Establishing Water Quality-based Effluent Limitations in NPDES Permits: Part III—Determine the Need for WQBELs

Today’s Speakers

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Part I Review: Relationship Between WQS and Effluent Limitations

- **Recall from Part I (Identify Applicable WQS):**
  - Water quality *standards* apply throughout the waterbody (or segment of a waterbody) as defined by the state, territory, or tribe
  - *Effluent limitations* apply at the compliance point established in the permit (generally “end of pipe”)
Part I Review: Relationship Between WQS and Effluent Limitations

- Water Quality Criteria
  - Magnitude
  - Duration
  - Frequency

- Effluent Limitations
  - Magnitude
  - Averaging Period

Permit writers calculate end-of-pipe water quality-based effluent limitations where necessary to ensure that water quality standards are attained in the receiving water.

Part I Review: WQS Implementation Procedures

- Water quality standards and their implementing procedures (including NPDES requirements) specify methods for determining the need for WQBELs and for calculating WQBELs that ensure that standards are attained.

- Where can these methods be found?
  - EPA’s Technical Support Document
  - State regulations
  - State water quality management plans
  - State guidance
  - past practices
  - We never thought about this before!
Part II Review: Identify Pollutants of Concern

Recall from Part II (Characterize Effluent and Receiving Water) that pollutants of concern are:

- With an applicable technology-based effluent limitation (TBEL)
- With a wasteload allocation (WLA) from a total maximum daily load (TMDL)
- Identified as needing WQBELs or monitoring in the previous permit
- Identified as present in the effluent through monitoring
- Otherwise expected to be present in the discharge

Part II Review: Determine the Allowable Dilution or Mixing Zone in the Receiving Water

Also recall from Part II (Characterize Effluent and Receiving Water) that we need to:

- Determine whether water quality standards permit dilution allowances or mixing zones
- Determine critical conditions (e.g., critical stream flow)
- Determine type of mixing under critical conditions
  - rapid and complete mixing
  - incomplete mixing
- Determine dilution allowance or regulatory mixing zone size for calculations
Part III: Determine the Need for WQBELs

Part III: Determining the Need for Chemical-specific WQBELs

*When must a permit writer establish effluent limitations using water quality criteria?*

**Answer:** Limitations must be established in permits to control all pollutants or pollutant parameters that 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 [40 CFR 122.44(d)(1)(i)].
Is There Reasonable Potential?

Limitations must be established in permits to control all pollutants or pollutant parameters that 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.

Steady-State Modeling

- Predicts the impact of the effluent on the receiving water for a single set of conditions
- Can be used in both rapid and complete mixing and incomplete mixing situations
- Generally assumes that the single set of conditions are the critical conditions for flow, pollutant concentrations, and environmental effects
Dynamic Modeling

- Accounts for *variability* of model inputs
- Projects *probability distributions* rather than a single value based on critical conditions
- *Data intensive* and *complex*

Is There Reasonable Potential?

For steady-state modeling under critical conditions:

- If the receiving water concentration *exceeds* the applicable water quality criterion, then there is *reasonable potential* and the permit writer *must* establish WQBELs
- If the receiving water concentration is *equal to or less than* the applicable water quality criterion, then there is *no reasonable potential* and we have not demonstrated a need to establish WQBELs
The discharge of Pollutant X from ABC, Inc., would cause, have the reasonable potential to cause, or contribute to an excursion of the acute aquatic life criterion.

*The permit writer must calculate WQBELs for Pollutant X.*

**Expected Receiving Water Concentration for Steady-State, Rapid and Complete Mixing Under Critical Conditions**

Mass-Balance Equation: \( Q_s C_s + Q_d C_d = Q_r C_r \)

- \( Q = \) Flow (mgd or cfs)
- \( C = \) Pollutant concentration (mg/l)
- Mass = [Concentration] [Flow]
### Steady-State Complete Mix Assessment

\[ Q_s C_s + Q_d C_d = Q_r C_r \]

Determine the pollutant concentration of Pollutant X (the pollutant of concern) in the water body downstream of the discharge:

\[ Cr = \frac{Q_s C_s + Q_d C_d}{Q_r} \]

### Calculating Receiving Water Concentration Under Critical Conditions

Criterion for protection of aquatic life from acute effects from Pollutant X: \( C_r = 1.0 \text{ mg/L} \)

- \( Q_s \) = Critical stream flow \((1Q_{10})\) for acute criterion = ???????
- \( Q_d \) = Critical effluent flow from discharge flow data = ???????
- \( Q_r \) = Sum of critical stream flow and critical effluent flow = ???????
- \( C_s \) = Critical upstream pollutant concentration = ???????
- \( C_d \) = Critical effluent pollutant concentration = ???????

\[ Cr = \frac{Q_s C_s + Q_d C_d}{Q_r} \]
**Steady-State Complete Mix Assessment**

\[ Q_s C_s + Q_d C_d = Q_r C_r \]

**Calculating Receiving Water Concentration Under Critical Conditions**

Criterion for protection of aquatic life from acute effects from Pollutant X: \( 1.0 \text{ mg/L} \)

- \( Q_s \) = Critical stream flow (1Q10) for acute criterion \( = 1.2 \text{ cfs} \)
- \( Q_d \) = Critical effluent flow from discharge flow data \( = \) ???????
- \( Q_r \) = Sum of critical stream flow and critical effluent flow \( = \) ???????
- \( C_s \) = Critical upstream pollutant concentration \( = \) ???????
- \( C_d \) = Critical effluent pollutant concentration \( = \) ???????

\[ C_r = \frac{Q_s C_s + Q_d C_d}{Q_r} \]
### Steady-State Complete Mix Assessment

\[ Q_s C_s + Q_d C_d = Q_r C_r \]

- **Cr** = \( \frac{Q_s C_s + Q_d C_d}{Q_r} \)
- **Qd** = Critical effluent flow from discharge flow data

### Calculating Receiving Water Concentration Under Critical Conditions

**Criterion for protection of aquatic life from acute effects from Pollutant X:** 1.0 mg/L

- **Qs** = Critical stream flow (1Q10) for acute criterion = 1.2 cfs
- **Qd** = Critical effluent flow from discharge flow data = 0.31 cfs
- **Qr** = Sum of critical stream flow and critical effluent flow = ???????
- **Cs** = Critical upstream pollutant concentration = ???????
- **Cd** = Critical effluent pollutant concentration = ???????

**Cr** = \( \frac{Q_s C_s + Q_d C_d}{Q_r} \)
### Steady-State Complete Mix Assessment

\[ Q_s C_s + Q_d C_d = Q_r C_r \]

**Cr** = \( \frac{Q_s C_s + Q_d C_d}{Q_r} \)

**Qr** = *Sum* of upstream flow (Qs) and discharge flow (Qd)

### Calculating Receiving Water Concentration Under Critical Conditions

Criterion for protection of aquatic life from acute effects from Pollutant X: = 1.0 mg/L

- **Qs** = Critical stream flow (1Q10) for acute criterion = 1.2 cfs
- **Qd** = Critical effluent flow from discharge flow data = 0.31 cfs
- **Qr** = Sum of critical stream flow and critical effluent flow = 1.51 cfs
- **Cs** = Critical upstream pollutant concentration = ???????
- **Cd** = Critical effluent pollutant concentration = ???????

\[ Cr = \frac{Q_s C_s + Q_d C_d}{Q_r} \]
**Steady-State Complete Mix Assessment**

\[ Q_s C_s + Q_d C_d = Q_r C_r \]

\[ C_r = \frac{Q_s C_s + Q_d C_d}{Q_r} \]

**Cs** = Critical *background* (upstream) pollutant *concentration* from ambient monitoring data

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**Calculating Receiving Water Concentration Under Critical Conditions**

Criterion for protection of aquatic life from acute effects from Pollutant X: = 1.0 mg/L

- \( Q_s \) = Critical stream flow (1Q10) for acute criterion = 1.2 cfs
- \( Q_d \) = Critical effluent flow from discharge flow data = 0.31 cfs
- \( Q_r \) = Sum of critical stream flow and critical effluent flow = 1.51 cfs
- \( C_s \) = Critical upstream pollutant concentration = 0.80 mg/L
- \( C_d \) = Critical effluent pollutant concentration = ??????

\[ C_r = \frac{Q_s C_s + Q_d C_d}{Q_r} \]
Determine the Need for WQBELs

Steady-State Complete Mix Assessment

\[ Q_{sC}s + Q_{dC}d = Q_{rC}r \]

Cr = \( \frac{Q_{sC}s + Q_{dC}d}{Q_{rC}} \)

Cd = Critical effluent pollutant concentration

Determining a Maximum (Critical) Value for Cd

Examine data for ABC, Incorporated

- Number of samples (N) = 6
- Concentrations of Pollutant X:
  - Cd(1) = 1.2 mg/L
  - Cd(3) = 0.87 mg/L
  - Cd(5) = 0.74 mg/L
  - Cd(2) = 0.82 mg/L
  - Cd(4) = 1.3 mg/L
  - Cd(6) = 1.0 mg/L

- Maximum Observed Value of Effluent Concentration = 1.3 mg/L

Would this Cd represent the “critical” condition?
Determining a Maximum (Critical) Value for Cd

- **Answer: Not likely**
  - Our limited data set does not account for day-to-day *variability* in effluent quality (i.e., the facility probably did not self-monitor on its worst possible day).
  - When determining reasonable potential, “…..the permitting authority shall use procedures which account for…..the *variability* of the pollutant or pollutant parameter in the effluent…” [40 CFR 122.44(d)(1)(ii)].

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Follow permitting authority procedures to determine the critical value for Cd

- Permitting authority regulation, policy, or guidance
- EPA’s *Technical Support Document for Water Quality-based Toxics Control* (TSD)
  - Uses a statistical analysis that assumes effluent data follow a *lognormal distribution*
Some Key Terms

- **Lognormal Distribution**: the probability distribution of any random variable whose logarithm is normally distributed
  - **Relative Frequency**: the fraction or ratio of the number of observations in a category or class to the total number of observations

Some Key Terms

- **Long-term Average (LTA)**: for a continuous random variable (in our case, pollutant concentration), the value at which the area under the distribution curve to the left of the value equals the area under the distribution curve to the right of the value

- **Coefficient of Variation (CV)**: a statistical measure of the relative variation of a distribution or set of data (in our case, pollutant concentrations) calculated as the standard deviation divided by the mean
Defining a Lognormal Distribution Using LTA and CV

Steady-State Complete Mix Assessment
QsCs + QdCd = QrCr

Recall….we want to determine the critical effluent pollutant concentration (Cd)
Determine the Need for WQBELs

**Determining a Critical Value for Cd**

Examine data for ABC, Incorporated using the TSD statistical approach

- Number of samples \((N)\) = 6
- Concentrations of Pollutant X:
  - \(Cd(1) = 1.2\) mg/L
  - \(Cd(2) = 0.92\) mg/L
  - \(Cd(3) = 0.87\) mg/L
  - \(Cd(4) = 1.3\) mg/L
  - \(Cd(5) = 0.74\) mg/L
  - \(Cd(6) = 1.0\) mg/L
- \(CV = 0.6\) (EPA recommends a default \(CV\) value of 0.6 if there are < 10 data points available)
- Maximum Observed Value of Effluent Concentration = 1.3 mg/L
Statistics tell us that we can be 99% sure that the largest value of our 6 measurements of the concentration of Pollutant X will be at or greater than the 46th percentile of the lognormal distribution of all effluent pollutant concentrations for ABC, Inc.

Determining a Critical Value for Cd

To be 99 percent sure that we have captured the 99th percentile concentration of Pollutant X (which we will call the critical or upper-bound concentration), we need the highest concentration measured from 330 samples of ABC Inc.'s effluent.
Determine the Need for WQBELs

Determining a Critical Value for \( \text{Cd} \)

Our options:

1. Measure the concentration of Pollutant \( X \) in **330 separate samples** of ABC, Inc.’s effluent

2. Use statistics for the lognormal distribution to find a **multiplier** that lets us **estimate** the 99\(^{\text{th}}\) percentile (which is what we want to find) from the 46\(^{\text{th}}\) percentile (which is represented by the highest of our 6 measured concentrations)

- For any data set, to estimate the upper bound value, we need to know:
  - Number of samples collected (\( N \))
  - Coefficient of variation (\( CV \))
- Use a default of 0.6 if \( N < 10 \)

Reasonable Potential Multiplying Factors

(99\% Confidence Level and 99\% Probability Basis)

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- Number of samples (N) = 6
- Concentrations of Pollutant X:
  - Cd(1) = 1.2 mg/L
  - Cd(2) = 0.92 mg/L
  - Cd(3) = 0.87 mg/L
  - Cd(4) = 1.3 mg/L
  - Cd(5) = 0.74 mg/L
  - Cd(6) = 1.0 mg/L
- CV = 0.6 (default value if N < 10)

Maximum Observed Value of Effluent Concentration = 1.3 mg/L

Projected Critical (99th percentile) Value of Cd =

1.3 mg/L x multiplier =

1.3 mg/L x 3.8 = 5.0 mg/L

Cd = 5.0 mg/L
Determining the Need for WQBELs

**Calculating Receiving Water Concentration Under Critical Conditions**

Criterion for protection of aquatic life from acute effects from Pollutant $X$: $1.0 \text{ mg/L}$

- **$Q_s$** = Critical stream flow ($1Q_{10}$) for acute criterion = 1.2 cfs
- **$Q_d$** = Critical effluent flow from discharge flow data = 0.31 cfs
- **$Q_r$** = Sum of critical stream flow and critical effluent flow = 1.51 cfs
- **$C_s$** = Critical upstream pollutant concentration = 0.80 mg/L
- **$C_d$** = Critical effluent pollutant concentration (projected) = 5.0 mg/L

$$\text{Cr} = \frac{Q_sC_s + Q_dC_d}{Q_r}$$

$$\text{Cr} = \frac{(1.2 \text{ cfs})(0.80 \text{ mg/L}) + (0.31 \text{ cfs})(5.0 \text{ mg/L})}{1.51 \text{ cfs}}$$

$$\text{Cr} = 1.7 \text{ mg/L}$$

**Expected Receiving Water Concentration**

(Steady-State, Rapid and Complete Mix Under Critical Conditions)

$$\text{Cr} = \frac{Q_sC_s + Q_dC_d}{Q_r}$$

$$\text{Cr} = 1.7 \text{ mg/L}$$
Is There Reasonable Potential?
(Steady-State, Rapid and Complete Mix Under Critical Conditions)

For ABC, Incorporated:
- Projected Cr = 1.7 mg/L > 1.0 mg/L (acute criterion)
- The discharge of Pollutant X from ABC, Incorporated would cause, have the reasonable potential to cause, or contribute to an excursion of the acute aquatic life criterion.
- **The permit writer must calculate WQBELs for Pollutant X.**

What Next?

- In our example, where we considered only the acute aquatic life criterion, we still would need to consider, if available:
  - chronic aquatic life criterion
  - human health criteria
  - wildlife criteria
  - etc.
What Next? (continued)

- Repeat the entire analysis for additional pollutants of concern and additional outfalls
- For each pollutant for which we determine there is reasonable potential to exceed any of the criteria for that pollutant, calculate chemical-specific WQBELs (Part IV)
- When there is no reasonable potential
  - determine whether any existing limitations should be retained
  - consider appropriate monitoring requirements

Feedback and Other Presentations

Questions or comments?
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