Proposed Revisions to James River Chlorophyll-*a* Criteria and Assessment Methodology

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JRCS RAP Meeting

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DEQ

Virginia Department of Environmental Quality

Based on the information generated by the James River Chlorophyll Study, VADEQ has determined there is sufficient cause to revise both the James River chlorophyll-*a* criteria and the methodology used to test attainment.

The proposed revisions are the result of improved understanding of 1) the distribution and dynamics of chlorophyll-*a* and 2) the ecological effects related to chlorophyll-*a* in the James River.

VADEQ decided to use an alternative approach to the one used by the JRCS SAP to derive the chlorophyll criteria.

SAP Approach	VADEQ Approach
More novel methods are used to establish relationships and thresholds	Conventional methods are used to establish relationships and thresholds
The scientific bases for chlorophyll criteria are not established for all segments-seasons	The scientific bases for chlorophyll criteria are confirmed for all segment-seasons
Results are difficult to interpret objectively	Results are interpreted objectively
Results are ambiguous in the form of ranges	Results are definitive in the form of a single number
Did not consider baseline conditions	Incorporates the baseline condition

VADEQ's approach has the following elements:

- Estimation of segment-season baselines
- Subtraction from baseline when there is evidence of excessive effects on the aquatic life use.
- Excessive effects determined from 1) modeled relationships of chlorophyll-*a* and effect, 2) the spatial and temporal variability of the monitoring datasets, 3) systematically applied risk levels.

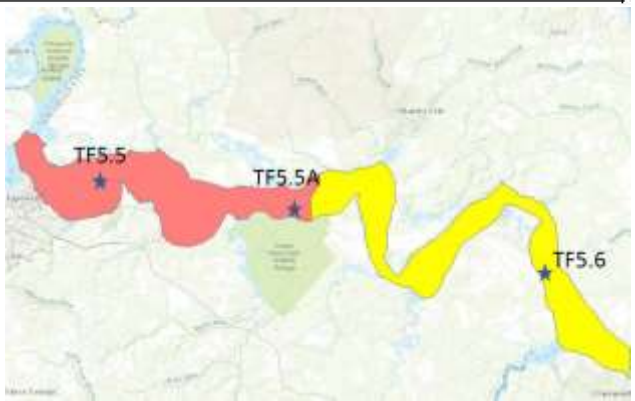
Estimation of baseline condition

- Monitoring data collected from 2005 to 2015 were used to estimate seasonal chlorophyll-*a* means for each segment.

- Multiple data sources were used:
  - Monthly VADEQ/CBPO sampling
  - Weekly VCU sampling
  - Monthly/semi-monthly VIMS Dataflow
  - Weekly HRSD Dataflow

Season Year	Upper Zone Mean	Data Source	Lower Zone Mean	Data Source
Spring 2005	6	monthly Dataflow	4	monthly Dataflow
Spring 2006	14	monthly Dataflow	4	monthly Dataflow
Spring 2007	9	monthly Dataflow	3	monthly Dataflow
Spring 2008	5	monthly Dataflow	5	monthly Dataflow
Spring 2009	11	TF5.5, TF5.5A	4	TF5.6
Spring 2010	5	TF5.5, TF5.5A	3	TF5.6
Spring 2011	10	TF5.5, TF5.5A	6	TF5.6
Spring 2012	16	TF5.5, TF5.5A	9	TF5.6
Spring 2013	6	TF5.5, TF5.5A	5	TF5.6
Spring 2014	5	TF5.5, TF5.5A	6	TF5.6
Spring 2015	7	TF5.5, TF5.5A	8	TF5.6
Summer 2005	29	monthly Dataflow	6	monthly Dataflow
Summer 2006	17	monthly Dataflow	5	monthly Dataflow
Summer 2007	17	monthly Dataflow	4	monthly Dataflow
Summer 2008	25	monthly Dataflow	12	monthly Dataflow
Summer 2009	36	TF5.5, TF5.5A	9	TF5.6
Summer 2010	43	TF5.5, TF5.5A	7	TF5.6
Summer 2011	43	TF5.5*, TF5.5A*	23	TF5.6*
Summer 2012	39	TF5.5*, TF5.5A*	19	TF5.6*
Summer 2013	31	TF5.5*, TF5.5A*	12	TF5.6*
Summer 2014	25	TF5.5, TF5.5A	13	TF5.6
Summer 2015	29	TF5.5, TF5.5A	28	TF5.6

Seasonal estimates used to characterize the baseline for JMSTFL



Seasonal estimates used to characterize the baseline for JMSMH

Season Year	Mean	Data Source
Spring 2005	9	weekly Dataflow
Spring 2006	6	weekly Dataflow
Spring 2007	4	weekly Dataflow
Spring 2008	6	weekly Dataflow
Spring 2009	6	weekly Dataflow
Spring 2010	5	weekly Dataflow
Spring 2011	4	weekly Dataflow
Spring 2012	5	weekly Dataflow
Spring 2013	8	weekly Dataflow
Spring 2014	6	weekly Dataflow
Spring 2015	6	weekly Dataflow
Summer 2005	10	weekly Dataflow
Summer 2006	6	weekly Dataflow
Summer 2007	5	weekly Dataflow
Summer 2008	9	weekly Dataflow
Summer 2009	6	weekly Dataflow
Summer 2010	4	weekly Dataflow
Summer 2011	4	weekly Dataflow
Summer 2012	3	weekly Dataflow
Summer 2013	4	weekly Dataflow
Summer 2014	6	weekly Dataflow
Summer 2015	3	weekly Dataflow

Spring average = 6

Summer average = 5

Spring 95% UCL = 7

Summer 95% UCL = 7

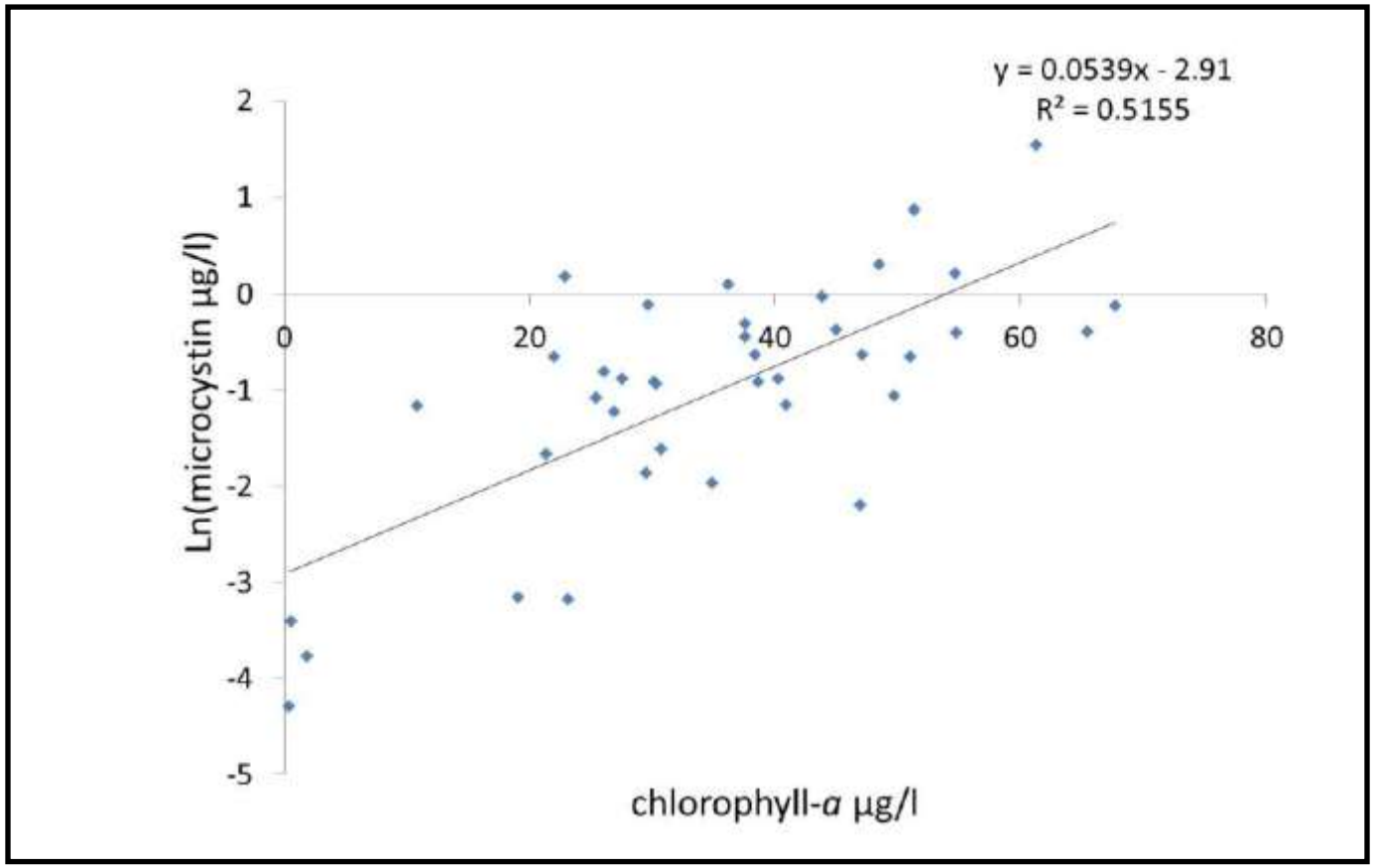
Once baseline concentrations were estimated, evidence of excessive algae-related effects was sought.

Metrics examined:

- HABs (microcystin and *Cochlodinium*)
- pH
- Dissolved oxygen
- Water Clarity
- PIBI/BIBI

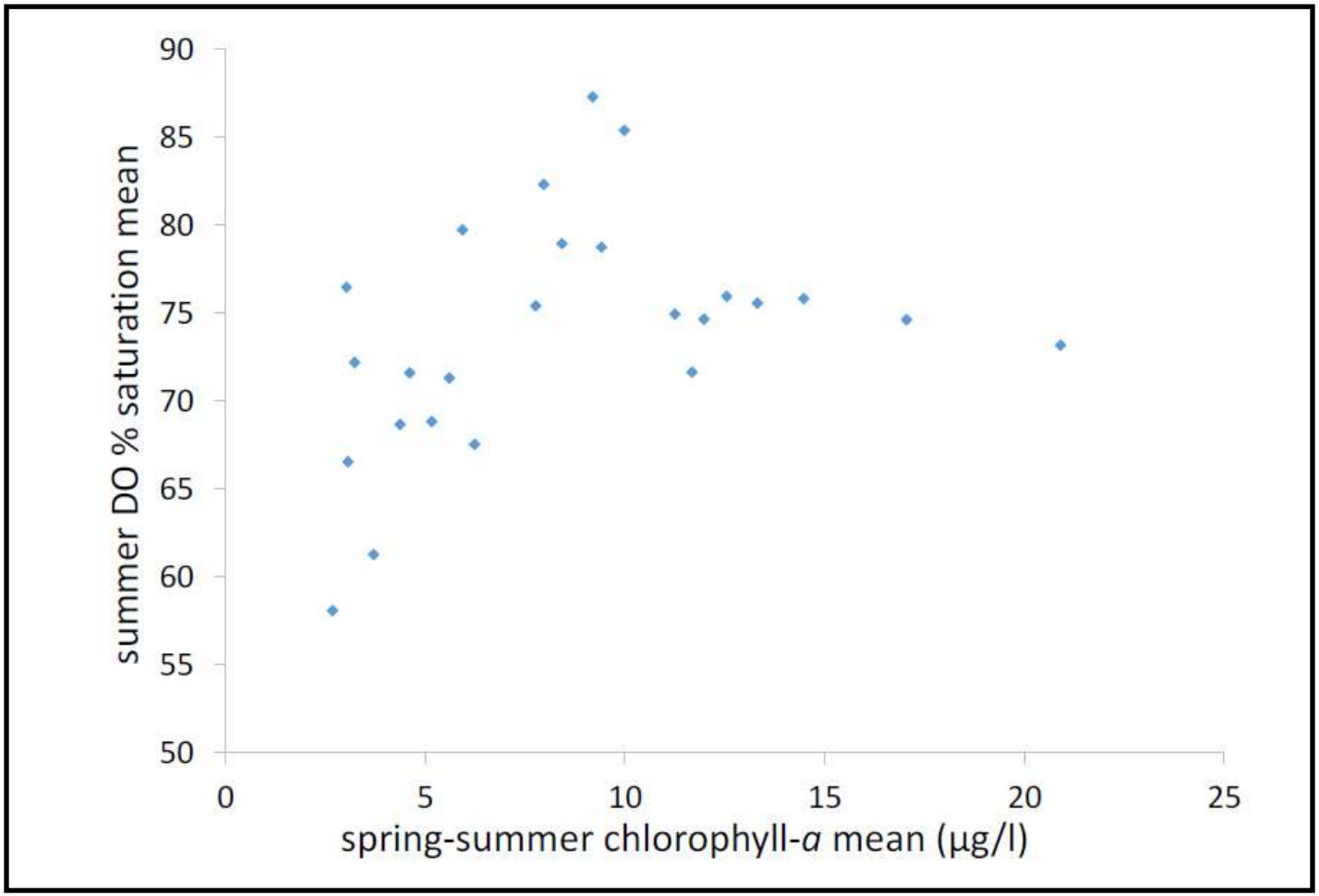
Conventional statistical tools were used to relate chlorophyll-*a* to the above metrics.

Relationship of chlorophyll-*a* to dissolved microcystin concentration



Using this relationship, the chlorophyll-*a* concentration linked to a harmful effect is 53 µg/l.

Scatterplot of chlorophyll-*a* and DO % saturation at station TF5.6



Because no statistically significant correlation was found, VADEQ concluded that low DO is not an effect related to chlorophyll-*a*.

Metrics that were tied to James River chlorophyll-*a*:

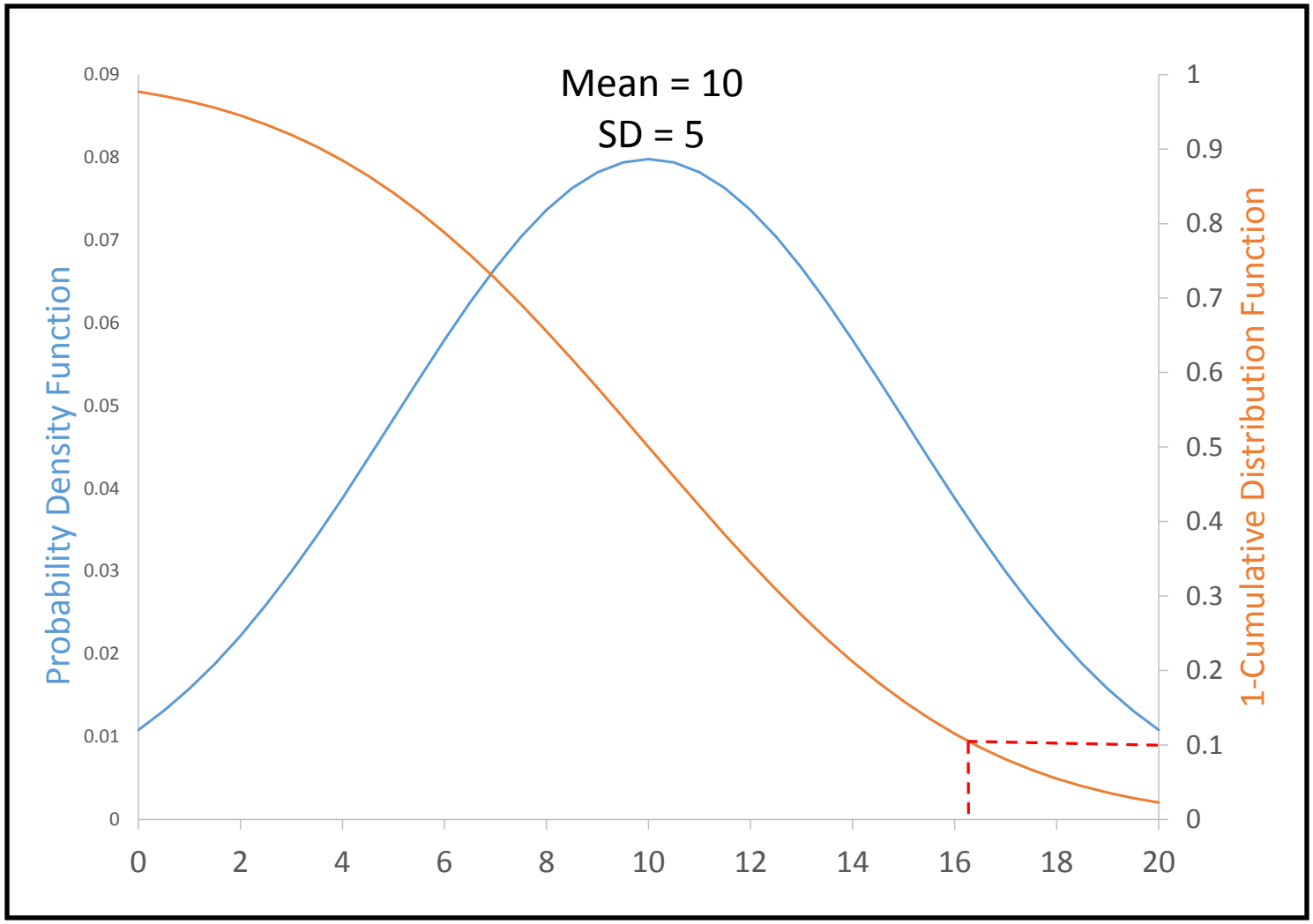
- pH
- Microcystin concentration and *Cochlodinium* cell density
- Water clarity

Metrics that were not tied to James River chlorophyll-*a*:

- Dissolved oxygen
- PIBI and BIBI scores

Once the chlorophyll concentration associated with an effect was determined, the probability of the segment experiencing chlorophyll equal to or greater than that value was estimated using the segment-specific cumulative distribution function.

Spatial and temporal CDFs for each segment-season were constructed using the baseline chlorophyll concentration and standard deviations calculated from Dataflow and continuous monitoring data.



A waterbody exhibiting this kind of chlorophyll distribution is not threatened by effects that occur at concentrations greater than or equal to 16 µg/l.

How to calculate the CDF….

- For a non-negative continuous random variable having an expectation, Markov's inequality states that[1]

$$\bar{F}(x) \leq \frac{\mathbb{E}(X)}{x}.$$

- As $x \to \infty, \bar{F}(x) \to 0$, and in fact $\bar{F}(x) = o(1/x)$ provided that $\mathbb{E}(X)$ is finite.

Proof:[citation needed] Assuming X has a density function f, for any $c > 0$

$$\mathbb{E}(X) = \int_0^\infty x f(x) dx \geq \int_0^c x f(x) dx + c \int_c^\infty f(x) dx$$

Then, on recognizing $\bar{F}(c) = \int_c^\infty f(x) dx$ and rearranging terms,

$$0 \leq c\bar{F}(c) \leq \mathbb{E}(X) - \int_0^c x f(x) dx \to 0 \text{ as } c \to \infty$$

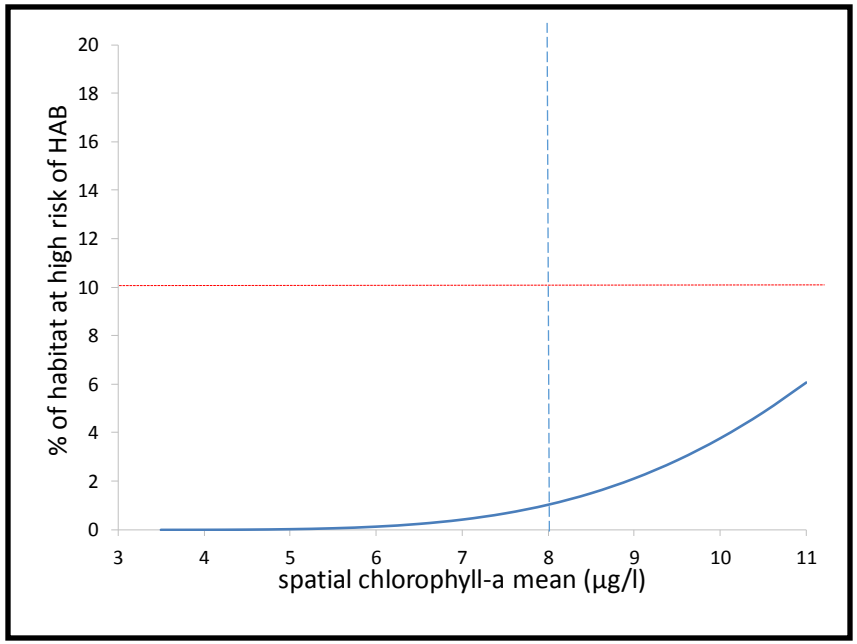
or alternatively,

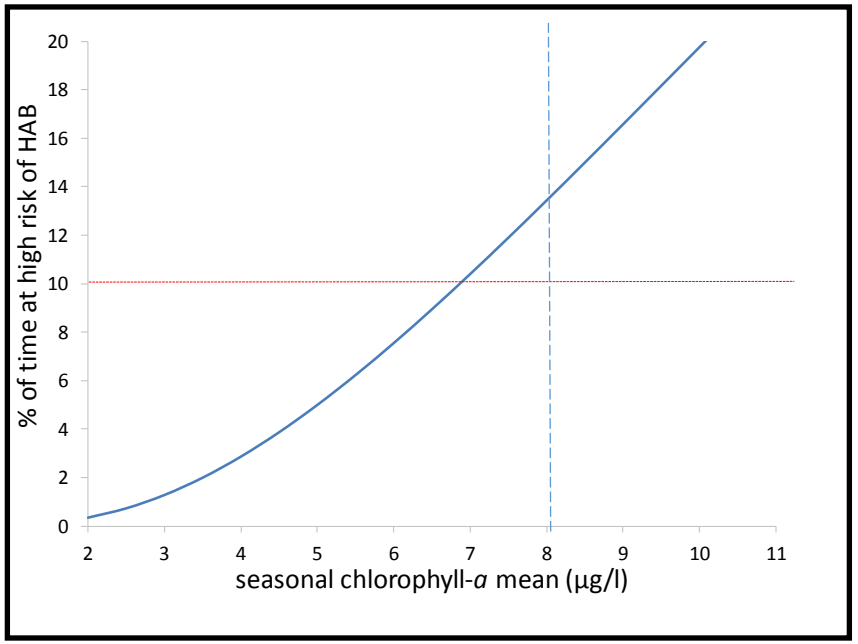
= NORMDIST (x, mean, SD, TRUE)

Subtracting the above from 1 returns the probability of meeting or exceeding a particular value.

Prediction of HAB Risk in Space and Time for JMSPH-Summer At a Range of Chlorophyll-a Means

Chlorophyll value linked to harmful *Cochlodinium* = 21 ug/l





Baseline (8 µg/l) is not protective at a 10% risk level.

An acceptable risk level of 10% was applied to pH and HAB effects, This threshold is consistent with USEPA guidance for acute effects.

On December 7th, the JRCS RAP Technical Workgroup met to discuss the technical details of VADEQ's criteria derivation approach.

The workgroup expressed strong support for the approach and its conclusions. However, the following recommendations were made to enhance the proposal:

- Provide a justification for using nearshore data to characterize pH in the tidal fresh regions
- Incorporate spatially intensive and recently collected *Cochlodinium* data
- Provide more documentation in some areas (e.g., basis for selected confidence limits)

VADEQ has agreed to make revisions to its proposal document in light of these recommendations

Proposed VADEQ Staff Recommended JR Chlorophyll-*a* Criteria

Segment-Season	Original	Recommended	Basis for recommended criteria lower than baseline	Baseline
JMSTFU-spring	10	8		8
JMSTFU-summer	15	21	Enhanced protection from elevated pH	23
JMSTFL-spring	15	10		10
JMSTFL-summer	23	24	Enhanced protection from elevated pH and harmful algal blooms	28
JMSOH-spring	15	13		13
JMSOH-summer	22	11		11
JMSMH-spring	12	7		7
JMSMH-summer	10	7		7
JMSPH-spring	12	8		8
JMSPH-summer	10	7	Enhanced protection from harmful algal blooms	8

Questions?

The proposed chlorophyll criteria were derived with the assumption that they would be implemented in a manner consistent with VADEQ's proposed assessment methodology.

Current Assessment Method

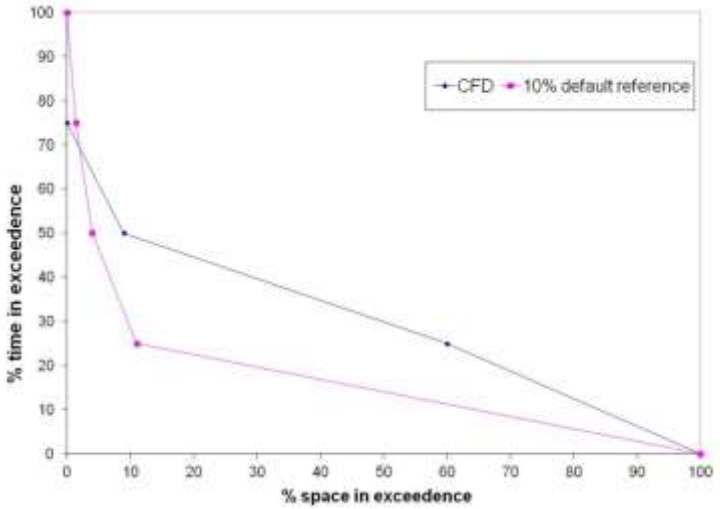
1-Jul	30			30	30	40	50	30
			50		40	40	50	20
					30	30	40	10
	10			10	20	30	30	10
1-Aug	10			10	10	20	30	10
			30		20	20	30	20
					10	30	20	10
	20			10	10	10	10	10
1-Sep	40			20	40	30	20	20
			20		30	20	20	10
					20	20	10	10
	10			10	10	10	10	10

Cell-by-cell seasonal averaging

23	29	31	18
29	25	31	16
18	26	20	10
13	14	14	10

Exceedence layer

X	X	X	X
X	X	X	X
X	X	X	✓
✓	✓	✓	✓



Cumulative Frequency Distribution

Season-Year	Ranked Spatial Exceedence Rate	Temporal Exceedence Rate
	100%	0%
Spring Year2	33%	25%
Spring Year1	25%	50%
Spring Year3	10%	75%
	0%	100%

Ranking and Calculation of Temporal Exceedence Rates

Strengths

Innovative

Provides the means to regulate the spatial/temporal variability of a pollutant to ensure optimal protectiveness

Enables compliance to be based on similarity to a biological reference community

Weaknesses

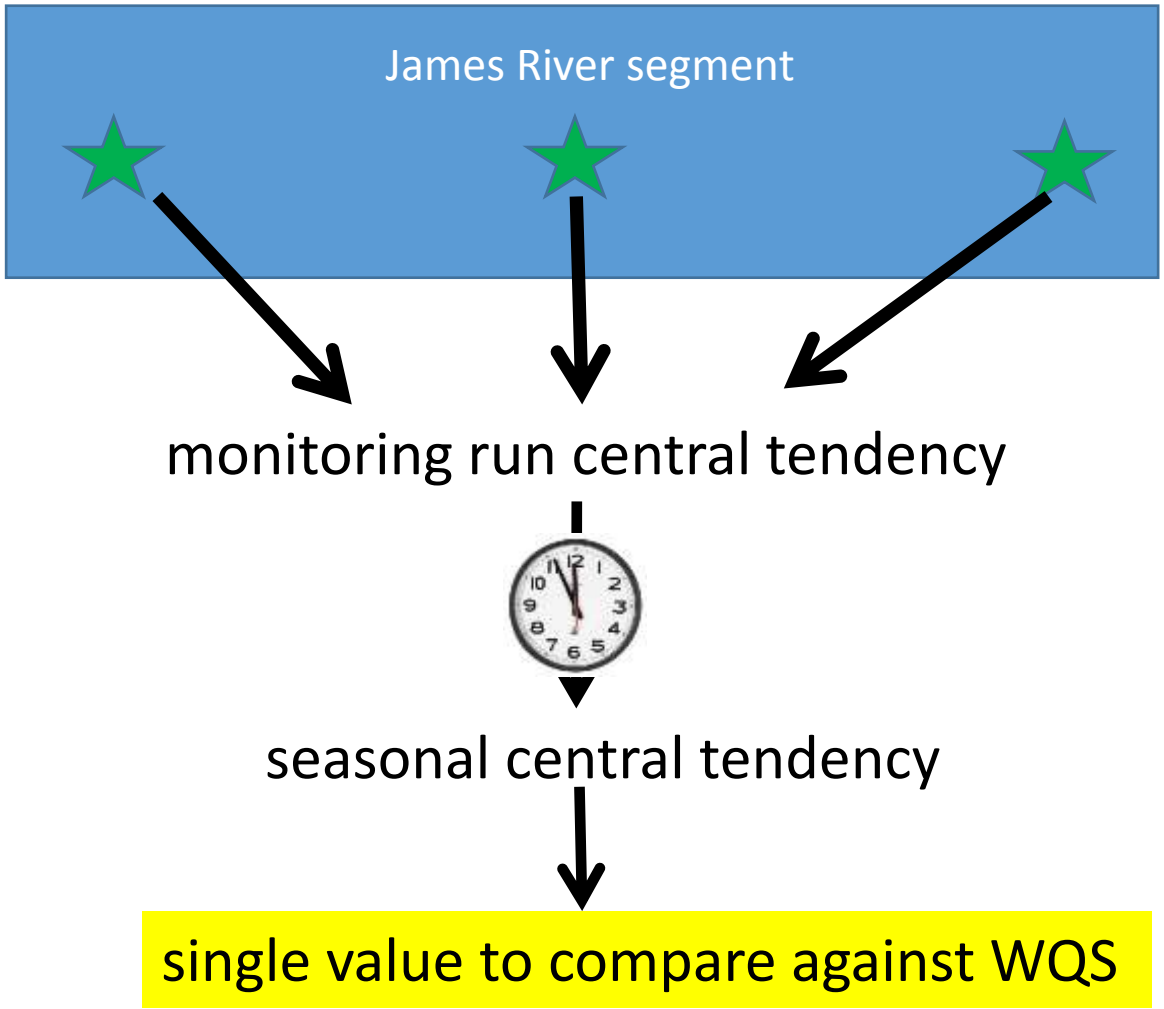
Experimental

A non-intuitive interpretation of the WQS

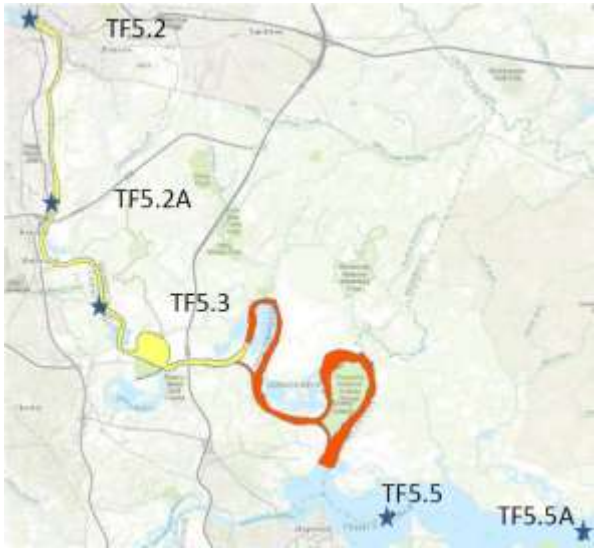
The current reference curve is not appropriate for seasonal mean criteria.

The method is prone to bias and error when used with fixed station datasets.

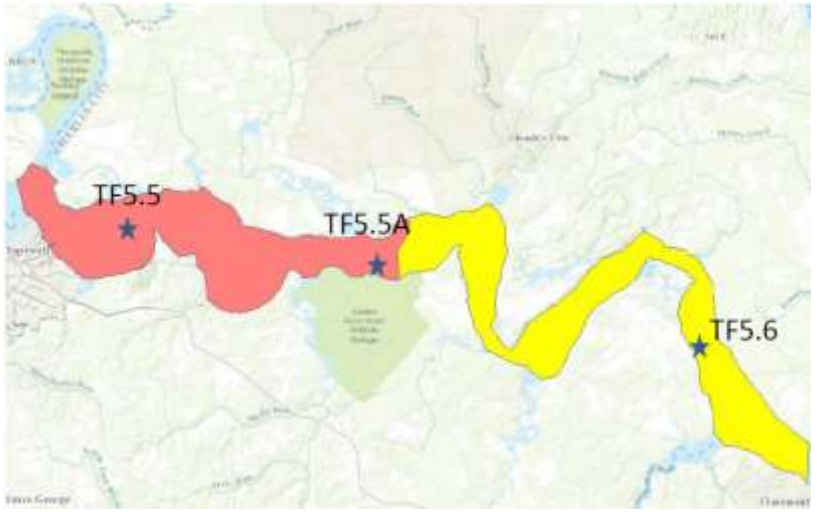
Proposed Assessment Method



The proposed assessment method does not presume that all James River segments are consistently uniform with respect to chlorophyll-*a*.



JMSTFU



JMSTFL

Segment seasonal means are to be calculated using area-derived weighting for JMSTFU and JMSTFL.

For the other segments, chlorophyll-*a* shows no consistent pattern, so data can be averaged without any weighting.

Assessment Period and Allowable Exceedence

The current assessment period is three years. VADEQ has proposed to expand this to six years, which is how most conventional pollutants are assessed statewide.

VADEQ believes a 2 out of 6 allowable exceedence rate is sufficiently protective.

Year	Spring	Summer
1	15	23
2	10	20
3	9	25
4	10	20
5	18	27
6	6	19

Strengths

Similar to other VADEQ and other state's methodologies

Direct interpretation of the WQS

Easier to implement and explain (compared to current method)

Less prone to error and bias (compared to current method) when only fixed station datasets are available

Weaknesses

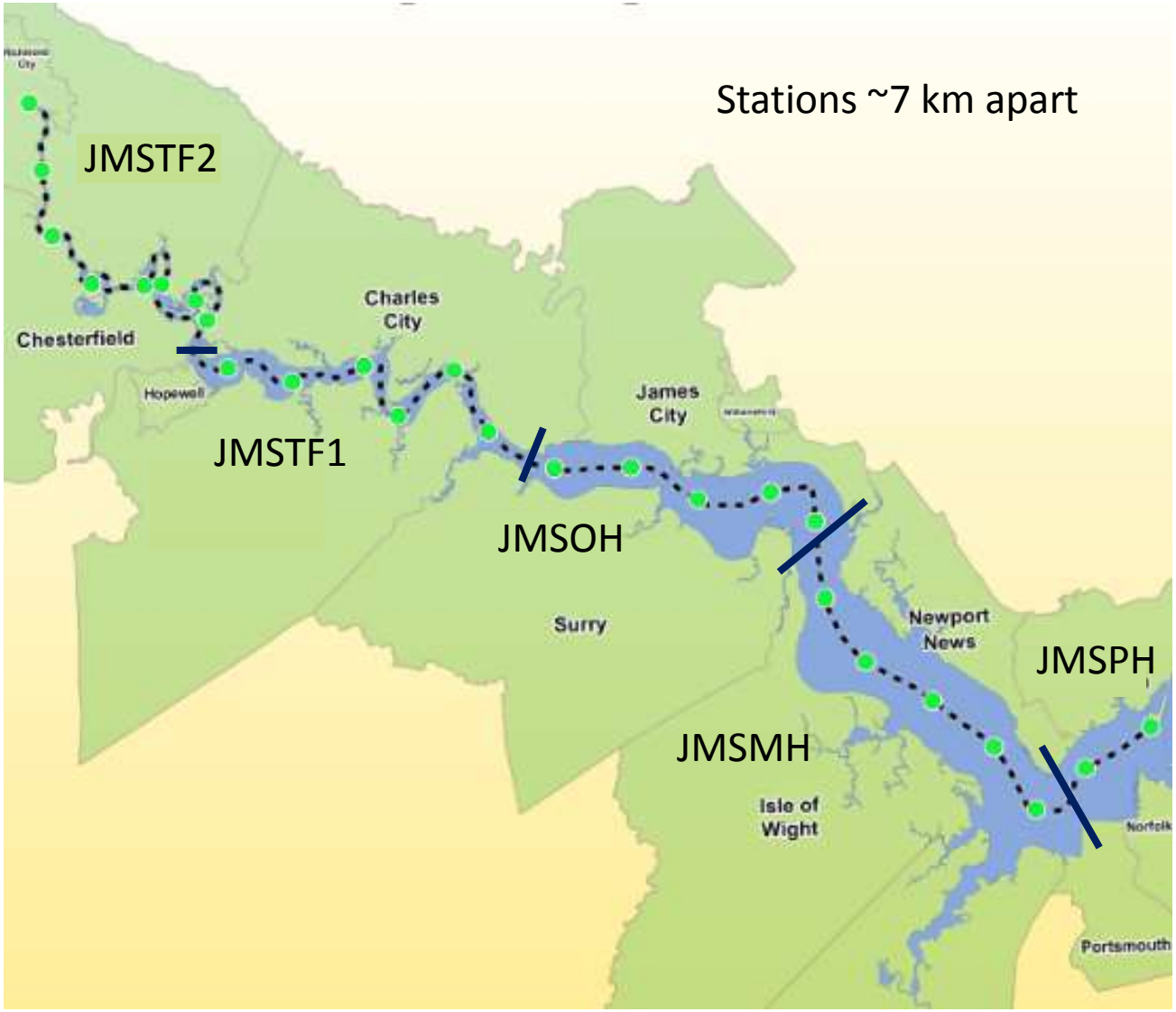
Not as protective as current method.

Not sensitive to "hot spots" since it focuses solely on segment-wide central tendency

Is VADEQ's current monitoring network sufficient to enable defensible assessments using the proposed method?

There are “gaps” in the current station design

A monitoring design that minimizes “gaps”



Questions:

1. Are the data generated at the current CBP stations sufficient for rolling out the proposed assessment method AND the proposed criteria?

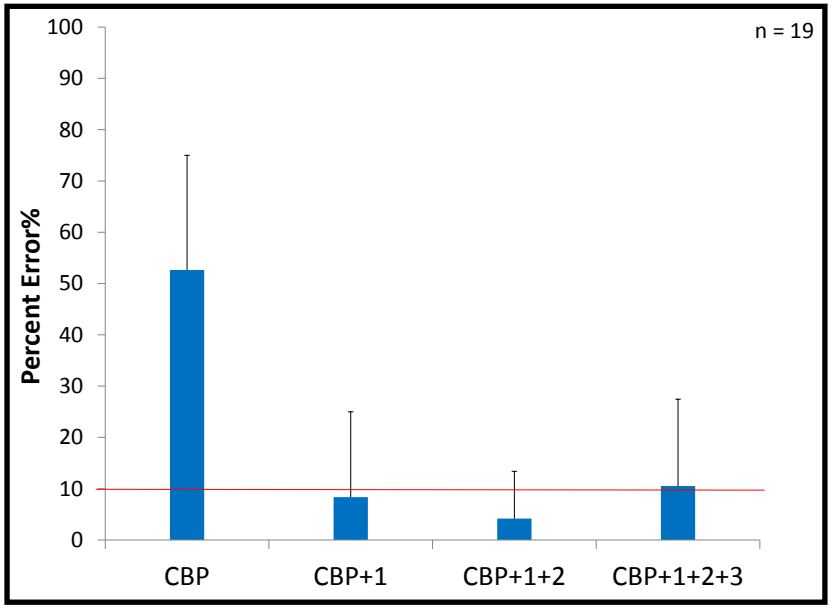
2. If no, how many additional stations do we need? And where?

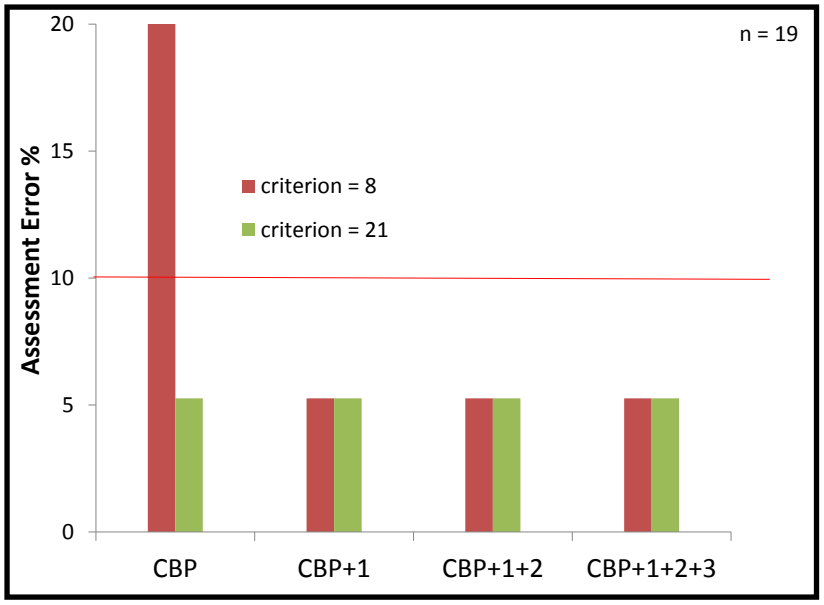
There are two ways we can measure accuracy. Both assume that Dataflow provides the "true" picture of chlorophyll.

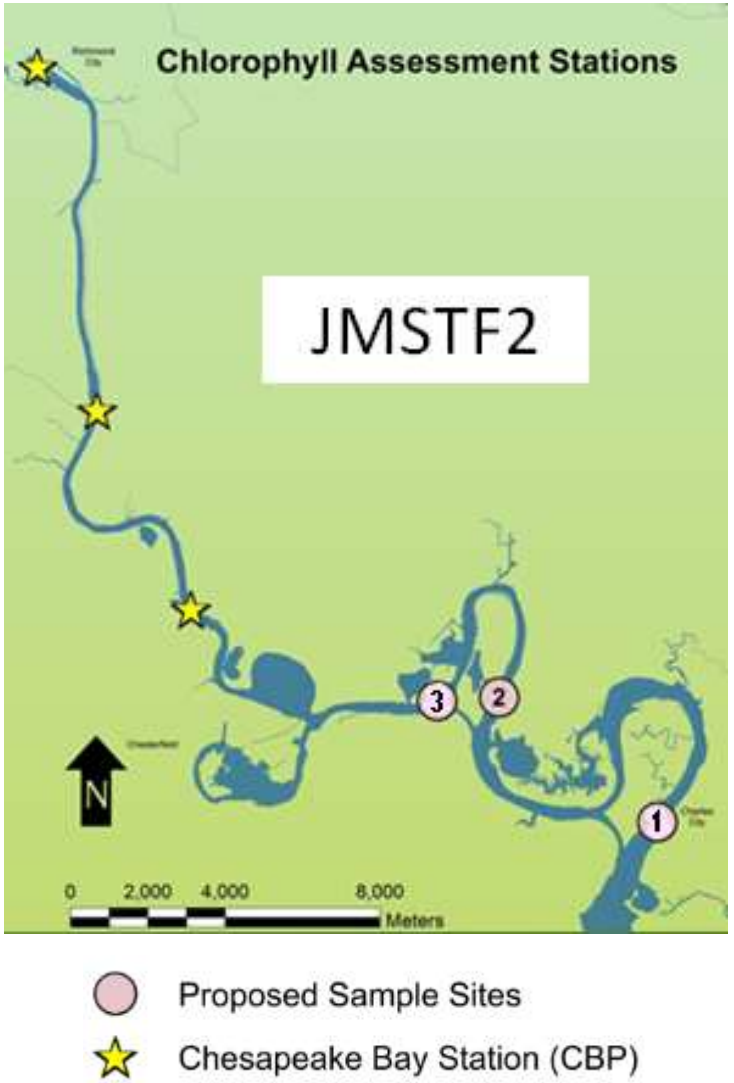
- Compare the magnitude of fixed station estimates to Dataflow estimates.

OR….

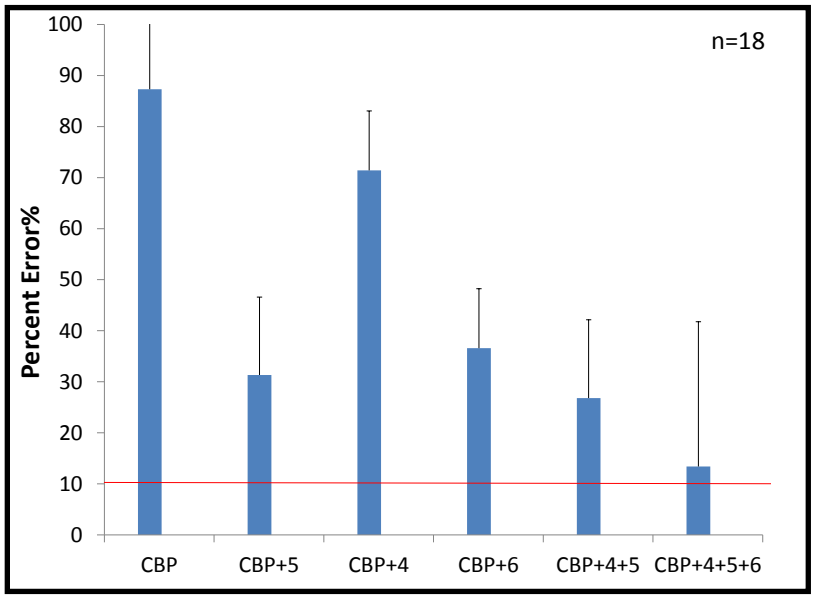
- Compare the fixed station-based assessment outcomes to Dataflow-based assessment outcomes

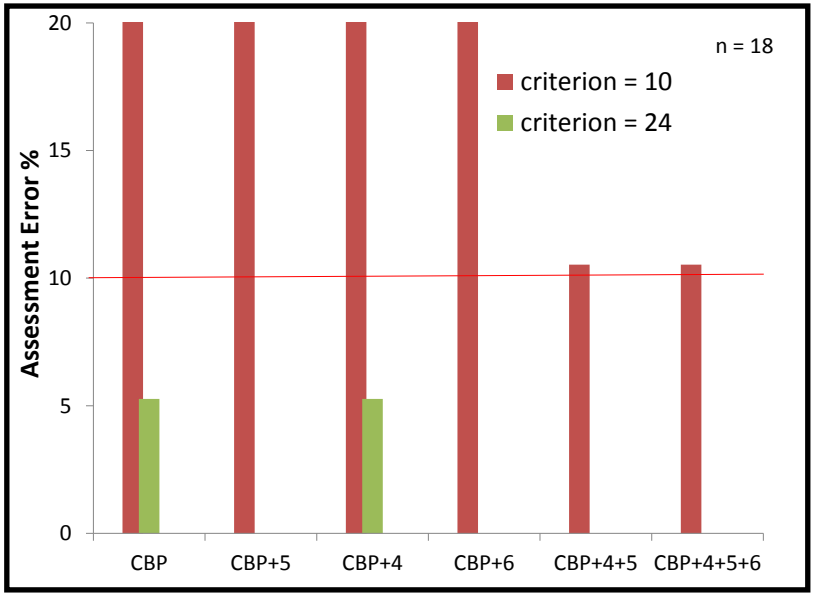


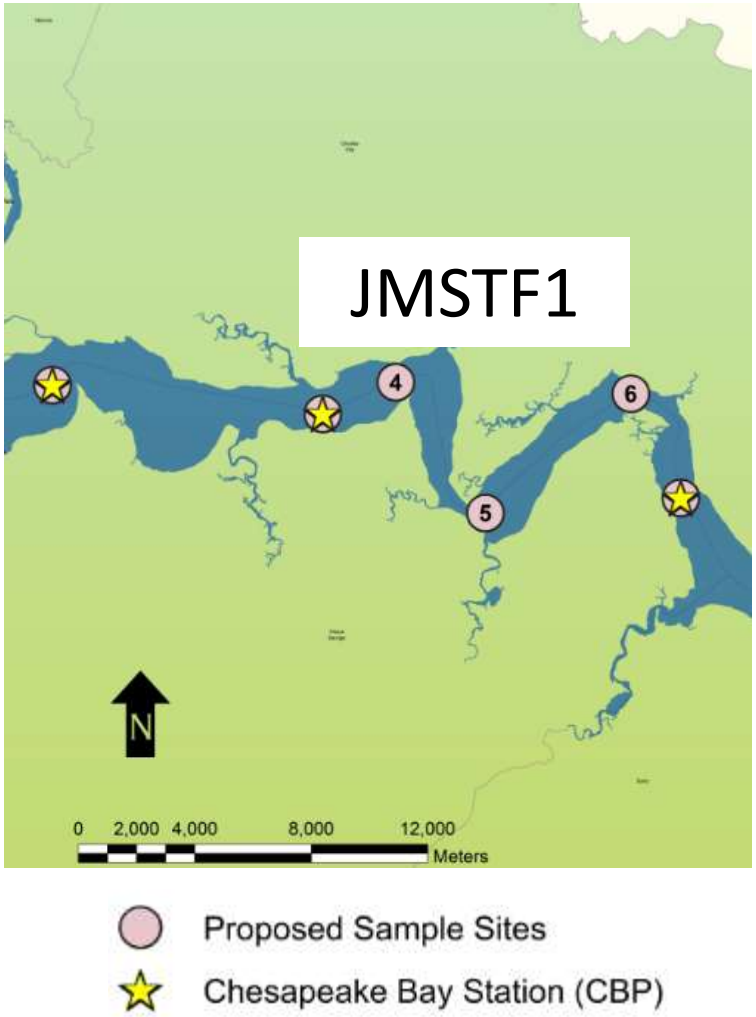




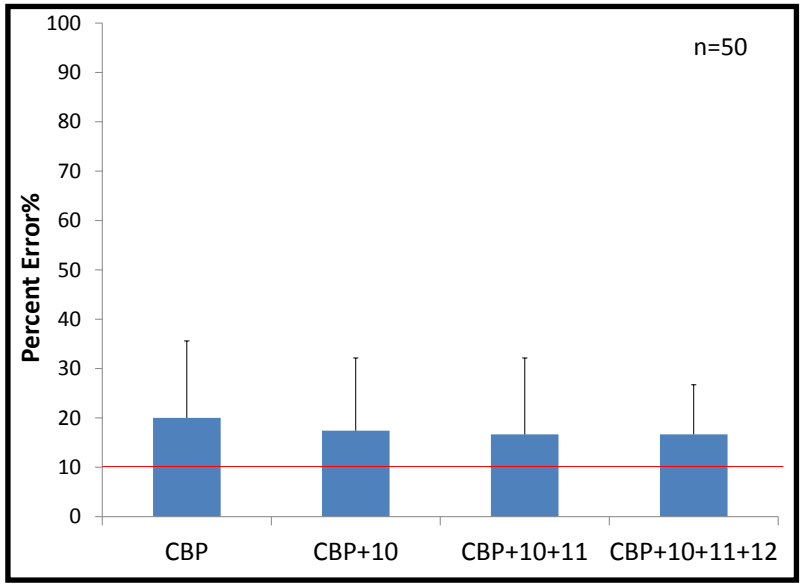
Adding one more station to the current network would enable VADEQ to produce defensible assessments

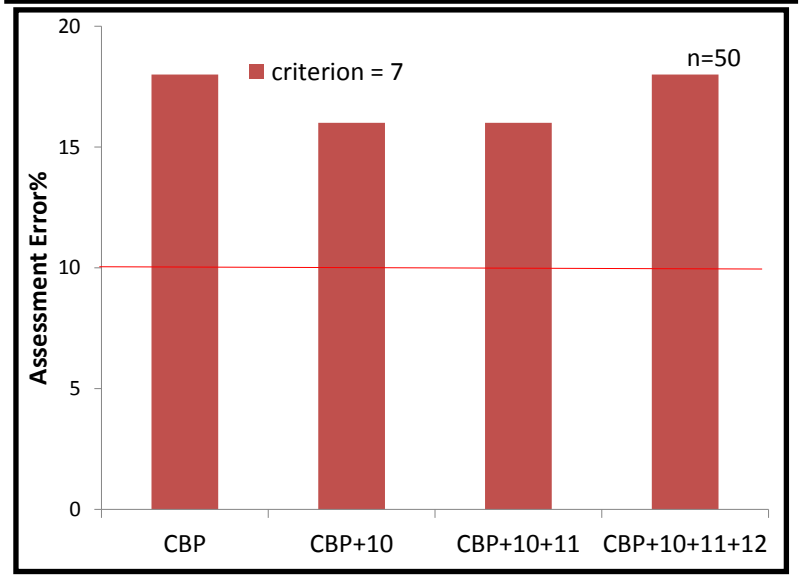


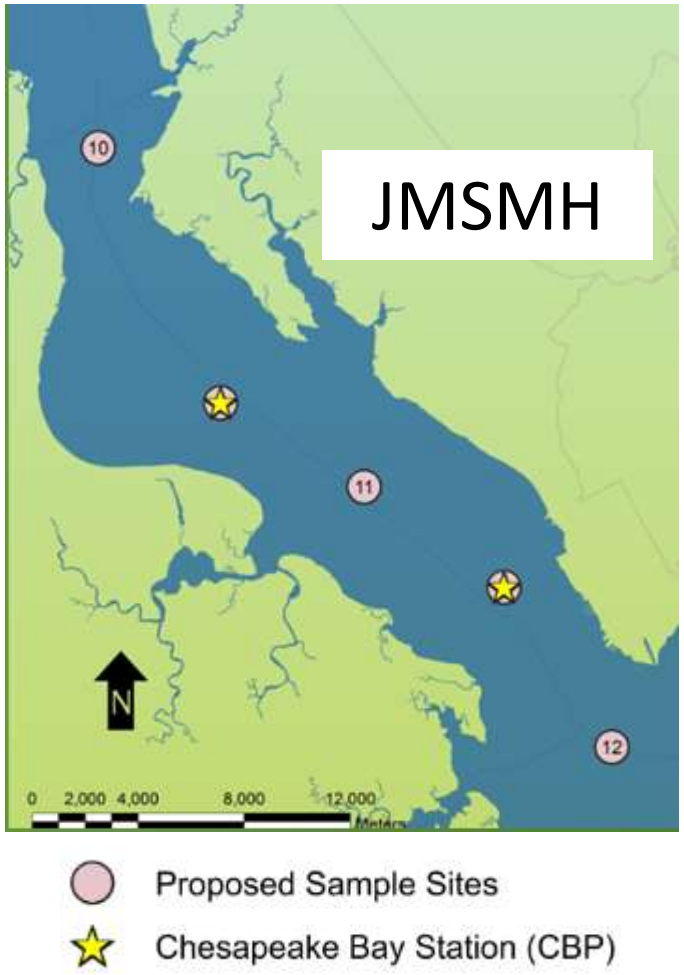




Adding two more stations to the current network would enable VADEQ to produce defensible assessments.







Dataflow is a must for JMSMH. Fixed stations just aren't going to cut it.

During the JRCS RAP Technical Workgroup, concerns were expressed about the stringency of the proposed assessment method.

A recommendation was made for VADEQ to consider options that would increase stringency.

Questions