections ~~250.603~~250.603 and ~~250.604~~250.604]

The exposure assessment determines or estimates (qualitatively or quantitatively) the magnitude, frequency, duration and routes of exposure. The assessment is typically performed in three steps:

(1) Characterization of the exposure setting including:

- the physical setting
- potential exposed populations

(2) Identification of complete exposure pathways which includes:

- sources and receiving media
- fate and transport in the release media
- exposure points and exposure routes

a) The information on sources, fate and transport (including biodegradation), exposure points and exposure routes are then integrated to determine the potential exposure pathways. Complete pathways exist when all components are present. Information for complete pathways should be summarized.

(3) Quantification of exposure of the receptor including:

- environmental concentration
- intake

The exposure assessment process is well defined in various EPA guidance documents ~~(including primarily EPA 1989a, 1991a,b and 1992b but see also the attached list of select references)~~ and is not reiterated here. This section discusses some key issues pertaining to performing the site-specific exposure assessments.

i) Exposure Scenarios and Exposure pathways

Exposure Pathways: The exposure pathway describes the mechanism by which receptors (individuals~~, or~~ populations, and ecological receptors) may be exposed to the source. Pathways consist of a source, receptor, route of exposure and a transport mechanism, if the exposure point is not the same as the source. The analysis of the fate and transport of the chemical can help to predict future exposures, to link sources with currently contaminated media and to identify exposure pathways. The intent of the fate and transport analysis at this stage is to identify media that are receiving or may receive site-related chemicals. The EPA provides guidance ~~(e.g., EPA, 1989a)~~ on fate and transport analysis.

As discussed above, the site conceptual model is useful in defining potential exposure pathways. However, only complete pathways should be advanced through the assessment process. The effects of engineering or institutional controls that are to be implemented, which will eliminate exposure pathways, must be considered for the conceptual model development. The EPA provides guidance (*e.g.*, EPA, 1989a, 1991a,b, 1996a) on potential pathways for given land use scenarios.

Realistic current and future land use scenarios (*e.g.*, residential, industrial, agricultural, etc.) provide the basis for selecting the controlling exposure scenarios/pathways. Guidance on land use considerations can be found in the EPA OSWER Directive*: Land Use in The CERCLA Remedy Selection Process* (1995) as well as earlier EPA guidance on exposure assessments as referenced above. Sources and types of information that may aid in determining the reasonably anticipated future land use include, but are not limited to:

- Current land use
- Zoning laws
- Zoning maps
- Comprehensive community master plans
- Local land use authorities
- Local officials

- Population growth patterns and Bureau of Census projections
- Accessibility of site to existing infrastructure (such as transportation and public utilities)
- Institutional controls currently in place
- Site location in relation to urban, residential, commercial, industrial, agricultural and recreational areas
- Federal/State land use designation (such as state parks)
- Historical or recent development patterns
- Cultural factors (such as historical sites)
- Natural resources information
- Stakeholder input - allows for all affected parties to define land use
- Location of onsite or nearby wetlands
- Proximity of site to a floodplain
- Proximity of site to critical habitats of endangered or threatened species
- Geographic and geologic information
- Location of wellhead protection areas, recharge areas, and other areas identified in the state's Comprehensive Groundwater Protection Program.

These types of information should be considered when developing the assumptions about future land use.

Some direct pathways, such as direct ingestion of soil or groundwater and direct inhalation of volatiles and/or particulates from soil, are fairly well established and can be used routinely where they have been identified as complete pathways. At issue would be defining appropriate exposure factors (such as intake rate for the given population) since these factors exhibit a range of possible values. Typically, the choice of factors (high-end exposure vs. average exposure) is defined by the level of conservatism desired.

Dermal contact (with soil or groundwater), on the other hand, is less well defined particularly in terms of estimating intake (the mass of substance in contact with the body per unit body weight per unit time) and more importantly absorbed dose (intake multiplied by an absorption factor to account for mass actually in the body). This pathway is best addressed at a site-specific level when identified as relevant. Although there is some guidance (EPA, 1991c), professional judgment may play a significant role in estimating dermal exposure. The rationale behind these judgments (and indeed professional judgments wherever they are used) and, as far as possible, documented evidence in support of these judgments should be clearly provided.

Some indirect pathways (*e.g.*, inhalation of vapors via intrusion into enclosed spaces), are also best addressed on a site-specific basis because of the inherent uncertainty associated with the defining the transport from the source to the

receptor. In the case of vapor intrusion into enclosed spaces, for example, actual data from direct measurements, *i.e.*, a monitoring approach, would be preferred to the use of models which have been shown to be imprecise (EPA, 1996a; PA RA Subcommittee, 1996). Other indirect pathways (*e.g.*, soil leaching to groundwater and subsequent ingestion of groundwater) can be addressed by simple analytical models. Although site-specific data inputs to these models are typically favored as producing a more realistic estimate of exposure, site-specific data may not be accessible. The use of a combination of default and site-specific parameters may be used provided the rationale for the choice of values is included.

Receptors and Human Exposure Factors: Receptors should be defined on a site-specific basis taking into account future land use considerations. Guidance on potential receptors for given land use are provided in EPA guidances (EPA 1989a, 1991a,b). Care should be taken to identify potential sensitive subpopulations (*e.g.*, children) as appropriate for site-specific conditions.

~~Section 250.603~~Section 250.603 of the regulations specifies requirements to select exposure factors. A risk assessment may use site-specific exposure factors in accordance with EPA's Final Guidelines for Exposure Assessment, 1992 (57 FR 22888-22938) or exposure factors used in the development of the Statewide health standards identified in Subchapter C of the regulations. Site-specific exposure factors shall be clearly justified by supporting data.

Human exposure factors may be divided into receptor physiologic parameters (*e.g.*, body weight, skin surface area); contact rate (*e.g.*, consumption of water, soil ingestion rate); and time activity patterns (*e.g.*, time spent indoors/outdoors, time spent at work). Some of these variables, particularly the physiologic parameters, have been well characterized but others such as time/activity patterns are less well documented. All parameters are subject to variability (true heterogeneity) and/or uncertainty (ignorance about a measurement). Thus, a range of values may be available for any given parameter. The choice will depend to some extent on the problem and the level of conservatism desired. Typical sources for these parameters are the EPA Exposure Factors Handbook (~~1996d~~2011) ~~which is in the process of being updated~~ and the American Industrial Health Council (AIHC) Exposure Factors Sourcebook (AIHC, 1994) ~~also being updated~~.

Fate and Transport Parameters and Models: Constituents of concern can both migrate (via leaching, advection, dispersion) and transform (via biodegradation, hydrolysis, photolysis) in the environment. These migration and transformation processes must be considered when determining environmental concentration under indirect exposure. A range of fate and transport models (from simple analytical to complex numerical) are available to account for these processes. However, the level of site-specific data needed to make proper use of the models also increases with the level of sophistication of the model (*i.e.,* the increase of model technical capabilities). A tiered approach, based on level of model complexity, is best, *i.e.*, using the least resource intensive method to achieve the objective of the evaluation. The selected model must adequately represent the physical setting (*e.g.,* the geometric configuration of hydrogeological systems, soil profiles, river widths and depths, etc.) and migration and transformation processes that affect the problem. Input

parameter values should be representative of field conditions. The choice of model and input parameters will need to be justified as appropriate for given site-specific conditions. Justifications should include why a model is appropriate when limitations of the selected model are considered. In addition, some measure of model validation will be required. This may be as simple as corroborating the conservative assumptions with field measurements.

~~For the application of a groundwater model, the following quality assurance and quality control procedures as described in Chapter 6 (relating to Models and Computers in Ground-Water Investigation) of EPA's Ground Water Handbook (EPA, 1991d) should be considered:~~

- ~~Verification of the mathematical basis of a model by comparing its output with known analytical solutions to specific problems.~~
- ~~Validation of the applicability of a model to various problem categories by successful simulation of observed field data.~~
  - ~~i) Calibrating the model using one set of historical records: the aquifer coefficients and other model parameters are adjusted to achieve the best match between model outputs and known data.~~
  - ~~ii) Attempting to predict a subsequent set of historical records: No adjustments are made except for actual changes. A mismatch means that the model either is not correctly formulated or does not treat all of the important phenomena affecting the actual field situation.~~
- ~~Benchmarking the efficiency of a model in solving problems by comparison with the performance of other models.~~
- ~~Critical review of the problem conceptualization to ensure that the modeling effort considers all physical, chemical, and biological processes that may affect the problem.~~
- ~~Evaluation of the specifics of the model's application, e.g., appropriateness of the boundary conditions, grid design, time steps, etc. Calibration and sensitivity analysis to determine if the model outputs vary greatly with changes in input parameters are important aspects of this process.~~

Comment [B7]: Removed because not applicable to this section.

For selection of groundwater models~~, some important technical capabilities for groundwater models are identified in Table IV-13. Additional guidance on the selection and use of fate and transport models can be found in the EPA and ASTM documents listed in Table IV-14.~~ refer to section III.A of this manual.

The use of monitoring methods may also be appropriate for defining environmental fate as in the case of natural attenuation. All supporting data should be provided to support such an evaluation. ~~ASTM is in the process of developing a guide for addressing natural attenuation.~~

Generic vs. Site-Specific Considerations:

In general, risk assessments should be based upon realistic exposure scenarios using current or planned future land use, incorporating any changes from early response

actions known or planned. Site-specific information on exposure pathways, receptors and exposure factors, including actual data, should be used to the maximum extent possible.

However, not all exposure parameters need to be site-specific. Certain generic human physical parameters (*e.g.*, body weight ~~and air intake~~) that do not vary significantly in the general human population and, thus, from site to site are such exceptions. Default values, from single point estimates to distributions for these parameters, are available from such sources as the EPA Exposure Factors Handbook (EPA, ~~1989b~~2011) and the AIHC Exposure Factors Sourcebook (AIHC, 1994). ~~Both of these data sources are in the process of being updated. A draft update (EPA, 1996d) of the EPA Exposure Factors Handbook, 1989 version (EPA, 1989b) is undergoing final revisions.~~ Default values of single point estimates for these parameters are also available from ~~Subchapter C~~Subchapter C of the regulations.

Factors affecting the choice of exposure scenario (land use), complete exposure pathways, the distribution of contaminants in the media, the characteristics of the media, and the activity patterns and demographics of the surrounding populations should be considered, whenever possible, as site-specific. For example, if the planned future land use is industrial, the appropriate population would be adults and default physiological information may be obtained from the above named sources. However, if the concern is for a residential land use, children may be the population of concern. Default physiological information is still available from the above sources but the actual values would be different because the site-specific considerations dictate a different land use and receptor population.

It is possible that for a given situation, a sensitive subpopulation may be of concern (*e.g.*, pregnant women, subsistence fishermen). Some data for these populations may be available from national or regional surveys incorporated in the above sources but in some instances the data may need to be generated. The choice of data must be supported in the peer review literature and proved to be appropriately applied. For information generated on a site-specific basis, proper QA/QC measures should be exercised and the data should be generated with the understanding of the regulatory agency as to how the information will be used.

ii) Exposure characterization

Exposure characterization is the quantification step in the process. In the forward calculation of risk, both the environmental concentration and the intake must be determined. In the reverse calculation of site-specific standards, an acceptable concentration is derived based on intake and a predetermined level of risk.

~~Environmental~~ Exposure point Concentration: This is the concentration expected to be contacted over the exposure period. Since, risk assessments are typically performed for a chronic exposure scenario, *i.e.*, the contact period is long (typically 30-70 years), ~~an average concentration (or~~ an upper confidence limit on the ~~arithmetic average)~~mean is used. It is important, therefore, to assess the potential fate of the material in the environment to provide the best estimate of its environmental concentration over time. In some instances, short-term exposure is to

be evaluated, in which case some other metric (*e.g.*, maximum concentration) may be more appropriate. EPA OSWER Directive 9285.7-081 provides guidance on the concentration term.

Intake: Three types of variables are associated with defining intake: chemical related variables, *i.e.*, the concentration term and its associated fate and transport parameters; variables that describe the exposed population such as physiologic parameters, contact rate and time/activity patterns; and an assessment-determined variable, *i.e.*, the period over which the exposure is averaged.

Since most exposure factors exhibit both variability and uncertainty, ~~recent~~ EPA ~~guidance~~ encourages the development of a range of exposure (and risk) descriptors ~~(Habicht memo, EPA, 1992a; Browner, EPA, 1995b; Science Policy Council, EPA, 1995d)~~. The use of probabilistic analysis (such as Monte Carlo simulations) is one way to account for variability and uncertainty. However, these evaluations are resource intensive and so may be inappropriate for simple sites. Deterministic evaluations, *i.e.*, point estimates, are ~~a~~ useful alternatives. If single point estimates are developed, however, it is recommended that a most likely exposure (MLE) be quantified in addition to the typical high-end exposure (comparable to the reasonable maximum exposure or RME used in the generation of the Statewide health standards). In this way, a range of exposures can thus be provided as context for risk management decisions. Thus, even within the site-specific evaluation, a tiered approach may be useful (*i.e.*, from point estimates to ranges) depending on the level of sophistication required to address the problem at hand.

iii) Good exposure Assessment practices

As a fundamental practice, the methods and data used in the exposure assessment should clearly support the conclusions within the known and stated bounds of uncertainty. Documentation is a core principle of a good exposure assessment. Hawkins, Jayjock and Lynch (1992) provided eight general practices that make for good exposure assessments. Burmaster and Anderson (1994) further defined good practice as it relates to probabilistic assessments. It is suggested that exposure assessments be consistent with these practices as appropriate.

c) Toxicity Assessment [~~Section 250.605~~Section 250.605]

The purpose of toxicity assessment is to collect and weigh the available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide an estimate of the relationship between the extent of exposure to a contaminant and the increase likelihood and/or severity of adverse effects.

The carcinogenic and noncarcinogenic (systemic) effects of each chemical of concern at the site should be evaluated.

For toxicity assessment, the person should use appropriate reference doses and cancer slope factors from one of the following sources, in the order indicated:

a) Integrated Risk Information System (IRIS);

b) United States Environmental Protection Agency, National Center for Environmental Assessment (NCEA) Provisional Peer-Reviewed Toxicity Values (PPRTV).
c) Other sources
d) (i) Health Effects Assessment Summary Tables (HEAST)
e) (ii) Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles.
f) (iii) California EPA, California Cancer Potency Factors and Chronic Reference Exposure Levels.
g) (iv) EPA criteria documents, including drinking water criteria documents, drinking water health advisory summaries, ambient water quality criteria documents and air quality criteria documents.

~~b) Health Effects Assessment Summary Tables (HEAST);~~

~~c) United States Environmental Protection Agency, National Center for Environmental Assessment (NCEA) provisional values;~~

~~d) Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles;~~

~~e) California EPA, California Cancer Potency Factors; and~~

If no toxicity values are available from the sources identified above, the person may develop, for the Department's review in the risk assessment report, toxicity values from appropriately justified surrogates or chemical-specific toxicity values with consideration of the following:

- Available data should first be evaluated to determine the likelihood that the agent is a carcinogen. If the chemical is determined that it is likely or possibly a human carcinogen then a toxicity value (slope factor) should be calculated based on the most recent and available information from peer reviewed journals. EPA has developed its most recent approach for defining carcinogens and developing slope factors in the Proposed Guidelines for Carcinogen Risk Assessment (EPA, 1996b). This approach should be applied when determining whether a chemical is a carcinogen and determining its slope factors.
- A toxicity factor should also be developed for the potential noncarcinogenic effects based on the most recent and available information from peer reviewed journals. A reference dose is the toxicity value used most often in evaluating noncarcinogenic effects. EPA's Risk Assessment Guidance for Superfund describes the protocol for developing reference doses. Depending on the exposure duration anticipated at the site, a chronic reference dose would be developed for exposure expected to last 7 to 70 years; a subchronic reference dose would be calculated for exposure less than 7 years (EPA, 1989a).
- The toxicity value must be based on peer reviewed literature that includes all relevant sources of data and must be a balanced description of both positive and negative findings on the toxicity of the chemical, the weight of evidence supporting the toxicity value, and the main sources of uncertainty of the toxicity value documented in the risk assessment report's uncertainty section.

The toxicity of lead is not easily defined by the above approach. EPA has developed the Integrated Exposure Uptake Biokinetic (IEUBK) Model to determine cleanup numbers for children exposed to lead in soil under a residential exposure scenario. For adult exposure in either the residential or nonresidential scenario, the IEUBK model does not apply and other models, such as the Bower model (Bowers et al., 1994), or the physiologically-based pharmacokinetic model (O'Flaherty, 1995, 1997) developed to determine the effects of lead on adults may be used to determine site-specific cleanup numbers.

d) Risk Characterization

The risk characterization section summarizes the toxicity and exposure assessments into either a quantitative estimate of risk ~~or~~ and the development of cleanup concentrations, if needed, for each of the chemicals of concern at the site. The objectives of the risk assessment that were described in the introductory paragraphs of this section should again be defined and a description of how the results of the report meet those objectives should be provided. The report should exemplify the values of clarity, transparency, reasonableness and consistency as stated in the Policy for Risk Characterization at the Environmental Protection Agency (EPA, 1995b).

The conceptual model for the site should be described and for each completed pathway, the total cancer risk and non-cancer hazard quotient should be defined ~~or~~ and a cleanup concentration for that pathway determined if necessary. In developing cleanup numbers for the site, cumulative excess risk to exposed populations, including sensitive subgroups, shall not be greater than 1 in 10,000 for known or suspected carcinogens. The risks associated with carcinogens should be cumulative if the same individuals are exposed to these carcinogens consistently. For noncarcinogens (systemic toxicants), cleanup standards shall represent the level to which an exposed human population could be exposed on a daily basis without appreciable risk of deleterious effect. Where several systemic toxicants affect the same target organ or act by the same method of toxicity, the hazard index shall not exceed one. The risks associated with systemic toxicants also should be cumulative in the toxicity assessment if these toxicants affect the same target organ or act by the same method of toxicity.

To evaluate the short-term and long-term effectiveness of a selected remedy, the potential risk associated with implementation of the remedy and the risk associated with exposure to the remediated media must be evaluated. The algorithms that were defined in the exposure assessment should be used to characterize these potential risks.

The risk characterization associated with short-term effectiveness considers the exposure of workers at the site and the exposure of receptors in the vicinity surrounding the site to migrating media during the implementation of the selected remedy. A comparison of a focused list of remedial alternatives may help predict the risks associated with the implementation of the selected remedy or whether the implementation of alternatives may have any significant impact to human health and the environment.

The risk characterization associated with long-term effectiveness demonstrates whether the selected remedy attains the remedial objectives (site-specific cleanup standards) and whether postremedial risks achieve the acceptable levels of risk. There may be times when a specific cleanup level for one constituent may not be attained, but the overall postremedial risk may be within acceptable levels. Evaluation of the postremedial risk is based on a prediction of what the postremedial exposure concentrations would be. For example, a cap would eliminate exposure to surface soils, thus, rendering the risk from surface soils to be negligible. If bioremediation is considered, the remedial objective would be the concentration that provides the basis for characterization of the postremedial risk. If the calculated postremedial risk is within the acceptable range, the selected remedy would be considered a viable solution.

e) Uncertainty Analysis

An often forgotten component of the risk assessment process is the characterization of uncertainty. Uncertainty represents ignorance (or lack of perfect knowledge) about poorly-characterized phenomena or models (Burmaster and Anderson, 1994). The concept is important and indeed implicit in the risk-based approach but is often ignored in practice. For example, the Statewide health standards are acknowledged to be conservative and one of the rationales for being conservative is to account for the uncertainty inherent in developing the standards. In the site-specific evaluation, it is recommended that a tiered approach to addressing uncertainty be used. In applying the tiered approach, the level of effort should be commensurate with the magnitude of the decision to be made.

At an initial level, point estimates of exposure and risk (or site-specific standards) may be developed that describe both the high-end individual (RME) and a mid-range individual (MLE). If the level of risk is below the level of regulatory concern, the analysis need go no further. A qualitative evaluation of the uncertainty should be included at a minimum indicating what the most uncertain and most sensitive parameters are and their likely impact on the results. It is important to put in perspective uncertainties inherent in the toxicity assessment as well as the exposure assessment.

At some middle level of effort, statistical estimates (experimental estimates, population variability, estimation error) should be listed and the impact of these on the results discussed. A more formal sensitivity analysis may be performed to rank the input parameters on the basis of their contribution to the uncertainty.

At the highest levels, methods to quantitatively address variability and uncertainty (including but not limited to probabilistic analysis) should be used to carefully determine the overall precision of the risk estimates as they relate to scenarios, models and inputs.

Probabilistic Analysis: Typically, risk assessments have used a deterministic (single point) approach to estimating risk. However, risk is defined as a probability of injury or damage. Further, exposure-related variables are generally recognized as having a range of possible values. Thus, probabilistic analysis is a useful tool for estimating risk since it can account for both variability and uncertainty.

However, probabilistic analysis is resource intensive and may be inappropriate for simple evaluations. ~~Although the use of probabilistic analysis for risk assessments associated with site remediation has advanced significantly in the last five years, there are still data gaps which also limit its utility on a routine basis. Recent advances include methods for backcalculating soil cleanup levels (Burmaster et al., 1995 and Burmaster and Thompson, 1995); EPA's guiding principles for Monte Carlo analysis (EPA, 1997) as a result of an EPA sponsored workshop on the issue in May 1996 (EPA, 1996c). Both Regions III and VIII have also recently provided guidance (EPA, 1994, 1995c).~~

~~It t~~Therefore, it is suggested that probabilistic analysis be used as part of a tiered approach to risk assessment in the site remediation process.

If an uncertainty analysis includes Monte Carlo simulations, the person should consider the following guidelines as described in EPA's guiding principles for Monte Carlo analysis (EPA, 1997) to ensure high quality science:

- The purpose and scope of the assessment should be clearly articulated in a "problem formulation" section that includes a full discussion of any highly exposed or highly susceptible subpopulations evaluated (e.g., children, the elderly, etc.). The questions the assessment attempts to answer are to be discussed and the assessment endpoints are to be well defined.
- The methods used for the analysis (including all models used, all data upon which the assessment is based, and all assumptions that have a significant impact upon the results) are to be documented and easily located in the report. This documentation is to include a discussion of the degree to which the data used are representative of the population under study. Also, this documentation is to include the names of the models and software used to generate the analysis. Sufficient information is to be provided to allow the results of the analysis to be independently reproduced.
- The results of sensitivity analyses are to be presented and discussed in the report. Probabilistic techniques should be applied to the compounds, pathways, and factors of importance to the assessment, as determined by sensitivity analyses or other basic requirements of the assessment.
- The presence or absence of moderate to strong correlations or dependencies between the input variables is to be discussed and accounted for in the analysis, along with the effects these have on the output distribution.
- Information for each input and output distribution is to be provided in the report. This includes tabular and graphical representations of the distributions (e.g., probability density function and cumulative distribution function plots) that indicate the location of any point estimates of interest (e.g., mean, median, 95th percentile). The selection of distributions is to be explained and justified. For both the input and output distributions, variability and uncertainty are to be differentiated where possible.
- The numerical stability of the central tendency and the higher end (i.e., tail) of the output distributions are to be presented and discussed.

- Calculations of exposures and risks using deterministic (e.g., point estimate) methods are to be reported if possible. Providing these values will allow comparisons between the probabilistic analysis and past or screening level risk assessments. Further, deterministic estimates may be used to answer scenario specific questions and to facilitate risk communication. When comparisons are made, it is important to explain the similarities and differences in the underlying data, assumptions, and models.
- Since fixed exposure assumptions (e.g., exposure duration, body weight) are sometimes embedded in the toxicity metrics (e.g., reference doses, reference concentrations, unit cancer risk factors), the exposure estimates from the probabilistic output distribution are to be aligned with the toxicity metric.

f) References for Human Health Risk Assessment

American Industrial Health Council, 1994 Exposure Factors Sourcebook,.

American Society for Testing and Materials, Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, E-1739, Philadelphia, PA, Tier 2 Guidance Manual.

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Burmaster, D. E., K.J. Lloyd and K.M. Thompson, 1995. The Need for New Methods to Backcalculate Soil cleanup Targets in Interval and Probabilistic Cancer Risk Assessments. Human and Ecological Risk Assessment, Vol 1, No 1, pp. 89 - 100.

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EPA, 1991b. Human Health Evaluation manual, Supplemental Guidance: Standard Default Exposure Factors. Office of Solid Waste and Emergency Response Directive 9285.6-03, March 25.

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EPA, 1992c. Supplemental guidance to RAGS: Calculating the concentration term. Washington, D.C.: Office of Solid Waste and Emergency Response. Publication 9285.7-081. May.

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EPA, 1995b. Policy for Risk Characterization at the US Environmental Protection Agency. Carol Browner, March. (Available at Internet: http://www.epa.gov/ORD/spc/rcpolicy.htm)

EPA, 1995c. The Use of Monte Carlo Simulation in Risk Assessment. Region VIII Superfund Technical Guidance, RA-10, Denver, CO, September.

EPA, 1995d. Guidance for Risk Characterization. Science Policy Council, February. (Available at Internet: http://www.epa.gov/ORD/spc/rcguide.htm)

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EPA, 1996b. Proposed Guidelines for Carcinogen Risk Assessment, EPA/600/P-92/003C, April.

EPA, 1996c. Summary Report for the Workshop on Monte Carlo Analysis. EPA/630/R-96/010. September.

EPA, 1996d. Draft Exposure Factors Handbook (3 volumes: Volume I - General Factors - EPA/600/P-95/002Ba; Volume II - Food Ingestion Factors - EPA/600-P-95/002Bb; Volume III - Activity Factors - EPA/600/P-95-002Bc). National Center for Environmental Assessment, August. (Available at internet: http://www.epa.gov/ncea/exposfac.htm)

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TABLE ~~IV~~III-~~12~~10. Risk Assessment Guidelines for Human Health Evaluation

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1. Interim Final Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A, Baseline Risk Assessment (RAGS Volume 1 Part A). EPA/540/1-89/002.
2. Interim Final Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part B, Development of Risk-based Preliminary Remediation Goals (RAGS Volume 1 Part B), OSWER 9285.7-01B, EPA, Office of Solid Waste and Emergency Response, December 1991.
3. Interim Final Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part C, Risk Evaluation of Remedial Alternatives (RAGS Volume 1 Part C). EPA/540/R-92/004.
4. Interim Final Human Health Evaluation Manual, Supplemental Guidance, `Standard Default Exposure Factors', OSWER Directive 9285.6-03.
5. Interim Final Guidance for Soil Ingestion Rates. OSWER Directive 9850.4.
6. Exposure Factors Handbook. EPA/600/8-89/043. (This document is in a process of being updated.)
7. Interim Final Guidance for Data Usability in Risk Assessment. EPA/540/G-90/008.
8. Superfund Exposure Assessment Manual. EPA/540/1-88/001, OSWER Directive 9285.5-1.
9. US EPA Region III Technical Guidance Manual, Risk Assessment, Chemical Concentration Data Near the Detection Limit. EPA/903/8-91/001.
10. US EPA Region III Technical Guidance Manual, Risk Assessment, Exposure Point Concentrations in Groundwater. EPA/903/8-91/002.
11. US EPA Region III Technical Guidance Manual, Risk Assessment, Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening. EPA/903/R-93-001.
12. US EPA Region III Technical Guidance Manual, Risk Assessment, Assessing Dermal Exposure from Soil. EPA/903-K-95-003.
13. Guiding Principles for Monte Carlo Analysis. EPA/630/R-97/001.
14. Dermal Exposure Assessment: Principles and Applications (Interim Report). US EPA Office of Research and Development. EPA/600/8-91/011B. NTIS PB92205665.
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18. Guidelines for the Health Risk Assessment of Chemical Mixtures; 52 Fed Reg., September 24, 1986, p. 34014-34025.
19. Proposed Guidelines for Neurotoxicity Risk Assessment; 60 Fed Reg., October 4, 1995, p. 52032-52056.
20. Guidelines for Mutagenicity Risk Assessment; 51 Fed Reg., September 24, 1986, p. 34006-34012.
21. Proposed Guidelines for Carcinogen Risk Assessment; 61 Fed Reg., April 23, 1996, p. 17960-18011.
22. Guidance for Risk Characterization; EPA Science Policy Council, February 1995. (Available at Internet: http://www.epa.gov/ORD/spc/rcguide.htm).
23. ASTM E 1739, Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.
24. ASTM E 1689, Standard Guide for Developing Conceptual Site Models for Contaminated Sites.
25. ASTM E 978, Standard Practice for Evaluating Mathematical Models for the Environmental Fate of Chemicals.

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~~**TABLE IV-13. Technical Capability Criteria for Groundwater Models**~~

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Comment [B8]: Table unnecessary, reference to fate and transport section

~~Ability to estimate a mixing zone in the uppermost aquifer under a site and model the contaminants in this mixing zone.~~

~~Ability to account for contaminant sorption with the aquifer solids including the ability to account for mass transfer or kinetic limitations in contaminant sorption and desorption.~~

~~Ability to account for soil and bedrock heterogeneity.~~

~~Ability to account for the gas phase transport.~~

~~Ability to account for dispersive and advective transport in flowing groundwater.~~

~~Ability to account for special rules described in Act 2, such as 15' direct contact depth.~~

~~Ability to be implemented on a PC hardware/software platform.~~

~~Ease of use/availability of program/level of documentation.~~

~~Ability to account for volatilization.~~

~~Ability to simulate varying recharge conditions (infiltration rates) and varying background groundwater flows.~~

~~Ability to handle degradation.~~

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~~G.~~H. Site-Specific Ecological Risk Assessment Guidance

INTRODUCTION

The objectives of the site-specific ecological risk procedure are to:

- Evaluate the threat posed by regulated substances to species and habitats of concern through a series of steps which progressively focus the assessment with an emphasis on developing site-specific empirical data and a weight-of-evidence;
- Compile a site-specific weight-of-evidence to determine if a substantial impact has occurred to species or habitats of concern; and
- Develop the information necessary to determine what remedial action, if any, could be taken to reduce substantial impacts, if present, without causing greater injury to species or habitats of concern than no further action or less disruptive remedial alternatives.

The Department recommends the use of EPA's interim final guidance on Ecological Risk Assessment Guidance for Superfund (EPA, 1997), with some modification, as

the process for designing and conducting site-specific ecological risk assessments. To accommodate the provisions of Act 2, points of emphasis and specific modifications of the EPA process are detailed in this document. In addition, other EPA guidance on ecological risk assessment and specific ASTM standards for ecological risk procedures and methods should be utilized as appropriate to achieve the objectives noted above. This approach contains the same fundamental concepts and components found in the Statewide Health Ecological Screen. However, the Statewide ~~H~~health ecological screen cannot be applied to sites attaining the site specific standard because that process assumes all of the Statewide health standard MSCs have been met. If a site is directed to the site-specific ecological risk assessment process in Step 8 of ~~fails to meet~~ the Statewide ~~H~~health ecological screen, steps 3 through 8 of the site specific ecological risk assessment process should be applied to the ~~site~~evaluation. ~~Consequently, a site-specific ecological evaluation shall be consistent with the Statewide Ecological Screen.~~

The EPA ecological risk assessment process is comprised of eight steps. At the end of Steps 2 and 7, the qualified investigators ~~(See the Statewide Health Ecological Screening Process Rationale in Section V.D)~~ determine whether a substantial impact has resulted from regulated substances. The initial screen (Steps 1 and 2) is ~~only~~ necessary for all sites which are to attain the site specific standard ~~have not gone through the ecological screening process under the Statewide health standard as described in Section II.B.5 of this manual.~~

INITIAL SCREEN (TWO STEPS)

Step 1 - Fundamental Components

The following items should be evaluated carefully in the context of site-specific conditions:

- Environmental Setting and Site History. ~~This may include a Pennsylvania Natural Diversity Inventory (PNDI) search and a~~An evaluation of wetlands via the wetlands mapping tool provided by the US Fish and Wildlife Service may be used to help investigate the environmental setting.
- Site Visits - Evaluate receptors and chemical migration pathways. Remediators may use the Pennsylvania Natural Diversity Inventory (PNDI) Environmental Review Tool to search for habitats and species of concern. The PNDI search tool can be accessed at the Pennsylvania Natural Heritage Program's Pennsylvania Conservation Explorer website.
- Contaminant Fate and Transport - emphasize gradients of contamination.
- Preliminary Ecotoxicity Evaluation - focus on probable site-specific toxicity mechanisms to species or habitats of concern.
- Preliminary Exposure Pathway Analysis - potential for completed pathways to impact species or habitats of concern.

- Review of similar case studies to assist in the Preliminary Problem Formulation (EPA, 1992; EPA, 1997).
- If any habitats or species of concern are identified; separate areas of concern shall be distinguished where relatively distinct risk scenarios are apparent. These areas of concern should be based ~~Based~~ on an evaluation of distribution patterns of regulated chemicals, habitat changes along contaminant migration pathways, and changes in species of concern across a site~~, separate areas of concern shall be distinguished where relatively distinct risk scenarios are apparent~~.
- Choose a limited number of species or habitats of concern for assessment endpoints (EPA, 1992; Suter, 1993; EPA, 1997).

Step 2 - Preliminary Exposure Estimate and Risk Assessment

If complete exposure pathways are identified, the~~The~~ regulated party has the option to evaluate the exposure and risk to selected assessment endpoints (Step 1) by either:

- Community-based analysis such as Rapid Bioassessment Protocols for fish or aquatic macroinvertebrates (EPA, 1989) or
- Hazard Quotient Method (EPA, 1997) with emphasis on representative exposure conditions~~[1]~~ and toxicity data that most directly relate to the assessment endpoints selected in Step 1. Refer to the EPA website for the Region 3 BTAG (Biological Technical Assistance Group) screening tables and the SSL (Soil Screening Levels) tables as well as the NOAA website for the SQuiRT (Screening Quick Reference Tables) ecological screening values.

In addition, the uncertainty associated with either of these approaches should be discussed.

Decision Point

The qualified investigator must understand that the Scientific/Management Decision made at the end of the preliminary risk calculation will not set a clean-up goal. Instead, one of the following will be decided:

- The ecological risk assessment should be continued to develop a site-specific clean-up goal, or to reduce uncertainty in the evaluation of risk and impact;
- The preliminary screening is adequate to determine that no substantial ecological risk exists; or
- There is substantial impact (*de manifestis*) and proceed to remediation that can eliminate or reduce exposure to an acceptable level (Suter, et al., 1995).

All steps are the same from this point whether the site started with the Statewide Ecological Screen or Steps 1 and 2 of this process (flow chart, ~~Figure IV-10~~Figure IV-10). The qualified investigator shall follow the steps of the EPA Guidance but take

~~[1] The qualified investigator shall use a mean exposure concentration or other reasonable exposure point concentration estimate, not the maximum concentration detected.~~

into account factors noted below which shall be emphasized in Pennsylvania under Act 2.

Step 3 - Problem Formulation: Assessment Endpoint Selection and Testable Hypotheses

Identify CPECs with particular emphasis on Table 8 in Appendix A of the regulations (included as ~~Table II-2~~Table II-2 of this manual).

Further develop Assessment Endpoints shall be based on evaluation of keystone species and ecological dominants that influence the ecosystem's structure and function as they relate to species or habitats of concern (EPA, 1992; Suter, 1993; EPA, 1997).

The conclusion of this step shall integrate the available information into a determination of which exposure pathways are most likely to result in a substantial ecological impact (see Statewide Ecological Screen for discussion) to habitats or species of concern. Only these prioritized pathways are evaluated in detail in the following steps of the process. All hypotheses shall be focused on the prioritized pathways and selected assessment endpoints.

Step 4 - Problem Formulation: Site Conceptual Model, Measurement Endpoint Selection, and Study Design

The focus in this step shall be on the prioritized exposure pathways identified in Step 3, emphasizing development of a study design which will determine if there is a causal relationship between a regulated substance and any substantial ecological impact that may be detected at a site.

Regarding bioaccumulation and tissue studies, the regulated party has the option of:

- Utilizing bioaccumulation factors reported in the literature which are most relevant to habitats or species of concern at the site; or
- Measuring bioaccumulation directly through tissues analysis and environmental media analysis.

Note that bioconcentration or bioaccumulation in and of itself is not evidence of environmental injury or a substantial ecological impact. Tissue levels shall be related to a toxicity effect in a species of concern to be considered relevant in the evaluation.

Since the habitats and species of concern are readily identified and evaluated through field studies, the investigator shall emphasize population/community evaluations over less direct measures of potential impact such as laboratory toxicity testing, literature references, or media chemistry, recognizing that a combination of these evaluations is usually conducted. In addition, laboratory toxicity testing should only be conducted with species that may potentially inhabit or survive at the subject site.

The conclusion of this step should describe the measurement endpoints (EPA, 1992; Suter, 1993; EPA, 1997) for the prioritized exposure pathways and provide a clear outline of the study design.

Step 5 - Site Assessment for Sampling Feasibility

Ensure that the measurement endpoints are present in sufficient quantity or abundance so that sampling and analysis can be collected across a gradient of contamination and include a representative background or control area.[2] If necessary, the measurement endpoints should be modified to ensure the study objectives can be met (EPA, 1997).

Step 6 - Site Investigation

Only persons qualified and experienced in ecological assessment[3] methods can direct field activities or make modifications of methods in the field.

Step 7 - Risk Characterization

The chemical data should be presented in a manner which illustrates the contamination gradients at the site and areas of substantial environmental impact distinguished, based on the site-specific weight-of-evidence. Hazard quotients and/or population/community analysis data shall be summarized on figures with the analytical data. The uncertainties associated with either of these approaches shall be discussed.

Similar to Step 2 of this process, one of two conclusions shall be reached for the site or separate areas of concern within the site (if applicable, see Step 1), based on the site-specific weight-of-evidence. The conclusion shall be:

- There is no substantial ecological impact; or
- There is a substantial ecological impact, and remediation options shall be evaluated (Step 8).

Step 8 - Risk Management

Risk management is a balancing of factors (~~Figure IV-10~~Figure III-10). Consistent with current and intended future use, the risk manager shall consider the following in determining whether to remediate or allow natural attenuation processes to complete the recovery:

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[2] Reference area is defined as an area not contaminated by regulated substances originating on the site and used for comparison to the site (EPA, 1997). In addition, a reference area should be near the site and have similar geochemical, physical, and biological conditions, but be uncontaminated with regulated substances from the subject site (i.e., unimpacted by the site).

[3] Qualified and experienced means: a certified ecologist or hold a college degree in ecology or environmental sciences or natural resources and at least five years of experience conducting ecological field work and risk assessments.

- Only differences of greater than 20% in the density of species of concern or greater than 50% in the diversity and habitats of concern shall be regarded as potentially substantive impacts (Suter, 1993; Suter, et al., 1995).
- Where substantive impacts are determined, an evaluation of the risk reduction and restoration options shall be completed, taking into account:
    1. Environmental injury caused by any remedy shall not exceed the injury caused by regulated substances;
    2. The primary source of the regulated substance release has been or will be removed or controlled;
    3. That at many sites, risks to native terrestrial organisms are likely to be low because the current or intended future use is for human activity (such as residential, industrial or commercial land use) and consequently the probability of habitats of concern existing on the site is low;
    4. Natural physical and chemical attenuation mechanisms act on the released regulated compounds resulting in degradation or sequestration and consequent reduced bioavailability of remaining chemical residuals;
    5. The substantial acclimation capacity of natural populations to exposure to low or moderate concentrations of chemical residuals;
    6. That most remedial actions cause substantial injury to areas of concern beyond the toxicological impacts, as well as impacts to previously unimpacted areas along the perimeter of the remediation area; and
    7. That natural systems are self-organizing, and an attempt~~s~~ to manage these processes to produce a particular result requires long-term management, and even then can result in undesirable results.
- Implementation of the selected remedy that will reduce the risks and restore the structure and function of the impacted ecological system to a condition which is capable of sustaining species and habitats of concern without substantial adverse effect from residual regulated substances.
- Sources of regulated substances will be removed and natural attenuation/acclimation processes in relatively small areas will mitigate impacts naturally to the point that they are no longer substantive.
- The restoration objective is to return the substantially impacted ecological system to a structure and function which is capable of sustaining species and habitats of concern without adverse effects, consistent with planned future use of the site within a reasonable time frame. The restoration objective is not to return to pre-stressed conditions but something that is similar structurally and functionally.

REFERENCES

EPA. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers. EPA/444/4-89-001.

EPA. 1992. Framework for Ecological Risk Assessment. EPA/630/R-92/001.

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Suter, II, G.W., B.W. Cornaby, C.T. Haddne, R.N. Hull, M. Stack, and F.A. Zafran. 1995. An Approach For Balancing Health and Ecological Risks at Hazardous Waste Sites. Risk Analysis 15(2)221-231.

Figure III-10

Site-Specific Ecological Risk Assessment Procedure

Comment [B9]: New figure to replace previous deleted figure