PHILADELPHIA WATER DEPARTMENT

Randy E. Hayman, Water Commissioner

Michael S. Regan
Administrator
Environmental Protection Agency
Office of Water
1200 Pennsylvania Avenue NW
Washington, DC 20460

February 9, 2024

Re: Water Quality Standards to Protect Aquatic Life in the Delaware River
Docket ID No. EPA–HQ–OW–2023–0222

VIA ELECTRONIC MAIL

Dear Administrator Regan,

Via this letter, the Philadelphia Water Department (PWD) is submitting comments that were originally provided to DRBC regarding draft DRBC documents and work products that, in part, serve as the critical scientific and technical foundation of EPA's December 21, 2023 proposed rulemaking *Water Quality Standards to Protect Aquatic Life in the Delaware River* (Docket ID No. EPA–HQ–OW–2023–0222).

PWD is a member of DRBC's Water Quality Advisory Committee and participated throughout DRBC's work to assess the attainability of water quality standards for zones 3, 4, and upper zone 5 of the Delaware River prior to EPA's Administrator's Determination regarding proposed federal water quality standards for these zones.

On January 19, 2023, PWD submitted the attached letter to EPA Office of Water and EPA Region 3 after reviewing the EPA's Determination. PWD's letter included previously submitted comments on several DRBC draft documents, including:

- November 23, 2022 Letter to Namsoo Suk, DRBC, PWD comments on DRBC draft report *Analysis of Attainability: Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary.*
- March 28, 2022 Letter to Jake Bransky, DRBC, PWD Comments on DRBC draft report *Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary*
- December 16, 2022 Letter to Thomas Amidon, DRBC, PWD comments on DRBC draft report *Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary*
- February 14, 2022 Letter to Thomas Amidon, DRBC, PWD comments on DRBC draft report *Modeling Eutrophication Processes in the Delaware Estuary: Three-Dimensional Hydrodynamics Model for the Delaware Estuary.*

PWD is also including our February 9, 2018 Letter to John Yagecic, DRBC, regarding DRBC/ANS draft *Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary.*

As the majority of these DRBC reports were never finalized, nor were any responses received from DRBC or EPA addressing PWD's comments, PWD respectfully requests that EPA review and consider these previous comments on DRBC's technical reports as part of the official administrative record for the proposed rule.

Sincerely,

Jason Cruz
Environmental Scientist
Philadelphia Water Department

PHILADELPHIA WATER DEPARTMENT
Randy E. Hayman, Water Commissioner

Radhika Fox
USEPA Assistant Administrator
1201 Constitution Ave NW
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January 19, 2023

Deborah Nagle
Director, USEPA Office of Science and Technology
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Ms. Lisa Garcia
USEPA Region 2 Administrator
290 Broadway
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Mr. Adam Ortiz
USEPA Region 3 Administrator
1600 John F. Kennedy Boulevard
Philadelphia, PA 19103-2852

VIA ELECTRONIC MAIL

Dear Assistant Administrator Fox, Director Nagle, and Regional Administrators Garcia and Ortiz,

The City of Philadelphia Water Department ("PWD") has reviewed EPA Administrator's Determination[1] letter, dated December 2, 2022, regarding proposed federal water quality standards ("WQS") for zones 3, 4, and upper zone 5 of the Delaware River in response to a petition from environmental groups. PWD is concerned that EPA's determination substantively relies on a draft DRBC report *Analysis of Attainability: Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary* ("AA Report"), as well as related technical reports prepared by DRBC staff pursuant to DRBC Resolution 2017-04[2].

PWD has submitted the following comments to the DRBC, which are attached to this letter as Appendices:

- -Comments on the DRBC draft AA Report to DRBC, dated Nov 23, 2022 (Appendix A);
- -Comments on DRBC reports linking dissolved oxygen and aquatic life uses, dated March 28, 2022 and December 16, 2022 (Appendices B and C); and
- -Comments on DRBC's hydrodynamic modeling report, dated February 14, 2022 (Appendix D)

[1] https://www.epa.gov/system/files/documents/2022-12/Administrator-Determination-DRBC-December-2022.pdf
[2] https://www.nj.gov/drbc/library/documents/Res2017-04_EstuaryExistingUse.pdf

PWD requests that EPA review and give consideration to PWD's comments when determining the need for and attainability of changes to WQS for zones 3, 4, and upper zone 5 for protection of aquatic life uses. PWD shares the goal of protecting and restoring Delaware estuary sturgeon and other aquatic life with EPA, DRBC and the basin states. We look forward to working with all basin stakeholders to build on past successes, continue to make progress, and identify attainable water quality improvements that are based on sound science, technologically feasible; and especially – equitable and affordable for communities. If EPA has any questions regarding PWD's comments, please contact Jason Cruz (jason.cruz@phila.gov).

Sincerely,

Marc Cammarata, PE
Deputy Commissioner, Planning & Environmental Services
Philadelphia Water Department
1101 Market St. 5th Floor
Philadelphia, PA 19107

CC:
Melanie Garrow, Kelly Anderson, Jason Cruz (PWD)
Steve Tambini (DRBC)
Javier Laureano, Brent Gaylord, Wayne Jackson (EPA Region 2)
Catherine Libertz, Kuo-Liang Lai, Greg Voigt (EPA Region 3)
Charles Hurst (DELCORA)
Scott Schreiber (CCMUA)

Appendix A

PWD Comments on DRBC Sept 30, 2022 Draft Report *Analysis of Attainability: Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary*

(Including PWD Comments on Sept 2022 DRBC Draft Reports *Social and Economic Factors Affecting the Attainment of Aquatic Life Uses in the Delaware River Estuary Nitrogen Reduction Cost Estimation Study*, and *Modeling Eutrophication Processes in the Delaware River Estuary: Three-dimensional Water Quality Model*)

Dr. Namsoo Suk
DRBC Science and Water Quality Management Director

November 23, 2022

Dear Namsoo,

PWD appreciates the opportunity to provide informal comments on DRBC's September 2022 draft report entitled *Analysis of Attainability: Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary* ("AA Report"). PWD has also reviewed and is providing comments on supporting DRBC documents, including the draft *Social and Economic Factors Affecting the Attainment of Aquatic Life Uses in the Delaware River Estuary* ("Socio-economic Report"), *Nitrogen Reduction Cost Estimation Study*, *Modeling Eutrophication Processes in the Delaware River Estuary: Three-dimensional Water Quality Model* ("Water Quality Model Report"), and *Modeling Eutrophication Processes in the Delaware Estuary: Three-dimensional Hydrodynamics Model for the Delaware Estuary* ("Hydrodynamic Model Report").

Overall, PWD commends DRBC on the transparency and openness shown throughout the Analysis of Attainability effort. DRBC has utilized the Water Quality Advisory Committee (WQAC) to communicate with permitted dischargers and affected stakeholders, solicited data and socio-economic information from dischargers, repeatedly met with dischargers and discharger groups such as the DO Partnership, and lastly, made some changes in response to previous stakeholder comments on DRBC model reports and presentations.

PWD has organized its comments into separate sections for general comments; detailed comments, questions, and requests related to the draft AA Report; and detailed and editorial comments related to the Water Quality Model Report. Comments on all reports reviewed are included in this single letter due to applicability of comments to more than one report. We look forward to working with DRBC and co-regulators to ensure that the Analysis of Attainability is based on sound science, appropriate water quality management principles, and equitable allocation of costs that are affordable to communities. If DRBC should have any questions regarding PWD comments, please contact Jason Cruz (jason.cruz@phila.gov) or Kelly Anderson (kelly.anderson@phila.gov).

Sincerely,

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Philadelphia Water Department
1101 Market St. 5th Floor
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CC:
Melanie Garrow, Kelly Anderson, Jason Cruz, Kinman Leung (PWD)
Steve Tambini, Thomas Amidon, Namsoo Suk (DRBC)

GENERAL COMMENTS

1. **PWD's Comments on the draft AA report and supporting documents should be considered preliminary based on the informal draft status of the AA report and unavailability of several key supporting documents. PWD reserves the right to submit additional comments on future versions of the AA Report and supporting documents.**

   PWD has reviewed the draft AA report and supporting documentation provided to date in earnest, recognizing that DRBC intends to make additional edits and provide additional information in draft or updated versions of supporting reports. PWD notes that DRBC has indicated that the Nitrogen Reduction Cost Estimation Study will be updated to include estimates for capital and operating costs for selected dischargers to maintain effluent DO at or above 4 mg/L. DRBC has also committed to updating construction cost estimates in the draft Socio-economic Report and releasing an updated Hydrodynamics Model Report.

2. **Conclusions regarding attainability of Aquatic Life Uses and affordability in the draft AA report are premature and inappropriate pending needed changes in the Socio-economic report and due to the incomplete status of other supporting documentation.**

   DRBC Resolution 2017-04 to "Review the Designated Aquatic Life Uses and Associated Water Quality Criteria for Zones 3, 4 and a Portion of Zone 5 of the Delaware Estuary" requires an "evaluation of the *physical*, *chemical*, *biological*, *social* and *economic* factors [emphasis added] affecting the attainment of uses". Several of these critical factors have yet to be fully considered, as discussed in more detail below.

3. **DRBC's draft AA report improperly frames the analysis as a determination of the "Highest Attainable Dissolved Oxygen" condition, rather than an analysis of aquatic life uses currently being attained or uses that would be attainable considering physical, chemical, biological, social and economic factors.**

   While DRBC Resolution 2017-04 is not a Use Attainability Analysis *per se*, the Resolution's "steps required before rulemaking" are based on attainability factors as described in the federal Clean Water Act at 40 CFR § 131.10(g). The "highest attainable dissolved oxygen" condition is not mentioned in or supported by the Clean Water Act or USEPA guidance. DRBC's draft AA report should be revised to first evaluate whether aquatic life uses are currently being attained. If uses are not being attained, DRBC should then determine the "highest attainable use", which is a combination of 1.) the use itself, and 2.) the water quality that supports the use, after fully considering the physical, chemical, biological, social and economic factors that affect attainability.

4. **The Socio-economic Report contains critical deficiencies, causing it to understate the burden on affected communities. Despite these biases, cost estimates for ammonia removal scenarios in the draft AA and Socio-economic Reports identify a high burden for affected communities for many measures of economic impact. These increased wastewater treatment costs would represent a substantial and widespread social and economic impact. The draft AA Report in its current state demonstrates that the proposed**

use is unattainable, and correction of the Socio-economic Report deficiencies will only strengthen this conclusion.

As stated in the draft AA Report, estimated costs for many ammonia removal scenarios would place a “high burden” on ratepayers in affected communities. These impacts are also inequitably distributed along social and demographic dimensions, raising fairness and environmental justice concerns.

5. **Use of 2021 costs and rates as the basis for cost estimates in the draft AA and Socio-economic Reports are only a snapshot of utility costs (*i.e.*, in recent/2021 dollars). 2021 rates only include CSO Long Term Control Plans (LTCPs) and other regulatory compliance costs as of FY 2021. Projected future revenue increases, that more fully capture the implementation of CSO Long Term Control Plans (LTCPs) along with other anticipated regulatory compliance costs provide a better sense of the potential financial burden placed upon the City and its customers. In PWD’s case, estimated wastewater and stormwater costs were provided to DRBC through 2026 based upon cost projections at that time. It is unclear how these data were utilized in the analysis. Correction of this critical bias will only strengthen the conclusion that the proposed use is unattainable.**

As stated above, estimated costs for many ammonia removal scenarios would place a “high burden” on ratepayers in affected communities. By focusing on 2021 rates and costs for wastewater conveyance and treatment (and therefore not including costs over the next few years), DRBC’s analysis does not include substantial increases in ratepayer costs that are projected for the ongoing ramp up in implementation of CSO Long Term Control Plans or increases required for other regulatory programs. The impact of proposed changes to wastewater treatment would be even more severe for affected communities if these additional costs are taken into consideration. Additional comments regarding these aspects of the Socio-economic Report are presented in the technical comments section below.

Beyond the above comments, the previously provided rates and projections of future operating expenses and capital financing costs do not include recent cost impacts related to inflationary pressures. PWD would caution DRBC in relying upon previous rates and outdated cost projections to assess the financial implications of attainability. Current economic conditions and recent inflation data resemble escalation in costs that have not been seen since the 1970s. As such, previously provided operating expense projections likely significantly underestimate costs. Debt service cost projections are likely to underestimate both capital improvement costs as well as interest payments related to the issuance of revenue bonds. Further, DRBC did not request future projections of water operating and capital related expenses. In the case of PWD, the provided 2021 rates do not reflect the planned improvements and system expansion under the Department’s Water Revitalization plan, potential increased regulatory costs related to the lead and copper rule (among other regulatory updates), nor do the capture major operating costs implications related to increased salary costs, employee benefits, natural gas, electricity and chemical costs.

PWD strongly recommends that DRBC consider obtaining updated rate and cost data from all utilities participating in this study to better evaluate and understand the future cost implications of the proposed attainability targets. More current economic circumstances and financial pressures facing both utilities and their customers should be considered in the evaluation process and used in DRBC’s ultimate conclusions in this matter.

Further, as noted in the response to the data request, PWD's 2021 rates were established assuming the use of the Department's Rate Stabilization Fund, which serves as the Department's primary reserves, to help mitigate and manage the level of rate increases. FY 2021 rates therefore do not reflect the full cost of service for water or wastewater (including sewer and stormwater) related services.

6. **DRBC should evaluate additional scenarios representing phased implementation of reasonable and cost-effective ammonia removal improvements and changes in the distribution of ammonia loads by major dischargers in the draft AA Report.**

Given the widespread social and economic impact that would be imposed on ratepayers for the proposed ammonia removal scenarios and high level of uncertainty surrounding benefits of proposed changes, PWD urges DRBC to evaluate the potential ammonia load reduction and modeled DO increase for scenario(s) in which certain major dischargers implement cost-effective ammonia reduction strategies. DRBC Resolution 2017-04 recommended consideration of these "early actions" to be investigated by major dischargers concurrent with DRBC's Analysis of Attainability. PWD has designed a sidestream treatment facility to treat high strength ammonia centrate from biosolids handling that presently contributes to elevated ammonia loading at the PWD SWWPCP. Other major dischargers have also investigated similar projects. The combined ammonia reduction attributable to these projects and changes is estimated at 12,500lbs/day or approximately 20% of the current ammonia load from Tier I dischargers.

7. **DRBC should consider an adaptive management strategy that pairs phased, incremental, and adjustable investments with continued monitoring, rather than mandating aggressive, unaffordable ammonia load reductions from point source dischargers.**

In its singular focus on point sources, DRBC's proposed HADO approach would require substantial public investment tied to relatively uncertain assumptions. Much uncertainty remains regarding relative DO depletion due to nitrification and other processes, potential benefits to be realized for aquatic life uses, and unintended environmental consequences of building massive new facilities with expanded energy and chemical needs. In the current water management environment, which is generally moving away from prescriptive investments and compliance schedules, an adaptive approach – as advocated by USEPA and codified into the Clean Water Act in 2019 – is not only well justified, but almost essential.

An adaptive management approach would couple incremental reductions in ammonia with continued monitoring of DO and fish communities to gauge the effectiveness of incremental investments and adapt as necessary prior to making enormous and uncertain investments. Such an approach also resonates with the continual and commendable upward trends in DO in zones 3, 4 and upper zone 5 over the past decades.

8. **In August 2020, PWD submitted comments on DRBC's Nitrogen Reduction Cost Estimation Study, indicating that some of the technologies described as "technically feasible" to achieve prescribed effluent limits would not be technically feasible for implementation at PWD's facilities.**

PWD requests that DRBC incorporate cost estimates associated with applicable, feasible technologies into its draft Socio-economic and AA Reports; PWD can share cost estimates developed through its own facility-specific wastewater treatment ammonia and total nitrogen removal alternatives analyses.

9. **Ammonia loads in the draft AA report baseline scenario are unrealistic and over-conservative due to "double counting" the flow from DELCORA Eastern Service District at both DELCORA and PWD SWWPCP.**

PWD understands that DRBC amended the Nitrogen Cost Estimation study and baseline loads in the draft AA report to reflect a re-rating of the DELCORA wastewater plant from 40MGD to 70MGD, however this flow is not a new source of pollutant loading to the estuary. The flow in question is currently treated at the PWD SWWPCP, where it is accounted for in the 200MGD permitted flow. Including this flow and associated loads in the baseline scenario overestimates the actual pollutant loading to the estuary.

10. **Cost estimates in the draft AA and Socio-economic Reports are expressed in 2019 dollars corresponding to the September 2019 Engineering News Record Construction Cost Index (ENRCCI) and must be updated as soon as possible to reflect current costs.**

PWD understands from previous communications with DRBC staff that DRBC and its contractor intend to update cost estimates in the Nitrogen Reduction Cost Estimation Study, draft AA Report, and Socio-economic Report to be consistent with present-day costs based on the ENRCCI. Given that updated cost increases over the 2019 ENRCCI values are substantial and would likely affect the interpretation of affordability for some communities, the draft AA and Socio-economic Reports are currently unsuitable for stakeholder review due to outdated, unrealistically under-estimated costs.

As previously noted, PWD strongly recommends that DRBC obtain updated rate and cost data from all utilities participating in this study given current inflation levels. Recent cost indices data clearly illustrates the need to update all cost estimates (including operating and capital related data) as illustrated in the tables below.

Index	Average Annual Change[1] 12-Month	24-Month	36-Month
CPI - All Urban Consumers Philadelphia Area	7.77%	6.70%	4.69%
PPI - Materials for Construction	12.16%	15.34%	11.67%
PPI - Construction Machinery & Equipment	10.12%	9.41%	6.63%
PPI - Industrial Chemicals	4.89%	23.82%	11.43%
CPI - Electricity Philadelphia Area	18.67%	10.48%	6.59%
CPI - Gas Philadelphia Area	37.45%	21.46%	10.92%

1) Period Ending October 2022

Index	Average Annual Change[1] 12-Month	24-Month	36-Month
H.W. Index Cost of Construction Pump Plant - Equipment	10.93%	7.67%	8.10%
H.W. Index Cost of Construction Treatment Plant - Equipment	9.76%	7.79%	6.75%
H.W. Index Cost of Construction Transmission Plant - Steel Mains	23.79%	12.67%	9.72%
H.W. Index Cost of Construction Distribution Plant - Mains	11.44%	7.78%	6.31%
H.W. Index Cost of Construction Distribution Plant - Meters	9.82%	6.44%	5.37%
McGraw-Hill (ENR) Construction Cost Index[2]	8.24%	7.07%	5.18%

H.W. = Handy-Whitman
1) Period Ending in January 2022
2) Period Ending in June 2022

11. Socio-economic and demographic information for household affordability metrics should be based on the largest available sample sizes from the most representative geographical areas for populations that would be impacted.

As acknowledged by DRBC in the draft AA and Socio-economic Reports, economic and demographic estimates from population-weighted aggregation of census tract data are subject to bias. DRBC has addressed this discrepancy by evaluating socio-economic metrics at both the county and tract level. PWD notes that while the Philadelphia county-level census geography is congruent with PWD's service population as assessed in the draft AA Report, other Tier I discharger counties may have a wider range of income inequality or heterogeneity in socio-economic factors affecting affordability. There may be instances where a different census geographic level other than tract or county levels may provide more appropriate socio-economic characteristics estimates for potentially affected communities.

While the Water Department has a robust assistance program via the Tiered Assistance Program (TAP), which provides protection to the Department's most vulnerable customers by allowing them to pay a fixed bill based upon a percentage of their income, not all low-income customers are currently enrolled in this program. Further, the cost of providing discounts to TAP customers is borne by all other water and sewer retail customers. It is unclear from the analysis as well as the underlying financial capability assessment and household affordability guidance, how the above factors can be taken into account in this analysis.

12. **DRBC's AA Report ammonia reduction scenarios are not based on a fair and equitable equal percent removal, equal effluent concentration, or an equal cost formula for all sources of ammonia or even all point sources of ammonia. The AA scenarios inappropriately limit additional ammonia removal controls to a few large point source dischargers, which would lead to inequitable distribution of costs and eliminate options for flexibility in permitting and creative implementation approaches.**

    While contributions of ammonia from smaller point source dischargers (and other sources in general) were modeled as having small or unmeasurable effects on DO, all ammonia loads contribute to the DO sag regardless of whether they can be modeled at the scale of DRBC's water quality model. Relative ammonia loading per capita for other point source discharges may also be as high or higher than the selected Tier A and/or Tier A' dischargers. This inequitable distribution of costs raises fairness and environmental justice concerns. While focusing on the largest loads may make sense from a technical standpoint, ignoring loads from smaller dischargers effectively eliminates incentives for creative and/or more equitable implementation approaches such as trading.

13. **DRBC's baseline scenario is unrealistic and excessively conservative, which could lead to selection of controls that are excessively conservative and unaffordable for affected communities.**

    The draft AA Report "design condition" uses relatively dry and warm 2012 hydrologic conditions coupled with permitted flow rates and seasonal median pollutant concentrations for dischargers. This scenario is an unrealistic combination of conditions, as dischargers do not discharge at permitted flow rates under dry conditions. Additional comments regarding the design condition and alternative scenarios are presented in the technical comments section below.

14. **DRBC's selection of an overly conservative design condition scenario baseline inflates the projected DO increase under alternative ammonia removal scenarios.**

    As described above, ammonia load calculations in DRBC's design condition are overly conservative. This discrepancy leads to overly conservative ammonia load calculations and an unrealistically low DO condition for the baseline, inflating the projected DO increase from baseline conditions under ammonia removal scenarios. The DO increase "benefit" of ammonia reduction scenarios would be much smaller if realistic and appropriate assumptions were used for the baseline.

15. **DRBC's draft AA Report places too little emphasis on observed DO and does not evaluate the duration, magnitude, and frequency of biologically relevant DO statistics under existing conditions.**

    While DRBC's draft AA and Water Quality Model Reports include basic boxplot charts of historic observed DO data, the reports are predominantly focused on an unrealistic baseline "design condition", divorced from the biologically relevant and important duration, magnitude, and frequency of actual observed DO conditions. Additional technical comments regarding existing DO water quality and model evaluation metrics are presented in the technical comments section below.

16. **DRBC's "critical propagation season" (May 1 through October 15) in the draft AA and Water Quality Reports is overly conservative and could lead to selection of controls that are excessively conservative and unaffordable for affected communities.**

The selected period of May 1 through October 15 for proposed ammonia reductions may be longer than biologically necessary in most years due to the interaction between water temperature and dissolved oxygen in the receiving water. This timeframe is also unjustifiable from a wastewater treatment perspective, as the resulting implementation window for ammonia removal could require start-up and/or maintenance of temperature-dependent and sensitive wastewater treatment processes such as nitrification during cooler periods when DO water quality conditions are favorable for aquatic life yet wastewater treatment conditions for ammonia removal are potentially very challenging.

17. DRBC should recognize in the draft AA and related supporting reports that the physiological effects of hypoxia (low DO) are caused by the partial pressure, or percent saturation of DO. DO percent saturation should be used when comparing DO conditions to suitable levels to support propagation in general.

While DO can be measured in concentration units of mg/L, it is the partial pressure of oxygen, or percent saturation, that is responsible for the physiological adverse effects of hypoxia on fish and other aquatic life. Using percent saturation will make it easier to compare DO conditions or model results at different temperatures. For comparison purposes, the saturation level of 5 mg/L DO, which is suggested as a suitable DO level for all fish species in all seasons, is equivalent to 55% saturation at 20º C (or 4.55 mg/L DO at 25º C or 4.15 mg/L DO at 30º C).

18. DRBC should include a description of the benefits of the proposed changes, including the marginal benefits of increased DO and fish propagation compared to existing conditions.

Benefits described in the current draft AA and Socio-economic Reports are limited to describing projected DO increases (expressed as magnitude of increase in minimum DO in mg/L, percent of time over certain threshold values, and Relative Stress Index, "RSI") over a conservative baseline low DO scenario. Even if the effects of proposed changes to wastewater treatment on DO and fish propagation are uncertain, DRBC should include estimates of the marginal benefits of increased DO (in terms of magnitude, duration, and frequency) and fish propagation. Ratepayers that would be responsible for increased costs have the right to understand the benefits associated with the proposed changes.

19. The draft AA Report makes claims of a direct causal relationship between DO and fish populations in the Delaware estuary without sufficient supporting evidence.

Statements regarding potential effects of low DO should be appropriately qualified to reflect the uncertainty of factors affecting fish populations in general, and fish propagation in particular. For example, the draft AA Report states, "DO levels below 4.3 mg/L will not support propagation of one or more DO-sensitive species in the Delaware River Estuary"; this is based on interpretation of laboratory studies, not an empirical observation from the Delaware Estuary. It would be more appropriately stated that such DO levels are within a range that produced adverse physiological effects in some laboratory studies. PWD is unaware of any direct (*i.e.*, pathological) evidence or mesocosm studies that conclusively show a causal effect of ambient low DO water quality conditions on propagation of sturgeon or other fish species in the Delaware Estuary.

20. The draft AA Report does not adequately utilize or address observed fish data in its conclusions about attainability of aquatic life uses.

PWD has commented previously that DRBC's Analysis of Attainability should establish baseline population and propagation information for species of concern, including all threats and stressors.

Additional information has become available since DRBC's 2015 review of the status of propagation for select fish species in the Delaware Estuary. For example, the Delaware Department of Natural Resources and Environmental Control (DNREC) and a contractor for the US Army Corps of Engineers navigation channel deepening project have documented more than 5,000 records of juvenile sturgeon from the urban Delaware river in DRBC zones currently designated for fish maintenance between 2014 and 2019. As the juvenile sturgeon life cycle begins in freshwater and salinity tolerance develops gradually, fish in the first two years of life are geographically restricted and exposed *in situ* to the DO regime of their natal estuaries, making them excellent indicators of propagation and growth. The relative importance of other anthropogenic stressors such as vessel strikes and bycatch in commercial fisheries has also evolved since DRBC's 2015 review. PWD anticipates providing more information on observed fish data and submitting additional comments for DRBC's second draft DO Report by December 16, 2022.

21. **The DO budget in the calibrated eutrophication model may not be accurately representing the processes in the river by overstating the influence of nitrification and SOD on DO sinks in the model and understating the influence of phytoplankton.**

    This should be addressed in the Water Quality Model Report as it has implications for the DO results estimated in the Analysis of Attainability scenarios. Additional technical comments regarding the DO budget in the eutrophication model calibration are presented in the technical comments section below.

22. **The metrics used to evaluate the eutrophication model calibration in the Water Quality Model Report should focus on shorter time periods, with an emphasis on the critical summer DO period, to understand how the model responds during the period that will be the focus of management decisions.**

    These additional metrics should be included in the Water Quality Model Report as the ability of the model to represent observed DO conditions during the critical low DO periods during calibration years is important to ensure that the model can adequately estimate low DO conditions in the Analysis of Attainability scenarios. Additional technical comments regarding metrics related to the eutrophication model calibration are presented in the technical comments section below.

23. **Outstanding questions on the hydrodynamic model, submitted as comments on the Hydrodynamics Model Report in February 2022, have implications for the eutrophication model, especially concerns over constituent transport and modeled water temperature, and need to be addressed before the final Water Quality Model Report can be reviewed.**

24. **In conclusion, based on the serious concerns regarding the social and economic impact of proposed changes to achieve ammonia removal, lack of supporting documentation, technical and water quality modeling issues, uncertainty of benefits, and issues of equity and environmental justice, PWD cannot support the draft AA in its current form.**

25. **PWD thanks DRBC for their continued communication and cooperation regarding the analysis of attainability of aquatic life uses as well as thoughtful consideration of our comments on the draft AA and supporting documentation. PWD kindly requests a meeting with DRBC to discuss our comments and concerns regarding the draft AA and Socio-economic Reports.**

DETAILED COMMENTS

Throughout this Detailed Comments section, the following reports may be referenced

- Draft Analysis of Attainability: Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary ("AA Report"),
- Draft Social and Economic Factors Affecting the Attainment of Aquatic Life Uses in the Delaware River Estuary (“Socio-economic Report”),
- Nitrogen Reduction Cost Estimation Study,
- Modeling Eutrophication Processes in the Delaware River Estuary: Three-dimensional Water Quality Model (“Water Quality Model Report"), and
- Modeling Eutrophication Processes in the Delaware Estuary: Three-dimensional Hydrodynamics Model for the Delaware Estuary (“Hydrodynamic Model Report").

1. Draft Analysis of Attainability Report

Comments within this section mirror the structure of the draft AA Report, unless there were no comments for a particular section of the report, in which case that section is omitted. Comments will be bolded with supporting text below and any section with more than one comment will have comments numbered. Note, any page number references refer to the page number of the actual draft AA Report (as opposed to the PDF page number).

1.1. Analysis of Attainability Methodology

Water Quality Model

Comments on the calibrated water quality model (as well as the draft Water Quality Model Report) have been included in a separate, dedicated section: **4. Water Quality Model Report**.

Metrics to Compare Scenarios

1. **PWD understands that DRBC has selected a conservative “design condition” for developing the AA baseline and ammonia effluent reduction scenarios and presenting model-simulated DO results. Concerns over the conservative baseline aside, and acknowledging that DRBC presented boxplot charts of observed July & August DO conditions 2010-2022, PWD urges DRBC to more fully contextualize the results from model simulations of DO with long-term observed DO data, not merely the 2012 design condition. Wastewater treatment characteristics and continuous water quality monitoring have remained relatively stable in the estuary over the past 20 years. A very robust data set exists for DO conditions in the estuary, which would allow DRBC to develop more robust metrics, such as empirical DO cumulative distribution function curves for different durations. PWD notes that simulated improved DO levels in the design conditions attributable to ammonia reductions are already being achieved and even surpassed in most years monitored.**

2. **In general, the documentation of how the metrics were calculated from the WASP eutrophication model results for the Analysis of Attainability scenarios and sensitivity analysis should be more detailed. From the draft AA Report text, it is unclear how the 3D and 2D model results were post-processed into the timeseries on which the Longitudinal Percentile and “Percent-Above” Plots, Relative Stress Index, and Tabular Maps were based. More detail on the metrics calculations is needed to evaluate and recalculate the metrics related to the results shown in the draft AA Report.**

3. **PWD suggests that DRBC provide additional metrics and plots to evaluate the draft AA Report results, including DO timeseries of model results, baseline and ammonia effluent reduction scenario model results compared to actual 2012 observed DO data, and the fraction of the critical propagation season that was below a 5 mg/L DO threshold.**

Metrics included in the Water Quality Model Report were often calculated on an annual basis, and not focused on the critical periods for DO. When put in context with the baseline scenarios that are focusing on low DO at the 1st percentile, there is the potential that if the calibrated model does not perform as well in the lower critical range of DO values, the metrics for the results of the Analysis of Attainability may not be valid. As stated below in our comments on the Water Quality Model Report, results metrics for the critical DO period are necessary to demonstrate that the water quality model has adequate performance to assess the Analysis of Attainability scenarios.

In addition, results from both the 2012 baseline 2D and 3D models should be plotted against the 2012 observed data. Timeseries of DO results from the 2012 baseline model should also be plotted with the results of the different ammonia reduction scenarios at the monitored locations. Another possible metric may be during what fraction of the "critical propagation season" DO was simulated to be less than 5 mg/L. For example, under the baseline condition, DO is less than 5 mg/L in all months, but with the proposed improvements, it is less than 5 mg/L only in the months of July and August.

Longitudinal Plots: DO Percentiles and "Percent-Above"

The 1st percentile is an extreme condition and does not exhibit correlation between the baseline scenario and historic measurements of DO over the past decade.

It may be more useful to include a series of frequency-exceedance curves within the FMA for each scenario, perhaps at the upstream and downstream ends of the FMA and at the point of lowest DO. These could be evaluated more effectively in the context of suitable biological habitat, while not losing the information on the lower percentiles. While the 1st percentile can be used as a surrogate for the minimum DO, a better measure in the context of attainability may be to evaluate alternatives against higher percentiles, such as 5% or 10%, which are less extreme.

DO Relative Stress Index

The DO Relative Stress Index ("RSI") is a novel index developed by DRBC with the intention of measuring theoretical increasing stress to aquatic life as DO decreases. Given its complexity, untested theoretical basis, and uncertain applicability of the RSI to fish populations in the Delaware estuary, PWD recommends discontinuing the use of the RSI metric and revising the AA and water quality model reports to express DO metrics in units of DO percent saturation, which is the factor responsible for physiological effects of hypoxia on fish and other aquatic life. If continued to be used at all, the RSI should be re-formulated to use DO percent saturation DO rather than DO concentration.

DRBC considered observed data from short-term experiments on the effects of hypoxia on shortnose sturgeon by Jenkins, *et al*. 1993 to parameterize a severity exponent term K_s that varies from $K_s = 1$ at 5mg/L DO to $K_s = 2.5$ at 2.5mg/L DO. The final computed RSI value for a given time series is the cumulative sum of severity of exposure to low DO over time. The RSI more heavily weights exposure to increasingly lower DO values. PWD has concerns regarding the underlying assumptions for the RSI, parameters chosen to develop the index, and applicability of the general relative stress function to different life stages of fish and other aquatic life in the Delaware estuary.

By using DO concentration rather than DO percent saturation, the relative stress index fails to fulfill its basic premise – which is to measure relative stress over time – when applied to an estuary with temporal variations in DO and temperature. Many species of interest in the Delaware river exhibit annual cycles in reproduction with spawning typically occurring in spring and larval and juvenile growth occurring during summer and fall. Typical temperatures may vary between approximately 15-30 ºC for the period of active growth between May and October. Assuming freshwater (salinity = 0), DO saturation concentration values vary between 7.6-10.1mg/L in this temperature range. As formulated with DO concentration, time series model output or observed data with similar RSI values could have substantially different effects on aquatic life due to the timing and severity of low DO conditions relative to temperature and life stage exposed. The RSI calculated for a given time series could underestimate effects during cooler portions of the growing season while identifying or exaggerating stress during warmer portions of the growing season when DO concentration may be lower than the RSI baseline value (*e.g.*, 5mg/L) but DO percent saturation remains suitable to support larval survival and juvenile growth.

It is not clear from the draft AA Report discussion how a Relative Stress Index (RSI) value correlates to stress on aquatic life.

As DRBC notes in Section 2.3.2, stress caused by low DO conditions is a combination of frequency, magnitude, and duration. However, it is unclear how RSI accounts for these factors. It would be helpful to provide an illustrative example of the application of RSI to DO improvements *(e.g.*, show how RSI decreases when DO increases from 3.5 mg/L to 4 mg/L). It would also be helpful to indicate whether there is a maximum RSI value that permits the desired aquatic life use to be attained.

If, as is stated in Section 2.3.2, a DO increase of equivalent magnitude starting higher on the DO scale represents less relative stress reduction than it would starting lower on the scale, the stress reduction may be exaggerated by starting at a hypothetical value significantly lower than what has been observed. Phrased differently, because the baseline condition represents a hypothetical future scenario, changes in relative stress index might more accurately be presented as "potential avoidance" results rather than improvement, which is the intuitive interpretation.

Also, it would help to clarify how the index changes as the starting point moves up and down the scale – the listed reference point is 1 = 1 day at 4 mg/L, but it isn't clear how the index exhibits "exponentially more stress" for lower DO values than higher, as stated in Section 2.3.2.

Tabular Maps

The tabular maps of DO results can be a useful way to communicate model results. However, the results in Figure 2-4 on page 15 show that in the 3D baseline scenario, the minimum DO is 2.1 mg/L, which is considerably lower than observed DO values, including the actual year 2012. This raises some concerns with the baseline scenario, which is discussed in other comments.

Design Condition

1. **DRBC's choice to use 2012 as the basis for its baseline scenario requires further elaboration.**

While 2012 experienced the most extreme DO condition in the recent decade, the analysis did not explore and/or adequately explain what caused the 2012 DO condition to be worse than other dry years. For instance, the summers of 2015 and 2016 were drier than 2012 but did not experience as extreme low DO.

The processes that caused the 2012 DO condition should be represented in the model and explained in the reports. The variability in observed conditions should be represented in the analysis and its impact on the model results should be analyzed and documented. Understanding the causes and probability of occurrence of low DO conditions in the period since WWTP upgrades in the 1990s would help to determine the most appropriate year or condition to use for an attainability analysis baseline condition, as 2012 seems to be an extreme year.

While DRBC states that the choice of 2012 as the basis for the baseline scenario is justified because "dry weather and low flow from tributaries in 2012 brought lower DO in the Estuary, likely due to less dilution by ambient waters and longer residence time for the consumption of oxidizable organic material than during other years over the last decade" (page 17), this should not exclude other years from being candidates for the baseline scenario basis.

PWD recommends that DRBC include in its draft AA Report an investigation of other dry years and their associated DO and hydrologic conditions as well as a detailed exploration of the causes of the extreme DO condition observed in 2012.

2. **Some discussion on the treatment of temperature and how observed water temperature in the critical period in 2012 compares to other years in the period of record should be included. Water temperature and its relationship to DO saturation in the river is a very important driver in DO concentration not to be overlooked.**

Wastewater Characteristics

Use of WWTP permitted flow rates for the baseline condition risks calculation of overly conservative effluent loadings, especially considering that actual WWTP discharges during critical dry periods in the summer are unlikely to reach the permitted flow rates. This methodology may have implications for the determination of effluent limits; if effluent ammonia load is overestimated by using permitted flow rates, there could be an overstatement of the load reduction required in the Analysis of Attainability scenarios.

More background information on actual wastewater flows and loads is needed in the draft AA Report. Observed flows and associated loads, especially data collected concurrently by major dischargers for periods of expanded wastewater monitoring required by DRBC should be compared to design flows and loads for each plant as well as the baseline "design condition". It is important to understand how often actual wastewater flow rates approach permitted flow rates.

In Figure 2-14 on page 26, there seems to be a difference greater than 0.5 mg/L in model-simulated DO between the loading scenarios using permitted flow rates versus observed flow rates. The difference in ammonia load (kg N) calculated using permitted flow rates versus observed flow rates should be quantified to understand the load reduction that resulted in the change in DO.

Additionally, it is worth noting that in the case of WWTPs receiving combined sewage, peak loading may not coincide with peak flow, since peak flow will be more dilute. Also, this peak flow is unlikely to occur at the same time as minimum DO at the DO sag, thus this approach would be overly conservative.

Sensitivity of DO to Effluent Flow Rates

The limited sensitivity of the model to flows and loads suggests that other modeled sources could be primary DO sinks, and the model results may overstate the required reductions from effluent discharges to attain a higher DO concentration within the FMA than would otherwise be required based on the underlying data used in the model development, calibration, and corroboration.

DRBC evaluated the sensitivity of the calibrated water quality model to the discharge load by comparing the 1st percentile DO condition for permitted flow rates and observed 2012 flow rates using the baseline condition (actual ammonia load) and Tier 1 facilities discharging at 1.5 mg/L ammonia. DRBC's conclusion is that "…the conservative use of permitted effluent flows […] is less significant for load reduction scenarios compared to the Baseline scenario" (page 26). This conclusion stops short of suggesting the reasons for this result. If the primary cause of the DO deficit in the FMA is effluent ammonia load (as is implied by DRBC in the development of the scenarios), it follows that reducing effluent ammonia to near the limit of technology should significantly reduce the DO sag. This is not the case here. Instead, the model results indicate that the DO sag remains below 5 mg/L and does not change when flow rates are reduced from permitted to observed.

DRBC should consider additional sensitivity analyses to evaluate whether the recommended ammonia reduction in the HADO scenario will permit attainment of a more stringent, future DO criterion.
For instance,

- Compare the calibrated model with no discharge ammonia load to 5 mg/L DO
- Determine the other principal DO sinks impacting modeled DO in the absence of ammonia discharges
- Quantify the impact of DRBC's conservative treatment of SOD within the FMA on the modeled DO demand in the FMA and compare to measurements.

Pollution Load Reduction Scenarios

1. **DRBC should evaluate a specific additional scenario representing implementation of ammonia removal through sidestream treatment by PWD and CCMUA and changes in the magnitude and spatial distribution of ammonia loads from DELCORA's Eastern Service District currently treated at PWD SWWPCP.**

   Both PWD and CCMUA are currently in the design phase of sidestream treatment projects to treat recycled centrate flows from biosolids processing. These high-strength, low volume sources make up a substantial portion of the ammonia load to the PWD SW and CCMUA plants. Sidestream treatment is expected to result in 35-40% reduction in ammonia loading from these two largest sources of ammonia to the estuary. DELCORA's ESD flow is currently treated at PWD SW, a plant which was designed as a high-purity oxygen plant with relatively rapid solids retention time. When this flow is re-directed to DELCORA's Chester wastewater plant that achieves lower levels of effluent ammonia, the net result will be an overall reduction of ammonia load and broader spatial dispersion of the ammonia load due to the location of the DELCORA plant farther downstream from the PWD, CCMUA and GCUA plants. Preliminary estimates suggest a 20% overall ammonia load reduction compared to existing conditions due to these relatively near-term, cost-effective changes.

2. **While not discounting the important, and perhaps dominant, role that nitrification plays in depleting oxygen levels due to ammonia loading, the review of the supporting Water Quality Model Report raised the prospect that the impacts of nitrification were potentially being exaggerated in the water quality model relative to other oxygen-depleting processes (*e.g.*, phytoplankton metabolism and decay, SOD, CBOD, etc.).**

   The recommendations in the draft AA Report appear to be based solely on the presumption that nitrification dominates all other processes and is the only process targeted by the load reduction scenarios. It is important to revisit the perceived imbalance between nitrification and other processes, as this could lead to revised estimates of expected DO improvements associated with ammonia reduction alone.

1.1.1. Factors That Can Improve Dissolved Oxygen in the Fish Maintenance Area

Sensitivity of Source Categories

1. **The results of the source sensitivity analysis suggest that reducing effluent ammonia loads from the largest discharges would result in substantial DO improvement in the FMA in the summer season. Since levels of DO in the river are highly temperature-dependent, this dry warm year may be overly conservative for application to analysis of propagation.**

2. **DRBC notes that its sensitivity runs associated with reducing total nitrogen (TN) to 4 mg/L "did not provide additional benefit to DO in the FMA" (page 30). This statement should be supported with the model results presented in the Water Quality Model Report, which indicate that the urban estuary is slightly phosphorus-limited with respect to nutrients such that further reduction of nitrogen will not have a significant impact on primary productivity and therefore on DO levels in the estuary.**

3. **DRBC should provide the criteria used to determine modest, substantial, or no benefit to DO improvement in sensitivity plots in Figure 3-1 (page 31).**

   Through an analysis of Philadelphia CSOs on DO by PWD, it was determined that CSOs had a very minor impact to DO. This is contrary to the CSO sensitivity results provided in plots E and F in Figure 3-1 where CSO loads had a marginal impact on DO results. If DRBC elaborated upon how they determined the relative impact of improvement, this difference could be reconciled.

   Additionally, plots C and D in Figure 3-1 show the impact to the 2D Baseline when WWTP effluent DO levels are > 6 mg/L. This change is described as having a *modest beneficial impact* on DO in the FMA. Plots G and H show adjustments to non-point sources and MS4 and the changes in these plots were *not considered a substantial improvement* to DO in the FMA. When comparing plots C versus G and D versus H, the plots look nearly identical. Elaboration upon criteria used to determine relative impact could provide understanding as to why one of these scenarios was described as modestly beneficial while the other is a non-substantial improvement.

1.2. Analysis of Attainability Results

Wastewater Ammonia Effluent Reduction AA Scenarios

1. **There are additional scenarios that we would like to see considered in the Analysis of Attainability.**

   Variation on AA03: Scenario AA03 includes setting Class A' and A dischargers to a summer effluent ammonia level of 5 mg/L. Since the 1% DO result is close to observed 2012 DO and the current criteria (3.5 mg/L DO), this scenario could be investigated further. PWD is interested in seeing the results of a variation of this scenario where different groups of dischargers are set to 5 mg/L ammonia (i.e., PWD SW, CCMUA), which would demonstrate how load reductions would impact DO during conditions more similar to observed 2012 conditions.

2. **Review of the Water Quality Model Report suggests that the calibrated nitrification rate is high in the eutrophication model, which may affect the modeled benefits to DO resulting from WWTP effluent ammonia reductions.**

   In general, implementing reductions in ammonia-nitrogen discharges appears to be an appropriate method for increasing DO concentrations in the river. However, due to the possible over-simulation of nitrification in the eutrophication model, the DO improvements in the river may be overstated in the alternative ammonia effluent reduction scenarios. In addition, any impacts to DO associated with phytoplankton, which was a substantial part of the DO budget in the calibration, should be considered.

Wastewater Treatment Costs and DO Improvements

Additional scenarios should be added to the figures and cost curves to better illustrate the cost of incremental DO benefits and a cost curve related to ammonia reduction should be provided.

Additional proposed scenarios (*e.g.*, the previously described, desired phased implementation of sidestream treatment and variation on AA03 scenario, etc.) should be added to the curve in Figure 4-4 on page 60 to better understand the knee of the curve. This can help inform prioritization once updates are made to the affordability piece of this analysis.

Additionally, figure illustrating the cost-benefit of DO improvement should be produced, similar to Figure 4-4, using the "Percent-Above" metric. It is beneficial to look at findings from multiple perspectives to affirm consistency of findings or identify key differences that can inform decision-making for large capital investments that would have significant ratepayer impacts.

Are the costs in Figure 4-4 on pg. 46 expected to be a linear relationship between $/year and change in DO from scenario AA01 to AA07?

Lastly, a cost curve showing the cost versus reduction in ammonia loading would be beneficial to understand the relationship between cost, ammonia reduction, and DO improvement.

Recommended Scenarios

1. **The lack of affordability considerations in the selection of the recommended scenario AA08 leads to questioning of this scenario as the most appropriate to determine ammonia reduction**

requirements. Economic impact is a major element that needs emphasized consideration before policy decisions are made to upgrade the designated use, establish criteria, and prioritize improvements in alignment with revised effluent discharge limits.

This Analysis of Attainability supports including propagation as an attainable designated use in the Fish Management Area (FMA), *only if affordable*. The recommended scenario of AA08 was stated to "represent the estimate of the best DO condition that can be expected under critical conditions" (page 57). It was also stated that "socio-economic factors including cost and affordability were both considered but did not impact the recommended scenario". The recommended Analysis of Attainability scenario should consider socio-economic constraints. Further, metrics that ratepayers can understand and budget for are needed.

2. **More scrutiny should be applied to the differences among the alternatives in making the recommendation of scenario AA08.**

   There seems to be a negligible performance difference between alternatives AA08 and AA10, yet the allowable summer effluent ammonia limit for AA10 is twice as high as AA08. Costs are similar, which may warrant a check, but the recommendation of AA08 when an effluent ammonia limit twice as high is projected to yield nearly indistinguishable improvements in DO must be better defended.

   The actual loads of ammonia in kg/N should be presented for comparison to the baseline design scenario and recommended scenario in Table 4-2. This would put the recommended percent ammonia reductions in context with current plant discharge conditions to aid in evaluation of the scenarios.

3. **The recommended scenarios focus exclusively on reduction of ammonia from point source dischargers. The finding that 93% of ammonia originates from treated wastewater is well-documented, but watershed management at this scale is usually incomplete without the inclusion of land-based practices for nonpoint sources, especially when the contributions of other pollutants and processes that also deplete oxygen remain substantially unclear, as noted in comments on the Water Quality Model Report.**

Socio-economic Evaluation

PWD's technical comments on the draft Socio-economic Report are based on our review of the report and a collection of raw data tables and analysis scripts written in the R programming language that were shared with PWD. PWD commends DRBC for its commitment to transparency and reproducible analysis as exemplified by this approach underlying the socio-economic analysis. PWD also recognizes DRBC's solicitation of financial information from PWD and other Tier I dischargers in June 2021 and several clarifications and corrections that were made prior to release of the draft Socio-economic Report.

1. **Cost estimates in the draft AA and Socio-economic Reports are only a snapshot of utility costs and do not include projected rate increases associated with implementation of CSO Long Term Control Plans (LTCPs) or other major anticipated regulatory compliance costs. If the future costs of CSO compliance and other regulatory responsibilities are not included in the socio-economic analysis, the ability of impacted utilities and ratepayers to pay for nutrient-related capital investments will**

be significantly overestimated. All financial commitments of utilities should be considered when determining the burden category.

CSO controls are one of several large future capital investments facing many permittees, along with MS4 compliance costs, renewal and replacement of aging infrastructure, capacity management, and climate change-related considerations. The baseline cost "Baseline: Drinking Water + Wastewater & Sewer + Stormwater + Other Associated Fees" does not appear to include all significant future wastewater and stormwater costs for PWD. It appears that the socio-economic analysis does not consider the combined financial burden of implementing CSO LTCP controls in parallel with WWTP ammonia removal, not to mention any other significant program investments that have not been a part of annual CIPs and past rate-setting procedures. The financial indicators need to include major current and future investments together. These factors need to be considered in the metric categories in Table 4-4 on page 51.

Further, as previously noted, the FY 2021 rates the serve as the baseline for the analysis do not reflect full cost of service and understate the actual rate needs of the utility.

In the Executive Summary it is stated, "The HADO condition (AA15) associated with scenario AA08 was developed incorporating: 1) full implementation of CSO long-term control plans." If the LTCPU/COA implementation is considered a component of the DO improvement, the costs associated with that implementation must also be considered.

2. **Cost estimates in the Nitrogen Reduction Cost Estimation Study and draft AA and Socio-economic Reports are expressed in 2019 dollars corresponding to the September 2019 Engineering News Record Construction Cost Index (ENRCCI) and must be updated as soon as possible to reflect current costs.**

The draft Nitrogen Cost Estimation Study completed by Kleinfelder in January 2020 on behalf of DRBC used Engineering News Record Twenty City Construction Cost Index (ENRCCI) value of 11,311 for September 2019. As described on the ENR website at https://www.enr.com/economics/faq, the ENRCCI is updated monthly to track the cost of a standardized package of goods and labor. The index can be used as a simple method to adjust construction cost estimates from one time to another.

As a point of reference, the August 2022 index is 13,171, reflecting substantial increases in the costs of materials and labor since September 2019. PWD requests that all construction costs in the draft Socio-economic and AA Reports be updated to reflect increases in costs as indicated by the latest ENRCCI index for the proposed changes to wastewater treatment scenarios.

As previously noted, PWD strongly recommends that DRBC obtain updated rate and cost data from all utilities participating in this study given current inflation levels.

3. **The City and County of Philadelphia are geographically congruent. The County of Philadelphia is thus the appropriate geographic area for analyzing socio-economic information for the City's service population as defined by the draft Socio-economic Report.**

PWD understands that DRBC compiled and evaluated socio-economic information for the areas served by Tier I dischargers using census tract-level estimates and Geographic Information System

(GIS) software analysis. DRBC also recognized in the draft Socio-economic Report that population weighted aggregation of census tract estimates may be subject to bias. DRBC has considered this discrepancy for the Lowest Quintile Income (LQI) measure used to calculate the Household Burden Indicator (HBI) in AWWA et al. 2019 Guidance, calculating the HBI benchmark as the lower of the population-weighted tract average estimate or the county-level estimate for LQI. PWD requests that a similar adjustment procedure be used for the Median Household Income (MHI) used to calculate the Residential Indicator (RI) described in the draft EPA 2022 FCA Guidance.

4. **Spatial data sets representing service areas for Tier I dischargers should be cross-checked against tabular data.**

   PWD identified errors in the "FullAssembledCensusDataV2.csv" where areas outside Philadelphia were assigned to PWD's service area. Polygons representing portions of census tracts in the state of New Jersey and PA counties other than Philadelphia were identified by the "STATEFP" and "COUNTYFP" columns in the CSV file.

5. **DRBC's tabulation of service area population for Tier I dischargers erroneously refers to an incorrect US Census Bureau American Community Survey (ACS) Table. The total population of Philadelphia (i.e., Philadelphia County) is available in line 1 of ACS table S0101.**

   For calculating baseline annual cost, DRBC's R script file "MakeCostPerHousehold.R" sums tract-level data from line 1 of ACS table DP03 - Population 16 years and over, which is the denominator used to calculate unemployment rate, not the census estimate for the City's total population. The City's total population for the 2020 decennial census from line 1 of ACS table S0101 is 1,538,102.

6. **The City of Philadelphia cost per household estimates for ammonia removal scenarios should be calculated based on the number of PWD water accounts rather than an estimated number of households based on an assumed number of persons per household.**

   As described above, underestimating the City's total population by summing tract-level data from line 1 of ACS table DP03 potentially results in an underestimate of the number of households. However, by coincidence, this value is approximately equivalent to the number of PWD accounts, which is 496,000. Dividing the estimated cost of proposed ammonia removal scenarios by the number of water accounts will provide a more accurate measure of the actual cost per household.

1.3. Highest Attainable Dissolved Oxygen (HADO)

1. **Costs associated with the HADO scenario should be incorporated into the socio-economic analysis if they have not been already and results of this should be included in the reports. PWD anticipates that updating socio-economic information for the HADO scenario would identify a high burden category for most indicators for PWD ratepayers.**

2. **There exists a preponderance of research on suitable levels of DO to support large fish populations of specific species. It seems that the HADO approach may be discounting research and observations specific to aquatic species of concern or pre-conditioning results on a presumption that desirable levels of DO may be unattainable, when in fact, the river may be already attaining or far closer to such levels than assumptions in the report would suggest.**

A more in-depth justification for this approach in lieu of specific DO targets would add credibility to this draft AA Report and its ultimate intent and may prompt the establishment of incremental goals as part of a more adaptive management plan. It is possible that the HADO approach might overshoot necessary levels of DO by not aiming for specific and well documented targets.

Additional HADO Factors

Effluent DO Concentration

PWD is eager to see the results in terms of cost and feasibility associated with minimum effluent DO levels for WWTPs to see if the resulting seemingly small improvement in Estuary DO is worth potential increased costs and burden of operation and maintenance of potential new technology.

In Figure 5-2 on page 53, there is a slight increase in the 1st percentile DO when effluent DO is set to 4 mg/L. The impact of minimum effluent DO levels for WWTPs on in-stream DO at higher percentiles should be included to understand the magnitude of a potential benefit. The DO increase should be stated within the context of model uncertainty before a recommendation is made that would require additional plant upgrades and associated costs.

Reserve Capacity

Is reserve capacity possibly unnecessary if the baseline conditions account for full plant capacity with the implementation of permitted flows?

This is an example of how the baseline condition, which is then applied to the HADO, is overly conservative. In using permitted flows, future conditions have already been assumed. It is also confounding that there is there no noticeable change in DO results when the ammonia load is increased by 10% (Figure 5-3, page 55); this should be explained by DRBC within the draft AA Report. Possible explanations include no impact of further reduction since ammonia is already low in scenario AA08 or a limitation in the model, among others.

Estimated HADO Result

1. **There is concern that an accumulation of conservative assumptions built into the HADO scenario will result in the overstatement of the impact of aggressive effluent ammonia reductions, which runs the risk of over-designed unaffordable controls.**

   The Analysis of Attainability is based on the eutrophication model baseline/design condition using the 2012 condition, which was an extreme condition for DO, and modified to be even more extreme through the implementation of permitted flows from WWTPs and seasonally constant nutrient and carbon concentrations. Since the permitted flow is higher than the actual discharge for PWD WWTPs, the resulting loading is higher than the actual loading. When using the higher ammonia loads that would be associated with permitted flows, this methodology could overestimate necessary nitrogen load reductions to achieve desired levels of instream DO. Therefore, this approach is highly conservative. From the perspective of increasing DO in the river, such load reduction scenarios could be reasonable because they are conservative. However, from the management perspective, this may cause unnecessary financial burdens by recommending ammonia load reductions that are higher than necessary to achieve the desired DO condition.

2. **There is concern that the eutrophication model may not adequately simulate low DO conditions, and the magnitude of DO improvement suggested by the HADO scenario may not be realized in actual conditions.**

   The improvement in DO of 2.3 mg/L between the baseline and HADO (AA15) scenarios may not be achieved in conditions where observed in-stream DO is higher than the baseline condition *(i.e.*, 3.5 or 4 mg/L as opposed to lowest baseline value of 2.1 mg/L). There are also concerns over whether the eutrophication model is adequately predicting low DO conditions, which could be addressed by the inclusion of additional metrics during observed critical DO periods. This coupled with the uncertainty of the high nitrification rates, high representation of DO, and under simulation of phytoplankton, could overstate DO improvements that could be achieved with the proposed effluent ammonia reductions.

2. Requests Related to the Draft AA Report

1. Please provide the following minutes
   a. Resolution for the Minutes of June 12, 2019: Consultation services for enhancement of source code for the hydrodynamic model (EFDC) from GHD
   b. Resolution for the Minutes of Dec. 11, 2019: Analytical services for algal composition from Academy of Natural Sciences, Drexel University
2. Please provide the following model results and information
   a. 2012 observed flow rates for all dischargers
   b. 2012 observed loads and/or concentrations for all dischargers (see legend in Figure 2-13 page 39)
   c. Concentrations that were used to ensure "the total annual loads were identical"
   d. Design condition effluent concentrations (if different from Table 2-1 and Table 2-2)
   e. Total observed 2012 nutrient loads at each location
   f. Total 2012 design condition annual nutrient loads at each location
   g. Metrics and figures on 2012 observed flow rates with 2012 observed loads
   h. Metrics and figures on 2012 observed flow rates with design effluent concentrations
   i. Metrics and figures on permitted flow rates with 2012 observed loads
   j. Definition of "baseline" in Figure 2-13 and all the figures in the section
   k. Baseline (permitted flows rates) versus Baseline (observed flow rates).
3. Please provide a list of the simulation runs that were used in the classification of wastewater discharges.
4. Please provide the Tier 1 effluent ammonia reduction results in an appendix.
5. Please provide a list of source sensitivity simulation information in a table including what was changed and what stayed the same.
6. For the HADO analysis, please provide the following
   a. Exact values used in the model
   b. Differences between observed conditions in 2012, 2018, and 2019, and AA15 for 2012, 2018, and 2019
   c. Constant flow rates or varying flow rates used
   d. Constant effluent concentrations or varying effluent concentrations used
   e. Methodology if DRBC downscaled the 2012, 2018, and 2019 observed models to perform this analysis.
7. It is stated on page 75 that the baseline condition was developed utilizing the permitted flows for 67 wastewater dischargers. The report didn't provide the permitted flows and corresponding

information for all these locations. It only provided 19 out of 67 locations. Please provide this information.

8. Please provide a chart with the observed 2012 model and 2012 observed data like Figure 2-11 and Figure 2-12 for ammonia and carbon.
9. Some clarification is needed in Section 2.4.3. The text suggests that "baseline" regardless of 2D or 3D would be wastewater permitted flows with actual wastewater concentrations. The legend on Figure 2-13 suggests that "Baseline" in this case is actual flows and concentrations. Therefore, neither of the results shown in Figure 2-13 are a "Baseline" or "Design" condition and should not be labeled as such. Both runs reflect loads less than the "Baseline" condition of permitted flows and actual concentrations.
10. Please provide a list of the simulation runs that were used in the classification of wastewater discharges in Section 3.2.
11. Please provide more information on how volume with ΔDO = 1 mg/L and percent reduction in DO stress within the FMA were calculated.
12. For the Sequential Testing of Discharges using the 3D model, please provide individual discharge location ammonia reduction model results. In Figure 3-3, the individual impact of CCMUA, DELCORA, and City of Wilmington discharges are difficult to infer. Lower Bucks and Hamilton are listed as Class A, yet Morrisville and Cinnaminson are designated Class B, while they are closer to the DO sag, which should be noted.
13. In the description of the Analysis of Attainability scenarios, please more thoroughly define and describe Analysis of Attainability model settings. What is the difference between AA01 (current conditions) and AA07 (Figure 4-3)? AA07 is defined as Class A at existing levels of ammonia while Table 4-1 stated "Class A' only: summer ammonia = 1.5 mg/L".
14. Table 4-3 lists the annualized cost in 2019 to achieve reduced effluent levels. It would be preferred to keep at least one decimal digit in the table. For example, the cost of reducing ammonia from 10 mg/L to 5 mg/L at Morrisville looks like no change in the table, but Figure 6-2 from the Nitrogen Reduction Cost Estimation Study clearly shows an increase of cost.
15. The actual loads of ammonia in kg/N should be presented for comparison to the baseline design scenario and recommended scenario in Table 4-2. This would put the recommended percent ammonia reductions in context with current plant discharge conditions to aid in alternative evaluation.

3. Questions Related to the Draft AA Report

1. Can more clarification be provided for these two 3-D simulations: Same effluent pollutant loads but different flow rates for wastewater plants? Were the actual flow rates from 2012 constant flow rates? If not, are these the 2012 annual flow rates, annual median, seasonal average, or seasonal median flow rates? What was the timestep of the timeseries – daily, weekly, or monthly flow rates?
2. Were the same effluent concentrations used for the scenarios in Figure 2-14? Please describe the difference between the Permitted Flows baseline and the Actual Flows baseline in Figure 2-14: 1% DO for 2D model results. Based on the report, it seems as if different concentrations were used.
3. Can DRBC share how baseline 2D compared with baseline 3D model results? There are some concerns with using the 2D model for sensitivity analysis in the absence of comparable results using the 3D model.
4. Can more details be provided on how the DO results from the model are used in the calculation of the DO percentile and "Percent-Above" plots (Figure 2-2 on page 13)?
   a. How is the DO value for the entire transect at each river mile determined for the simulation?
   b. Is the median or average value calculated for each timestep?

    c. How are the results from the vertical layers incorporated?
    d. Are the 2D and 3D model outputs in 2-hour intervals for each cell, and if so does DRBC downscale the 2-hour DO timeseries into daily timeseries before calculating the metrics?
5. Can more details be provided on how the DO results from the model are used in the calculation of the Relative Stress Index (RSI) (Figure 2-3 on page 13)?
    a. How is the RSI value for the entire transect at each river mile determined for the simulation?
    b. Can the calculation and procedure be explained?
6. Can more details be provided on how the DO results from the model are used in the development of the Tabular Maps (Figure 2-4 on page 15)?
    a. How is the minimum DO calculated for each grid cell in the tabular maps?
    b. How is the vertical resolution of the WASP model results resolved?
    c. Is the water depth and resulting volume in each cell accounted for in aggregating the water quality DO results of the cells?
7. Can the differences between the 2012 model and the design condition be provided, including model settings? Was one constant used for the entire year or were summer/winter constants used in the design condition? See Table 2-1 and Table 2-2.
8. What are the concentration or load limits for constituents such as ammonia-nitrogen? The current effluent limits for the discharges should be stated in addition to the monitoring data.
9. In Figure 2-14 on page 26, what is the difference in load (kg N) between the permitted flow and actual 2012 flow scenarios?
10. Did DRBC cap the summer effluent concentration from May 1 to October 31 or set the concentration as constants in the load reduction scenarios? For the load reduction scenarios, a constant concentration of ammonia (10 mg/L, 5 mg/L, 1.5 mg/L) was applied to the effluent flow. It would be beneficial to understand how often the discharge could be below this concentration, both theoretically and in observed data.
11. Can the concentrations applied to CSO discharge be provided in the Analysis of Attainability Report?
12. For the CSO reduction scenario (Figure 3-1, plots E and F), why were the reduction of ammonia and reduction of CBOD considered separately? Realistically, if a reduction of CSO discharge was occurring, it would reduce both pollutants.
13. When summer effluent ammonia was reduced, summer effluent DO was reduced to 2 mg/L or the discharger's existing permit limit. Can the reason behind this methodology be explained?
14. Why are the results in Figure 5-9 based on July 1 through September 30 when other graphs were based on May 1 through October 15, which is considered the "critical propagation season". Is this mislabeled? The results look like the May 1 – October 15 figure in the appendices.
15. The text above Figure 5-9 suggests that the length of the river that will see DO below 5 mg/L is reduced from 51 to 12 miles in the HADO scenario. However, Figure 5-9 seems to show a decrease from 44 miles to 24 miles. Which is correct?
16. Can the methodology of the ammonia load increase in the reserve capacity model assumption be described in more detail?
    a. Was this increase applied to all 67 locations?
    b. Was the 10% increase applied across all timeseries?

4. Water Quality Model Report

4.1. Summary of Comments

A thorough review of hydrodynamics and the impact on water quality constituent transport cannot be completed until previous comments are addressed and the Final Hydrodynamic Model Report can be reviewed.

Comments related to the hydrodynamic model were listed in the review of the Hydrodynamic Model Report submitted to DRBC in February 2022. Additional comments specific to the eutrophication model described in the Water Quality Model Report review are included with these comments on the Analysis of Attainability Report. A thorough review of hydrodynamics and the impact on water quality constituent transport cannot be completed until previous comments are addressed and the final Hydrodynamic Model Report can be reviewed. Outstanding questions on the hydrodynamic model have implications for the eutrophication model, including concerns over constituent transport and modeled water temperature. We request the same details on the bathymetry, cell size and depth as in previously submitted comments, and also reiterate questions on the coarseness of the grid and impact on model time step. These questions directly impact modeled pollutant and DO transport, which determines attainable DO conditions in the urban Delaware River. These factors may result in effluent load reductions that are potentially burdensome to the targeted dischargers.

Water quality model calibration should focus on both long-term trends and shorter-term comparisons.

The metrics used to evaluate the eutrophication model calibration should focus on shorter time periods in addition to the existing focus on longer term seasonal trends. An emphasis should be placed on the critical summer DO period, to understand how the model responds during the period that will be the focus of management decisions. Calibration should evaluate how well the model reproduces conditions that are critical to low DO formation. This process occurs on a shorter time scale than the current metric of May1 – October 15. More details related to this comment can be found in the **Model Validation and Sensitivity** section of this document.

Nitrification rates are high in the water quality model and could be over-estimating the benefit of removing ammonia load to in-river DO.

Observed nitrification rates have a wide range of values, and the effective rates in the eutrophication model are on the upper end of observations. This is a conservative assumption that could over-estimate the change in DO that would result from reducing ammonia loads from municipal dischargers. Model-data comparisons of ammonia concentrations in the river corroborate this notion. More details related to this comment can be found in the **Water Quality Processes** section of this document.

Sediment Oxygen Demand (SOD) may be overestimated in the water quality model, which can impact the overall DO budget and modeled DO results.

The temperature adjustment imposed on sediment oxygen demand creates an SOD that is higher than almost all observations in high temperature conditions; this overestimation of SOD could misrepresent the relative significance of other DO sinks, such as phytoplankton production and respiration, and CBOD and NBOD consumption. The DO balance should be evaluated before the model is used to evaluate impacts on DO due to changes in ammonia effluent loading. More details related to this comment can be found in the **Water Quality Processes** section of this document.

The impacts of phytoplankton on modeled DO are possibly under-represented in the water quality model, which can impact the overall DO budget and modeled DO results.

Capturing the nuances that cause algal blooms in eutrophication models can be difficult, but the role of phytoplankton in the DO budget is greatest during and following blooms. Understanding the relationship between algal population changes and DO highs and lows is critical in understanding critical low DO periods. The eutrophication model currently does not capture phytoplankton dynamics in a way that represents this relationship in the Upper Delaware estuary. This shortcoming renders modeling critical low DO periods difficult. More details related to this comment can be found in the **Water Quality Processes** section of this document.

4.2. Hydrodynamics and Transport

Hydrodynamics

The impact of hydrodynamics on the water quality model validation cannot be thoroughly assessed until the Hydrodynamics Model Report is finalized and reviewed. The hydrodynamics will have an impact on pollutant transport and is especially critical in the region of the urban dischargers in the vicinity of the DO sag.

Modeled tidal excursions directly determine the spatial extent of critical low DO events, and modeled tidal dispersion directly impacts values of DO, ammonia, and other water quality constituents with spatial gradients. It would be helpful in assessing the advection and oscillation dynamics associated with the eutrophication model to see a more granular assessment of the calibrated water velocities in the Hydrodynamic model. Specifically, it would be useful to see results and a discussion of near shore vs. shipping channel variances, and more velocity stations than the three presented in the Hydrodynamics Model Report and its Appendix I. More detailed comments and questions related to the hydrodynamics model are included in comments submitted to DRBC in February 2022.

Salinity and Temperature as They Relate to Water Quality

Modeled salinity and temperature directly influence the water quality model in several ways. PWD's comments to the Hydrodynamics Model Report discusses specific questions that PWD has regarding temperature and salinity representation in EFDC. This section refers to those comments in discussing potential impacts on modeled water quality constituents, including dissolved oxygen.

Salinity

As discussed in comments on the Hydrodynamics Model Report, the salinity validation of the EFDC Hydrodynamics Model is both sparse geographically and shows non-negligible model-observation discrepancies. Any model limitations due to salinity transport errors should be clearly stated, and should this model be used in the future to represent conditions of potentially high salinity (for example scenarios of sea level rise).

Dissolved oxygen saturation depends on Salinity and Temperature, and algae is also sensitive to modeled salt concentrations. Salinity transport errors only impact water quality in the urban river during times of salt intrusion. Intrusion events occur in occasional episodes, and are typically in the early-mid fall, which is often past the most critical DO time period. However, salt intrusion episodes earlier in the summer have been observed. While a frequency analysis has not been completed, a coincident event where salt intrusion and critical low DO occur at the same time is likely to be exceedingly rare under current conditions.

Temperature and Atmospheric Inputs

The hydrodynamic report discusses modeled temperature comparisons with observed data, but it does not provide isolated, short-term comparisons that assess the model's accuracy in capturing summertime high temperatures in particular.

Temperature directly impacts several aspects of water quality modeling. Most modeled processes have rates that are temperature-dependent, including:

- DO saturation
- SOD
- Nitrification
- Algae growth

At 30 degrees C (a typical critical low DO condition) and 0 psu salinity, a 1-degree difference in modeled temperature can result in a 0.13 mg/L difference in DO saturation, a difference of 0.1 day-1 in nitrification rate (at a critically low DO of 4 mg/L), a 0.18 g/m2-d change in SOD, and a 15% change in the algal growth rate. Visual inspection of temperature calibration results time series plots in Appendix J of the Hydrodynamic Model Report suggest that the model overpredicts temperature by 2-3 degrees C in the summer at Chester and Marcus Hook, and by 1 degree C at Ben Franklin Bridge.

Because of the direct impact of solar radiation on algae growth, a discussion of modifications made to the solar radiation applied by DRBC should be included and related back to a clear-sky theoretical radiation, either in the Hydrodynamics Model Report or in the Water Quality Model Report.

In addition to impacts from ambient temperatures, algae growth is also impacted directly by solar radiation. A difference between clear sky theoretical short wave radiation and a 20% reduction from clear sky radiation (typical for calibrated systems) can be significant. A discussion of radiation applied to the WASP model should be included in model documentation.

Transport Fidelity

Mass Balance

The total error in mass balance that is documented in the Water Quality Model Report Appendix C should be discussed, as it is higher than is expected.

In the urban river, mass balance errors appear to be generally between 1% and 2%, with short episodes of up to 5% error (this appears to coincide with salt intrusion). This is higher than we would expect from a hydrodynamic/water quality model and is surprising due to the mass-conservative scheme in WASP. Speculation on the origin of this error would give context to the implications of this for modeled water quality constituents. It is likely that the total error in mass balance is small compared to various sources of uncertainty in the water quality model.

Modeled Dispersion

Because it appears that dispersivity may be connected to apparent mass balance errors, an estimation of effective along-channel, bulk dispersion should be included to provide confidence in the transport properties of the EFDC and WASP models. This calculation would also be recommended to help quantify the bulk transport impacts of using a different turbulent mixing coefficient in WASP than in EFDC.

Section 3 of Appendix C in the Water Quality Model Report provides a good demonstration of the impact that different vertical dispersivities can have on ultimate modeled DO in terms of metrics. Additional discussion on differences in DO would be supported by adding a timeseries comparison.

4.3. Model Configuration

This section contains comments on the overall modeling approach and configuration. We ask questions related to overall model setup, such as the way WASP and EFDC interact and how model loadings are calculated, and questions related to specific modeled processes, such as nitrification, SOD, and other modeled processes.

This section also touches on some bigger picture concepts, such as the DO budget, which are impacted by several processes interacting with each other.

Water Quality Model Overall Configuration

Model Selection

A model selection section should be added to briefly discuss the rational of choosing WASP rather than EFDC's water quality module.

While the overall configuration of WASP seems appropriate for the stated model objective, this discussion would provide context for the WASP limitations, such as the large external hydro file required for WASP-EFDC compatibility.

Discussion on the differences in model results between the 2D and 3D models should be included.

It is a common practice to utilize a coarsened model version for initial model development, similar to the use of a 2D version of the water quality model that DRBC employs. However, the decision to use the 2D vs 3D model is unclear in some cases, and the basis for this decision is also unclear. Additional discussion would clarify the purpose of the 2D model version.

Validation Year Selection

Years used to calibrate/validate a water quality model should ideally have two properties: a rich dataset to support model-data comparisons, and physical/chemical/biological conditions that reflect the objectives of the model. An explanation of the selection of 2018-2019 for calibration due to data rich conditions, and 2012 due to conditions reflecting the model's intended purposes, is needed.

This discussion should include the following information:

- A discussion of regulatory low flows in the non-tidal portion of the Delaware River as defined in the DRBC Water Quality Regulations, and a comparison of the flows recorded in 2012, 2018, and 2019 relative to this condition.
- A reference to the data description section that describes 2018/2019 as ideal for calibration.
- Comparison of the hydrologic conditions for 2018, 2019, and 2012 with the historical record (including recent years up to the present) also help build confidence that the model is designed in a robust way to represent both "typical" and more conservative hydrologic conditions, rather than wet years.

- A description of the hydrologic conditions that are thought to be conducive to low DO in the Delaware River and a demonstration that 2012 exhibits these conditions (temperature, river flow).

Loadings and Open Boundaries

Tributaries

The discussion of loadings from point and non-point sources aggregates all loads across wet and dry periods and should be expanded to show the difference between wet weather and dry weather sampling and incorporate seasonal variability into the analysis.

Since the critical period for the stated goal of this analysis is summer low flows, understanding the boundary conditions during the period of interest is important for understanding the factors that cause and contribute to DO deficits in the FMA.

More clarity is needed on how the LOADEST-WRTDS combined tool was used to make water quality loading estimations. DRBC should consider adding an appendix documenting the data and assumptions used for the LOADEST model and provide the model input files.

In addition, the discussion is not clear with respect to the treatment of unmonitored tributary areas. The number of tributaries impacted and the total drainage area of the unmonitored area as a proportion of the total watershed area should be included along with the water quality parameter values that were assigned summarized in a table. Was LOADEST-WRTDS used for filling gaps in observations, or solely to provide loadings where no data exist? The hierarchical agglomerative cluster analysis used to group sub-watersheds should also be described in greater detail. Figures 2-11 and 2-12 on pg. 35 show the proportion of phosphorus and nitrogen loading from monitored tributaries and other sources. The assumed load in the model from "unmonitored" watershed areas should be included based on the applied loading assumptions.

It appears from section 3.1.4.1 that the tributary loads are computed from established USGS algorithms to account for temporal and hydrologic variability. This approach seems reasonable. Text discussing this suggests that the performance of these algorithms was assessed graphically and statistically, but comparisons to measured data are not included. This would be useful in building confidence, since tributaries (and the upstream Delaware) account for approximately 70% of the total phosphorus and total nitrogen loads. If this information is included elsewhere in the report, we recommend referencing appropriate figures or appendices.

CSOs

Additional information should be provided on the treatment of CSOs in the water quality model.

No information on which CSOs were combined and where they enter the system was included. In addition, DRBC notes that the CSO concentrations "were compared with PWD's CSO modeling methodology, and DRBC's concentrations (sic) assignments generally fall within the range PWD assumed for stormwater and wastewater, respectively." However, no further analysis is provided on the differences between DRBC's approach and PWD's assumptions for wastewater and stormwater concentrations. DRBC should consider adding additional information on the differences between the two approaches.

Water Quality Processes

Sediment Fluxes

The decision to use the prescriptive sediment fluxes for SOD and nutrient fluxes based on observations was appropriate for this system. This approach removes the need for uncertain parameterization and diagenesis simulation and allows for easy sensitivity analysis to assumed rates.

However, caution should be used in varying sediment fluxes to fit model results, as calibrating SOD and sediment flux can often result in too many unnecessary degrees of freedom, especially when data are available to guide model input values as they are in this case. Please clarify how values described in Table 3-7 were ultimately determined. It is not clear whether this was part of the calibration process. The following sections highlight questions on nutrient flux values, SOD baseline values and the temperature adjustment term.

Nutrient Fluxes

The approach of applying one value throughout the season to represent nutrient flux would be appropriate given no other options. However, significant difference between summer and non-summer NH3 flux appears to be present, and this is not accounted for in the uniform nutrient flux assumed in the final calibrated WASP model.

DRBC indicates that only nutrient flux data from August were used in the calibrated model. This approach is used because temperature correction factors are not available for nutrient fluxes in WASP and using the higher August benthic fluxes can be considered a conservative assumption.

Similar patterns are evident in the comparison of nitrate + nitrite in Figure 3-8, SRP in Figure 3-9, and SOD in Figure 3-10. While WASP does not correct flux rates for temperature, a benthic flux timeseries can be entered in WASP. In this way, changes in sediment fluxes corresponding to seasonal temperatures could be implemented. Discussion on why this option was not pursued would be helpful in model documentation.

In addition to temporal variation, there is also variation among sediment core flux measurements within each benthic zone. Unlike SOD, the nutrient fluxes are input with lower percentiles of observed data (10th – 75th). Discussion on the logic behind the values selected and the variability in statistical quantity among Zones is needed. The low percentiles result in a net nutrient sink when in many places observations suggest neutral flux or net source (especially for the algae-limiting nutrient, phosphorus). See Figure 3-11.

Sediment Oxygen Demand

Base Values

Within the urban river, the benthic fluxes and SOD are assumed to be relatively high, based on the upper end of the observed August data (75th to 95th percentile). This results in SOD estimates that are much higher than most observations. It is not clear why such high SOD values were assumed, and this may be contributing to an imbalance with other oxygen-depleting processes, especially in the critical hot summer months, see Figure 3-11.

The discussion in the report indicates that this was selected based on a best fit to the available DO data. Additional discussion should be added to the report documenting the sensitivity analyses underlying the final parameterization. SOD was input at levels between the 75th and 95th percentile of measurements and varied spatially. This effect is compounded by temperature adjustments in the model that raise the modeled SOD during hot summer months.

It is unclear what the input values for SOD and nutrient fluxes from River Mile 60 – 0 are based on.

They are all set at constant input values, and it is unclear what data were used to support these assumptions. Was there sampling done in the estuary/bay? Some statements in the report suggest that algal dynamics are under-represented in the estuary, and SOD and nutrient fluxes could be contributing to uncertainty here, both in nutrients in the water column, and the balance between all oxygen-depleting processes.

Temperature Adjustment

The temperature adjustment factor value for SOD of 1.065 seems high for this particular system, where seasonality is not particularly strong. Please include a discussion of any attempts made to assign another, site-specific value to the SOD data. The overall DO budget's balance, particularly in low DO, high temperature conditions, should be discussed considering potential over-estimation of the SOD in using this adjustment factor.

The Water Quality Model Report states that the temperature correction factor 1.065 was used to assess SOD data, and that this value was also applied in the WASP model. Chapra (1997) does report that 1.065 is a typical value; it would help to know what the logic was behind selecting it for the Delaware River. **Figure 1** shows the effect of a 1.065 temperature adjustment on a baseline SOD of 1.5 g/m2-d, applied to the temperature recorded at Ben Franklin Bridge in 2012. This adjustment results in a fairly high extended period of SOD above 2 g/m2-d during the critical DO period. There are very few observations of SOD this high in the observed record.

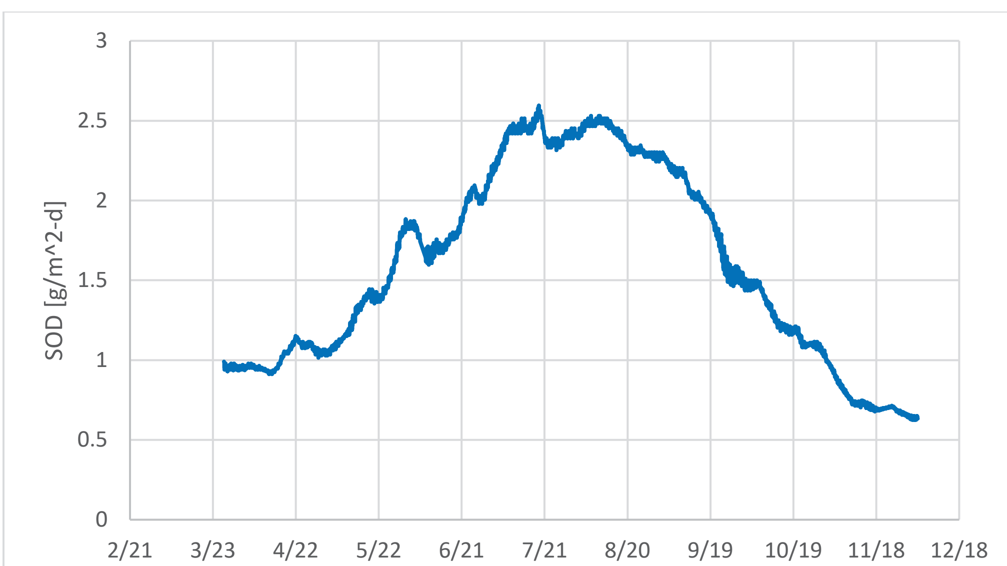

Figure 1. SOD adjusted per WASP formulation for temperature using an adjustment factor of 1.065 and a base value of 1.5 g/m2-d. This is comparable to several sediment flux zones in the FMA of the DRBC WASP model.

As an order of magnitude approximation, a 2.5 g/m2-d SOD in a 10-m deep water column results in a DO sink of 0.25 mg/L-d. In the shallower banks, for example where water depth is 5 meters, this sink would increase to 0.5 mg/L-d. For shallow sections, this is a significant impact on the cross sectional DO budget and modeled DO concentrations. The sensitivity section of the calibration report varies both base SOD and the temperature correction by 10%, but this does not inform the impacts of variations in SOD on the order of the variations in SOD resulting from adjustments in temperature, and characterizing variability in observed data.

Ultimately, the result of choosing the 90th percentile of SOD values and then adjusting that value with a temperature coefficient is that SOD will become a larger portion of the overall oxygen budget. As discussed in other sections of this document, the overall DO budget's balance, particularly in low DO, high temperature conditions, should be discussed considering potential over-estimation of the SOD.

Nitrification

Figure 3-18 in the Water Quality Report shows simulated levels of ammonia frequently below observations and only rarely above suggesting a bias, which may be the result of too much simulated nitrification. This relates to an overall systematic question on model configuration regarding the potential imbalance of water quality dynamics and their impacts on DO.

To model the impacts of nitrification on DO accurately, it is key to evaluate impacts of temperature on nitrification rates. It would help build confidence in the model if DRBC were to include plots of actual modeled temperature and DO adjusted nitrification rates along channel.

Observed DO at Penn's Landing (roughly River Mile 100) is plotted against temperature in **Figure 2**. The figure demonstrates that DO tends to decrease as Temperature increases. DO values below 5 mg/L only occur at temperatures above 20 degrees C, while most DO values below 5 mg/L occur at temperatures above 25 degrees C.

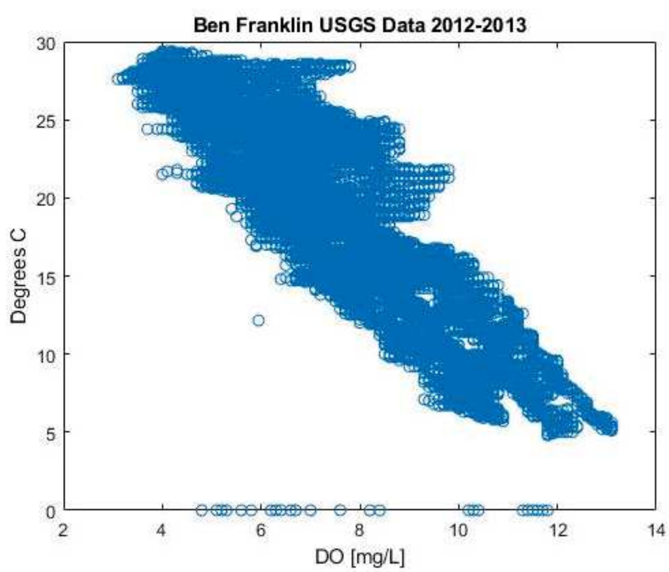

Figure 2. Observed DO at Ben Franklin Bridge during 2012 and 2013, plotted against temperature. Upper left region indicates values below 5 mg/L and above 25 degrees C.

At 30 degrees C, at a relatively low DO of 4 mg/L, DRBC's modeled nitrification rate would be 1.2 day-1. For comparison, for typical ammonia concentrations in the Penn's Landing area in the low DO period of 0.25 mg/L NHx, PWD's EFDC water quality model's representation of nitrification would estimate the nitrification rate at 0.2 day-1. If the two formulations as they evolve with temperature (holding DO at 4 mg/L and NHx at 0.25 mg/L) are plotted, the divergence of the two models can be seen in **Figure 3**. Data points of observations near Penn's Landing are also included on the figure for samples collected in July 2017 and August 2013. Between the two observations, there is one datapoint that supports each curve.

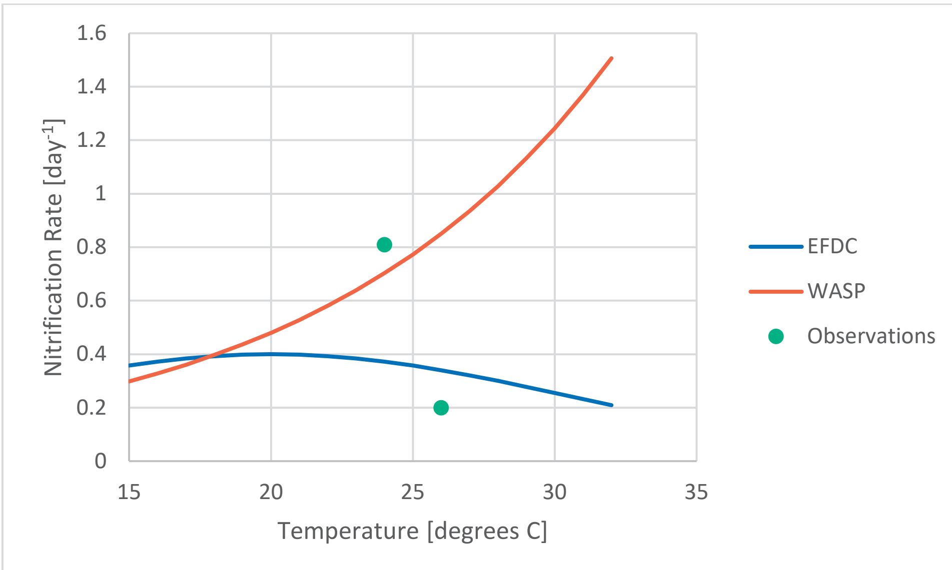

Figure 3. Nitrification rates in WASP and EFDC, calculated at 4 mg/L DO and 0.25 mg/L ammonia.

As Figure 3 demonstrates, WASP modeled nitrification can get very high during the summer. When the two formulas are applied to the temperature at Ben Franklin Bridge in 2012, there is a large divergence between modeled nitrification as represented in WASP and EFDC (**Figure 4**). Because of the discrepancy among theoretical temperature dependencies results in large differences in modeled nitrification rates, some discussion of the uncertainty associated with nitrification and its implications for modeled DO and modeled DO improvements from loading adjustments should be included.

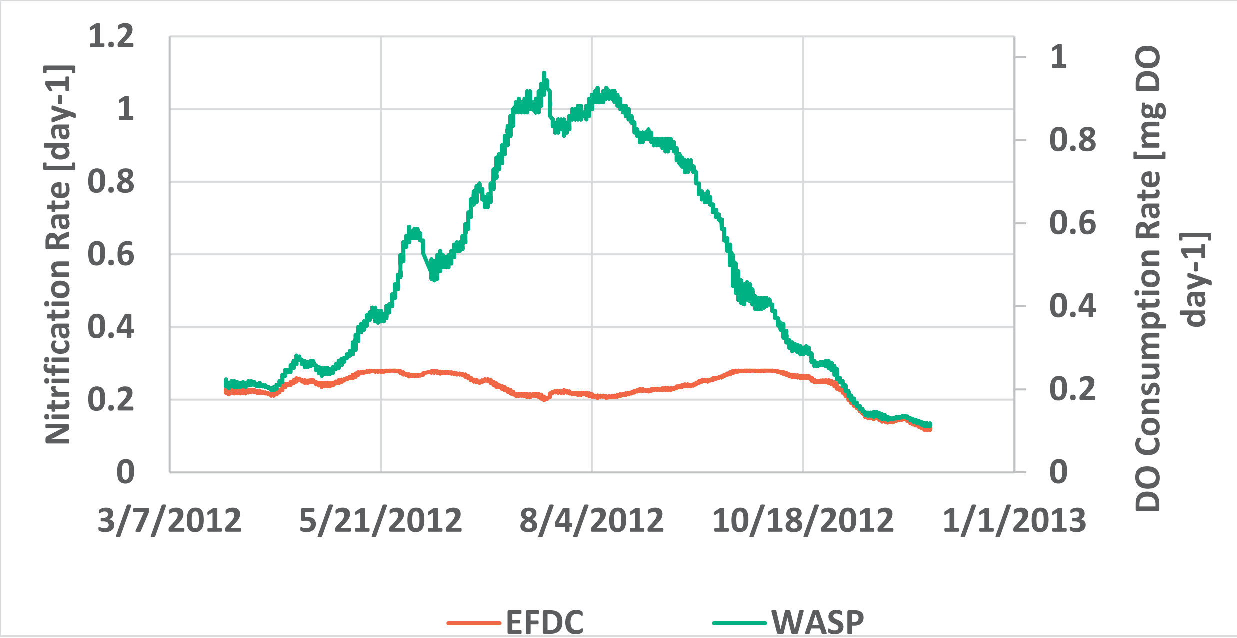

Figure 4. Nitrification rates in WASP and EFDC at Ben Franklin Bridge in 2012, calculated at 4 mg/L DO and 0.25 mg/L ammonia.

Carbon-related Processes

Dissolved Organic Carbon (DOC) is often under-represented in the model per Figure 3-16, which suggests that the overall carbon-related model constituents may warrant some additional loading/process calibration. Additional discussion of CBOD sources would be useful.

Figure 3-63 suggests a significant impact of CBOD on DO depletion, but this is not discussed in the report with the same rigor as SOD, nitrification, or phytoplankton dynamics. Two parameters related to CBOD are included in Table 3-11 (sensitivity analysis) and Appendix H demonstrates very little sensitivity of DO to CBOD rate constants.

Phytoplankton Dynamics and Taxonomy

The phytoplankton calibration metrics create a concern that the impacts of phytoplankton on DO are understated, and that other simulated phenomena, such as nitrification, may be artificially compensating for DO. Similar to DO, the critical time period surrounding low DO should be evaluated using a short-term model evaluation in addition to metrics that evaluate season-long trends.

Table 3-8 demonstrates that while the overall DO calibration is quite reasonable (R^2 = 0.94), the relative causes affecting DO depletion may not be in proper balance. Impacts of algal dynamics on DO may be missed because of the long-term nature of metrics evaluating modeled DO compared with the time frame for algal blooms to impact DO. Modeling ephemeral algal processes in a eutrophication model, and their impacts on DO, is a difficult task; most eutrophication models tend toward an equilibrium. However, the difference between modeled and inferred or observed processes needs to be discussed regarding potential impacts on model results.

Phytoplankton Taxonomy

Additional discussion should be added to the report justifying the selection of the three classes of algae, including references and analysis of the taxonomic analysis used to support this model parameterization.

The model uses three classes of algae: spring marine diatom, summer freshwater diatom, and summer marine diatom. Given that only three algal groups are allowed in WASP and that the critical period for DO in the urban estuary and FMA is summer, DRBC's parameterization of algal groups within the estuary model is appropriate. PWD's analysis of algal taxonomy completed by the Academy of Natural Sciences on data collected between March 2012 and September 2014 within the urban estuary and on the Schuylkill River indicated that the dominant class were diatoms. However, significant populations of green algae, cyanobacteria, and cryptophytes were observed, especially when assessed using cell count. This raises two important points that should be documented in the model calibration report:

1. The calibrated model may be missing a portion of the algal dynamics within the FMA by focusing on only the diatom portion. While PWD believes that the relative impact of this is small given the dominance of the diatom population in summer in the FMA, this does introduce some uncertainty into the results.
2. The calibrated model is suitable for its intended use, but the limitations of the selection of the algal groups parameterized in the WASP model should be clearly stated in the calibration report. For instance, the model should not be used to evaluate or set WQBELs for pollutants that cause or contribute to excessive algal growth in either the urban estuary or Delaware Bay without a more comprehensive understanding of the taxonomy and the associated model parameterization.

PWD's taxonomic analysis, chlorophyll a data from PWD and DRBC Boat Run data, and the continuous chlorophyll a data at USGS gage locations all indicate that blooms typically occur in spring (late March to early April) and in summer. The spring bloom may have implications for sediment fluxes if a time-varying sediment diagenesis model is implemented in the future. Since the current DRBC model formulation does not have an algal group intended to match the spring bloom, any impacts from the spring bloom on fluxes will not be reflected in the current model. This is not an issue currently since the model uses a constant, fixed SOD rate, but will need to be considered if a diagenesis model is implemented in the future and should be noted as a potential model limitation.

In addition to clearly stating limitations associated with algae representation, reasons for parameter selection of the individual species are needed. Phytoplankton growth rates in the WASP model are unusually high. PWD can provide on request an excerpt from the CE-QUAL-W2 manual, where several tables provide sample phytoplankton growth rates applied to other system for comparison. In the Water Quality Model Report Section 3.1.2.2.3.1 discusses the phytoplankton growth process, and Appendix F contains the parameter values. In addition, Section 2.4.2 discussed field data with estimates of growth rates in situ. These sections need to be tied together, and some discussion on how the final modeled growth rates were determined should be provided. Similarly, salinity sensitivities as modeled in WASP should also be discussed, including the role that salinity plays in actual modeled phytoplankton dynamics in the urban river.

Light Penetration

The regression equation used to approximate light attenuation needs additional discussion to describe its development.

The analysis in Section 3.1.3.3 describing the analysis that DRBC completed to establish a predictive function for Ke based on DOC, chlorophyll a, salinity, and river mile should be expanded to show the regression against the available light penetration data and describe how the final Ke regression was selected relative to the available data. Alternatively, the report could also reference slides and meeting minutes from a previous WQAC meeting where this was described.

The assumptions made to establish light attenuation are based on a method that by design represents long term trends and misses key ephemeral processes. While this is an inevitable feature of almost any eutrophication modeling approach, the processes omitted have potentially significant impacts on modeled DO.

Section 3.2.5.3 discusses uncertainties associated with various factors that influence light attenuation and the implications that these uncertainties have on modeled DO. A key conclusion from this analysis is that light attenuation is governed by processes that the model is unable to represent. The most appropriate approach for representing light attenuation is to develop regressions that capture long-term trends and to quantify to the extent possible the impacts from other uncertain terms. A sensitivity test performed in Section 3.2.5.3 demonstrated that when light attenuation is manually adjusted to account for anomalies that are not described by regression relationships, phytoplankton growth patterns more closely match observations for 2019 specifically. The fact that this match in phytoplankton population also then results in high DO that are well above observations indicates that the DO sources and sinks being modeled are possibly incorrect and may need revisiting. This result should be discussed in the context of the overall modeled DO budget.

The rationale of using salinity as a surrogate of suspended solids is acceptable. However, the relationship is developed for 2018 and 2019. For a year with significantly different flow (2012), please provide some discussion justifying the use of the same relationship. Will salinity and suspended solids change accordingly so that the assumption is still valid during low flows?

Documentation of Reaeration and Other WASP Code Modifications

Documentation of changes in reaeration using the Zappa method should include plots comparing reaeration rates themselves. The ultimate impacts on DO are of course important to see, but the scales on the plots make diagnostic assessments difficult. It is difficult to quantify the actual differences in the plots. The discussion would also be improved with a comparison of statistics in DO model-observation comparisons.

Appendix D of the Water Quality Model Report discusses the reaeration modifications made to the WASP model. The new method by Zappa (2007) uses scaling arguments that are intended to represent turbulence at the water surface. The equation used relies on the turbulent dissipation rate. It appears from the appendix that the dissipation rate as implemented in WASP uses scaling arguments that reflect turbulence at the bed, rather than at the surface. The turbulent dissipation rate for reaeration should be based on dissipation at the surface, which scales on the shear velocity at the water surface. This may explain why the modeled DO using Zappa is so similar to the “max” between O’Connor Dobbins and wind reaeration. The length scale used in the actual implementation is also the total water depth, which is what is used in O'Connor-Dobbins.

Overall DO Budget

The Water Quality Model Report shows that there is perhaps too much simulated nitrification, and not enough simulated phytoplankton dynamics and some uncertainty regarding SOD.

The target diagrams in Figure 3-48 and 3-49 are very useful in supporting the discussion about the phytoplankton results. While the DO results demonstrate balanced bias and low error, the phytoplankton results exhibit consistent downward bias and much higher error. This is suggestive of an imbalance in the causes of DO depletion – nitrification and other effects may be too high in the model, while phytoplankton growth and attendant DO depletion may be under-represented.

Ninety three percent of ammonia in the water column originates from point sources as a boundary condition input and it may be that the model is consuming more ammonia than perhaps it should. Figure 3-20 illustrates that while nitrate is well represented by the model, it is often biased a little high in upstream reaches. This suggests too much nitrification, since it is principally downstream that ammonia is depleted. Further supporting the prospect of an imbalance is Figure 3-22, which shows a small, but fairly consistent, upward bias of total nitrogen in the system, underestimated only in June of 2018. Overall nitrogen dynamics warrant some discussion in the report.

Additional discussion surrounding supporting figures is needed to fully incorporate the figures into water quality model evaluation.

The processes described in Section 1.3 Processes Affecting Dissolved Oxygen on pg. 5 are important in evaluating the simulated DO budget, accounting for the DO produced or consumed from each process in the validated model. This will identify the dominant processes in the model that impacts modeled DO. This is somewhat described in Section 3.7.2 Model Limitations on pg. 149 and in Figure 3-69 for the base case in July, but the contribution to DO production or consumption for each process could be better quantified and explained in better detail. Improving this discussion would also relate the model sections back to the stated model purpose.

Figure 3-35 demonstrates overall reasonable representation of DO patterns spatially and temporally, but while DO is not frequently overestimated, it is often underestimated, particularly in the middle reaches where the sag occurs. In a study in which 0.5 mg/L of DO, for example, may be enough to make a difference in conclusions and ultimate regulatory guidance, this is a concern because the deviations below measured values are frequently at or greater than this order of magnitude.

This may be a function of the graphics as a snapshot in space, as Figure 3-42 and 3-43 demonstrate clear consistency between the model and observations, though in the summer of 2019 the model does tend to predict lower DO levels than observed at Chester. In some cases this creates an artificial DO sag, and in others it exaggerates the observed sag.

Similarly, DO saturation appears to be under-predicted by the model in the FMA (Figure 3-37) during peak low DO periods. Sections 3.2.4.1.6 and 3.2.4.1.7 need more narrative discussion on these points. The scale on the figures in 3-35 is 0 to 15 mg/L, which make it impossible to estimate the relative model-observation error at the individual datapoints in the FMA.

4.4. Model Validation and Sensitivity

The WASP water quality model has generally good calibration results, as presented in the Water Quality Model Report. Many detailed, useful figures are included to document model performance. The following sections highlight main questions and potential areas to include additional detail or clarification. Comments are included on qualitative overall calibration, specific metrics or figures, and the sensitivity analysis.

Calibration Objectives and Context

Model calibration objectives should be stated clearly in the report. The model calibration report (see Section 3.2.2) mentions a Quality Assurance Project Plan developed in 2019 that uses a weight of evidence approach to judge the acceptability of the model for its intended purpose. However, the calibration assessment throughout the model calibration report does not reference the objectives established in the QAPP.

Additional details should be added to the calibration report describing whether the model results meet the objectives established in the QAPP and whether the model results are suitable for the intended uses. Qualitative terms such as "reasonably well" representation are vague.

Section 3.2.4.1 contains valuable information on the model's performance; many water quality constituents are compared with observations, which provides insight into modeled processes and overall model performance, and this section would be enhanced by additional discussion accompanying the figures.

For example, demonstration that a model appropriately represents DOC builds confidence in the carbon-related portion of the DO budget as modeled. Figure 3-16 in the report suggests that DOC is often significantly underestimated in the estuary and bay, and some discussion of this and any sensitivity or low degree of impact would be helpful.

Performance Statistics, Metrics, and Figures

The statistics presented in Section 3.2.4.1 consist of grab sample data, which are taken on intervals of weeks. Modeled constituents being evaluated respond to variations on a much shorter timescale. While this is simply a limitation of the data available, this should be born in mind when evaluating model statistics.

Data collected on this time scale cannot reflect phenomena on a shorter timescale, such as days or even weeks. Algal blooms can be inferred from some boat run data, but a clearly identified bloom is difficult to characterize without continuous data. The frequency of the grab samples precludes assessment of any trends beyond seasonal values. The inclusion of modeled ranges on the along channel plots helps add context to the model-data comparison. A brief discussion of the decision to include model results over the course of one day would help inform this context further.

Similarly, using boat run grab sample data to calculate statistics poses limitations to the statistics. Because the frequency of the observed data is longer than the frequency of the main influencing phenomena for some constituents, such as DO, care should be taken when comparing model and observation results. Median daily modeled values are plotted in the calibration plots in Section 3.2.4.1. A discussion should be included describing what model results were used to compare with observations for statistics calculation. Using median daily modeled values for DO, for example, would not be appropriate.

The statistics and figures presented in Section 3.2.4.1 are very useful in assessing model performance. Ensuring clarity on how the statistics are calculated, interpreting results in an appropriate way, and producing clear and easily read figures are all key in identifying modelled processes as they relate to observations.

Many of the calibration plots are very useful in ascertaining the strengths and weaknesses of the model. However, they are also very small and hard to read, and have a compressed scale due to outliers in either the observed data or model output. DRBC should consider improving the readability of these plots to permit a better understanding of model performance.

Performance Metric Time Interval

Calibration metrics should reflect the phenomena being modeled. Seasonal metrics capture the seasonal development of critical conditions, and subsequent recovery. These metrics should be paired with metrics that focus on model performance during the most critical 4-6 weeks of seasonal low DO events.

These short term metrics would complement existing metrics and are critical to understanding the model's ability to represent extreme events within the 1-2% occurrence range, especially if the model will eventually be used to support regulation setting based on modeled 1-2% DO values. The importance of short-term metrics is evident from inspection of Figure 3-35, where DO appears to be underpredicted relative to observations in all years within the DO sag when DO is less than 5 mg/L. Since this is the critical period for compliance, more attention should be given to this deficit, and DRBC should consider using DO during the critical period as another metric for assessing calibration.

Sensitivity Analyses

The sensitivity assessment conducted as described in the Water Quality Model Report is useful in evaluating parameters where small changes in their values could influence model results significantly as the model is currently configured. Some clarification on the uses of this analysis, and other similar analyses that are needed to build confidence in the model, is discussed in this section.

The seasonal adjustment presented in Figure 3-61 and the sensitivity analysis discussed in section 3.2.6 were not completed for critical low DO time periods. DRBC should consider documenting the results of the sensitivity analysis in conditions where critically low DO occurs.

To quantify model results variability due to model parameter uncertainty, model simulations should include scenarios where parameter values are modified on the order of their potential variability.

The function of a sensitivity analysis in which parameters are varied by 10% is to evaluate model sensitivity. For example, SOD and nitrification rates are known to have observed values well outside the range evaluated in the sensitivity study. Uncertainty could be related to sensitivity, but they are essentially different concepts. It is suggested to provide more discussions on differences between uncertainty and sensitivity. A model sensitive to some parameters does not necessarily mean that the model is highly uncertain, and a model sensitive to some parameters may be just because the water quality processes in the surface water are sensitive by nature.

Modeled DO results were most sensitive to parameters related to phytoplankton, with up to 1.2 mg/L change in simulated DO. This sensitivity highlights concepts discussed throughout this comment document regarding the potential importance of algal dynamics in the overall DO balance. Discussion of the implications on modeled DO resulting from this analysis is needed. Analyses such as presented in figure 3-53 can be taken a step further to understand relative importance of various factors. Nitrification is the dominant source of oxygen depletion in the model, but the comparison of simulated nutrients, phytoplankton, etc. suggest that this may be overstated.

The nitrification temperature correction factor was not included in Table 3-11 as a parameter for sensitivity testing. Given the significance of nitrification in the Delaware Estuary and the temperatures at which low DO events occur, this parameter warrants investigation. Similarly, including other water quality constituents besides DO, such as ammonia, in the results evaluation for the sensitivity analysis is recommended.

4.5. Overall Comments and Conclusions

This is a very comprehensive modeling effort. In the eutrophication model results presented in the Water Quality Report, long-term average concentrations seem to match observations reasonably well. However, shorter term phenomena and exploratory tests discussed in the report indicate that some key factors in the DO balance of the model may be over or underestimated.

There is some concern with the potential overestimation of nitrification and SOD, and the authors' identified issues with the model capability of simulating the algal blooms, particularly in June 2018 and 2019. It is possible that the model is overstating the relative impact of nitrification on the DO sag by not reproducing the nutrient/algae dynamics effectively enough to reproduce these impacts. Total nitrogen is very high in the model, while ammonia is generally lower than observed, suggesting that there may be too much nitrification simulated although simulated nitrate values match observations well. Conversely, simulated total nitrogen is generally modestly higher than observations, total phosphorus, the limiting nutrient for algal growth, is frequently substantially higher than observations, and simulated phytoplankton are significantly lower than observations. These results suggest an under-representation of algal dynamics and their potential impact on DO.

It is stated in Section 1.1 Purpose and Objective of the Modeling Study, pg. 2, "Nonetheless, significant dissolved oxygen sags still occur in Zones 3 (River Mile RM] 95 - 108) and 4 (RM 79 - 95), especially during summer periods, limiting the degree of propagation amongst resident fish populations." It should be reiterated that the degree to which fish propagation is limited, if at all, by the DO sag has yet to be determined.

Care should be exercised in examining future climate trends with this model, since the 2012 corroboration period that exhibits lower flow is marked by ammonia, total nitrogen and total phosphorus values that are considered high, while phytoplankton exhibits a more reasonable and lower trend in 2012 than it does in the calibration years.

4.6. Editorial/Formatting Comments

The review process resulted in several comments and clarification questions that do not require a narrative discussion but will improve the report. The table below contains these comments, with references to their location in the document.

Location in Document	Comment
Page 28	The text states that "*The range of Total Phosphorus (TP) concentration data is non-detect to 64.0 mg/L*". 64 mg/L is a very high value for TP. Please confirm that this text is correct.
Page 26: Table 2-9	Phosphate is more important than TP for this system, and nitrate is more important than TN. It is recommended to include phosphate and nitrate (or nitrate+nitrite) in Table 2-9.
Page 29: Figure 2-6	Figure 2-6 Please consider including ammonia on the Y axis title before the unit. Same comment for other similar figures.
Page 30: Table 2-10	Table 2-10 Please consider including phosphate and nitrate+nitrite.
Page 42	Please confirm the unit of primary productivity on this page and in Figure 2-18. Should the unit be by area or by volume?
Section 3.1.2.2.4	Please confirm that the units for reaeration in equation 3-31 are correct.
Page 57: 3.1.2.2.10	How significant is the sorption of NH4 in the Delaware River? Is it necessary to include sorption of NH4 in the model?
Section 3.1.3.3	Is the total DOC used to calculate the Ke or only the fraction of DOC with color used?
Section 3.1.4.1	This section should refer to Appendix A, which contains the data used to establish tributary loads.
Section 3.1.4.2	• There appears to be missing text at the beginning of the section. • There is a figure link that's broken at the beginning of the section. • There is a reference to "Section 0". • Please provide loading locations and corresponding winter and summer concentration information for all modeled DMRs.
Page 64: Table 3-2	• The state variables should be defined. • Are these concentrations EMC or straight average concentrations?
Page 84: Table 3-7	• It is suggested to include the optimal light conditions in the table since the Delaware River is light limited. Section 3.1.4.1 should refer to Appendix A, which contains the data used to establish tributary loads. • Please include the nitrification rate. • It would help to include a discussion of why the values in Table 3-7 were identified as "Key calibration parameters," especially when Table 3-11 lists many more parameters that were deemed to be highly sensitive. Did Table 3-11 inform the list of parameters in Table 3-7? Were these the parameters which

Location in Document	Comment
	were indicated by the initial sensitivity tests as being the most useful or relevant? • It would be useful to include relevant literature ranges for the key parameters identified in Table 3-7.
3.2.4.1 Figures starting with page 89	• For all the plots, the y axis title should include both water quality variable name and unit consistently in the report. And it is suggested to use chlorophyll *a* in the plots consistently instead of "phyto". Appendix A plots of various water quality data in the tribs does not include chlorophyl data. • A spike of phosphate is present in August 2018. But there is no spike for nitrate and solids. The algae level is low based on Figure 3-30. • Silica is not included in section 3.4.2. Why was it not included in model calibration? • What is the reason for the spike of ammonia in August 2018?
NA	• Please provide loading locations and corresponding winter and summer concentration information for all modeled DMRs
Page 70: Table 3-5	This table should include final flux values applied in the model.
Page 83: Section 3.2.2	These runs were conducted before the final calibration. To avoid the confusion with the sensitivity analyses conducted based on the calibrated parameter values, it is suggested to call them model response test or some other term.
Page 84: Table 3-7	Comment: It is suggested to include the optimal light conditions in the table since the Delaware River is light limited.
Section 3.2.4.2	Please discuss the post processing of continuous chlorophyll data for model-data comparison. Penn's Landing continuous chlorophyll measurements are reported in RFUs.
Page 119: Figure 3-46	Figure caption may have an error in itis inconsistent with axis labels (the plots are labeled for ChlA, and the Figure title is for DO).
Page 131: Figure 3-55	Figure 3-55: the total growth limitation factor looks very low compared with the limitation factors shown above it. It would also help clarify to include the total effective modeled growth rate in the table.
Section 3.2.6	Sensitivity study plots 3-63 through 3-67: a daily average plot would make it easier to see.
Section 3.4.2	Silica is not included in section 3.4.2. Why was it not included in model calibration?
Appendix A	Plots of various water quality data in the tribs does not include chlorophyl data.

Location in Document	Comment
Appendix A	Individual Tributary monitoring plots show monthly to weekly DO/10 day and for Trenton and Schuylkill NO3 data points. Are these the smallest time increments (weekly or monthly) for the tributary boundary condition timeseries?
Appendix C.	The WQ report and Appendix C do not provide a detailed description of the EFDC model setup for these runs such as observations or predicted values for discharge and salinity inputs for tributaries, or the tidal boundary forcings including water level, salinity and temperature, which appears to be an omission.
Appendix F	Are the optimal light intensities in Appendix F1 calibrated or default values?
Appendix F or Section 2	We did not see discussion on the fraction of the constituents that is assumed to be dissolved (e.g., 0 for solids, 1.0 for nitrate nitrogen). In particular, the fraction for organic N and organic P should be provided.

Appendix B

PWD Comments on DRBC November 2022 2nd Draft Report *Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary*

PHILADELPHIA WATER DEPARTMENT
Randy E. Hayman, Water Commissioner

Thomas Amidon
Manager, Water Resources Modeling

December 16, 2022

Dear Mr. Amidon,

PWD appreciates the opportunity to provide comments on DRBC's November 2022 second draft report entitled *Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary* ("DO Report"). As a municipal representative serving on DRBC's Water Quality Advisory Committee (WQAC), PWD has actively participated in DRBC's process to evaluate the attainability of changes to Aquatic Life Uses and Water Quality Standards (WQS) for DRBC zones 3, 4, and a portion of zone 5 as required by DRBC Resolution 2017-04. PWD commented 3/28/2022 on an earlier draft of the DO Report and previously on reports prepared by the Academy of Natural Sciences of Drexel University under contract to DRBC. PWD also submitted comments 12/2/2022 on DRBC's draft report *Analysis of Attainability: Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary* which includes information derived from the DO Report. While DRBC has made some improvements to the DO Report compared to the previously shared version, our most serious concern that DRBC has used secondary and technically inappropriate sources as reference material for developing DO targets remains unaddressed.

PWD has also reviewed EPA's recent Administrator's Determination in response to a petition from DRN *et al.* released 12/1/2022 during the informal comment period for DRBC's DO report. Our preliminary review finds that, in making the determination, EPA relied on many of the same sources that DRBC has used for the DO Report, underscoring our concerns regarding the escalation of non-scientific and technically inappropriate sources of information into a regulatory rulemaking context. Overly stringent DO targets, when used in combination with DRBC's overly conservative and unrealistic "design condition" water quality model baseline scenario and "Highest Attainable DO" implementation approach, could lead to imposition of excessive and unnecessary changes to wastewater treatment that would be unaffordable for affected communities, while providing little if any additional benefits to aquatic life. Regarding benefits, PWD has compiled and urges further evaluation of recent estuary sturgeon data by regulatory agencies prior to making changes to WQS.

PWD shares the goal of protecting and restoring Delaware estuary sturgeon and other aquatic life with DRBC, EPA, and the basin states. We look forward to working with DRBC and other stakeholders to build on past successes, continue to make progress, and identify attainable water quality improvements that are based on sound science, technologically feasible; and especially – equitable and affordable for communities. If DRBC has any questions regarding PWD's comments, please contact Jason Cruz (jason.cruz@phila.gov).

Sincerely,

Marc Cammarata, PE
Deputy Commissioner, Planning & Environmental Services
Philadelphia Water Department
1101 Market St. 5th Floor
Philadelphia, PA 19107

CC: Melanie Garrow, Kelly Anderson, Jason Cruz, Kinman Leung (PWD)
Steve Tambini, Namsoo Suk, John Yagecic, Jake Bransky (DRBC)

PWD Comments

1. **PWD continues to have serious concerns about the extent to which DRBC's DO report (and EPA's recent determination) cite and rely on non-scientific, inadequate, incomplete, or technically-flawed sources as the basis of determining appropriate DO levels to support propagation of sturgeon and other aquatic life in the Delaware estuary. WQS must be based on evidence from appropriate primary sources.**

   Appendix A of the DO Report presents a review of sources of information for hypoxia effects on shortnose and Atlantic sturgeon in which a distinction was made between "novel" study sources in the primary literature and other sources which were described as "interpretations (or interpretations of interpretations) of the primary literature". Given that DRBC ostensibly recognizes the difference between primary literature and sources which represent merely "interpretations", it is troubling that DRBC continues to rely so heavily upon the latter for developing DO targets in the main draft DO Report. Anecdotal observations and secondary sources may be useful to *corroborate* findings from primary laboratory-based studies but should not be used as *substitutes* for primary sources in cases where primary sources are limited or non-existent.

2. **DRBC's draft DO Report relies heavily on a 2001 study of the effects of hypoxia on juvenile Atlantic sturgeon by Niklitschek & Secor to develop a chronic DO endpoint. This study, which was described in Dr. Edwin Niklitschek's doctoral dissertation from the University of Maryland and a series of peer-reviewed publications in 2009, tested multiple stressors (*i.e.*, hypoxia, salinity, and temperature) simultaneously in an incomplete factorial design that was not consistent with accepted methods for identifying toxicological endpoints.**

   PWD does not intend to suggest that the authors acted inappropriately or that the 2001 Niklitschek & Secor study was poorly done. Our objection centers on DRBC's use and extrapolation of the experimental findings from the study well beyond the original intent of the experiment and accepted scientific methods for measuring toxicity in laboratory exposure experiments. The factors that make this study inappropriate for deriving a DO endpoint for aquatic life include:

   1.) Very small sample size – some treatments only tested 2 or 3 individual fish
   2.) Inadequate number of experimental exposure treatments
   3.) Potential confounding effects of multiple stressors
   4.) Lack of clear monotonic trend in results

   Methodological shortcomings of the 2001 Niklitschek & Secor study for the purpose of deriving DO endpoint(s) are illustrated by a comparison between the experimental design of the 2001 Niklitschek & Secor study and Whole Effluent Toxicity Testing (WETT) requirements. Conceptual diagrams of a typical WETT test and the 2001 Niklitschek & Secor study are included below as Figure 1 A & B. WETT involves testing invertebrates (Water flea; *Ceriodaphnia dubia*) and fish (Fathead minnow; *Pimephales promelas*) with a series of wastewater effluent dilutions. The dilution series is specified in NPDES permits and intended to represent the actual instream concentration of effluent and characterize the expected increasing response in potential toxicity at increasingly higher effluent concentrations. WETT is performed under standard laboratory conditions of 20ºC and 0 PSU salinity for freshwater organism tests. The minimum number of individuals (10) and replicates (4) for each treatment level is also specified. In contrast, the 2001 Niklitschek and Secor study used relatively very few individuals per treatment, such as only three fish tested at 20ºC, 40% DO

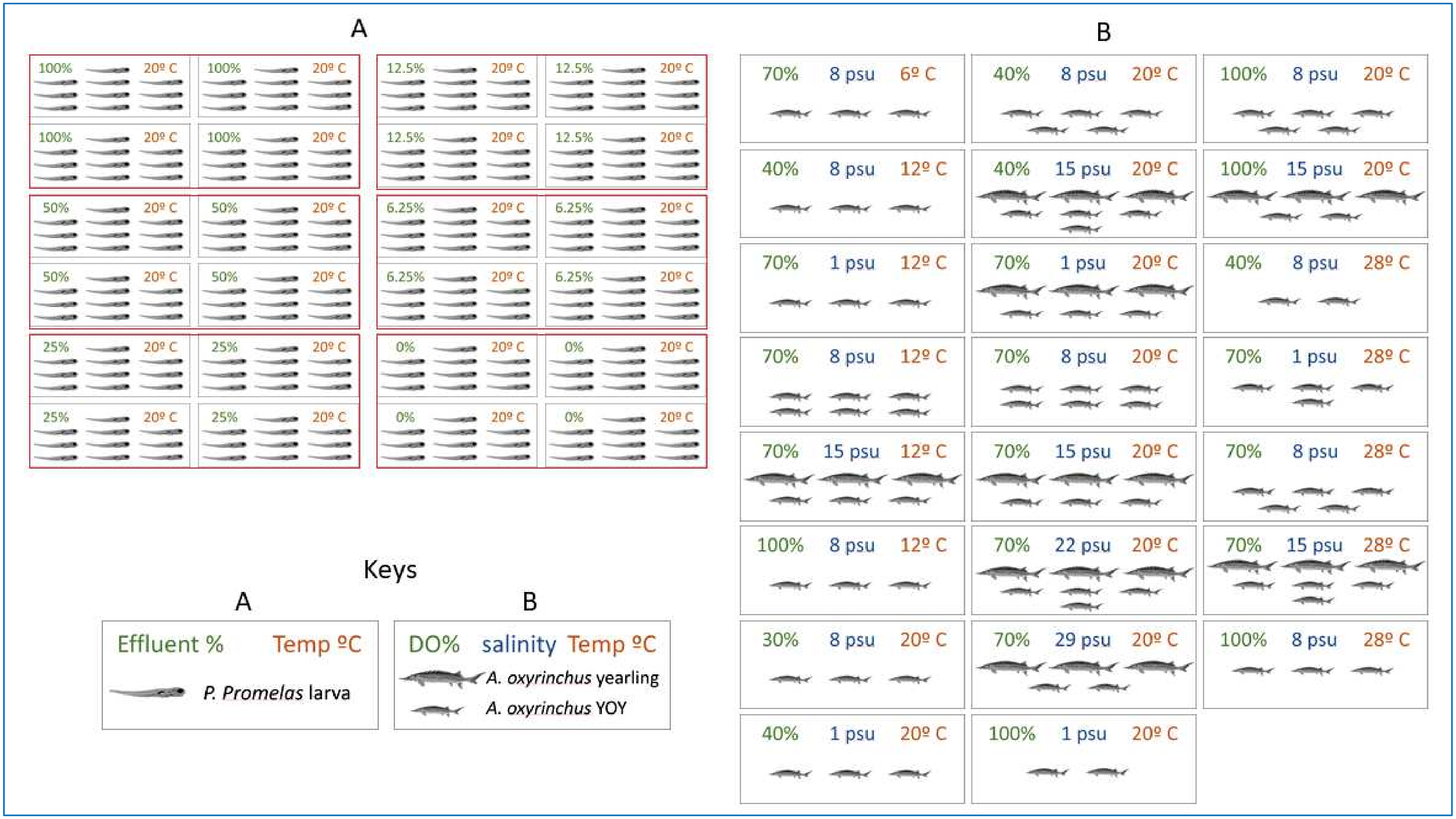

Figure 1. Conceptual diagrams of experimental design for A: Chronic WET Test for toxicity with larval Fathead minnow (*Pimephales promelas*) EPA Method 1000.0; B:Incomplete factorial design to measure effects of DO saturation, temperature and salinity on juvenile Atlantic sturgeon(*Acipenser oxyrinchus*); PWD graphic based on Table 1 in Niklitschek & Secor 2009.

saturation and salinity 1, and did not test *any* fish at the conditions of 28ºC, 40% DO saturation and salinity 1 most likely to be observed in very warm and dry summers in the Delaware river (Fig. 1A).

In addition to the methodological concerns of inadequate sample sizes and number of treatments, it should be noted that a non-monotonic effect was observed with instantaneous death rate in the 2001 Niklitschek & Secor study. Juvenile sturgeon exposed to 70% DO saturation at 28ºC experienced nearly twice the rate of mortality as fish exposed at 40% saturation (Figure 2). Non-monotonic and unexpected results were also observed in the DRBC-funded 2018 study of Atlantic sturgeon early life stages by Wirgin and Chambers. These types of effects would be unacceptable in WET tests, requiring re-tests. While experimental designs were not exactly similar, effects of low DO on Atlantic sturgeon survival and prey consumption also varied substantially between the two studies. These differences should not be dismissed as inconsequential. Given the enormous potential costs of changes to wastewater treatment, DRBC's criteria for use of laboratory DO tests for development of suitable DO endpoints should not be set at a lower standard than WETT.

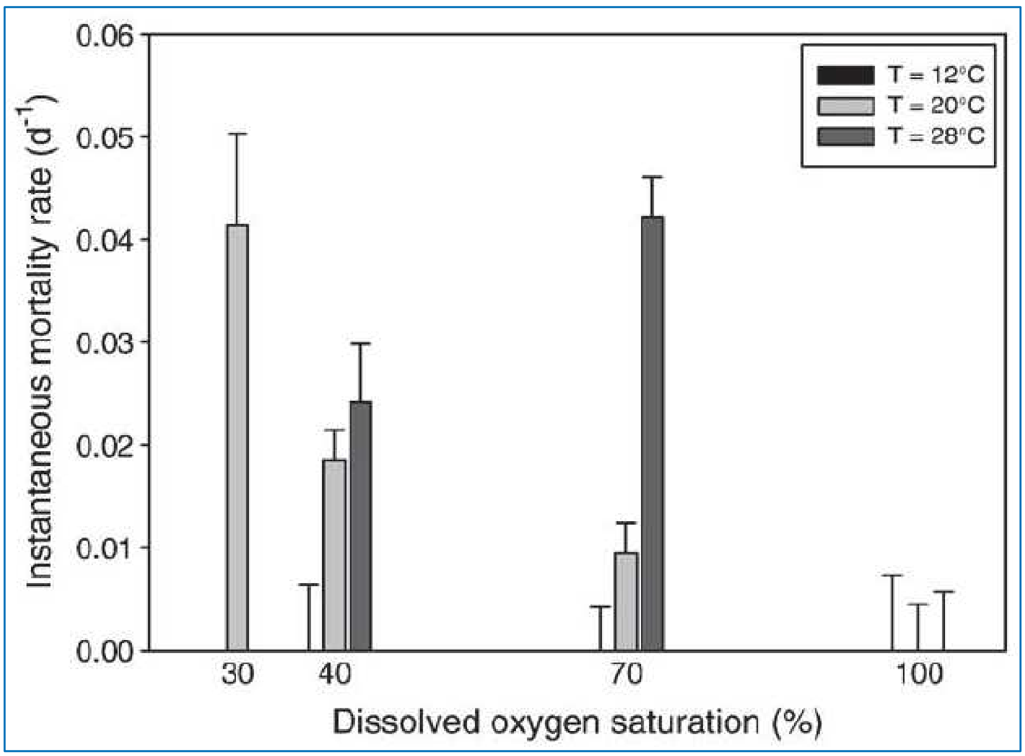

Figure 2.) Instantaneous mortality Rate vs DO saturation for juvenile Atlantic sturgeon at three exposure temperatures. Reproduced from Fig. 7 in Niklitschek & Secor 2009a.

DRBC's derivation of suitable DO levels in Appendix A of the draft report is based on DRBC's interpretation of the 2009 bioenergetic model paper by Niklitshek & Secor (2009b). It should also be noted that this bioenergetic model is based on the same 2001 experiments with very low sample size, large variation observed in effects, and often unexpected and counterintuitive results. Any model is only as good as the input data. DRBC should also consider evidence from observed DO and fish data from the estuary in a comprehensive weight-of-evidence approach to evaluating DO levels.

3. **Delaware sturgeon data are not fully utilized in the DO Report. PWD is providing with our comments a draft compilation of sturgeon observation data in Microsoft Excel format for further review and discussion with DRBC, co-regulators and other stakeholders.**

The Atlantic sturgeon has been the focus of petitions by environmental activist groups to increase DO water quality standards in the Delaware River. These NGO groups have lobbied DRBC and other regulatory agencies with the seemingly incongruous claims that 1.) sturgeon are observed propagating in the Delaware River every year, and 2.) DO levels lower than 6.3mg/L (a common occurrence in the Delaware during summer) are lethal to juvenile sturgeon. NGOs have also used "cherry-picked" unpublished data in claims of adverse effects of low DO on sturgeon recruitment.

Recognizing that DRBC's 2015 review of the status of DO-sensitive fish species in the Delaware River was based primarily on PSEG 2002-2004 ichthyoplankton surveys and that recent Delaware estuary observed fish data have not been fully utilized in the evaluation of DO levels that are protective of larval fish and allow for normal development of juveniles, PWD sought to compile and perform a preliminary review of the available data for sturgeons collected from the Delaware River. Similar records were also obtained from the Hudson River, which is believed to have the largest extant population of Atlantic sturgeon in the New York Bight Discrete Population Segment (DPS). Hudson River DO levels are also notably consistently higher than those in the Delaware River during the growing season.

PWD identified monitoring information for Delaware and Hudson River sturgeons primarily using resources from National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) reviews of the Endangered Species Act status of the Atlantic sturgeon, NMFS Biological Opinion documents, grant reports, academic journal articles, state resource agency publications and web searches. Brief descriptions of the individual publications and resources consulted are summarized below and in Tables 1 & 2. PWD transcribed Delaware River sturgeon data from PDF files of DNREC grant reports from 2011 and 2015; additional data for 2016-2019 were obtained in Microsoft Excel format from DNREC in June 2022. Sturgeon surveys and relocation were conducted by Environmental Research and Consulting (ERC) 2014-2019 under contract to the USACE during rock blasting for the Delaware River Navigation Channel Deepening Project. PWD transcribed ERC sturgeon data from PDF reports that were obtained from NMFS via a Freedom of Information Act (FOIA) request in April 2022. For the Hudson River, PWD obtained data from the New York State Department of Environmental Control (NYSDEC) Hudson River biological monitoring program 2003-2022 in Microsoft Excel format via a NY State Freedom of Information Law (FOIL) request. PWD transcribed sturgeon collection records collected 2001-2020 by Normandeau Associates on behalf of a Hudson River electrical generators group from PDF files obtained from NMFS via FOIA request.

PWD's preliminary conclusion from reviewing the assembled sturgeon data is that there are more than 5,000 sturgeon records available covering the past two decades for both the Delaware and Hudson Rivers. Many of the data sets include length and weight measurements, which could be used to estimate weight-length relationships, or fish "condition", for juvenile sturgeon in the Delaware and Hudson Rivers in years with adequate numbers of fish collected. Fish condition metrics should also be compared to DO metrics to evaluate the effects of hypoxia. Many specimens also had PIT tag information, which could allow for empirical growth rate estimates for fish that were tagged and recaptured. PWD recognizes the substantial fisheries knowledge and experience of DRBC, EPA and state agency staff and look forward to collaboratively analyzing these data. We also acknowledge and do not intend to jeopardize scientific publication opportunities from this work.

Table 1. PWD Preliminary Review of Sturgeon Collection Information for the Delaware River

Publication	Title/Description	n	Total length	Fork length	weight	PIT tag ID
Lazzari *et al.* 1986	Occurrence of Juvenile Atlantic Sturgeon, *Acipenser oxyrhynchus*, in the Upper Tidal Delaware River	20	1	1	1	
Brundage 2009	Investigations of Juvenile Shortnose and Atlantic Sturgeons in the Lower Tidal Delaware River	6	1	1	1	
Calvo *et al.* 2010	Effects of Flow Dynamics, Salinity, and Water Quality on the Atlantic Sturgeon, Shortnose Sturgeon and Eastern Oyster in the Oligohaline Zone of the Delaware Estuary	53	1	1	1	
Fisher *et al.* 2011	Atlantic Sturgeon Final Report State Wildlife Grant Project T-4-1 Period covered: October 1, 2006 to October 15, 2010	46	1	1		1
Sturgeon Management Board 2013	Atlantic States Marine Fisheries Commission Sturgeon Management Board Meeting Minutes May 23, 2013 (Tables 3 & 4)	54	1	1	1	1
ERC 2014	Report of A Study to Determine the Feasibility of Relocating Sturgeons Out of the Blasting Area for the Delaware River Main Channel Deepening Project	36	1	1	1	1
Savoy 2015	Final Report Section 6 Species Recovery Grants Program Award Number: NAIONMZF4720030 Report period: 06/01/2010 - 05/31/2015 (Tables 2.1, 2.2, Appendix A Table 5)	138	1	1	1	1
ERC 2016, ERC 2017, ERC 2018, ERC 2019	Report of Sturgeon Monitoring and Protection During Rock Removal for the Delaware River Main Channel Deepening Project • December 2015 - March 2016 • November 2016 - March 2017 • November 2017 - February 2018 • January 2019 - March 2019	5,042	1	1	1	1
Park 2020	Final Report Section 6 Species Recovery Grants Program Award Number: NA16NMF4720072 Report period: 07/01/2016 - 06/30/2020	434	1	1	1	1
	Estimated Total Delaware River Records*	**5,809**				

***Estimated total may include duplicate records of specimens in more than one data set**

Table 2. **PWD Preliminary Review of Sturgeon Collection Information for the Hudson River**

Resource/ Publication	Description	n	Total length	Fork length	weight	PIT tag ID
NYSDEC FOIL Request 2022	Atlantic and shortnose sturgeon collection records from the tidal Hudson River in NY and NJ 2003-2020 by the Hudson River Biological Monitoring Program.	5390	1	1	1	1
NOAA NMFS FOIA Request 2022	Hudson River Generators Fall Shoals Survey (FSS) Annual Reports 2001-2020	1330	1	1	1	1
	Estimated Total Hudson River Records*:	**6720**				

*** Estimated total may include duplicate records of specimens in more than one data set**

References

Niklitschek, E. J., and D. H. Secor. 2009a. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic Sturgeon in estuarine waters: I, Laboratory Results. Journal of Experimental Marine Biology and Ecology 381(supp-S): S150–S160.

Niklitschek, E. J., and D. H. Secor. 2009b. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic Sturgeon in estuarine waters: II. Model development and testing. Journal of Experimental Marine Biology and Ecology 381(supp-S): S161–S172.

USEPA, 2002. Method 1000.0: Fathead Minnow, Pimephales promelas, Larval Survival and Growth; Chronic Toxicity. Excerpt from Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms 4th edition EPA-821-R-02-013

Wirgin, I. and R. C. Chambers. 2018. An experimental approach to evaluate the effects of low dissolved oxygen acting singly and in binary combination with toxicants on larval Atlantic Sturgeon, Acipenser oxyrinchus oxyrinchus. New York University Department of Environmental Medicine and Northeast Fisheries Science Center NOAA Report: 46pp.

Attachments

Microsoft Excel file containing sturgeon records from Delaware and Hudson Rivers compiled by PWD.

Appendix C

PWD Comments on DRBC March 2022 Draft Report *Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary*

Randy E. Hayman, Water Commissioner

Jake Bransky
Aquatic Biologist
Delaware River Basic Commission
P.O. Box 7360
West Trenton, NJ 08628

March 28, 2022

Subject: PWD Comments on DRBC Draft Report "*Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary*" (DRBC Draft Dated March 2022)

As one of the municipal members of DRBC's Water Quality Advisory Committee (WQAC), PWD would like to offer the following comments on DRBC's Draft Report entitled "*Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary*" ("The Draft Report") which was circulated to the WQAC and other stakeholders on March 4, 2022. PWD previously submitted comments on a report titled "*Draft Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary*" produced by the Academy of Natural Sciences of Drexel University ("ANSDU") under contract to DRBC. Our previous comments are attached as Appendix A, as we feel they have yet to be fully addressed by DRBC. PWD is also a member of the Delaware Estuary PCB TMDL Coalition, a discharger group that reviewed and submitted comments on the above methodology report and the draft report entitled "*A Review of Dissolved Oxygen Requirements of Key Sensitive Species in the Delaware Estuary*". These previous comments, submitted by the Coalition on February 8, 2018 and August 6, 2018, respectively, are attached as appendices B and C, as these comments have not been fully addressed by DRBC. PWD is incorporating by reference the comments included at Appendices A through C.

1.) *Many of the sources included in Appendix 1 of the draft report are inappropriate for use as the basis of determining dissolved oxygen (DO) criteria.*

As stated in our earlier comments, PWD would like to reiterate our concern regarding the extent to which DRBC and ANSDU have used secondary sources and simple observational statements in general publications rather than controlled laboratory studies as the basis for determining DO levels to support certain life stages of sensitive species. Only a handful of the cited sources in Appendix 1 (*e.g.*, Hanks and Secor 2011, Niklitschek and Secor 2009, Secor and Niklitschek 2001, Jenkins, *et al.* 1993) describe actual laboratory exposure studies. The majority of the cited sources are either: 1.) secondary references (*i.e.*, Author A summarizing findings by Author B, typically in only a few sentences), which do not contain enough detail to determine whether they are of appropriate quality for developing DO criteria, or 2.) general observational statements. The latter may be useful as background information but are clearly not of appropriate technical quality to be used as the basis of determining DO criteria. The only new reference that appears to have been included, Setzler-Hamilton and Hall 1991, is not a laboratory study, but a habitat summary document for the Chesapeake Bay which cites secondary sources including Jones, *et al.* 1988, Krouse 1968, O'Malley and Boone 1972, and Turner and Farley 1971, some of which are already cited as sources in Appendix 1.

2.) *The draft report should more explicitly acknowledge the paucity of high-quality controlled laboratory experimental data available for sensitive species and clearly communicate the variability of the types of information cited in Appendix 1.*

Page 1 of the draft report, describing the literature review, states:

> "The literature, information, and data sought throughout the methodology were from appropriate scientific or published sources, and special effort was made to identify and obtain the most recent and reliable studies and reports."

Considering that, as stated above in comment 1, Appendix 1 of the draft report contains a combination of controlled laboratory studies as well as secondary sources and general information, this statement could mislead the reader to believe that all the cited sources are of equally high technical quality. We recommend that DRBC more openly acknowledge the varying quality of cited sources and recognize the inherent uncertainty that would be associated with using secondary sources and general information for developing DO criteria.

3.) *The draft report should clarify that laboratory experiments described in sources cited in Appendix 1 generally used relatively few hypoxia exposure levels and were not specifically designed with a toxicological approach to identifying DO endpoints for hypoxic effects.*

USEPA’s 1985 guidance document “*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and their Uses*” (Stephan, *et al*. 1985) establishes minimum requirements for studies, including the number of animals per replicate, number of experimental exposure levels, controls, etc. as well as an overall experimental design approach that ensures a biologically-relevant range of experimental exposures yield an adequate range of effects to determine the desired endpoint. Most of the laboratory studies cited in Appendix 1 had fewer than the recommended five levels (*i.e.*, four treatments and a normoxic control) of experimental hypoxia treatments for a given temperature. For example, the studies by Hanks and Secor 2011, Niklitschek and Secor 2009, and Secor and Niklitschek 2001 only evaluated two or three levels of hypoxia (*i.e.*, 20%, 40% and 70% with no normoxic control; 30%, 40% and 70% with a normoxic control in an incomplete factorial design by temperature; and 40% and 70% with a normoxic control, respectively). It should be noted that the range between 40% and 70% in all three of these studies is very large (equivalent to 6.4mg/L vs. 3.6mg/L at 20º C), and it should not be assumed if there are no adverse effects at 70% and some adverse effects at 40%, that 70% represents an "optimal" value. If additional intermediate levels of hypoxia had been included in these studies, it may have been the case, for example, that effects at 55% saturation (5mg/L at 20ºC) would have been not statistically different from effects at 70%. The very large range of exposure values may be related to researchers' actual original research objectives, which may have been to evaluate whether there are statistically different effects, such as reduced metabolism, growth rate, etc. These effects would be presumably easier to demonstrate when the range of exposure levels is large. With such a large exposure range, the only inference that can be made when, for example, no adverse effects occur at 70% DO (6.4mg/L at 20º C) is that 70% is AN optimal value. One cannot conclude that 70% is THE optimal value or that levels below 70% are not also optimal.

4.) *DRBC should include a brief discussion of the physiological effects of hypoxia as it relates to DO percent saturation, include equivalent DO saturation values in the table in Appendix 1, and consider DO percent saturation when developing DO criteria in general.*

While DO can be measured in concentration units of mg/L, it is the partial pressure of oxygen, or percent saturation, that is actually responsible for the physiological adverse effects of hypoxia. Including percent saturation for the studies cited in the table in Appendix 1 will make it easier to compare DO endpoints that were measured at different temperatures. For comparison purposes, the saturation level of 5mg/L DO that is suggested as suitable DO level for all species in all seasons is equivalent to 55% saturation at 20º C, or 4.55mg/L DO at 25º or 4.15mg/L DO at 30º.

5.) *The draft report should not omit a 2018 study by Wirgin and Chambers entitled "An Experimental Approach to Evaluate the Effects of Low Dissolved Oxygen Acting Singly and In Binary Combination with Toxicants on Larval Atlantic Sturgeon, Acipenser oxyrinchus oxyrinchus*"

While there may be some methodological concerns regarding this study, such as the Atlantic sturgeon stocks chosen for the experiment and exposure temperatures; as well as the potentially confounding effects of including two different stressors (*i.e.*, hypoxia and toxicants) in the experimental trials, this study nevertheless provides additional data that could be considered in a weight-of-evidence evaluation of DO level endpoints for Atlantic sturgeon.

6.) *The table in Appendix 1 contains a record for optimal DO for white perch juveniles attributed to Hanks and Secor 2011 with the Note "Growth threshold effect in this range". This is a misinterpretation of the experimental findings.*

It can be seen in Figure 4 on pg. 810 of Hanks and Secor 2011 that there was no statistically significant difference between 70% and 40% (equivalent to 6.4mg/L vs. 3.6mg/L at 20º C). Box plots for white perch juvenile growth rate at 40% and 70% saturation are labeled with the letter B, indicating no significant difference (Tukey's test $p > 0.05$).

7.) *The Table in Appendix 1 contains a Yellow perch adult record indicating an optimal level of 5mg/L, but there are no accompanying sources or notes.*

8.) Lastly, it was noted that there is a typographic error on page 2 "The second phase of the review involved *pairing* down the list..."

PWD appreciates the opportunity to review the draft report and provide our comments.

Sincerely,

Jason Cruz
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CC:
Kelly Anderson, PWD
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References

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Wirgin, I. and R.C. Chambers. 2018. An Experimental Approach to Evaluate the Effects of Low Dissolved Oxygen Acting Singly and in Binary Combination with Toxicants on Larval Atlantic Sturgeon, Acipenser oxyrinchus oxyrinchus. Final Report. 46 p.

Appendices

Appendix A: PWD comments on "*Draft Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary*"

Appendix B: Delaware Estuary PCB TMDL Coalition comments on "*Draft Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary*"

Appendix C: Delaware Estuary PCB TMDL Coalition comments on "*A Review of Dissolved Oxygen Requirements of Key Sensitive Species in the Delaware Estuary*"

PHILADELPHIA WATER DEPARTMENT
Debra A. McCarty, Water Commissioner

John Yagecic
Manager, Water Quality Assessment
Delaware River Basin Commission
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Re: Draft Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary

Dear Mr. Yagecic,

Along with the City of Wilmington, the Philadelphia Water Department (PWD) represents the regulated municipal discharger community on the Delaware River Basin Commission (DRBC) Water Quality Advisory Committee (WQAC). As a WQAC member, PWD is grateful for the opportunity to provide feedback to DRBC on the "Draft Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary" ("Draft Methodology").

PWD is also a founding member of the Delaware Estuary TMDL Coalition ("the Coalition") and supports the comments on the Draft Methodology prepared by Ramboll and submitted to DRBC by Coalition and WQAC member Bart Ruiter of Chemours. Rather than repeating the specific comments made by Ramboll, PWD would like to acknowledge our agreement with their review of the Draft Methodology.

PWD would like to offer comments about the Draft Methodology, DRBC's overall Existing Use evaluation process and the role of the WQAC.

1. *The premise of the Draft Methodology is flawed and needs revision*

The Draft Methodology is based on the premise that an unlimited number of scientifically rigorous studies exist, and simply need to be read and summarized to inform DRBC as to the range of temporal dissolved oxygen (DO) requirements for multiple aquatic species in their various life stages within the Delaware Estuary. This premise is unrealistic and flawed. This is demonstrated by the lack of information available for one of the most sensitive species occurring in the Estuary, the Atlantic sturgeon. Only two references are identified in the Draft Methodology as being used to inform the DO requirements for Atlantic Sturgeon. These studies only provide limited information on a small number of individual life stages, exposure levels, test durations and test endpoints. Moreover, for anadromous fish species it is important to also evaluate the effects of temperature and salinity in conjunction with hypoxia in laboratory tests.

Evaluating the DO requirements for the Atlantic Sturgeon and other potentially sensitive species/life stages in a water quality criteria development context is more complicated than performing a literature review, especially when the available literature is simply inadequate. While the Draft Methodology recognizes that persistent data gaps may be identified in steps 7-9, the Draft Methodology does not indicate how these critical information gaps will be filled, other than to say that an "internal and external review will be conducted to identify additional sources of information". PWD recognizes that numerous researchers and organizations in the Estuary and region can potentially supplement published information on the spatial and temporal patterns of distribution for sensitive species. However, in this regulatory context scientifically rigorous studies of appropriate exposure and averaging periods for DO are critical, and it is not appropriate – as suggested in the Draft Methodology – to substitute subject matter expert opinion for carefully controlled laboratory exposure experiments. The Draft Methodology needs to be revised to include a strategy for initiating, funding, contracting and administering scientifically rigorous studies of dissolved oxygen needs of key sensitive species, such as the Atlantic sturgeon.

2. *A baseline must be established for species of concern, including all threats and stressors*
PWD recognizes that the Draft Methodology is focused on identifying the DO requirements of Estuary species which are sensitive to low DO. PWD also recognizes that the Draft Methodology is one component of a larger effort to evaluate aquatic life uses and water quality criteria to support these uses. However, there is a high level of uncertainty associated with sampling and estimating the population sizes of Estuary species, particularly anadromous species. Small population size and highly uncertain population estimates will make it difficult to predict the impacts of changes in water quality on populations of some species of concern. Furthermore, species of concern in the Estuary are affected by multiple anthropogenic, environmental and ecosystem-level stressors. The existence of multiple stressors may also make it difficult to predict (or monitor) individual population or ecosystem changes resulting from changes in water quality. PWD recommends that, in addition to water quality, other stressors including vessel strikes, bycatch, ecosystem-level stressors, and other commercial activities should be systematically evaluated as threats to species of concern.

3. *The WQAC is under-utilized*

As a long-standing participant on the WQAC and many other DRBC advisory committees, PWD values the role of the WQAC and the opportunity to participate in the regulatory development process. PWD acknowledges the significant effort to be expended by DRBC in the next few years while working to evaluate the existing use and attainability of potential changes in DO criteria in the Delaware Estuary. Given this workload, PWD would like to encourage DRBC to reach out to the WQAC on a more regular basis for advice. WQAC member organizations are skilled in a variety of disciplines and can provide feedback and assistance to DRBC. In addition to providing DRBC with feedback on research methodologies, the WQAC can be called upon to advise DRBC on research direction prior to the commencement of technical work.

PWD is committed to participation on the WQAC and is grateful to DRBC for the opportunity to provide feedback on the Draft Methodology. PWD looks forward to more opportunities to support DRBC as a member of the WQAC.

Sincerely,

Jason Cruz
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Philadelphia, PA. 19107

ENVIRONMENT
& HEALTH

John Yagecic
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Delaware River Basin Commission
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West Trenton, NJ 08628-0360

COMMENTS ON THE DRAFT
"A METHODOLOGY FOR EVALUATING DISSOLVED OXYGEN REQUIREMENTS OF SPECIES IN THE DELAWARE ESTUARY"

Date February 08, 2018

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Dear Mr. Yagecic,

On behalf of the Industrial and Municipal Representatives to the Water Quality Advisory Committee (WQAC) and the Delaware Estuary TMDL Coalition, Ramboll US Corporation (Ramboll, formerly ENVIRON International Corporation and Ramboll Environ) is providing the Delaware River Basin Commission (DRBC) with the following comments on the draft "A Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary" (the Draft Methodology), which was prepared by the Patrick Center for Environmental Research, of the Academy of Natural Sciences of Drexel University on behalf of the Delaware River Basin Commission (DRBC).

1. **The Draft Methodology should employ systematic review practices to help ensure that work is comprehensive.**
   The objective of a systematic literature review[1] is to yield a comprehensive set of literature relevant to a specific research question. Systematic reviews require definition of methods prior to beginning the literature search. Specifically, transparent and objective decision rules are established at the outset of the study for determining the relevance of available studies, judging quality, evaluating results, ensuring that content is extracted error-free, and defining what constitutes a data gap. Specifying decision rules prior to conducting the literature review helps ensure consistent practices are employed by all individuals undertaking the review, and helps prevent relevant studies from being omitted. We identified a number of potentially relevant studies that were not included in the Draft Methodology's reference list (e.g., Niklitschek and Secor 2009; Shimps 2005; Brake 1972), suggesting that the Patrick Center

[1] http://handbook-5-1.cochrane.org/ is an example of a handbook on how to conduct systematic literature reviews.

should incorporate systematic review practices to ensure a more thorough review of the existing literature.

Specific practices that warrant discussion in the methodology include but are not limited to:

- Which databases will be searched?
- What keywords will be used in the searches?
- What steps will be taken to verify the completeness of the online search?
- What years of studies will be included?
- What are the minimum criteria for acceptability of studies (e.g., study duration, endpoints, number of test groups, control performance)?
- What practices will be used to verify the accuracy of information extracted from included studies?
- How will the rationale for exclusion of individual studies be documented?
- What fields will be defined in the database used to store extracted information (e.g., life stage tested, duration of exposure, test temperature,)?

2. **The Draft Methodology also should describe how the findings from the literature review will be reported—that is, what specific information will be provided in the resulting work product.** A key outcome of the work to be undertaken will be detailed characterization of what species inhabit which parts of the river during which life stages, and the dissolved oxygen required to support that species in that life stage. Those findings, however, must be reported with sufficient context to support science-based decision-making for regulatory purposes. Ramboll here offers three examples of context that should be provided in the work product that results from the literature review:
   - Due to the important influence of water temperature, and in some cases salinity, on the distribution of aquatic species and the sensitivity of aquatic species to dissolved oxygen limitations, reporting should separately consider water temperature and applicability of test results along a salinity gradient.
   - The literature review is likely to identify multiple studies for the same species, with the different studies varying in quality and yielding conflicting conclusions; consequently, the work product should include a weight-of-evidence analysis that objectively and transparently resolves such conflicts.
   - The report stemming from the literature review is also expected to discuss data and knowledge gaps—what constitutes a gap, which are most critical, and how those critical gaps should be filled?

3. **The Draft Methodology includes a step for identifying knowledge gaps, but does not specify how such gaps will be prioritized and addressed.** The most appropriate methods for addressing knowledge gaps likely will depend on what those gaps are. It may therefore be premature to name next steps. However, the Final Methodology would be strengthened by identifying examples of approaches for addressing different types of knowledge gaps.

4. **Section 3, Species Absent Due to Dissolved Oxygen Limitations, is not relevant to the evaluation of DO needs of sensitive species in the Estuary or the existing use of the Estuary; it therefore warrants no further investigation and should be omitted from the final methodology.**

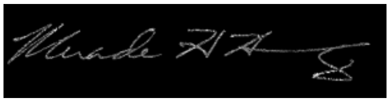
The Draft Methodology is intended to support an evaluation of the dissolved oxygen needs of sensitive species within the Estuary and is described as a "key component" of DRBC's aquatic life use and Estuary eutrophication modeling effort. As such, DRBC's work must focus on the dissolved oxygen requirements of the fish and other aquatic life *that currently inhabit the relevant Zones of the river*—not the dissolved oxygen requirements of fish that do not inhabit the river. Although the authors frame Section 3 as relevant based on causality, no persuasive case is made that the three species addressed in Section 3 are absent from the Delaware Estuary wholly or in part due to dissolved oxygen limitations. Furthermore, despite linking the elements of the Draft Methodology to DRBC's evaluation of the existing use and the ongoing Estuary eutrophication modeling, the authors do not explain how Section 3 is relevant to such efforts.

5. **Methods and assumptions to be employed in Next Steps (p. 8) are not described in sufficient detail to allow evaluation.**
   The discussion on Next Steps focuses primarily on the approach that may be used to narrow the list of sensitive species, describing in extremely general terms two approaches that could be used. Insufficient detail is provided on how they would be implemented, and the strengths, weaknesses and differences between the two. Although the section is not sufficient to support a decision as to which approach is more appropriate—and details of all additional activities should certainly be provided in the final methodology—it does appear that the second alternative listed is the more holistic one and could better recognize data gaps, the difficulty of comparing multiple studies, and the complexity of conditions that influence dissolved oxygen sensitivity in the field.

6. **Section 5, Secondary Pathways of Oxygen Sensitivity does not relate to an assessment of dissolved oxygen needs of estuarine species.**
   The purpose and utility of Section 5 are unclear. In this section, the Draft Methodology offers generalizations about secondary pathways, but fails to explain how the information provided will inform the underlying objectives described in the Draft Methodology. Furthermore, to the extent the Draft Methodology is relevant to DRBC's aquatic life use and estuary eutrophication modeling effort, as the Draft Methodology states, the authors fail to explain how. Even assuming that the secondary pathways discussed are relevant to DRBC's efforts, such effects would only be meaningful if the secondary pathways are more sensitive than the primary pathways by which dissolved oxygen limitations can affect aquatic life use. Section 5 does not explain if and how secondary pathways affect estuarine species in a detectable and biologically relevant manner, nor does it inform the question of whether secondary pathways are more or less sensitive than primary pathways. The available scientific literature is unlikely to contain sufficient reliable information to answer such questions. As such, we recommend that Section 5 be omitted from the final methodology.

Thank you for the opportunity to present the above comments. Ramboll may provide additional comments on the Draft Methodology or subsequent work products relating to DRBC's evaluation of the dissolved oxygen needs of estuarine species or its Estuary eutrophication modeling effort at a later date. If you have any questions, please feel free to reach me at the contact information provided below.

Yours sincerely



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***Partner responsible – Brenda H. Gotanda*

August 6, 2018

John R. Yagecic, P.E.
Manager, Water Quality Assessment
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25 Cosey Rd., PO Box 7360
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Re: Comments on ANSDU's Draft Report "*A Review of Dissolved Oxygen Requirements of Key Sensitive Species in the Delaware Estuary*"

Dear John:

On behalf of the Industrial and Municipal representatives to the Water Quality Advisory Committee ("WQAC") and the Delaware Estuary TMDL Coalition, we submit the attached comments on the draft report entitled, *A Review of Dissolved Oxygen Requirements of Key Sensitive Species in the Delaware Estuary*, which was prepared by the Patrick Center for Environmental Research of the Academy of Natural Sciences of Drexel University ("ANSDU") on behalf of the Delaware River Basin Commission ("DRBC") (the "Draft Report").

We appreciate the opportunity to submit these comments on the Draft Report. If you have any questions, please let us know.

Sincerely,

Michael Dillon
FOR MANKO, GOLD, KATCHER & FOX, LLP

cc: Delaware Estuary TMDL Coalition
Brenda H. Gotanda, Esq.

Comments of the Delaware Estuary TMDL Coalition on the Draft "A Review of Dissolved Oxygen Requirements of Key Sensitive Species in the Delaware Estuary"

On behalf of the industrial and municipal representatives to the Water Quality Advisory Committee ("WQAC") and the Delaware Estuary TMDL Coalition (the "Coalition") the following comments are submitted to the Delaware River Basin Commission ("DRBC") on the draft report entitled *A Review of Dissolved Oxygen Requirements of Key Sensitive Species in the Delaware Estuary* prepared by the Patrick Center for Environmental Research of the Academy of Natural Sciences of Drexel University ("ANSDU") for DRBC (the "Draft Report"). The Coalition also fully incorporates herein by reference the comments it submitted on February 8, 2018 on the draft methodology underpinning the Draft Report entitled *A Methodology for Evaluating Dissolved Oxygen Requirements of Species in the Delaware Estuary*, which was also prepared by ANSDU, as those prior comments have not yet been adequately addressed.

1. **These Comments are preliminary pending additional information on DRBC's intended use of the Draft Report.**

At this point, it is unclear how DRBC intends to use the Draft Report or the references cited within it, and how, if at all, the Draft Report may impact DRBC's efforts related to potential development of new dissolved oxygen ("DO") criteria in Zones 3, 4, and Upper Zone 5 of the Delaware Estuary. Given that, these comments cannot address all issues with the Draft Report, its appendices, or cited references. Rather, these comments will describe certain types of issues observed in the Draft Report and identify examples. We presume that DRBC will not use each referenced literature source from the Draft Report directly in formulating potential new DO criteria, but it remains unclear how they will be used. Therefore, we may have additional comments on the references or uses of them by DRBC in the future.

2. **The Coalition appreciates the effort undertaken by ANSDU to review the available literature on DO needs of sensitive species in the Delaware Estuary, but cautions that the variability among studies may impact the ability to draw scientifically-based conclusions from the collection as a whole.**

The Coalition recognizes the significant effort that ANSDU undertook to review and synthesize available literature on DO needs of sensitive Delaware Estuary species. Such review and synthesis is made challenging by the myriad methodological variations in the available studies, including in life-stage or age tested; exposure subject source and origin; exposure type, test duration, test endpoint, exposure temperature, salinity and other water quality conditions; and presence or absence of co-stressors. The extent to which test conditions were described also varied substantially for the references that were reviewed. As such, care must be taken to ensure that conclusions drawn from the multitude of studies account for such variability.

3. **Recognizing the importance of life stage, temperature, and salinity on the sensitivity to hypoxia, we commend ANSDU for the attempt to include columns with this information in the summary tables two and three (lethal and sublethal dissolved oxygen literature values, respectively) and recommend certain modifications to the tables.**

We recognize that life stage, temperature and salinity may not always be available for each study, and that when available the manner in which such information is presented varies in the source material, making it difficult to summarize in tabular form consistently across studies. Given the additional importance that time of exposure, age, and size range of test organisms may have on DO findings for a given species, we recommend that this information also be included in separate columns (when available), one each for time of exposure, age, and size range of test organisms. Many of the experimental studies with sturgeons, for example, include the age or size range of the test organisms but currently age information is only included in a subset of the records in the description column. The tables should indicate if a test DO endpoint was reported as %saturation and converted to mg/L by ANSDU. We suggest that the tables could accommodate the recommended exposure, age and size range columns by abbreviating genus names, numbering references, and rotating or abbreviating column names. The table would also be easier to read with gridlines.

4. **We recommend avoiding the use of ranges in the summary tables whenever possible unless the cited primary reference explicitly documents a range rather than a specific endpoint.**

Each record in tables two and three should identify a specific endpoint from a controlled laboratory test trial, including as much information as possible about the trial. The Description column should be changed to "Endpoint" and each endpoint described in detail (*e.g.*, "LC_{50}", "21% mortality"). References for which a specific endpoint cannot be identified should not be included in the table.

5. **DRBC must use primary, reliable, published source references describing results of controlled laboratory experiments as the basis of any proposed new DO criteria.**

While secondary references, non-specific endpoints, and observational-only findings may be useful as background information, they are not appropriate for use in developing DO criteria. Secondary sources and reports, by definition, do not include sufficient detail to determine whether the information is of appropriate quality for consideration during DO criteria development. Many secondary sources are currently included in tables two and three. Examples of secondary sources that should be removed from table two and three are Bain and Bain 1982 and Vaquer-Sunyer and Duarte 2008 (also abbreviated "VSD 2008"). Bain and Bain (1982), cited 4 times in table 2, describes a Habitat Suitability Index (HSI) for striped bass that cites and incorporates information about DO from other sources. As such, it is not a primary reference source and should not be cited in table two.

Further, Vaquer-Sunyer and Duarte 2008 is described inaccurately in the Atlantic Rock Crab (Cancer irroratus) section:

> "In an experiment by Vaquer-Sunyer and Duarte (2008), larval Atlantic Rock Crab were the most sensitive species tested with a median LC_{50} of 8.6 mg/l which exceeded the 95th percentile for all crustaceans in their tests."

This reference is a ***meta-analysis*** of studies of hypoxia. Vaquer-Sunyer and Duarte did not perform any experiments themselves, and instead conducted only a literature search and reported LC_{50} and other information from other published sources. Additionally, the reference to 8.6mg/L as a larval LC_{50} attributed to Vargo and Sastry 1977 in the supporting information http://www.pnas.org/highwire/filestream/597256/field_highwire_adjunct_files/1/ST3.xls was not found in the Vargo and Sastry 1977 publication and appears to be an error on the part of Vaquer-Sunyer and Duarte. Overall, many of the references currently in tables two and three are either secondary sources or redundant. These references should be removed from tables two and three. It may be appropriate in some cases to move information from secondary sources in tables two and three to the table in Appendix C of the Draft Report.

6. **DRBC should adopt a set of explicit standard criteria for evaluating the information contained in each reference describing controlled laboratory experiments.**

Identifying references and documenting test endpoints is only the first step in the process of documenting appropriate research studies for identifying DO needs of species. As a necessary second step, ANSDU must also perform a thorough review for each reference to determine whether (a) the reference adequately describes the experiment, and (b) whether the study was free from technical problems, consistent with United States Environmental Protection Agency ("USEPA") guidance entitled, "Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life" ("Guidelines"; Stephan et al. 1985). The Guidelines describe an objective, internally consistent, appropriate, and feasible way of deriving national recommended water quality criteria under section 304(a) of the Clean Water Act. Such Guidelines should be followed to fully assess the values of the referenced studies to potential DO criteria development.

USEPA has also published supporting information regarding the review of toxicity tests for evaluating the appropriateness of studies with aquatic organisms. This information is summarized in Appendix A of these comments. Toxicological testing procedures have been standardized for many years and resulted in development of scientifically sound criteria for many different toxic substances. While DO is not a toxicant, the principles and methods of laboratory toxicological research and subsequent calculation of regulatory endpoints are appropriate for the effects of low DO, with appropriate modifications. Since adverse effects increase with a decrease in DO, compared to the typical response of toxicants where effects increase as the toxicant concentration increases, the calculations are essentially reversed (USEPA 2000).

According to USEPA guidance (USEPA 1985, USEPA undated) the first requirement for having high confidence in a test result relates to whether the study documents "sufficient information," and the second requirement is that the test be free from "technical problems." Detailed lists of these requirements as they apply to the findings in the Draft Report are presented in Appendix A of these comments. We believe that these guidelines represent an appropriate standard by which to review the studies identified in the ANSDU literature review and for additional studies that subsequently may be recommended by the WQAC.

Examples of USEPA guidelines that would be appropriate for consideration:

1.) "In order to be considered sufficient, the available information must describe:

a. the test chambers, including their size and the material that is in contact with the test solutions.
c. the preparation of test solutions.
d. the test organisms, including name, size (or age), source, acclimation, diseases, and treatments.
e. the dilution water, including source.
f. the experimental design, including dilution factor, randomization, and replication.
g. test conditions, including temperature, pH, and concentration of dissolved oxygen.
h. controls and control results.
i. the calculation of the results."

2.) "The problems that might cause results of acute and chronic tests to be incorrect are listed below [excerpted - see Appendix A of these comments for full list]

12. The test organisms were from two or more sources
31. There were fewer than ten test organisms per treatment
64. There were fewer than four treatments, not counting controls
65. No treatment other than a control killed or affected less than 37 percent of the test organisms exposed to it, unless the value is reported as a "less than" value
66. No treatment killed or affected more than 63 percent of the test organisms exposed to it, unless the value is reported as a "greater than" value
69. More than ten percent of the control organisms died or showed signs of disease, injury, stress, and/or other adverse effects, except that a higher percentage is acceptable for a few species"

The complete list of relevant guidelines is included in Appendix A of these comments. Based on a preliminary review of the references cited by ANSDU, many if not most of the studies fail to meet one or more of the information sufficiency guidelines in the USEPA guidance. Most studies reviewed also exhibit one or more of the major technical problems identified in the USEPA guidance. Because the authors of such studies do not provide sufficient information, such studies would be defined by the USEPA guidance as ranging from "moderate confidence," "low confidence," to "unknown confidence." The most common shortcoming was failure to properly document the experimental conditions such as test water quality parameters and the variability of these parameters throughout the test. Few authors explained the randomization procedure, or whether test subjects had diseases or parasites or had been treated for these conditions. The list of technical problems for acute tests (conditions 60-70, see Appendix A of these comments) includes very specific guidelines for acute toxicity tests, such as the requirement that the minimum number of treatments, other than controls, is a range of 4 treatments and 10 individuals per treatment. Very few studies cited by ANSDU met these guidelines.

7. **In addition to the guidelines described above and in USEPA Guidance, we recommend that DRBC also consider the caveats that were included by study authors in deciding whether study results are appropriate for evaluating the DO needs of Estuary species**

Several of the studies included in ANSDU's literature review contain statements qualifying the studies' findings. For example, Jenkins et al. 1993 wrote:

> "Due to various constraints including limitations of facilities and test animals, strictly controlled and standardized methods could not be followed in all tests. The findings reported should be considered as preliminary until such time as more rigorous testing can be accomplished."

DRBC should consider qualifications such as this when deciding the relative value of a study in determining the DO needs of Estuary species.

8. **DRBC should also consider laboratory exposure chamber and handling effects when evaluating the results of laboratory studies, particularly when a large range of DO endpoints or contradictory information is found for a species.**

For example, Chittenden (1973) demonstrated significant effects of handling on the hypoxia tolerance of American shad (*Alosa sapidissima*). A similar study performed on striped bass, however, did not find any difference in hypoxia tolerance when the fish were handled soon before introduction to the test chambers. (Chittenden 1971)

9. **The review by ANSDU appears to be lacking in physiological studies, particularly determination of critical oxygen (P_{crit}) in respirometry experiments.**

A 2016 review by Rogers *et al*. found several studies that had conducted laboratory experiments, including studies on the striped bass (*Morone saxatilis*).

10. **DRBC should continue to work closely with the WQAC for assessing gaps and next steps in the process of developing recommended DO criteria.**

The full WQAC is the appropriate venue for the continued evaluation of DO needs of sensitive species and next steps involving the potential development of new DO criteria. As such, DRBC and ANSDU's response to comments received on the Draft Report should be included on the agenda of an upcoming WQAC meeting to facilitate discussion and deliberation among members of the WQAC.

References:

Chittenden Jr, M.E., 1971. Effects of handling and salinity on oxygen requirements of the striped bass, Morone saxatilis. *Journal of the Fisheries Board of Canada*, *28*(12), pp.1823-1830.

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Stephan, C.E., Mount, D.I., Hansen, D.J., Gentile, J.H., Chapman, G.A. and Brungs, W.A., 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses (p. 98). Duluth, MN: US Environmental Protection Agency. https://www.epa.gov/sites/production/files/2016-02/documents/guidelines-water-quality-criteria.pdf

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U.S. EPA. 2011. Evaluation guidelines for ecological toxicity data in the open literature. [cited 2015 June 2]. Available from: http://www.epa.gov/pesticide-science-and-assessing- pesticide-risks/evaluation-guidelines-ecological-toxicity-data-open

U.S. EPA. "Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Salt-water): Cape Cod to Cape Hatteras." *EPA-822-R-00-012.* Office of Water, Office of Science and Technology, Washington, D.C. and Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, RI (2000). Print.

Appendix A Summary of Technical Problems from U.S. EPA Review of Results of Toxicity Tests with Aquatic Animals.
*Asterisks indicate significant problems

#	Technical Problem	Applies to DO studies	Applies to DO studies with mod.
1	All test chambers and any compartments within the chambers were not identical in all replicates in all treatments	X	
10	Measured concentrations of test material varied too much during a flow-through test		X
11*	The test solutions were aerated before or during the test, unless the test material was ionic or the concentrations of the test material were measured during the test		
12*	The test organisms were from two or more sources	X	X
14*	The test was begun with organisms within 10 days after they were treated to cure or prevent disease and/or the organisms were treated during the test	X	X
16*	The test organisms were not either cultured in, acclimated to, or maintained in the dilution water at the test temperature for at least 48 hours before the beginning of the test; *e.g.*, the test organisms were acclimated in one water and tested in another	X	X
17	The test organisms were mishandled or excessively disturbed before or during the test	X	X
18*	The test organisms were infected with parasites during the test	X	X
20*	A freshwater species or a freshwater life stage of an anadromous species was tested in salt water, or vice versa	X	X
21*	Distilled or deionized water was used as the dilution water without addition of appropriate salts	X	X
22*	Chlorinated water was used as the dilution water without appropriate dechlorination	X	X
24*	River water was used as the dilution water without a demonstration that TOC and PM were each less than 5 mg/L and that the water is chronically acceptable to at least one aquatic species		
25	The dilution water contained unusual amounts of inorganic salts	X	X
26	Turbulence in the test chambers, resulting from aeration, stirring, or the design of flow-through chambers, was excessive	X	X
27	One or more water quality characteristics, such as pH and hardness, varied excessively over time or among test chambers during the test	X	X

#	Technical Problem	Applies to DO studies	Applies to DO studies with mod.
28*	The pH of the dilution water was below 6.5 or above 9.0 at any time during the test	X	X
30*	The temperature of the test solutions varied excessively over time or between chambers or was outside the range usually inhabited by the test species	X	X
31*	There were fewer than ten test organisms per experiment	X	X
32	Treatments, test organisms, and experimental units were not appropriately randomized	X	X
34*	There was no control treatment	X	X
35*	There was a control treatment, but it was not comparable to the other treatments	X	X
	60-70 Acute Tests Only		
61*	The test organisms were fed, unless:		
	a. The test organisms were saltwater annelids or mysids		
	b. A relationship was developed between toxicity and TOC or PM		
	c. The test material is miscible with or very soluble in water or does not sorb or complex readily		
	d. Data are available to show that the presence of food probably would not affect the test result		
63*	There was no differentiation between immediate and delayed effects, although such a test might produce a useful "greater than" value	X	X
64*	There were fewer than four treatments, not counting controls	X	X
65*	No treatment other than a control killed or affected less than 37 percent of the test organisms exposed to it, unless the value is reported as a "less than" value	X	X
66*	No treatment killed or affected more than 63 percent of the test organisms exposed to it, unless the value is reported as a "greater than" value	X	X
69*	More than ten percent of the control organisms died or showed signs of disease, injury, stress, and/or other adverse effects, except that a higher percentage is acceptable for a few species	X	X
	70-79 Chronic Tests Only		
71*	The test was not flow-through, except that renewal is acceptable for cladocerans	X	X
72*	The concentrations of the test material were not measured often enough using an acceptable analytical method		X
73*	There was only one test chamber for each treatment	X	X

#	Technical Problem	Applies to DO studies	Applies to DO studies with mod.
74*	Survival, growth, and/or reproduction were not acceptably high in the control treatment(s); the specific requirements are species-dependent and test-dependent	X	X
75*	There were fewer than four treatments, not counting controls	X	X
76*	The data are from a microcosm or model ecosystem study		

Appendix D

PWD Comments on DRBC December 28, 2021 Draft Report *Modeling Eutrophication Processes in the Delaware Estuary: Three-Dimensional Hydrodynamics Model for the Delaware Estuary*

Randy E. Hayman, Water Commissioner

Thomas Amidon
Delaware River Basic Commission
P.O. Box 7360
West Trenton, NJ 08628

February 14, 2022

Subject: Comments on DRBC Draft Modeling Eutrophication Processes in the Delaware Estuary: Three-Dimensional Hydrodynamics Model for the Delaware Estuary (DRBC Draft Dated December 28, 2021)

Dear Mr. Amidon,

The Delaware River Basin Commission (DRBC) has provided an informal opportunity for the Water Quality Advisory Committee ("WQAC") to review and submit comments on a draft version of DRBC's report entitled *Modeling Eutrophication Processes in the Delaware Estuary: Three-Dimensional Hydrodynamics Model for the Delaware Estuary* (the 'Draft Report'*).* This Draft Report describes the hydrodynamic model that DRBC has developed in connection with its larger eutrophication modeling study of the Delaware Estuary required pursuant to DRBC Resolution 2017-04 (the "Resolution"), which calls for DRBC to conduct a study to determine the attainability of potential additional designated aquatic life uses and water quality criteria (*e.g.*, dissolved oxygen or "DO") necessary to support those uses in Water Quality Zones 3, 4 and the upper portion of Zone 5. The study requires development and calibration of a water quality model of eutrophication processes in the tidal Delaware River and Bay to enhance DRBC's understanding of the impact of nutrient loads on dissolved oxygen conditions. The hydrodynamic model that is the subject of the Draft Report will provide the foundation for and be linked to a water quality model also being developed by DRBC. DRBC has not yet issued a report on the water quality model. The Philadelphia Water Department (PWD) is submitting this letter to DRBC to offer our initial comments on the Draft Report. Further comments may be provided as additional information is released for review and/or during the formal regulatory comment period.

PWD supports DRBC's work to improve the water quality and aquatic ecosystem health of the Delaware Estuary and commends DRBC on the significant work being undertaken, in consultation with the Expert Panel, on the development of this complex modeling study. The 3-D hydrodynamic model is a key component of DRBC's larger modeling effort necessary to understand and evaluate potentially attainable options for Aquatic Life designated uses and water quality criteria. Given the model's importance in the overall attainability analysis, PWD is providing comments identified at this time and also seeking additional information so as to better understand certain aspects of the modeling effort as described in the Draft Report and to ensure that DRBC can minimize any potential bias in the hydrodynamic model results, characterize uncertainty in model projections, and describe how uncertainty may ultimately influence DRBC's analysis of attainability of potentially higher DO levels.

Prior to DRBC's decision to develop an enhanced model system for the Delaware Estuary, PWD began investing considerable resources towards the development of hydrodynamic and water quality modeling capabilities and creating technical tools to represent the localized conditions of the tidal estuary in the vicinity of Philadelphia. These capabilities and tools have been developed for the purpose of informing multiple planning objectives including internal PWD capital planning, asset management decision making, and multiple regulatory compliance programs. The tools differ from the suite of tools DRBC is developing in that they are necessarily more detailed in the vicinity of Philadelphia's receiving waters, yet smaller in total geographic scope than DRBC's estuary-wide modeling tools. PWD has developed a specialized water quality modeling team dedicated to the development and maintenance of these tools and associated data, and this technical staff has developed substantial knowledge and expertise in analysis of the localized conditions in this portion of the estuary. We welcome the opportunity to collaborate and share information between DRBC's modeling team, the Expert Panel convened by DRBC, and PWD's modeling experts.

The PWD water quality modeling team provided a letter to DRBC on November 30, 2021, outlining our recommendations for hydrodynamic model validation report documentation. The PWD staff have relied on their extensive local knowledge and experience in preparing both the November 30 letter and this letter providing feedback on the draft report. PWD believes that our goals are aligned with those of DRBC: an unbiased, scientifically defensible representation of hydrodynamic and water quality conditions, with uncertainty of projections thoroughly characterized and accounted for. This approach will be necessary for the model to serve as a sound basis for informing potential changes to existing water quality standards or regulatory policy.

PWD has several comments, questions, requests for more report documentation, and recommendations in response to the Draft Report, which are set forth in this letter and the document entitled Technical Comments and Discussion of DRBC's Draft Hydrodynamic Model Report ("Technical Comments"), which is attached to this letter and incorporated herein by reference.

Most of our comments and questions relate to the following topics:

- Model uncertainty should be addressed in the validation documentation.
- More detailed information is needed on the model spatial grid configuration in the upper estuary.
- Validation metrics should be included for all evaluated results for the 2012 model year.

- Validation metrics should be included for monitored stations in the upper Estuary near Philadelphia, especially for water level and velocity.
- Additional documentation is needed to evaluate whether the model configuration adequately represents solute transport phenomena, including vertical mixing, especially in the upper estuary around Philadelphia.

These topics are more fully discussed the Technical Comments document attached to this letter.

Based on our preliminary review, the 3-D hydrodynamic model should not be used for other purposes without further opportunity for review in connection with any other potential future uses. The Draft Report explained that the hydrodynamic model provides the foundation for the linked eutrophication model of the Delaware Estuary being developed pursuant to Resolution 2017-4. It did not discuss the suitability of this model for use in other contexts. Based on PWD internal review, the model would need modifications in order to be utilized for other non-eutrophication modeling purposes. While the Flexible Flow Management Program was mentioned in the Draft Report, the current state of the hydrodynamic model would need further evaluation to be used for salinity modeling applications. PWD requests that the Regulated Flow Advisory Committee be engaged if the model is being utilized as the technical foundation for flow policy and water supply planning purposes. Likewise, if it is to be used in connection with other water quality standard setting or criteria development, further review would be required. PWD requests that DRBC advise as to whether it plans to use the model for other purposes and, if so, to describe them. Also, PWD would like to understand if the model is informing other DRBC priorities such as salinity modeling or water supply planning. A subsequent evaluation of the hydrodynamic model would be necessary to determine the appropriateness of applying the model to simulate other conditions, including but not limited to, salinity.

PWD appreciates the opportunity to provide comments on the Draft Report and has included in this letter questions specific to model representation in the vicinity of the Philadelphia region necessary to aid in our understanding and interpretation of validation results. We request that DRBC provide answers to our questions, with input from the Expert Panel, to afford us the opportunity to meaningfully review and engage on the issues raised by our questions in connection with DRBC's eutrophication modeling.

While PWD performed an initial review of the material presented in the Draft Report as the basis for the comments provided today, it is important for both the hydrodynamic and water quality modeling components to be reviewed in concert to understand how these two important model validation components interact with one another. It is possible that some aspects of the hydrodynamic model validation on which PWD may wish to comment may not be readily apparent until viewed along with the eutrophication model validation report and analysis of attainability. PWD therefore reserves the right to provide further comments on the hydrodynamic model once all model validation reports and the analysis of attainability are made available.

We request the opportunity to meet with the DRBC modeling team, the Expert Panel and ultimately review an updated Hydrodynamic Model Report. We welcome the opportunity to discuss any points within this letter and look forward to continuing to work together and sharing information on model development for the Delaware Estuary.

Sincerely,

Marc Cammarata
Deputy Commissioner
Philadelphia Water Department
1101 Market St. 4th Floor
Philadelphia, PA 19107

CC:
Melanie Garrow, PWD
Kelly Anderson, PWD
Jason Cruz, PWD
Kinman Leung, PWD
Steve Tambini, DRBC
Namsoo Suk, DRBC

Attachment: Technical Comments and Discussion of DRBC's Draft Hydrodynamic Model Report

PWD has compiled a pair of summary tables, below, to facilitate DRBC's review of our comments, questions, and requests for additional information.

Summary of Questions

1. Can the calibration acceptability criteria that were evaluated by the Expert Panel be provided?
2. Can DRBC provide more information about the cell size or a finer scale graphic of the grid resolution around the Philadelphia region of the model?
3. Can the Expert Panel provide a discussion of why the longitudinal grid resolution is considered adequate to represent tidal transport in the urban river and in the vicinity of the "DO sag"?
4. How many cells across is the grid in the urban river and can the Expert Panel provide a discussion of why this is considered adequate to represent lateral transport?
5. Can DRBC provide more information or a finer scale graphic of the number of vertical layers?
6. Will the coarse representation of the inflow cells of the tributaries have an effect on loading patterns and/or concentrations and impact numerical dispersion?
7. Can validation metrics be provided for velocity at the Philadelphia db0301 NOAA station?
8. Are the hydrodynamic model and eutrophication model grids the same resolution?
9. Was solar radiation adjusted for temperature calibration?
10. How were the flows and pollutant loads for point source dischargers represented for the 2012 model? Were monthly estimates used?
11. Was flow from the un-gaged areas added to the existing tributary flow boundaries or was it omitted?
12. How was flow estimated for direct runoff areas that drain directly into the mainstem Delaware River?
13. Where within the model grid were the five Philadelphia CSO time series inputs specified as loading? Which PWD CSO time series were combined? How were the other (non-PWD) communities' CSO inputs accounted for within the model?
14. Why was the Schuylkill River not resolved up to its tidal extent in the model?
15. Are the vertical datums consistent for the observed data being analyzed (*i.e.*, Mean Sea Level and NAVD88)?

16. Was the salt front in the Appendix M figures only calculated from observed salinity and not calculated for the model results?
17. How could the assumptions employed to represent the C&D Canal impact the validation and water quality model, especially during critical periods; were any sensitivities explored?
18. What are the intended current and future uses for this model beyond the application to the eutrophication model? Specifically, is this model the foundation for salinity modeling efforts underway at DRBC evaluating water supply and salinity?

Information Request Summary

Topic	**Request**
Input Data	
Meteorological Data	Compare meteorological data from different sources, including air temperature, relative humidity, and solar radiation. This could take the form of a time series plot, boxplot, or statistical distribution plot.
Solar Radiation	Details of calculations implemented in model.
Boundary condition inputs	Provide a summary of inputs for 2012.
Salinity inputs	Provide assumptions for all salinity inputs.
Un-gaged area flow	More detail on the statistical sub-model used to estimate flow for un-gaged areas.
Direct Precipitation	Figure 24-3 shows Direct Precipitation contributing 10% toward total inflows into the estuary. Can this value be further described and the source of the estimate and how it is implemented in the model be discussed?
Water level open boundary for C&D Canal	Provide information on how the water level open boundary was developed.
Model Results	
Velocity	Performance metrics for stations db0301 and others near the urban river. PWD is happy to share ADCP data in this region.
Water Level Performance Metrics	Metrics for 2012, t-tide periods and settings.
Tidal Constituents	An explanation for why the M2 water level difference at Reedy Point/Delaware City was 7 cm, but it was below 1 cm error for the rest of the upper estuary.
Temperature Performance Metrics	Metrics for 2012 and 2018-2019, subdivided into seasonal or bi-monthly intervals.
Mixing Coefficient	The Executive Summary mentions the intention to use a mixing coefficient as a

	calibration parameter, but no model results for this parameter are presented in the report. We request that model results and analysis be included.
Figure 2.4-5 Predicted Daily-Averaged Salinity at Chesapeake City	There are no colored markers as specified in the legend to understand the results.

Overall Calibration Approach

For clarity and transparency, quantifiable model performance acceptability criteria should be clearly identified for velocity, water level, temperature, and salinity. These criteria should reflect the intended stated purpose of the hydrodynamic model, which is to support analysis of attainability of higher dissolved oxygen levels in the urban Delaware River. Hydrodynamic processes such as tidal dispersion and tidal excursion are critical for evaluating treatment plant discharge fate and transport, and for evaluating larger scale river features such as the urban dissolved oxygen sag (DO sag). Demonstration of acceptability within the urban tidal river should be provided. If it cannot be provided, a discussion of associated model uncertainty should be included.

The report states in Section 3.1 with respect to performance metrics, “To provide a succinct method to evaluate and report the accuracy of a large number of comparisons, MacWilliams M.L. *et al*. (2015) established a standardized set of cutoff values for both the skill scores and target statistics. In this study, statistical measures such as bias, RMSE, ubRMSE, and Correlation Coefficient (r) or R-squared are used to quantitatively evaluate the model performance. In accordance with the established Quality Assurance Project Plan (DRBC, 2019) for this project, a “weight of evidence” approach was used in close coordination with the Expert Panel in order to judge the acceptability of the model for its intended purpose.”

Can the acceptability criteria that was evaluated by the Expert Panel be provided?

The report states in Section 1.4, “Model fitness is impacted not just by the quality of calibration, but also by boundary data and field data, neither of which are perfect. These realities must temper expectations and dictate a multiple lines of evidence approach to optimize model fitness. Model performance was evaluated for major parameters such as tidal harmonic constituents, water surface elevation, water temperature, and salinity, through model to data comparisons.”

For quantities that vary significantly over the course of the year, taking the RMSE over a 2-year period is not as meaningful as taking a seasonal RMSE. For example, temperature results of the PWD model were evaluated on 2-month intervals. We would like to see model performance metrics that isolate smaller time intervals, by season or month, for example.

Representation and Documentation of the 2012 Model

This report is inconsistent in referring to the simulation year 2012. In some sections it is referred to as an additional calibration period, in some sections it is referred to as a validation year, and in some instances, it is omitted completely. For example, there is no documentation of 2012 input data, and no documentation of model performance in 2012. The only exceptions are velocity data and the sensitivity study for salt vertical layering in the lower bay. There is no water level data comparison for 2012.

It is anticipated that simulations of 2012 low flows more closely reflect conditions for simulations that will be used to evaluate attainability of higher DO levels than the relatively wetter years of 2018 or 2019. Therefore, from the perspective that the model may be used in a regulatory setting, model year 2012 performance is more critical than 2018 or 2019.

PWD would appreciate inclusion of 2012 model inputs, results and performance metrics in the appendices.

Grid Resolution and Model Domain

Grid resolution is an important element of 3-dimensional hydrodynamic models. A balance must be made between computational efficiency and adequate resolution to capture the complex dynamics in the system being modeled. Transport dynamics of pollutants, including mixing and tidal influences are very important, especially in the vicinity of Philadelphia, and the grid resolution should be adequate to reflect these phenomena. Grid resolution is also important because of the numerical dispersion effects of the grid cell size on the model.

The horizontal model resolution in the upper estuary appears to be significantly more coarse than the grid PWD's modeling team considers appropriate in this area. The report states that zones 2-4 are resolved by 946 cells, while PWD's coarse grid has about double the resolution (~2000 cells). In this area the PWD model is 8-10 cells across at Marcus Hook, 5-8 cells across around Philadelphia, 4-6 cells across up to Burlington, and 3 cells across up to Trenton.

PWD tested the effect of grid resolution on advective transport using both a coarse and fine grid. The fine grid resolution included four times the number of cells as the coarse grid. The investigation determined that as grid cell size was increased, numerical dispersion increased, which led to a greater plume extent, yet a more dispersed and lower concentration contaminant plume. A further loss of resolution with a coarser grid would most likely exacerbate this issue and should be taken into account when the hydrodynamic model is used to support the eutrophication model.

Vertical grid resolution is important in hydrodynamic models, especially for vertical mixing. It appears that the minimum grid depth is 2 m in the hydrodynamic model. This minimum value does not account for the extensive shoals in the upper estuary, where water depth can be below 2 m. The shoals have an effect on roughness and energy transfer from the M2 tidal constituent into overtides M4 and M6, thus on non-tidal transport. This representation would also result in an overestimate of volume that would lower bottom drag friction in the model with the likely outcome being a poor representation of lateral shear and lateral mixing. This representation would have consequences for using this model to evaluate water quality criteria in the upper estuary near Philadelphia. The overestimation of volume resulting from a minimum depth of 2 meters would also increase the modeled tidal prism, which could complicate attempts to calibrate to both water level and velocity. Wetting and drying is also an important feature of this area around the shoals and should not be neglected. We would also like to understand the Expert Panel's justification for using fewer than 10 layers.

There is a lack of fine-scale graphics of the number of vertical layers around the Philadelphia region in the report. All locations presented in "Appendix N: The evaluation of vertical resolution" are below Wilmington, Delaware.

PWD poses the following questions to DRBC with respect to the model grid:

- Can DRBC provide more information about the cell size or a finer scale graphic of the grid resolution around the Philadelphia region of the model?
    - How many cells across is the grid in the urban river and can the Expert Panel provide a discussion of why they consider this adequate to represent lateral transport?
    - Is the longitudinal grid resolution adequate to represent tidal transport in the urban river and in the vicinity of the DO sag?
- Can DRBC provide more information or finer scale graphics of the number of vertical layers?
- Are the hydrodynamic model and eutrophication model grids the same resolution?
- Will the coarse representation of the inflow cells of the tributaries have an effect on loading patterns and/or concentrations and impact numerical dispersion?

The Schuylkill River is an important tributary to the tidal Delaware River, especially in the region of Philadelphia, however the model does not include the full tidal extent of the Schuylkill River. Why was the Schuylkill River not resolved up to its tidal extent in the model? We observe significant interaction between the Schuylkill River and the main stem Delaware River, including tidal trapping. The Schuylkill also receives discharges from PWD's CSOs along with stormwater and other pollutant loads from upstream of Philadelphia. The timing of the influence of the CSOs on the main stem Delaware River would be altered when the full extent of the tidal Schuylkill River is not represented in the model domain.

Boundary Conditions

Un-gaged Tributary Flow

The estimation of flow inputs from all watershed areas is important to ensuring that the mass balance of water in the model is well represented. For watersheds that are not monitored for discharge, estimates need to be made. The approach to estimate flow for un-gaged tributaries is interesting and we would appreciate learning more about the way land use data was used to make flow estimates where flow data was not available. We are requesting more detail on the statistical sub-model used to estimate flow for un-gaged areas. From the information included in the report, it is unclear if flow from all un-gaged watersheds has been included. The list of tributary inflows only includes 4 un-gaged tributaries upstream of Delaware City. For the same area PWD included all 20 un-gaged tributaries and small watersheds. Was flow from the remaining un-gaged areas added to the existing tributary flow boundaries or was it omitted? How was flow estimated for direct runoff areas that drain directly into the mainstem Delaware River?

Dischargers

It was indicated that fine scale discharges were applied to the 2018 and 2019 models. How were the dischargers represented for the 2012 model?

CSOs

Due to the coarse grid in the Philadelphia region, all Philadelphia CSO discharges were aggregated into 5 time series inputs. As stated in the grid section, this may misrepresent wet weather plumes and flow dynamics and transport patterns in the area around Philadelphia. Where in the model are these five time series loaded and which CSO time series were combined?

The aggregation of CSOs from the other cities may also be a concern.

Direct Precipitation

At the end of Section 2.4.2, Freshwater inflows, Figure 24-3 shows Direct Precipitation contributing 10% toward total inflows into the estuary. Can this value be further described along with the source of the estimate and how it was implemented in the model?

Salinity

Salinity is an important component of hydrodynamic models, especially for models where there is an interaction of fresh and marine water environments that are also tidally-influenced. PWD has found through our salinity modeling efforts that background salinity is important in simulating pollutant transport, even in the regions characterized as fresh water. More clarity is requested describing the salinity boundary condition inputs for each input type. Except for tributaries, the report indicates that all other point sources were assigned zero salt load. This assumption can dilute the instream salinity concentration. Assigning salinity to all boundary inputs is important for setting a background salinity in the Delaware River and for quantifying the salt front and salinity intrusion. In the PWD salinity model, it was determined that using realistic salinity concentrations for all inputs had order one importance for model accuracy in the region near Philadelphia.

What salinity is assigned to the boundary condition inputs other than the open boundary?

Turbulence Closure Scheme

Turbulent Closure settings and effects on transport

PWD reviewed the hydrodynamic model settings in the report and has concern over how turbulent closure is implemented. A possible major flaw exists in the use of the Mellor-Yamada buoyancy term (CTE3) in the EFDC turbulent closure settings as the primary calibration parameter for salinity intrusion. In Section 3.2.2 Turbulent Model Parameter, the justification for more than doubling the recommended value of approximately 5 by Burchard (2001) to 12 is unfounded. The report misquotes the citations referenced in the Burchard paper based on analytical calculations from other turbulent model formulations or from laboratory experiments that fall between 4.752 and 7.784. The report then cites the paper to justify using the CTE3 parameter as a calibration parameter while lacking any explanation based on estuarine physics. [While not described, CTE = 5 appears as a suggested alternative value in Section 'Card Image 13', p 55, EFDC Model User Manual US EPA Version 1.01.]

One consequence of this unrealistic value appears to result in overestimation of salinity in the area just below and near Philadelphia, a key area of interest for salinity intrusion. Two plots for salinity are shown for Chester in Appendix K, but the Y axis of Figures 3.3-15 (4) and 3.3-16 (4) is set to 35 psu, making it impossible to see the result. There are also no statistics presented in Table 3.3-4 for this station. Chloride plots appear in Appendix L for Chester and Ben Franklin with no statistics presented in the report, where Figure 3.3-17 (2) at Chester shows an overestimate for chloride of approximately 25 mg/L while totally missing the small intrusion event in mid-October (Y axis units labeled as Days but is Months), and Figure 3.3-17 (4) at Ben Franklin shows an overestimate of 10-20 mg/L. While the metrics reported in Table 3.3-4 show an adequate performance for salinity at the stations in the lower Delaware estuary apparently due to the choice of CTE = 12, a consequence of this appears to be overestimation of chloride (salinity) in the upstream stations Chester and Ben Franklin.

Another important consequence of using a turbulent closure setting outside of the recommended range could be unintended distortion of the transport of other model constituents such as nutrients and dissolved oxygen. Increasing the CTE3 value suppresses vertical mixing, but beyond the limits outlined in Burchard (2001) may unrealistically restrict vertical mixing. A possible outcome of this could be simulation of a low-dissolved oxygen layer at depth in the Delaware Bay that may lead to hypoxia in the model under certain conditions. This inaccurate result could lead to inappropriate analysis and interpretation (Ji, 2008).

The results for axial and lateral salinity and velocity structure that appear in Appendix L show a label for turbulent closure setting value of CTE3 = 8 in the metadata starting with Figure 3.4-5 (1) through Figure 3.4-11 (2) on pages 40-53. This contradicts the statement in Section 3.2.2 that CTE = 12 was used as the final value for this parameter. If this label is correct, the report provides no way to evaluate these results for axial and lateral salinity and velocity structure.

The model report Executive Summary section mentions the intention to use the mixing coefficient as a calibration parameter, but no model results for this parameter are presented in the report. We request that model results and analysis be included.

Bottom Roughness

While the general magnitude of roughness values upstream to downstream is similar to the PWD model, there is no differentiation between the roughness of the deep channel and the shoals, except in the most downstream reaches on the bay. In the PWD model this was modified in calibration, where the shoals were assigned a coarser and the channel smoother roughness, which had a positive impact on upstream tidal transport. It was found that a large difference between channel and shoal roughness height were of order one importance in validating both model current and salinity for the entire model domain. Assigning the same roughness to the channel and shoals, or defining a coarser channel, could potentially underestimate upstream transport via the channel in the model results.

Temperature and Meteorology

Temperature and solar radiation play key roles in modulating eutrophication-related processes. Algal processes are impacted on a direct, first-order basis by temperature-related growth limitations and also by light availability provided from incident solar radiation. PWD's studies have found this relationship to be significant. In addition, most other kinetic and biological processes in the eutrophication model are adjusted by modeled temperature. The performance metrics presented on temperature were quite good, and PWD would like to understand model setup and performance better.

Section 2.4.4 mentions that shortwave solar radiation was calculated, but this calculation is not discussed. PWD requests that a discussion of this calculation be included. In addition, input data for the year 2012 should also be included. Was solar radiation adjusted for temperature calibration?

Section 2.4.4 also indicates that several data sources were relied upon for meteorological forcings. A comparison of the input parameter values included in EFDC from these sources would be very helpful, including air temperature, solar radiation and relative humidity. A time series plot, boxplot, or statistical distribution plot would help readers understand the spatial variability that these stations capture.

For quantities that vary as much over the course of a year as temperature does, breaking the temperature up into seasonal responses for the purpose of performance metric evaluation is very useful. This is particularly useful in assessing the model's appropriateness for use in eutrophication modeling and assessments of attainability, as the critical summer period should be evaluated in an isolated fashion. PWD is interested in temperature performance on the basis of 2-month intervals, rather than 2-year intervals.

Chesapeake and Delaware Canal

The Chesapeake and Delaware Canal (C&D Canal) has a complex relationship with the hydrodynamics of the tidal Delaware River. Can more information be provided in the report on how the water level open boundary for the C&D Canal was developed? We are also interested in how the representation of the C&D Canal impacts the validation results. Were any sensitivities explored? How could the assumptions employed to represent the C&D Canal impact the water quality model, especially during critical periods?

Treatment of the C&D Canal as a tidal open boundary with Eqn 2.4-1 linear regression model used to predict salinity values when no data is available appears appropriate, but the linear regression model does not include discharge at the USGS Delaware River at Trenton station, missing potential impacts from periods when flows in the Delaware Basin are large compared to the Susquehanna Basin. Comments related to the assumptions applied to the C&D Canal open boundary to estimate salinity are further discussed in the salinity validation section of this review.

Hydrodynamic Validation

Tidal Analysis and Water Level

Tidal analysis and water level metrics are valuable indicators for evaluating the performance of a validated hydrodynamic model. PWD provided an overview of validation metrics in a letter shared with DRBC on November 30, 2021. We applied these concepts in the review of the DRBC hydrodynamic model report.

Given the relatively high RMSE of 13-16 cm in the upper estuary, the results seen in the scatter plots, and respectively missed peaks in the time series plots, the M2-amplitude errors of <1 cm are surprising. Also, how is the sudden increase in error to 7cm explained at Delaware City? For reference, the M2 amplitude errors in the PWD model are under 2 cm at Marcus Hook, but around 7-10 cm in the upstream areas, and usually increase when going to a coarser model resolution. This warrants further investigation or explanation. Was there a miscalculation? Does tidal analysis over a 2-year period average out short-term errors when peaks aren't met?

For RMSE calculations, are the vertical datums consistent, *i.e.*, Mean Sea Level vs. NAVD88? Can the t-tide period and settings be provided?

Before we agree with the statement that "The hydrodynamic model simulates water surface elevation with sufficient accuracy to satisfy the objectives of this study," we need more information to rule out any error.

The hydrodynamic report only includes tidal analysis and RMSE results for the 2018/2019 period. PWD requests results for the year 2012. The importance of showing the performance in this year was previously discussed. The tidal harmonics in Appendix E are only presented for 2018/2019, can results for 2012 also be provided? Appendix G only includes water level results for 2018/2019, can results be provided for 2012? Can the time period used for tidal analysis be confirmed as 1/1/2018-12/31/2019?

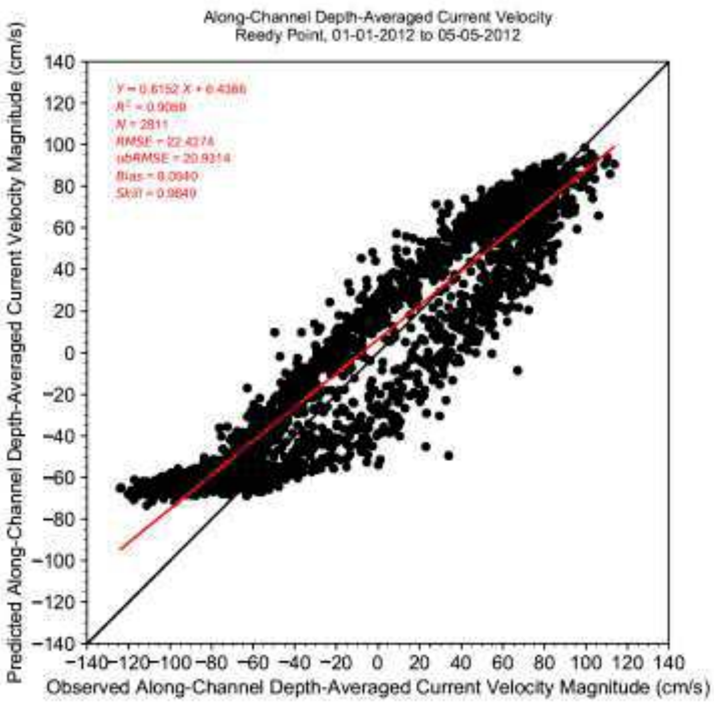
Additionally, the hydrodynamic report does not include subtidal analysis on the model results. This analysis was included in our November 30, 2021, letter on recommendations for a hydrodynamic model calibration report, and we request to see it.

Velocity

In addition to tidal analysis of water levels, velocity is an important calibration metric for evaluating the performance of a validated hydrodynamic model. However, no model performance is shown for velocity at the Philadelphia db0301 NOAA station for any year. This is critical because even though water level performance can be in good agreement with observed data, when velocity is misrepresented, there can be issues with transport of nutrients, algae, and salinity that are dependent on accurate representation of the water velocity. Without the velocity performance at the Philadelphia station, we cannot evaluate how the DRBC model performs around Philadelphia. This station is identified in Figure 3.1-3, NOAA Stations for Current Velocity Data, and Table 3.1-3, Summary of NOAA Current Velocity Data for Model Calibration in Appendix C, p 32. The lack of metrics for model velocity results leaves a key hydrodynamic variable out of this report in the primary area of interest for PWD. Omitting this velocity analysis makes it more difficult to conclude that the upper estuary is well represented in the model. Can validation metrics be provided for velocity at the Philadelphia db0301 NOAA station?

The omission of 2012 validation results at the Philadelphia station in the hydrodynamic report is concerning for velocity performance. PWD undertook an extensive velocity calibration exercise on our model using all available velocity data. PWD can provide detailed vertical velocity measurements in the Burlington area (PWD Buoy A), south of the Navy Yard (PWD Buoy B) and Marcus Hook (PWD Buoy C) for September to December 2012. Representative tidal constituents from our 2012-2013 model time period can also be used to compare these locations to the DRBC 2018-2019 models. While not an exact match, this can provide insights to determine if the velocity harmonic constituents are within an acceptable range of magnitude. Including just depth average velocity might not tell the whole story. Especially for the PWD Buoy locations, comparison of model layer results to the respective vertical bins is possible and provides more information on model performance.

The most upstream location for velocity results for the hydrodynamic model is at Reedy Point. From the figure, it seems as if the high velocity ebbs are missed. Without information at the Philadelphia station, the impact of this result cannot be evaluated.



Salinity Validation

Having salinity well represented in an estuary model is critical to demonstrate its ability to transport solutes, including nutrients and dissolved oxygen throughout the water column. For PWD this is especially important during low flow periods. When salt is driven into the freshwater section of the Delaware River below and near Philadelphia, salinity can be viewed as a tracer for all mass transport. Salinity performance in this part of the river can be inferred from the chloride figures at Chester and Ben Franklin Bridge that show the model generally overestimates chloride by 10-25 mg/L, Figures 3.3-17 (2-4). On the other hand, the model shows no response to an intrusion event in summer 2012 during low flows at Chester, Figure 3.3-18 (2).

There are no metrics presented for salinity or chloride at these stations, which is explained in the report as “Since the salinity intrusion for the simulated years was limited to below RM 77.2, the model-to-data comparison at three USGS stations located above RM 83 were not considered (salinity was negligible during calibration periods).” This argument doesn’t consider the importance of salinity concentrations as a general tracer tool and ignores the importance of validating the model’s transport capabilities in the tidal freshwater reach of the model. By describing the salinity above RM 83 as negligible, this infers there are no impacts from density on hydrodynamics. However, PWD has determined through our modeling efforts that salinity presence upstream through PWD Buoy C at Marcus Hook can impact hydrodynamics.

The report also explains that all point source inputs have zero salinity, while inputs for small tributary salinity are not presented. Point source discharge salinity observations are typically higher than the ambient mainstem concentration and increase the salinity of the tidal fresh reach of the river. In the PWD Salinity model, it was found that realistic concentrations for tributaries, CSOs, and DMRs had first order importance in validating the model in the domain near Philadelphia.

In addition to passive tracer transport, appropriate salt transport in the Upper Estuary is also important from a eutrophication process perspective. Salinity levels as low as 1 psu can reduce freshwater phytoplankton production by half (Cerco *et al.*, 2000). The DRBC formulation for light extinction shared in the Water Quality Advisory Committee Meeting on November 3, 2021, indicated that a salinity of 2 psu would reduce the light attenuation coefficient by almost 0.2 m^{-1}. These salinity conditions are not uncommon in the area of the DO sag from the urban fresh tidal river.

The treatment of the C&D Canal as a tidal open boundary with the linear regression model (Eqn 2.4-1) used to predict salinity values when no data is available appears appropriate, but the linear regression model does not include discharge at the USGS Delaware River at Trenton station, missing potential impacts from periods when flows in the Delaware Basin are large compared to the Susquehanna Basin. Figure 2.4-5 has no colored markers as specified in the legend. It is therefore unclear what impacts the predicted Chesapeake City salinity will have on salinity in the Delaware Estuary. The Section 3.2.4 approach toward surface elevation adjustments as a calibration parameter that may impact salinity intrusion in the Delaware River appears appropriate.

As described in Section 2.4.3, the ocean boundary salinity forcing was driven by surface observations of specific conductance and temperature at Lewes, DE, when these observations were available. Using Brandywine Shoal Light data as a proxy with an adjustment of +3 ppt for 2012 appears appropriate. Creating a vertically stratified forcing profile as described on page 25 appears appropriate.

In the Delaware Bay through Reedy Island, the model appears to adequately represent near surface salinity in Table 3.3-4 with a Skill Factor greater than 0.7, but a vertical profile plot (Appendix N, Fig 3.4-6(2)) shows the DRBC model underestimates the vertical salinity difference near RM 37 when compared to a recent study by Geyer, *et al.* (2020) at km 65 in the Delaware Estuary (see below). Also, Fig 3.4-9(2) shows that the model underestimates vertical velocity differences and the magnitude of upstream bottom layer flow crucial for salt transport. This is despite altering the of the EFDC CTE3 parameter beyond the recommended range to inhibit vertical mixing. The underestimate of the vertical salinity difference in this area of the domain could lead to uncertainties in hydrodynamics and transport.

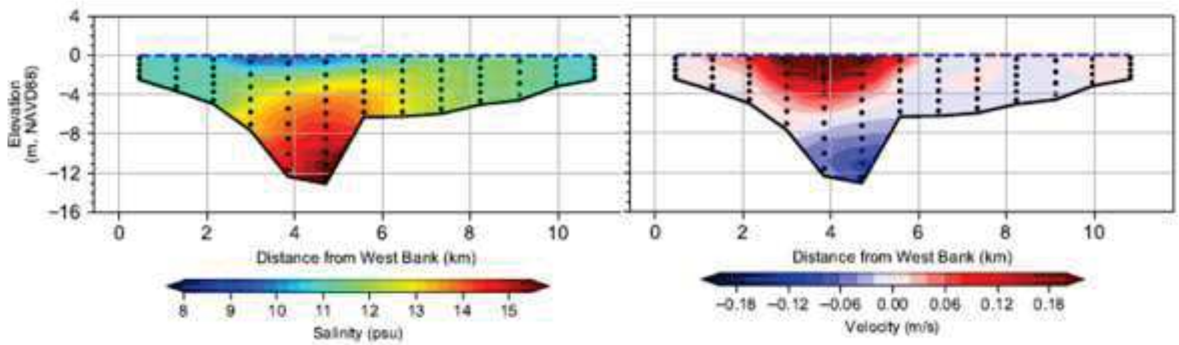


Figure 1: DRBC Figures 3.4-6(2) and 3.4-9(2) with 10 GVC layers at RM 37 showing vertical structure for salinity and velocity during neap tide. Positive velocity is seaward.

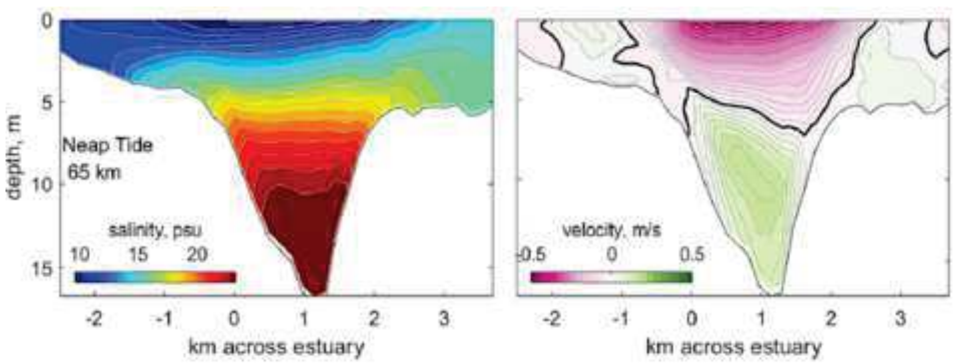


Figure 2: Geyer, *et al.* (2020) for a ROMS model with 20 sigma layers at 65 km (RM 40.4) showing vertical structure for salinity and velocity during neap tide. Positive velocity is landward.

Appendix M of the Hydrodynamic Model Report included along-channel plots where the salt front location was indicated. Was the salt front only calculated from observed salinity and not calculated for the model results? There are specific conductance data available in the Philadelphia region that can be used to validate the upper estuary of the model.

References

Burchard, H. (2001). “On the q^2l Equation by Mellor and Yamada (1982).” Journal of Physical Oceanography 31(5): 1377-1387.

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Geyer, W. R., D. K. Ralston, and J. L. Chen (2020). “Mechanisms of Exchange Flow in an Estuary With a Narrow, Deep Channel and Wide, Shallow Shoals.” Journal of geophysical research. Oceans 125(12): n/a.

Ji, Zhen-Gang. Hydrodynamic and Water Quality: Modeling Rivers, Lakes, and Estuaries. Hoboken, NJ, Wiley, 2008.)