APPENDIX E

DISSOLVED OXYGEN LISTING METHODOLOGY

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SURFACE WATER QUALITY BUREAU

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Purpose and Applicability

This document establishes a listing methodology for determining impairment due to dissolved oxygen (DO) excursions in streams, rivers, lakes, and reservoirs. This protocol is not applicable to streams with limited aquatic life use and wetlands because the research and implementation procedures necessary have not been investigated or developed by the Surface Water Quality Bureau (SWQB) or adopted in 20.6.4 NMAC.

1.0 Introduction/Background

Oxygen content in fresh waters is determined by several factors acting in concert. These factors include temperature, atmospheric pressure, salinity, turbulence, and photosynthetic activity of algae and plants in the water. Healthy aquatic systems have DO content that at least approaches 100% saturation[1]. Oxygen content may fall substantially below 100% saturation during the night when oxygen consumption coupled to the heterotrophic decay of organic matter, and other ecosystem respirations, reduce DO in the water column (Deas and Orlob 1999). The diel changes in DO content is normal and can be particularly pronounced in systems with excessive nutrient enrichment and consequent algal and plant growth. See the SWQB Nutrient Listing Methodology (available at: https://www.env.nm.gov/surface-water-quality/calm/) for more details.

Currently, New Mexico's criteria for DO are expressed only in units of mass per volume (mg/L). However, in certain circumstances such as high altitudes where atmospheric pressure is comparatively low or high air temperatures that reduce oxygen solubility (and particularly when these two conditions are both present), DO may be reduced so much so that the concentration-based criterion is physically impossible to attain. New Mexico's listing methodology considers concurrent percent saturation because this integrates several naturally-occurring factors that influence the amount of oxygen that water can contain. Specifically, the SWQB will further examine listing based on data points when concurrently-measured percent saturation was greater than or equal to 90% to determine the site-specific reason for the high percent saturation. Surrounding states have also incorporated percent saturation into their impairment determinations. For example, water quality criteria for DO concentration in Arizona are considered met if the measured DO percent saturation is equal to or greater than 90 percent. Arizona has incorporated this approach into their water quality standards (AAC 2013).

2.0 Data Collection Procedures and Considerations

DO data from flowing waters typically exhibit a diel pattern that is usually at its lowest (i.e., most likely to have an excursion of the criteria) in the early morning in streams with excessive aquatic plant growth. For these reasons, continuous recording devices (sondes or data loggers) are used to record diel fluctuations, especially where excessive aquatic plant growth is suspected or evident.

[1] All references to saturation are defined as percent saturation at the local elevation, as opposed to global percent saturation (the percent saturation a given concentration would be at sea level).

SWQB typically deploys sondes or data loggers in streams and rivers to record parameters including DO, pH, specific conductance, temperature, and turbidity. If DO is the only parameter of concern, DO data loggers may be deployed instead of sondes. Both sondes and data loggers are deployed and the data reviewed following the guidelines specified in the SWQB Standard Operating Procedures (SOPs, available at: https://www.env.nm.gov/surface-water-quality/sop/) . DO data from periods where the record indicates that the sonde or data logger was exposed or buried are censored and not used for assessment. Sondes or DO loggers should be used to collect DO data in order to observe diel fluctuations, as opposed to the "snapshot" that grab data provide; however, in some cases only grab data are available. For SWQB collected data, additional information regarding the preferred timing of sonde deployment is typically provided in applicable Field Sampling Plans or Water Quality Survey Reports (available at: https://www.env.nm.gov/surface-water-quality/water-quality-monitoring/). The preferred sonde deployment period for measuring DO is within the growing season (Table 1).

Table 1. Growing seasons for New Mexico ecoregions and elevations

Site Class	Level 3 Omernick Ecoregion	Growing Season
Mountain >7500 ft	22 & 23	July 1-Oct 15
Mountains <7500 ft & Plateau	20, 21, 22 & 23	Jun 15-Nov 1
S. Deserts and Plains	24, 25, 26, & 79	May 15-Nov 15

For rivers and streams, sonde or data logger data sets deployed for ≥72 hours with a maximum one-hour frequency interval are preferred for assessment purposes and required to determine Full Support of the applicable criteria. The likelihood of capturing adequate data to determine natural vs. anthropogenic influences to DO concentrations increases with increased sonde or data logger data, so longer deployments with interim equipment checks and data downloads are encouraged. DO listings based on grab data from streams or rivers will be noted as Category 5C (needing sonde or data logger data to confirm).

Reviewers of long-term data should make note of other factors that may cause DO excursions due to natural increases in biological oxygen demand (BOD), such as deciduous litter drop or post-fire stormflow events. If these conditions were present during collection, the data review should include a sampling event comment.

The SWQB is exploring the feasibility of sonde deployment in lakes and reservoirs. If it is determined that sondes or data loggers can be safely deployed in this waterbody type and generate valuable data that can meet 20.6.4.14.C(3) NMAC, the SWQB will develop a standard operating procedure and listing methodologies for lake continuous monitoring data.

3.0 Assessment Procedure

New Mexico DO criteria found in 20.6.4.900.H NMAC (available at: https://www.env.nm.gov/surface-water-quality/wqs/) are based on the aquatic life use designation (Table 2). The SWQB typically deploys sondes or DO loggers for three to fourteen days to record at least hourly DO values. Sonde or data logger data sets greater than 72 hours with a maximum one-hour frequency interval are required to assess with the continuously recorded data set assessment method in Table 3. If this resolution of sonde DO data is not available, the instantaneous grab method is used to determine attainment. DO impairment listings determined from grab data from streams or rivers will be noted as Category 5C and prioritized for sonde or logger deployment to confirm the assessment.

Table 2. New Mexico's DO criteria

Aquatic Life Use	DO Criterion*
High Quality Coldwater Coldwater Marginal Coldwater	6.0 mg/L or more
Coolwater Warmwater Marginal Warmwater	5.0 mg/L or more
Limited	No default established

NOTES: * Listing based on data points when concurrently-measured percent saturation was greater than or equal to 90% will be further examined to determine the site-specific reason for the high percent saturation.

A determination of Not Supporting is made if there are DO criteria excursions for four or more consecutive hours on more than one day and the excursions are not statistical outliers from the minimum daily DO measurements measured during the calendar year. A potential outlier is defined as a DO value lower than the 25th percentile (Q1) of the measured daily minimum DO values minus three times the inter-quartile range (IQR). The IQR is defined as the difference between the 25th percentile (Q1) and Q3 (Tukey 1977, Seo 2006). This approach is intended to 1) reduce the influence from autocorrelation of continuous data, 2) demonstrate the repeatability of an observation and 3) take into consideration potential anomalies in the DO data set due to extreme deviations from seasonal norms, other anomalous events such as runoff from catastrophic fire areas, or instrument errors. Anomalies are determined in the either the 15 min or 1 hour SWQB Long-term Dataset (LTD) Data Management Spreadsheet based on the sampling interval[2]. Non-assessable data are censored to generate the final assessment dataset.

[2] For a copy of this spreadsheet, please visit https://www.env.nm.gov/surface-water-quality/sop/.

Table 3. Determination of aquatic life use support using DO data

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•Instantaneous (grab) DO data **A)** Rivers or streams **B**) Lakes or reservoirs[a]	**A)** Not assessable (cannot determine Fully Supporting with grab data only) **B)** No DO criteria excursions[a]	**A)** DO criteria excursions in ≥ 10% of measurements, or more than one measurement if 4 to 10 data points are available. [b] **B)** 1 or more DO criteria excursions[a]	[a] Lakes are typically sampled once in the spring, fall, and summer. DO measurements taken at intervals are averaged for the epilimnion, or in the absence of an epilimnion, for the upper one-third of the water column of the lake to determine attainment of DO criteria. See 20.6.4.14.C(3) NMAC for additional information. [b] DO listings based on grab data will be noted as Category 5C (need sonde data to confirm). Less than 4 samples = not assessed. See Section 2.1.4 Main Listing Methodology (CALM) for details. [c] Statistical outliers are identified prior to assessment via the SWQB LTD Data Management Spreadsheet. Listing based on data points when concurrently-measured percent saturation was greater than or equal to 90% will be further examined to determine the site-specific reason. [d] If an AU is determined to be impaired for both excessive nutrients and DO following respective listing methodologies, the AU will be listed for the causal variable (nutrients) rather than the response variable (DO).
•Continuously recorded DO data (≥72 hours, ≤one hour frequency interval)	DO criteria excursion(s) for <u>less than four</u> consecutive hours on more than one day.	DO criteria excursions for <u>four or more</u> consecutive hours on more than one day, and the excursions are not outliers. [c] [d]	

REVISION HISTORY:

2014 listing cycle – Clarified concurrent minimum approach (i.e., ≥90% saturation = no excursion of criterion). Removed "Additional Thresholds Under Consideration" section (passed on to the SWQB Standards and Reporting Team for evaluation). Clarified relationship between nutrient and DO assessments.

2016 listing cycle – Minor wording clarifications. Reduced grab data Non Support for lakes to 1 or more excursions because lakes are typically sampled once in the spring and fall, and twice in the summer; each seasonal sampling event is intended to be representative of the entire season. Changed ≥90% saturation = no excursion of criterion exclusion to further review of associated data vs. censoring of these data from the assessment dataset.

2018 listing cycle – "Assessment Protocol" changed to "Listing Methodology." Added reference to data logger. Removed reference to segment-specific DO criteria in 20.6.4.113 NMAC because they no longer exist. Changed Table 2 from "10 or fewer" to "2 to 10" because n=2 is a minimum data requirement for assessment (added related footnote).

2020 listing cycle – Clarified that growing season is preferred sonde deployment period. Added reference to the SWQB Field Sampling Plans for additional sonde deployment information. Added a provision to test and remove statistical outliers in long-term DO dataset prior to assessment.

REFERENCES:

Arizona Administrative Code (AAC). 2013. Title 18, Chapter 11, Supp. 08-4, Article 1, Water Quality Standards for Surface Waters. R18-11-109 (E)(3). Available at: http://www.azsos.gov/public_services/title_18/18-11.htm.

Deas, M.L. and G.T. Orlob. 1999. Klamath River Modeling Project. Project #96-HP-01. Assessment of alternatives for flow and water quality control in the Klamath River below Iron Gate Dam. University of California Davis Center for Environmental and Water Resources Engineering. Report No. 99-04. 236 pp.