APPENDIX H

TURBIDITY LISTING METHODOLOGY FOR COLDWATER PERENNIAL STREAMS AND RIVERS

NEW MEXICO ENVIRONMENT DEPARTMENT
SURFACE WATER QUALITY BUREAU

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Purpose and Applicability

This document establishes a listing methodology for determining impairment due to excessive turbidity perennial streams and rivers with high quality coldwater, coldwater, and marginal coldwater designated uses. This protocol was developed to assess the first sentence of the *State of New Mexico Standards for Interstate and Intrastate Surface Waters* narrative criterion for turbidity found at 20.6.4.13.J NMAC (available at: https://www.env.nm.gov/surface-water-quality/wqs/):

> ***Turbidity**: Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.* Activities or discharges shall not cause turbidity to increase more than 10 NTU[1] over background turbidity when the background turbidity, measured at a point immediately upstream of the activity, is 50 NTU or less, nor to increase more than 20 percent when the background turbidity is more than 50 NTU. However, limited-duration turbidity increases caused by dredging, construction or other similar activities may be allowed provided all practicable turbidity control techniques have been applied and all appropriate permits, certifications and approvals have been obtained.

The rest of the narrative turbidity standard at 20.6.4.13.J NMAC is generally used to determine whether anthropogenic activities in the riparian corridor of a river or stream cause a deleterious effect.

Exclusions

This protocol is not applicable to the following water body types because the necessary research and implementation procedures have either not been investigated by the Surface Water Quality Bureau (SWQB) or are not yet developed. As resources allow, the scope will be expanded to include these water body types:

- Lakes, reservoirs, and playas;
- Intermittent streams;
- Ephemeral streams;
- Wetlands; and
- Stream segments with a coolwater (or dual coldwater and warmwater), warmwater, or marginal warmwater aquatic life designated use per the current version of 20.6.4 NMAC.

1.0 Introduction/Background

Prior to the 2005 triennial review of water quality standards, New Mexico had numeric turbidity criteria for certain aquatic life uses. When these numeric criteria were removed, it became necessary to develop numeric translators or thresholds for the narrative criterion found at 20.6.4.13 NMAC in order to continue making impairment determinations for turbidity. Water quality criteria for turbidity and total suspended sediments vary greatly among states. New Mexico is one of many states that do not have absolute numeric criteria for turbidity or total suspended solids (EPA 2006). No other examples of states assessing a similar narrative turbidity criterion in order to determine aquatic life use attainment for Clean Water Act §303(d) purposes could be found when this listing methodology was initially developed for the 2012 listing cycle.

[1] Nephelometric turbidity unit.

There is a recognized relationship between total suspended sediment (TSS) and turbidity in New Mexico (Jessup et. al 2010). New Mexico also has a narrative TSS criterion found at 20.6.4.13.A(2) NMAC. Turbidity and TSS data were collated and examined to determine potential sediment benchmarks or thresholds in New Mexico following EPA's guidance (EPA 2006). Unfortunately, data available at the time were not sufficient for identifying a biologically-based low-flow or high-flow turbidity or TSS threshold using this approach (Jessup et. al 2010). The SWQB hopes to revisit this approach as well as other potential approaches such as Schartz et. al (2008) in the future as resources allow.

The approach described below relies on the use of biotranslators to derive numeric thresholds for New Mexico's narrative turbidity criterion. A biotranslator is most simply obtained in controlled experiments that isolate a physical or chemical water quality parameter and determine a threshold level of that parameter above which a quantifiable attribute of an indicator organism is impaired. This approach has been used with a wide variety of fish species to define lethal doses (LD_{50}) and lethal concentrations (LC_{50}) values that have in turn been used to establish water quality standards criteria for parameters such as temperature, dissolved oxygen, metals and organic compounds. In turbidity studies, a less well-defined endpoint is usually determined based on observations of behavior and the resulting values are referred to as Effect Levels (EL).

To minimize the potential for the effects of bedded sediment to influence turbidity assessment, this protocol will consider primarily those biotranslators which have been developed from experiments on biota that isolated turbidity from other water quality parameters. These experiments used fish because the effects of turbidity in the water column can be observed as changes in feeding, growth, or social interactions. Benthic macroinvertebrate data from turbidity studies that controlled for effects from sedimentation and other parameters were also considered.

Several aquatic life uses, including High Quality Coldwater (HQCW), Coldwater (CW), Marginal Coldwater (MCW), Coolwater, Warmwater, and Marginal Warmwater, are defined in 20.6.4.7 NMAC. The correlation between temperature tolerance and turbidity tolerance is not well documented. Also, there is a wide variation in trophic levels among temperature classes of fish species. A correlation may exist between coldwater species and turbidity tolerance due to the fact that all coldwater species in New Mexico (with the exception of Southern redbelly dace) are salmonids, and salmonids are known to have low turbidity tolerances. A literature search was conducted to find turbidity tolerance biotranslators for fish species native to New Mexico. When data on native species were unavailable, well-established introduced species were considered. Additionally, the Oregon Department of Environmental Quality has prepared a thorough turbidity technical review which includes a comprehensive summary of turbidity studies (OR DEQ 2014).

1.1 Coldwater (including Marginal and High Quality) Species

Most coldwater species in New Mexico are generally considered "sensitive" to items such as increased siltation, temperature, turbidity, or lowered dissolved oxygen (Sublette et al. 1990, Zaroban et al. 1999), and tend to be greatly reduced in association with human disturbance (Karr et al. 1986). The most representative fish to use in determining the appropriate turbidity thresholds for stream segments assigned these aquatic life uses are salmonids. The majority of studies on the effects of turbidity on fish have been conducted with salmonids due to their economic importance and relatively low tolerance to elevated turbidity. Data on several species of salmonids indicate that at turbidities in the vicinity of 10 NTU reactive distance is halved, and passive feeding is replaced with an active feeding. This turbidity level, if maintained for a sufficient duration, results in impaired growth (Berg and Northcote 1985, Sweka and Hartman 2001, Newcombe 2003). Brown trout, a non-native species, are widespread throughout New Mexico. Reduced feeding was observed in brown trout at 7.5 NTU (Bachman 1984) indicating that growth could potentially be impaired at lower turbidity levels. This suggests a long duration threshold of <10 NTU is appropriate for waters with these aquatic life uses. Additional support for a threshold near 10 NTU is provided in a study of benthic macroinvertebrates above and below clay-laden discharges from placer mines (Quinn et al. 1992). In this study, invertebrate densities were halved at turbidity levels between 0 and 7 NTU. No physical effects of sediment were found on macroinvertebrates, indicating the observed reductions in densities were due to reduced food production as a result of reduced light transmission.

1.2 Coolwater Species

Smallmouth bass can be considered a coolwater aquatic life species based on temperature needs, and may be a useful indicator of limited to moderate disturbance based on "intermediate tolerance" to influencing variables such as increased siltation, temperature, turbidity, or lowered dissolved oxygen (Zaroban et al. 1999). Changes in smallmouth bass prey selection between round goby, golden shiner, and northern crayfish were noted at various turbidity levels between 0 and 40 NTU. Although this study was not designed to directly test long-term feeding rates, a correlation revealed a negative relationship between turbidity and feeding rate with a significant difference between 0 and 5 NTU (Carter et al. 2009).

1.3 Warmwater and Marginal Warmwater Species

Bluegill typically occupy warmwater aquatic life habitat and are native to New Mexico. Bluegill feeding activity was reduced approximately 20% at 60 NTU relative to clear water conditions (Gardner 1981). A second warmwater species is the Largemouth bass, although this species is not native to New Mexico. No changes in feeding behavior were observed in Largemouth bass exposed to turbidities ranging from 0-37 NTU (Reid et al. 1999), indicating that an upper threshold for warmwater aquatic life habitat should be at least 37 NTU and possibly higher. Conversely, other native New Mexican warmwater species such as the Sand shiner, Arkansas River shiner, Red shiner and Flathead chub, all showed little or no change in prey consumption rate at turbidities ranging from 0-1,000 NTU, and prey consumption was enhanced in Arkansas River shiner as turbidity increased from 0-2,000 NTU (Bonner and Wilde 2002).

2.0 Turbidity Thresholds for Perennial Streams with Coldwater (including Marginal or High Quality Coldwater) Designated Aquatic Life Uses based on Newcombe (2003)

Duration of exposure can vary greatly from study to study, making it difficult to compare results. In addition, information on duration is not always provided (OR DEQ 2014). In order to generate a larger dataset to develop a severity of ill effects (SEV) index that describes the combined effects of turbidity levels and duration of exposure on clear water fishes, Newcombe (2003) used the information cited in some of the above studies as well as others. Turbidity effects considered for the model include fish reactive distance, predator prey dynamics, egg and larval development growth rates, and habitat alteration effects. Newcombe (2003) assigned SEV scores to the results of the studies, and then regressed against water clarity measurements and exposure duration from literature to develop a log-linear regression (OR DEQ 2014).

Newcombe states that only data from fishes with one or more life stages intolerant of cloudy conditions, or those usually found in clear water systems that "…perhaps benefit from seasonal improvements in water clarity…" were available in sufficient quantities to develop the index. Coldwater (i.e., typically pollution sensitive) fish species in New Mexico clearly meet this definition, whereas coolwater fish species cover a wider range of pollution tolerances and there is no direct translation between temperature and turbidity tolerances. Therefore, Newcombe's SEV index is evidently applicable to coldwater aquatic life, including high quality and marginal designated uses. The limited availability of data for coolwater and warmwater fish species native to New Mexico, together with conflicting tolerances and needs for turbidity among species for which data are available, prevents derivation of a suitable biotranslator and SEV index for coolwater and warmwater aquatic life designations. Additionally, this assessment approach derived from the SEV index will not be applied to stream segments that list both a coldwater and a warmwater designated aquatic life use as these dual aquatic life use waters are currently under water quality standards review to determine the most appropriate aquatic life use designation. As resources and research allow, the SWQB hopes to be able to develop assessment approaches for coolwater and warmwater fish species in the future.

An SEV index value of 3.5 was selected to develop thresholds for turbidity assessment in New Mexico. This value corresponds to the boundary between conditions that produce changes in feeding and those that reduce growth rate and habitat size. The SWQB's selection an SEV index value of 3.5 balances the potential for both type I and II error with respect to impairment listings, is conservative given the scale provided in Newcombe (2003), and addresses the goal of 20.6.4.13.J NMAC. Aquatic organisms are adapted to episodic disruptions in feeding, especially in southwest streams that experience intense, short-duration, localized precipitation events.

The power relationship between turbidity and duration for a severity index of 3.5 is given in Equation 1:

Equation 1. Relationship of NTU and allowable duration for SEV = 3.5:

$$x = (37{,}382)*(y^{-1.9887}) \quad \text{or} \quad y = (199.2)*(x^{-0.5028})$$

where x = duration in hours and y = NTU.

Solving Equation 1 for various NTU and durations gives a range of turbidity thresholds for clear water fish species. If the turbidity threshold (y) is exceeded consecutively for more than the corresponding allowable duration (x), the water body is documented as impaired. Similarly, if the maximum of all recorded minimum turbidity values for a given duration (x) is greater than the corresponding allowable turbidity threshold (y), the water body is documented as impaired. Impairment thresholds were determined using Equation 1 with a minimum duration (x) of 72 hours (three days) and a minimum turbidity threshold (y) of 7 NTU (Table 1). Sonde data that do not meet this minimum duration cannot be used to make final impairment or de-listing determinations.

Table 1. Turbidity impairment thresholds and durations at which ill effects (SEV = 3.5) are expected to occur in clear water fish, based on Newcombe (2003).

Turbidity Threshold (y) (NTUs)	Allowable Duration (x) (consecutive hours)	Allowable Duration (consecutive days)
23	72[(a)]	3
20	96	4
18	120	5
16	144	6
15	168	7
11	336	14
7	720[(b)]	30

NOTES:
[(a)]Turbidity levels above this duration are assumed to impact feeding behavior while turbidity levels for shorter-duration turbidity excursions are unlikely to impair the growth and reproduction of aquatic life as required by New Mexico's narrative turbidity water quality criterion.
[(b)]Thresholds for duration longer than this result in turbidity values lower than supported by the literature review presented in section 1.0.

A graph of the relationship between turbidity and duration for a severity index of 3.5 within the turbidity threshold and duration limits in Table 1 is shown in Figure 1.

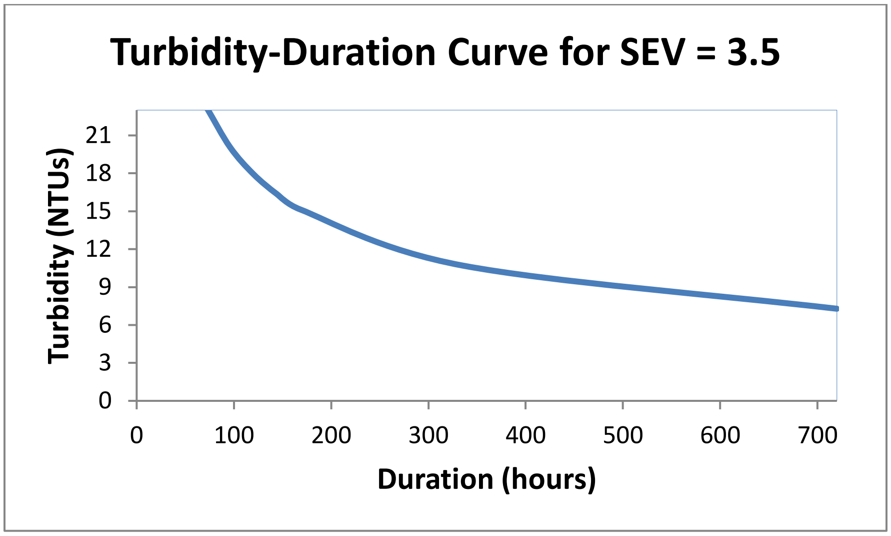

Figure 1. Chart of turbidity impairment thresholds and durations at which ill effects (SEV = 3.5) are expected to occur in clear water fish, based on Newcombe (2003).

3.0 Assessment Procedure

The first step is to collate available instantaneous (grab) and continuous (sonde) monitoring turbidity data (Figure 1). The SWQB collects grab turbidity measurements generally once a month during water quality surveys. The SWQB typically deploys sondes for three to fourteen days to record at least hourly dissolved oxygen, pH, specific conductance, temperature, and turbidity values. Only validated datasets that meet the QA/QC requirements described in the SWQB's most recent quality assurance project plan (QAPP), available at: https://www.env.nm.gov/surface-water-quality/protocols-and-planning/) are used for assessment purposes.

Sonde (long-term) data

The SWQB typically deploys sondes or data loggers in streams and rivers to record DO, pH, specific conductance, temperature, and turbidity values over a specific period of time. Sondes are deployed and the data reviewed following the guidelines specified in the SWQB's SOPs. 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 is within the agricultural growing season (Table2).

Table 2. 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

If at least 72 hours (3 days) of turbidity sonde data with a maximum one-hour frequency interval are available, these data are evaluated to determine impairment status. The likelihood of capturing a variety of turbidity events and conditions increases with increased sonde deployment so longer deployments are encouraged. The data are evaluated against impairment thresholds in Table 1 and attainment status is determined per Table 2 (see also Figure 1). If less than 72 hours of data are available, the data will only be evaluated to determine priority for subsequent longer sonde deployment.

To evaluate a sonde dataset with sufficient data against the impairment thresholds, determine the maximum of all recorded minimum turbidity values (i.e., turbidity duration maximum) for each duration in Table 1. The SWQB provides a Long-Term Dataset (LTD) Data Management Spreadsheet tool[2] to assist with the calculation. If this turbidity duration maximum is less than the corresponding turbidity threshold in Table 1, the assessment conclusion is **Fully Supporting**. If the corresponding turbidity threshold has been exceeded, the assessment conclusion is **Not Supporting**.

<u>Instantaneous (grab) data</u>

If less than 72 hours of sonde data are available, grab data may be evaluated to determine Non Support and to prioritize future sonde deployments. Only grab data collected during low or baseflow conditions will be assessed. All flood flow samples (i.e., high flow in response to recent precipitation) will be removed from the dataset prior to assessment. This may be determined by either a corresponding flow condition rating of 2 or 3 as recorded on the SWQB Field Sampling Form or by analysis of available quantitative flow data. If there are at least four assessable data points that were collected at least 21 days apart (to ensure temporal independence of the grab data) within the same calendar year, and four or more consecutive values are greater than 7 NTU, the assessment unit (i.e., stream reach) will be noted as **Not Supporting** for turbidity and prioritized for sonde deployment. **Fully Supporting** cannot be determined with grab data. In cases where both continuous data and instantaneous data are available, continuous data will be used for assessment.

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

Table 2. Assessing turbidity data to determine HQCW, CW, or MCW Aquatic Life Use Support [a]

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
Continuously recorded turbidity data (≥72 hours, ≤one-hour frequency interval)	Turbidity duration maximum does not exceed any turbidity impairment thresholds in Table 1.	Turbidity duration maximum exceeds one or more turbidity impairment thresholds in Table 1. [b]	[a] As stated in Section 2.0, this assessment approach derived from the SEV index will not be applied to stream segments that list both a coldwater and a warmwater designated aquatic life use.
Instantaneous (grab) turbidity data **A)** ≥ 4 samples in same calendar year and data points ≥ 21-days apart **B)** < 4 samples in same calendar year or data < 21-days apart	**A)** Not assessable (cannot determine Fully Supporting with grab data only) **B)** Not Assessed	**A)** ≥ 4 consecutive measurements > 7 NTU [c] **B)** Not Assessed	[b] The AU may also be listed as Not Supporting on a case-by-case basis if the data set clearly indicates that an impairment threshold would be exceeded had the sonde remained in the water based on the trend of the data at retrieval. [c] Only grab data collected during low or baseflow conditions) will be assessed. Turbidity listings based on grab data will be noted as Category 5C (need sonde data to confirm).

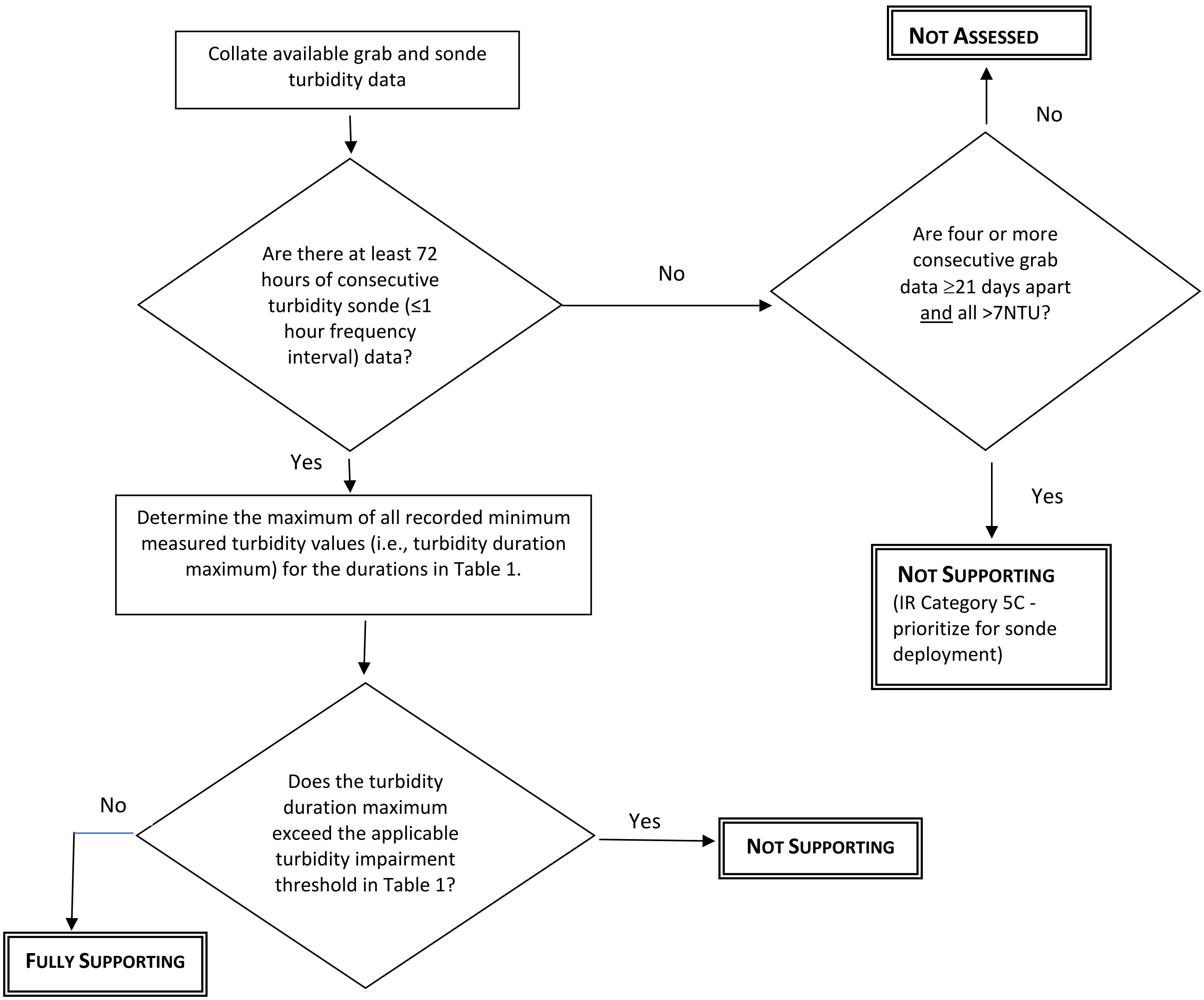

Figure 1. Generalized flowchart for determining turbidity attainment status

<u>REVSION HISTORY:</u>

2012 listing cycle – Initial protocol using SEV translator approach.

2014 listing cycle – Removed application to coolwater aquatic life. Minor clarifications and re-organization.

2016 listing cycle – Minor clarifications/revisions. Added history of NM's turbidity and TSS criteria, and Tetra Tech analyses based on EPA's suspended and bedded sediments (SABS) guidance.

2018 listing cycle – "Assessment Protocol" changed to "Listing Methodology." Clarified that < 72 hours of sonde data cannot be used to make final impairment or de-listing determinations.

2020 listing cycle – Added description of "turbidity duration maximum" and how to use determine this value using the SWQB's LTD Data Management Spreadsheet to assess turbidity sonde data. Clarified that growing season is preferred sonde deployment period. Revised instantaneous (grab) data assessment approach to better match other protocols where grab data can only be used to determine impairment (i.e., IR Category 5C and prioritized for future sonde collection). Added acknowledgement that elevated turbidity may be natural during snowmelt runoff. Updated ORDEQ reference to latest edition that is available online.

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