MI/EGLE/WRD-25/013

Guidance to Monitor and Assess Nutrient Expression of Filamentous Algae and Macrophytes in Michigan's Wadeable Rivers and Streams

-Including a Guidance Development Summary-

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Introduction

The Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Division (WRD), receives reports each year about nutrient expression in rivers and streams. Typically, these reports are investigated by aquatic biologists in the Great Lakes Watersheds Assessment, Restoration, and Management Section (GLWARMS). R 323.1060(2) of the Part 4, Water Quality Standards (WQS), promulgated pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, provides narrative nutrient criteria to protect designated use support by limiting nutrients. Michigan's 2024 federal Clean Water Act Sections 303(d), 305(b), and 314 (Integrated Report) Assessment Methodology, specifically Section 3.6.2.2 *Bacteria, Algae, Macrophytes, and Fungi*, specifies, "A determination of not supporting will be made if excessive growths of algae (particularly, *Cladophora*, *Rhizoclonium*, and cyanobacteria) or aquatic macrophytes are present" but acknowledges that best professional judgement is the primary tool used to make these determinations. Given the potential effects of excessive filamentous algae and macrophytes on water quality and designated uses, this guidance document was developed to provide a more systematic monitoring and assessment approach, which is the Nutrient Expression Survey.

Methods

Site Selection

These methods are intended to be applicable to wadeable flowing rivers and streams in Michigan; they are not appropriate for waters that lack flow, wetland streams, or waters under the immediate influence of lake outlets. Although developed based primarily on observed conditions in the lower half of the lower peninsula of Michigan, and thus most clearly applicable to streams in similar areas, these methods and scoring summaries are intended to be helpful in monitoring and interpreting nutrient expression in wadeable streams throughout Michigan with appropriate contextual understanding.

Equipment

Below is a list of equipment needed to complete the field portion of the Nutrient Expression Survey. Digital datasheets for the Nutrient Expression Survey123 App are found in Appendix A.

- Nutrient Expression Survey123 App on iPhone.
- Clinometer.
- Range finder and/or tape measure.
- Water quality sonde or meter (e.g., YSI EXO1).
- Flagging tape (optional).
- Site Sketch datasheet (hard copy, Appendix B).

General Guidelines

Sampling will generally occur during the growing season, between May and October. Monitoring will be most informative if conducted during this timeframe, when there are typically stable discharges of low to moderate flow in Michigan's rivers and streams. Low flow reduces the likelihood that study sites become scoured by flood waters, increases consistency between sampling events, and generally allows for more light penetration to the substrate. Furthermore, these months coincide with the longest and warmest days of the year, which are generally considered optimal conditions for filamentous algae and macrophyte growth.

Reach Delineation

To capture information on a reasonable scale relative to stream width, the sample survey reach should be scaled to the average width of the stream. Approximately 20 times the average width should be sampled, with a minimum reach of 330 feet and a maximum of 1000 feet. As such, streams 16 feet and narrower will be surveyed using the minimum 330 foot reach, while streams 50 feet wide and larger will be capped at a 1000-foot survey reach. This reach will be divided into ten segments labeled A through J with cross-section cutoffs every 1/10th of the total reach (e.g., every 33 feet at the minimum and 100 feet at the maximum) for a qualitative assessment (Figure 1). A range finder is recommended to determine the length of each segment. Flagging tape may also be used if marking the segments assists in reviewing filamentous algae/macrophyte coverage. After establishing the segments, start at the furthest downstream location (Segment J) and proceed upstream to ensure the least disruption (i.e., sediment agitation). Note the left and right bank are defined when facing downstream.

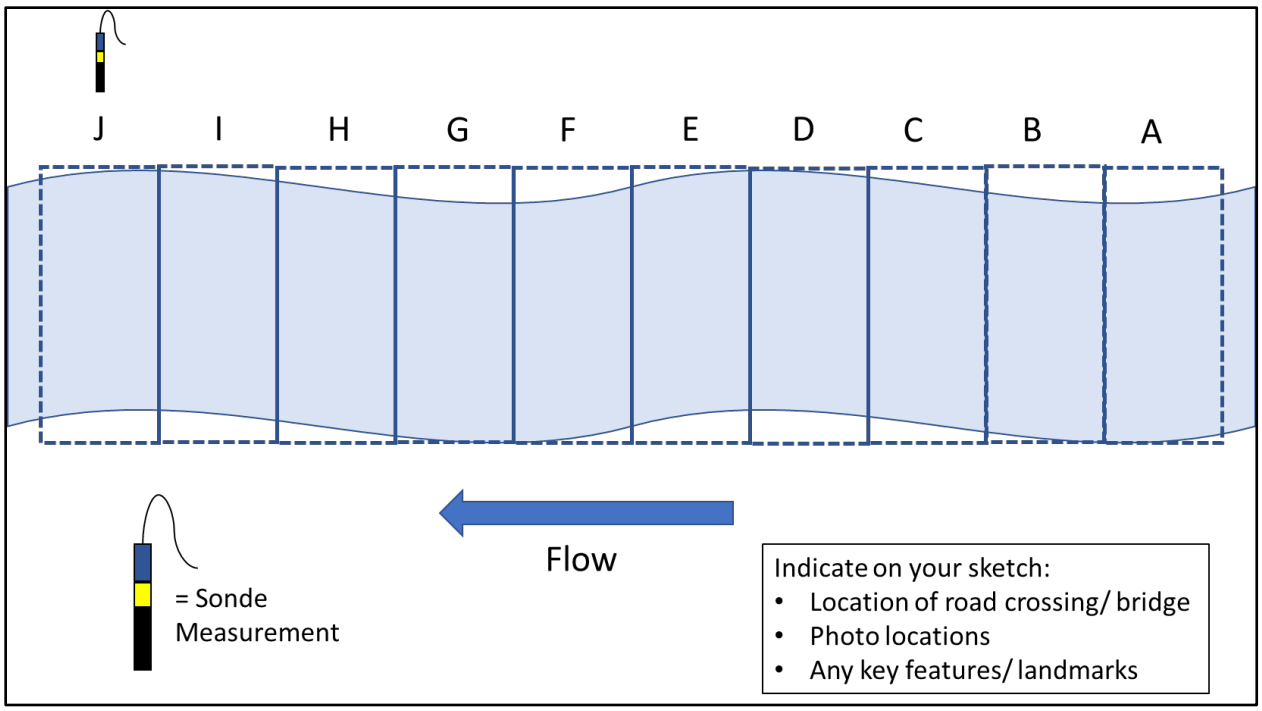

Figure 1. Sampling reach layout for the nutrient expression survey.

Field Data Collection

The following data are collected during the nutrient expression survey. Data are recorded within the Nutrient Expression Survey ESRI Survey123 App (Appendix A shows the App layout used during the pilot study discussed in Section IV of this document; note the layout may change as staff use it and request updates). Parameters to be collected include:

- Photos of the Site.
- *in situ* Sonde Measurements.
- Visual Filamentous Algae and Macrophyte Coverage (Qualitative).
- Volume of expressive growth in the water column (Qualitative).
- Dominant Habitat Type.
- Dominant Substrate Type.
- Stream Turbidity/Depth.
- Canopy Cover.
-

Additional details about each parameter can be found below.

Photos of the Site

To include (at a minimum):

- Area representative of greatest expression within the reach.
- From Segment J looking upstream.
- From Segment J looking downstream.

Photos of sampling locations provide visual context for filamentous algae and macrophyte coverage data. This documentation can be used for comparisons among sites, comparison within one site over time, if applicable, and for the benefit of biologists not present onsite. Photos should illustrate canopy cover, the size of the river/stream, and the surrounding landscape to provide supporting evidence for potential impacts to the water body. At least three photos are required at each site including: (1) "Area representative of greatest expression within the reach" to provide context for the greatest filamentous algal/macrophyte coverage at a location; (2) "From Segment J looking upstream" to capture an aerial view of the entire sampling reach and illustrate the extent of expression; and (3) "From Segment J looking downstream" to assess whether nutrient expression continues further downstream or is limited to the upstream portion. If biologists choose to take additional photos during field sampling, the Nutrient Expression Survey ESRI Survey123 App allows more than one photo in any category and has an option for "Other" photos as well.

Sonde Measurements

Parameters measured in the field using a water quality sonde or meter (e.g., YSI) will include:

- Dissolved oxygen (DO) in percent saturation **and** milligrams per liter (mg/L).
- Temperature in Fahrenheit (°F).
- Specific conductance in microsiemens per centimeter (µS/cm).
- pH.

Sonde (or meter) measurements are taken at the most downstream segment (J), prior to the qualitative assessment, to assess DO, temperature, specific conductance, and pH at each site. DO elevated beyond 100% saturation during the afternoon period is a condition known as supersaturation and is potential evidence for excessive nutrient expression leading to excess photosynthetic oxygen in the system. Conversely, morning DO sampling (ideally within 2 hours of sunrise) captures the lowest DO concentrations in the daily cycle, which may be indicative of excess respiration from excessive nutrient expression, directly impacting aquatic life if DO concentrations drop below WQS.

While not used directly in this guidance, the remaining sonde parameters may provide additional contextual information on stream conditions. Temperature informs whether WQS may be exceeded for warmwater or coldwater streams and helps provide context for observed DO measurements. Specific conductance and pH are parameters that, if found at levels outside of normal ranges or those seen elsewhere in the same water body, can indicate potential issues with pollutants at the site either in runoff or venting groundwater. Diurnal pH fluctuations are also indicative of photosynthesis and respiration activities (United States Environmental Protection Agency [USEPA], 2021).

Filamentous Algae and Macrophyte Areal Coverage

- 0 percent (%) - 100%, rounded to the nearest 10%.

This survey uses visual estimates to determine the areal coverage of filamentous algae and macrophytes, separately, at each of the ten segments. While filamentous algae and macrophytes may naturally be present in a water body, they could impact aquatic life if the extent of their growth and occurrence is excessive. Nutrient expression in the form of excess filamentous algal and macrophyte growth can impair designated uses through biological impacts or stressors, including:

- DO depletion.
- DO fluctuations that cause injurious stress to the fish community and other aquatic life.
- Breeding and spawning habitat destruction.
- Fish navigation impediment, including predator/prey interactions.
- Stream flow alteration (e.g., filling the water column with biomass).
- Substrate availability loss for habitat by the fish community and other aquatic life.
- Sensitive taxa losses (Heiskary, 2008).

Visual estimates of filamentous algal and macrophyte areal coverage will be recorded within each segment from 0-100% of the wetted channel, rounded to the nearest 10%. Algae is documented in this survey as the filamentous, stringy, non-macrophyte growth that is visible while standing in a stream. This type of survey does not typically account for diatoms or other thin, less visible layers of algae or periphyton on surfaces.

Volume of Filamentous Algae

- 0% - 100%, rounded to the nearest 10%.

In assessing the impacts of nutrient expression, the volume of the stream reach affected is an important consideration. Each segment with at least 50% areal coverage of filamentous algae (see above) should also be assessed for the percentage of the segment volume filled with filamentous algae. This volume estimate refers to the segment as a 3-dimensional space and the percent filled with algal biomass. Excessive filamentous algal volume can potentially impact the quality and availability of habitat, alter DO dynamics, and create physical disruption or barriers to the movement of aquatic organisms.

Dominant Habitat Type (select one)

- Riffle.
- Run.
- Pool.

At the outset of this project, the premier habitat for nutrient expression was believed to be riffles with stable cobble substrate; however, after assessing numerous sites during the pilot study, it was observed that nutrient expression can occur in a wide range of habitat types including silty runs in agricultural drains and shallow pools. Dominant habitat type will provide more context for nutrient expression and will be characterized at each segment.

Dominant Substrate Type (select one)

- Bedrock.
- Boulder.
- Cobble.
- Gravel.
- Sand.
- Silt.
- Clay.

Michigan's current Procedure 51 (EGLE, 2024) guidance related to identifying excessive nutrient conditions refers to *Cladophora* attached to cobble substrate in riffles; however, during the fieldwork associated with this project it was observed that filamentous algae and macrophytes are not limited to growth on cobble and can be located on various forms of substrate. Capturing the dominant type of substrate will summarize site characteristics for assessment and reporting purposes.

Stream Turbidity/Depth

- Is the bottom of the stream visible (within the segment)? Yes/ No

Two factors are likely to impede growth of filamentous algae and macrophytes by limiting light penetration when conditions are otherwise favorable: (1) turbidity; and (2) water depth. If the bottom of the stream is not visible due to either turbidity or depth, it is likely not ideal habitat for nutrient expression as growth is supported by sunlight. This coarse measure of clarity, along with canopy cover in the section below, assists in determining whether conditions are conducive for expression within a segment. Although filamentous algae and macrophyte presence is *more likely* to be observed in clear, shallow streams with limited canopy cover, there are instances when excessive amounts are present even though sites are considered *less likely* due to deeper water with protection from sunlight by a canopy. Documenting whether the bottom of the stream is visible at each segment assists in determining whether expression is likely or not likely and provides context to observed conditions.

Canopy Cover

- Peak Canopy Angle for Left Bank (0-90˚).
- Peak Canopy Angle for Right Bank (0-90˚).

Canopy cover from trees and shrubs shade water bodies from the sun and reduce the likelihood of nutrient expression. Assessing the amount of canopy cover at each segment informs whether nutrient expression is likely or not likely to occur at a site based on exposure to sunlight. Canopy cover is evaluated using a clinometer to measure the peak angle of the riparian canopy on either side of the stream. Following the procedure of Miltner (2010), an observer stands in the center of the stream channel and measures the angle to peak canopy at a standardized height of approximately one meter above the surface of the water. The two measurements (one for either streambank) are combined and subtracted from 180º to determine the open canopy angle. Miltner (2010) found that algal expression was significantly greater when the open canopy angle exceeded 40º. Therefore, if a segment has greater than 40º of open canopy between the left and right bank, and the stream bottom is visible, conditions are more likely for nutrient expression at that segment (assuming concentrations of dissolved nutrients support growth). An example calculation for this method of canopy cover estimation is illustrated in Figure 2.

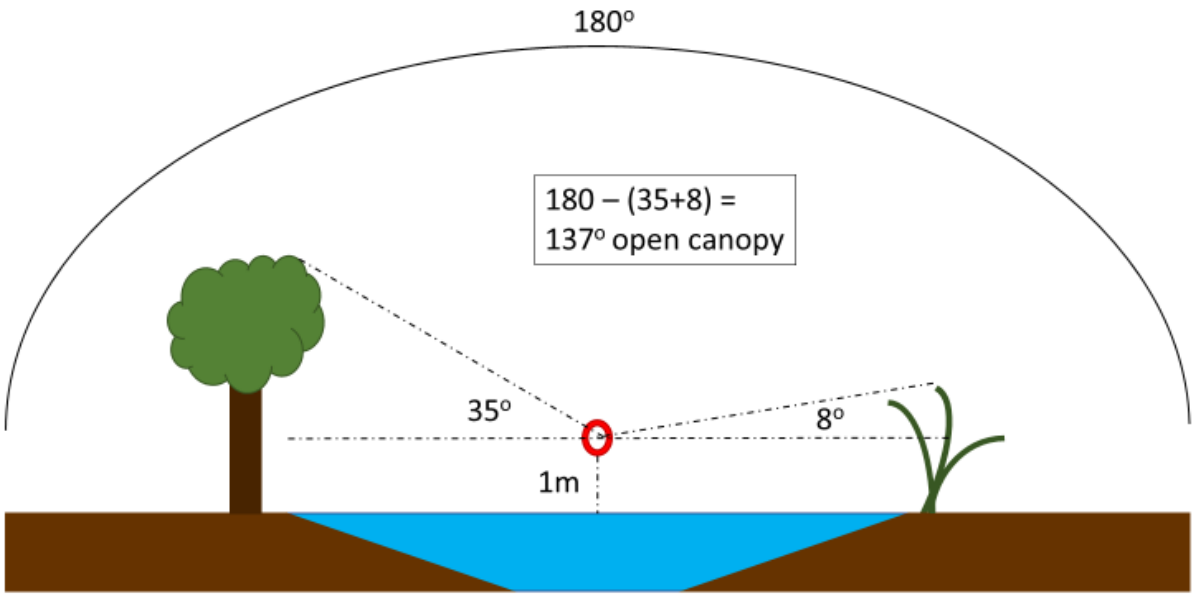

Figure 2. A depiction of canopy cover measurements collected using a clinometer at the left and right streambanks, along with the calculation to determine the degree of open canopy.

Nutrient Expression Assessment and Scoring

A scoring system was developed to summarize priority nutrient expression lines of evidence, weighted (where relevant) and combined to produce a summary score (Table 1). These scores are intended to be useful in communicating the level of nutrient expression, the potential for impact to aquatic life-related designated uses, and to inform the designated use assessment in the context of the biennial Integrated Report. Total score for filamentous algae and macrophytes denotes the level of expression observed while the score for DO refers to values found that reflect either low concentrations or diurnal swings.

Table 1. Maximum points for each parameter in the Nutrient Expression Survey.

Parameter	Score
Filamentous Algae	50
Macrophytes	25
Dissolved Oxygen	25
	100

Filamentous Algal Coverage Scoring (up to 50 points)

The extent of areal filamentous algal coverage was consistently identified throughout the data collection and analysis process as a critically important measure of nutrient expression. Potential habitat alterations, barriers to movement of fish and other aquatic organisms, and shifts in DO with extensive filamentous algal growth were noted as likely impactful to various aquatic life uses. As such, the estimation of mean filamentous algal coverage is vital for monitoring sites with possible nutrient impacts and, accordingly, is heavily weighted for scoring with a maximum potential for 50 points out of 100 total points (Table 1).

As discussed previously, open canopy greater than 40 degrees and visibility of the stream bottom are taken as indicators of conditions suitable for sunlight penetration through the water column, facilitating algal and macrophyte growth. Therefore, segments where both conditions are met are identified as “Likely” for nutrient expression. Conversely, segments where only one or neither is met are considered “Not Likely” for nutrient expression due to shading or other light transmittal impediments like turbidity. Individual segments are categorized as either “Likely” or "Not Likely” to show nutrient expression based on supporting field data gathered in the Survey123 App (Table 2).

Table 2. Summary of the point allocation based on filamentous algal coverage.

Level of Expression	Points	Filamentous algae Mean Coverage (%) *Likely*		Filamentous algae Mean Coverage (%) *Not Likely*
Excessive	50	>75	or	>50
Very Dense	40	50-75	or	25-50
Dense	25	25-49	or	10-24
Expression Present	0	<25	or	<10

At some survey reaches, not all segments (A-J) will be identified as having the same potential for nutrient expression. In those cases, mean filamentous algal coverages (percentages) should be calculated separately for the group of segments falling into either category (Likely or Not Likely), provided there are at least 3 segments available in each category. For example, if a reach has 5 segments identified as Likely to express and 5 segments identified as Not Likely to express, a mean coverage will be calculated for each (Figure 3). However, if 8 segments were identified as Likely and only 2 segments as Not Likely, a mean coverage would only be calculated for the Likely to express segments. In situations where two mean filamentous algal coverages are calculated for a reach, the higher scoring mean coverage is chosen as the most indicative of expression for the overall assessment. An example of filamentous algal mean coverages along with points allocated for each coverage range is summarized in Figure 3.

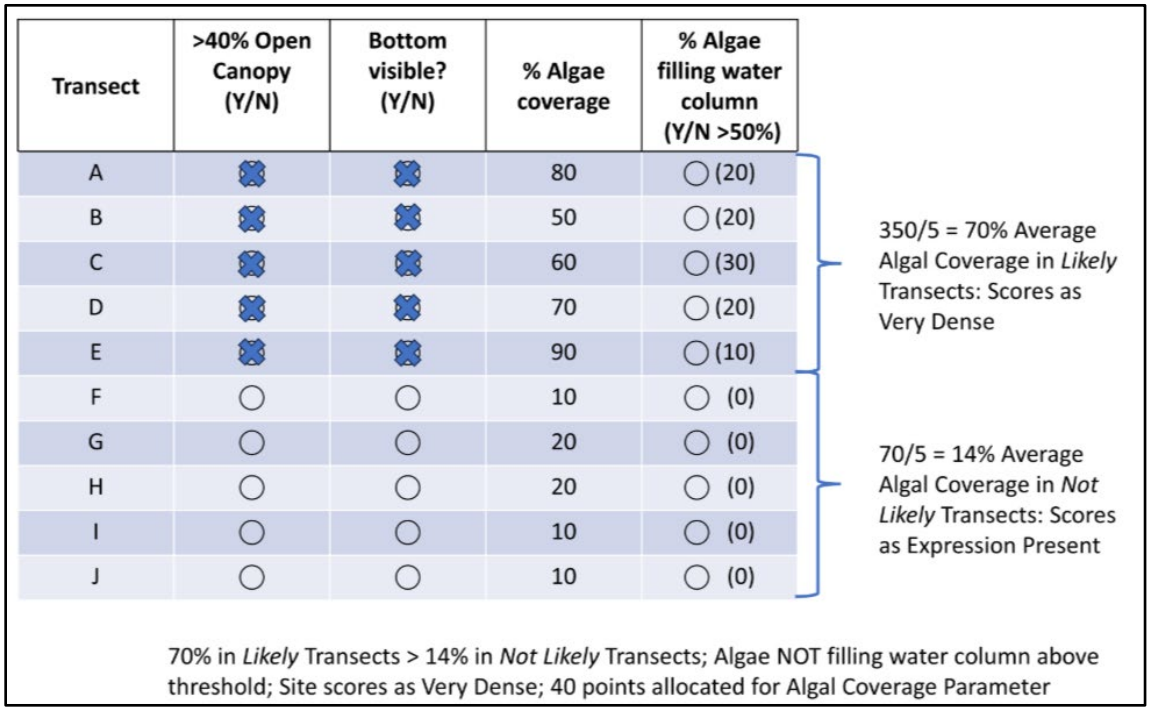

Figure 3. Filamentous algal coverage segment data for an example site with the scoring procedure for Likely and Not Likely segments. **X**s in the chart reflect "yes."

Filamentous Algal Volume Scoring Consideration

The volume of the stream reach affected by filamentous algal biomass was consistently recognized as an important consideration in understanding nutrient impacts. Volume here considers the stream segment as a 3-dimensional space wherein the estimated percentage of that space comprised of algal biomass is taken as the volume measurement. This volume measurement is only estimated in segments with 50% or more areal coverage. If a reach contains five or more segments with at least 50% of the 3-dimensional volume comprised of algal biomass (regardless of segment type: Likely

or Not Likely), the score given under Filamentous Algal Density should be increased one level to reflect this additional biomass expression. For example, if filamentous algal density at a reach is calculated as Dense (25 points), but the reach also has five or more segments with at least 50% of the segment volume comprised of filamentous algae, the reach is adjusted to the Very Dense level (40 points).

Macrophyte Coverage Scoring (up to 25 points)

The spatial extent of macrophyte coverage was consistently identified throughout the data collection and analysis process as an important measure of nutrient expression. Potential habitat alterations and shifts in DO with extensive macrophyte growth were noted as possibly impactful to various aspects of aquatic life-related uses. It should be noted that a diverse macrophyte community can be important to the ecology of rivers/streams for the habitat and colonizable structure they form for a broader array of aquatic organisms when compared to a macrophyte monoculture or filamentous algae; therefore, macrophytes are afforded a lower point scale and macrophyte coverage needs to be higher than filamentous algae coverage to be considered contributing to excessive conditions (keeping in mind that best professional judgement is the primary tool for making assessment determinations). As such, the estimation of mean macrophyte coverage based on supporting field data gathered in the Survey123 App is vital for monitoring sites with possible nutrient impacts and has a maximum potential for 25 points.

Table 3 illustrates how points for macrophyte density are awarded based on the mean percent coverage of macrophytes over segments where expression is identified as either *Likely or Not Likely*, using the process described under Filamentous Algal Coverage. Similarly, in situations where two mean macrophyte coverages are calculated for a reach, the highest mean coverage is chosen as the most indicative of expression for scoring purposes (Figure 4).

Table 3. Summary of the point allocation based on macrophyte density.

Level of Expression	**Points**	**Macrophyte Mean Coverage (%) *Likely***		**Macrophyte Mean Coverage (%) *Not Likely***
Excessive		--	or	--
Very Dense	25	>75	or	>50
Dense	15	50-75	or	25-50
Expression Present	0	<50	or	<25

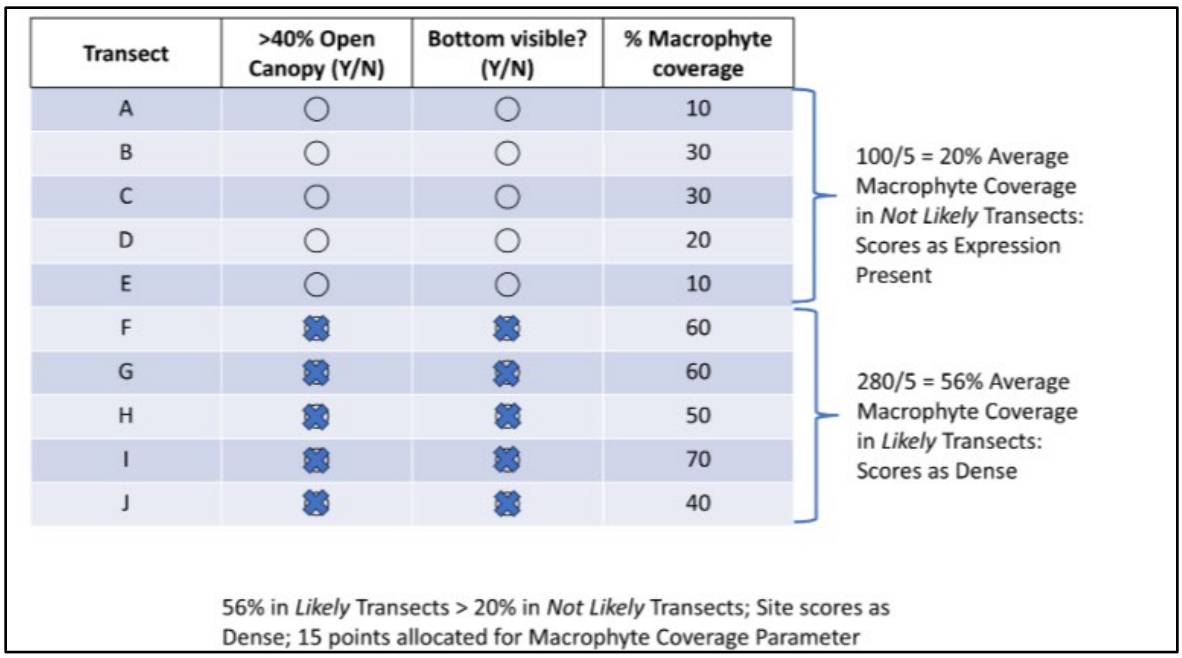

Figure 4. Macrophyte coverage segment data for a site with the scoring procedure for Likely and Not Likely segments. **X**s in the chart reflect "yes."

Dissolved Oxygen Scoring (up to 25 points with continuous data)

Afternoon Sampling (10 points)

Sampling in the afternoon, ideally between 1:00 p.m. and 5:00 p.m., is meant to capture the highest DO saturation within the daily cycle. Sites that are potentially exhibiting excessive nutrient expression will often have DO elevated beyond 100% saturation. This is known as "supersaturation." Table 4 summarizes the point allocation based on afternoon sampling. Sampling outside the ideal afternoon time window may still be useful if supersaturation is encountered, recognizing that in-stream conditions are likely worse during the critical afternoon window. These points will typically be based on individual grab samples but can also be taken from observations made during a continuous monitoring study.

Table 4. Dissolved oxygen (DO) percent saturation data ranges and scoring cutoffs from afternoon grab samples in relation to nutrient expression. Note that points may be awarded to a site regarding DO saturation any time of day, but the highest DO readings would likely occur in the afternoon.

Level of Concern	Points	% Dissolved Oxygen Saturation
Concerning	10	Greater than 200%
Potentially Concerning	5	Between 130% and 200%
Not Concerning	0	Less than 130%

Morning Sampling (5 points)

Morning sampling within two hours of sunrise captures the lowest DO concentrations in the daily cycle. The morning samples are weighted less than the afternoon samples and the DO diurnal swing values in the scoring rubric primarily because there are other potential causes of low DO (such as point source loading of oxygen-demanding wastewater, sediment oxygen demand, stormwater runoff, etc.) not related to nutrient expression. Table 5 summarizes the point allocation based on morning sampling for coldwater and warmwater streams. These points will typically be based on individual grab samples but can also be taken from observations made during a continuous monitoring study.

Table 5. DO concentration data ranges for warmwater and coldwater streams from morning grab samples with scoring cutoffs in relation to nutrient expression. Note the lowest DO readings would likely occur in the early morning hours.

Level of Concern	Points	Warmwater Stream – Measured DO	Coldwater Stream – Measured DO
Concerning	5	Less than 5.0 mg/L	Less than 7.0 mg/L
Potentially Concerning	2	5.0 - 6.0 mg/L	7.0 - 7.5 mg/L
Not Concerning	0	Greater than 6.0 mg/L	Greater than 7.5 mg/L

Dissolved Oxygen Diurnal Variation with 2-Week Study Data (10 points)

A minimum of seven precipitation-free days are needed for a continuous monitoring study to allocate points based on the daily DO diurnal variation. Stream flow should be near baseflow on these seven days. The seven days do not need to be consecutive; rain events will extend the study period. Typically, a two-week study will ensure that enough precipitation-free, base flow days are monitored for scoring purposes. The diurnal variation of DO in this case is defined as the difference between the daily minimum DO concentration around sunrise and the daily maximum DO concentration in the afternoon.

The daily DO swing varies from day to day depending on environmental factors such as cloud cover, temperature, precipitation, and changes in turbidity. This variability is the primary justification for requiring multiple days of observation to determine the diurnal variation. Average daily diurnal variation should be used to allocate points (Table 6).

Table 6. Average DO diurnal variation data ranges with scoring cutoffs in relation to nutrient expression. (Heiskary, 2008).

Level of Concern	Points	Average Dissolved Oxygen Diurnal Variation (Maximum-Minimum)
Concerning	10	Average ≥4 mg/L
Not Concerning	0	Average < 4 mg/L

Overall Parameters and Potential Scores

Tables 7 and 8 provide a list of all sampling parameters with their potential scores.

Table 7. Summary table of filamentous algae and macrophytes, density descriptions, and point allocations (in parentheses).

Level of Expression	Filamentous algae Mean Coverage (%) *Likely*		Filamentous algae Mean Coverage (%) *Not Likely*	Macrophyte Mean Coverage (%) *Likely*		Macrophyte Mean Coverage (%) *Not Likely*
Excessive	>75 (50)	or	>50 (50)	--		--
Very Dense	50-75 (40)	or	25-50 (40)	>75 (25)	or	>50 (25)
Dense	25-49 (25)	or	10-24 (25)	50-75 (15)	or	25-50 (15)
Expression Present	<25 (0)	or	<10 (0)	<50 (0)	or	<25 (0)

Table 8. Summary table of DO and point allocations (in parentheses).

Level of Expression	Warmwater Measured DO a.m. (points)	Coldwater Measured DO a.m. (points)	% Dissolved Oxygen Saturation p.m. (points)	Average DO Diurnal variation (max-min) (points)
Concerning	< 5.0 mg/l (5)	< 7.0 mg/l (5)	> 200% (10)	≥ 4.0 mg/L (10)
Potentially Concerning	5.0 - 6.0 mg/l (2)	7.0 - 7.5 mg/ (2)	130% - 200% (5)	--
Not Concerning	> 6.0 mg/l (0)	> 7.5 mg/l (0)	< 130% (0)	< 4.0 mg/L (0)

II. Score Interpretation

Above or Equal to 50

A site with an overall score of 50 or greater is likely experiencing expression exceeding WQS for nutrients (R 323.1060) with potential impacts to the Other Indigenous Aquatic Life and Wildlife and/or the Warmwater or Coldwater Fish Community Designated Use(s). Excessive expression was identified with this guidance either in the form of extensive algae or as a mixture of heavy algae and macrophyte coverage, often including potential impacts to DO availability and diurnal patterns; therefore, these conditions present the potential for injury to aquatic life, possibly including the fish community.

40 to 49

A site with a score in the range of 40 to 49 is potentially exceeding WQS for nutrient expression (R 323.1060) with possible impacts to the Other Indigenous Aquatic Life and Wildlife Designated Use and/or the Warmwater or Coldwater Fish Community. Review the expression data along with other available information as noted under Overall Considerations to determine whether there are conditions that are or may become injurious to aquatic life, including the fish community. Factors include heavy algae and macrophyte coverage and potential impacts to DO availability and diurnal patterns.

Below 40

A site with a score below 40 is less likely to be exceeding WQS for nutrient expression. Scores in this range indicate there was not excessive expression observed as currently defined by this guidance; however, it remains important to review all expression data, including the composition of the macrophyte community (diverse or monoculture) and other available information noted under Considerations. Depending on observations and totals within each metric, aquatic biologists may still find a site with a score in this range to be exceeding WQS.

Considerations

- It is important to consider all observations when making impairment decisions for Other Indigenous Aquatic Life and Wildlife and/or the Fish Community designated use(s). Observations of dense algal expression and even dense macrophyte monoculture expression include, at a minimum, a loss of useful macroinvertebrate habitat from physical displacement of otherwise available stream structures (cobble, gravel, sand, woody debris, undercut banks, and natural overhanging vegetation). Fish community impacts, if observed, may be from loss of habitat for spawning, feeding, avoiding predation, and even the ability to freely move through the water column in particularly dense areas.

- It is important to evaluate whether macrophyte points were awarded, and if so, whether those points represent a system dominated by a single species or a diverse population. Site photos will be helpful to make this distinction. A mix of vegetation may reflect conditions that are expected depending on substrate and flow conditions, while a system dominated by a monoculture may reflect a nutrient enriched and disturbed community that may cause stressful conditions to multiple aspects of the system's fishery and some macroinvertebrate taxa.

- The DO metric is important to review. A system dominated by macrophytes and or algae may produce diurnal swings of DO that may be injurious to the fish community and some macroinvertebrate taxa. DO conditions related to high diurnal swings, overnight/early morning hypoxia, and midday supersaturation all indicate likely stressful conditions. A follow-up DO study may be warranted.

- If the site was evaluated with this guidance due to past water quality concerns from nutrient expression, but the findings during this visit do not reflect historical conditions, the biologist should consider revisiting this site during a different period of the growing season. In addition, defining the spatial extent of nutrient assessments using survey data will rely on field biologists' knowledge and additional information (e.g., upstream and downstream stream crossing visual inspections, additional Nutrient Expression Surveys, aerial imagery, land use) for context.

- If excessive expression was not observed for algae or macrophytes, yet the DO values were awarded points, factors other than nutrients may be causing diurnal swings (e.g., sediment oxygen demand). Aquatic biologists should discuss these findings with WRD environmental engineers to consider next steps.

- It is important to remember the secondary considerations that may increase overall point scores, which were described above. To reiterate:

    - If a reach contains five or more segments with at least 50% of the segment volume comprised of algal biomass (regardless of segment type: Likely or Not Likely), the score given under Filamentous Algal Density should be increased one level to reflect this additional biomass expression.
    - Where continuous DO study data are available, if the average 24-hour DO fluctuation within the two-week period is greater than or equal to 4 mg/L, the site receives an additional score of 10 points. If the average DO fluctuation is less than 4 mg/L, the site does not receive additional points for the evaluation.

III. Pathway to Using the Guidance

Expression Category Determination Pathways

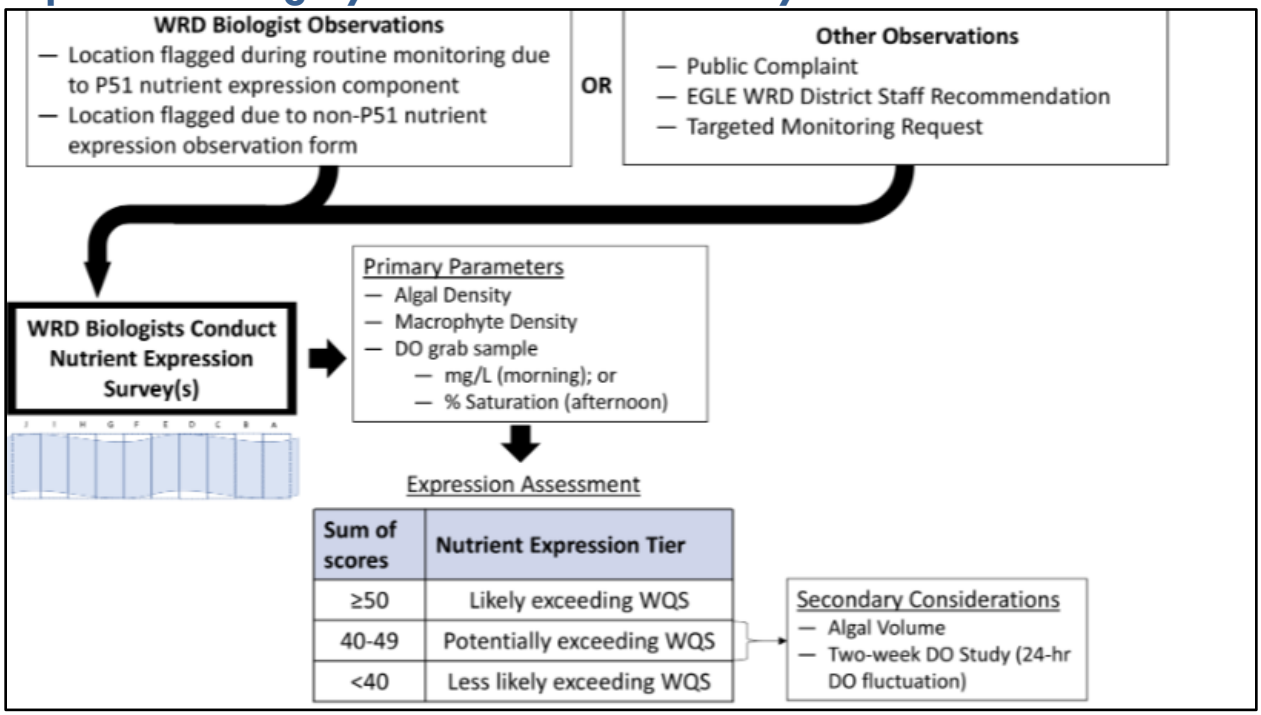

Figure 5. Guidance flow chart for nutrient expression data collection and interpretation in wadeable rivers and streams.

The process used to classify the observed expression of nutrients is detailed in the above flow chart (Figure 5). Note there are several ways that EGLE biologists may be made aware of water quality concerns regarding nutrient expression:

- The WRD receives complaints of excess algal growth in rivers and streams from members of the public via traditional communication channels (phone, email) or through the targeted monitoring request process.
- WRD district staff are often aware of locations with historic or ongoing nutrient expression issues.
- Nutrient expression may be observed and flagged by field staff using the non-Procedure 51 observation form when performing other monitoring duties.
- WRD watershed biologists fill out a nutrient expression screening form during a Procedure 51 biosurvey assessment, the results of which can be used to identify nutrient expression sites for follow-up.

Additionally, even if a Nutrient Expression Survey is not specifically identified as recommended but screening information from the Procedure 51 or non-Procedure 51 Survey123 App shows filamentous algal coverage greater than 25%, macrophyte

coverage greater than 50%, or DO percent saturation values greater than 130%, monitoring using the Nutrient Expression Survey may still be warranted. Similarly, complaints from either the public or district staff with photos and other information to support analysis and prioritization for additional monitoring is important.

Future biennial Integrated Report Assessment Methodologies will document how these Nutrient Expression Survey data and protocol outcomes will be useful in designated use support assessment. As additional field work and site data are gathered, additional modifications to the protocol may be necessary, maintaining the focus of identifying wadeable riverine sites that are visually expressing nutrients at a volume that is or may become injurious to aquatic life throughout Michigan.

IV. Guidance Development Summary

Introduction

EGLE, WRD, receives reports each year about nutrient expression in rivers and streams. Typically, these reports are investigated by aquatic biologists in the GLWARMS; however, there is no consistent method to track, monitor, and assess these conditions beyond investigation and surveillance of blue-green blooms and algal toxins. R 323.1060(2) provides narrative nutrient criteria to protect designated use support by limiting nutrients. Michigan's 2024 federal Clean Water Act Sections 303(d), 305(b), and 314 (Integrated Report) Assessment Methodology, specifically Section 3.6.2.2 *Bacteria, Algae, Macrophytes, and Fungi*, specifies: "A determination of not supporting will be made if excessive growths of algae (particularly, *Cladophora*, *Rhizoclonium*, and cyanobacteria) or aquatic macrophytes are present" but acknowledges that best professional judgement is the primary tool used to make these determinations. Given the potential effects of excessive filamentous algae and macrophytes on water quality and designated uses, a more systematic monitoring and assessment approach is desired.

To meet this need, the GLWARMS assembled a workgroup of aquatic biologists tasked with developing guidance for assessing and documenting the extent, duration, and frequency of nutrient-related conditions in rivers and streams. Aquatic biologists and engineers from the WRD, Permits Section, were invited to participate to provide additional expertise. The workgroup established the overarching goal of developing a consistent approach for the identification of excessive filamentous algae/macrophyte conditions in Michigan rivers and streams in support of advancing the implementation of Michigan's narrative nutrient criteria (R 323.1060(2)). To meet this goal, the workgroup identified the following deliverables:

1) Protocol for delineating nutrient expression conditions in rivers and streams, including visual documentation, monitored parameters, and sampling methods.

2) Guidance for use by WRD aquatic biologists when determining whether nutrient expression constitutes filamentous algae/macrophyte conditions that may exceed WQS (i.e., constitute an impairment to designated uses) in rivers and streams.

3) Protocols for responding to and documenting complaints of nutrient expression (may include development of standard forms/reporting format; guidance on when and how to follow up on nutrient expression reports; and approaches for data analysis and reporting).

Monitoring locations chosen for the pilot study (2020-2022) were selected to be wadeable, while encompassing a wide range of stream orders where EGLE biologists recommended a revisit due to nutrient expression issues during Procedure 51 macroinvertebrate sampling or expression was otherwise known to occur (EGLE, 2024). Sampling locations comprised both warmwater and coldwater streams and included

natural channels and maintained agricultural drains (Figure 6). Site selection also considered drive time to maximize efficiency; however, this guidance is intended to be applicable to wadeable stream and river locations throughout Michigan.

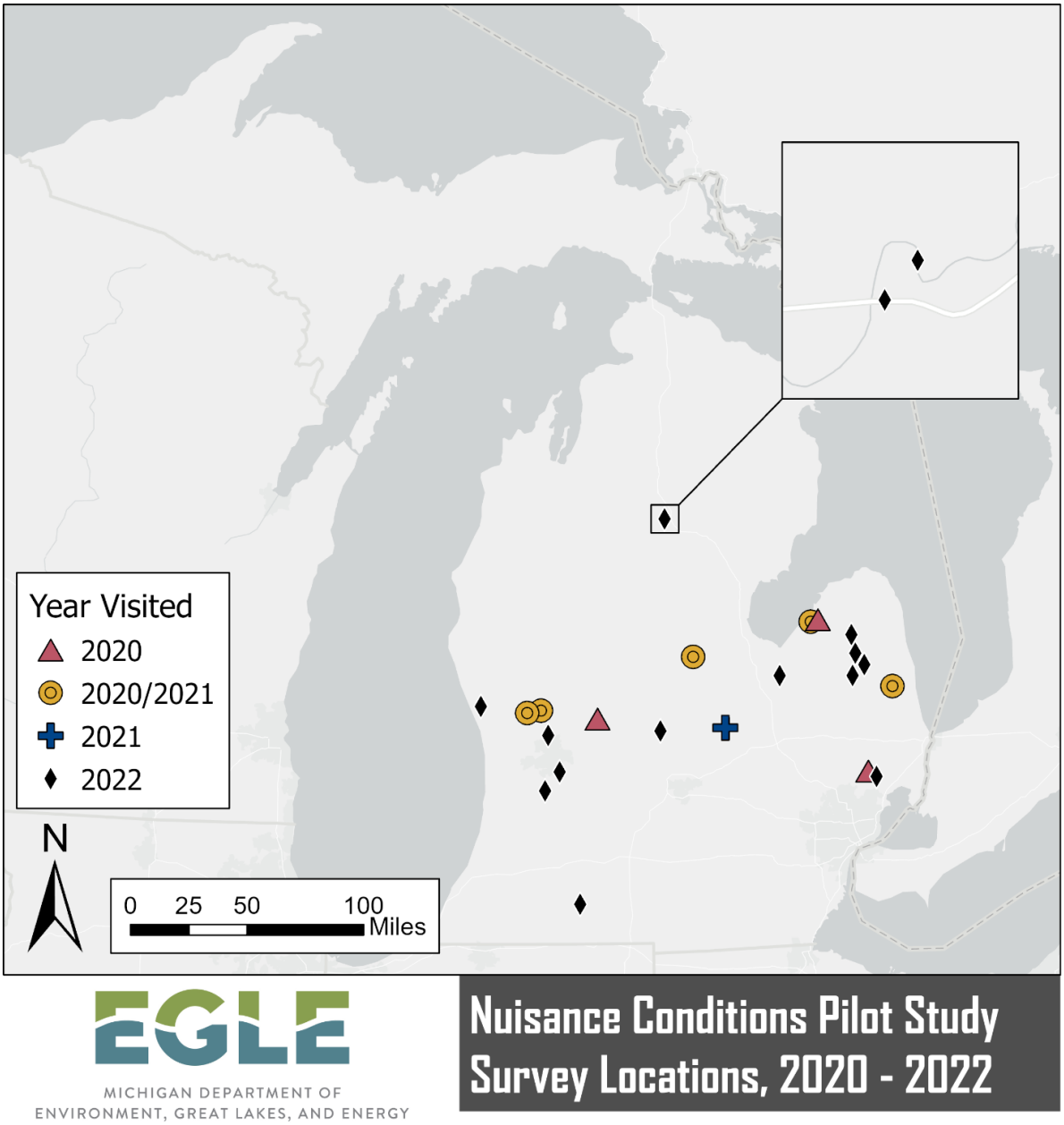

Figure 6. Survey locations visited during each year of the EGLE pilot study investigating nutrient expression in rivers and streams in Michigan.

2020 Monitoring Summary

The WRD initiated, prepared, and implemented a work plan, Quality Assurance Project Plan, and a pilot project to develop guidance for documenting and assessing the extent,

duration, and frequency of nutrient-related conditions at eight rivers or streams in Michigan identified as having potentially excessive nutrient expression. WRD aquatic biologists surveyed eight sites every two weeks (totaling between 5-8 visits per location) collecting qualitative and quantitative nutrient expression survey data as well as water nutrient samples (Total Phosphorus [TP], Orthophosphate, Total Kjeldahl Nitrogen, Nitrite/Nitrate, and Turbidity), photographs, and in situ sonde measurements (i.e., pH, temperature, DO, and specific conductance).

2021 Monitoring Summary

To collect more field data, observations, and practical experience for the project, WRD biologists used the same methods on a subset of the 2020 sites (the five most expressive sites from the original eight), and one new site. New in 2021, EGLE contractors conducted two-week continuous DO (mg/L) and temperature (°F) studies at these six locations, overlapping with EGLE's single field visit to each site.

2022 Monitoring Summary

After reviewing the DO results from 2021, there was interest in a larger sample size of two-week studies to evaluate: (1) how often sites with observed, anecdotal nutrient expression also have DO WQS violations; and (2) DO diurnal swings at sites with known nutrient expression. Added sites with measurements of physical characteristics, nutrient expression, and two-week DO studies were anticipated to be helpful in identifying stream conditions with the potential to become injurious to aquatic life. The additional data, furthermore, were hoped to be helpful in developing guidance useful for designated use assessment, even without a DO study.

For the 2022 effort, EGLE employed contractors to conduct continuous DO (mg/L) and temperature (°F) monitoring at 16 new locations previously identified by watershed biologists as having nutrient expression characterized by long algal filaments, extensive macrophyte/algal coverage, and/or were recommended for further investigation. It is important to note that at either logger installation or removal contractors collected only the qualitative measurements of filamentous algae/macrophyte coverage, substrate types, water depths, and photographs. In addition, in-situ sonde measurements of temperature (°F), DO (mg/L and percent saturation), conductivity (µS/cm), specific conductance (µS/cm), pH, and turbidity (Nephelometric Turbidity Unit) along with a suite of water chemistry parameters, including TP, Orthophosphate, Total Kjeldahl Nitrogen, Nitrite/Nitrate, and Turbidity were collected by grab sample.

In 2022 EGLE aquatic biologists conducted Nutrient Expression Surveys at 14 locations in the Lower Peninsula. Twelve of the 14 locations were visited twice by members of the workgroup. Both visits to a site (visit and revisit) included: completion of the Nutrient Expression Survey, photographs, and a site sketch [hardcopy] field sheet. The

workgroup examined data from the previous two years of monitoring during technical meetings to pare down the variables collected in 2022 and kept those considered most informative for identifying excessive conditions (see Section II). As a result, 2022 monitoring focused on a subset of variables determined to be the most meaningful indicators of nutrient expression.

2023 Summary

In 2023 to finalize the Nutrient Expression Survey guidance, data collection methods were further streamlined and refined to include the most critical variables, as described in Section II. Methods were finalized for the Nutrient Expression Survey as described in Section IV. Scoring metrics and threshold values were then developed for these variables to build the Nutrient Expression Survey (see Section V). EGLE biologists developed a data collection application (App) using ArcGIS Survey123 Connect to streamline data collection and store data in ESRI's ArcGIS Online platform.

Nutrient Expression Data Review

Qualitative estimates of nutrient expression (i.e., algal and/or macrophyte growth) are a key component of this guidance. Methods used to capture the extent of expressive growth have focused on the areal coverage and volume of photosynthetic biomass, as well as the suitability of the habitat where growth is occurring (e.g., relative canopy cover, substrate, water clarity). Empirical studies have shown that extended periods of low DO or drastic diurnal swings in DO concentration negatively impact aquatic ecosystems (e.g., Miltner, 2010; Heiskary and Bouchard, 2015; Maasri et al., 2019; USEPA, 1986). Similarly, resource managers may expect that excess nutrient expression affects aquatic life by smothering suitable habitat, inhibiting movement, or monopolizing the oxygen budget of a stream. However, few studies have identified thresholds at which elevated algal or macrophyte densities may begin to impact aquatic life in rivers and streams. As such, EGLE biologists evaluated qualitative data from the pilot dataset as well as available literature to provide thresholds to incorporate into a weight-of-evidence approach for nutrient expression assessment. Data were sourced from a group of Michigan streams known to experience elevated nutrient input from surrounding land use.

In 2020 qualitative expression scores, quantitative viewing bucket measurements, habitat assessments, and nutrient water chemistry parameters (phosphorus and nitrogen) were collected in eight streams every 2-3 weeks (n=5-8 visits) throughout the summer field season. These data were then summarized for each site (e.g., Figure 7) and the nine EGLE biologists within the workgroup were asked to provide their professional evaluations whether each site presented conditions indicative of nutrient expression potentially impactful to designated uses, particularly Michigan’s aquatic life-related uses of other indigenous aquatic life and wildlife and warmwater/coldwater fishery.

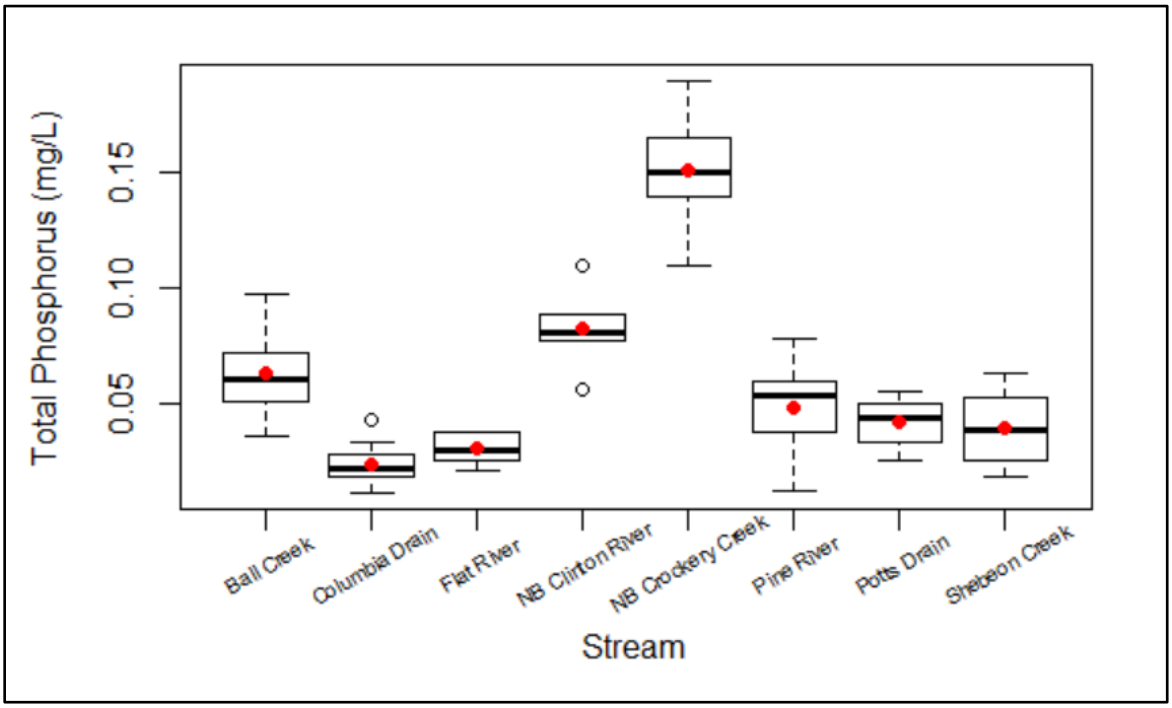

Figure 7. Range of TP measurements collected at each sampling location during the 2020 field season. Similar figures were generated for other water chemistry parameters and qualitative expression scores, then compared alongside stream photographs to identify potential excessive expression conditions.

A consensus decision among biologists with experience monitoring and interpreting biological communities and habitat quality in Michigan streams found that conditions at five of the eight sites evaluated in 2020 showed levels of nutrient expression that appeared to be injurious, or potentially so, to aquatic life-related designated uses (primarily Other Indigenous Aquatic Life and Wildlife and/or Coldwater/Warmwater Fishery) following Michigan's narrative nutrient criteria. Of these five sites, areal coverage of filamentous algae or macrophytes, filamentous algal volume throughout the water column, and DO abnormalities were important factors that led to the classification. Three of the eight sites were not considered to represent excessive nutrient-related conditions based on a lack of substantial macrophyte/algal expression and other DO data measurements indicating WQS were being met.

Quantitative viewing bucket counts and nutrient water chemistry results from limited grab samples were not found particularly helpful for this effort. Qualitative estimates of expression were found to be more useful than the time-intensive viewing bucket collections. Water chemistry results showed no predictability in their usefulness for this work, possibly due to the likelihood that dissolved nutrients are subject to uptake by macrophytes and filamentous algae, so concentrations may decrease when photosynthetic biomass increases. However, this relationship is tenuous, and situations could occur where nutrient inputs could exceed the uptake capabilities of macrophytes

and filamentous algae even when covering a majority of the stream. Water chemistry data continued to be collected in sampling years beyond 2020 to provide context for survey results and to support other EGLE programs.

The 2020 sampling revealed filamentous algae would grow and senesce at different times and rates across sampling locations and throughout the sampling season. For this reason, we determined one survey showing excessive nutrient expression may be enough information to identify a potential designated use impairment listing; however, a site *not* showing excess expression during one visit may benefit from additional surveys during the growing season to better inform expressive conditions over time.

The refined list of prioritized parameters was implemented for the 2021 and 2022 field seasons; 20 sites were visited among both years (6 in 2021, 14 in 2022). Moreover, a subset of the sites visited in 2022 (n=12) were visited twice, once in early summer and once in late summer. From these data, "site profiles" were generated (Figure 8) for further data exploration and to inform guidance development.

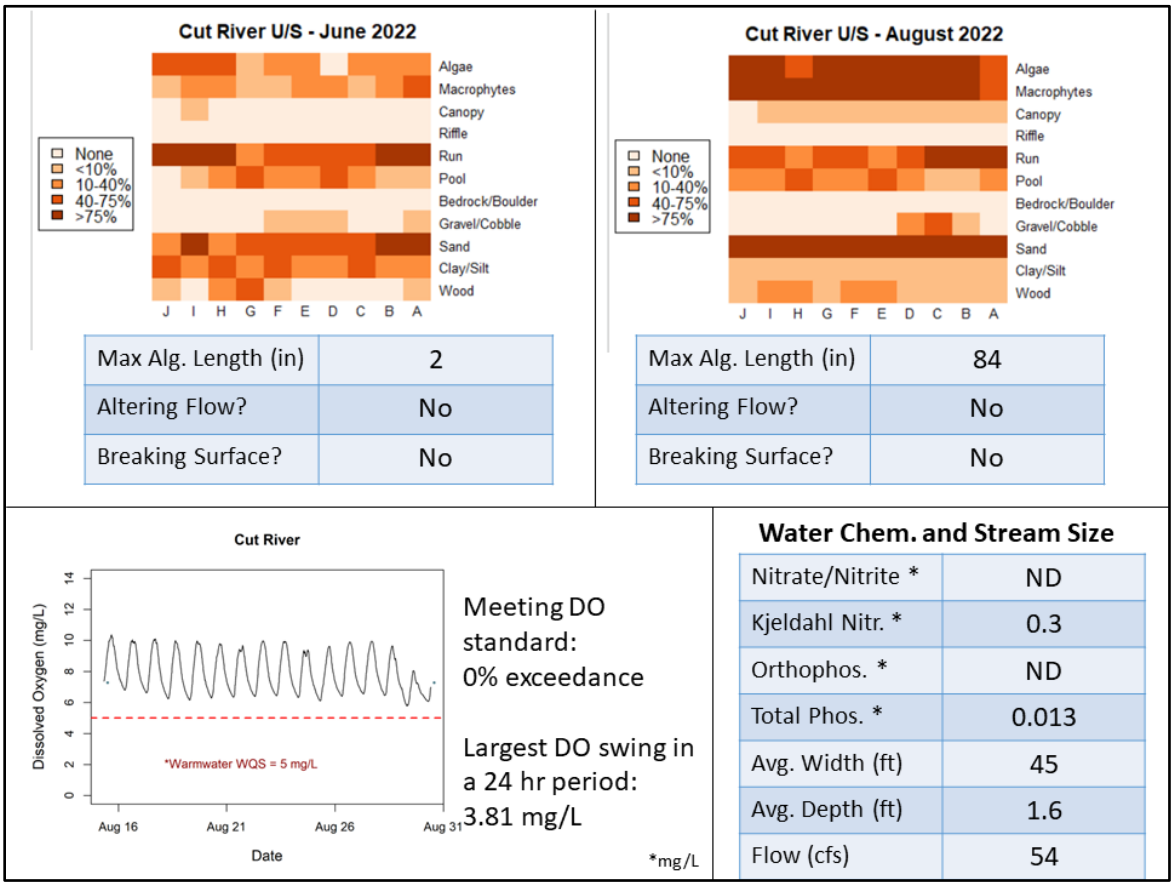

Figure 8. An example of the site profiles generated for each of the sampling locations visited in 2021 and 2022. Site profiles were used for guidance development.

These site profiles were provided to the workgroup of nine EGLE biologists for use in determining preliminary threshold values that constitute excessive nutrient expression. Biologists were given a blind poll and asked to identify values of the following metrics that rose to the level of excessive based on their expertise, experience, observations, and data interpretation:

- Filamentous algal density (percent areal coverage).
- Diurnal DO swings (mg/L).
- DO grab sample (time of day dependent) or continuous DO study.
- Percent of reach with filamentous algae breaking the surface or altering streamflow.
- Percent of reach with submerged macrophytes breaking the surface or altering streamflow.
- Macrophyte density (percent areal coverage).
- Maximum Algal strand length (inches).

Biologists were then asked to rank each of these metrics by importance when assessing excessive conditions. The list above reflects the order of the consensus rankings from most (top) to least (bottom) important. This ranking exercise informed the decision for the final list within the guidance. In accordance with this ranking, the following parameters were chosen:

- Filamentous algal density (percent areal coverage).
- DO fluctuation (24-hour swing).
- DO grab sample.
- Macrophyte density (percent areal coverage).
- Filamentous algal water column volume (modification of expression breaking surface/ altering flow).

Algal strand length was dropped as it was highly variable and not correlated with the density or extent of expression in the survey reach. The quantitative measurements for filamentous algae and submerged macrophytes breaking the surface were modified into a qualitative volume component, which informs the results but does not directly contribute to scoring. Suggested threshold values for each criterion (proposed individually by each biologist on the workgroup) were examined and discussed in a series of technical meetings where biologists were asked to provide justification for their selections and the group was tasked with developing final thresholds. These thresholds and their associated scores are detailed below in Section V.

Objectives

The overall objective of the Rivers and Streams Nutrient Expression Work Group was to develop a consistent approach to track, monitor, and ultimately assess nutrient expression in rivers and streams. Nutrient expression, particularly in an

overabundance, may affect the ability for various designated uses to be supported. While currently understood to be most impactful to the Other Indigenous Aquatic Life and Wildlife and Warmwater/Coldwater Fishery uses, information gathered related to nutrient expression may be informative for other designated use assessment. Future biennial Integrated Report Assessment Methodologies will document how these data and protocol outcomes will be useful in designated use support assessment. The resulting protocol will give aquatic biologists a tool to consistently identify and delineate nutrient expression in Michigan rivers and streams in support of advancing the implementation of Michigan's narrative nutrient criteria in the following ways:

- Assist WRD aquatic biologists in assessing whether designated uses are being or have the potential to be impacted in rivers and streams by excessive macrophyte/filamentous algae conditions.
- Assist Michigan's Nonpoint Source Program with identifying reaches wherein targeting upstream nonpoint source contributors and implementing best management practices may benefit a watershed.
- Assist EGLE's Permits Section with identifying and documenting in-stream concerns and supporting potential limits on National Pollutant Discharge Elimination System sources of nutrient contributions.

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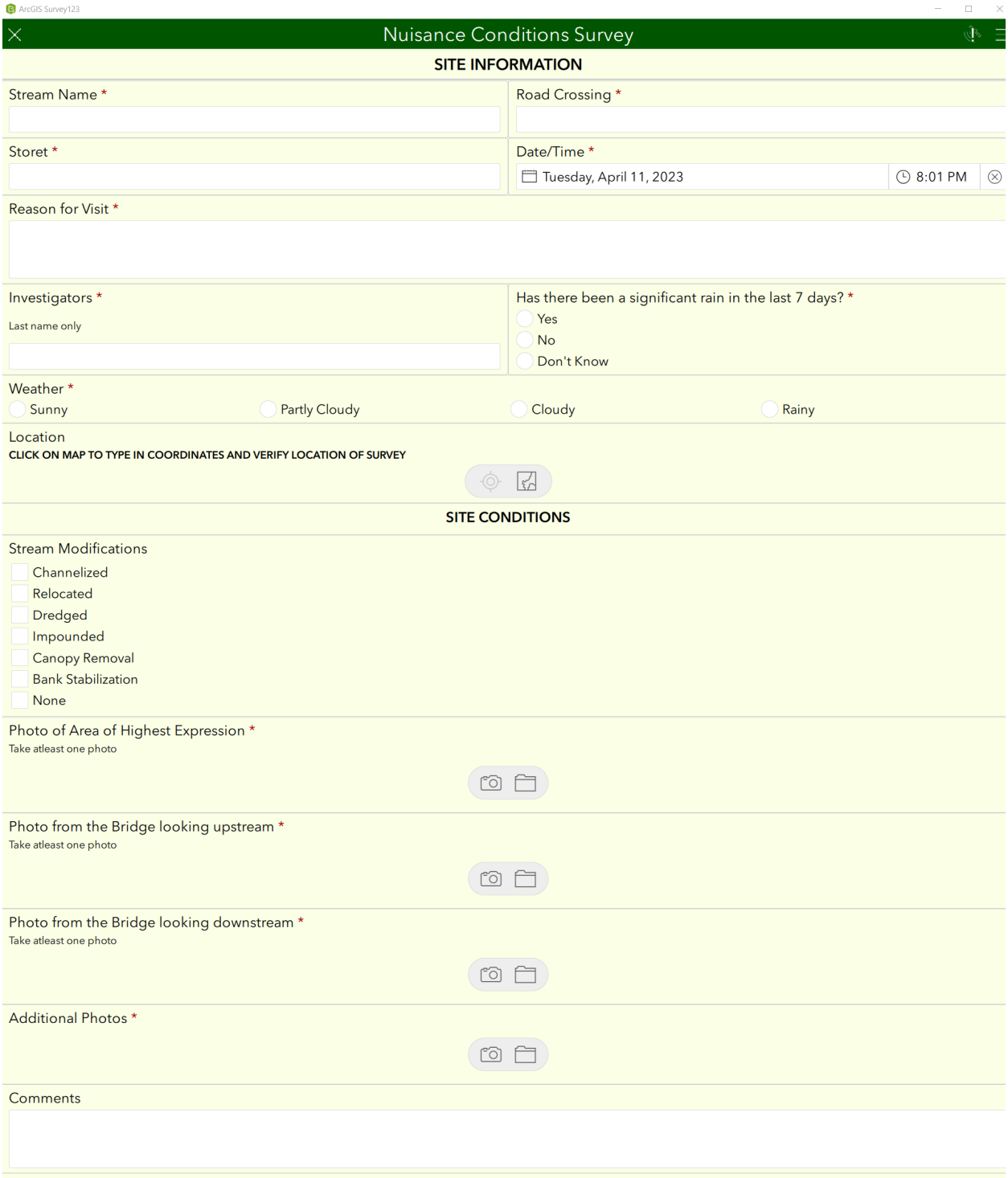
V. Appendices for Section IV – Guidance Development Summary

APPENDIX A: Nutrient Expression Survey



ArcGIS Survey123

Nuisance Conditions Survey

SITE INFORMATION

Stream Name *

Road Crossing *

Storet *

Date/Time *

Tuesday, April 11, 2023 8:01 PM

Reason for Visit *

Investigators *

Last name only

Has there been a significant rain in the last 7 days? *

- Yes
- No
- Don't Know

Weather *

- Sunny
- Partly Cloudy
- Cloudy
- Rainy

Location

CLICK ON MAP TO TYPE IN COORDINATES AND VERIFY LOCATION OF SURVEY

SITE CONDITIONS

Stream Modifications

- Channelized
- Relocated
- Dredged
- Impounded
- Canopy Removal
- Bank Stabilization
- None

Photo of Area of Highest Expression *

Take atleast one photo

Photo from the Bridge looking upstream *

Take atleast one photo

Photo from the Bridge looking downstream *

Take atleast one photo

Additional Photos *

Comments

ArcGIS Survey123

Nuisance Conditions Survey

SEGMENT J

Temp. (F)

DO % Saturation

DO mg/L

pH

Specific Conductivity (µS/cm)

Percent Coverage of Algae *

Percent Coverage of Macrophytes *

What percent of transect is filled from substrate to surface with expression?

Dominant Habitat Type *

- Riffle
- Run
- Pool

Dominant Substrate Type *

- Bedrock
- Boulder
- Cobble
- Gravel
- Sand
- Silt
- Clay

Is the bottom of the stream visible *

- Yes
- No

Peak Canopy Angle for Left Bank *

Range of 0-90 degrees per streambank

Peak Canopy Angle for Right Bank *

Range of 0-90 degrees per streambank

ArcGIS Survey123

Nuisance Conditions Survey

SEGMENT I

Percent Coverage of Algae *

Percent Coverage of Macrophytes *

What percent of transect is filled from substrate to surface with expression?

Dominant Habitat Type *

- Riffle
- Run
- Pool

Dominant Substrate Type *

- Bedrock
- Boulder
- Cobble
- Gravel
- Sand
- Silt
- Clay

Is the bottom of the stream visible *

- Yes
- No

Peak Canopy Angle for Left Bank *

Range of 0-90 degrees per streambank

Peak Canopy Angle for Right Bank *

Range of 0-90 degrees per streambank

ArcGIS Survey123

Nuisance Conditions Survey

SEGMENT H

Percent Coverage of Algae *

Percent Coverage of Macrophytes *

What percent of transect is filled from substrate to surface with expression?

Dominant Habitat Type *

- Riffle
- Run
- Pool

Dominant Substrate Type *

- Bedrock
- Boulder
- Cobble
- Gravel
- Sand
- Silt
- Clay

Is the bottom of the stream visible *

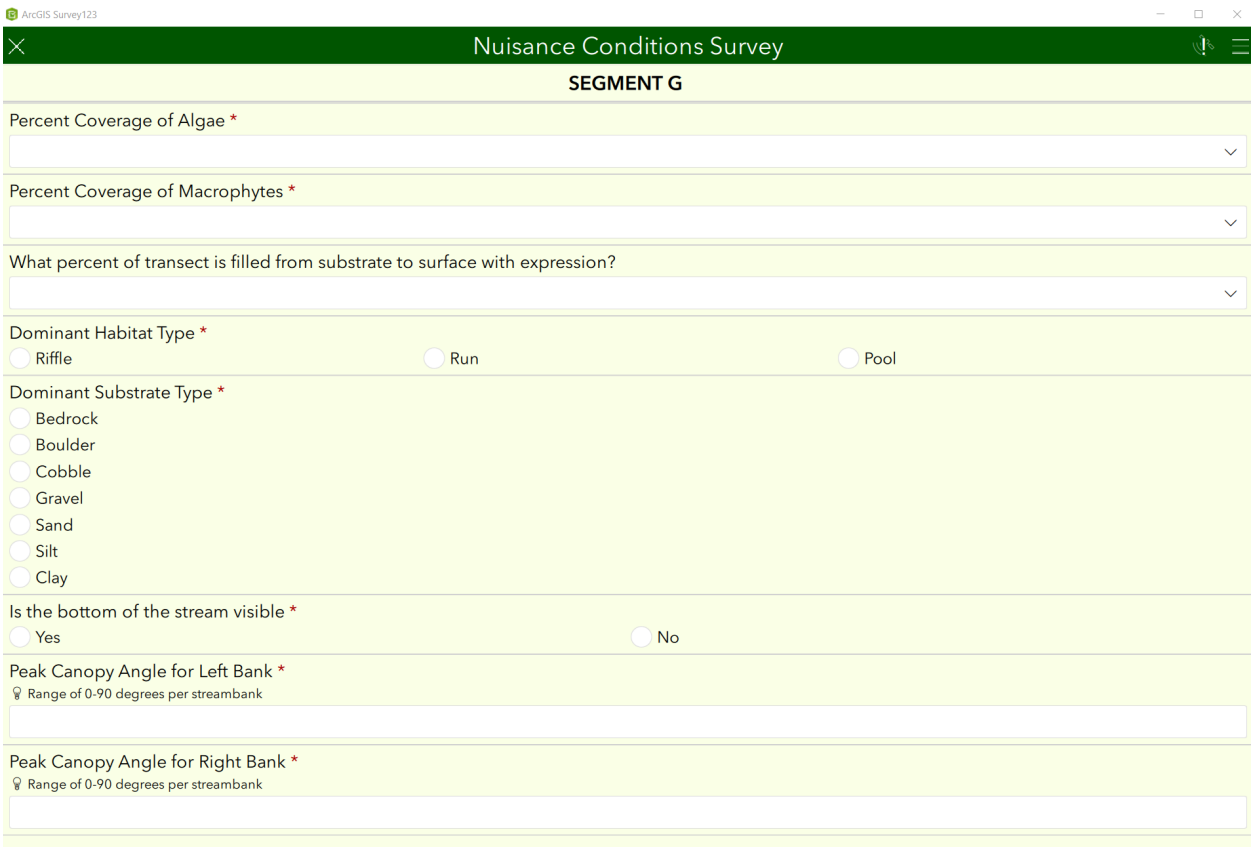
- Yes
- No

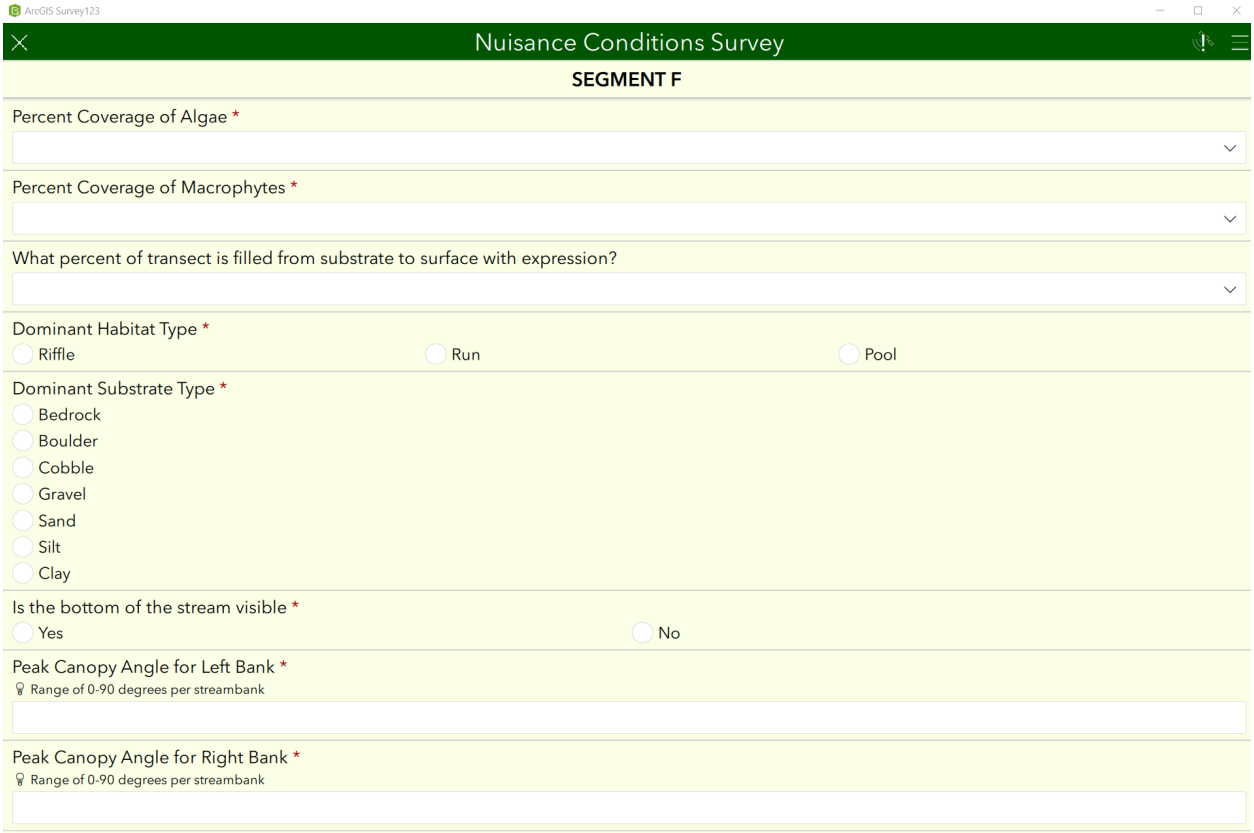
Peak Canopy Angle for Left Bank *

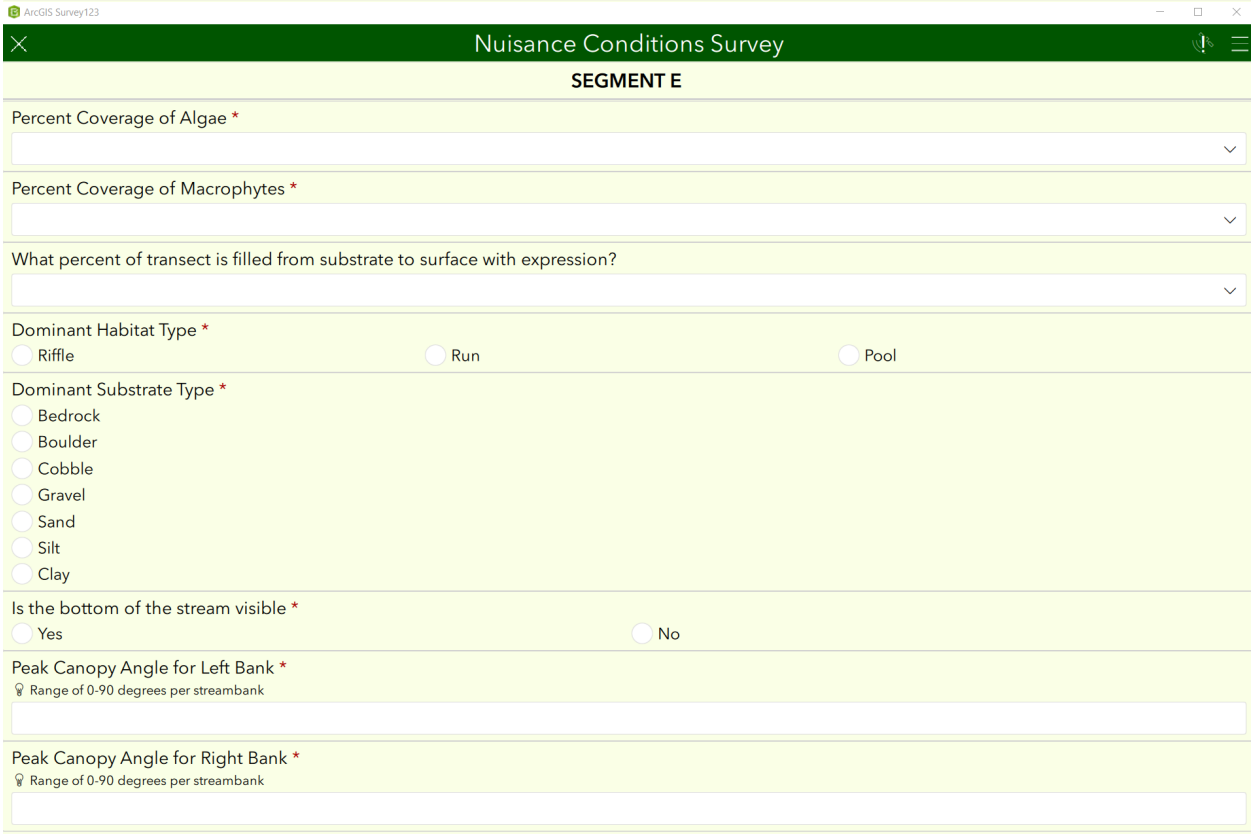
Range of 0-90 degrees per streambank

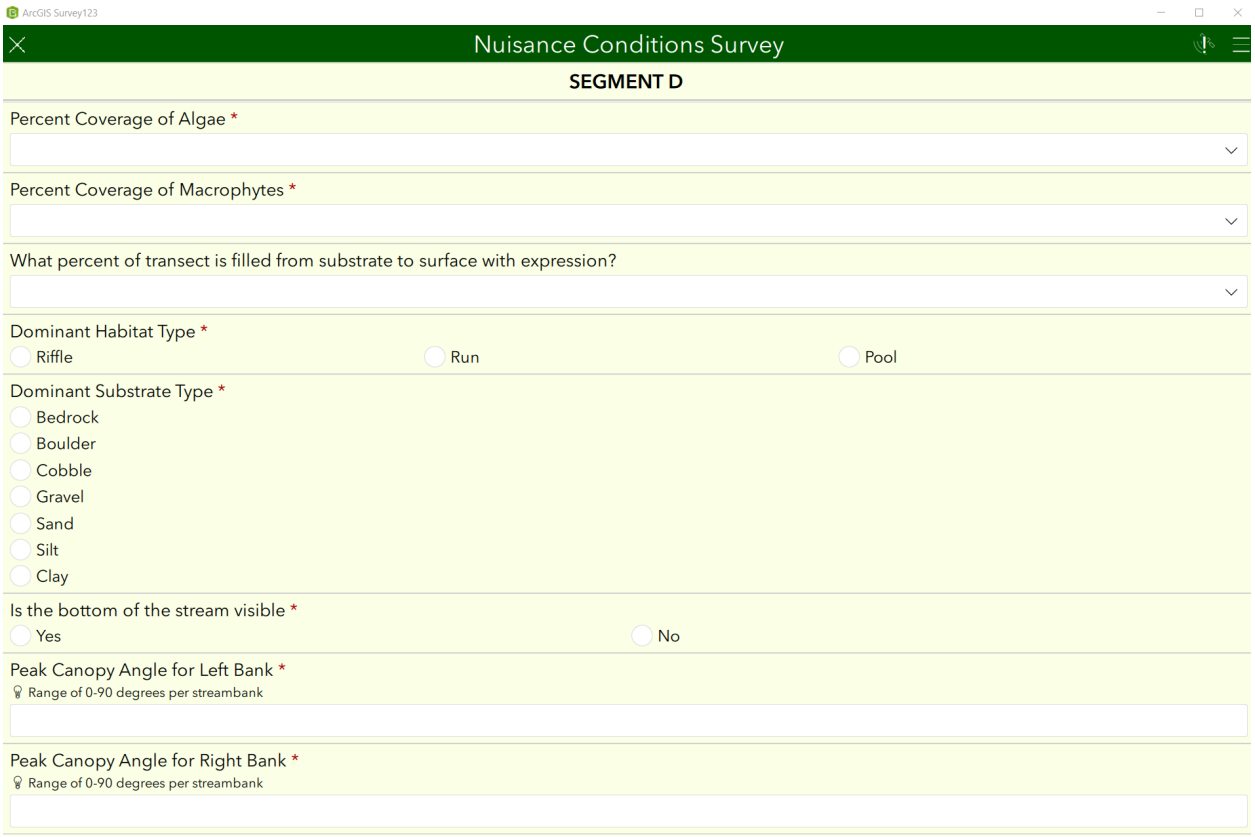
Peak Canopy Angle for Right Bank *

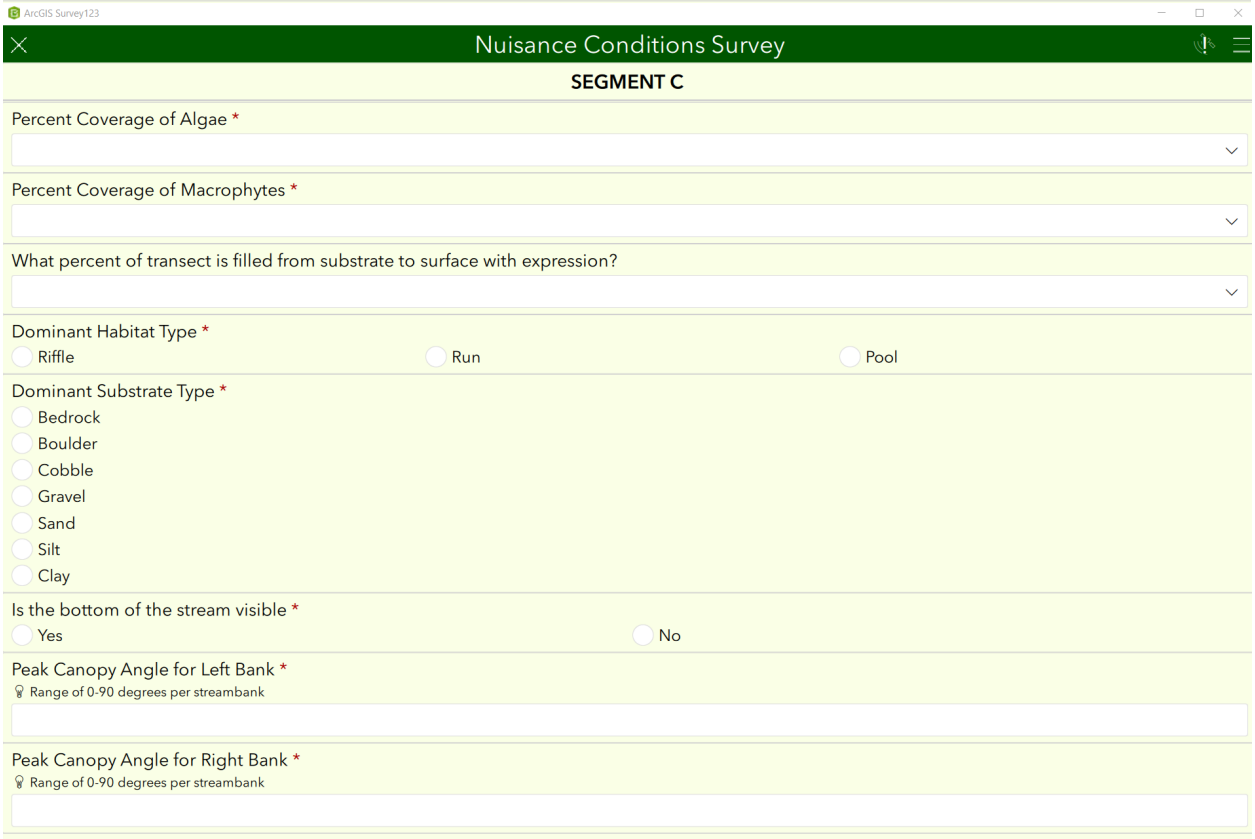
Range of 0-90 degrees per streambank

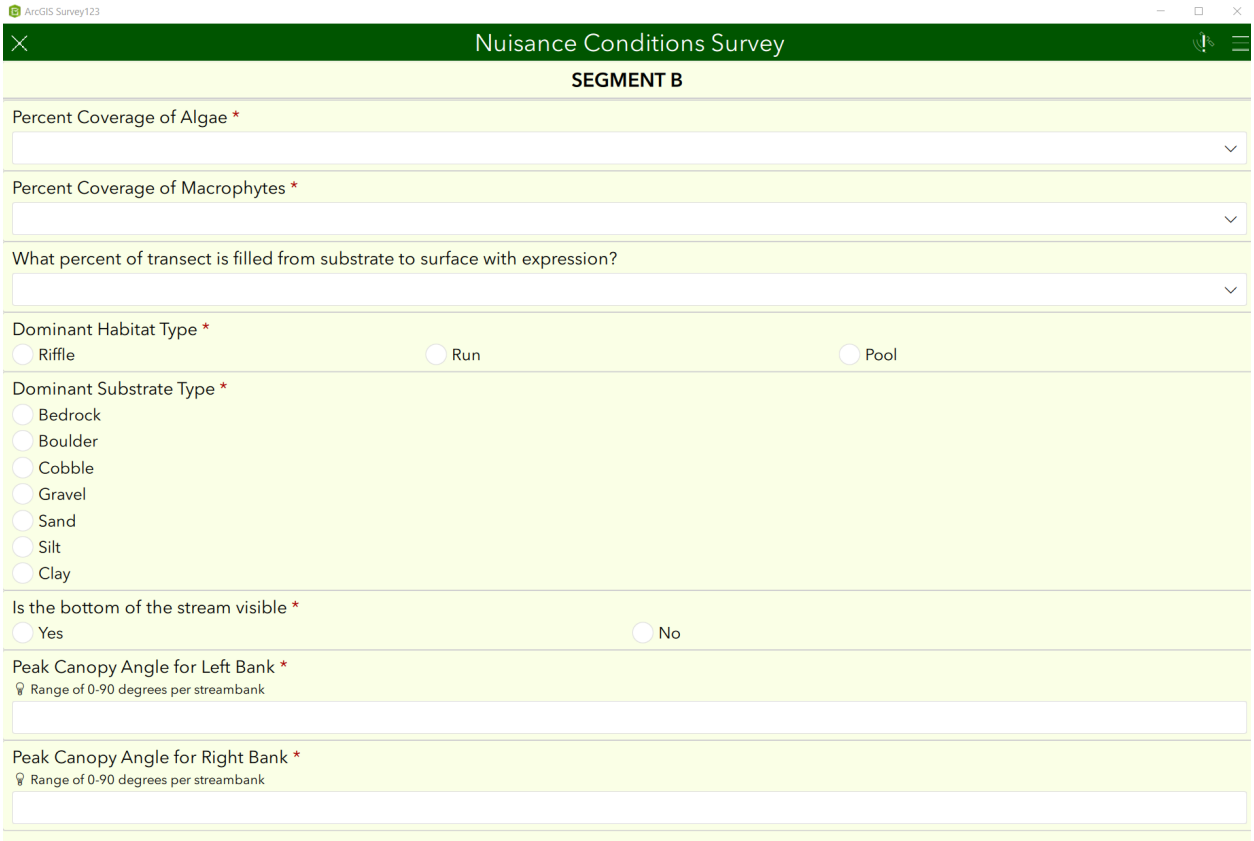

ArcGIS Survey123
Nuisance Conditions Survey
SEGMENT G
Percent Coverage of Algae *
Percent Coverage of Macrophytes *
What percent of transect is filled from substrate to surface with expression?
Dominant Habitat Type *
Riffle
Run
Pool
Dominant Substrate Type *
Bedrock
Boulder
Cobble
Gravel
Sand
Silt
Clay
Is the bottom of the stream visible *
Yes
No
Peak Canopy Angle for Left Bank *
Range of 0-90 degrees per streambank
Peak Canopy Angle for Right Bank *
Range of 0-90 degrees per streambank

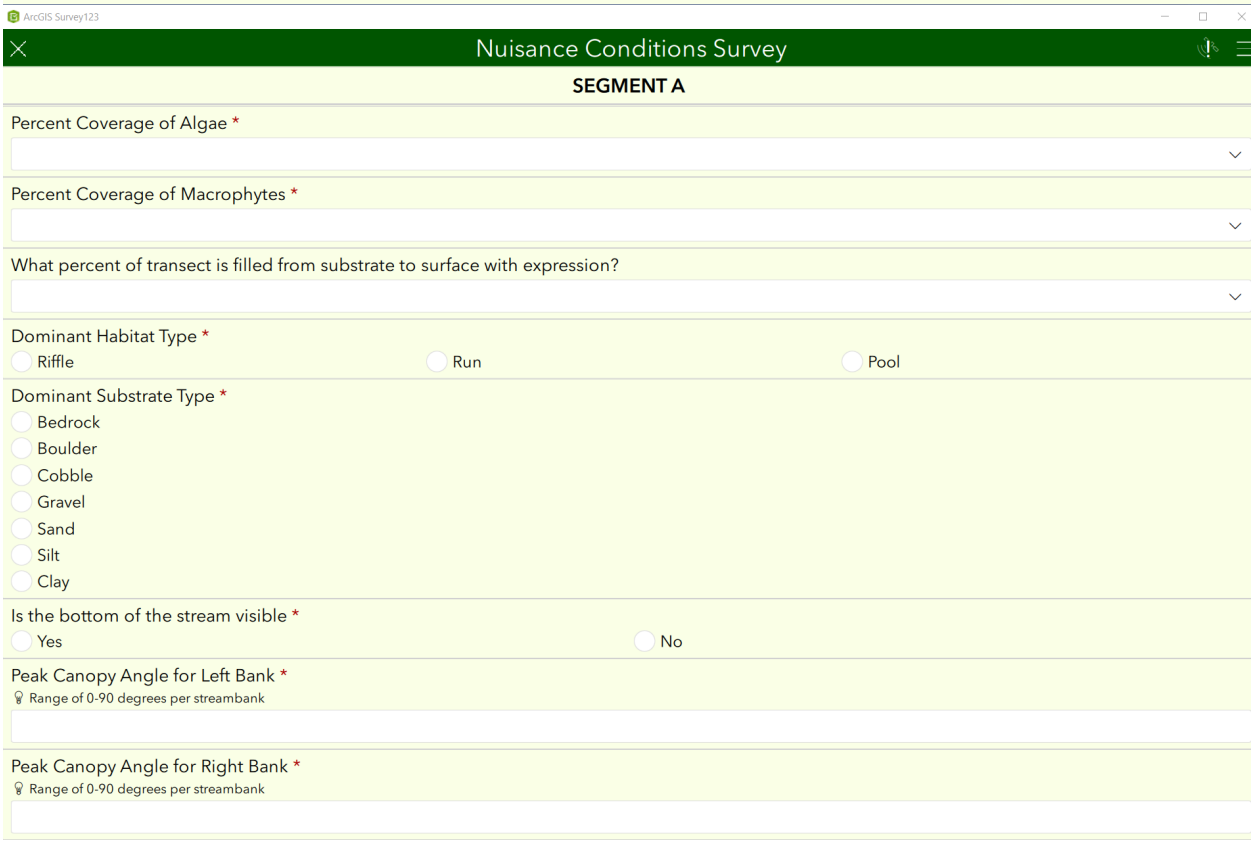

ArcGIS Survey123
Nuisance Conditions Survey
SEGMENT F
Percent Coverage of Algae *
Percent Coverage of Macrophytes *
What percent of transect is filled from substrate to surface with expression?
Dominant Habitat Type *
Riffle
Run
Pool
Dominant Substrate Type *
Bedrock
Boulder
Cobble
Gravel
Sand
Silt
Clay
Is the bottom of the stream visible *
Yes
No
Peak Canopy Angle for Left Bank *
Range of 0-90 degrees per streambank
Peak Canopy Angle for Right Bank *
Range of 0-90 degrees per streambank


ArcGIS Survey123
Nuisance Conditions Survey
SEGMENT E
Percent Coverage of Algae *
Percent Coverage of Macrophytes *
What percent of transect is filled from substrate to surface with expression?
Dominant Habitat Type *
Riffle
Run
Pool
Dominant Substrate Type *
Bedrock
Boulder
Cobble
Gravel
Sand
Silt
Clay
Is the bottom of the stream visible *
Yes
No
Peak Canopy Angle for Left Bank *
Range of 0-90 degrees per streambank
Peak Canopy Angle for Right Bank *
Range of 0-90 degrees per streambank

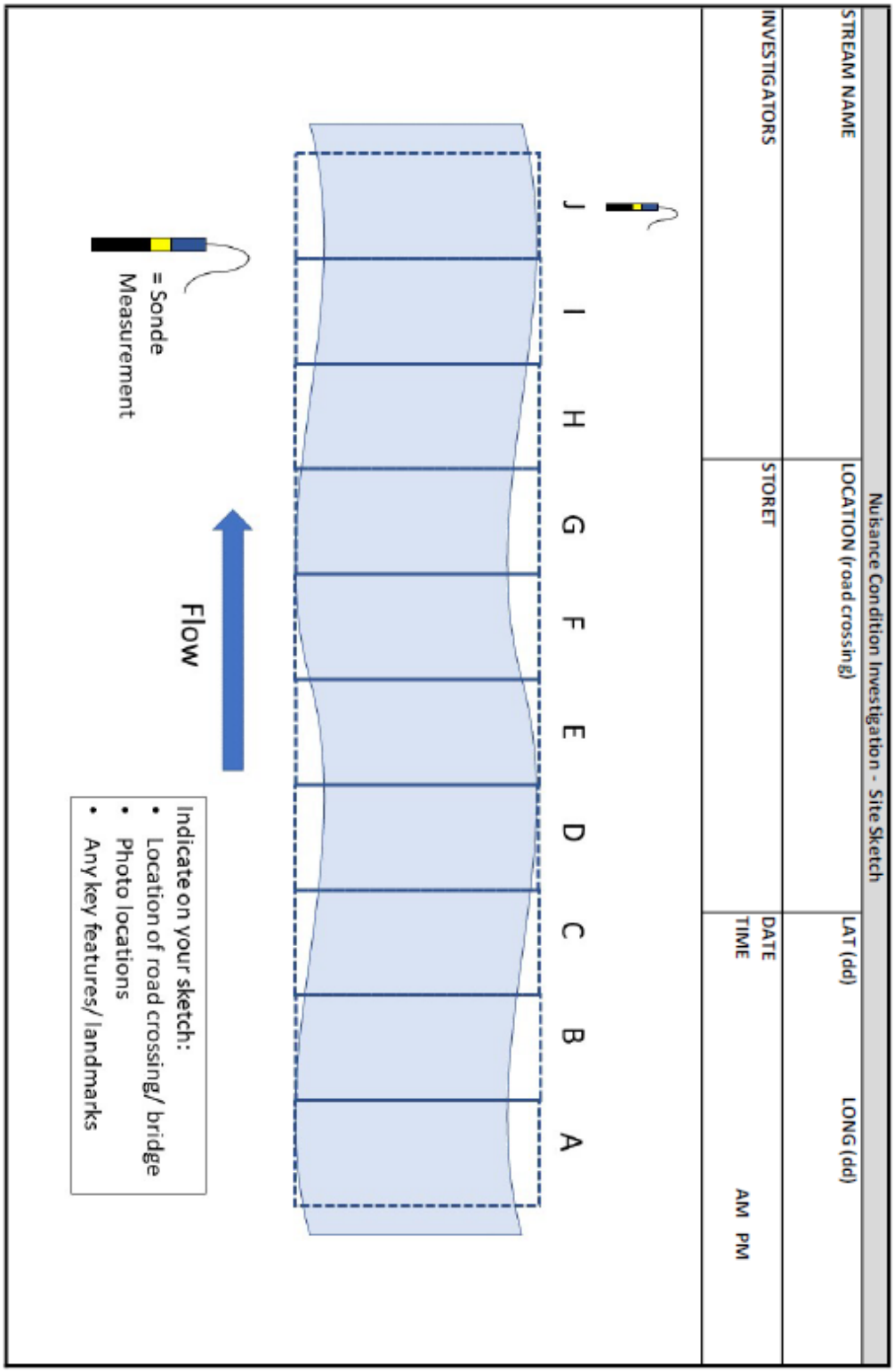

ArcGIS Survey123
Nuisance Conditions Survey
SEGMENT D
Percent Coverage of Algae *
Percent Coverage of Macrophytes *
What percent of transect is filled from substrate to surface with expression?
Dominant Habitat Type *
Riffle
Run
Pool
Dominant Substrate Type *
Bedrock
Boulder
Cobble
Gravel
Sand
Silt
Clay
Is the bottom of the stream visible *
Yes
No
Peak Canopy Angle for Left Bank *
Range of 0-90 degrees per streambank
Peak Canopy Angle for Right Bank *
Range of 0-90 degrees per streambank


ArcGIS Survey123
Nuisance Conditions Survey
SEGMENT C
Percent Coverage of Algae *
Percent Coverage of Macrophytes *
What percent of transect is filled from substrate to surface with expression?
Dominant Habitat Type *
Riffle
Run
Pool
Dominant Substrate Type *
Bedrock
Boulder
Cobble
Gravel
Sand
Silt
Clay
Is the bottom of the stream visible *
Yes
No
Peak Canopy Angle for Left Bank *
Range of 0-90 degrees per streambank
Peak Canopy Angle for Right Bank *
Range of 0-90 degrees per streambank


ArcGIS Survey123
Nuisance Conditions Survey
SEGMENT B
Percent Coverage of Algae *
Percent Coverage of Macrophytes *
What percent of transect is filled from substrate to surface with expression?
Dominant Habitat Type *
Riffle
Run
Pool
Dominant Substrate Type *
Bedrock
Boulder
Cobble
Gravel
Sand
Silt
Clay
Is the bottom of the stream visible *
Yes
No
Peak Canopy Angle for Left Bank *
Range of 0-90 degrees per streambank
Peak Canopy Angle for Right Bank *
Range of 0-90 degrees per streambank


ArcGIS Survey123
Nuisance Conditions Survey
SEGMENT A
Percent Coverage of Algae *
Percent Coverage of Macrophytes *
What percent of transect is filled from substrate to surface with expression?
Dominant Habitat Type *
Riffle
Run
Pool
Dominant Substrate Type *
Bedrock
Boulder
Cobble
Gravel
Sand
Silt
Clay
Is the bottom of the stream visible *
Yes
No
Peak Canopy Angle for Left Bank *
Range of 0-90 degrees per streambank
Peak Canopy Angle for Right Bank *
Range of 0-90 degrees per streambank

APPENDIX B: Site Sketch Datasheet



APPENDIX C: Non-Procedure 51 Nutrient Expression Survey