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Alexander B. Grannis
Commissioner

November 4, 2008

MEMORANDUM

***** N O T I C E *****

This document has been developed to provide Department staff with guidance on how to ensure compliance with statutory and regulatory requirements, including case law interpretations, and to provide consistent treatment of similar situations. This document may also be used by the public to gain technical guidance and insight regarding how the department staff may analyze an issue and factors in their consideration of particular facts and circumstances. This guidance document is not a fixed rule under the State Administrative Procedure Act section 102(2)(a)(I). Furthermore, nothing set forth herein prevents staff from varying from this guidance as the specific facts and circumstances may dictate, provided staff's actions comply with applicable statutory and regulatory requirements. This document does not create any enforceable rights for the benefit of any party.

Previous Date: **New**

TO: **Bureau Directors, Regional Water Engineers, Section Chiefs**

SUBJECT: **Division of Water Technical and Operational Guidance Series (1.1.6)**

INTERPRETATION GUIDANCE FOR MARINE DISSOLVED OXYGEN (DO) STANDARD

(Originator: Phil O'Brien)

PURPOSE:

The primary purpose of this document is to provide guidance for interpreting compliance with the chronic DO standard for Class SA, SB and SC waters. This document facilitates determining whether a single low DO event violates this standard and whether multiple low DO events are to be evaluated together or independently when determining compliance.

DISCUSSION:

The ambient water quality standards for DO for Class SA, SB and SC waters are 4.8 mg/L, with allowable excursions to not less than 3.0 mg/L for certain periods of time. The standards can be found at 6 NYCRR 703.3. and are repeated below for the convenience of the reader. This standard is continuously applicable throughout the year.

A low DO event is defined as the occurrence of a daily average dissolved oxygen concentration of less than 4.8 mg/L at any vertical strata in the water column at a given site or location. Water column or spacial averages should not be used to determine compliance.

In this document, "marine water(s)" and "salt water(s)" are synonymous and are used interchangeably.

The determination of compliance with the chronic marine DO standard requires the use of daily average DO concentrations that reflect diurnal fluctuations in the DO concentrations. This TOGS assumes that adequate information is available to demonstrate that the daily average DO concentrations reflect the diurnal fluctuations. This can be demonstrated through either sufficient measurements or predictions of an acceptable analytical model. If there is doubt about the adequacy of the daily average DO please refer to the note on page 10 of this TOGS.

STANDARDS:

Classes	Standard
SA, SB, SC	Chronic: Shall not be less than a daily average of 4.8 mg/L *

Remark: * The DO concentration may fall below 4.8 mg/L for a limited number of days, as defined by the formula: $DO_i = \frac{13.0}{2.80 + 1.84e^{-0.1t_i}}$

where DO_i = DO concentration in mg/L between 3.0 - 4.8 mg/L and t_i = time in days. This equation is applied by dividing the DO range of 3.0 - 4.8 mg/L into a number of equal intervals. DO_i is the lower bound of each interval (i) and t_i is the allowable number of days that the DO concentration can be within that interval. The actual number of days that the measured DO concentration falls within each interval (i) is divided by the allowable number of days that the DO can fall within interval (t_i). The sum of the quotients of all intervals (i .. .n) cannot exceed 1.0: i.e., $\sum_{i=1}^{n} \frac{t_i(actual)}{t_i(allowed)} < 1.0$

The DO concentration shall not fall below the acute standard of 3.0 mg/L at any time.

SA, SB, SC, SD	Acute: Shall not be less than 3.0 mg/L at any time.
I	Shall not be less than 4.0 mg/L at any time

GUIDANCE:

The NYS Standard is based on U.S. EPA (2000). The EPA demonstrated that populations of marine organisms could tolerate DO concentrations below 4.8 mg/L for short periods of time and that these short excursions were unlikely to have any significant impact (i.e., ≤ 5%) on populations of exposed organisms as measured by larval recruitment (USEPA, 2000). To estimate the duration and magnitude of DO excursions below 4.8 mg/L that would meet that criterion, the EPA developed a larval recruitment model to evaluate hypoxia-related dose response effects on the recruitment of larvae. The model was used to determine the maximum number of days that larval cohorts could be exposed to different low DO concentrations and still maintain a larval recruitment rate of at least 95% of that expected when DO concentrations were maintained above 4.8 mg/L. Nine genera of marine organisms representing a range of sensitivities to hypoxia were evaluated in the model analysis. From the four most sensitive genera, the following equation was derived:

$$DO_i = \frac{13.0}{2.80 + 1.84e^{-0.1t_i}} \qquad \text{(Eq 1)}$$

where DO_i = Allowable DO concentration in mg/L;
t_i = Time interval in days at that DO concentration.

Using equation 1, a curve can be drawn that graphically illustrates the time and DO concentrations that do not cause a greater than 5% impact to larval recruitment.

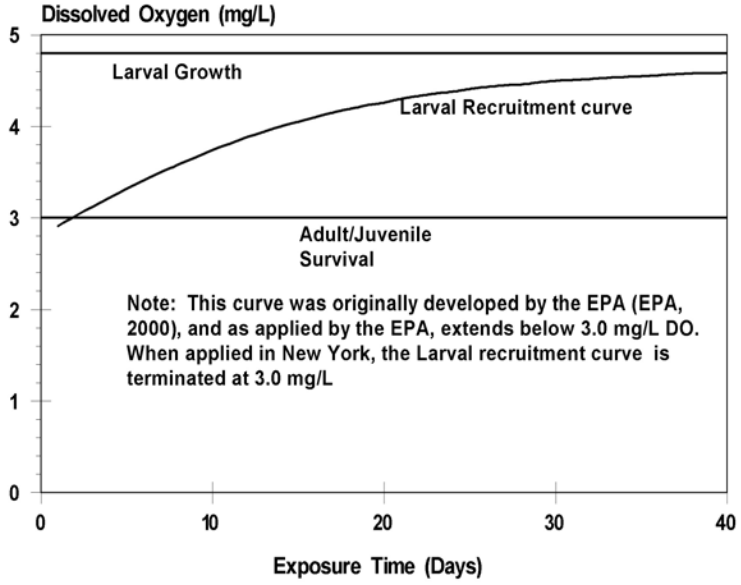

Figure 1. Graphic depiction of water quality standards for dissolved oxygen in saltwater. Shown are the saltwater chronic water quality standard (4.8 mg/L DO based on larval growth); the larval recruitment curve produced by equation 1; and the saltwater acute water quality standard (3.0 mg/L DO based on adult/juvenile survival).

By solving equation (1) for t_i, the number of allowable days during which the DO can remain within an interval can be calculated.

$$t_i = -10 \bullet \ln\left(\frac{\frac{13 - 2.8DO_i}{DO_i}}{1.84}\right) \qquad \text{(Eq 2)}$$

Equation 2 is equation 1 solved for t_i.

This TOGS assumes the average DO concentrations being used are accurate and adequately represent any diurnal fluctuations in the dissolved oxygen concentrations. With this assumption an interval of one-tenth of a milligram per liter (0.1 mg/L) DO can be used. Please refer to the section on the use of an alternative interval on page 10 for a discussion of diurnal fluctuations and the use of a larger interval in determining compliance.

Note that with the 0.1 mg/L interval, the larval recruitment curve does not apply to a DO_i of 4.7 mg/L. The natural log of a negative number does not exist. A concentration of 4.7 mg/L will be included and considered in the 4.6 mg/L interval.

Also note that the "allowable days" is the maximum number of days in which the DO concentration can be within an interval, assuming no days in any other low DO interval below 4.8 mg/L.

To determine if a low DO event is in violation of the chronic saltwater quality standard for DO, the actual number of days that the measured DO lies within a given interval is divided by the allowable number of days as calculated by equation 2 above for that same interval. The actual days/allowable days quotient for the DO concentration intervals are then summed. If the total is less than one, no violation of the standard has occurred. If the sum is greater than one, the chronic saltwater DO standard was violated.

Note: Anytime the DO concentration drops below 3.0 mg/l the acute standard is violated and the marine DO standard is in violation.

The following is an example calculation to determine compliance with the Chronic DO standard. Figure 2 shows a hypothetical low DO event. Table 1 shows the data for the event and Table 2 shows the analysis of the event and the calculation of the cumulative fraction of allowable days. The DO concentration represents the lowest concentration observed in the water column and not a vertically-averaged DO concentration.

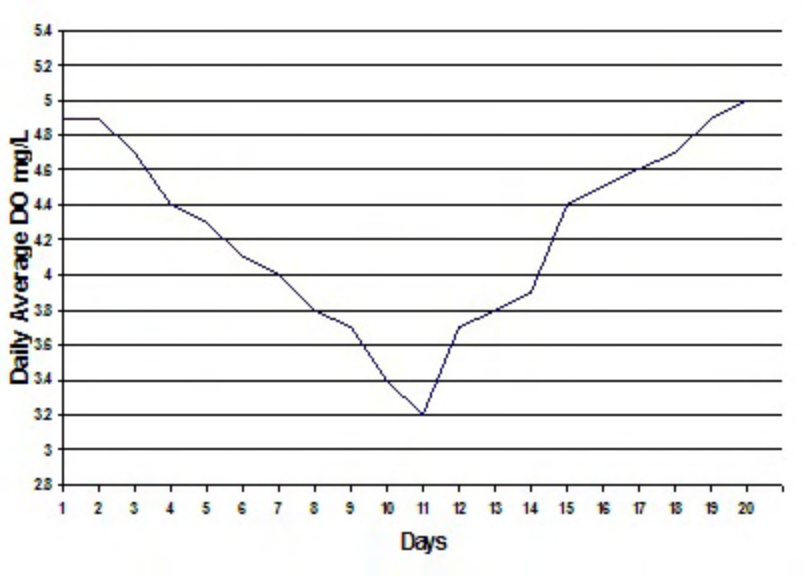

Figure 2. A hypothetical low DO event.

Table 1. The average daily DO data in mg/L for the low DO event shown in Figure 2.

Day	1	2	3	4	5	6	7	8	9	10
DO average	4.9	4.9	4.7	4.4	4.3	4.1	4.0	3.8	3.7	3.4
Day	11	12	13	14	15	16	17	18	19	20
DO average	3.2	3.7	3.8	3.9	4.4	4.5	4.6	4.7	4.9	5.0

Table 2. Analysis of the hypothetical low DO event shown in Figure 2.

DO Interval (mg/L)	No. Days Within Range	No. Days Allowed	Fraction of Allowed Days
< 4.8 ≥ 4.6	3	43	0.07
< 4.6 ≥ 4.5	1	30	0.03
< 4.5 ≥ 4.4	2	25	0.08
< 4.4 ≥ 4.3	1	21	0.05
< 4.3 ≥ 4.2	0	18	0
< 4.2 ≥ 4.1	1	16	0.06
< 4.1 ≥ 4.0	1	14	0.07
< 4.0 ≥ 3.9	1	12	0.08
< 3.9 ≥ 3.8	2	11	0.18
< 3.8 ≥ 3.7	2	9	0.22
< 3.7 ≥ 3.6	0	8	0
< 3.6 ≥ 3.5	0	7	0
< 3.5 ≥ 3.4	1	6	0.17
< 3.4 ≥ 3.3	0	5	0
< 3.3 ≥ 3.2	1	4	0.25
< 3.2 ≥ 3.1	0	3	0
< 3.1 ≥ 3.0	0	2	0
		Cumulative fraction of allowable days	1.26
The cumulative fraction of allowable days exceeds 1.0, therefore, this event constituted a violation of the chronic saltwater standard for DO.			

EVALUATING MULTIPLE LOW DO EVENTS

In the marine waters of New York State spawning by some species of fish, shellfish, or crustacea occurs from January to November. Thus, protection of larval recruitment is needed practically throughout the year. If multiple low DO events occur, a determination must be made whether the effects are cumulative or independent.

The larval recruitment model described above is based on a 66-day recruitment period for a sensitive invertebrate species with a 45-day hatching season and a 21-day larval developmental period. The Department has found that these model parameters are suitable for and protective of the organisms that inhabit the marine waters of New York State. However, we do not know when that recruitment period will occur so we must assume that every 66-day period could be the critical recruitment period.

We assume a 66-day recruitment period begins the first day the DO falls below 4.8 mg/L. This is also considered the first day of a low DO event which continues until the daily average DO returns to concentrations of 4.8 mg/L or greater. If the DO falls again below 4.8 mg/L it is considered the beginning of another low DO event. If there are at least 66 days between the last day of a low DO event and the first day of a subsequent low DO event, each event can be treated independently when evaluating if the DO standard was exceeded (Figure 3).

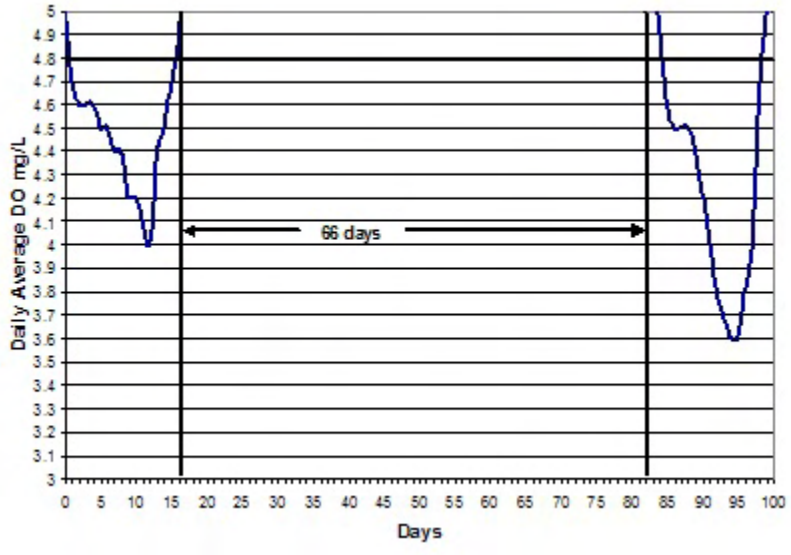

Figure 3. Example of DO events that are evaluated independently. The second low DO event occurs more than 66 days after the end of the first low DO event.

If other low DO events occur within 66 days of the first day of a preceding low DO event, the cumulative impacts of the low DO events must be assessed to determine whether or not the DO standard was exceeded (Figure 4).

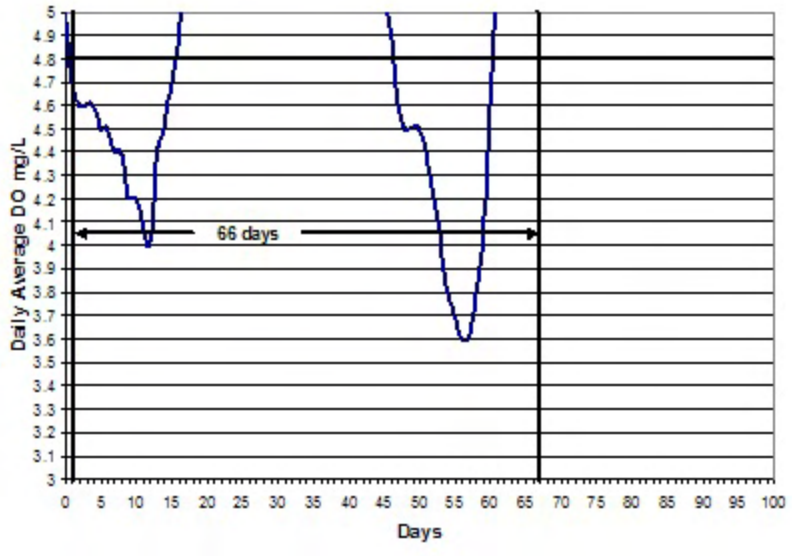

Figure 4. An example of low DO events that must be combined to determine if the marine DO standard was exceeded. Both low DO events occur within the 66-day period.

If other low DO events occur within 66 days of the first day of a preceding low DO event but continue beyond the 66-day period, only that part of the subsequent DO events that falls into the 66-day period needs to be analyzed. However, multiple 66-day periods may need to be assessed to determine whether the cumulative impacts of the low DO events exceed the DO standard (Figure 5).

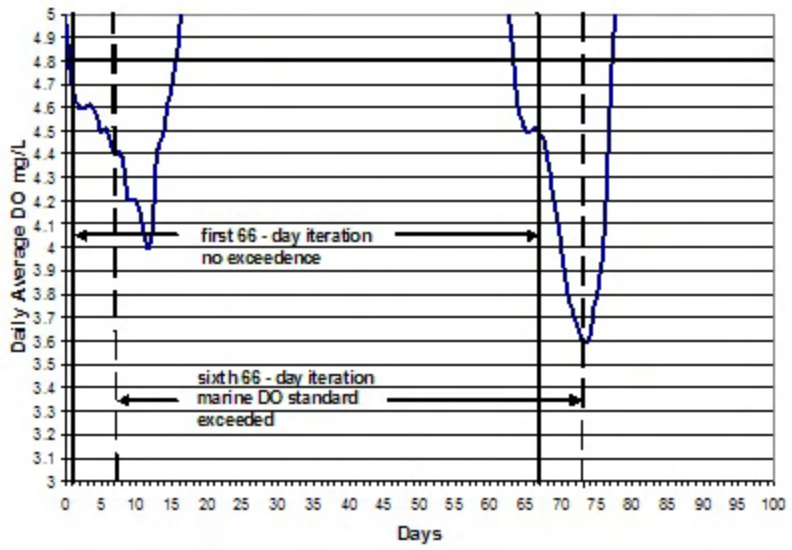

Figure 5. An example of low DO events that must be combined and evaluated iterative ly in order to determine if the chronic marine DO standard is exceeded. In this example the standard is not exceeded until the sixth 66-day period that begins on the sixth day of the first low DO event.

In order to assess if the DO events shown in figure 5, violate the marine DO standard multiple 66-day periods must be evaluated. Begin by using the first day of the first low DO event as the first day of the 66-day recruitment period and calculate the cumulative fraction of the allowed days for that 66-day period. If the results of the evaluation show that the DO standard was not exceeded, repeat the analysis using day 2 of the first low DO event as the first day of the 66-day recruitment period. Continue analyzing 66-day periods, until either a determination has been made that the DO standard was exceeded or the last day of the first low DO event is reached. If by the last day of the first low DO event the DO standard has not been exceeded, start over using the first day of the next low DO event as the first day of the 66-day recruitment period.

Only that portion of the subsequent low DO events that occurs within the same 66-day period being evaluated must be assessed with the previous low DO event for cumulative impacts. By the end of day 66, the recruitment period for the species is over, and recruitment into the population is no longer affected by low DO. The remaining portion of the second low DO event is assessed as a separate, independent event in the next 66-day period.

Figures 3, 4, and 5 use the same low DO events (the data is shown in Table 3). It is only the timing of the second event that changes. The cumulative fractions of allowable days for the DO events analyzed separately (Figure 3) are 0.58 and 0.97. When both events are considered together (Figure 4), the cumulative fraction of allowable days is 1.55. In the condition shown in figure 5, the cumulative fractions of allowable days for the first 66-day periods are 0.74, 0.78, 0.80, 0.89, 0.98,and1.07 respectively.

Table 3. Hypothetical data for Figures 3,4, and 5.

First Low DO Event		Second Low DO Event			
Day	Average Daily DO mg/L	Day			Average Daily DO mg/L
Figures 3,4 &5		Figure 3	Figure 4	Figure 5	
1	4.7	85	47	64	4.6
2	4.6	86	48	65	4.5
3	4.6	87	49	66	4.5
4	4.6	88	50	67	4.5
5	4.5	89	51	68	4.4
6	4.5	90	52	69	4.2
7	4.4	91	53	70	4.0
8	4.4	92	54	71	3.8
9	4.2	93	55	72	3.7
10	4.2	94	56	73	3.6
11	4.1	95	57	74	3.6
12	4	96	58	75	3.8
13	4.4	97	59	76	4.0
14	4.5	98	60	77	4.6
15	4.7				

USE OF AN ALTERNATIVE INTERVAL

The determination of compliance with the chronic marine DO standard will require a significant amount of data. If that data is not available, a definitive determination of compliance can not be made.

Diurnal Fluctuations in the DO concentrations usually occur in the presence of algae which produce oxygen through photosynthesis during the daylight hours while constantly consuming oxygen through respiration. Under these conditions the lowest concentrations usually occur during the night when it can be inconvenient to monitor. Another potential cause of diurnal DO fluctuations in the marine environment is the movement of water due to tides. Whatever the cause, when diurnal DO fluctuations occur an adequate number of measurements or predictions must be made throughout

the 24 hour period to represent the entire range of the daily DO fluctuations. The number of measurements will depend on the extent of the DO fluctuations and the site specific conditions.

As mentioned above, the determination of compliance requires the use of daily average DO concentrations that reflect the diurnal fluctuations in the DO concentrations. If the sampling or analytical predictions are considered inadequate to accurately determine the daily averages, a determination of compliance can still be made using a larger interval in the calculation to account for the uncertainty in the daily average.

When DO monitoring is the sole source of the compliance determination the precision of the sampling equipment should be considered and the use of a larger interval may be appropriate. If the DO sampling effort lacks the precision of continuous monitoring but contains multiple measurements at the same site over the span of the low DO event sufficient to characterize the event, compliance can be determined but a larger interval should be used when applying the larval recruitment curve.

If a larger interval is to be used, a six tenths (0.6) mg/L interval is recommend. Table 4 shows the analysis of the hypothetical low DO event shown in Figure 2 using a 0.6 mg/L interval.

Table 4. Analysis of the low DO event shown in Figure 2 using a 0.6 mg/L interval.

DO Interval (mg/L)	No. Days Within Range	No. Days Allowed	Fraction of Allowed Days
< 4.8 4.2	7	18	0.39
< 4.2 3.6	7	8	0.88
< 3.6 3.0	2	2	1.0
Cumulative fraction of allowable days			2.27
The cumulative fraction of allowable days exceeds 1.0, therefore, this event constituted a violation of the chronic saltwater standard for DO.			

Literature Cited

US EPA, 2000. Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras. U.S. EPA-822-R-00-012, November 2000

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Alexander B. Grannis
Commissioner

NOV 04 2008

MEMORANDUM

TO: Bureau Directors, Division Directors,
Regional Directors, and Regional Water Engineers

FROM: James DeZolt, Director, Division of Water

SUBJECT: Division of Water Technical and Operational Guidance Series (TOGS) 1.1.6,
Interpretation Guidance for Marine Dissolved Oxygen Standard

Last February, the Department amended 6 NYCRR Parts 700 - 704, including a revised marine dissolved oxygen standard in Part 703. Attached is the interpretation guidance for that standard; Technical and Operational Guidance Series (TOGS) 1.1.6, Interpretation Guidance for Marine Dissolved Oxygen Standard.

Consistent with Department guidance, a draft of the TOGS was reviewed by the appropriate Department personnel and received Executive approval. The TOGS was noticed in the Environmental Notice Bulletin (ENB) with a 45 day comment period which ended on July 16, 2008. The public review was also noticed using the e-mail address lists for the Harbor Estuary Program and Long Island Sound Study. No comments or concerns were received during or subsequent to the review period. Commissioner Grannis approved the TOGS on September 29, 2008. The availability of the TOGS will also be noticed in the ENB.

Attachment

c: A. Crocker/B. Little