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Final Regulation
Agency Background Document

Agency name	State Water Control Board
Virginia Administrative Code (VAC) citation(s)	9 VAC 25-260-310
Regulation title(s)	Water Quality Standards
Action title	Amendments to the tidal James River special standard for chlorophyll-a
Date this document prepared	May 16, 2019

This information is required for executive branch review and the Virginia Registrar of Regulations, pursuant to the Virginia Administrative Process Act (APA), Executive Order 14 (as amended, July 16, 2018), the Regulations for Filing and Publishing Agency Regulations (1 VAC7-10), and the *Virginia Register Form, Style, and Procedure Manual for Publication of Virginia Regulations.*

Brief Summary

Please provide a brief summary (preferably no more than 2 or 3 paragraphs) of this regulatory change (i.e., new regulation, amendments to an existing regulation, or repeal of an existing regulation). Alert the reader to all substantive matters. If applicable, generally describe the existing regulation.

The amendments include modified and new site-specific chlorophyll-*a* criteria applicable to the tidal James River. Chlorophyll-*a* criteria enable watershed management of nitrogen and phosphorus, nutrients which drive algal blooms in the tidal James River. The amendments are the result of a comprehensive scientific study overseen by DEQ that focused on chlorophyll-*a* dynamics and linkages to aquatic life effects in the James River. Among the most notable changes to the regulation are modified seasonal mean criteria (eight proposed criteria are lower than the existing criteria and two proposed criteria are higher) and new short-duration criteria that protect aquatic life from the effects of toxic algae.

Since publication of the proposal, the only substantive change is the addition of language that gives the Department the flexibility to review additional lines of evidence in determining the appropriate water quality assessment category when consecutive exceedances of a seasonal mean criterion occur in a water body segment.

Acronyms and Definitions

Please define all acronyms used in the Agency Background Document. Also, please define any technical terms that are used in the document that are not also defined in the "Definition" section of the regulations.

DEQ = Department of Environmental Quality
EPA = United States Environmental Protection Agency

Statement of Final Agency Action

Please provide a statement of the final action taken by the agency including: 1) the date the action was taken; 2) the name of the agency taking the action; and 3) the title of the regulation.

The State Water Control Board adopted the amendments at its meeting on June 27, 2019.

Legal Basis

Please identify (1) the agency or other promulgating entity, and (2) the state and/or federal legal authority for the regulatory change, including the most relevant citations to the Code of Virginia or Acts of Assembly chapter number(s), if applicable. Your citation must include a specific provision, if any, authorizing the promulgating entity to regulate this specific subject or program, as well as a reference to the agency or promulgating entity's overall regulatory authority.

Section 62.1-44.15(3a) of the Code of Virginia, as amended, mandates and authorizes the State Water Control Board to establish water quality standards and policies for any State waters consistent with the purpose and general policy of the State Water Control Law, and to modify, amend or cancel any such standards or policies established. The federal Clean Water Act at 303(c) mandates the State Water Control Board to review and, as appropriate, modify and adopt water quality standards. The promulgating entity is the State Water Control Board.

The corresponding federal water quality standards regulation at 40 CFR 131.6 describes the minimum requirements for water quality standards. The minimum requirements are use designations, water quality criteria to protect the designated uses and an antidegradation policy. All of the citations mentioned describe mandates for water quality standards.

The Environmental Protection Agency (EPA) Water Quality Standards regulation (40 CFR 131.11) is the regulatory basis for the EPA requiring the states to establish water quality criteria to protect designated uses and the criteria are used to assess whether or not a waterbody is meeting those uses.

Purpose

Please explain the need for the regulatory change, including a description of: (1) the rationale or justification, (2) the specific reasons the regulatory change is essential to protect the health, safety or welfare of citizens, and (3) the goals of the regulatory change and the problems it's intended to solve.

The amendments to the special standards and requirements section (9 VAC 25-260-310) of the Virginia Water Quality Standards Regulation reflects new understanding resulting from a seven-year-long study aimed at updating the chlorophyll-*a* criteria for the tidal James River with best available science. Chlorophyll-*a* criteria, which enable the regulatory management of nutrients (nitrogen and phosphorus), were adopted for the tidal James River in 2005. The scientific basis of the existing James River chlorophyll-*a* criteria was questioned in response to the stringent nutrient load reductions determined by the EPA to be necessary for attainment of these criteria, as a component of the Chesapeake Bay TMDL.

The study of the existing regulation revealed some substantial weaknesses. First, the existing chlorophyll-*a* criteria were developed from datasets that were relatively limited in scope and were drawn from areas of the Chesapeake Bay that may not be representative of the James River. Secondly, while the existing criteria were developed to promote a balanced phytoplankton assemblage that is relatively free from harmful taxa, the absence of clear relationships between chlorophyll-*a* and phytoplankton composition necessitated some subjective decision-making in the selection of thresholds. Also, physicochemical effects stemming from algal blooms, like poor water clarity and high pH, were not considered when the existing criteria were developed. Thirdly, the study found that the existing criteria must be assessed as geometric means (as directed by implementation guidance specified in subsection D of 9 VAC 25-260-185) even though they were developed as arithmetic means. Research conducted by the EPA-Chesapeake Bay Program Office in 2010 determined that the geometric mean is the more appropriate statistic for characterizing James River chlorophyll-*a* central tendency. Finally, the existing assessment

methodology and the rules used to delineate allowable exceedance frequency, both described in references cited in subsection D of 9 VAC 25-260-185, were developed separately from the existing criteria and were found to be ill-suited for a parameter like chlorophyll-*a*, which can vary considerably in space and time even under ideal conditions. The mismatch between these elements and the existing criteria likely accounts for some of the stringency of the nutrient load reductions determined by EPA under the Chesapeake Bay Total Maximum Daily Load (TMDL) to be necessary for criteria attainment. Another factor was the modeling framework used at the time had limitations in its ability to accurately predict chlorophyll-*a* concentrations resulting from simulated nutrient reduction scenarios. An enhanced model is now being used in the analysis with improved calibration and validity.

The amendments to the regulation address the above weaknesses. DEQ staff have concluded that implementation of the amendments will benefit the health, safety and welfare of the citizens of the Commonwealth by protecting the water quality and living resources of the tidal James River from the effects of excessive nutrients and the resulting elevated chlorophyll-*a* levels.

Substance

Please briefly identify and explain the new substantive provisions, the substantive changes to existing sections, or both. A more detailed discussion is provided in the "Detail of Changes" section below.

9 VAC 25-260-310 (bb) provides the criteria for site-specific chlorophyll-*a* levels in the tidal James River (excluding tributaries) and contains a table listing two seasonal mean criteria (spring and summer) for each of the five James River segments (delineated by salinity regime), for a total of ten paired sets of criteria. The amendments lower eight of these values and raise two of them. Compliance with these revised criteria is expected to minimize both long-term and short-term effects on aquatic life. Additionally, a new table of criteria that apply only during the summer is inserted. Compliance with these new criteria is expected to minimize short-term effects on aquatic life stemming from potentially toxic harmful algal blooms. Finally, the amendments remove the reference to subsection D of 9 VAC25-260-185 and inserts new language stipulating that: 1) seasonal means should be calculated as geometric means; 2) the allowable exceedance frequencies of both sets of criteria and the length of the assessment period over which they should be evaluated; 3) the manner in which chlorophyll-*a* data should be aggregated and how segments should be subdivided for the purposes of data aggregation; 4) the reference to the EPA technical document that provides the boundaries of the James River segments, and 5) assessment guidance will be developed to address the appropriate assessment category if consecutive exceedances of the same seasonal mean criterion occur in a water body segment.

Issues

Please identify the issues associated with the regulatory change, including: 1) the primary advantages and disadvantages to the public, such as individual private citizens or businesses, of implementing the new or amended provisions; 2) the primary advantages and disadvantages to the agency or the Commonwealth; and 3) other pertinent matters of interest to the regulated community, government officials, and the public. If there are no disadvantages to the public or the Commonwealth, include a specific statement to that effect.

There are a number of advantages that result from the amendments. First, DEQ will be able to better detect potentially harmful changes to the tidal James River stemming from excessive nitrogen and phosphorus loads that may affect the aquatic life designated use. DEQ will also be able to produce more confident assessments so that the public can be properly informed about the status of water quality in the tidal James River. Additionally, the amendments strengthen the technical defensibility of the regulation so that the regulated community and resource managers can better understand the benefits expected to be gained with regulatory compliance. More defensible permit limits and non-point source management plans will result from the adoption of these amendments. A final benefit is that the costs needed to attain the amended criteria may be less than what attainment of the existing criteria has been estimated to cost.

There is no disadvantage to the agency or the Commonwealth that will result from the adoption of this final regulation.

Requirements More Restrictive than Federal

Please list all changes to the information reported on the Agency Background Document submitted for the previous stage regarding any requirement of the regulatory change which is more restrictive than applicable federal requirements. If there are no changes to previously-reported information, include a specific statement to that effect.

The proposed amendments do not exceed applicable federal minimum requirements.

Agencies, Localities, and Other Entities Particularly Affected

Please list all changes to the information reported on the Agency Background Document submitted for the previous stage regarding any other state agencies, localities, or other entities that are particularly affected by the regulatory change. If there are no changes to previously-reported information, include a specific statement to that effect.

Other State Agencies Particularly Affected:
No state agencies are known to be particularly affected.

Localities Particularly Affected:

The 38 counties and 17 cities that will be particularly affected all drain into the James River: Counties: Albemarle, Alleghany, Amelia, Amherst, Appomattox, Augusta, Bath, Bedford, Botetourt, Buckingham, Campbell, Charles City, Chesterfield, Craig, Cumberland, Dinwiddie, Fluvanna, Giles, Goochland, Greene, Hanover, Henrico, Highland, Isle of Wight, James City, Louisa, Montgomery, Nelson, New Kent, Nottoway, Orange, Powhatan, Prince Edward, Prince George, Roanoke, Rockbridge, Surry, and York; Cities: Buena Vista, Charlottesville, Chesapeake, Colonial Heights, Covington, Hampton, Hopewell, Lexington, Lynchburg, Newport News, Norfolk, Petersburg, Portsmouth, Richmond, Suffolk, Williamsburg, and Virginia Beach.

Other Entities Particularly Affected:
No other entities are known to be particularly affected.

Public Comment

Please summarize all comments received during the public comment period following the publication of the previous stage, and provide the agency response. Ensure to include all comments submitted: including those received on Town Hall, in a public hearing, or submitted directly to the agency or board. If no comment was received, enter a specific statement to that effect.

See Attachments 1 and 2.

Detail of Changes Made Since the Previous Stage

Please list all changes that made to the text since the previous stage was published in the Virginia Register of Regulations and the rationale for the changes. Explain the new requirements and what they mean rather than merely quoting the text of the regulation.
**Please put an asterisk next to any substantive changes.*

Current chapter-section number	New chapter-section number, if applicable	New requirement from previous stage	Updated new requirement since previous stage	Change, intent, rationale, and likely impact of updated requirements

Current chapter-section number	New chapter-section number, if applicable	New requirement from previous stage	Updated new requirement since previous stage	Change, intent, rationale, and likely impact of updated requirements
9VAC 25-260-310		The following statement has been added: "Should consecutive exceedances of the same seasonal mean criterion occur in a water body segment after the effective date of these chlorophyll-a criteria, the Department will examine additional lines of evidence including, but not limited to, the occurrence of harmful algal blooms, physicochemical monitoring and phytoplankton datasets, and fish kill reports in the evaluation of the appropriate assessment category for the water body segment. The Department will develop guidance for inclusion in the Water Quality Assessment Guidance Manual to address evaluating the appropriate assessment category when consecutive exceedances of the same seasonal mean criterion occur. The Department will determine if additional monitoring for harmful algal blooms is warranted."		The change does not alter the proposed criteria but it does give the Department the flexibility to review additional lines of evidence in determining the appropriate water quality assessment category when consecutive exceedances of a seasonal mean criterion occur in a water body segment.

Current chapter-section number	New chapter-section number, if applicable	New requirement from previous stage	Updated new requirement since previous stage	Change, intent, rationale, and likely impact of updated requirements
9VAC 25-260-310			The statement reading, "The following site-specific seasonal mean criteria should not be exceeded in the specified tidal James River segment more than twice over six consecutive spring or summer seasons" has been modified thusly: "The following site-specific seasonal mean criteria should not be exceeded in the specified tidal James River segment more than twice in six years."	Comments from EPA suggested that the use of the "consecutive" is unnecessary and potentially confusing. The change does not impact the updated requirements.
9VAC 25-260-310			The statement reading, "The following site-specific chlorophyll a concentrations at the specified duration should not occur more than 10% of the time over six consecutive summer seasons in the specified area of the tidal James River" has been modified thusly: "The following site-specific chlorophyll a concentrations at the specified duration should not be exceeded more than 10% of the time over six summer seasons."	Comments from EPA suggested that the use of the "consecutive" is unnecessary and potentially confusing. The insertion of the phrase "should not be exceeded" provides much needed clarity. These changes do not impact the updated requirements.

Detail of All Changes Proposed in this Regulatory Action

*Please list all changes proposed in this action and the rationale for the changes. Explain the new requirements and what they mean rather than merely quoting the text of the regulation. *Please put an asterisk next to any substantive changes.*

[For changes to existing regulation(s), please use the following chart otherwise delete:]

Current section number	New section number, if applicable	Current requirement	Change, intent, rationale, and likely impact of new requirements
9VAC 25-260-310		Site-specific chlorophyll criteria expressed as seasonal means and a reference to subsection D of 9VAC25-260-180 for implementation guidance.	The reference to subsection D of 9 VAC25-260-180 is removed and a reference to the EPA document that describes the Chesapeake Bay segment boundaries is added. Language has been added stipulating how chlorophyll-*a* data should be aggregated in time and space. Seasonal mean criteria have been modified, with eight being in lower in magnitude and two being higher in magnitude. New table of criteria has been inserted that apply only during summer. The allowable exceedance frequencies and assessment periods for both sets of criteria are provided, with a statement that additional lines of evidence may be evaluated when consecutive exceedances occur.

ATTACHMENT 1

Public Comment and DEQ Response

The Board's authorization to hold a public hearing and receive public comments on the proposal was received at their September 20, 2018 meeting. Notice of Public Comment on the proposed criteria amendments was issued January 21, 2019, and the public review period ran from January 21, 2019 to March 22, 2019. A public hearing was held on February 26, 2019. There were 19 attendees at the public hearing and 7 persons provided oral comment. Written public comments were received from: EPA; two environmental organizations; 124 citizens; Virginia Association of Municipal Wastewater Agencies; Virginia Manufacturers Association; three industrial owners; nine local governments; and, four Water and Sewer Authorities on the proposed changes to the water quality standards regulation. A summary of comments received and DEQ's response is presented below. DEQ made one change in the proposal to address comments received by adding the following text in section 9VAC25-260-310 (bb), preceding the numeric seasonal mean criteria table:

> Should consecutive exceedances of the same seasonal mean criterion occur in a water body segment after the effective date of these chlorophyll-*a* criteria, the Department will examine additional lines of evidence including, but not limited to, the occurrence of harmful algal blooms, physicochemical monitoring and phytoplankton datasets, and fish kill reports in the evaluation of the appropriate assessment category for the water body segment. The Department will develop guidance for inclusion in the Water Quality Assessment Guidance Manual to address evaluating the appropriate assessment category when consecutive exceedances of the same seasonal mean criterion occur. The Department will determine if additional monitoring for harmful algal blooms is warranted.

Commenter:
U.S Environmental Protection Agency (EPA)
EPA Comment 1: A reference to the conceptual model developed by Hagy et al. (2008) would provide additional conceptual rigor, since VADEQ utilizes a couple of the approaches presented in that model.

> **DEQ Response**: VADEQ agrees with this suggestion and has incorporated this reference in its technical support document, which can be found on the DEQ website: https://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityStandards/James%20River%20Chl%20A%20Study/Rulemaking_materials/James_R_Chlorophyll_TSD_DEC2018.pdf?ver=2019-03-13-140711-020.

EPA Comment 2: There are inconsistencies in the log-transformation of data in empirical relationships. Log-transforming pH is questionable, since pH is logarithmic.

DEQ Response: Given the importance of the empirical models, model variables were transformed to maximize model fit. This required log-transforming both variables for some models, while the fit of other models was better when only one variable was transformed. VADEQ agrees that it is questionable to log-transform pH. However, redeveloping the pH- chlorophyll-*a* models using only a log-transformed independent variable (chlorophyll) results in predictions that are very similar to those generated by the original models.

EPA Comment 3: The temporal expression of the DO water quality standard is a 30-day mean, but the DO variable in the DO- chlorophyll-*a* empirical relationships is expressed as a summer mean. These different temporal scales need to be reconciled. Additionally, by averaging summer DO measurements, physiologically significant observations in the data could be masked.

DEQ Response: VADEQ agrees that its treatment of DO could be enhanced, especially given the diversity of available datasets. Monthly mid-channel grab samples were used to relate chlorophyll-*a* and DO because such data form the basis of the biennial assessment of the 30-day DO mean criterion. However, it actually makes more sense to use the continuous monitoring (ConMon) data for this purpose, since this information enables the calculation of robust 30-day means. Monthly data were averaged across each summer-year because other researchers (Harding et al., 2014 and Sutula et al., 2017) have had success finding a relationship between chlorophyll-*a* and DO when they are averaged over long periods (seasons). However, VADEQ agrees that presenting plots of chlorophyll-*a* and DO at different temporal scales would be equally informative, as it would support VADEQ's assertion that the relationship between James River chlorophyll-*a* and low DO cannot be substantiated with the available data. The technical support document has been revised to incorporate EPA's recommendations.

EPA Comment 4: A prediction interval (the upper prediction limit) would be the more appropriate approach for deriving a baseline criterion.

DEQ Response: VADEQ agrees with EPA that an upper prediction limit (rather than upper confidence limit) is a superior way of pinpointing a seasonal chlorophyll-*a* mean threshold that distinguishes "normal" from "extreme", since the upper prediction limit (UPL) takes into account measurement uncertainty. The table below compares the baseline criteria derived from the upper confidence limit of the mean (UCL) with those derived from the UPL. While the UPL is a statistically valid way of selecting criteria developed to protect baseline conditions, for the following reasons VADEQ has decided to continue to use the UCL to inform the criteria for those segment-seasons without documented harmful chlorophyll-related effects:

- Criteria derived from the UPL would be substantially greater in magnitude than those derived from the UCL. The baseline criteria are developed to mitigate any unknown or poorly understood harmful effects that could occur by allowing phytoplankton biomass to increase above current levels. UPL-derived criteria would not provide this protection as well as UCL-derived ones would, given the former's greater magnitude. Long-term compliance with UCL-derived criteria would prevent upward trends in chlorophyll-*a* concentrations in the segments that would be regulated by those criteria. UPL-derived criteria would only prevent extreme upward shifts in chlorophyll-*a* concentrations and would thus allow degradation in the segments regulated by them.
- By definition, values greater than the UPL are expected to occur very rarely. In contrast, while values greater than the UCL would be unusually high, such values are still expected to occur occasionally. For example, the upper 95% confidence limit of the spring mean estimates for JMSMH is 7 µg/l, a value that was exceeded twice over the 2005-2015 period (in 2005 and 2013). In contrast, the upper 95% prediction limit for JMSMH spring means—10 µg/l—was not exceeded in any spring season over the 2005-2015 period. Thus, two exceedances of UCL-derived criteria over six years would not be incompatible with the normal variability of chlorophyll. But two exceedances of the UPL over six years would be a considerable departure from "normal".

Segment-Season	UCL*	U95%PL
JMSTFU spring	8	10
JMSTFL spring	10	13
JMSOH spring	13	20
JMSOH summer	11	15
JMSMH spring	7	9
JMSMH summer	7	10
JMSPH spring	8	11

* U99%CL for TF and OH segments, U95%CL for JMSMH and JMSPH

EPA Comment 5: It is not clear from the descriptions in the technical support document whether VADEQ accounted for differences in scale between the Continuous Monitoring (ConMon) data and the Dataflow data.

DEQ Response: The different high-frequency monitoring datasets (ConMon and Dataflow) were used for different purposes. ConMon datasets were used to develop empirical relationships and to characterize baseline temporal variability in those segments that were *not* monitored with weekly Dataflow (the tidal fresh and oligohaline segments). In JMSMH and JMSPH, weekly Dataflow datasets were used to estimate baseline central tendency and temporal variability. ConMon datasets in those segments were only used to determine the frequency of pH exceedances and were not combined with other datasets.

While VADEQ does agree that spatial and temporal scales are important considerations, VADEQ believes that it treated the different high-frequency datasets properly.

EPA Comment 6: The proposed chlorophyll-a criteria index period for assessment needs to be clarified.

DEQ Response: VADEQ intends to use a static index period for determining compliance with the proposed criteria for 305(b)/303(d) purposes. That is to say, the proposed criteria would be assessed for the same six-year assessment window that VADEQ uses to determine aquatic life use support for the majority of the state's waters.

The proposed frequency statement for the seasonal mean criteria will be modified to read as follows: "The following site-specific seasonal mean criteria should not be exceeded in the specified tidal James River segment more than twice in six years."

Commenters:
Chesapeake Bay Foundation, James River Association, and 124 Citizens

Comment: VADEQ should revise the assessment methodology to prohibit consecutive seasonal mean exceedances due to remaining knowledge gaps regarding the effects of algal blooms and because allowing consecutive exceedances is not consistent with the EPA-recommended allowable exceedance frequency for most water quality standards.

DEQ Response: VADEQ appreciates the concerns expressed over unknown impacts stemming from algae in the James River and how those effects may manifest if exceedances occur in back-to-back years. VADEQ does prohibit closely spaced exceedances of toxic pollutants in accordance with EPA's recommended frequency statement, "No more than one exceedance every three years".[1] When this frequency rule is successfully implemented through pollution control measures, exceedances should occur no frequently than once every three years, on average. However, this recommendation pertains to substances that always cause aquatic life mortality at high concentrations. It is reasonable to expect the effect of high exposure events to compound the closer they occur in time when mortality is always an outcome of such events. Toxic substances also tend not to naturally occur at a concentration relevant to regulatory standards. However, chlorophyll-*a* is a non-toxic substance that naturally occurs in all waterbodies in appreciable amounts. VADEQ believes a less stringent allowable frequency is justified on this basis. The following arguments add further support to the position that VADEQ's frequency statements for the proposed criteria are sufficiently protective of aquatic life:

[1] United States Environmental Protection Agency. 1985. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. U.S. Environmental Protection Agency, Office of Research and Development, Duluth, MN, Narragansett, RI, Corvallis, OR. PB85-227049.

1. The proposed allowable frequencies of both sets of criteria (seasonal mean and short-duration) are consistent with EPA recommendations for the kind of effects the criteria are developed to protect aquatic life from. EPA's "one exceedance in three years" recommendation applies to toxic substances which comprise the overwhelming majority of the Commonwealth's regulated pollutants. It does not apply to conventional pollutants/parameters which are evaluated based on this requirement. VADEQ believes that chlorophyll, as an indicator parameter, is much more like a conventional parameter (e.g., dissolved oxygen or pH) than a toxic substance. The frequency statements for the seasonal mean and short-duration chlorophyll-*a* criteria are compatible with EPA's recommended exceedance frequency for conventional pollutants2 and the EPA-approved "two exceedances in three years" rule used for Chesapeake Bay water clarity restoration goals.

2. Chlorophyll-*a* concentrations are influenced by a number of non-nutrient, non-anthropogenic variables (e.g., flow, light availability, temperature, tides, wind, and grazing rates). Marginal exceedances of the seasonal mean criteria are expected to occasionally occur simply due to natural variability. The spacing of these exceedances is expected to occasionally cluster in time (e.g., two back-to-back years) but would not necessarily be indicative of harmful water quality conditions.

3. In segments where harmful algal blooms have been documented, the seasonal mean criteria would work in tandem with the proposed short-duration criteria. Compliance with the latter would place a constraint on the upper limit of summer mean concentrations, since these criteria are designed to minimize the frequency of the very high chlorophyll-*a* concentrations one would expect to see during harmful algal blooms. The goal of the amended water quality criteria for chlorophyll-a is for "high risk" seasonal chlorophyll-*a* concentrations—those most likely to be driven by severe HABs—to occur no more frequently than once every six years. VADEQ believes long-term compliance with the seasonal mean and short-duration criteria will achieve this goal.

Commenters: Virginia Association of Municipal Wastewater Agencies, Virginia Manufacturers Association, AdvanSix, DuPont Spruance, WestRock, and Town of Buena Vista, Hanover County, City of Richmond, Rivanna Water and Sewer Authority, South Central Wastewater Authority, County of Henrico, Dinwiddie County Water Authority, City of Lynchburg, Campbell County, Chesterfield County, Town of Amherst, City of Hopewell, Hampton Roads Sanitation District

Comment: The proposed summer mean criteria for the two tidal fresh segments should be increased from 21 µg/l to 23 µg/l (JMSTFU) and from 24 µg/l to 25 µg/l (JMSTFL) because the proposed values are based on a very limited dataset that is not representative of the tidal fresh

[2] United States Environmental Protection Agency. 2002. Consolidated Assessment and Listing Methodology—A Compendium of Best Practices. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington D.C. July 2002.

segments in their entirety. Additionally, the short-duration criteria should not be adopted since they are "late additions" to the proposal and because the "patchiness" and non-toxicity of chlorophyll-*a* makes these criteria questionable.

DEQ Response: Attachment 3 provides a presentation and discussion of analyses that challenge the commenters' assertions that (1) the dataset that VADEQ used to generate the summertime tidal fresh chlorophyll-pH empirical relationship is not spatially representative and (2) a more accurate relationship can be constructed from more recent data using a different modeling technique. The analyses show that even if VADEQ were to accept the second assertion, no adjustments would need to be made to the currently proposed criteria.

The seasonal mean criteria are developed to protect aquatic life from the short-term and long-term harmful effects caused by phytoplankton. Because these criteria were derived using conservative assumptions regarding spatial and temporal variability of James River chlorophyll-*a* expression, VADEQ expects that these criteria will be protective of aquatic life the majority of the time. However, when these assumptions are not met (i.e., when spatial and/or temporal chlorophyll-a variability is unusually high), it is possible for a segment to demonstrate compliance with its seasonal mean criteria despite experiencing numerous HAB events. The short-duration criteria help to ensure that the frequency of potentially harmful high exposure events is minimized. The short-duration criteria also constrain the duration of potentially harmful algal blooms much more effectively than the seasonal mean criteria do. For instance, in the absence of the short-duration criteria, very intense, month-long *Microcystis* blooms would be permitted every year in JMSTFL. The short-duration criterion for JMSTFL would limit such blooms to once every six years.

It is also important to note that the efficacy of the seasonal mean criteria is highly dependent on the robustness of the assessment dataset. According to the power analysis performed by VADEQ, an average of 20 stations is needed in each James River segment to generate a highly accurate estimate of spatial chlorophyll-a central tendency most of the time, and these stations would have to be sampled twice weekly to generate a highly accurate estimate of seasonal chlorophyll-a central tendency. VADEQ is currently unable to support such a monitoring program and it is unlikely it ever will. The relatively high sampling error rates expected from a conventional monitoring program (2-3 stations sampled monthly) necessitates a "stop-gap" to minimize the likelihood of false negatives, i.e., an assessment decision that a segment meets a criterion when it actually fails it. The short-duration criteria provide this function, since they approximate instantaneous criteria the smaller the assessment dataset becomes.

ATTACHMENT 2

Response to Technical Memorandum Cited by VAMWA to Recommend Upwards Adjustments to the Proposed Tidal Fresh Summer Mean Criteria

Subject: Response to Technical Memo "Comparison of pH and Chlorophyll-a at the Rice Center Pier and Other Stations"
Date: May 6, 2019
From: Tish Robertson

Introduction

The primary driver for the proposed chlorophyll-*a* criteria in the two tidal fresh segments in the James River is protection against elevated pH (DEQ, 2018), a stressor observed at a high frequency by the continuous monitor deployed by the Virginia Institute of Marine Science (VIMS) from 2006 to 2008 at the Virginia Commonwealth University (VCU) Rice Rivers Center Pier (hereafter referred to as the "Rice Pier"). At the Spring 2017 James River Chlorophyll-*a* Regulatory Advisory Panel (RAP) meeting, Clifton Bell from Brown & Caldwell asserted that the statistical relationship derived from chlorophyll and pH samples taken from the Rice Pier is different from the relationships derived from samples collected at other locations nearby. He contended that this difference is sufficient enough to warrant a "correction" to the relationship used for estimating effect thresholds and ultimately the proposed tidal fresh criteria. By using Bell's "corrected" relationship, the proposed summer criterion would be raised from 21 µg/l to 23 µg/l for JMSTFU and from 24 µg/l to 25 µg/l for JMSTFL. In response to Bell's presentation, Tish Robertson (DEQ) presented analyses that support DEQ's assumption that water quality at the Rice Pier is adequately representative of the surrounding area.

On October 31, 2017, Bell submitted a technical memorandum to DEQ that expands on the work he presented at the Spring 2017 RAP meeting. This memo is also enclosed with VAMWA's comment letter to DEQ dated March 22, 2019. Bell's position can be distilled into two separate assertions: 1) pH is biased high at the Rice Pier compared to the pH observed in the adjacent mid-channel—a bias consistently high enough to warrant a 0.08 standard unit subtraction to the chlorophyll-pH relationship used to develop effect thresholds, and 2) the model used by DEQ to develop effect thresholds (simple linear regression) produces pH predictions that are biased high at high chlorophyll-*a* concentrations, therefore warranting a more accurate model that implicates a higher effect threshold than the one used to develop the proposed criteria. To make both cases, Bell makes inferences based on statistical analyses of the 2006-2016 continuous data collected at the Rice Pier. During the 2006-2008 period, VIMS managed the continuous monitoring station under contract with DEQ. The generated data were used by DEQ to develop the proposed criteria for the tidal fresh segments. VCU managed

the continuous monitoring station after 2008. DEQ declined to use the VCU-managed continuous data for developing the chlorophyll-pH relationship due to their questionable quality[3]. The continuous data used in Bell's analyses were submitted to Robertson along with his memorandum. A brief critique of Bell's assertions is presented below.

Assertion 1#: Higher pH at Rice Pier compared to the surrounding habitat

Bell presents a statistical comparison of chlorophyll-*a* and pH sampled by DEQ staff visiting mid-channel stations to observations recorded by the Rice Pier continuous monitor over the 2006-2016 period. Bell asserts statistical comparisons of station datasets support a finding that water quality at the Rice Pier is different from water quality at other stations. The following describes some weaknesses to this argument:

1. It is unclear whether the continuous data used in this analysis are raw fluorescence values or estimates of extracted chlorophyll-*a* derived from a calibration model. Since the mid-channel samples collected by DEQ were extracted chlorophyll, the Rice continuous data should be calibrated to ensure an "apples to apples" comparison. If these data were not properly calibrated, then any differences in chlorophyll-*a* concentration between Rice and mid-channel data might be due to mismatched parameters rather than site differences. DEQ used standardized parameters (extracted chlorophyll-*a* compared to extracted chlorophyll) in the comparison of station samples (see slide 6 of the PowerPoint presentation entitled "Representativeness of pH and Chlorophyll at Rice Center Pier", which was presented at the Spring 2017 RAP meeting).

2. Bell compares data collected by different data collectors (DEQ, VIMS, and VCU), so any differences may be due to different instrumentation, sampling techniques, and/or calibration. Only VIMS data were used in DEQ's comparison of station samples (slides 5 and 6 of the aforementioned PowerPoint presentation).

3. Bell does pairwise comparisons of station datasets. However, an assertion that the Rice Pier habitat is different from the "rest of the tidal fresh" necessitates evidence that Rice Pier samples are sufficiently different from the *set* of samples collected from the "rest of the tidal fresh". DEQ did not find that there was enough statistical certainty to reject the hypothesis that the Rice samples are similar to samples from the closest mid-channel stations to the Rice Pier when the station datasets are compared collectively (slides 5 and 6 of the aforementioned PowerPoint presentation).

[3] The questionable quality of the VCU continuous data is acknowledged by Bell. While VIMS includes QA/QC flags with its datasets, VCU does not provide such metadata. Bell describes how the data were "cleaned" prior to being analyzed. However, it is important to note that the continuous data that Bell submitted to DEQ did not include observations that DEQ has deemed valid (for instance, the majority of observations taken during July 2007) and some VIMS observations were deemed valid despite having QA/QC flags that indicate they should not be used due to probe malfunction.

4. Bell's pairwise comparisons indicate that the Rice Pier pH is statistically different (with 95% confidence) from pH measured at the mid-channel stations TF5.2A, TF5.3, and TF5.6. While not exactly corroborated by DEQ's analysis (slide 5 of the aforementioned PowerPoint presentation), this finding is not unexpected given that DEQ has already acknowledged these stations are located in habitats that differ from the one represented by the Rice Pier. These three stations are located in habitats with lower chlorophyll-*a* concentrations (and thus less intense algal photosynthesis) than the habitat represented by the Rice Pier. DEQ assumes that the stations TF5.5 and TF5.5A are located in the same habitat as the Rice Pier, and Bell finds that the pH samples taken at these stations are statistically different from the Rice Pier samples at the 90% confidence level. However, DEQ used a 95% confidence level for the majority of the decision points underlying the proposed criteria. The only exception is the 99% level chosen for the estimation of baseline central tendencies for the tidal fresh and oligohaline segments. DEQ is able to justify the use of a less conventional confidence level by citing the fact that baseline datasets were generated from different data sources and data types. There is no justification with comparable defensibility for using a lower confidence level, especially in a case involving uncontrolled confounders and questionable data integrity.
5. Bell compares the chlorophyll-pH relationship derived from Rice continuous data to the relationships derived from DEQ samples taken from the mid-channel stations and finds that the mid-channel relationships are different from the Rice relationship. However, the difference is only significant at the 90% confidence level. Moreover, even if this difference is considered significant, the cause of the difference cannot be attributed solely on habitat effects given the aforementioned confounding variables (i.e., dissimilar parameters, instrumentation, and data collectors). Admittedly, DEQ's comparison of relationship (slide 8 of the aforementioned PowerPoint presentation) was also complicated by mixed data sources (in this case, VIMS versus DEQ). However, DEQ found there was not enough evidence to reject the hypothesis that the Rice relationship is similar to the relationship derived from samples at the closest mid-channel station.

Assertion 2#: Alternative model produces better predictions of pH

Bell uses the 2006-2016 continuous dataset to simulate the relationship between chlorophyll-*a* and pH. He finds that these data generate a simple linear regression model that is similar to the model that DEQ used to develop the proposed tidal fresh criteria. However, Bell asserts this model overestimates pH at high chlorophyll-*a* concentrations. A locally weighted scatterplot smooth (LOWESS) regression model that Bell fits to the same data predicts a higher effect threshold than the simple linear regression model does (55 µg/l versus 50 µg/l). Bell asserts that because the LOWESS model generates more accurate predictions than the other model, the higher effect threshold is the more preferable of the two. The following issues were found with this analysis:

1. It is unclear whether Bell's relationship is based on raw fluorescence (reported directly from the continuous monitor) or extracted chlorophyll-a equivalents as predicted from a calibration model. The chlorophyll-a data that were enclosed with his technical memorandum (hereafter referred to as the "Bell dataset") were fluorescence values. The relationship used by DEQ to develop the proposed criteria was not based on raw fluorescence, but rather on estimates of extracted chlorophyll. To facilitate the consideration of Bell's recommendation, the Bell dataset was "corrected" using the annualized correction factors developed by HRSD/VAMWA for the James River Chlorophyll-a Study and then aggregated into daily chlorophyll-a medians and daily 90th percentile pH values (Figure 1). The resulting scatterplot is not the same as the scatterplot that Bell presents in his technical memorandum and thus the resulting empirical models are different from his. Because observations that are known to be suspect are present in the Bell dataset and observations that VIMS and DEQ have deemed valid are missing for unknown reasons (see Footnote 1), the validity of any model derived from this dataset is questionable.
2. Bell does not provide measures of fit so that his simple linear regression and LOWESS models can be objectively compared. To verify his assertion that the LOWESS curve produces better predictions, LOWESS and simple linear regression models were fit to the corrected Bell dataset. The LOWESS curve does indeed fit better in terms of root mean square error (RMSE). The RMSE for the LOWESS model is 0.44 versus 0.46 standard unit for the simple linear regression model. However, the effect threshold predicted by both models is the same (47 µg/l). This is lower than the effect threshold used by DEQ to develop the proposed tidal fresh criteria.

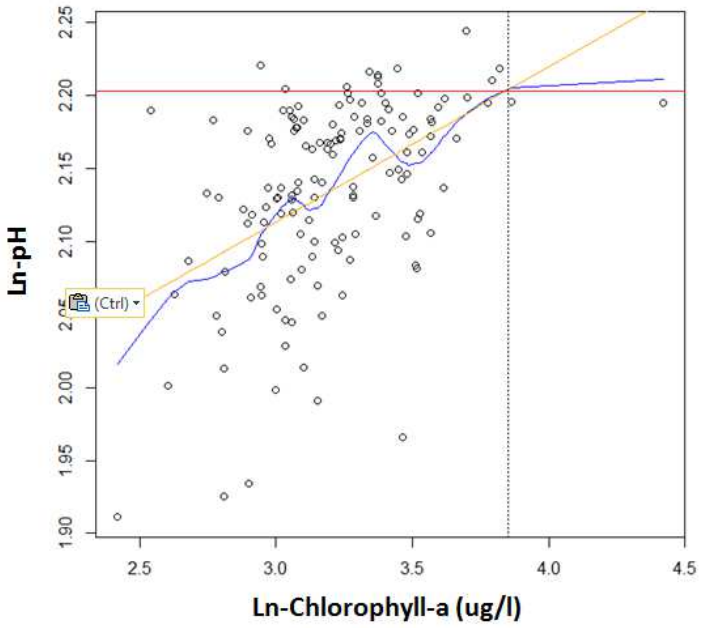

Figure 1. Scatterplot of pH (daily 90th percentile) and chlorophyll-*a* concentration (daily median) calculated from the Bell dataset, fit with a LOWESS model (blue) and simple linear regression model (yellow). Red line indicates pH = 9.1. Vertical line indicates the effect threshold. Bandwidth = 0.3126708

3. If the Bell dataset is to be considered valid, then its use should not just be restricted to developing an effect threshold for elevated pH. DEQ used the 2006-2008 continuous data not only for this purpose, but also to quantify temporal variability in the stretch of the tidal fresh between river miles 67 and 95. Using this dataset, DEQ estimated the upper 95% confidence limit of the summertime average chlorophyll-a standard deviation (log-normal) to be 0.396182296 µg/l. The corresponding estimate produced from the Bell dataset is 0.347734817509471 µg/l (see Table 1). Using this estimate of variability and the effect threshold of 47 µg/l, the proposed criteria for the tidal fresh segments would remain unchanged.

Year	Criteria Development Dataset	Bell Dataset
2006	0.389447572	0.462046075
2007	0.307853703	0.305545355
2008	0.244400857	0.196826473
2009	—	0.199938688
2010	—	0.239356215
2011	—	0.367498736
2012	—	0.33692055
2013	—	0.165795743
2014	—	—
2015	—	—
2016	—	0.295249743
mean	0.313900711	0.285464175
U95%CL	**0.396182296**	**0.347734818**

Table 1. Estimates of summer standard deviation (log-normal) derived from the Rice Pier continuous data.[4]

Despite the aforementioned concerns with the quality of the Bell dataset, Bell's suggestion to use LOWESS regression for the tidal fresh chlorophyll-pH relationship may be worth considering. A LOWESS curve was fit through the chlorophyll-pH dataset used by DEQ to develop the proposed tidal fresh criteria (using a simple linear regression model), as shown in Figures 2A and 2B. The LOWESS model predicts an effect threshold of 61 µg/l, which if

[4] According to Bell, the majority of the summer data points collected in 2014 were not retained by VCU due to quality issues. Bell declined to use the 2015 data due to a high number of suspicious observations.

accepted by DEQ would adjust the proposed tidal fresh summer criteria to the same ones recommended by Bell (23 µg/l for JMSTFU and 25 µg/l for JMSTFL).

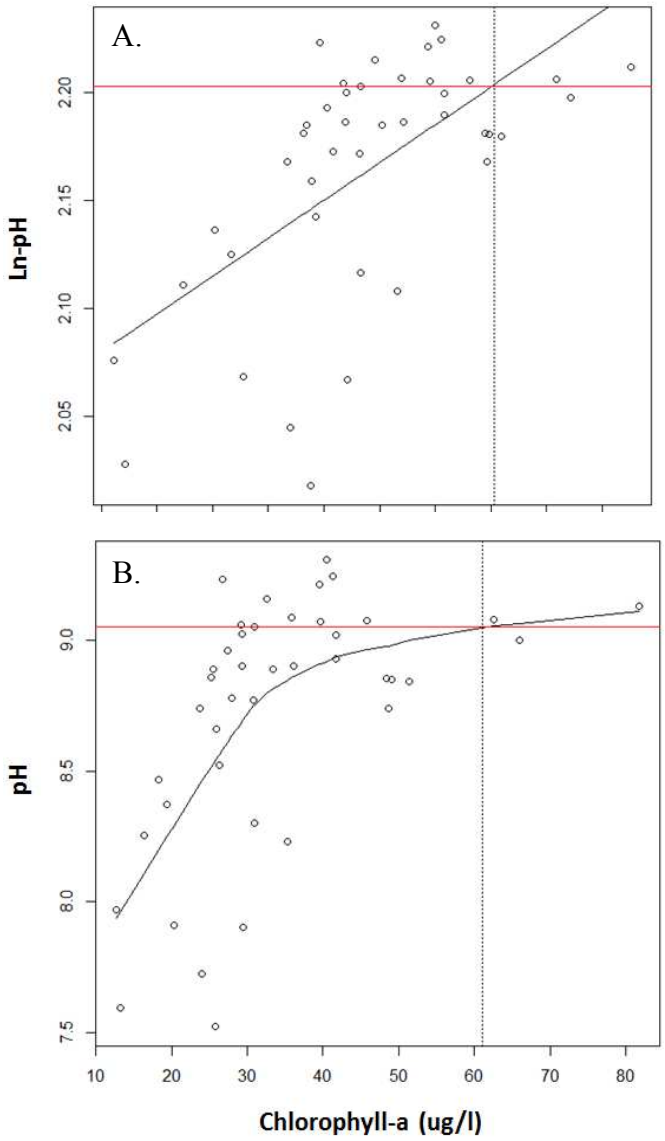

Figure 2. Scatterplot of pH (daily 90th percentile) and chlorophyll-*a* concentration (daily median) from 2006-2008 continuous data taken from the Rice Pier, fit with A) a simple linear regression model (RMSE= 0.37) and B) a LOWESS model (RMSE = 0.35). Red line indicates pH = 9.1. Vertical line indicates the effect threshold. Bandwidth = 0.9076968

On the basis of RMSE, LOWESS regression models were found to be marginally better than all the simple linear regression models that were used by DEQ to estimate other effect thresholds. However, in almost every case the LOWESS model predictions would not result in changes to the proposed criteria. The exception is the effect threshold for microcystin for the tidal fresh. The simple linear regression model predicts an effect threshold of 53 µg/l (Figure 3A). The LOWESS model fit through the same data predicts 48 µg/l (Figure 3B), which would

then shift the proposed summer criteria for the tidal fresh back to the originally recommended numbers (21 µg/l for JMSTFL and 24 µg/l for JMSTFL).

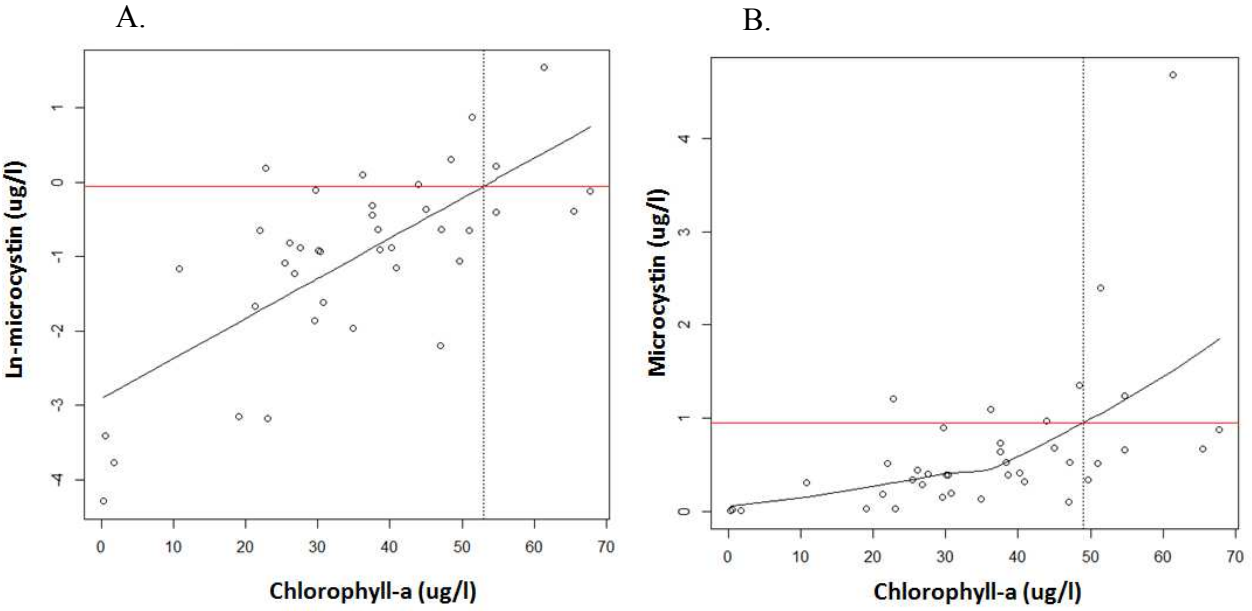

Figure 3. Scatterplot of microcystin and chlorophyll-a concentrations taken at TF5.5A. A) The simple linear regression model (RMSE = 0.71 µg/l) used to develop the effect threshold (chlorophyll=53 µg/l) underpinning the currently proposed criteria. B) The LOWESS model (RMSE = 0.68), which predicts the effect threshold (chlorophyll=48 µg/l). Red line indicates microcystin concentration = 1 µg/l. Bandwidth = 0.7260913

There are strengths and weaknesses to all modeling approaches, and LOWESS is no exception (see the discussion provided by Basu et al., 2015). While LOWESS regression has an advantage over parametric methods like simple linear regression in that it does not presume that data fit any particular distribution, it does require an analyst to specify a smoothing parameter (bandwidth) and the degree of local polynomial. Usually these parameters are chosen based on visual interpretation, but for the models presented here, a computer software program (the R-statistical software package fANCOVA) was used to select parameters on the basis of generalized cross-validation. Another weakness is that LOWESS regression is more "data hungry" than simple linear regression. The datasets shown here are quite modest in size compared to the datasets that are usually explored using LOWESS regression. Finally, relationships discerned using simple linear regression can be more thoroughly compared to each other and can be replicated and scrutinized without the underlying dataset. This is not the case for LOWESS regression. Given these weaknesses and the marginal differences in the goodness-of-fit between the two types of models, DEQ has sufficient cause to continue using the effect thresholds derived from simple linear regression models.

Conclusions

While larger datasets are always more preferable than smaller ones, the breadth of the Rice Pier continuous dataset poses a special challenge. The 2006-2008 continuous dataset, which DEQ used to develop the proposed tidal fresh criteria, was screened by VIMS before it was analyzed by DEQ. Its high quality is evidenced by its accompanying QA/QC flags. The post-2008 continuous data collected at the Rice Pier lack these measures, and this is a very important shortcoming given that unsupervised continuous monitoring is so error-prone. An analyst should not be responsible for ensuring data quality. Thus, DEQ will continue to disregard the post-2008 Rice Pier continuous dataset for the purposes of criteria development until VCU implements a more rigorous QA/QC process for its continuous monitoring program. However, regardless of whether these data are considered valid or not, Clifton Bell's assertion that there are localized effects on pH at the Rice Pier cannot be substantiated statistically.

Bell's recommendation to consider an alternative model (LOWESS) to simulate the tidal fresh summer chlorophyll-pH relationship is well-taken, though. If LOWESS regression is used solely for this purpose, DEQ would have sound justification for adopting the alternative criteria Bell recommends. But the desire for methodological consistency compels the use of LOWESS regression to pinpoint the effect thresholds for all the other metrics examined in the tidal fresh James. Using a LOWESS model to simulate the relationship of the tidal fresh chlorophyll-*a* and microcystin relationship confirms the protectiveness of criteria originally proposed by DEQ. While LOWESS regression is a defensible modeling approach, DEQ believes that simple linear regression is more appropriate given the modest size of the monitoring datasets. For these reasons, no changes will be made to the proposed criteria for the tidal fresh James segments.

References

Basu, K., M.C. Mariani, L. Serpa and R. Sinha (2015) Evaluation of interpolants in their ability to fit seismometric time series. Mathematic s 3: 666-689.

Bell, C. (2017) Comparison of pH and chlorophyll-a at the Rice Center Pier and other stations. Technical memorandum submitted to DEQ on October 31, 2017. 14 pg.

Virginia Department of Environmental Quality (2018) Recommended numeric chlorophyll-a criteria for the James River estuary. 65 pg.