DRAFT EUTROPHICATION CAUSE METHOD

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INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) describes nutrient pollution as one of America's most widespread, costly, and challenging environmental problems. Within the context of nutrient pollution of streams, the term eutrophication refers to the process by which elevated nutrient levels (phosphorus and nitrogen) stimulate the growth of algae and/or aquatic plants, alter the quantity and quality of organic matter available as food for aquatic organisms, change physical habitat conditions, and impact stream dissolved oxygen characteristics.

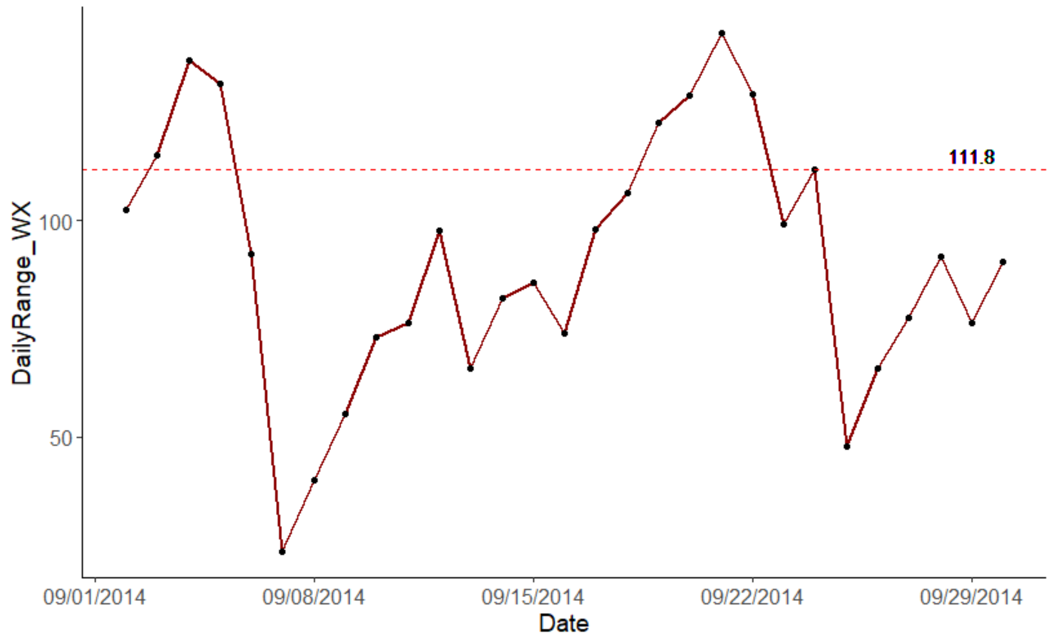
Pennsylvania does not currently have numeric nutrient criteria that can be used to identify nutrients as a cause of Aquatic Life Use (ALU)-impairment in streams. This is due to the complexity of the response of stream biological communities to nutrient enrichment. In the absence of directly toxic conditions associated with ammonia or nitrite, most nutrient-related impacts on stream biological communities are indirect and associated with altered trophic conditions which are reflected in their primary productivity and ecosystem respiration rates, and thus, their dissolved oxygen (DO) characteristics.

This document summarizes the Pennsylvania Department of Environmental Protection (DEP) Eutrophication Cause Method (ECM). The ECM is intended to replace the Eutrophication Cause Determination Protocol (ECDP, McGarrell 2018) previously used by DEP to identify eutrophication as a cause of impairment in aquatic life use-impaired streams with a drainage area of ≤50 mi^2. The ECM is applicable to streams with a drainage area of up to 500 mi^2 and is designed for use in streams with an ALU impaired benthic macroinvertebrate community. The technical background behind the development of the ECM can be found in the *Eutrophication Cause Method: Technical Support Document* (McGarrell and Gocek 2023).

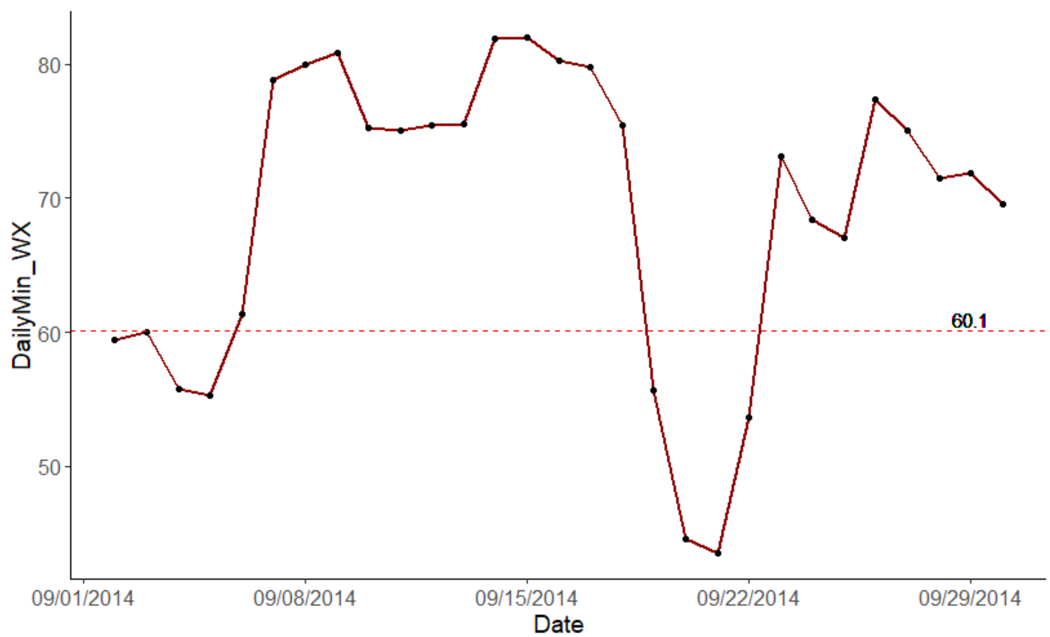
DATA COLLECTION AND ANALYSIS

Data sondes are to be deployed between April 1 and October 31 throughout the field season. Dissolved oxygen, water temperature, specific conductance, and pH are continuously measured at half-hour intervals, and data are collected, graded, and approved for use in accordance with the DEP *Chapter 4.3, Continuous Physicochemical Data Collection Protocol* (Hoger and Arnold 2023). Diel values are calculated for days with continuous data representing at least 75% of the day (e.g., a minimum of 36 readings at ½ hour intervals). Days that do not meet this usability criteria (75% of the day) are removed from the dataset and excluded from analysis.

Percent saturation values are used to compensate for the influence of water temperature on stream dissolved oxygen levels. Daily range values are calculated as the difference between the maximum and minimum value recorded on a given calendar day, and daily minimum values are the minimum value recorded on a given calendar day. Proximate stressor variables (%Sat daily range and %Sat daily minimum) are summarized by month using the 75th percentile value (p75) of %Sat daily range (p75DailyRange_WX) and the 25^{th} percentile value (p25) of %Sat daily minimum (p25DailyMin_WX) values recorded at a given station within a given month (Figure 1).



(A)



(B)

Figure 1. Example of (A) daily and monthly 75th percentile values of DailyRange_WX (p75=111.8 %Sat) and (B) daily and monthly 25th percentile values of DailyMin_WX (p25=60.1 %Sat) recorded at a stream in southeast Pennsylvania in September of 2014. Points represent daily values and horizontal lines represent monthly percentile values.

Monthly p75DailyRange_WX and p25DailyMin_WX values are used to characterize the degree of metabolic activity (primary production (P) and ecosystem respiration (ER)) occurring under peak conditions (highest P and ER rates) at a given station within a given month. Monthly p75 and p25 values are generated for months that have approved daily values recorded for a minimum of 14 days in that month. Therefore, the minimum amount of data required to identify eutrophication as a cause of impairment in an ALU impaired stream can be as little as 14 days of usable data collected within a given calendar month.

During sonde maintenance visits (approximately monthly), discrete water chemistry samples are collected for laboratory analysis of total phosphorus (TP) and total nitrogen (TN) in accordance with *Chapter 4.2, Discrete Water Chemistry Data Collection Protocol* (Shull and Arnold 2023). A single benthic macroinvertebrate sample will be collected between the months of November and April and will be processed in accordance with (Shull 2017, Shull 2023, Williams 2017a, Williams 2017b). Assessment status will be determined in accordance with DEP benthic macroinvertebrate assessment methods (Shull 2023, Williams 2017b).

A sample eutrophication tolerance index (ETI) score (McGarrell and Gocek 2023) will be calculated from the macroinvertebrate sample collected at the sonde location. A sample's ETI score reflects the overall tolerance of its benthic macroinvertebrate community to stressful eutrophication conditions (i.e., elevated p75DailyRange_WX and depressed p25DailyMin_WX values). The ETI is a relative abundance-weighted tolerance index value calculated in a manner like the commonly used Hilsenhoff Biotic Index (Hilsenhoff 1977) using the following equation:

$$\text{Sample ETI Score} = \frac{\Sigma n_i \; x \; a_i}{N}$$

Where, *n* is the number of individuals of taxon *i*, *a* is the eutrophication tolerance value (ETV, Table 1) of taxon *i*, and *N* is the total number of individuals in the sample with an ETV.

Table 1. Eutrophication tolerance values.

Order	Family	Taxa	ETV
Ephemeroptera	Baetidae	*Acentrella*	3
		Diphetor	3
		Baetis	8
	Caenidae	*Acerpenna*	9
		Caenis	10
	Ephemerellidae	*Eurylophella*	3
		Teloganopsis	5
		Ephemerella	6
		Serratella	7
	Heptageniidae	*Epeorus*	2
		Maccaffertium	6
		Leucrocuta	8
		Stenacron	8
	Isonychiidae	*Isonychia*	7
	Leptophlebiidae	*Paraleptophlebia*	3
Plecoptera	Capniidae	*Paracapnia*	3
		Allocapnia	5
	Chloroperlidae	*Alloperla*	1
		Sweltsa	4
	Leuctridae	*Leuctra*	2
	Nemouridae	*Prostoia*	2
	Perlidae	*Paragnetina*	1
		Acroneuria	3
		Agnetina	6
	Perlodidae	*Isoperla*	3
	Taeniopterygidae	*Taenionema*	3
		Strophopteryx	5
		Taeniopteryx	5
Trichoptera	Apataniidae	*Apatania*	4
	Brachycentridae	*Brachycentrus*	4
	Glossosomatidae	*Glossosoma*	4
	Hydropsychidae	*Diplectrona*	1
		Ceratopsyche	7
		Cheumatopsyche	8
		Hydropsyche	8
	Hydroptilidae	*Hydroptila*	6
		Leucotrichia	8
	Lepidostomatidae	*Lepidostoma*	4
	Limnephilidae	*Pycnopsyche*	1
	Odontoceridae	*Psilotreta*	8
	Philopotamidae	*Dolophilodes*	1
		Chimarra	9
	Polycentropodidae	*Polycentropus*	6
	Rhyacophilidae	*Rhyacophila*	2
	Thremmatidae	*Neophylax*	5

EUTROPHICATION CAUSE DECISION

The first step in the ECM is to categorize the sample station into the appropriate stream class based on its drainage area size class (<38.6 mi^2 or 38.6-500 mi^2) and the Pennsylvania Eutrophication Region in which it's located (Figure 2). Based on size class and Pennsylvania Eutrophication Region, sample stations are delineated into one of four stream types:

1. <38.6 mi^2 – Pennsylvania eutrophication region A
2. <38.6 mi^2 – Pennsylvania eutrophication region B
3. 38.6-500 mi^2 – Pennsylvania eutrophication region A
4. 38.6-500 mi^2 – Pennsylvania eutrophication region B

To account for seasonal variations in abiotic factors influencing stream ecosystem metabolic rates, the ECM also has four distinct sample periods:

1. April
2. May & October
3. June & September
4. July & August

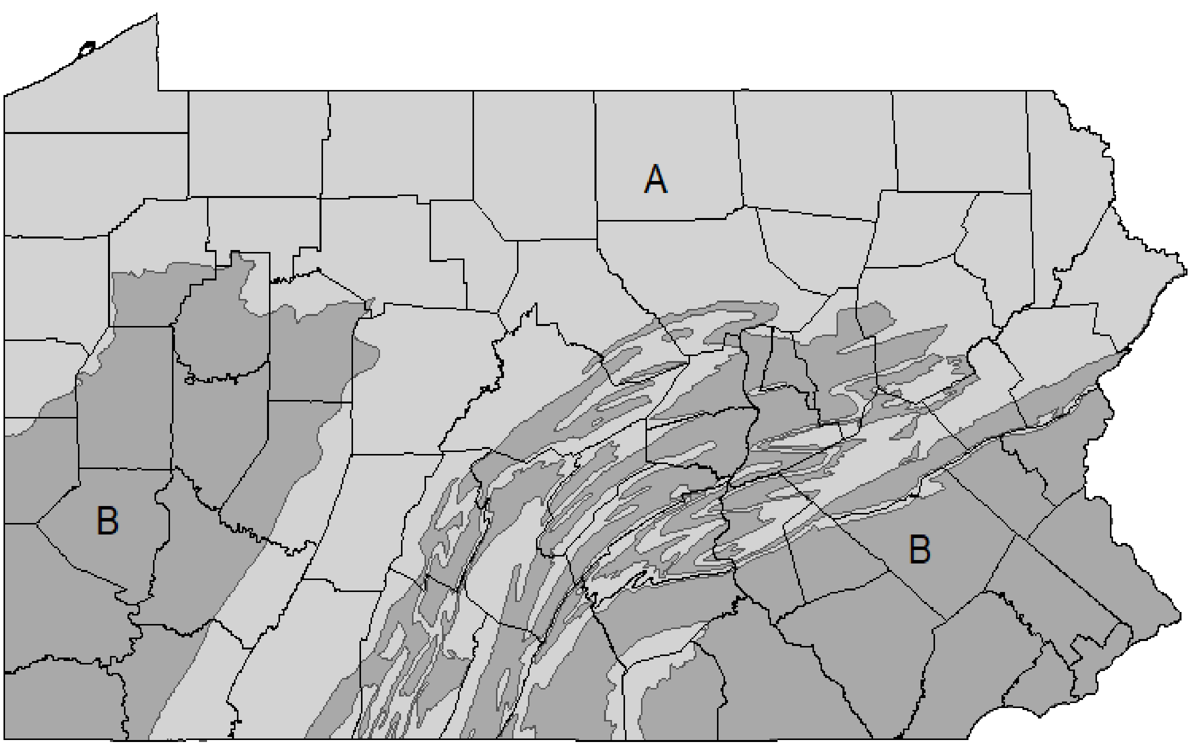


Figure 2. Pennsylvania eutrophication regions

The ECM is designed for use in streams with a benthic macroinvertebrate community that does not support it's ALU or Special Protection Use. In the ECM, eutrophication is identified as a cause of impairment in an impaired stream when the stream's p75DailyRange_WX value is above, and the p25DailyMin_WX value is below, the applicable benchmark value in the same month in the same year. ECM benchmark values (Table 2) provide a means for categorizing individual months of data into one of the four monthly ECM status categories shown below. Eutrophication is identified as a cause of impairment in an impaired stream when one or more months of data are categorized as ECM status 4. The ECM process is summarized in Figure 3.

ECM Status 1	Both proximate stressor benchmarks supported
ECM Status 2	The p25DailyMin_WX proximate stressor benchmark supported, but the p75DailyRange_WX proximate stressor benchmark not supported
ECM Status 3	The p75DailyRange_WX proximate stressor benchmark supported, but the p25DailyMin_WX proximate stressor benchmark not supported
ECM Status 4	Both proximate stressor benchmarks simultaneously not supported in the same month, eutrophication is identified as a cause of impairment in an ALU or Special Protection Use impaired water

Table 2. Summary table of proximate stressor benchmarks.

Proximate Stressor	Stream Type	April	May & October	June & September	July & August
p75 Daily Range WX	<38.6 mi^2 - A	N/A	N/A	14.78	17.54
	<38.6 mi^2 - B	29.84	26.26	27.42	34.91
	38.6-500 mi^2 - A	N/A	30.21	42.64	52.61
	38.6-500 mi^2 - B	29.84	30.21	42.64	52.61
p25 Daily Min WX	<38.6 mi^2 - A	N/A	N/A	82.88	82.31
	<38.6 mi^2 - B	87.15	83.87	80.07	80.36
	38.6-500 mi^2 - A	N/A	81.82	77.82	74.86
	38.6-500 mi^2 - B	87.15	81.82	77.82	74.86

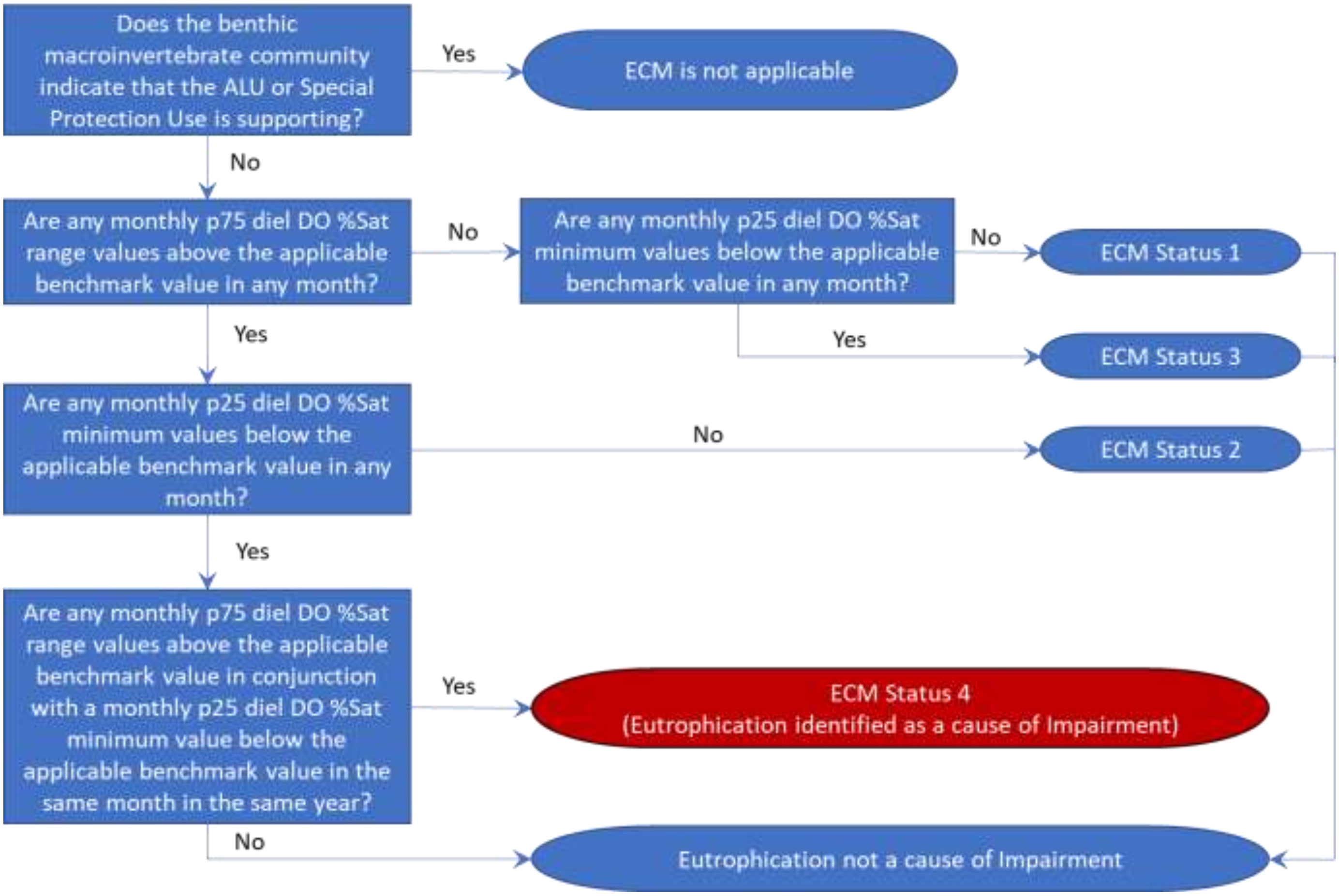


Figure 3. Schematic diagram of the Eutrophication Cause Method (ECM)

Macroinvertebrate sample ETI scores in conjunction with ECM DO %Sat benchmark values can be used as a screening tool for identifying impaired streams as candidates for implementation of the ECM. Sample ETI scores can be used to categorize impaired streams as having high, moderate, or low potential for eutrophication as a cause of impairment (Table 3). ETI calculations are appropriate when >85% of individuals in the subsample have an ETV.

Table 3. Macroinvertebrate sample ETI score ranges for categorizing impaired streams as having high, moderate, or low potential for eutrophication as a cause of impairment.

Stream Type	Low Potential	Moderate Potential	High Potential
<38.6 mi^2 - A	<6.72	6.72 – 8.04	>8.04
<38.6 mi^2 - B	<7.28	7.28 – 8.26	>8.26
38.6 - 500 mi^2	<6.82	6.82 – 7.76	>7.76

Next, after a period of at least 14 days without a substantial scour event, discrete measurements of late-afternoon and early-morning stream DO percent saturation values can be compared to the appropriate p75DailyRange_WX benchmark value to determine if the waterway shows signs of elevated primary productivity, and early-morning discrete measurements of stream DO percent saturation can be compared to the appropriate p25DailyMin_WX benchmark, to determine if the waterway is subject to elevated ecosystem respiration rates. This potential ECM screening tool is shown in the flow chart in Figure 4.

In addition, discrete measurements of late-afternoon and early-morning stream DO percent saturation values can be used to delineate the upstream and downstream extent of eutrophication impacts in impaired streams in which eutrophication is identified as a cause of impairment using the ECM.

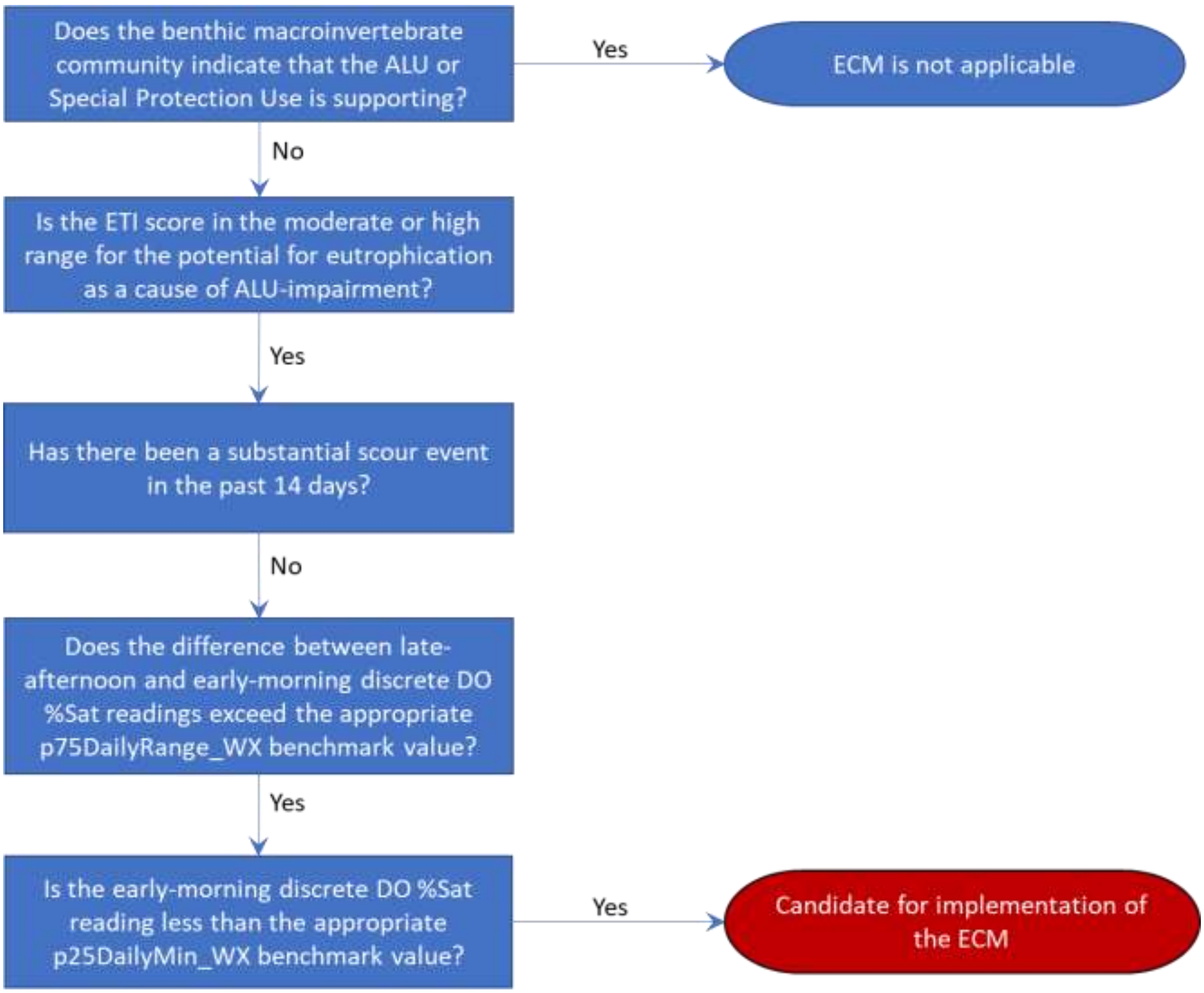


Figure 4. Schematic diagram of the screening process used to categorize an ALU impaired stream segment's potential for the implementation of the Eutrophication Cause Method (ECM).

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