Reasonable Potential Procedure
For
Water Quality Based Effluent Limits
APDES Permits

FINAL

January 2009

A. Background

The Alaska Pollutant Discharge Elimination System (APDES) permit program regulations *(18 AAC 83.435)* require permit limits be placed in APDES permits to achieve water quality standards established under 33 U.S.C. 1313, including state narrative criteria for water quality. Alaska water quality standards are found in *18 AAC 70* and the *Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances, dated May15, 2003*.

Under *18 AAC 83.435(b)*, "Effluent limits in a permit must control all pollutants or pollutant parameters, either conventional, non-conventional, or toxic pollutants, that the department determines are or may be discharged at a level that will cause, have the reasonable potential to cause, or contribute to an excursion above any state water quality standard, including state narrative criteria for water quality."

Under *18 AAC 83.435(c)*, "To determine whether a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric criteria within a state water quality standard, the department will use procedures that account for existing controls on point and non-point sources of pollution, the variability of the pollutant or pollutant parameter in the effluent, the sensitivity of the species to toxicity testing when evaluating whole effluent toxicity, and, if applicable, the dilution of the effluent in the receiving water."

Under *18 AAC 83.435(d),* "When the department determines, using the procedures in (c) of this section, that a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the allowable ambient concentration of a state numeric criteria within a state water quality standard for an individual pollutant, the permit must contain effluent limits for that pollutant."

Under *18 AAC 83.435(e),* "When the department determines, using the procedures in (c) of this section, that a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the numeric criterion for whole effluent toxicity, the permit must contain limits for whole effluent toxicity."

Under *18 AAC 83.435(f),* "Except as provided in this subsection, when the department determines, using the procedures in (c) of this section, toxicity test data, or other information, that a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the narrative criterion within an applicable water quality standard, the permit must contain limits for whole effluent toxicity. Limits on whole effluent toxicity are not required if the department demonstrates in a fact sheet of the APDES permit, using procedures in (c) of this section, that chemical specific limits for the effluent are sufficient to attain and maintain applicable numeric and narrative state water quality standards."

Under *18 AAC 83.435(g),* "When the state has not established a water quality criterion for a specific chemical pollutant that is present in an effluent at a concentration that causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative criterion within an applicable water quality standard, the department will establish effluent limits using one or more of the following options:

(1) establish effluent limits using a calculated numeric water quality criterion for the pollutant that the department demonstrates will attain and maintain applicable narrative water quality criteria and will fully protect the designated use; the criterion

may be derived using a proposed state criterion, or an explicit state policy or regulation interpreting its narrative water quality criterion, supplemented with other relevant risk assessment data, exposure data, or other information that may include EPA's *Water Quality Standards Handbook* as revised as of August 1994, adopted by reference;

(2) establish effluent limits on an indicator parameter for the pollutant of concern, if

(A) the permit identifies which pollutants are intended to be controlled by use of the effluent limitation;

(B) the fact sheet sets out the basis for the limit, including a finding that compliance with the effluent limit on the indicator parameter will result in controls on the pollutant of concern that are sufficient to attain and maintain applicable water quality standards;

(C) the permit requires all effluent and ambient monitoring necessary to show that during the term of the permit the limit on the indicator parameter continues to attain and maintain applicable water quality standards; and

(D) the permit contains a re-opener clause allowing the department to modify or revoke and reissue the permit if the limits on the indicator parameter no longer attain and maintain applicable water quality standards."

Under *18 AAC 83.435 (h),* "When developing water quality based effluent limits under this section, the department shall ensure that

(1) the level of water quality to be achieved by limits on point sources established under this paragraph is derived from, and complies with, all applicable water quality standards; and

(2) effluent limits developed to protect a narrative water quality criterion, a numeric water quality criterion, or both, are consistent with the assumptions and requirements of any available wasteload allocation for the discharge prepared by the state and approved by EPA under 40 C.F.R. 130.7, as revised July 1, 2005."

This procedure has been developed to assist permit writers for the APDES program including DEC staff, contractors, and other persons who are involved in writing, reviewing and issuing APDES permits. It is intended to establish a framework only for implementing the regulatory provisions above for determining reasonable potential. DEC reserves the right to use best engineering or scientific professional judgment in cases that differ from those anticipated under this procedure. In such cases, the permit writer may include documentation that supports a deviation from the procedure in documentation supporting the administrative record for that permit.

B. Purpose of RP Procedure

The procedure contained in this document will allow an APDES permit writer to determine if a pollutant contained in a discharge to surface waters has "*reasonable potential*" to cause or contribute to an excursion above a numeric water quality standard for that pollutant.

This procedure is not applicable to a determination of reasonable potential for a pollutant to cause or contribute to an excursion of an Alaska narrative water quality standard including narrative standards for acute whole effluent toxicity.

Where no *reasonable potential* is found using this procedure, a limit is not required to be placed in an APDES permit, however, monitoring requirements for that pollutant may be included in the permit where appropriate.

A flow chart describing the major steps of the Reasonable Potential Procedure process is presented in Appendix 1.

C. Basis

The procedure is based on EPA's procedure for reasonable potential in Chapter 3 of the *Technical Support Document for Water Quality Based Toxics Control EPA/505/2-90-001* (USEPA 1991) referred to in this document as the "TSD". The TSD procedure was developed for use with chemical specific effluent limits established as equally protective alternatives to whole effluent toxicity limits in a permit where the toxicants contributing to whole effluent toxicity have been identified.

The Department may use this approach to establish reasonable potential for toxic pollutants as well as conventional and non-conventional pollutants that have a numeric water quality criterion associated with the water quality standard. In addition, the procedure may be used to establish reasonable potential for pollutants that may pose a risk to aquatic life and/or human health but there are no approved state water quality standards. In this determination, the Department can compare the reasonable potential information against EPA Water Quality Criteria or other risk based information that the Department deems appropriate for the analysis.

D. Evaluation of Reasonable Potential

Step One- Determining Pollutants of Concern

The permit writer must determine what pollutants of concern are present in the discharge that will undergo further analysis. These can be identified, in cooperation with the permittee from the following sources of information:

- Permit Application Information
- Effluent Monitoring Data
- Special monitoring requirements or studies
- Industry Specific Data (EPA Effluent Guidelines Development Documents)
- Intake or Process water data
- Permit writer's best professional judgment

Step Two- Monitoring Data Quality

The discharge information obtained from Step One should be assembled and checked to assure the data is sufficient to continue a quantitative analysis of reasonable potential. The data should be assembled in a manner that allows the permit writer to evaluate minimums, maximums, seasonally grouped data, or other site specific considerations. Daily maximum data and monthly average data should be assembled separately as data sets. If only one sample was collected during a monthly period, the data represents both daily maximum and monthly average data. A Microsoft Excel spreadsheet or similar software can be used for data assembly and statistical analysis. An Excel spreadsheet called "Reasonable Potential Procedure" has been developed to follow this procedure and is attached to this guidance.

Number of Valid Data Points

A minimum data set consisting of 10 valid data points within the last five years is necessary to perform a valid statistical analysis. Limiting data to the last five years ensures data is timely and relevant to the current analysis. If needed, additional historic data can be used in the analysis as long as the data is representative of the current condition. Data that was collected prior to changes in industrial operations, service areas, plant expansions, etc. should not be included in the analysis. Smaller data sets can also be evaluated by the statistical procedure. However, statistical determinations using small data sets can produce unreliable outputs. In these cases, the permit writer should use the EPA recommended default value for the statistical analysis and reasonable potential determination. The "Reasonable Potential Procedure" spreadsheet will automatically use the default value when less than 10 valid data points are entered. (Additional data could be collected by the permittee and provided to the permit writer to produce a more robust data set.)

Data Reporting Limit

The data reporting limits for each parameter should be verified by the permit writer as acceptable under quality assurance/quality control guidelines set by the Department. Reporting limits are expressed as method detection limit (MDL), level of detection (LOD), practical quantitation limit (PQL), minimum level (ML), reporting level (RL), etc. Elevated reporting limits may mask concentrations of pollutants that would otherwise have been considered valid results using a more sensitive analytical method. Data sets may also contain different reporting limits for the same parameter. The permit writer must decide how the data will be analyzed on a case-by-case evaluation of the situation. Data with highly elevated reporting or detection limits, e.g. one order of magnitude above other reported levels, could be determined to be invalid data and eliminated from the data set prior to statistical analysis. Values that represent the appropriate reporting limit must be entered into the "Reasonable Potential Procedure" spreadsheet in order to correctly calculate the statistical parameters for data sets with non-detected values. The statistical analysis for this procedure normally allows only one reporting limit value to be entered. An optional method for determining reasonable potential with multiple detection levels is available in the Reasonable Potential Spreadsheet and the statistical formulas for the option are presented in Appendix 1 of this document.

Significant Figures in Data Set

The limiting number of significant figures in the data set should be determined to ensure all intermediate calculations and the final answers reflect the quality of the data set that is used. All data has an inherent level of error represented by the way it is displayed. Proper use of significant figures will avoid "propagation of errors" that can be produced by calculators and spreadsheet operations that carry out mathematical calculations using a large number of places past the decimal and when rounding values to a limited number of decimal places, etc.

A value for the limiting number of significant figures of the data set must be entered into the appropriate cell on the "Reasonable Potential Procedure" spreadsheet for the calculations to proceed. This value is the number of significant figures of the least precise measurement in the data set. The "Reasonable Potential Procedure" spreadsheet will carry out the calculations using the correct number of significant figures when this value is entered correctly. For manual calculations using this procedure, special care should be used when performing mathematical calculations so unforeseen errors are not introduced into the process. The following assumptions will minimize errors when performing hand calculations and are automatically built in to the "Reasonable Potential Procedure" spreadsheet calculations.

Significant figure determination assumptions:

- All non-zero figures are significant, e.g. 22 has two significant figures and 22.3 has 3 significant figures.

- When zeros are included, the determinations are more complicated;

    - Zeros placed before other figures are not significant, e.g. 0.046 has only two significant figures
    - Zeros placed between other figures are always significant, e.g. 4009 has four significant figures
    - Zeros placed after other figures but behind a decimal point are always significant, e.g. 7.90 has three significant figures
    - Zeros at the end of a number are significant only if they are behind the decimal point, e.g. 7.0 has two significant figures but 70 has only one significant figure.
    - Zeros at the end of a number without a decimal point may be significant or not significant, you can't tell unless you have other information available, e.g. 8200 has at least two significant figures but there could be three or four. For the purposes of this reasonable potential procedure, the least number of significant figures here will be used (two) unless other information is available that justifies use of additional figures as significant.

Significant figure use in the calculations for this reasonable potential procedure should also follow additional significant figure usage assumptions:

- The number produced as a final answer to this procedure should have the same number of significant figures as determined in limiting the original data set.
- All intermediate calculations should carry one additional significant figure and the final result is rounded to the desired number of significant figures. Use of the additional significant figure in intermediate calculations avoids propagation of "round-off error."

Data Outliers and Anomalies

Data sets may also contain values that appear to be outside the normal expected range of the reported values, i.e. false positives, or outliers. The permit writer should first verify that the result is not due to a transcription error in the reporting of the result. A comparison of raw laboratory data and reported data can usually identify a transcription error and the data can be corrected. If a transcription error cannot be found, the permit writer should next check for a laboratory error. Laboratory errors may be corrected by contacting the laboratory and having a check done on the analysis of that sample and the correction made by the laboratory if an error is discovered. If transcription or laboratory errors can be determined and corrected, the corrected result should be included in the data set used in this procedure.

If a transcription or laboratory error cannot be identified, the permit writer should next verify with the permit applicant that the data is not a result of an unusual condition in the facility that is producing the discharge. Unusual conditions may include an operational change or other upset in a treatment system that produced an unusually high result. If the result is due to a verifiable unusual condition at the discharging facility, it is a valid sample that is representative of the discharge and the reported result should not be excluded from the data set used in this procedure.

If the reported result is not due to a transcription error, a laboratory error or verifiable unusual condition in the discharge, some adjustment of the data may be necessary to proceed with the statistical analysis. This could include procedures such as statistical outlier determinations or data trimming techniques of data sets which contain suspected outliers, non-detected or less than values. Those techniques are not included in this procedure but are readily available. EPA's ProUCL 4.0 Statistical Software is available for download at no charge from the following link: http://www.epa.gov/nerlesd1/tsc/software.htm

When the permit writer decides to remove data points from the original data set due to errors that cannot be corrected or identified, a written justification for removing the data should be documented in the administrative record for the permit.

Statistical Distribution of Data Set

This reasonable potential procedure (and the "Reasonable Potential Procedure" spreadsheet) assumes that the data set is lognormally distributed when all values up to 30 valid data points are above the reporting limit. In most cases, effluent data follows a lognormal distribution pattern. For data sets with more than 30 valid data points, a normal distribution is assumed. For data sets containing values above the reporting limit and non-detected data (below the reporting limit), a lognormal distribution is assumed for the data above the reporting limit and delta-lognormal statistical analysis is used on the entire data set of detects and non-detects, with a "censoring point" set at the reporting limit. A default calculation should be performed on data sets with less than 10 valid data points.

For data sets with less than 30 valid data points that do not follow a log-normal statistical distribution, i.e. normal distribution, a different statistical analysis must be followed. In these cases, the permit writer should ask the permit applicant to perform statistical analysis of their data to demonstrate the data follows a different distribution and provide the results of that analysis to the Department.

Step Three- Calculating the Coefficient of Variation (CV)

Assemble the effluent data set in a Microsoft Excel spreadsheet ("Reasonable Potential Procedure") or other spreadsheet/database as necessary and enter appropriate formulas to perform the statistical analysis. The object of the statistical analysis is to determine the Coefficient of Variation (CV) of the data set. The CV is defined as the standard deviation (SD) divided by the mean.

Valid effluent data must be assembled and analyzed using statistical distribution functions. The "Reasonable Potential Procedure" spreadsheet has two separate worksheets to evaluate RP for acute water quality criteria and RP for chronic and human health criteria. Raw effluent data that is representative of recent historical operations can be entered into both worksheets for acute and chronic/HH parameters.

If raw effluent data is not available, valid daily maximum and monthly average data reported on a DMR could be assembled separately for statistical analysis. Seasonal groupings of data points may also be appropriate for certain parameters with seasonal water quality considerations. The daily maximum DMR data could be used to project a maximum effluent concentration and receiving water concentration to compare with the acute water quality criteria while the maximum monthly average DMR data could be used to project an average effluent concentration and receiving water concentration to compare with the chronic and human health water quality criteria to determine reasonable potential.

Different statistical evaluations are used for data sets based on the distribution of sample analysis results. The first type of statistical evaluation (lognormal) assumes all reported values (10<= valid results<=30) are above the reporting limit, i.e. minimum level (ML), practical quantitation limit (PQL), method detection limit (MDL), etc. The second type of statistical evaluation (delta-lognormal) is used for data sets containing values above the reporting limit and values reported as "not detected". The third statistical analysis (normal) is used for data sets containing all values above the reporting limit with >30 valid results. The fourth evaluation uses a default calculation for data sets with <10 valid results. The "Reasonable Potential Procedure" spreadsheet will automatically determine the appropriate statistical analysis to perform based on the data values entered into the spreadsheet.

Step 3.1 – (Lognormal) CV for data sets with all values above reporting limit (10<=k<=30)

For data sets where all values are above the specified reporting limit and the number of valid data points is 10 or greater and less than or equal to 30, the data must be transformed into a lognormal format before standard statistics are applied. This procedure follows Appendix E of the TSD using the lognormal distribution statistical formulas. The formulas are:

$$\text{Coefficient of Variation} = cv(x) = [\exp(\sigma^2_y)-1]^{1/2}$$

Where: $\sigma^2_y = \text{variance} = \sum[(y_i-\mu)^2]/(k-1)$

$y_i = \ln(x_i)$ for $i=1,2,\ldots k$

$\mu_y = \text{mean} = \sum(y_i)/k$

k = number of samples

Step 3.2- (Normal) CV for data sets with more than 30 valid results (k>30)

For data sets with all values above the reporting limit and there are more than 30 valid results, a normal distribution of data is assumed and standard statistical procedures are used to calculate the Coefficient of Variation. The formulas are:

Coefficient of Variation = σ / μ

Where: μ = estimated mean
$= \sum[x_i]/ k$, $1 \leq i \leq k$

σ^2 = estimated variance
$= \sum[(x_i - \mu)^2] / (k - 1)$, $1 \leq i \leq k$

σ = estimated standard deviation
$= (\sigma^2)^{1/2}$

k = number of samples

Step 3.3 – (Delta-lognormal) CV for data sets with reported values and non-detects

For all data sets containing both detected and non-detected values (less than reporting limit), data should be analyzed using a different statistical approach that can effectively evaluate the non-detected values in the data set. The analysis uses the delta-lognormal distribution statistical formulas in Appendix E of the TSD. The formulas are:

Coefficient of Variation = $cv(X^*) = [V(X^*)]^{1/2}/E(X^*)$

Where: $E(X^*)$ = daily average
$= \delta D + (1-\delta) \exp(\mu_y + 0.5\sigma_y^2)$

$V(X^*)$= variance
$= (1-\delta) \exp(2\mu_y + \sigma_y^2)[\exp(\sigma_y^2)-(1-\delta)]+\delta(1-\delta)D[D-2 \exp(\mu_y + 0.5 \sigma_y^2)]$

And:

k = number of samples
D = reporting limit
r = number of non-detects below reporting limit
k-r = number of values greater than reporting limit
$y_i = \ln(x_i)$
$\mu_y = \sum(y_i)/ (k-r)$
$\sigma_y^2 = \sum(y_i - \mu_y)^2/ (k - r - 1)$
$\delta = r/k$

Step 3.4- (Default) CV for data sets with less than 10 valid results

For data sets containing less than 10 valid results above and below the reporting limit, 0.6 can be used as the Coefficient of Variation (CV) for input to Step Four.

Step Four- Determining Reasonable Potential Multiplier

The "Reasonable Potential Procedure" spreadsheet will automatically determine the appropriate multipliers based on the number of samples and desired confidence level and probability basis. For this procedure, either the 99% Confidence Interval and 99% Probability Basis or the 95% Confidence Interval and 95% Probability Basis is assumed to be appropriate for determining reasonable potential.

To hand calculate the reasonable potential multipliers, use the number of samples and the CV determined from above and the lookup tables found in the TSD (Page 54). Use Table 3-1 (99% Confidence Interval and 99% Probability Basis or Table 3-2 (95% Confidence Interval, 95% Probability) to find the multiplier value for the parameter. Tables 3-1 and 3-2 are included as Figure 1 of this document.

For data sets that were run through the log-normal distribution statistical analysis (Step 3.1: Data sets with more than 10 samples above the reporting limit) use the calculated CV and the number of samples to determine the multiplier from Table 3-1 or 3-2.

For data sets that were run through the delta-lognormal distribution statistical analysis (Step 3.3: Data sets with more than 10 samples above and below the reporting limit with non-detected values) use the calculated CV and the number of samples to determine the multiplier from Table 3-1 or 3-2.

For data sets that were run through the normal distribution statistical analysis (Step 3.2: Data sets with more than 30 valid results) use the calculated CV and the number of samples to determine a multiplier using appropriate statistical z-values and the formula provided in Section 3.3.2 of the TSD adjusted for the 99% C.I. and 99% probability basis or the 95% CI /95%PB.. (The TSD Tables 3-1 and 3-2 do not provide multipliers for sample sizes greater than 20.)

For data sets with less than 10 samples above and below the reporting limit, use a CV of 0.6 and the number of samples to determine the multiplier from Tables 3-1 or 3-2. The permit writer can also choose to calculate the CV of the data set using one of the procedures above and the number of samples to determine the multiplier from Table 3-1 or 3-2.

For data based on effluent guidelines expressed as a daily maximum and monthly effluent limitation, the multiplier value is set at 1.0. This is based on the statistical methodology used by EPA in determining effluent limits under an effluent guideline is essentially the same as the methodology to determine variability of a data set using this procedure. Normally this would be appropriate only when no effluent monitoring data is provided in a permit application for a new source and an effluent guideline applies to the discharge, and where an effluent guideline based limit is in effect in an existing permit.

Step Five- Determine Projected Maximum Effluent Concentration (MEC)

The "Reasonable Potential Procedure" spreadsheet will automatically calculate the projected Maximum Effluent Concentration (MEC) of the data set at the 99%ile effluent value at a 99% confidence interval or a 95%ile effluent value at a 95% C.I. using the maximum reported value of the data set and the reasonable potential multiplier determined in Step 4.

To hand calculate the MEC, multiply the highest recorded effluent value (daily maximum, monthly average) for the parameter by the multiplier from Table 3-1 or 3-2. This value is the projected maximum effluent concentration (MEC) which represents either the 99%ile effluent value at a 99% confidence level or the 95%ile effluent value at a 95 percent confidence level.

The projected MEC for a maximum daily and monthly average effluent guideline based limitation is equal to the limit. Where production based limits are established, e.g. lbs. pollutant/ 1000 lbs. product, conversion of the mass limit to a concentration value is necessary. For this conversion, a long term flow such as the average daily flow will be used. The daily maximum and monthly average mass limits are divided by the average daily flow and appropriate conversion factors to derive the daily maximum and monthly average projected MEC.

Step Six- Determine Maximum Projected Receiving Water Concentration (RWC)

Using the projected MEC and appropriate dilution factors, a maximum projected receiving water concentration (RWC) is determined at the edge of the mixing zone. Where no mixing zones are allowed, or when the receiving water critical low flow is zero, the RWC is equal to the projected MEC calculated above.

If any dynamic or steady state mixing zone modeling has been performed, e.g. CORMIX or PLUMES, the permit writer should use the dilution factor(s) produced from the model results to calculate the RWC. The dilution factor used in this procedure is the receiving water critical low flow (background or upstream critical low flow plus design effluent flow) divided by the effluent flow. The modeling should produce dilution factors for an acute, chronic and human health mixing zone as appropriate for individual pollutants.

If no modeling of the mixing zone has been completed, the permit writer can use a simple mass balance approach to project the RWC at the edge of the mixing zone. In this case, the permit writer assumes the effluent discharge will be completely mixed with the receiving water within a short distance of the discharge pipe:

$$C_3Q_3 = C_1Q_1 + C_2Q_2$$

$$C_3 = \frac{C_2Q_2 + C_1Q_1}{Q_3}$$

Where: C_3 = Downstream Receiving Water Concentration (RWC)
Q_3 = Downstream Receiving Water Flow at Critical Upstream Low Flow
C_1 = Upstream Water Concentration
Q_1 = Upstream Water Critical Low Flow
C_2 = Maximum Effluent Concentration (MEC)
Q_2 = Effluent Flow (Design or Actual Flow)

And: $Q_3 = Q_1 + Q_2$

Critical low flows available for fresh water dilution are set forth in the water quality standards (*18 AAC 70)*. Under the current EPA approved water quality standards (June 2003), the following critical low flows are used to establish the RWC at the edge of the mixing zone: for non-toxic and conventional pollutants, the 3Q2; for toxics, chronic criteria the 7Q10, and acute criteria the 1Q10; for human health carcinogens, the harmonic mean [see *18 AAC 70.255(f)*]. Also, under the current 2003 EPA approved water quality standards, no mixing zones are allowed in anadromous fish spawning areas or resident spawning redds for Arctic grayling, northern pike, rainbow trout, lake trout, cutthroat trout, brook trout, whitefish, sheefish, Arctic char (Dolly Varden), burbot, and landlocked coho, king, and sockeye salmon.

Under the 2006 adopted water quality standards for flowing fresh waters, the critical low flows available for dilution for aquatic life protection are the 7Q10 for chronic criteria and 1Q10 for acute criteria, the 7Q10 for conventional and non-toxic substances, the harmonic mean for human health carcinogens, and the 30Q5 for human health non-carcinogenic substances. [See *18 AAC 70.240(l)*].

The effluent flows to use in the mass balance are design flows for POTWs and industrial dischargers with treatment facilities. The design flow used should match the averaging period for the criteria evaluated for RP. Design flows represent the maximum expected flow that could be discharged into receiving waters and are used in wasteload allocation determinations and established directly as permit limits. For aquatic life protection, use the daily maximum design flow with acute criteria and long term daily average design flow with chronic criteria. For conventional and non toxic substances, human health based carcinogens and non-carcinogens, use the long term daily average design flow.

For dischargers without treatment systems, batch treatment systems, and where no design flow information is available, actual flows may be substituted as necessary for design flows in the mass balance calculation. The highest maximum daily flow and the highest monthly average flow for the last three to five years will be used in place of the design flows.

Where there is no background concentration of the pollutant present (C_1=0), the RWC is determined by multiplying the MEC by the inverse of the dilution factor, e.g. the ratio of the effluent flow (design or actual flow) over the receiving water critical low flow. The formula above simplifies to:

$$C_3 = \frac{C_2 Q_2}{Q_3}$$

The "Reasonable Potential Procedure" spreadsheet will automatically calculate a RWC using either a dilution factor or the mass balance equation described above. Separate acute and chronic/human health worksheet pages allow input of an acute dilution factor or acute low flow, facility design flow and background pollutant concentration, and chronic and human health dilution factors, chronic/human health low flows, facility design flow and background pollutant concentration.

Step 7- Compare Receiving Water Concentration with Water Quality Standard

For each pollutant, determine the appropriate water quality standards for that pollutant, i.e. aquatic life, conventional or non-toxic, or human health carcinogenic or non-carcinogenic numeric criteria. For ocean discharges use the marine water aquatic life numeric criteria. For fresh water discharges use the fresh water numeric criteria. There may be more than one listed marine or fresh water criterion for the same pollutant.

For conventional and non-toxic substances see *18 AAC 70.020* for the applicable fresh or marine water pollutant criteria. These substances include color, fecal coliform bacteria, petroleum hydrocarbons and oil and grease, turbidity, and total dissolved solids (fresh water only). The reasonable potential determination is not generally applicable for use with conventional or non-toxic criteria for dissolved oxygen, pH, radioactivity, residues, sediment, temperature, and for marine water dissolved solids.

For Whole Effluent Toxicity (WET), see *18 AAC 70.030*. Toxicity is expressed as 1.0 chronic toxic unit (TU_c) at the edge of the chronic mixing zone.

For drinking water primary MCLs, stockwater and irrigation criteria, aquatic life criteria and human health criteria for carcinogenic and non-carcinogenic substances, see *Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances, dated May 15, 2003.*

Note: Currently the Water Quality Criteria Manual does not differentiate between criteria based on carcinogenicity and non-carcinogenicity. The permit writer should consult with DEC Water Quality Standards staff to determine the basis for human health criteria.

For convenience, the "Toxicsbook" EXCEL spreadsheet containing Alaska Fresh and Marine water quality criteria has been incorporated into the "Reasonable Potential Procedure" spreadsheet. It allows adjustment of harness dependant criteria values as well as conversions between dissolved and total recoverable pollutant criteria.

For receiving waters listed under 303(d) where a Total Maximum Daily Load (TMDL) has been developed and approved, the calculated wasteload allocation (WLA) for the discharge is used instead of the water quality standard for comparison. A WLA is derived from and complies with water quality standards.

If there are no EPA approved water quality standards that apply to the pollutant, EPA Water Quality Criteria published in accordance with CWA 304(a), or other risk based criteria as determined by the Department to be applicable, may be used in this evaluation.

Next, compare the calculated RWC to the appropriate water quality standards. For daily maximum data sets, compare the RWC to the aquatic life acute criterion for that pollutant. For monthly average data sets, compare the RWC to the aquatic life chronic, human health, water supply, recreation, stockwater or irrigation water criteria.

If the RWC equals or exceeds (≥100%) the water quality standard for that parameter, there is "*reasonable potential"* for the effluent discharge to cause or contribute to an excursion above the water quality standard and a permit limit must be developed and included in an APDES permit.

If the RWC is between 50% and 100% of the water quality standard for that parameter, there is no "*reasonable potential*" for the effluent discharge to cause or contribute to an excursion above the water quality standard and a permit limit is not required, however, the permit should contain monitoring requirements for the parameter to ensure changes in the effluent quality that would result in "*reasonable potential"* are identified during the permit cycle.

If the RWC is <50% of the water quality standard, there is no "*reasonable potential*" for the effluent discharge to cause or contribute to an excursion above the water quality standard and a permit limit is not required. At this level, it is also not necessary for the permit to contain regular monitoring requirements for the parameter. However, as a backstop, additional effluent monitoring data for that parameter should be required in a renewal permit application and reasonable potential can be reevaluated at that time.

RP Summary

In addition to the individual RP worksheets and mixing zone modeling information, a summary of the RP determination should be included in the fact sheet or other documentation that supports the administrative record for the permit. The following table is an example of what summary information could be included in the record:

Example Summary Table for Reasonable Potential Determination

Facility Name:					Permit Number:		
Pollutant (ug/L)	Permit Limit Basis	Effluent Conc.[1]	Maximum Effluent Conc. (MEC)[2]	Dilution Factor[3]	Receiving Water Conc. (RWC)	Water Quality Criteria	Reasonable Potential? WQBEL/Monitor[4]
TRC (max.)	WQ	100	128	5	26	19	Yes/Yes
TRC (avg.)	WQ	10	32	25	1.3	11	No/No
Cd (TR) (max.)	BAT[6]	100	100	5	20	0.52[5]	Yes/Yes
Cd (TR) (avg.)	BAT[6]	50	50	25	2	0.10[5]	Yes/Yes
Mercury (T) (max.)	BAT[6]	2	2	5	0.4	1.7	No/No
Mercury (T) (avg.)	BAT[6]	1	1	25	0.04	0.9	No/No
Mercury (T) (avg)	BAT[6]	1	1	30	0.03	0.05	No/Yes

[1] For technology based limits, ELG values are used, for water quality based limits effluent data is used.

[2] 95% Confidence Interval and 95% Probability Basis.

[3]Aquatic life acute and chronic, human health dilution factors derived from modeling of mixing zones.

[4] Limits required when RWC exceeds WQC, monitoring required when 50% WQC<RWC<100% WQC.

[5] Total Recoverable Criteria at a hardness of 25 mg/L as $CaCO_3$. Total Recoverable Criteria is the dissolved water quality criteria divided by the conversion factors in the regulation.

[6] Where Technology Limits (BAT, BCT, BPT, NSPS) apply but no Reasonable Potential to exceed the WQC is demonstrated, the Technology Limits are required to be applied as permit limits.

Figure 1

TSD Tables 3-1 and 3-2

Table 3-1. Reasonable Potential Multiplying Factors: 99% Confidence Level and 99% Probability Basis

Number of Samples	Coefficient of Variation																			
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1	1.6	2.5	3.9	6.0	9.0	13.2	18.9	26.5	36.2	48.3	63.3	81.4	102.8	128.0	157.1	190.3	227.8	269.9	316.7	368.3
2	1.4	2.0	2.9	4.0	5.5	7.4	9.8	12.7	16.1	20.2	24.9	30.3	36.3	43.0	50.4	58.4	67.2	76.6	86.7	97.5
3	1.4	1.9	2.5	3.3	4.4	5.6	7.2	8.9	11.0	13.4	16.0	19.0	22.2	25.7	29.4	33.5	37.7	42.3	47.0	52.0
4	1.3	1.7	2.3	2.9	3.8	4.7	5.9	7.2	8.7	10.3	12.2	14.2	16.3	18.6	21.0	23.6	26.3	29.1	32.1	35.1
5	1.3	1.7	2.1	2.7	3.4	4.2	5.1	6.2	7.3	8.6	10.0	11.5	13.1	14.8	16.6	18.4	20.4	22.4	24.5	26.6
6	1.3	1.6	2.0	2.5	3.1	3.8	4.6	5.5	6.4	7.5	8.6	9.8	11.1	12.4	13.8	15.3	16.8	18.3	19.9	21.5
7	1.3	1.6	2.0	2.4	2.9	3.6	4.2	5.0	5.8	6.7	7.7	8.7	9.7	10.8	12.0	13.1	14.4	15.6	16.9	18.2
8	1.2	1.5	1.9	2.3	2.8	3.3	3.9	4.6	5.3	6.1	6.9	7.8	8.7	9.6	10.6	11.6	12.6	13.6	14.7	15.8
9	1.2	1.5	1.8	2.2	2.7	3.2	3.7	4.3	5.0	5.7	6.4	7.1	7.9	8.7	9.6	10.4	11.3	12.2	13.1	14.0
10	1.2	1.5	1.8	2.2	2.6	3.0	3.5	4.1	4.7	5.3	5.9	6.6	7.3	8.0	8.8	9.5	10.3	11.0	11.8	12.6
11	1.2	1.5	1.8	2.1	2.5	2.9	3.4	3.9	4.4	5.0	5.6	6.2	6.8	7.4	8.1	8.8	9.4	10.1	10.8	11.5
12	1.2	1.4	1.7	2.0	2.4	2.8	3.2	3.7	4.2	4.7	5.2	5.8	6.4	7.0	7.5	8.1	8.8	9.4	10.0	10.6
13	1.2	1.4	1.7	2.0	2.3	2.7	3.1	3.6	4.0	4.5	5.0	5.5	6.0	6.5	7.1	7.6	8.2	8.7	9.3	9.9
14	1.2	1.4	1.7	2.0	2.3	2.6	3.0	3.4	3.9	4.3	4.8	5.2	5.7	6.2	6.7	7.2	7.7	8.2	8.7	9.2
15	1.2	1.4	1.6	1.9	2.2	2.6	2.9	3.3	3.7	4.1	4.6	5.0	5.4	5.9	6.4	6.8	7.3	7.7	8.2	8.7
16	1.2	1.4	1.6	1.9	2.2	2.5	2.9	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.1	6.5	6.9	7.3	7.8	8.2
17	1.2	1.4	1.6	1.9	2.1	2.5	2.8	3.1	3.5	3.8	4.2	4.6	5.0	5.4	5.8	6.2	6.6	7.0	7.4	7.8
18	1.2	1.4	1.6	1.8	2.1	2.4	2.7	3.0	3.4	3.7	4.1	4.4	4.8	5.2	5.6	5.9	6.3	6.7	7.0	7.4
19	1.2	1.4	1.6	1.8	2.1	2.4	2.7	3.0	3.3	3.6	4.0	4.3	4.6	5.0	5.3	5.7	6.0	6.4	6.7	7.1
20	1.2	1.3	1.6	1.8	2.0	2.3	2.6	2.9	3.2	3.5	3.8	4.2	4.5	4.8	5.2	5.5	5.8	6.1	6.5	6.8

Table 3-2. Reasonable Potential Multiplying Factors: 95% Confidence Level and 95% Probability Basis

Number of Samples	Coefficient of Variation																			
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1	1.4	1.9	2.6	3.6	4.7	6.2	8.0	10.1	12.6	15.5	18.7	22.3	26.4	30.8	35.6	40.7	46.2	52.1	58.4	64.9
2	1.3	1.6	2.0	2.5	3.1	3.8	4.6	5.4	6.4	7.4	8.5	9.7	10.9	12.2	13.6	15.0	16.4	17.9	19.5	21.1
3	1.2	1.5	1.8	2.1	2.5	3.0	3.5	4.0	4.6	5.2	5.8	6.5	7.2	7.9	8.6	9.3	10.0	10.8	11.5	12.3
4	1.2	1.4	1.7	1.9	2.2	2.6	2.9	3.3	3.7	4.2	4.6	5.0	5.5	6.0	6.4	6.9	7.4	7.8	8.3	8.8
5	1.2	1.4	1.6	1.8	2.1	2.3	2.6	2.9	3.2	3.6	3.9	4.2	4.5	4.9	5.2	5.6	5.9	6.2	6.6	6.9
6	1.1	1.3	1.5	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.4	3.7	3.9	4.2	4.5	4.7	5.0	5.2	5.5	5.7
7	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9
8	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7	3.9	4.0	4.2	4.3
9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.6	3.8	3.9
10	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.7	2.8	3.0	3.1	3.2	3.3	3.4	3.6
11	1.1	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.3
12	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.0
13	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.9
14	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3	2.4	2.5	2.6	2.6	2.7
15	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.5
16	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.4
17	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.3
18	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2
19	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1
20	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0

EXAMPLE 1

The following data was collected from DMR data for an industrial discharger into a freshwater stream. Samples were collected once a month within the last five years and the data represents both daily maximums and monthly averages for the data. The data meets all minimum QA/QC requirements. The periodic calculated low flows (7Q10, 1Q10, 3Q5) of the receiving water equal zero because at most times of the year, there is no flow in the receiving water. There is no mixing zone allowed because the low flows are equal to zero. The hardness value of the receiving water is 25 mg/L as $CaCO_3$. The desired Confidence Interval and Probability Basis is 95/95.

<u>Data set 1: Copper</u>

Copper (Cu) (Total recoverable), ug/L: 29, 27.5, 38.7, 42, 26, 26, 20.1, 11.8, 22.1, 25.4, 26.2, 22.4,12.1. There are 13 total data points, all data is >reporting limit of 5.0 ug/L. The limiting number of significant figures in the data set is 2.

The data is entered into the "Reasonable Potential Procedure" spreadsheet, and the procedure applies lognormal statistical analysis to the data set (10<=k<=30). The MEC reported from the spreadsheet is **57 ug/L**.

> *For hand calculating:*
> *Apply lognormal statistical analysis to the data set and determine the CV of the data set.*
>
> *Using the CV=0.38 (round to 0.4), and 13 samples, a reasonable potential multiplier of 1.4 is obtained from Table 3-2 of the TSD.*
>
> *The MEC is calculated from the highest effluent monthly average (in this case the daily maximum is the same value) of 42 and the multiplier of 1.4 = 59 ug/L (Cu, total recoverable).*
>
> *Note: The hand calculated MEC of 59 ug/L is greater than the spreadsheet value of 57 ug/L due to rounding off error introduced into the CV (0.4 vs. 0.38) and multiplier values (Table 3-2 values are only carried to one place past the decimal and do not incorporate correct use of significant figures). Some of the error could be reduced by interpolating values in Table 3.2 of the TSD.*

The RWC is also = 57 ug/L (Cu, total recoverable) for both acute and chronic conditions because no mixing zone is allowed and only one sample per month was collected.

The receiving water criteria for copper to protect aquatic life and human health are:

Irrigation Water: 200 ug/L (total recoverable)

Aquatic life (expressed as dissolved (3.6 ug/L acute, 2.7 g/L chronic) with translator value (=0.96) to convert to total recoverable effluent limits for comparison): Acute = 3.8 ug/L (total recoverable), Chronic = 2.9 ug/L (total recoverable)

Human Health (non-carcinogenic): Water + Organism = 1,300 ug/L (total recoverable)

The RWC of 57 ug/L exceeds the aquatic life acute and chronic criteria for copper, and therefore there is reasonable potential for copper to cause or contribute to an excursion above aquatic life water quality criteria, and limits must be places in the permit for copper (acute and chronic). The RWC does not exceed the human health criteria for copper (1,300 ug/L) or the irrigation water criteria (200 ug/L) and therefore no reasonable potential exists for the discharge to cause or contribute to an excursion of the human health or irrigation water criteria for copper.

Data set 2: Antimony

Antimony (Sb) (Total recoverable), ug/L: 1.76, 2.17, 2.15, 2.29, 1.56, <1.00, <1.00, <1.00, <1.00, <1.00, <1.00, <1.00, <2.00. There are 13 total data points, 5 greater than the reporting limits, 8 non-detects with 2 different reporting limits, 1.00 and 2.00. The limiting number of significant figures in the data set is 3. The desired Confidence Interval and Probability Basis is 95/95.

Since one of the non-detected values (<2.00) has a reporting limit above other reported values, the value was discarded from the data set. This leaves 12 total data points, 5 greater than the reporting limit, and 7 non-detects.

Since there are less than 10 data points above the reporting limit, the permit writer can choose to use a default CV of 0.6 or choose to use the delta-lognormal statistical analysis. In this case, since there are actually 12 total valid data points, the permit writer has opted to use the statistical approach. The data is entered into a spreadsheet and a CV of 0.38 is determined from the delta-lognormal statistical analysis using a censoring value (reporting limit) of 1.00.

The data is entered into the "Reasonable Potential Procedure" spreadsheet, and the procedure applies delta-lognormal statistical analysis to the data set (which includes the ND values). The MEC reported from the spreadsheet is **3.15 ug/L**.

> *For hand calculating:*
> *Apply delta- lognormal statistical analysis to the data set and determine the CV of the data set.*
>
> *Using the CV = 0.38 (round to 0.4) and 12 samples, a multiplier of 1.4 is obtained from Table 3-2 of the TSD.*
>
> *The MEC is calculated from the highest effluent monthly average (and in this case the same value for daily maximum) of 2.29 and the multiplier of 1.4 = 3.21 ug/L (Sb, total recoverable).*
>
> *Note: The hand calculated MEC of 3.21 ug/L is greater than the spreadsheet value of 3.15 ug/L due to rounding of the CV and multiplier values.*

The RWC is also = 3.15 ug/L (Sb, total recoverable) for both acute and chronic conditions because no mixing zone is allowed and only one sample per month was collected.

The receiving water criteria for antimony to protect drinking water and human health are:

Drinking Water: 6 ug/L (total recoverable)

Human Health (non-carcinogenic): Water + Organism = 14 ug/L (total recoverable)
Organism Only = 4,300 ug/L (total recoverable)

The RWC does not exceed the human health criteria for antimony (14 ug/L, 4,300 ug/L) or the drinking water criterion (6 ug/L) and therefore no reasonable potential exists for the discharge to cause or contribute to an excursion of the human health or drinking water criteria for antimony.

If the permit writer had chosen to use the default value of 0.6 for the CV, a multiplier of 1.6 is obtained from Table 3-2 and a MEC and RWC of 3.66 ug/L is hand calculated. There is no reasonable potential for antimony shown using the default CV.

Since the RWC is between 100% and 50% of the drinking water criterion for antimony, the facility will be required to monitor for antimony (total recoverable) in the effluent discharge so that any potential changes of selenium concentration in the discharge can be identified and future reasonable potential determinations can be performed using current data.

References

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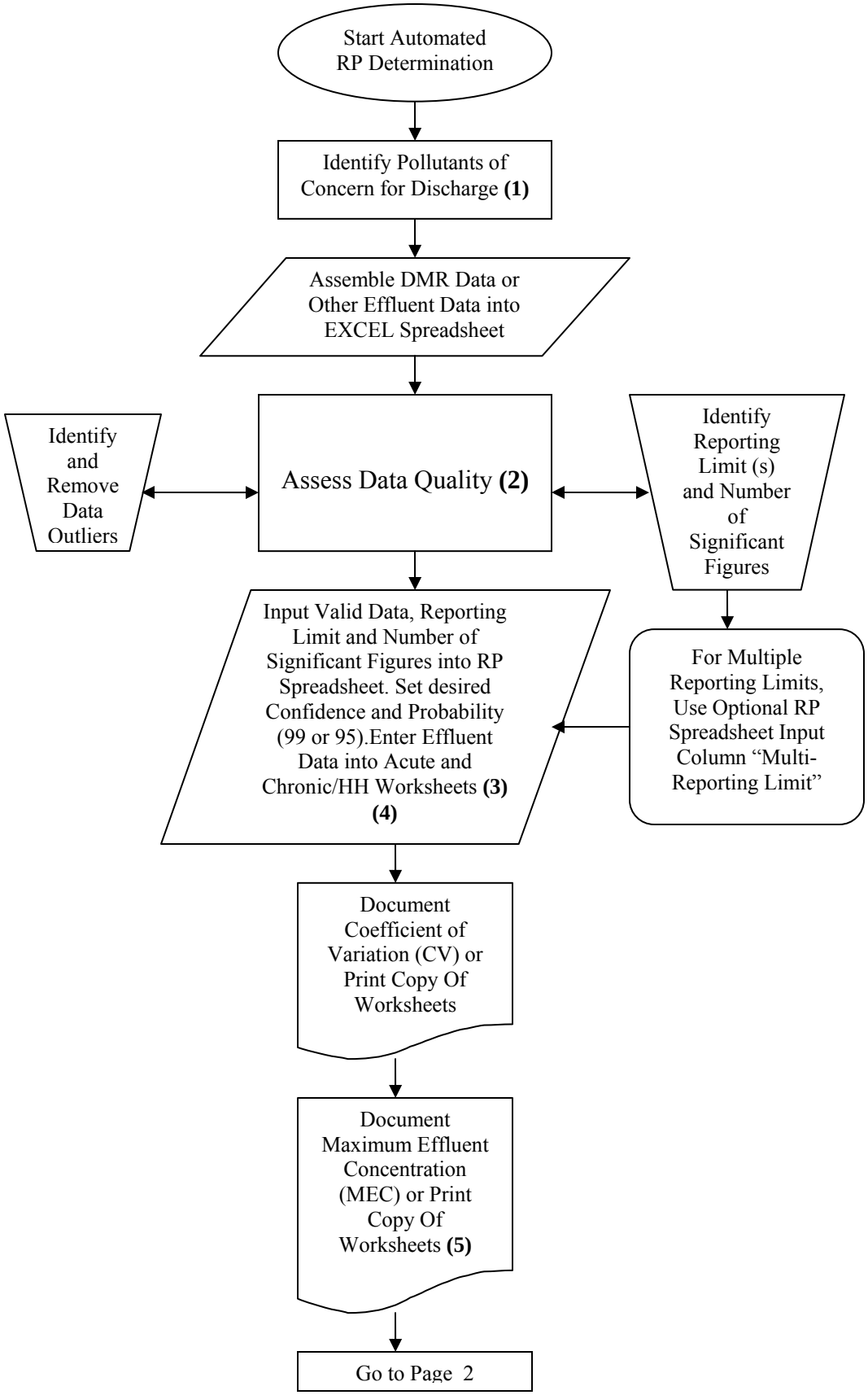
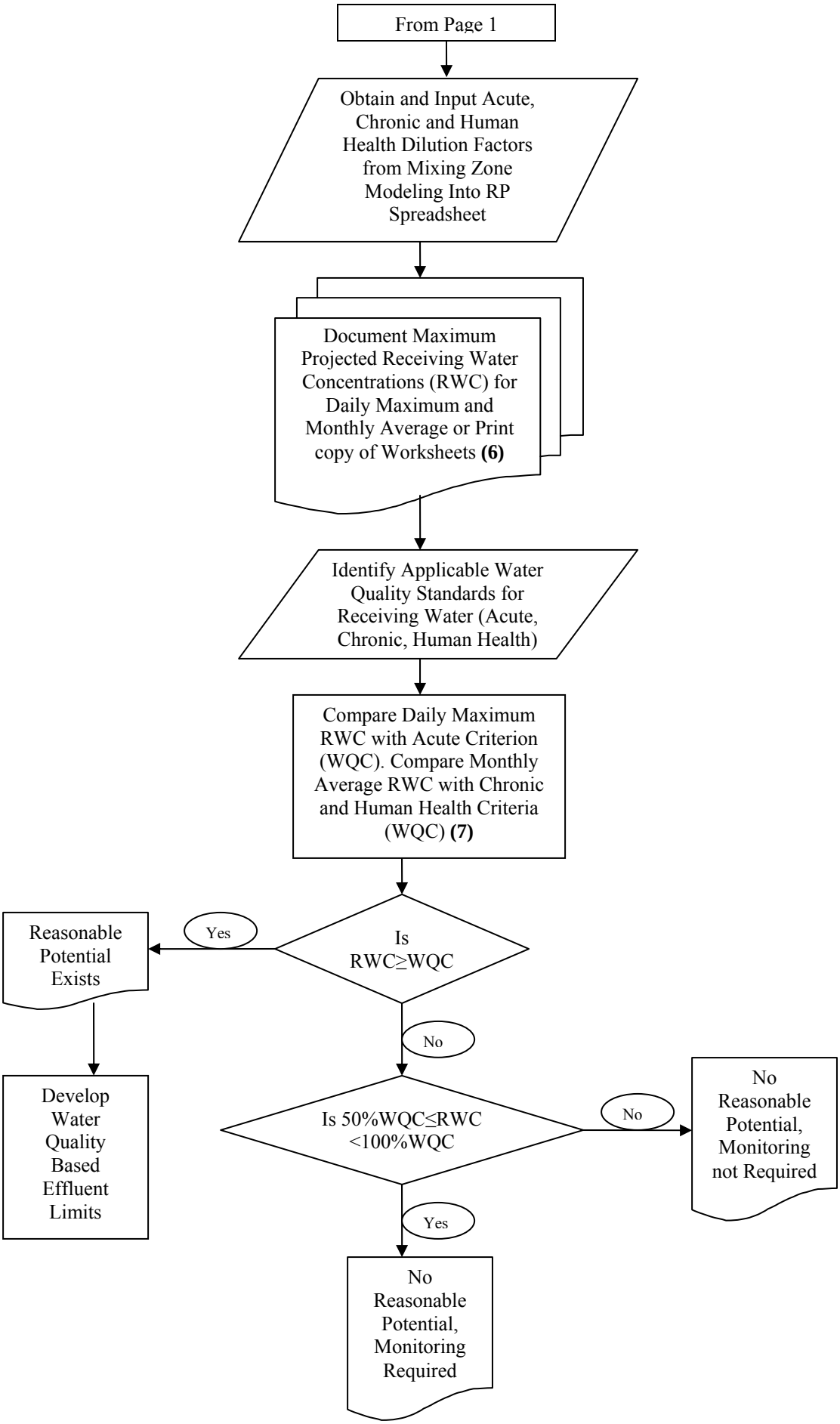
Appendix E of the Technical Development Document for the Final Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category EPA 821-R-04-012, August 2004.

Appendix 1
Reasonable Potential Flowchart




From Page 1
Obtain and Input Acute, Chronic and Human Health Dilution Factors from Mixing Zone Modeling Into RP Spreadsheet
Document Maximum Projected Receiving Water Concentrations (RWC) for Daily Maximum and Monthly Average or Print copy of Worksheets (6)
Identify Applicable Water Quality Standards for Receiving Water (Acute, Chronic, Human Health)
Compare Daily Maximum RWC with Acute Criterion (WQC). Compare Monthly Average RWC with Chronic and Human Health Criteria (WQC) (7)
Is RWC≥WQC
Yes
Reasonable Potential Exists
Develop Water Quality Based Effluent Limits
No
Is 50%WQC≤RWC <100%WQC
No
No Reasonable Potential, Monitoring not Required
Yes
No Reasonable Potential, Monitoring Required

Appendix 2
OPTIONAL
Modified Delta-Lognormal Statistical Procedure for Data Sets With Multiple Reporting Limits

In recent years, during development of long term averages and variability factors used to calculate Daily Maximum and Monthly Average treatment performance standards during development of Effluent Guidelines and Standards for industrial categories of discharges, EPA has adopted a modification of the delta-lognormal statistical application to apply to effluent data sets containing multiple reporting and detection levels.

This modification to the TSD statistical approach calculates statistical distribution parameters for the part of the data set below the reporting level referred to as the discreet portion of the data set and applies log-normal distribution statistics to the part of the data set above the reporting level referred to as the non-censored portion of the data set. The two distributions are then combined to give a statistical distribution that represents the entire data set.

Discreet portion of the data set

Where: δ represents the proportion of the non-detected (less than reporting limit) values in the data set and is the sum of smaller fractions, δ_i, each representing the proportion of non-detected values associated with each detection limit value. By letting D_i equal the value of the ith smallest distinct detection limit in the data set and the random variable X_D represent a randomly chosen non-detected measurement, the cumulative distribution of the discreet portion of the data set can be expressed as:

$$P_r\,(X_D \leq c) = 1/\delta \sum_{i:D_i \leq c} \delta_i \qquad 0<c$$

The mean and variance of the discreet distribution can be calculated using the following formulas:

$$E(X_D) = 1/\delta \sum_{i=1}^{k} \delta_i\, D_i$$

$$Var(X_D) = 1/\delta \sum_{i=1}^{k} \delta_i\, (D_i - E(X_D))^2$$

Non-censored portion of the data set

The cumulative distribution of the continuous lognormal portion of the data set (all values above the reporting or detection limit) can be expressed as:

$$P_r\,[\,X_c \leq c\,] = \Phi\left[\frac{\ln(c) - \mu}{\sigma}\right]$$

where the random variable X_c represents a randomly chosen detected measurement, Φ is the standard normal distribution, and μ and σ are parameters of the distribution.

The expected value E (X_c), and the variance Var (X_c), of the lognormal distribution can be calculated as follows:

$$E(X_c) = \exp(\mu + \sigma^2/2)$$

$$Var(X_c) = [E(X_c)]^2 [\exp(\sigma^2) - 1]$$

<u>Combined discreet and non-censored portions of the data set</u>

The modified delta-lognormal random variable U can be expressed as a combination of three other independent variables, that is,

$$U = I_u X_d + (1 - I_u) X_c$$

where X_D represents a random non-detect from the discreet portion of the distribution, X_c represents a random detected measurement from the lognormal portion of the distribution, and I_u is an indicator variable signaling whether any particular random measurement, u, is non-detected or non-censored.

Using a weighted sum, the cumulative distribution function from the discreet portion of the distribution can be combined with the function from the lognormal portion to obtain the overall cumulative probability distribution of the entire data set as follows:

$$P_r[U \le c] = \sum_{i:D_i \le c} \delta_i + (1 - \delta)\,\Phi\left[\frac{\ln(c) - \mu}{\sigma}\right]$$

where D_i is the value of the ith sample specific detection limit.

The expected value of the random variable U can be derived as a weighted sum of the expected values of the discreet and non-censored portions of the distribution as follows:

$$E(U) = \delta E(X_D) + (1 - \delta) E(X_c)$$

Similarly, the expected value of the random value squared can be expressed as a weighted sum of the expected values of the squares of the discreet and non-censored portions of the distribution as follows:

$$E(U^2) = \delta E(X_D^2) + (1 - \delta) E(X_c^2)$$

Although written in terms of U, the following relationship holds for all ramdom variables, U, X_D, and X_c.

$$E(U^2) = Var(U) + [E(U)]^2$$

Solving this equation for Var (U) results in the following:

$$Var(U) = \delta (Var(X_D) + [E(X_D)]^2) + (1 - \delta)(Var(X_c) + [E(X_c)]^2) - [E(U)]^2$$