Precision in Discharge Monitoring Reports

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1. INTRODUCTION

The results of monitoring required in wastewater permits must be reported as precisely as reasonably possible in order to enable the accurate determination of compliance with permit limits. Significant figures are an established means of expressing the precision of monitoring results.

This document provides guidance to promote the consistent use of significant figures in preparing Discharge Monitoring Reports (DMRs).

- Section 2 describes the use of significant figures, decimal places, and rounding to indicate precision in numbers. It also notes certain exceptions to the usual conventions for their use.
- Section 3 describes the proper use of significant figures in entering data on DMR forms.
- Section 4 describes special considerations for reporting mass loads, both for individual discharges and for groups of discharges subject to collective limits.
- The Appendices contain additional supporting information and sample calculations.

2. COMMON CONVENTIONS

2.1 Types of Numeric Values

Numeric values can be broadly classified as *approximate* or *exact*.

- All measurements are approximate values. The true precision of a measurement depends on several factors, including the method and equipment used, operator performance, and environmental conditions.
- Exact values are counted numbers or other values known with certainty or accepted as given.

Both types of values are used in wastewater permitting, and each affects the precision of monitoring results differently.

2.2 Significant Figures

There is uncertainty in any measurement. Results must be recorded as precisely as reasonably possible; or, as Standard Methods states it, "All digits in a reported result are expected to be known definitely, except for the last digit, which may be in doubt. Such a number is said to contain only significant figures."[1] Thus, the precision of a measurement is indicated by the number of significant figures (SFs) in the recorded result. Table 1 summarizes the standard conventions for counting significant figures:

[1] APHA/AWWA/WEF, *Standard Methods for the Examination of Water and Wastewater,* 22nd Edition, 2012, Part 1050 B. *http://www.mwa.co.th/download/file_upload/SMWW_1000-3000.pdf*

Table 1: Conventions for Determining Significant Figures

Conventions	Example Values	Significant Figures
1. Non-zero digits (1-9) are significant.	23	2
	231	3
2. Zeros between non-zero digits are significant.	4308	4
	40.05	4
3. Zeros to the left of the first non-zero digit are not significant.	0.00253	3
4. Trailing zeros (the right-most zeros) are significant in numbers that have a decimal point.	0.360	3
	4.00	3
5. Trailing zeros are ambiguous in numbers with no decimal point and require explanation to establish the number's precision.	470,000	2 to 6

Values with ambiguous zeroes can be expressed in different ways to eliminate the ambiguity. For example, if the value '470,000' is known to have 3 SFs, it could be recorded as '4.70×10^5 ', '470,000 ± 500', or '470,000, accurate to the nearest thousand'.

Proper use of significant figures ensures that results are recorded to their full and true precision. Recording less precise results (for example, using one reporting value when a lower value could be justified) censors potentially useful information. On the other hand, recording results with non-significant figures implies a greater precision than is justified and can be misleading.

Note: In the examples given in this document, the underlined digit in a number (such as the '8' in 3.<u>8</u>31) is the last significant figure in the number, and any digits to its right are non-significant.

2.3 Decimal Places

The number of decimal places (DPs) is another indication of a value's precision and is used instead of significant figures in some situations. Decimal places are typically counted to the right of the decimal place (tenths, hundredths, thousandths, etc.) but can also be counted to the left (10s, 100s, 1000s, etc.).

Appendix A lists typical levels of precision (as SFs and as DPs) for common wastewater parameters.

2.4 Rounding

Rounding is the process of removing non-significant digits from a number. The two steps in rounding are to:

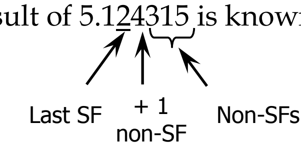
- *Step 1:* Drop all non-significant figures but the left-most one, then
- *Step 2:* Drop the last remaining non-significant figure and modify the final significant figure (or not) according to the standard conventions summarized in Table 2.

Column 2 of Table 2 shows the rounding conventions established in *Standard Methods* for the recording of analytical results. Column 3 shows the conventions for rounding the results of calculations. The two are similar except when the final digit to be dropped is a '5'. *Standard Methods* rounds up or down to the nearest *even* number (Convention 3.a.), while calculated values are simply rounded up (3.b.), consistent with the rounding conventions used in most handheld calculators and computer software applications.

Table 2: Conventions for Rounding of Measured and Calculated Values

Conventions for Rounding	Examples (Rounded to 2 SFs)	
	Measured Values	**Calculated Values**
1. If the digit being dropped is 0, 1, 2, 3 or 4, leave the preceding number as is.	1.10 → 1.1 1.11 → 1.1 1.12 → 1.1 1.13 → 1.1 1.14 → 1.1	Same
2. If the digit being dropped is 6, 7, 8 or 9, increase the preceding digit by one.	1.16 → 1.2 1.17 → 1.2 1.18 → 1.2 1.19 → 1.2	Same
3. If the digit being dropped is 5, a. *For measurements*: Round the preceding digit to the nearest even number (0 is considered as even). b. *For calculations*: Round the preceding digit up.	**1.15 → 1.2**	**1.25 → 1.3**

Example: A result of 5.124315 is known to be precise to 3 SFs.



To round this value, truncate the reading to 5.124 (keeping one non-SF), then round to 5.12 per Convention 1 in Table 2.

2.5 Exact Values

Exact values are known (or accepted) with certainty. Thus, the concept of precision and the conventions for significant figures and decimal places do not apply to exact numbers.

Exact values in wastewater permitting include:

- *Counted values*, such as:
  i. Bacteria measurements (cfu)
  ii. Numbers of samples
  iii. Values denoting time (days, months, etc.)
- *Conversion factors* are, in many cases, commonly accepted as exact numbers and are not considered in rounding.
- *Design flow of a treatment facility.* The design flow represents the actual treatment capacity for which a facility was designed, not more, not less. For permitting purposes, it is usually the same as the flow limit in the facility's discharge permit.
- *Values below the Practical Quantitation Limit.* Where non-detect results (<PQL) are treated as zero when calculating an average (or one, for geometric means), those zeroes (or ones) do not affect the number of significant figures in the result.
- *Mass Allocations/ Limits from a TMDL.* For permitting purposes, the Wasteload Allocation (WLA) established in a TMDL or similar study is considered an exact value.

2.6 Precision in Calculations

Just as there is uncertainty in any measurement, there is uncertainty in any calculation that involves measured values. The precision of each value must be taken into account in order to determine the precision of the calculated results. The following conventions describe how precision is determined in different types of calculations.

Significant figures, decimal places, and rounding are again used to indicate the precision of measured values. Exact values are treated differently in calculations, as described later. It is necessary to distinguish between measured (that is, approximate) and exact values, as they affect the precision of the calculated results differently.

Approximate Values in Calculations. The following conventions (or rules) are used to determine significant figures and decimal places when approximate values are used in calculations.

Calculation Rule #1 – Multiplication, Division, or Roots: The number of significant figures in the result is equal to the least number of significant figures in the measured values used in the calculation.

Example: $2.\underline{5} \times 3.4\underline{7} = 8.\underline{6}75 \rightarrow 8.7$

In this case, two measurements are multiplied. 2.5 has fewer significant figures (2 SFs) than does 3.47 (3 SFs), so the final result is rounded to two significant figures: 8.7.

Calculation Rule #2 – Addition or Subtraction: The number of decimal places (DPs) in the result is equal to that of the least precise value used in the calculation. In contrast to Rule 1, the measure of precision is the number of decimal places, not significant figures.

Example: $13.69\underline{1} - 0.\underline{5} = 13.\underline{1}91 \rightarrow 13.2$

In this case, 0.5 has one decimal place and is less precise than 13.691 (3 DP), so the final answer is rounded to one decimal place: 13.2.

Calculation Rule #3 – Multiple Operations: The number of significant figures in the result of multiple calculations is determined by applying both Rules 1 and 2. All Rule 1 operations are conducted, then followed by Rule 2 operations.

Note: Rounding of intermediate results can result in rounding errors and loss of precision; therefore, only the final result of multiple calculations is rounded.

Example: $(2.5 \times 3.47) + 13.691 - 0.5$

Step 1: Multiplication– use Rule 1:	$2.\underline{5} \times 3.4\underline{7} = 8.\underline{6}75$	(2 SFs)
Step 2: Addition – use Rule 2:	$8.\underline{6}75 + 13.69\underline{1} = 22.\underline{3}66$	(1 DP)
Step 3: Subtraction – use Rule 2:	$22.\underline{3}66 - 0.\underline{5} = 21.\underline{8}66$	(1 DP)
Step 4: Round final result:	$21.\underline{8}66 \rightarrow 21.\underline{8}6 \rightarrow 21.9$	(1 DP)

Example: $\sqrt[4]{8\underline{9} \times 22\underline{9} \times 16\underline{4} \times 7\underline{3}} = 1\underline{2}4.982\ldots = 120$

To calculate this geometric mean, the least precise number has two significant figures, so the result is rounded to 2 SFs: 120.

Tip: Preserving intermediate results in their entirety could quickly become burdensome. In practice, this can be made manageable:

> *Spreadsheets.* By default, spreadsheets and calculators retain all figures in intermediate results, limited only by the capabilities of the software or device. It is only necessary to note the final result and round as necessary.
>
> *Carry an extra digit.* If calculations are performed step-wise and the intermediate results are recorded at each step, it is acceptable to carry forward the significant figures plus two or three non-significant digit (rather than all digits) through the calculations.

With either approach, it is still necessary to track the right-most significant digit in each intermediate step (as in the examples just given) to ensure that the final result is rounded to the correct precision.

Exact Values in Calculations. Exact values are, by definition, known with certainty and so do not affect the number of significant figures (or decimal places) in calculated results.

Example: $3.27 \text{ mg/L TP} \times 5 \text{ MGD} \times 8.34 = 5.4\underline{5}44 = 5.45 \text{ lb/day TP}$

In this case, the Average Design Flow (5 MGD) and the conversion factor (8.34) are both exact values, so the number of significant figures in the TP concentration determines the precision of the final result.

Exception – Averages. Averages are an exception to the rounding rules. Consider the arithmetic average of three values:

$$9.2\underline{4} + 8.3\underline{1} + 8.8\underline{6} = 26.4\underline{1} \quad \text{(2 DPs (Calculation Rule \#2))}$$

$$26.4\underline{1} / 3 = 8.80\underline{3}33\overline{3} \rightarrow 8.803 \quad \text{(4 SF (Calculation Rule \#1))}$$

By Rule 1, the sum of the values is precise to two decimal places and, in this case, four significant figures. The divisor ('3') is an exact value, so the average would also have four significant figures, or one more decimal place than the original values. The increase in precision is not justified. Regardless of the rounding rules, averages should be no more precise than the least precise value in the data set. In this case, the result would be rounded to 8.80 (3 SFs).

Appendix B provides additional sample calculations illustrating the use of these conventions.

3. PRECISION IN DISCHARGE MONITORING REPORTS

3.1 Data Entry in DMRs

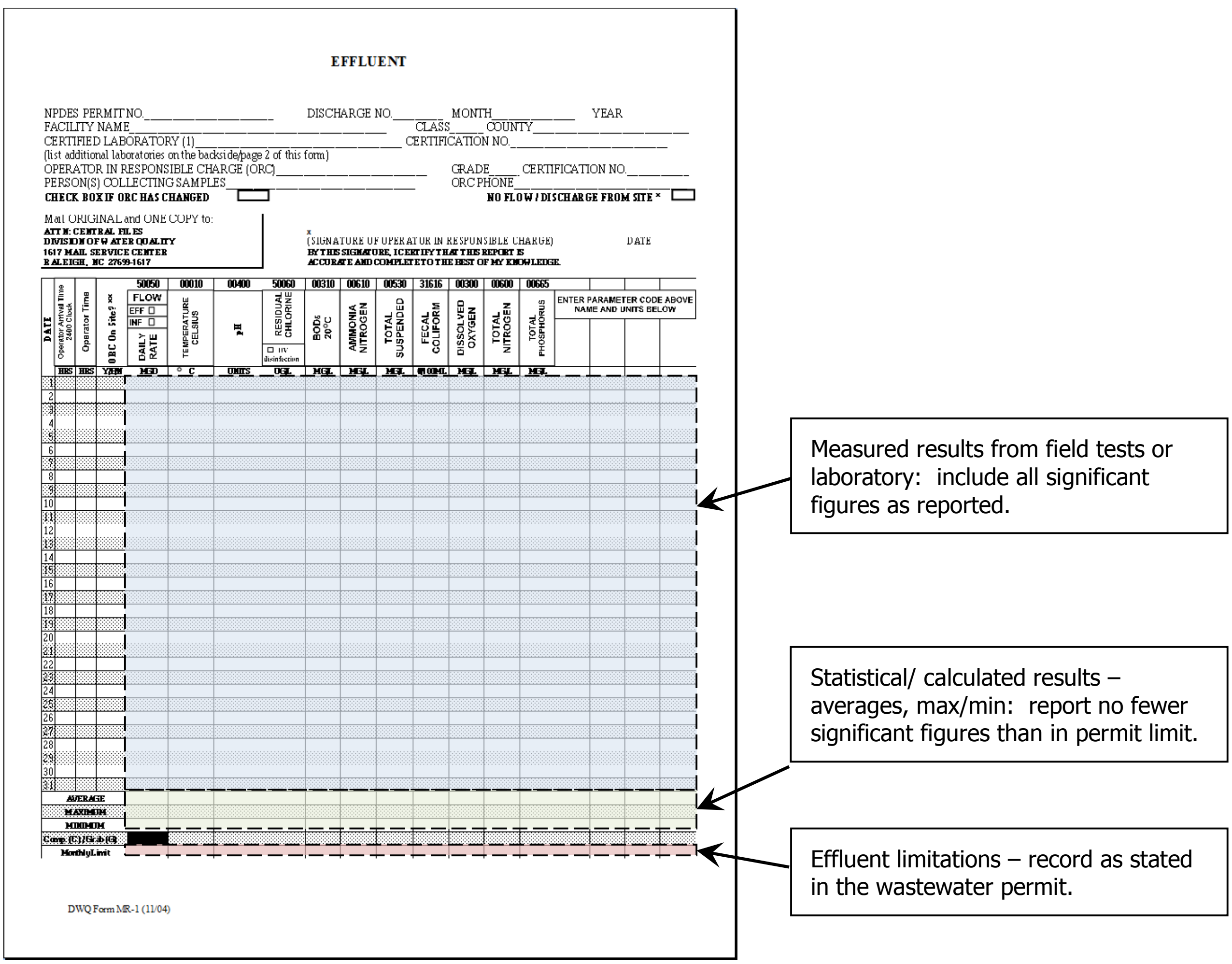
Permittees record three types of values on the DMR form: daily measurements, statistical data (average, maximum, minimum), and permit limits. The location and expected precision of each type of data are as follows and as illustrated in Figure 1:

- *Daily results* (Days 1-31) are entered in the main section of the DMR table.
  - Daily analyses must be performed using EPA-approved methods that are capable of producing results less than or equal to the corresponding permit limits, where such

methods exist.[2] In the case of 'non-detect' values, permittees (or their laboratories) are expected to report daily values to the Practical Quantitation Level (PQL) for each parameter (or "<[PQL]" for values less than the PQL).

- ◦ Daily values are reported to the same precision as the field or laboratory result.
- ◦ Daily results calculated from other daily values (for example, Total Nitrogen as the sum of TKN and NO_3-N + NO_2-N) are rounded according to the conventions for calculated numbers given in Column 3 of Table 2.
- ◦ Some calculated values, such as mass loads, require special attention and are addressed further in Section 4. Monthly, annual, and other loads are reported as 'daily' values and entered under the proper parameter code to indicate the time period.

Figure 1. Discharge Monitoring Report Form MR-1



- *Statistical values* calculated for compliance purposes (Monthly and Weekly Averages, Daily Maximum, Daily Minimum) are entered in the lower section of the DMR table.

[2] When such methods do exist and results are not sufficiently sensitive, the permittee must provide an explanation in the comments section of the DMR form.

- ◦ Statistical values are rounded according to the conventions described in Section 2.
- ◦ Statistical values are reported with no fewer significant figures than found in the permit limit (with the exception of annual mass loads or similar limits; see Section 4).

- *Permit limits* are also entered on the lower section of the DMR table, above or below the statistical data (location depends on the form used).
  - ◦ Limits are entered as expressed in the permit.

3.2 Compliance Determinations

Compliance with permit limits is determined by comparing the statistical values for each parameter with the corresponding effluent limits. Strictly speaking, the statistical values for each parameter should be rounded to the same precision as its limit(s) before the comparison is made. However, this is only necessary if the statistical value is very close to the limit. If the monthly average limit for NH_3-N is 4.0 mg/L and the actual average for the month is 2.68 mg/L, we do not have to round the average to 2.7 mg/L (2 SFs, 1 DP) to accurately conclude that the discharge met the limit. But if the actual average is 4.03 mg/L instead, proper rounding is essential; without it, one would incorrectly conclude that the discharge exceeded its limit.

Example – Compliance:	Without rounding:	4.03 mg/L actual > 4.0 mg/L limit Finding: Violates limit
	With rounding:	4.$\underline{0}$3 → 4.0 mg/L = 4.0 mg/L limit Result: Meets limit

3.3 BIMS and eDMRs

Data submitted on Discharge Monitoring Report (DMR) forms are entered into the Division's BIMS database either by Division staff (paper DMRs) or by the permittee (electronic DMRs, or 'eDMRs').

Paper DMRs. Division staff enter daily monitoring results and statistical values as reported on the form, up to 6 decimal places. Digits beyond 6 DPs are not entered. BIMS then recalculates all statistical data from the daily values to 6 DPs and compares its own statistical data with permit limits (if any) to determine compliance. BIMS identifies potential violations, and Division compliance staff review these to identify which findings merit further attention.

eDMRs. Permittees enter or upload their daily data through the eDMR system. The system calculates and displays statistical values in real time for the permittee's inspection. The eDMR system and BIMS both allow up to 6 DPs for daily and statistical values. Once the eDMR is submitted, BIMS performs compliance determinations in the same fashion as with paper DMRs.

The Division is working on changes to the eDMR system and BIMS to ensure they handle precision and rounding according to this guidance.

4. PRECISION IN ANNUAL MASS LOADS

Some dischargers in watersheds impacted by nutrients have seasonal or annual mass load limits for Total Nitrogen or Total Phosphorus or both. This section describes modified conventions for the calculation and reporting of annual mass loadings. The approach can also be adapted for use with seasonal loadings and for loadings of other parameters.

4.1 Setting Permit Limits (Mass)

The nutrient management strategies for the Neuse River estuary, Jordan Lake, and Falls Lake each set annual mass limits for nitrogen and/or phosphorus for the existing, nutrient-bearing dischargers. Limits can apply to groups of dischargers as well as to individual dischargers.

For permitting purposes, the Wasteload Allocations from nutrient TMDLs are treated as exact values. WLAs are divided among the dischargers in proportion to their permitted flows, which are based on Average Design Flow, also exact values. Thus, the individual nutrient allocations and resulting limits for the affected dischargers are themselves exact values and not subject to rounding.

In practice, the convention has evolved to calculate individual allocations without rounding and to display the allocations and corresponding limits to the nearest 1 lb/yr for brevity's sake.

4.2 Reporting Monitoring Results (Mass)

Current permits prescribe how nutrient loads are to be calculated; see Appendix C for more detail. Permittees must calculate and report monthly mass loads with each DMR and then report the sum of those monthly loads at the end of the calendar year.

Monitoring results for flow and nutrients are approximate values, so the mass loads calculated from them should be rounded to reflect the proper precision.

However, monthly loads are intermediate results in the calculation of annual loads and, according to the conventions in Section 2, should not be rounded: only the annual loads need be rounded for compliance purposes. In the case of compliance groups or 'bubble' permit limits, only the collective annual loads of the multiple facilities need be rounded.

Reporting the unrounded monthly loads would also be cumbersome (12,345.6789…) and of little real value. Also, additional rounding at each step in the calculations could cause errors in the annual loads, especially significant for dischargers with smaller loads. To avoid these pitfalls, permittees can report all significant digits plus one non-significant digit in their monthly loads, then round the annual load for compliance purposes.

An alternate approach would be to report monthly loads to the nearest 1 lb/mo (or greater increments for larger facilities) and, again, round only the final loads. The monthly values would include extra non-significant digits, but this approach is easier to implement where spreadsheets (or similar software) are used. The key would then be for the permittee to properly round its annual load for entry on its DMR.

Depending on the facility, annual loads will commonly be rounded to as low as the nearest 1 pound or as high as the nearest 10,000 pounds or more. Thus, loads reported by most facilities will have fewer significant figures than the corresponding limit. (They will appear less precise than the limit but, because the limit is an exact value, measures of precision do not apply to it.)

4.3 Determining Compliance (Mass)

Compliance is determined by comparing the calculated annual load (rounded annual value) with the corresponding annual limit (exact value). This is a direct comparison of the two values, with no further rounding of either value beforehand. An actual load that is less than or equal to the permit limit indicates compliance with that limit.

Appendix C provides examples of annual nutrient load calculations for individual dischargers and for groups of dischargers that report their collective loads.

APPENDIX A:
COMMON SIGNIFICANT FIGURES AND REPORTING CONVENTIONS FOR CONVENTIONAL AND TOXIC PARAMETERS[3]

Parameters	Typical Range of Permit Limits	Commonly Used Approved Methods	Significant Figures	Precision Typically Reported on DMRs:
Flow	Vary widely	Assorted flow measurement devices	2-3	Achievable accuracy of the measurement device used
BOD	5.0 to 50 mg/L	DO Probe	2 SF	If <10: 0.1 mg/L If ≥10: whole numbers*
CBOD	2.0 to 45 mg/L	DO Probe	2 SF	If <10: 0.1 mg/L If ≥10: whole numbers*
NH_3-N	0.5 to 30.0 mg/L	Distill w/ ISE or Colorimetric	If <10: 2 SF If ≥ 10: 3 SF	0.1 mg/L
TSS	5.0 to 80.0 mg/L	Filtration/Gravimetric	<10: 2 ≥10: 3	0.1 mg/L
Temperature	90-102 °F (steam electric)	Various	Various	Whole numbers*
Bacteria (Fecal, E. Coli, etc.)	200/400 fecal in domestic effluent, 5/14 fecal in reuse waters, 35/276 for Enterococci	Various	<10: 1 ≥10 to <100: 2 ≥100: 3	Whole numbers*
Dissolved Oxygen	5.0 to 10.0 mg/L	DO Probe	<10: 2 ≥10: 3	0.1 mg/L
Total Chlorine Residual (method dependent)	17-28 µg/L freshwater, 13 µg/L saltwater	Amperometric Titration, DPD Colorimetric	≥13: 2	≥13 to <100: 1 ug/L ≥100: 10 µg/L
pH	6.0 to 9.0 standard units	pH Probe	<10: 2 ≥10: 3	0.1 S.U.
Metals	Vary widely	-	2 -3	Varies
Nutrients				
Total Nitrogen (TN)	Vary widely	Sum of TKN and NO_3-N + NO_2-N	Depends on other analyses	Depends on results from other analyses
TKN	<2.0 - 20 mg/L to meet typical TN mass limits	Digest w/ ISE or Colorimetric	<10: 2 ≥10: 3	0.1 mg/L
Nitrate and Nitrite	<1.0 - 20 mg/L to meet typical TN mass limits	Colorimetric or IC	<10: 2 ≥10: 3	0.1 mg/L
Total Phosphorus	0.5 to 2.0 mg/L	Colorimetric	<0.1: 1 ≥0.1 to <10: 2 ≥10: 3	If <0.1: 0.01 mg/L If ≥ 0.1: 0.1 mg/L

* Integer values (0 DPs): 23 mg/L, 68°F, 34 CFM, etc.

[3] The Division does not require reporting of specific numbers of significant figures at this time. The values in this appendix are intended merely to illustrate commonly reported results.

APPENDIX B:
SAMPLE CALCULATIONS

Daily Measurements/ Analyses

Daily values include the full result reported by the lab or as appropriate for the field measurement (that is, without further rounding). Appendix A lists common levels of precision for a variety of parameters. For example,

7.9 mg/L BOD	<10 mg/L: 2 SF, or nearest 0.1 mg/L
14.3 mg/L TKN	≥10 mg/L: 2 SF, or nearest 0.1 mg/L
7.3 S.U. pH	<10 S.U.: 2 SF, or nearest 0.1 S.U.

Monthly/ Weekly Averages of Concentration Values

A permit includes a Monthly Average BOD limit of 5.0 mg/L.

⇨ Calculate the monthly average of four weekly concentrations: 4.6, 2.3, 5.3, and 2.9 mg/L

$$(4.\underline{6} + 2.\underline{3} + 5.\underline{3} + 2.\underline{9})/4 = 15.\underline{1} / 4 = 3.\underline{7}75 \rightarrow 3.8 \text{ mg/L}$$

<u>Comments</u>

The daily concentration values are reported to two significant figures and one decimal place, consistent with the permit limit and with the information in Appendix A.

In calculating the average, the sum retains one decimal place (Calculations Rule 2), which gives 3 SFs. The result of dividing by 4 (number of samples) would be rounded to two SFs (Calculations Rule 1). However, the 'averages' exception applies, and the final result is rounded to the same 2 SFs as the daily values.

Daily Maximum/ Minimum Values

A permit's Daily Maximum limit for lead is 17 µg/L. The lab reports a result of 17.3 µg/L for the required monthly sample.

The daily value is reported as 17.3 µg/L. The Daily Maximum value is reported to two or more significant figures, so as to be at least as precise as the permit limit.

$$1\underline{7}.3 \ \mu\text{g/L} \rightarrow 17.3 \ \mu\text{g/L or } 17 \ \mu\text{g/L}$$

Compliance is determined at the precision of the permit limit regardless of which Daily Maximum is reported. Neither result indicates a violation. If the limit were expressed as 17.0 µg/L (rather than 17), the Daily Maximum would be reported as 17.3 µg/L and would indicate an exceedance of the limit at its stated precision.

Daily Measurements/ Analyses – Summed Values

If daily values for a parameter are the sum of constituent parameters (e.g., TN), the daily values are rounded according to the conventions described in Section 2.

$$TN = TKN + [NO_3\text{-}N + NO_2\text{-}N]$$

Sample 1: $TN = 4.1\underline{4} + 1.2\underline{6} = 5.4\underline{0} \rightarrow 5.40$ mg/L TN

Sample 2: $TN = 11.\underline{2} + 7.2\underline{3} = 18.\underline{4}3 \rightarrow 18.4$ mg/L TN

Sample 3: $TN = 7.\underline{8} + <0.\underline{2} \rightarrow 7.8$ mg/L TN

The current practice is to treat any 'less than' values for TKN or NO_3-NO_2-N as zero when calculating TN (mg/L) and to report the result as a final value, without a "<" or other qualifier. (In the calculation of TN mass loads, the uncertainties of flow measurements should easily outweigh any bias these substitutions might introduce; so the practice is accurate enough for evaluating compliance with these mass limits.) This practice may also apply to other situations that involve the addition of constituent analyses.

APPENDIX C:
SAMPLE CALCULATIONS – NUTRIENTS

Some nutrient TMDLs and strategies establish annual mass limits for nitrogen or phosphorus or both. Establishing nutrient limits for the affected dischargers (individually or in groups), reporting effluent nutrient loads, and determining compliance with the limits requires special attention and some minor exceptions to the standard conventions described in this document.

Examples – Annual Mass Nutrient Limits

TN Allocations from a TMDL/ WLA

A TN Wasteload Allocation of 640,000 lb/yr is distributed among existing dischargers in proportion to their permitted flows. Both the WLA and flows are treated as exact numbers; thus, the resulting allocations are also exact. However, the convention is to display any such allocations and limits to the nearest pound in the facilities' permits.

			TN Allocations (lb/yr)	
Facility	Qpmt	% Total	Allocations	Displayed As
1	22	46.6%	297,989.41799...	297,989
2	16	33.9%	216,719.57672...	216,720
3	5	10.6%	67,724.86772...	67,725
4	3.75	7.9%	50,793.65079...	50,794
5	0.5	1.1%	6,772.48677...	6,772
	47.25	100%	640,000.00000	640,000

(Note: Subtotals of the exact allocations may appear to disagree with those of the corresponding display values. In this case, the cause of the apparent differences may require explanation.)

Examples – Reporting of Nutrient Mass Loads

Permits for affected facilities typically prescribe the following methodology for calculating nutrient loads:

CALCULATION OF TOTAL NITROGEN AND TOTAL PHOSPHORUS LOADS

(a.) The Permittee shall calculate monthly and annual TN Loads as follows:

(i.) Monthly TN (or TP) Load (lb/mo) = TN (or TP) x TMF x 8.34

where:

TN or TP = the average Total Nitrogen or Total Phosphorus concentration (mg/L) of the composite samples collected during the month

TMF = the Total Monthly Flow of wastewater discharged during the month (MG/mo)

8.34 = conversion factor, from (mg/L x MG) to pounds

(ii.) Annual TN (or TP) Load (lb/yr) = Sum of the 12 Monthly TN (or TP) Loads for the calendar year

(b.) The Permittee shall report monthly Total Nitrogen and Total Phosphorus results (mg/L and lb/mo) in the appropriate discharge monitoring report for each month and shall report each calendar year's results (lb/yr) with the December report for that year.

In short, permittees calculate monthly loads for each nutrient from daily flows and nutrient concentration values. They then sum the monthly loads at the end of each calendar year to calculate the annual loads.

The following examples illustrate how annual TN loads are calculated and reported to satisfy this condition. The same approach is used to calculate TP loads and can be adapted to calculate seasonal or other mass loads.

The discharger begins by determining its average TN and total flow for the month.

Monthly Average of Concentration Values – Total Nitrogen

A facility reports five weekly TN samples for January as follows: 9.24, 8.31, 6.9, 8.86, and 9.4 mg/L.

⇨ Calculate the monthly average concentration. The facility's permit does not have a TN concentration limit but does require reporting of the monthly average concentration.

Sum = 9.24 + 8.31 + 6.9 + 8.86 + 9.4 = 42.71 (1 DP)

The sum total of the concentrations is limited to one decimal place precision.

Average = 42.71 / 5 = 8.542 → 8.5 mg/L

Assuming the purpose of this monthly average is to calculate a monthly load, it is acceptable to retain an extra (non-significant) digit to minimize rounding errors in subsequent calculations.

Total Monthly Flow

Total Monthly Flow is required for calculation of monthly loads. Calculate the total monthly flow for the same facility for January. The facility reported 31 daily values:

1.842 + 1.982 + 1.996 + 1.959 + 1.924 + 1.902 + 1.823 + 1.809 + 2.000 + 1.954 + 2.653 + 2.455 + 2.127 + 1.893 + 1.852 + 1.980 + 2.024 + 1.988 + 1.932 + 1.972 + 2.319 + 2.064 + 2.090 + 2.046 + 2.014 + 2.025 + 2.733 + 2.081 + 1.991 + 2.054 + 2.030 = 63.514 MG/mo

Each value was reported with four significant figures and three decimal places. The sum (Calcs Rule 2) is then to be reported with three decimal places. (Note the increase in significant figures.)

These Total Monthly Flow and Monthly Average TN concentrations values are used to calculate the monthly mass load.

Monthly Mass Load – Total Nitrogen

Calculate the monthly TN Load for January for the same facility.

TN Load (lb/mo) = TN Conc. (mg/L) * TMF (MG/mo) * 8.34

8.54 * 63.514 * 8.34 = 4,523.69573 → 4,520 lb/mo TN (retaining 1 non-SF)
OR 4,523 lb/mo TN (truncate to nearest pound)

The precisions of the concentration values and the flow values are two significant figures and three decimal places, respectively. The precision of the TN measurements is more limiting in this case. There is no monthly limit, so the facility can record the monthly load with extra digits: either with one extra (non-significant) digit (4,520 lb/mo) or truncated to the nearest pound (4,523 lb/mo).

The precision of this monthly load is precise to the nearest 100 lb/mo. Assuming that other monthly values are similar, the annual load (as the sum of these values) will also be precise to the nearest 100 lb/mo and will be rounded accordingly.

Note: If all TN samples were precise to 2 DPs, this monthly load would have been precise to the nearest 10 lb/mo.

Monthly loads are calculated and reported in the facility's DMRs as the year progresses. At the end of the year, the permittee calculates its total load for the calendar year and reports the result on its December DMR.

Annual Mass Load – Total Nitrogen

Calculate the Annual TN Load for the same facility.

For compliance purposes, the 'end calculation' is the summation of the Monthly TN Loads to produce the Annual TN Load. Using the conventions described above, the partially rounded or truncated monthly loads should be used in the calculation, and the result should be rounded to the nearest 10 lb/mo, which is the least precision of the monthly values.

The twelve Monthly TN Loads and the resulting Annual TN Load for the calendar year are as follows. These assume the permittee truncated its monthly loads to the nearest 1 lb/mo:

4523 + 6378 + 5138 + 5718 + 3812 + 5987 + 6340 + 4197 + 4705 + 4341 + 6635 + 6371 = 64,145 lb/yr TN

Annual TN Load = 64,100 lb/yr (to the nearest 100 lb, same as the least precise of the monthly loads)

Here is the same calculation assuming the permittee elected to carry one non-SF digit in its monthly loads:

4520 + 6380 + 5140 + 5720 + 3810 + 5980 + 6340 + 4200 + 4710 + 4340 + 6640 + 6370 = 64,160 lb/yr TN

Annual TN Load = 64,200 lb/yr (to the nearest 100 lb)

The results are essentially the same, with only a 0.03% difference.

In the case of a group compliance association, the combined annual nutrient loads of all the individual members is calculated and reported to the Division on an annual basis.

Annual Mass Load – Total Nitrogen – Compliance Association

Calculate the Annual TN Load for a compliance association of five dischargers.

The member facilities have permitted flows of 0.5, 3.75, 5.0, 16 and 22 MGD. The Annual TN Load for each was calculated as in the examples above. For this exercise, assume that transport losses are negligible.

The association's Annual TN Load is the sum of its members' individual Annual Loads.

Annual TN Loads:

Facility	Q_{pmt}	Individual TN Loads (lb/yr)
1	22	359,000
2	16	142,000
3	5	64,200
4	3.75	42,200
5	0.5	8,980
	Total	616,380

Group Annual TN Load = 616,000 lb/yr

Comments

In each member's calculations, the monthly loads were limited to two significant figures by the TN concentration values. Two SFs translated to different precisions depending on the size of the facility – the nearest 10 lb/mo for the smallest to the nearest 1,000 lb/mo for the largest. The sum of the individual loads is then rounded to the nearest 1,000 lb to match the least precise of the members' calculated contributions.

In this example, the group reports 616,000 lb/yr TN, 24,000 lb/yr below its 640,000 lb/yr limit.

As with more conventional concentration limits, rounding is not always necessary to accurately determine compliance but becomes essential when actual discharges approach the stated limit.

REVISIONS HISTORY

Date	Description
10/23/2013	Initial draft
2/3/2014	Review draft
7/11/2014	First draft of ‘DMRs only’ version
3/20/2015	Editorial revisions; update of BIMS/eDMR explanation
5/5/2015	Revised in response to internal comments on revised draft
6/17/2019	Ver. 2: updates re: # DPs in BIMS & eDMR; corrections to TRC info in Appendix A; addition of ‘less than’ example in Appendix B.