WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Total Maximum Daily Load Development Guidelines

November 1996

Publication No. 97-315

Printed on Recycled Paper

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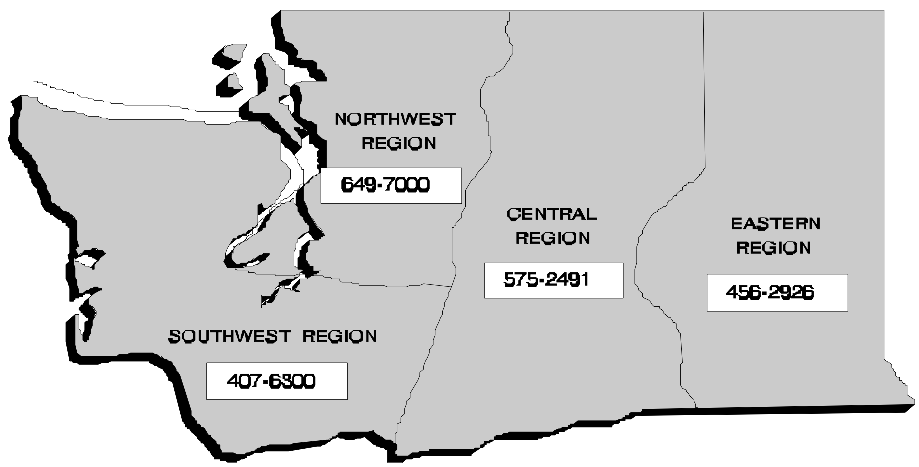

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Total Maximum Daily Load Development Guidelines

by
TMDL Workgroup

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Watershed Assessments Section
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Abstract

A set of seven guidelines were prepared to ensure consistency in developing Total Maximum Daily Load (TMDL) reports. The guidelines address the following issues:

- Application of dissolved oxygen standards (spatial and temporal variability)
- Definition of the critical low streamflow
- Point source effluent flow (for input to steady-state TMDL models)
- Translation of model results to permit limits for NPDES dischargers
- Establishing biochemical oxygen demand (BOD) for steady-state TMDL models
- Application of metals water quality standards
- Miscellaneous guidelines

The guidelines apply to TMDL reports developed by the Environmental Investigations and Laboratory Services Program at the Washington State Department of Ecology.

Acknowledgments

Emmanuel Nocon compiled these guidelines based on material submitted by the TMDL Workgroup. The workgroup members are: Greg Pelletier, Paul Pickett, Bob Cusimano, Joe Joy, Karol Erickson, Steve Butkus, and Gary Bailey. Barbara Tovrea did the final editing and formatting.

#1: Application of Dissolved Oxygen Standards

Issue:

Application of Dissolved Oxygen Standards: Spatial and Temporal Variability

Purpose:

In the development of a TMDL for the protection of the dissolved oxygen (DO) Standards in a water body, the DO criteria must be interpreted with regard to the temporal and spatial variability of the ambient values. In evaluating modeling inputs and results, assumptions must be made about the frequency, duration, and spatial extent of ambient DO that constitutes compliance with DO Standards.

The Surface Water Quality Standards (WQS) for the State of Washington include criteria for DO, which for both freshwater and marine in all classes use the language "*shall exceed*"(WAC 173-201A-030). The agency has interpreted this as meaning an absolute minimum. This interpretation is based on research cited in "Ambient Water Quality Criteria for Dissolved Oxygen" (USEPA, April 1986). This interpretation of the criteria raises practical difficulties for TMDL development. Guidelines are provided here for practical approaches to a DO TMDL that define the duration, frequency, and averaging period of model inputs and outputs, while meeting the regulatory requirements of the WQS.

Guidelines:

Discussion

Most water quality DO models assume a daily average modeling period. Modeling of diurnal DO cycles is difficult and only available in the most complex models. For this reason, modeling at EILS has often evaluated daily average DO and compared those results to the criteria. Some EILS studies have modeled early morning minimum DOs as a steady-state parameter. Daily average or daily minima data have not been applied consistently to evaluate compliance with criteria. Also, Water Quality Program (WQP) guidance used in permit development and engineering review does not address issues of spatial and temporal variability and does not specify the consideration of daily minima in the evaluation of WQS compliance.

If the WQS must be interpreted as requiring the daily minimum to meet the criteria, then a number of concerns are raised:

- Past studies conducted by EILS have equated compliance with the daily average dissolved oxygen. Assuring compliance with the minimum DO will cause more complex (expensive) studies and more stringent treatment for some dischargers.
- Ambient monitoring by EILS is currently and has historically not been scheduled to coincide with any particular point in the daily DO cycle. Therefore, the ambient monitoring data may report a value from anywhere in the diurnal cycle, depending on the time of sampling and on the conditions of the river monitored. Most data are likely biased above the daily minimum. In addition, the effect of established time schedules and occasional changes in them makes a time-of-day correction necessary in order to use Ecology ambient monitoring data for comparison of DO levels in different rivers or trend analysis at a single station.
- Technical reviews by EILS of permit and engineering report requirements generally has not addressed the need to apply daily minima DO data and modeling to the DO criteria, since typically mid-day values or daily average results are compared to the criteria. In some situations, this analysis may not be adequate, and the daily fluctuation of DO may need to be addressed. Also, the "Permit Writers Manual" (Ecology, 1994) has historically not addressed this issue, and some permit writers and engineers may not be aware of it.
- Modeling of DO and comparison to the WQS must take into consideration the difficulty in modeling the diurnal DO cycle and in predicting the change in diurnal DO range due to changes in pollutant loading. It may also not be realistically possible to find model input parameters such that the DO standards are never exceeded. Therefore, averaging periods and return frequencies would be chosen to represent conservative conditions with a specified low probability of DO exceedance. An analogous case would be the practice of applying the acute criteria for metals which have a one hour exposure duration and a 1 in 3 year recurrence frequency as a 1 in 100 probability of exceedance during a 7Q10 flow.

With regard to spatial considerations such as low hypolimnetic oxygen, the antidegradation sections of the WQS provide an approach by allowing "*natural*" conditions to be the criteria. However, the use of natural conditions presents several difficulties. Analysis using this approach is difficult because conditions prior to human impacts have to be approximated in some fashion.

Recommendations

The following guidelines are provided for addressing the temporal and spatial variability of DO when applying the WQS to modeling results during TMDL development:

Frequency/Duration Issues

Although the DO criteria are expressed as an absolute minimum never to be exceeded, the use of frequency/duration considerations for inputs is a practical necessity. For example, the 7Q10 flows are usually applied to represent critical low flows, even though the probability exists that lower flows will occur once in ten years on the average. Those low flows would potentially represent violations of criteria. However, use of a low flow that would never be exceeded is not possible or reasonable.

The frequency and duration values to be used for model inputs will be subject of future guidance. However, the "Ambient Water Quality Criteria for Dissolved Oxygen" (EPA, 1986) states that the daily minimum represents an acute criterion. As a starting point, a one hour duration with a three year return period such as used with the toxic metals criteria would be a reasonable approach. The Criteria Document also recommends using site-specific considerations to define frequency and duration, such as the size of the area not meeting criteria, the biological significance of the area, and the magnitude of the DO deficit. Best Professional Judgment must be employed, and as discussed below, it may also be desirable to include an additional safety factor.

Diurnal DO Variability:

There are three methods which can be used to account for diurnal DO fluctuation. These methods require different levels of effort and the choice of method is dependent upon the importance of accurately modeling diurnal DO.

1) ***Safety Factor Method:*** This option applies when no direct measurements are available of the daily range of DO. Model the ambient DO as a 24-hour average, but include a safety factor to ensure a very low probability that the true ambient DO levels can fall below criteria. Two possible ways of incorporating a safety factor are by using conservative input parameters, or by reducing the modeled DO concentrations by some default value before comparison to the criteria. The latter method is equivalent to increasing the DO criteria by some default value to account for the diurnal range.

   The magnitude of the safety factor should vary according to the waterbody classification and the productivity of the waterbody. The productivity of a waterbody is typically assessed by parameters such as chlorophyll-a, turbidity, nutrient concentrations, water clarity, water color and biological factors.

   Input parameters for modeling may introduce an adequate safety factor if sufficiently conservative values are chosen and criteria will be safely met. Often several conservative assumptions for input parameters may in combination be even more conservative. Another possibility is that, because of the limited availability of data or other reasons, the input data is believed to be extremely conservative or "*worst case.*" Sensitivity analysis could give some indication of the magnitude of the safety factor this approach builds in, by assessing the variability of output relative to the inputs.

   If the input data set is judged to be not so conservative that it adds a safety factor, and the water body is believed to have productivity that causes minimum DO levels to be significantly lower than the average DO, then a safety factor can be introduced by subtracting a default value from modeling results before they are compared to the criteria.

For Class AA fresh waters, a default value of 1.0 is suggested; that is, the average DO as modeled would have to be at least 1.0 mg/L above the criteria or at saturation. For Class A and B fresh waters, the average DO would have to be at least the default value of 0.5 mg/L above the criteria or at saturation. The 0.5 default value is recommended by EPA's *"Technical Guidance Manual for Performing Waste Load Allocations"* (although EPA recognizes that there is not a strong quantitative basis for this value). The 1.0 mg/L value allows a safety factor appropriate for the "*extraordinary*" quality of Class AA waters. These default values can be either increased or decreased if observations, data, or other information indicate that the water body appears to be either highly productive or non-productive, respectively.

> *Example:* A permit writer has requested assistance in establishing water-quality based limits for BOD to be included in the permit for the Glacoma municipal WTP discharge into the Snakomish River (a single-source TMDL). Ambient data in the Snakomish exist just upstream of the plant's outfall, but except for the last three years, the data are of questionable quality. The discharger has provided effluent data. Observation of the river indicates that the hydrology is dominated by releases from a dam that cause occasional scouring. Moderate to low productivity is indicated by low upstream nutrient levels, good water clarity, and unexceptional periphyton growth. Low ambient DO seems to correlate well with high temperatures, high ambient ammonia, and low flows; pH is fairly constant.

Worst case background data from the last three years are used. Using a Streeter-Phelps spreadsheet program, the critical downstream DO was predicted to be 0.1 mg/L below the criteria. Because the input data set was limited, the data were judged to be inadequately conservative to introduce a safety factor. Instead, a default value was chosen to be subtracted from modeling results as a safety factor. Since the river is classified as Class A and seems capable of moderate productivity, a safety factor of 0.5 mg/L was judged to be appropriate. Effluent loading was reduced until the critical downstream DO was 0.5 mg/L above the criteria.

2) ***Daily Range Method:*** If productivity is expected to be significant and direct measurements are available of the minimum and average DO values in the water body during periods of maximum productivity, then daily average modeling results can be adjusted downward to a daily minimum. Early morning and late afternoon DOs can be measured during late summer fair weather and low flow conditions, and the morning value compared to the average of the two. A more accurate measurement of the daily average and minimum can be obtained using a datalogger such as a Hydrolab Datasonde 3. The difference between the average and minimum DO would be added to the criteria for comparison to the daily average model results, in the same fashion as described for the Safety Factor Method. Measurement of DO on several different days would be recommended to improve the chances that the maximum DO range was observed.

Example: The Region indicates that it is uncomfortable modifying the Glacoma WTP permit to reduce BOD based on a default value safety factor, and requests a more detailed study. The Snakomish is modeled with QUAL-2E, and field data are collected, including the deployment of several Datasondes for several 24-hour periods during the summer month of lowest flow. The Datasonde data showed the maximum DO was 8.5 mg/L, the minimum DO was 7.3 mg/L, and the average DO was 8.0 mg/L. The difference between the average DO and the daily minimum was 0.7 mg/L. The QUAL-2E modeling results are used to develop load reductions from the Glacoma WTP that will result in downstream daily average DO at least 0.7 mg/L above the criteria.

3) ***Diurnal Modeling Method:*** If violation of the DO criteria appears to be largely due to diurnal DO swings, direct modeling of diurnal DO cycles would be recommended. This would be the method used when a TMDL is likely to include a nutrient allocation intended to reduce the daily DO range. Different complexities of modeling are available at this level, such as estimating DO ranges from a eutrophication model, or modeling with a complex model such as WASP using time steps of less than one day.

Example: Great Quack Lake is a large eutrophic lake that receives a permitted discharge from the Eastern Washington School for the Differently Legal. The state school installed a filter system several years earlier to reduce BOD loading, but nutrient loading is still quite high. Nonpoint sources with high nutrient loading have also been identified, such as septic system leachate and agricultural and residential fertilizer use. Although average DOs are near saturation, extreme diurnal DO swings of 5 mg/L from average to minimum are threatening the lake's fishery. After discussions with fisheries biologists and comparisons of less impacted lakes, an acceptable diurnal swing of 2 mg/L is decided upon. EUTRO/WASP4 is selected to model diurnal DO, and loading reductions are developed to reduce the daily DO swing to the target value.

Natural Conditions:

The WQS regulations specify that if "natural conditions" fall below a criteria, then the antidegradation policy applies, which states that "whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria." Natural conditions are defined as "surface water quality that was present before any human-caused pollution."

Water quality modeling or other analysis may determine that natural conditions are below criteria in a water body subject to a TMDL study. However, it will probably not be possible to determine specific numeric criteria that represent natural conditions, since the true water quality that occurred before human impacts would be very difficult to determine. Therefore, a more practical approach to use in this situation is to require that no significant degradation of DO be allowed below the estimate of natural conditions found by modeling or other analysis.

"*Significant*" degradation of DO may be interpreted as zero degradation or 0.2 mg/L degradation.

1. Allow zero degradation. An allowance of zero degradation would apply where the amount of loading that causes a reduction in DO is very low, and any capacity is only provided by the degradation allowance. In this case, keeping loading to zero would allow a margin of safety for the protection of the waterbody.

2. Allow 0.2 mg/L degradation. An allowance of 0.2 mg/L would apply where a large loading can be added to a waterbody with small levels of degradation. A value of 0.2 mg/L has been used in previous studies and this corresponds to the degradation allowed by the Water Quality Standards in marine waters. A value of 0.2 mg/L also reflects the accuracy of common DO measurement methods.

   Any TMDL study that finds natural conditions below the DO water quality criteria must address the situation through one of the two strategies described above.

   Example: Modeling has shown that this strategy would limit the degradation of DO to less than 0.2 mg/L below the modeled natural conditions.

   As part of a TMDL study, the investigator may recommend a Use Attainability Analysis for site-specific criteria.

   Example: Slugsleim Slough is a slow moving body of water with extensive wetlands in its headwaters. Several duck ranches operate near its banks, as well as the International House of Phrogs (IHOP) Frog Farm, an NPDES permitted facility. In addition, the watershed is seeing rapid residential growth from the nearby city of Kalamity. The DO criterion for this waterbody is 8.0 mg/L, but summer ambient DOs do not meet this criterion except on sunny days near the surface. The system is modeled, and nonpoint and point source loadings reduced to zero. Through this process it is discovered that natural conditions are less than the criterion. The TMDL report recommends that a basin-wide program of BMPs be implemented to reduce nonpoint loading of dissolved nutrients and organic solids to negligible levels, and the IHOP Frog Farm must either install a wetlands treatment system or remove its discharge during the summer months.

#2: River Critical Low Flows

Issue:

River Critical Low Flow for Steady State TMDL Modeling

Purpose:

Steady state modeling of water quality is a common method of determining TMDLs and WLAs in rivers. Use of steady state models requires assumption of design conditions for all input variables. Ecology has traditionally required the use of annual 7-day low flows with a recurrence interval of 10 years (7Q10). Chapter 173-201A WAC states that "*for steady-state discharges to riverine systems, the critical conditions may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department*." In addition to the 7Q10, minimum flow requirements and methods to estimate critical low flow may exist that should be considered in the evaluation of critical low flow. The annual 7Q10 river flows are typically used to derive NPDES permit limits that are applicable to all seasons (annual permit limits). Ecology allows seasonal effluent limits if they are protective of the water quality criteria. Guidelines for river critical low flows are needed to ensure that seasonal permit limits are at least as protective of water quality standards as annual permits based on the 7Q10 (Rossman, 1989; GKY, 1984).

Guidelines:

Annual Permit Limits

The annual 7Q10 should be used as the river critical low flow for TMDLs that are used to derive WLAs and permit limits which will apply during all seasons. The 7Q10 is appropriate for acute and chronic aquatic life criteria as well as conventional parameters such as dissolved oxygen. Critical low flows can be calculated using standard statistical methods for hydrology. Distributions of low flows commonly fit either a Log-Pearson Type III or Weibull distribution (Haan, 1977). Derivation of critical low flows from USGS data may be accomplished using software such as WQHYDRO (Aroner, 1992).

Seasonal Permit Limits

Seasonal NPDES permit limits may be allowed provided that the probability of violating water quality standards is no greater than under annual permit limits based on the annual 7Q10. The recurrence intervals for seasonal critical low flows can be selected to maintain environmental equivalency with the annual 7Q10 as follows (GKY, 1984):

Permit Interval	Annual Risk Equivalent Return Period (years)
Annual	10
Semiannual	20
Quarterly	38
Monthly	114

For example, if seasonal permits are calculated for semiannual periods (i.e., two seasons), then the critical low flow for equivalent annual risk would be 7-day low flows with 20-year recurrence intervals from each season (7Q20).

Selection of Semiannual Periods

The most popular type of seasonal permit limit is semiannual and divides the year into two periods (GKY, 1984). Semiannual permits often use assimilative capacity nearly as efficiently as quarterly or monthly limits with less administrative burden. The location and length of each semiannual period within the year can be crucial to efficiency.

A systematic method of determining semiannual periods was presented by GKY (1984). The method begins by determining monthly WLAs using appropriate monthly design conditions (e.g., using monthly 7Q114 critical low flows). The 12 months of the year are divided into two contiguous groups so that the sum of the minimum monthly WLA times the number of days in each group is maximized. The optimal semi-annual periods are found by systematic trials of selected groups of months. To start the process, the year is divided into two groups: the month with the lowest WLA (period 1); and the other 11 months (period 2). Next, the minimum WLA from periods 1 and 2 are multiplied by the number of days in each period and these products are added together to estimate the time-weighted annual average WTP load. For the next iteration the contiguous month with the next highest WLA is added to period 1 and deleted from period 2 and the time-weighted annual load is recalculated. This step is repeated until the periods which provide the maximum annual load are found. The systematic method is illustrated in Table 1 (from GKY, 1984).

Alternative methods for determining semiannual periods can also be considered. For example, semiannual periods may be selected by grouping the year into periods of equal length with one season selected based on occurrence of low river flows. There are disadvantages of methods which consider only one factor such as river flow. For example, factors other than flow may influence assimilative capacity (e.g., temperature and pH). Also, the optimal periods may not have equal length.

Table 1. Example of systematic method to determine semiannual permit periods.

Month	TMDL (lb/day)
Jan	13.1
Feb	12.3
Mar	23.0
Apr	12.5
May	5.35
Jun	3.60
Jul	2.02
Aug	1.68
Sep	2.19
Oct	3.23
Nov	4.78
Dec	7.26

The systematic method presented by GKY should be considered preferable to less systematic methods. However, if all variables that influence assimilative capacity are correlated (e.g., low flows occur at the same time as high temperature and pH), then less systematic methods may be justified. The systematic method may not be feasible in very complex TMDLs with multiple dischargers. Simpler approaches may need to be developed for specific cases.

Consideration of streams affected by dams and/or minimum instream flows

The following discussion assumes an annual permit limit. If a seasonal limit is used, the 7Q10 should be replaced with the appropriate equivalent critical low flow, as described in the previous sections.

Streamflow in many streams is affected by dams and/or agreements on minimum instream flows. These limitations on streamflow arise from many sources, including minimum flows set by regulation, section 401 certifications, interagency agreements, limits on individual water rights, Corps of Engineers operations rules, etc.

The critical flow to be used in these cases is still a low flow that represents a risk equivalent to the 7Q10. The critical low flow, however, should also reflect anticipated conditions in the stream, which will not always be consistent with the historical record. Thus, the critical low flow analysis should include both the calculated 7Q10 and any minimum flow requirements; the hydrologic history of the river or stream; the reliability of the minimum flow (that is, the consistency of flows or strength of the legal instrument controlling the flows); and any trends or other anticipated changes in flows for the future.

If the reliability of the minimum flow is very high, the critical low flow will be the minimum flow (*i.e.* the minimum flow is expected to be met or exceeded continuously over a 10-year period). An example of this situation is the Columbia River downstream of Bonneville Dam, which has a highly reliable minimum release schedule.

If the minimum flow cannot be met during drought conditions, the 7Q10 may be lower than the minimum flow and should be used as the critical low flow. An example of this situation is the Cedar River downstream of Cedar Falls Dam. Although there is a minimum flow in effect, this minimum flow cannot always be met in dry years. In this case, historical flows for the time period the minimum flow has been in effect could be used to calculate the 7Q10. If a sufficiently long historical record does not exist, it may be possible to adjust the historical record for current reservoir operations or minimum flow agreements.

This approach also applies to reaches downstream of diversions where minimum flows are in effect. An example of this situation is the White River, where most of the water is diverted for hydropower, but a minimum flow is maintained in the bypass reach.

The analyst should always check to be sure that the minimum flow being used reflects anticipated conditions. Changes in reservoir operations and minimum flow agreements are subject to change. Where possible, the assumed flow regime should be based on written agreements that apply to future conditions. The future time horizon for TMDLs is generally assumed to be ten years.

In some cases, dam operations may cause streamflow fluctuations over a time period of less than a day, which are not reflected in the daily streamflow record. These fluctuations may affect dilution for critical acute conditions (4-hour period). Special considerations need to be made for these situations, so the critical condition is accurately represented.

In certain cases, declining trends in minimum streamflows due to increasing water consumption may be suspected. Generally, this type of a trend would not be reflected in TMDL critical flows, due to the difficulty in quantifying the effect. If sufficient data exist to demonstrate and quantify such a trend, the analyst may chose to adjust the minimum flow accordingly. In addition, different flow scenarios can be modeled to simulate the effect of decreasing streamflows.

The record of water rights and claims is generally not a sufficiently accurate reflection of actual water consumptive use. Therefore, water right records should not be used as a basis for calculating the critical flow.

Iteration	Period 1			Period 2			Annual Load (lbs/yr)
	Months	TMDL lb/day	No. of days	Months	TMDL lb/day	No. of days	
1	Aug	1.68	31	Sep-Jul	2.02	334	727
2	Jul-Aug	1.68	62	Sep-Jun	2.19	303	768
3	Jul-Sep	1.68	92	Oct-Jun	3.23	273	1036
4	Jul-Oct	1.68	123	Nov-Jun	3.60	242	1078
5	Jun-Oct	1.68	153	Nov-May	4.78	212	1270
6	Jun-Nov	1.68	183	Dec-May	5.35	182	1281
7	May-Nov	1.68	214	Dec-Apr	7.26	151	1456
8*	May-Dec	1.68	245	Jan-Apr	12.5	120	1912*
9	Apr-Dec	1.68	275	Jan-Mar	13.1	90	1641

* Optimal periods

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Haan, C.T. 1977. Statistical methods in hydrology. Iowa State University Press. Ames, Iowa.

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#3: Point Source Effluent Flow Input for Steady-State TMDL Models

Issue:

Point Source Effluent Flow Input for Steady State TMDL Models

Purpose:

Point source effluent flows are important inputs for TMDL models and WLA determinations. A consistent and methodical approach is necessary to be able to select reasonable values to apply to the simulated critical condition. Difficulties arise because point source discharge volumes may fluctuate greatly over hourly, daily, weekly and seasonal time periods. In addition, design flows for point source discharges may be expressed in units which are not compatible with flows needed for the critical conditions simulated in the TMDL model.

Guidelines:

Sources of Data

Discharge permits, plant specifications, and effluent flow records of the point sources within the study area need to be screened as part of the TMDL modeling process. The intensity of the screening will depend on the TMDL variable, the time step modeled, and the types of dischargers in the study area.

Regional and Industrial Section permit writers should be the first people contacted to find information on point sources. They will know where specific plant design information is listed, which information is most current, and when plant upgrades or changes are anticipated. They will be able to locate or arrange for copies of documents.

Most point source facilities will have one or more files at the regional offices, or at the Industrial Section office in Olympia. The file should contain:

- National Pollutant Discharge Elimination System (NPDES), or state discharge permits,
- engineering reports, and
- discharge monitoring reports (DMRs).

<u>The NPDES or state discharge permit</u> may have design criteria for the facility, or may have discharge limits, monitoring, and reporting requirements. If the permit contains a limitation on flow, the limitation will generally be the same as the design criteria unless the plant is operating under an interim limit. Administrative orders, special conditions, and planning schedules are

usually outlined in, or attached to the permit as well. The flow limit is often expressed as one of the following:

- mean monthly
- daily average
- daily maximum
- weekly average
- or may be calculated from production-based effluent limitations of lbs/day

Monitoring requirements show whether instantaneous or continuous flow monitoring is being conducted, and where (influent or effluent) it is monitored. The plant design criteria are usually stated as average design flow or peak design flow.

Engineering and EILS Class II reports can contain additional information on facility design flows. Often more detail on seasonal flows and design criteria can be found in the engineering reports than is available in the permit. Class II inspection reports sometimes contain preliminary long-term flow analysis for a season of interest, and also have some information on recent facility capacity compared to design capacity.

Discharge monitoring reports (DMRs) are forms which contain monitoring data recorded by the discharger as required under the permit. DMRs are usually completed monthly, and are filed chronologically at the regional office or at the Industrial Section. DMRs for municipal wastewater plants generally have average influent or effluent (or both) volumes for each day of the month. Data are summarized to reflect permit compliance/non-compliance at the bottom of the form. A space is available for remarks concerning problems (e.g., bypasses, upset events or other reasons for permit non-compliance).

Electronic data management of permits under the Water Permit Life Cycle System (WPLCS) may provide limited information. WPLCS files only contain the monthly summary flow data required under the permit (e.g., maximum daily, mean monthly or daily average flows), not the daily flow information often found on the DMR sheets. WPLCS data entry may lag behind by several months, depending on the region.

Sometimes data from discharger records and charts can be used for TMDL evaluations where short-term cycles are important. These data can be more difficult to use than other sources because they are often on a circular chart recorder which needs processing into digital format. Usually three years of charts are available from the discharger's files, or as specified in the "*Monitoring and Reporting*" section of the discharge permit.

DMR flow data and discharger flow records and charts should pass some level of quality assurance before they are used. Class II inspection reports usually have information on the accuracy of the flow measuring device used by the discharger. Regional office staff and plant operators may also provide information about flow record equipment or procedure changes. Basic engineering calculations can also be used with smaller municipal and industrial facilities to calculate a range of expected discharge volumes to check against the reported data.

Data Review

Daily, weekly, or seasonal flow cycles of some or all of the dischargers may be important to the TMDL/WLA evaluation. The following situations are examples to consider:

- industrial dischargers may have daily or weekly production and wash down cycles,
- food processors may have a seasonal production cycle, or seasonal product lines with different wastewater composition,
- municipal wastewater systems may be subject to infiltration and inflow problems (winter/spring in western Washington, spring/summer in irrigated areas of eastern Washington),
- facilities may have areas of combined stormwater collection and discharge,
- municipal wastewater plants serving universities or tourist facilities may be subject to seasonal population changes,
- some treatment processes create intermittent discharge conditions.

Data for dischargers undergoing permit renewals, plant upgrades, plan reviews, or service area growth may require regional staff guidance for establishing near-future design conditions.

At least three years of daily discharge data should be reviewed to observe variability or to calculate summary statistics (e.g., annual, monthly or seasonal averages, percentile discharge volumes, or coefficients of variation). A data set from a definite climatic cycle (e.g. extended drought) would warrant additional years of data to remove bias.

If data are available, a test for correlation between effluent flow and the TMDL variable should be made. Stratification of data by flow volume or season may be appropriate if a correlation is found.

Design Flow as Model Input

Refer to the *"Permit Writer's Manual"* (Ecology, 1994) for guidance on plant design flow. Recognize, however, that the permit manual is written for permits with a five-year time horizon. The time horizon for TMDLs is typically ten years or more. Therefore more conservative assumptions for plant design flow may be warranted (Refer to TMDL Development Guideline #4 "Translating Between Permit Limits and Water Quality Models" for further discussion).

Adjusting the Permit Design Flow for Seasonal TMDLs

If monthly or seasonal TMDLs are being evaluated and the facility is not discharging at design capacity, an adjustment is needed to obtain model input values. To estimate the distribution of monthly average flows when the facility has reached its design capacity, the following adjustment procedure is suggested:

1) calculate monthly average flow based on three or more years of flow records,
2) identify the month with the highest monthly flow, and assign it the average design flow stated in the permit or engineering report,
3) estimate flows for the other months by proportionally adjusting them up using the observed highest monthly flow to average design flow ratio.

At least three years of daily discharge records should be used to calculate the average flow for each month, as mentioned earlier. If more years are used, the investigator should ensure discharge volumes have not changed over the period of time due to service area growth and development, and collection and treatment system changes.

#4: Translating Between Permit Limits and Water Quality Models

Issue:

1. Critical conditions for effluent loading for far-field modeling of dissolved oxygen and ammonia
2. Translating far-field model results into permit limits for NPDES dischargers.

Purpose:

Water quality models such as QUAL2E and WASP can be used to evaluate basin-wide water quality impacts of NPDES dischargers. Input variables for water quality modeling include estimated pollutant loads from point and nonpoint sources. Effluent quantity and quality must be specified for critical conditions and model results translated into appropriate permit limits (See TMDL Guideline #3 *"Point Source Effluent Flow Input for Steady State TMDL Models"* for related discussion). This guideline discusses several issues in the translation of model results and permit limits for compliance with dissolved oxygen and ammonia criteria in fresh water.

Guidelines:

- For modeling to determine compliance with dissolved oxygen standards, the weekly maximum or daily maximum BOD load and daily maximum ammonia load should be used for critical input conditions for far-field models such as QUAL2E and WASP. Weekly maximum or daily maximum BOD loads may be estimated as AKART loads determined according to guidelines in the *"Permit Writer's Manual"* (Ecology, 1994). Daily maximum ammonia concentrations for dissolved oxygen modeling should be based on the more restrictive daily maximum effluent limitation derived either from compliance with acute and chronic ammonia criteria at mixing zone boundaries as determined according to guidelines in the *"Permit Writer's Manual"*; or from technology-based considerations. Critical condition design flows for municipal and industrial dischargers should be the acute design flows determined according to guidelines in the *"Permit Writer's Manual."*

- If technology-based limits for BOD or ammonia, or the water quality-based (near field) limits for ammonia, are not found to be protective of dissolved oxygen standards, then the far field model may be used to solve for more restrictive loads which meet standards. The effluent loads which are found to meet water quality standards for dissolved oxygen are a daily waste load allocation (WLA) that equates to daily maximum permit limits. EPA Guidance and regulation also require a monthly average permit limit. Monthly average limits that correspond to the WLA may be calculated using guidelines in the *"Permit Writer's Manual"* (Chapter VI). A monthly average would be calculated from the variability of the treatment process, and therefore would be a function of the process used. However, if the plant cannot meet the water quality standards under their current operation, the treatment process will be changed and effluent variability may change.

- For ammonia modeling and comparison of model results with ammonia criteria, the chronic ammonia WLA load should be used for critical input conditions for far-field models such as QUAL2E and WASP. The chronic WLA may be determined in mixing zone evaluations according to guidelines in the *"Permit Writer's Manual."* Critical condition design flows for municipal and industrial dischargers for evaluation of far-field compliance with ammonia criteria should be the chronic design flows determined according to guidelines in the *"Permit Writer's Manual."*

- If technology-based permit limits or water quality-based (near field) limits for ammonia are not found to be protective of the far-field chronic ammonia criteria, then the far-field model may be used to solve for more restrictive loads which meet the criteria. The effluent loads which are found to meet chronic criteria for ammonia may be recommended as chronic WLAs. Chronic WLAs may be translated into monthly average and daily maximum permit limits following guidelines in the *"Permit Writer's Manual."*

#5: Effluent Biochemical Oxygen Demand

Issue:

Establishing Effluent Biochemical Oxygen Demand (BOD) for Steady State Point Source TMDL Models

Purpose:

Most effluents contain biologically oxidizable materials which exert an oxygen demand (BOD) in the receiving water. Because oxygen concentration is an important indicator of an aquatic system's health, BOD is one of the major wastewater constituents controlled under NPDES permits. When modeling the effects of BOD loading, it is important to establish appropriate effluent model input values for both carbonaceous (CBOD) and nitrogenous (NBOD) materials in the wastewater.

Guidelines:

For a detailed discussion on carbonaceous and nitrogenous deoxygenation, reference the EPA manual *"Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling"* (Bowie *et al.*, 1985. EPA /600/3-85/040, pp. 135 - 173) and *"Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water - Part I"* (Mills *et al.*, 1985. EPA/600/6-85/002a, p. 309).

CBOD

Typically, a wastewater's ultimate CBOD is determined by measuring the 5-day BOD (BOD_5) concentration and then applying an assumed ratio of ultimate CBOD to $CBOD_5$ as follows:

(ultimate CBOD mg/L) » 1/.68 * (BOD_5 mg/L)

This assumption can usually be made for most municipal wastewater treatment plants (WTPs), however, it should be noted that the ratio is both wastewater and receiving water specific and should not be assigned independently of the decay rate (the ratio of 1/.68 assumes a CBOD decay rate (base e) of 0.23/day). Therefore, for wastewaters other than WTPs, the investigator should establish the BOD decay rate and ultimate CBOD to $CBOD_5$ ratio for the specific study.

One method available to the investigator is the ultimate BOD (UBOD) analysis. This method can be used to estimate the ultimate BOD in wastewater and receiving water samples. The laboratory-derived CBOD decay rate for an instream sample taken downstream of the discharge's mixing zone can be used as an initial model input value, and the decay rate calibrated to observed instream CBOD. Methods to estimate instream decay rates are available in EPA guidance documents. The $CBOD_5$ value from the ultimate test can be used to establish the ultimate CBOD to $CBOD_5$ ratio.

The site specific ratio can then be applied to other $CBOD_5$ measurements and the established decay rate used to model the effects of the waste load on instream dissolved oxygen concentrations.

The initial model effluent input concentration of BOD should be set at the technology based $CBOD_5$ weekly permit limit converted to ultimate CBOD. Final ultimate CBOD loading from TMDL modeling should be converted back to a BOD_5 or $CBOD_5$ loading using the UBOD to $CBOD_5$ ratio.

NBOD

The wastewater's ultimate NBOD can be estimated as:

(ultimate NBOD mg/L) » 4.57 * (Ammonia+Organic-N mg/L)

Nitrite-N is also part of the equation, however, it is very unstable in the presence of oxygen such that the amount of nitrite measured is usually negligible relative to ammonia and organic-N and can be omitted (Mills *et al*. 1985).

In contrast to CBOD, the NBOD model input value is more difficult to establish because most discharges do not have existing NBOD permit limits from which to choose an initial value. Plus, CBOD entails a single decay rate for a single reaction, whereas NBOD is a three stage reaction which involves the conversion of organic-N to ammonia-N to nitrite-N to nitrate-N. In the reaction, organic-N is hydrolyzed to ammonia and does not consume oxygen in the process. In addition, in the first stage reaction (organic-N to ammonia-N) it is assumed that all organic-N has been transformed to ammonia.

In order to account for the multiple characteristics of the nitrification process the investigator must decide the level of sophistication needed to accurately simulate instream conditions. For example, the spreadsheet (DOSAG.WK1) treats CBOD and NBOD each as single reactions with the same instream decay rate. This may be appropriate for large rivers with high receiving water to effluent dilution and a corresponding small nitrifying bacteria community, however, in shallow rivers with a low dilution ratio, nitrification may play a greater role and should be modeled more precisely. QUAL2E and WASP allow the investigator to simulate all stages of nitrification, including the conversion of organic-N to ammonia-N. Still, the investigator must select initial model input values for either total NBOD or its specific components.

When using DOSAG.WK1, one method for picking an initial design condition NBOD input concentration is to assign an assumed value based on a typical effluent concentration. Because the rate of transformation of organic-N to ammonia is relatively slow (according to Bowie *et al*., 1985, a rate of 0.1/day is typically used), in many systems it is probably not appropriate to include organic-N. Therefore, when using the spreadsheet the investigator should input an ultimate NBOD value based on an expected effluent ammonia value. If no data are available, a WTP effluent ammonia concentration of 25 mg/L is recommended (NBOD = 4.57*25 mg/L). This value is equal to the 95th percentile of the distribution of effluent ammonia data from 29 Ecology WTP inspection reports done from 1980 through 1991.

Another method for establishing an initial model input value is to calculate an ammonia permit limit based on aquatic life criteria applied in the mixing zone, then use the resultant value to establish an NBOD concentration in the spreadsheet. When using QUAL2E or WASP, either an ammonia concentration of 25 mg/L, a value equal to the 95th percentile of effluent ammonia data, or a permit limit for ammonia based on mixing zone analysis can be assigned as the design condition ammonia concentration.

CBOD and NBOD WLAs

When modeling the impact of effluent on instream dissolved oxygen concentrations, both effluent CBOD and NBOD can be adjusted to meet the water quality standard. The investigator should present a few different scenarios where either CBOD or NBOD effluent concentrations are increased or decreased. By providing alternatives with several combinations of BOD and ammonia reductions, the permit writer and discharger can negotiate final WLAs based on cost and technology considerations.

References

Bowie, L.G. and others. 1985. Rates, constants, and kinetics formulations in surface water quality modeling. (second edition) EPA report 600/3-85/040. Athens, GA, 455 pp.

Mills, W.B. and others. 1985. Water quality assessment: A screening procedure for toxic and conventional pollutants in surface and ground water-part I (revised-1985). EPA report 600/6-85/002a, 609 pp.

#6: Application of Metals Standards

Issue:

- Application of Metals Standards
- Developing Metal Translators

Purpose:

Water quality criteria for cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), silver (Ag), and zinc (Zn) are based on the dissolved fraction of the metal (WAC 173-201A -040). However, Federal regulations require effluent limits in permits to be as total recoverable. A translator is required in order to determine reasonable potential and derive effluent limits. The translator can be one of the following options: (1) the criteria conversion factors used to convert the original total recoverable criteria to dissolved criteria listed in the Federal Register May 4, 1995; (2) the dissolved fraction of metal (fd) estimated by an empirical model based on environmental parameters; or (3) the dissolved to total recoverable metal ratio.

Guidelines:

Option 1: Conversion Factor

The first term in each metal criterion is a conversion factor (e.g., the acute freshwater Cu criterion is $(0.960)(e^{(0.9422[\ln(\text{hardness}) - 1.4640])})$, the conversion factor is 0.960). The conversion factors are a measure of the fraction of total metal in the dissolved phase during the toxicity tests used to develop the criteria. In the absence of receiving water data, the conversion factors can be used to change the receiving water dissolved criteria into total recoverable metal, which can then be used to establish NPDES permit limits. The details of option 1 are described in Ecology's *"Permit Writer's Manual"* (Ecology, 1994) and will not be discussed in this guidance. Either option 2 or 3 are recommended for Cd, Cu, Pb, and Zn.

Note: a conversion factor of one can be used (*i.e.*, assume all metal in an effluent becomes dissolved).

Option 2: Empirical Model of Dissolved Fraction

The fraction of dissolved metal in rivers and streams can be estimated using empirical models developed for Cd, Cu, Zn, and Pb from ambient data (Pelletier, 1996). Many toxic substances, including metals, have a tendency to leave the dissolved phase and attach to suspended solids. Pelletier (1996) evaluated models recommended by EPA for estimating the fractions of dissolved metals from measured total suspended solids (TSS). The EPA models were found to poorly represent the measured fractions of dissolved metals using Cd, Cu, Zn, and Pb data collected from Washington rivers. The results of Pelletier's work indicate that the EPA models should not be used to estimate fractions of dissolved metals in Washington rivers. Pelletier (1996) recommended the metal translators listed in Table 1 based on empirical models he developed from data in Washington rivers:

Table 1. Recommended estimates of the 90th and 95th percentiles of ambient dissolved fractions (f_d) of Cd, Cu, Pb, and Zn based on data from rivers in Washington (regressions assume TSS in mg/L). Conversion factors from option 1 are presented for comparison only.

	90th percentile of f_d	*95th percentile of f_d*	*Conversion Factor from Criteria (Option 1)*
Cd	0.898	0.943	0.89-1.0[1]
Cu	if TSS<6.7 mg/L: 1	if TSS<11.4 mg/L: 1	0.96
	if TSS ³ 6.7 mg/L: 1.91*TSS$^{-0.341}$	if TSS ³ 11.4 mg/L: 2.29*TSS$^{-0.341}$	
	if no TSS data: 0.968	if no TSS data: 0.996	
Pb	0.340	0.466	0.73-0.99[1]
Zn	if TSS<4.9 mg/L: 1	if TSS<12.5 mg/L: 1	0.978 (acute)
	if TSS ³ 4.9 mg/L: 1.44*TSS$^{-0.231}$	if TSS ³ 12.5 mg/L: 1.79*TSS$^{-0.231}$	0.986 (chronic)
	if no TSS data: 0.965	if no TSS data: 0.996	

[1]The conversion factor is dependent on hardness. The range for hardness of 25-150 mg/L
as $CaCO_3$ is shown.

Application to NPDES Permits

The metal translators for estimating the dissolved fractions of Cd, Cu, Pb, and Zn in Table 1 may be used to convert dissolved criteria for metals into total recoverable permit limits for effluents discharging to rivers. The following procedure is recommended for derivation of permit limits:

Step 1: Calculate the acute and chronic criteria for dissolved metals from the equations in Federal Register May 4, 1995. The 10th percentile of hardness from seasonally stratified data or 5th percentile from unstratified data is recommended for critical conditions. *[For example, the 10th percentile hardness during the critical season may be 25 mg/L as $CaCO_3$. Therefore, the acute and chronic water quality criteria for dissolved Cu would be 4.61 mg/L and 3.47 mg/L.]*

Step 2: Calculate the ambient dissolved fraction of Cd, Cu, Pb, or Zn from the equations in Table 1. The 10th percentile of TSS from seasonally stratified data or 5th percentile from unstratified data is recommended for critical conditions. *[For example, the 10th percentile TSS during the critical season may be 10 mg/L. Therefore, the equation for the 90th percentile of the dissolved fraction of Cu would result in f_d (fraction of dissolved Cu)= $1.91*10^{-0.341} = 0.871$.]*

Step 3: Calculate the acute and chronic waste load allocations (WLA) for effluent total recoverable metals.

If the background metals are measured as dissolved metals (CB_{dis}), then equation 1 should be used as follows to calculate acute and chronic WLAs for total recoverable metals:

$$WLA = [(WQC_{dis} * DF) - (CB_{dis} * (DF - 1))] / f_d \quad \text{equation 1}$$

where,

WQC_{dis}= acute or chronic water quality criteria for dissolved metals (in Federal Register May 4, 1995);

DF = acute or chronic dilution factors at the mixing zone boundary;

f_d = is the fraction of dissolved metals (from Step 2);

CB_{dis} = the background concentration of dissolved metals (should be the estimated 90th percentile during the critical season, or the 95th percentile if the data are not seasonally stratified.)

If the background metals are measured as total recoverable metals (CB_{trec}), then equation 2 is recommended to estimate the acute and chronic WLAs for total recoverable metals as follows:

$$WLA = [(WQC_{dis} * DF) / f_d] - [CB_{trec} * (DF - 1)] \quad \text{equation 2}$$

*[For example: if the acute and chronic DF are 10 and 30, and the 90th percentile of CB_{trec} is 2 mg/L, then, from equation 2, the acute WLA for total recoverable Cu = [(4.61*10)/0.871]-[2*(10-1)] = 35 mg/L, and the chronic WLA for total recoverable Cu = [(3.47*30)/0.871]-[2*(30-1)] = 62 mg/L.]*

Step 4: Calculate the daily maximum and monthly average permit limits for total recoverable metals from the acute and chronic WLAs using the procedures described in the "Permit Writer's Manual." Water quality-based effluent limits are calculated by the two-value WLA process as described by EPA (1991) and Ecology (1994). A spreadsheet for calculating permit limits is available from Ecology's home page on the Internet World Wide Web (http://www.wa.gov/ecology/).

Recommended sampling and analytical procedures for collecting effluent and ambient data are discussed under Option 3.

Option 3: Measured Fraction of Dissolved Metal

The fraction of dissolved metal in a waterbody can be determined directly by measuring the dissolved and total metal in a receiving water and establishing the dissolved fraction from their ratio. The following is a recommended procedure for determining a waterbody or site-specific metal translator as the dissolved/total recoverable metal ratio:

Parameters Measured

Ambient

- Total Recoverable Metal
- Dissolved Metal
- Total Suspended Solids (required for Option 2)
- Total Organic Carbon
- Hardness (required for freshwater)
- Conductivity or Salinity (required for marine water)
- Temperature
- pH

Effluent

- Total Recoverable Metal
- Temperature
- pH

Frequency of sampling

Collect either 10 pairs of dissolved and total recoverable metals concentrations during critical flow conditions or 20 pairs over all flow conditions. Sampling days should be evenly spaced over the period of interest, and, if in an estuary or marine environment, tide (high or low) should be sampled each time. High tide should be sampled during the beginning of the ebbing period after high slack and low tide sampled just before low slack.

Sampling Location

Freshwater:
During the sampling period, total recoverable metal should be measured in the effluent, and total recoverable metal and dissolved metal measured upstream of the mixing zone. Alternative sampling sites may need to be considered depending on site-specific issues (e.g., in effluent dominated streams, the ambient sampling location may need to be located downstream of the mixing zone).

Marine:
During the sampling period, total recoverable metal should be measured in the effluent, and total recoverable and dissolved metal measured upstream or away from the mixing zone, such that samples are collected at two different locations depending on ebbing or flooding tide. If the waterbody is either chemically or thermally stratified, samples should be collected from the zone or layer receiving the discharge.

Quality Assurance

Very low detection and quantification limits must be achieved to reduce analytical variation and the number of samples below the analytical detection limits. To help reduce sample variation, quality assurance procedures during sample collection and analysis should include careful attention to the major elements identified by EPA (1995a and 1995b), including: special cleaning procedures for sample containers and filter units, grab sample collection directly into pre-cleaned sample containers, field filtration with laboratory-cleaned filter units, field and laboratory blanks, standard reference materials, and field and laboratory duplicate samples. Quality assurance procedures and results should be documented in individual project plans and reports for any study.

Metals Analyses

Over the course of the sampling survey, effluent and ambient samples should be split (in the analytical laboratory) to provide an estimate of analytical variation; and standard reference samples should be submitted to provide an assessment of analytical accuracy. The number of splits and standard reference samples will depend on the sampling and analytical strategy employed for each study.

A filtered and unfiltered blank should be submitted with each days samples to assess possible sample contamination for dissolved and total recoverable metal, respectively.

Other Parameters

A minimum of three effluent and ambient samples should be split over the course of the sampling survey to provide an estimate of analytical variation.

Application to NPDES Permits

The following procedure is recommended for derivation of permit limits using the measured dissolved to total recoverable metal ratio as a translator:

Step 1: Calculate the acute and chronic criteria for dissolved metals from the equations in Federal Register May 4, 1995. In freshwater, the 10th percentile of hardness from seasonally stratified data or 5th percentile from unstratified data is recommended for critical conditions.

Step 2: Calculate dissolved/total recoverable metal ratio for each ambient data pair. Measurements of dissolved metal reported as below detection can be used by assuming the value to be one-half the detection level. The data pair should be eliminated if both the dissolved and total recoverable metal pair are nondetects.

Step 3: Determine the 90th percentile of the ratios from the critical flow data or 95th percentile from data collected over all flow conditions. The 90th percentile for the ratios established from the 10 samples collected during a single low flow period can be estimated from the assumed arcsine transformed (arcsine ratio) distribution as follows:

> Mean (of the arcsine transformed ratios) + 1.282 (standardized Z-score for the 90th percentile or use 1.645 if 95th percentile is estimated) * standard deviation (of the arcsine transformed ratios)
>
> Note: Alternative transformations may be used if necessary to normalize the data.

Step 4. If arcsine transformation used, re-transform the 90th percentile by taking the sine, then square the value.

Step 5. Use the 90th percentile of the ambient dissolved metal data from the critical flow sampling or 95th percentile from data collected over all flow conditions as "background" dissolved metal. The 90th percentile from the 10 samples collected during a single critical flow period can be estimated from the assumed log transformed distribution as follows:

> Mean (of the log transformed data) + 1.282 (standardized Z-score for the 90th percentile or use 1.645 if 95th percentile is estimated) * standard deviation (of the log transformed data). Re-transform the 90th or 95th percentile by taking the antilog.

Step 6. Calculate the Waste Load Allocation (WLA) for effluent total recoverable metals.

Equation 3 should be used as follows to calculate acute and chronic WLAs for total recoverable metals:

$$WLA = [(WQC_{dis} * DF) - (CB_{dis} * (DF - 1))] / Ratio \qquad \text{equation 3}$$

where:

Ratio = final site dissolved/total recoverable ratio
(see equation 1 for definition of other variables)

If there is more total recoverable than dissolved data (e.g., historical record of total recoverable data) or most of the dissolved data are below detection, then equation 4 should be used to estimate the acute and chronic WLAs.

$$WLA = [(WQC_{dis} * DF) / Ratio] - [CB_{trec} * (DF - 1)] \quad \text{equation 4}$$

Step 7. Calculate permit limits from WLAs per Ecology "Permit Writer's Manual" incorporating effluent variability, etc.

References

Ecology. 1994. Water Quality Program Permit Writer's Manual. Publication 92-109. Water Quality Program. Washington State Department of Ecology. Olympia, Washington.

EPA. 1991. Technical support document for water quality-based toxics control. EPA/505/2-90-001. U.S. Environmental Protection Agency. Office of Water. Washington, D.C.

EPA, 1995a. Method 1669: Sampling ambient water for trace metals at EPA water quality criteria levels. EPA 821-R-95-034. U.S. Environmental Protection Agency. Office of Water. Washington, D.C.

EPA, 1995b. Guidance on establishing trace metal clean rooms in existing facilities. EPA 821-B-95-001. U.S. Environmental Protection Agency. Office of Water. Washington, D.C.

Pelletier, G. 1996. Applying Metals Criteria to Water Quality-Based Discharge Limits, Empirical Models of the Dissolved Fraction of Cadmium, Copper, Lead, and Zinc. Watershed Assessments Section, Environmental Investigations and Laboratory Services Program, Washington State Department of Ecology. Olympia, Washington.

#7: Miscellaneous Guidelines

Issue:

Miscellaneous Guidelines for TMDL Modeling

Purpose:

When modeling the impacts of point and nonpoint pollutants on a waterbody a number of decisions must be made with respect to selecting appropriate design conditions. The following guidelines summarize a number of modeling considerations that apply to establishing design conditions.

Guidelines:

- Monte Carlo simulation techniques can be used for determining wasteload allocations (WLAs). Monte Carlo techniques involve randomly selecting values from simulated probability distributions of input variables such as flow, pollutant concentration, temperature, etc. In order to use Monte Carlo simulations, one must first evaluate the adequacy of data to develop the input probability distributions. The statistical characteristics of the data and the period and frequency of the data record must produce a probability distribution that characterizes expected variations in the future.

  The purpose of performing Monte Carlo analysis is to model the probabilistic nature of the system, which allows the frequency aspect of the aquatic life criteria to be evaluated. Therefore, when using Monte Carlo results, the 1 in 3 year frequency may be directly applied for determining the final WLA.

- Data used to determine design conditions for temperature and pH should be selected from the month(s) which contain the distribution of design low-flows. Selecting data from months associated with low-flows is suggested because using temperature and pH distributions for the entire permit period (e.g., annual or seasonal) will likely not represent the true values of temperature and pH associated with low-flows (i.e., low-flows may occur in a smaller window of time relative to the permit period).

- When selecting values for effluent and instream design condition variables, such as temperature and pH, the upper 10th percentile should be used; and for dissolved oxygen, the lower 10th percentile. The data used for the frequency distribution from which the percentile is selected should include at least three years of DMR or ambient data corresponding to the "*critical design period*" (i.e., the period of time within the year or season which corresponds to the most likely occurrence of the design flow). The 10th percentile is used because (1) in any large data base it is assumed that some of the values at either end will be statistical outliers (2) EPA guidance on TMDL studies recommends the 10th percentiles ("Technical Guidance Manual for Performing Waste Load Allocations," and "Initial Mixing Characteristics of Municipal Ocean Discharges"), and (3) the probability of multiple parameters occurring simultaneously at the upper or lower percentiles is less than 10%.

- If annual data (data from all months) are used to select design condition values, then the upper or lower 5th percentile of the distribution should be used.

- For limited data bases (n<20) the upper or lower quantile values can be estimated by methods in Gilbert (1987).

- If little or no ambient data are available in the immediate study area, data from a nearby station can be used to select the appropriate percentile value. When extrapolating data from an ambient station removed from the study area, consider potential problems with the ambient data set and the equivalency of the data with respect to the study site.

- In order to calibrate and verify model simulations used in establishing allocations, it is most desirable to collect two years of critical period data. One year would be used for calibrating and a second year used separately for verifying model simulations. Two years of critical period data reduces the risk of calibrating and verifying to anomalous or steady state conditions which could change between years, and also increases the confidence in the ability of the model to extrapolate to design conditions. If time constraints preclude two separate years of data collection, then two sets of data from the same year's critical period can be used. However, the two data sets should be temporally separated so as to minimize autocorrelation but still capture conditions during the critical period. Model parameters should be adjusted to provide a best fit to the calibration data set. Then the model should be run without further adjustment with the verification set, and the goodness of fit measured to assess the variability of model results. Quantitative measures of goodness of fit should be used, such as the Root Mean Square Error or %RSD. If more than two data sets are available, calibration with two or more data sets is desirable.

- The EPA manual "Rates, Constants and Kinetic Formulations" (EPA/600/3-85/040) is a good reference for explanations and suggestions in establishing waterbody processes (e.g., reaeration rates, nitrification, etc.). The EPA manual "Technical Support Document for Water Quality-based Toxics Control" (EPA/505/2-90-001) is an excellent reference for guidance on assessing and regulating discharge of pollutants to surface waters.

Reference:

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, New York.