Assessment Protocol for Numeric James River Chlorophyll-a Criteria: Issues and Options

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Criteria Assessment Protocol Workgroup
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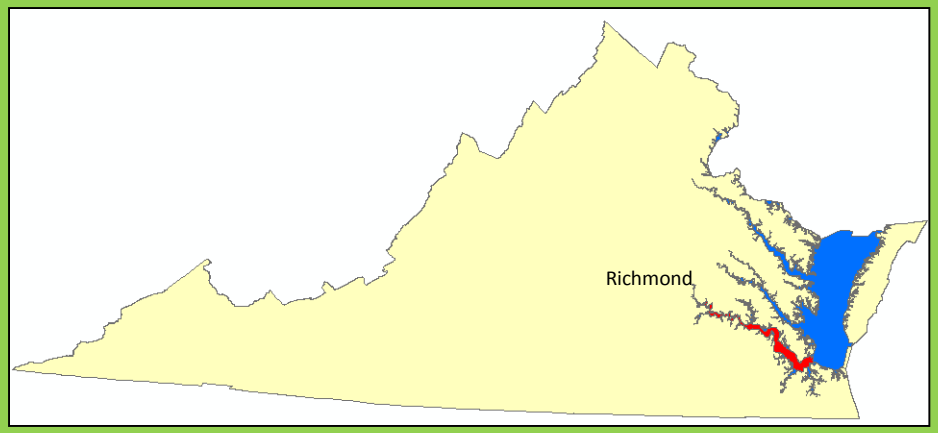
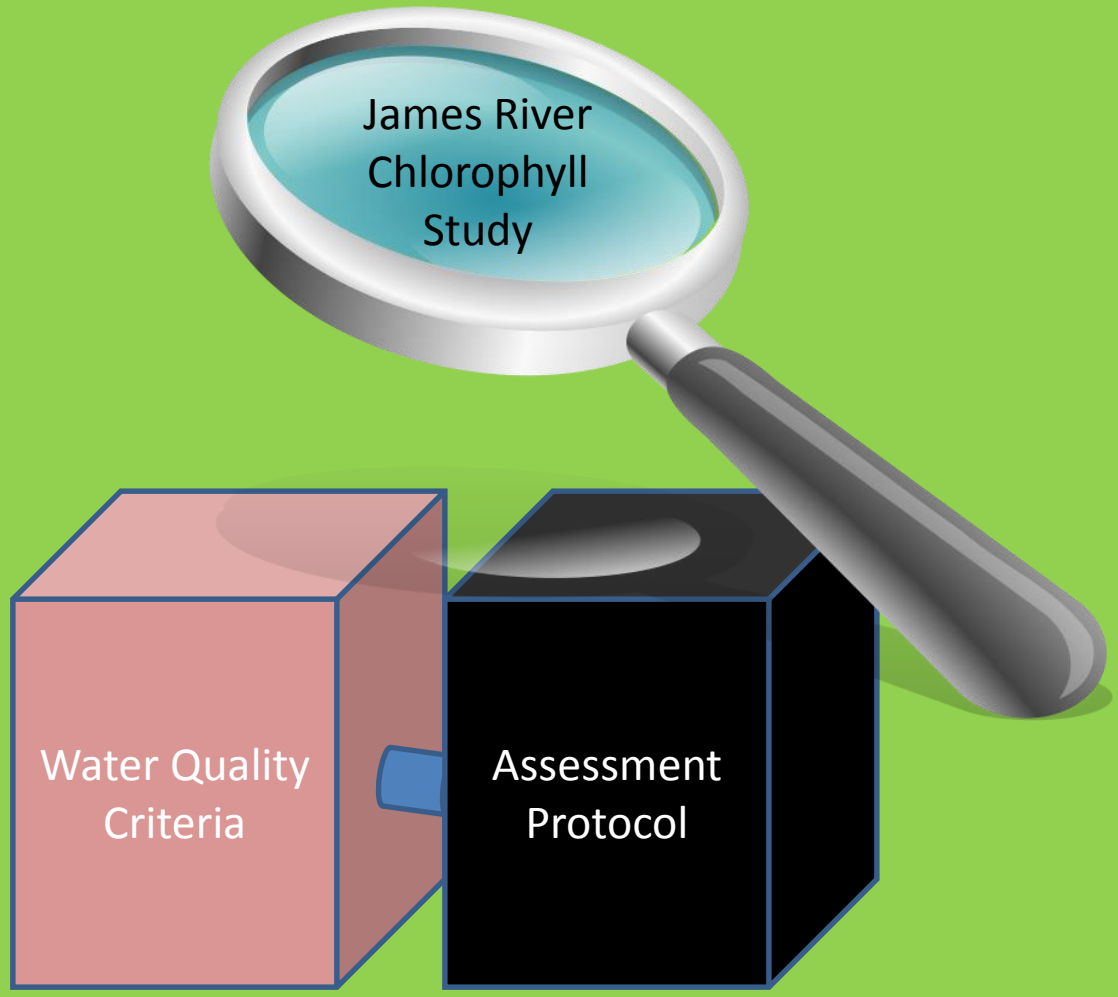
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

bb. The following site specific numerical chlorophyll a criteria apply March 1 through May 31 and July 1 through September 30 as seasonal means to the tidal James River (excludes tributaries) segments JMSTF2, JMSTF1, JMSOH, JMSMH, JMSPH and are implemented in accordance with subsection D of 9VAC25-260-185.

Designated Use	Chlorophyll a µ/l	Chesapeake Bay Program Segment	Temporal Application
Open Water	10	JMSTF2	March 1 - May 31
	15	JMSTF1	
	15	JMSOH	
	12	JMSMH	
	12	JMSPH	
	15	JMSTF2	July 1 - September 30
	23	JMSTF1	
	22	JMSOH	
	10	JMSMH	
	10	JMSPH	




James River
Chlorophyll
Study
Water Quality
Criteria
Assessment
Protocol

How does Virginia currently implement James River chlorophyll criteria?

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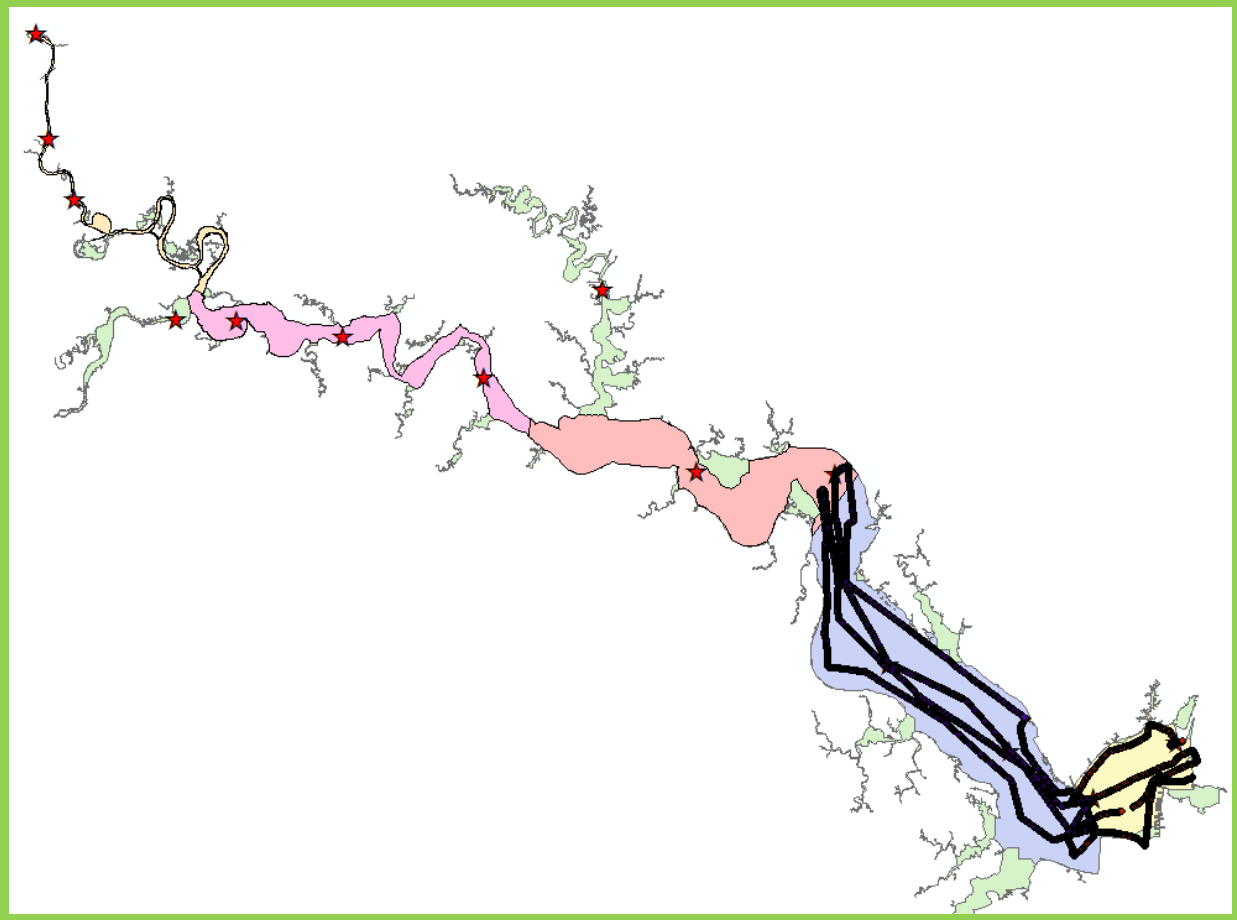
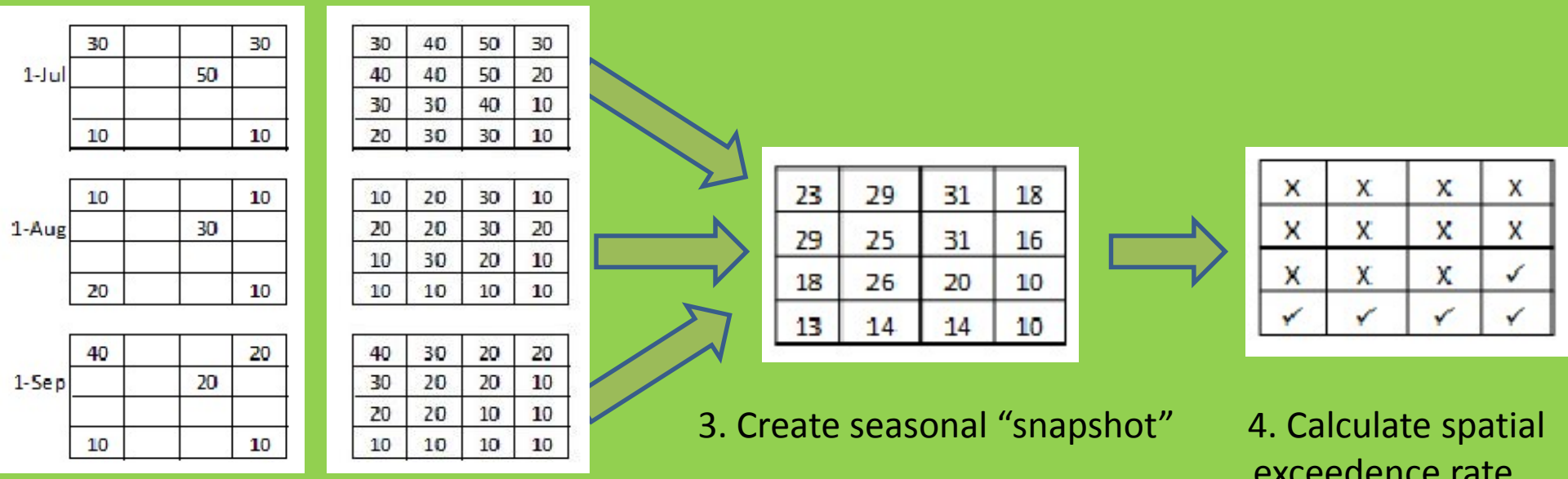


Fixed stations + Dataflow (currently not DEQ or CBP-funded)

How does Virginia currently implement James River chlorophyll criteria?



1. Conduct monthly monitoring runs

2. Interpolate each monitoring run using the Bay Interpolator

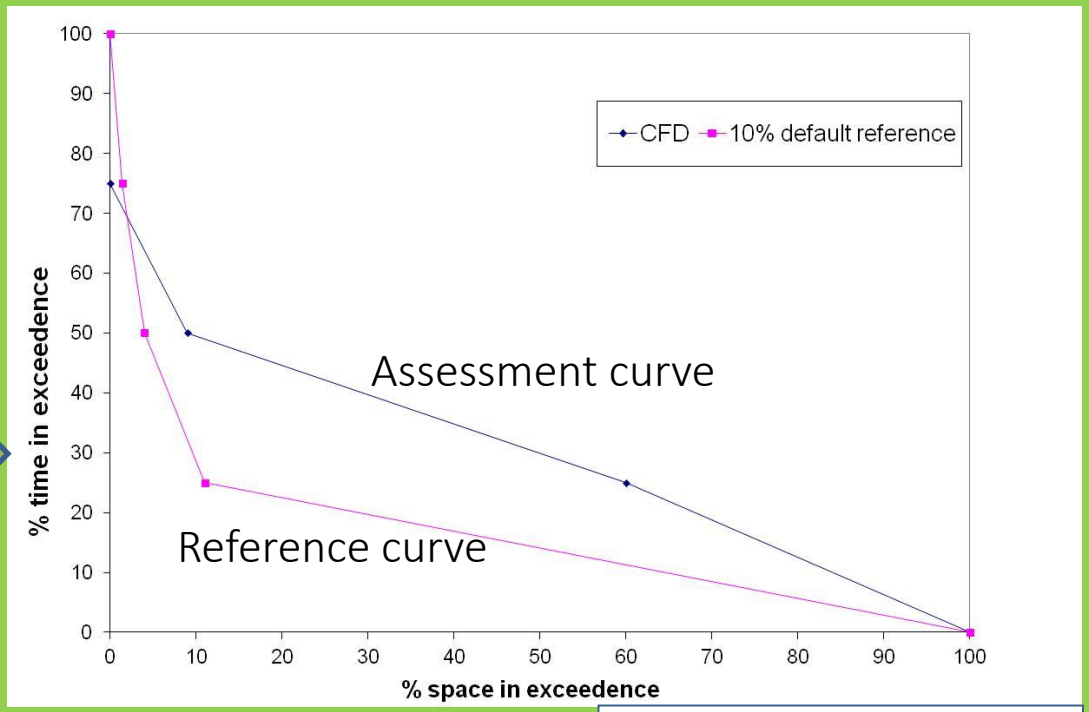
3. Create seasonal "snapshot"

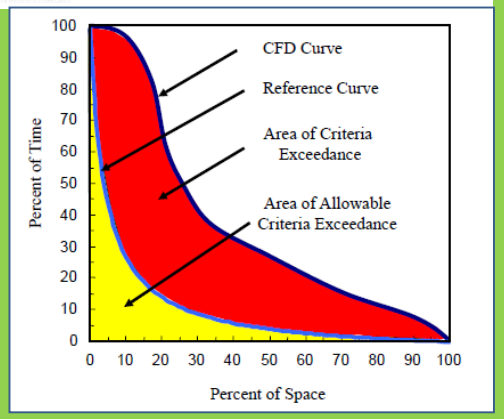
4. Calculate spatial exceedence rate

Perform the above steps for each season in the assessment period

How does Virginia currently implement James River chlorophyll criteria?

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%





VADEQ has identified some issues with the current assessment protocol.

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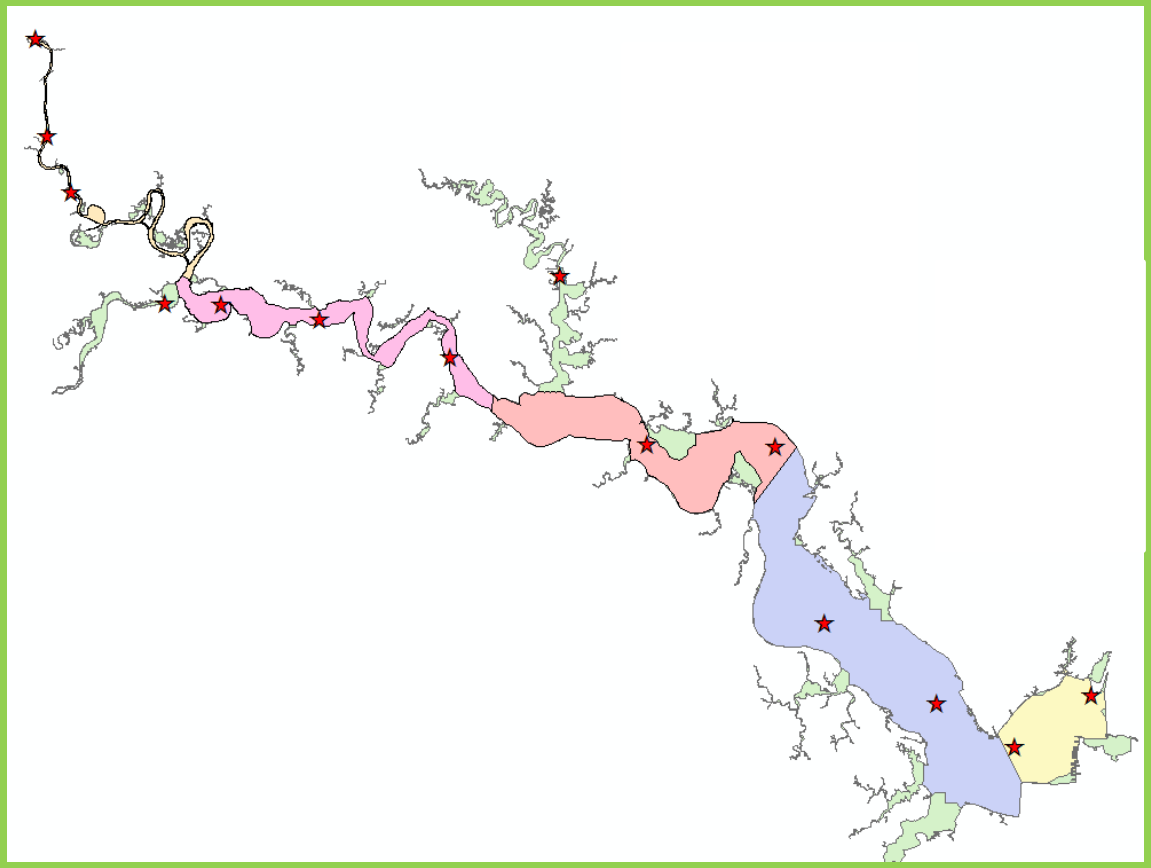
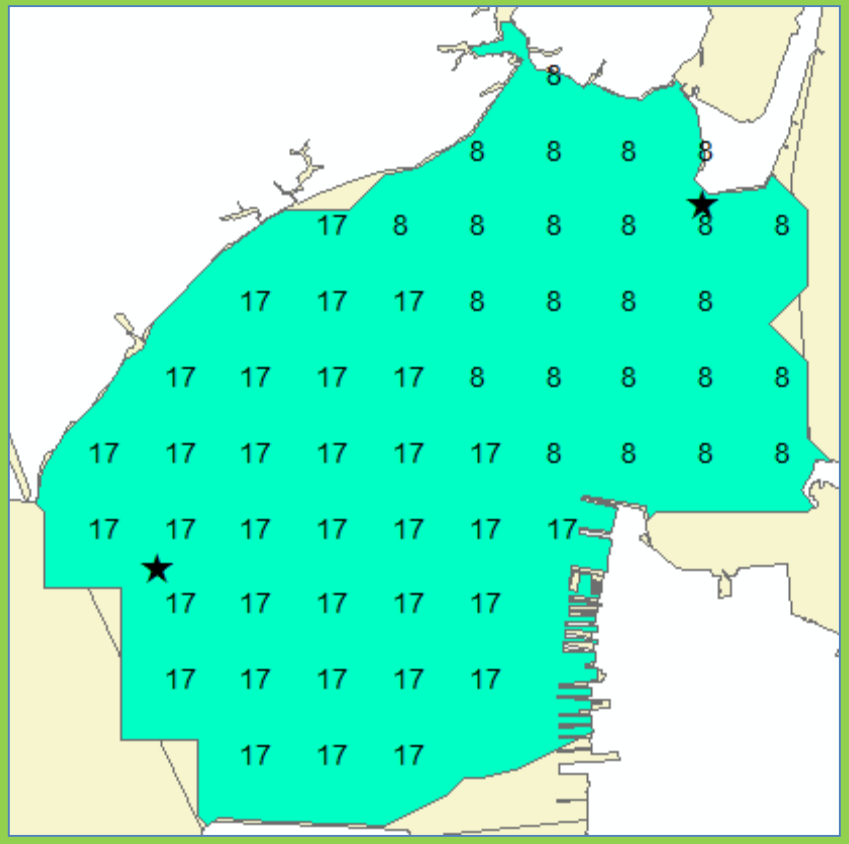
- High uncertainty when fixed station datasets are used

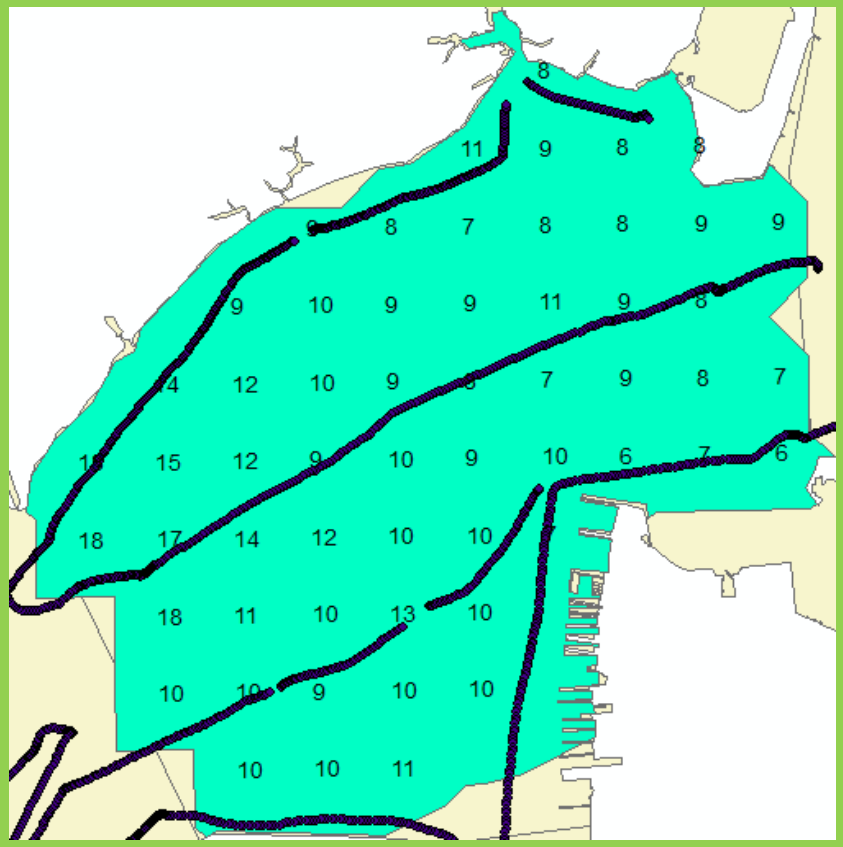


Fixed station datasets produce overly simplistic representations of chlorophyll concentration when processed by the Bay Interpolator.

JMSPH

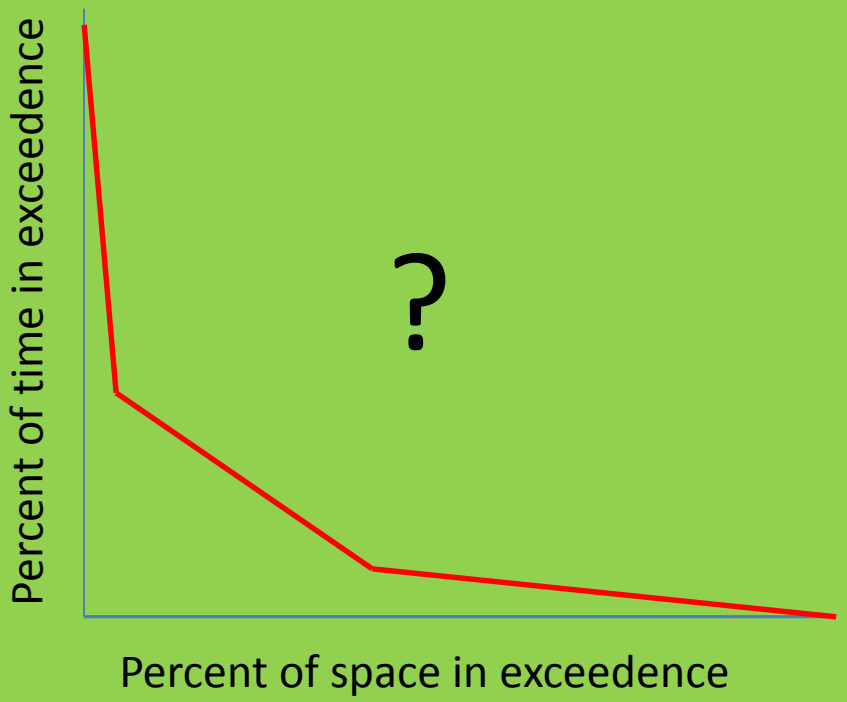


Interpolation based on two data points (represented by stars)



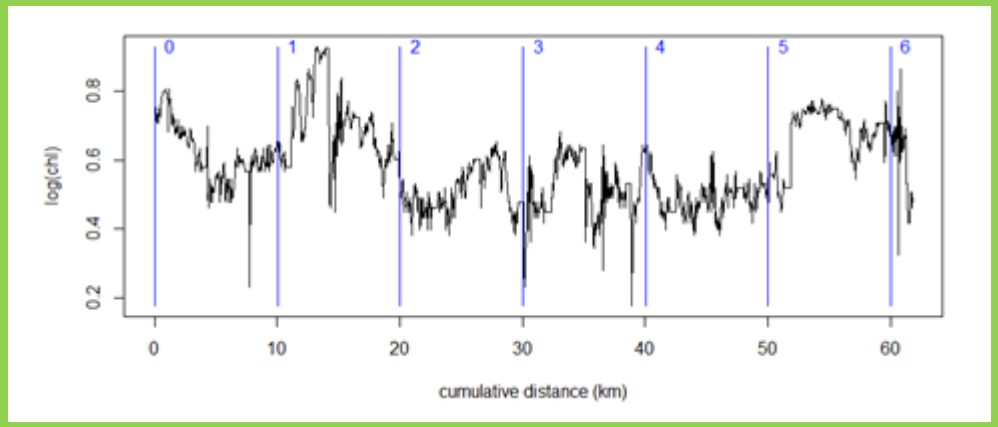
Interpolation based on **1,928** data points (represented by Dataflow cruisetrack)

But do fixed station datasets produce accurate CFDs?



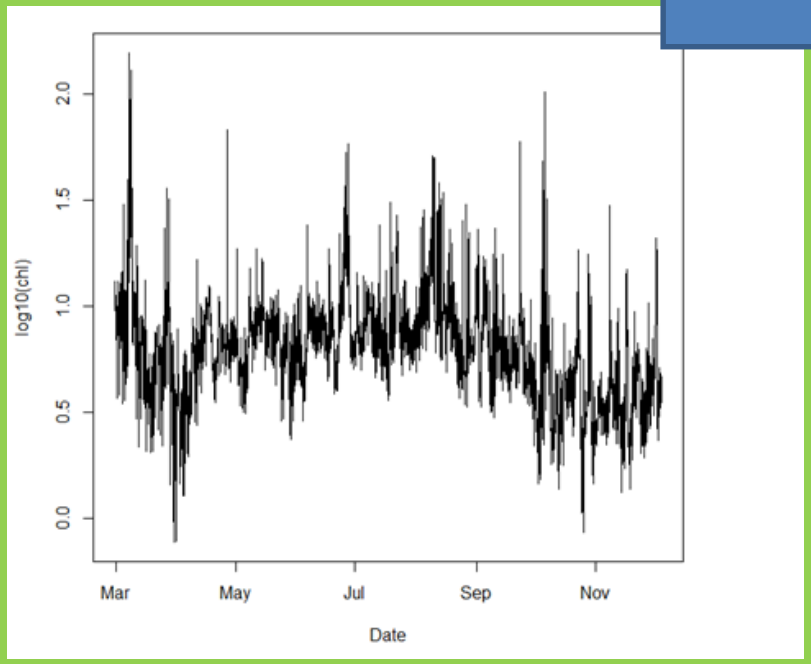
To answer this question…

Independent statistician Elgin Perry used Dataflow and ConMon to simulate the “true” chlorophyll during the spring and summer seasons 2005-2007 in JMSPH.

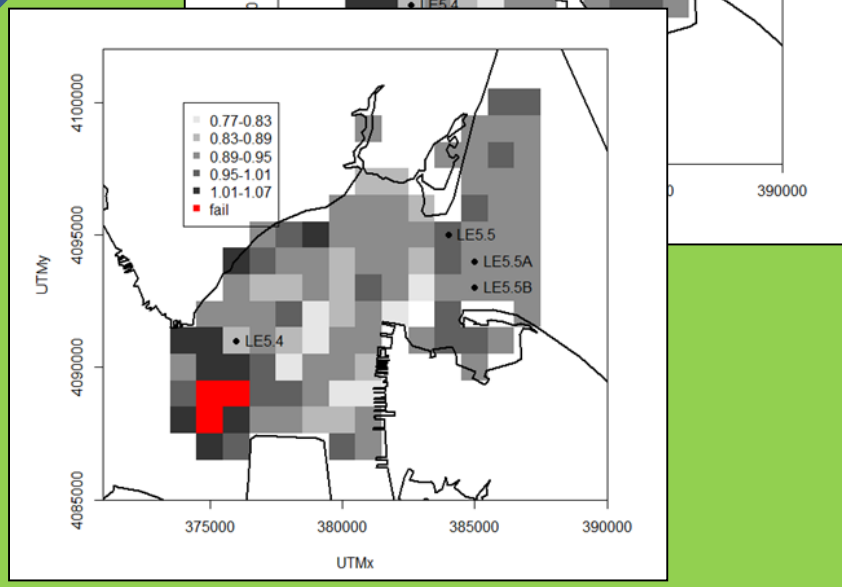


Spatial variability (Dataflow)

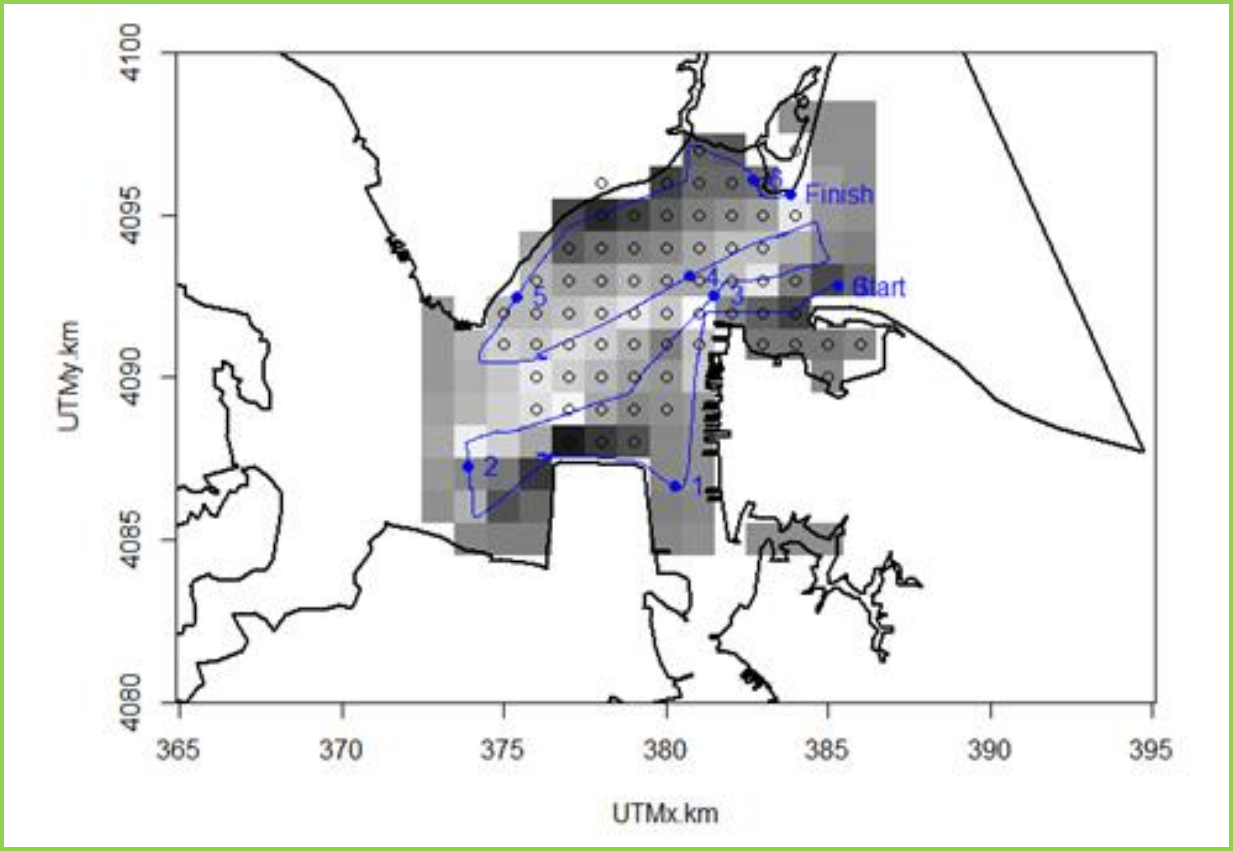
+



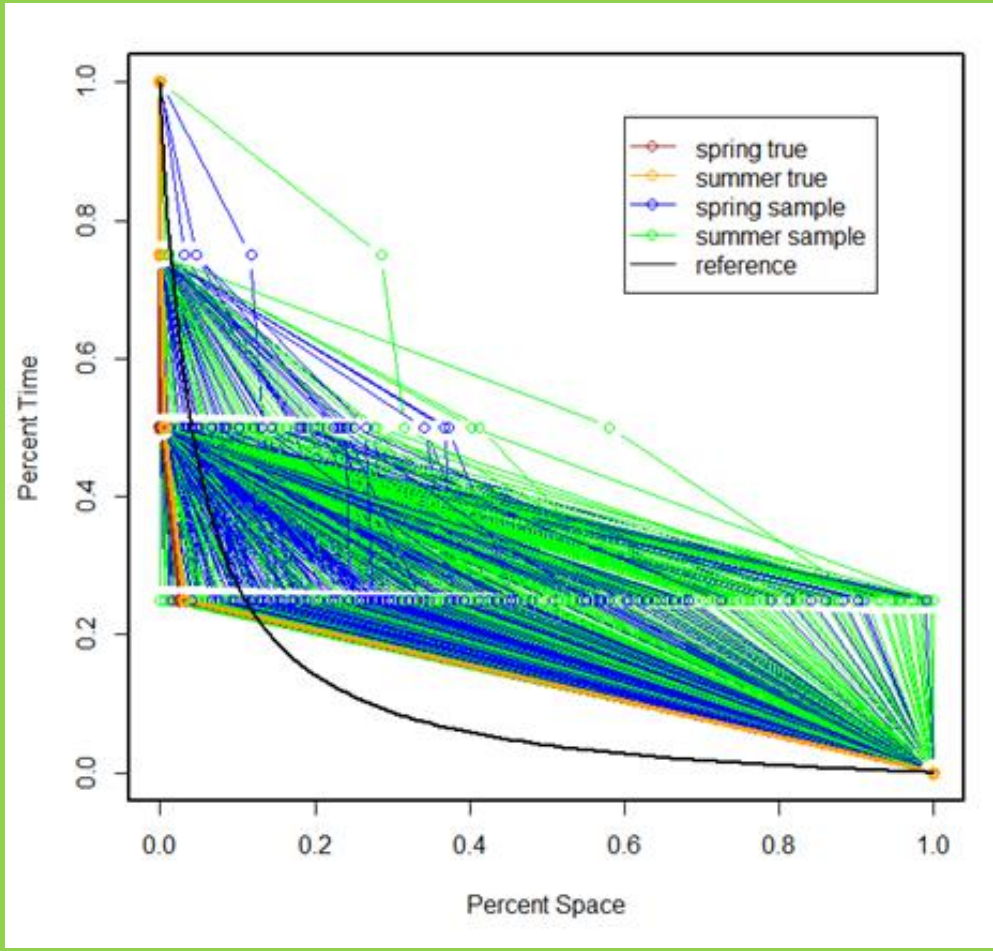
Temporal variability (ConMon)



"true" season means



From Elgin's synthetic dataset, "samples" were taken from six "stations" and interpolated via IDW. CFDs were then created. Repeat 1000 times.



Elgin found that assessments which are based on fixed station datasets tend to be highly biased towards non-compliance and bear little resemblance to the “true” picture of attainment.

Caveat:

Elgin's analysis just focused on JMSPH. It is possible that his conclusions only apply to JMSPH and not the rest of the estuary.

But we have other clues…

According to the fixed station data, JMSOH is impaired.

According to Dataflow+fixed station data, JMSOH is likely *not* impaired.

Season-Year	Fixed Stations	Dataflow+fixed stations
Spring 2006	23.1%	0%
Summer 2006	0%	0%
Spring 2007	0%	0%
Summer 2007	0%	0%
Spring 2008	0%	0%
Summer 2008	0%	0%
Spring 2009	68.4%	--
Summer 2009	0%	--
Spring 2010	0%	--
Summer 2010	0%	--
Summer 2011	0%	--
Spring 2012	32.6%	0%
Summer 2012	0%	0%
Spring 2013	0%	0%
Summer 2012	0%	0%
Summer 2013	0%	0%

VADEQ has identified some issues with the current assessment protocol.

- High uncertainty when fixed station datasets are used.
- Questionable defensibility of the 10% reference curve.

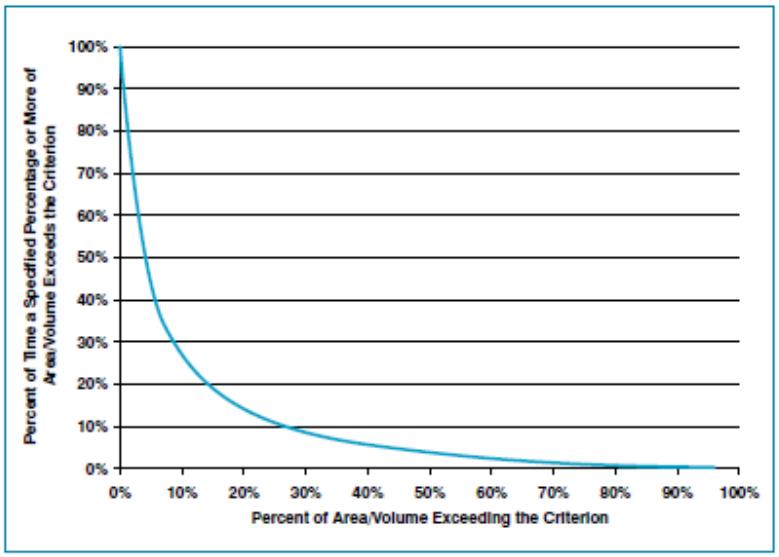


Figure II-4. Default reference curve for application in the attainment assessment of Chesapeake Bay water quality criteria for which biologically based reference curves cannot be derived.

DEQ contracted with Claire Buchanan (ICPRB) to generate bioreference curves based on exceedances of the JR chlorophyll criteria when nutrients are low and light availability is high (reference conditions).

Reference conditions are….

	Spring	June	Summer	Autumn	Winter
Secchi depth (m)					
TF	>0.9	>0.8	>0.8	>0.9	>0.6
OH	>0.7	>0.6	>0.6	>0.5	>0.6
MH	>1.8	>1.45	>1.45	>2.0	>1.8
PH	>2.15	>1.85	>1.85	>2.5	>2.3
DIN (mg/liter)		≤0.07 (all seasons and salinity zones)			
PO_4 (mg/liter)		≤0.007 (all seasons and salinity zones)			

Reference thresholds

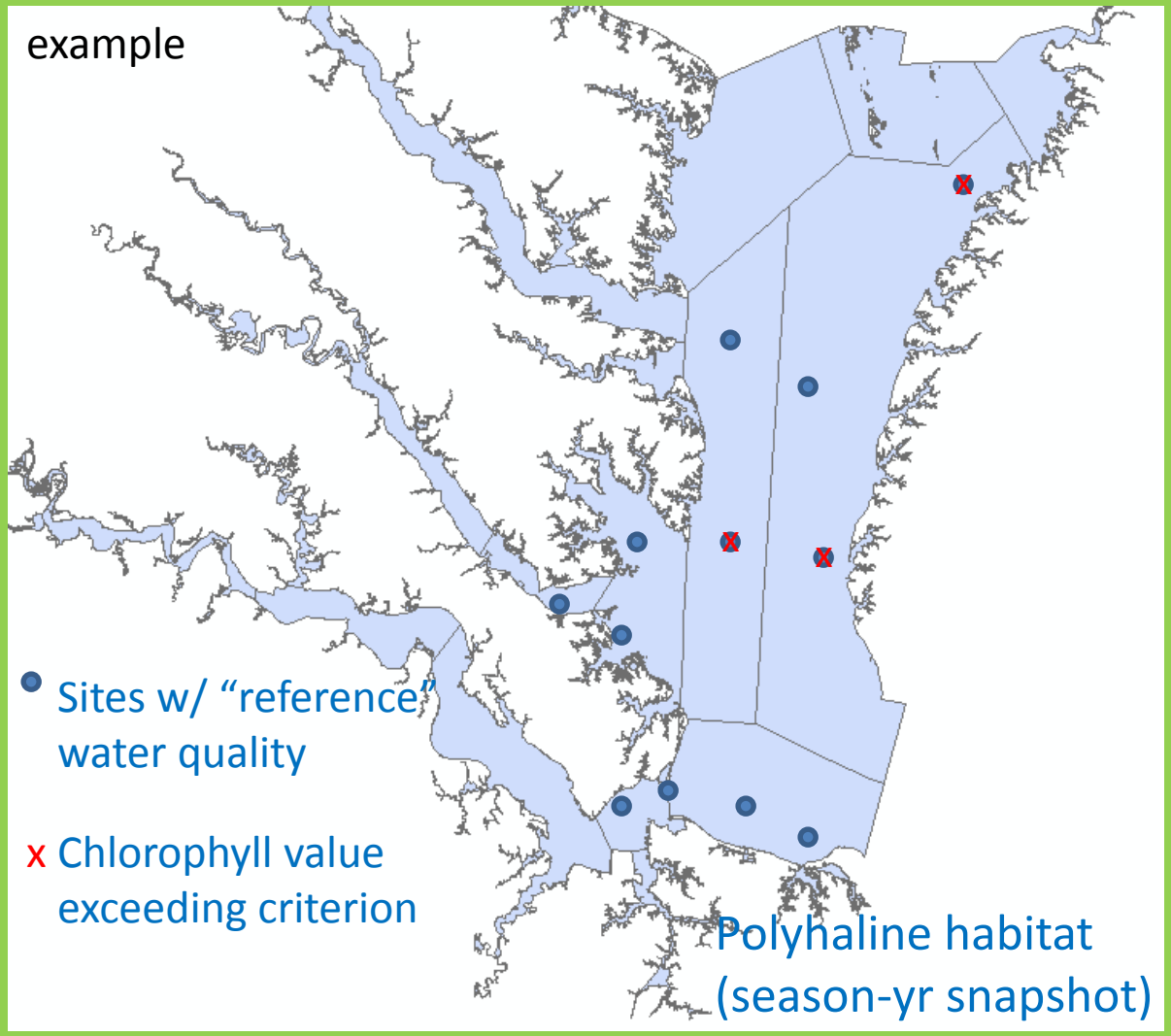
Table 2. Water quality categories. See Table 1 for classification thresholds.

Category name	Description
Better/Best	meets all thresholds for Secchi, DIN, & PO_4
Mixed Better Light (MBL)	meets Secchi threshold, fails DIN and/or PO_4 threshold
Mixed Poor Light (MPL)	fails Secchi threshold, meets DIN and/or PO_4 threshold
Poor/Worst	fails all thresholds for Secchi, DIN, & PO_4

Reference conditions

From Claire Buchanan's "Biological Reference Curves for Assessing the James River Chlorophyll a Criteria"

The reference samples were assumed to be adequately spatially representative of the habitat's area.



In this example, 25% of the fixed stations have chl values above the criterion. Thus, we assume 25% of the area of under "reference water quality" exceeded the criterion for this season-year.

Example curves….

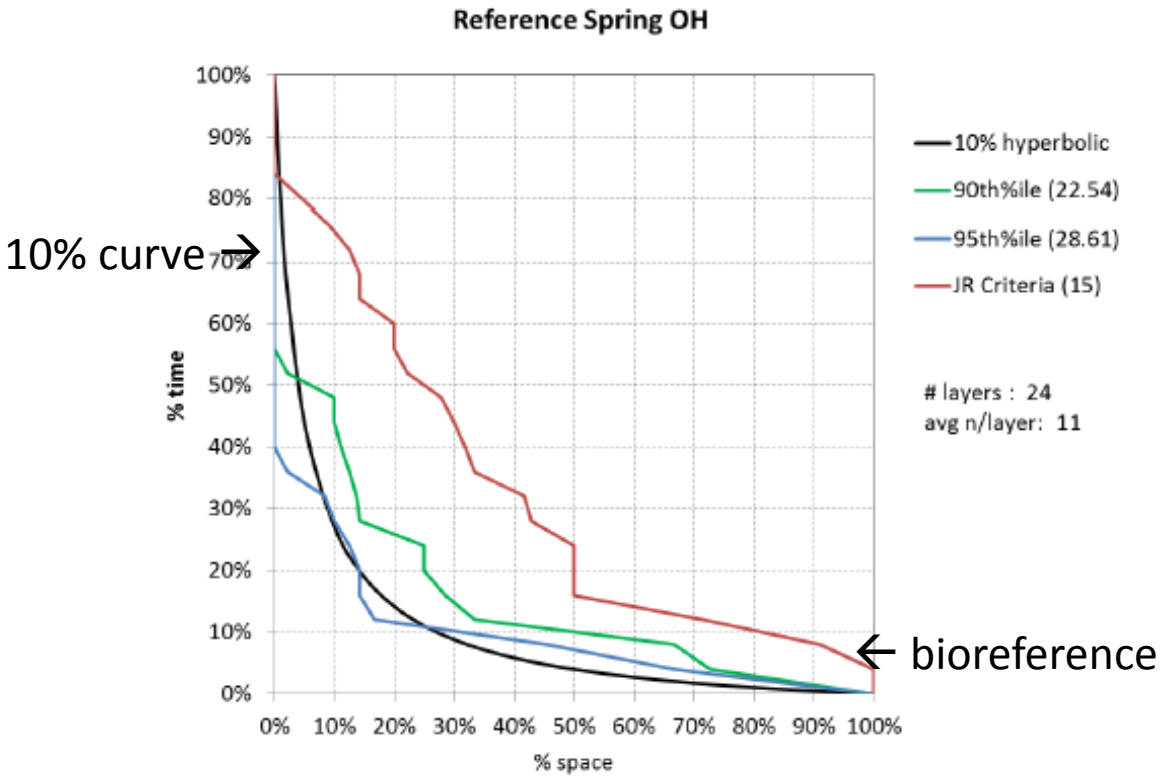


Figure 4b. Spring oligohaline CFD curves for chlorophyll *a* from reference water quality conditions.

Example curves….

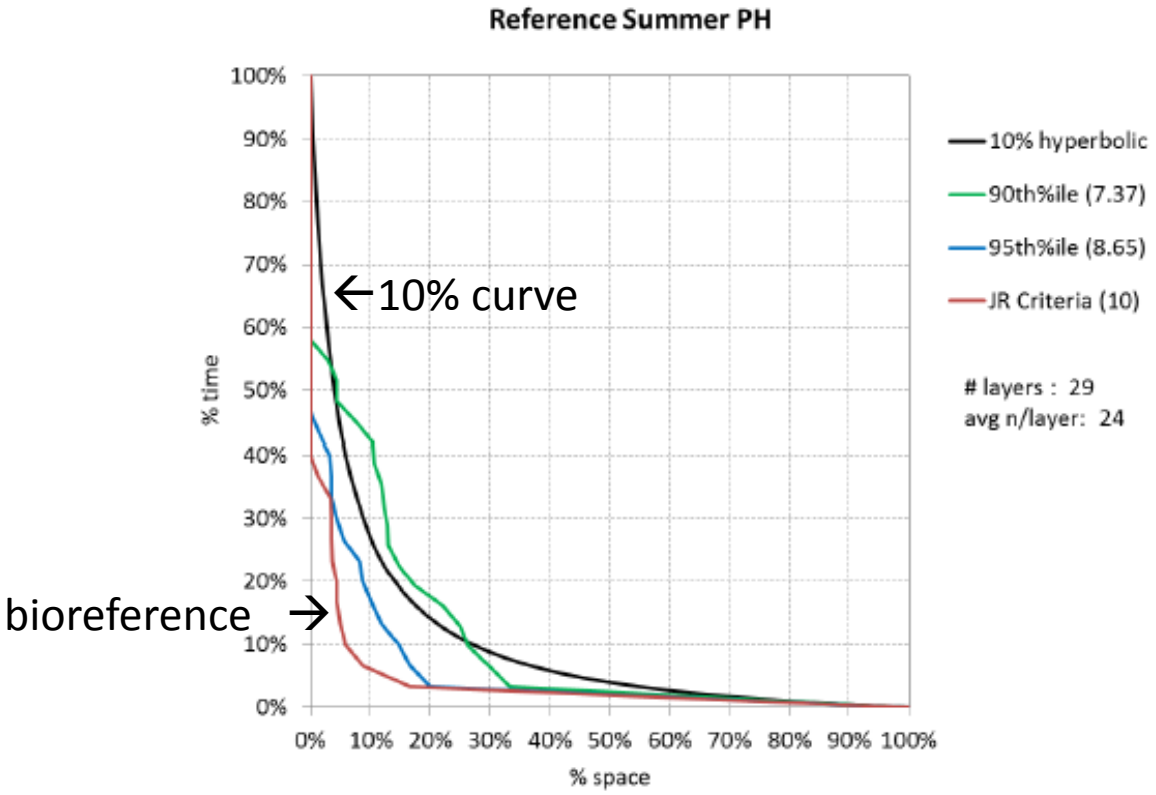
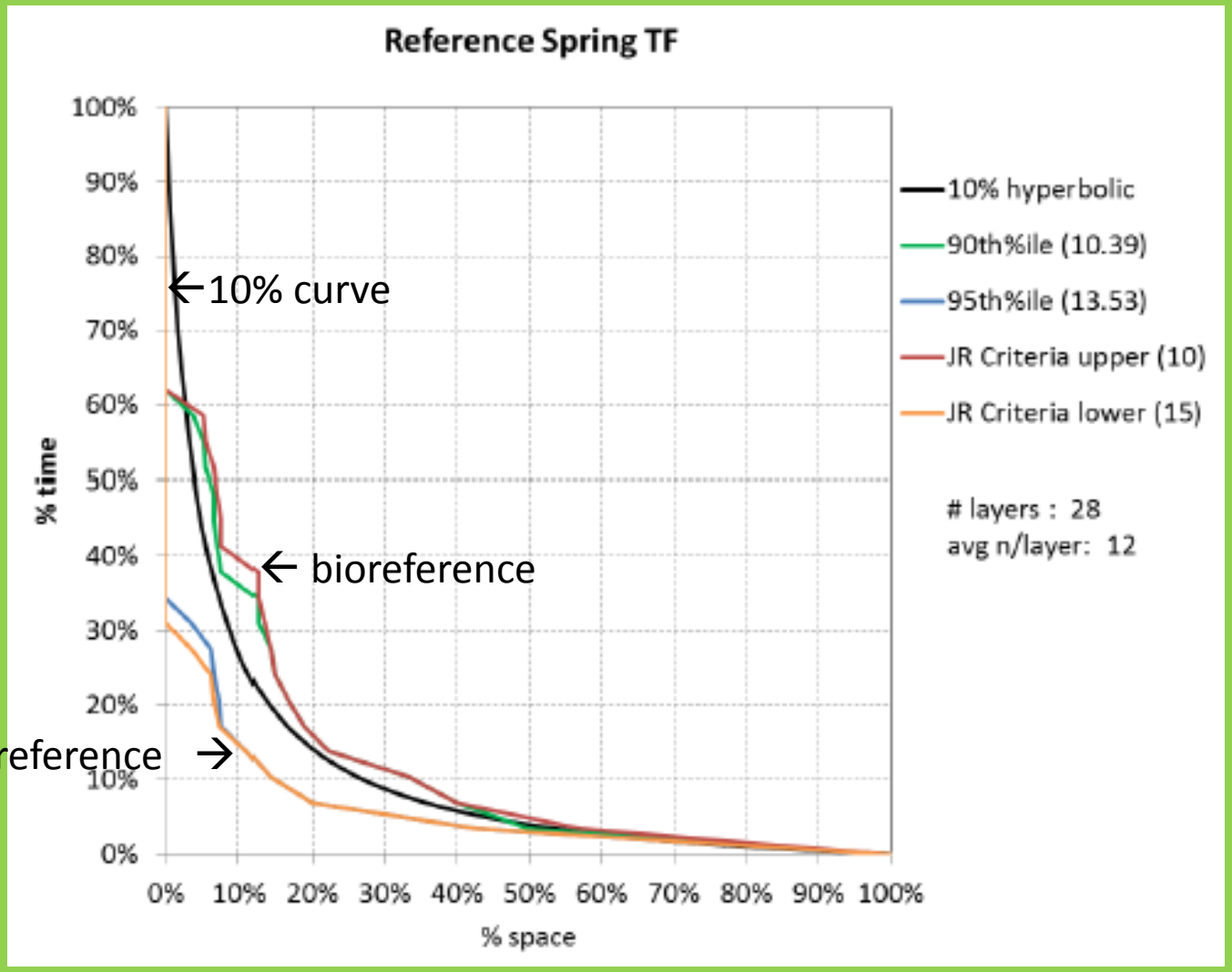


Figure 4h. Summer polyhaline CFD curves for chlorophyll *a* from reference water quality conditions.

Example curves….



Most of the bioreference curves that Claire developed do not conform to the 10% hyperbolic curve. Most of them allow more exceedence than what the 10% curve allows.

Caveat:

Claire's analysis is focused on instantaneous exceedences. The JR chlorophyll criteria are expressed as seasonal means. So we can't infer from her analysis what the "true" reference curve looks given the current criteria.

Still, it is a major assumption that a segment can only support the aquatic life use when it has an exceedence distribution similar to the 10% CFD, especially using such a short assessment period.

VADEQ has identified some issues with the current assessment protocol.

- High uncertainty when fixed station datasets are used.
- Questionable defensibility of the 10% reference curve.

For the above reasons, VADEQ believes alternative assessment protocols should be explored.

Let’s think outside the box!

Alternatives to Current JR Chlorophyll Assessment Procedure

Dataflow+fixed stations

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Dataflow+fixed stations

Surface samples

Depth-integrated samples

<-Select one

Can we increase accuracy by sampling differently?

Alternatives to Current JR Chlorophyll Assessment Procedure

Dataflow+fixed stations

Surface samples

Depth-integrated samples

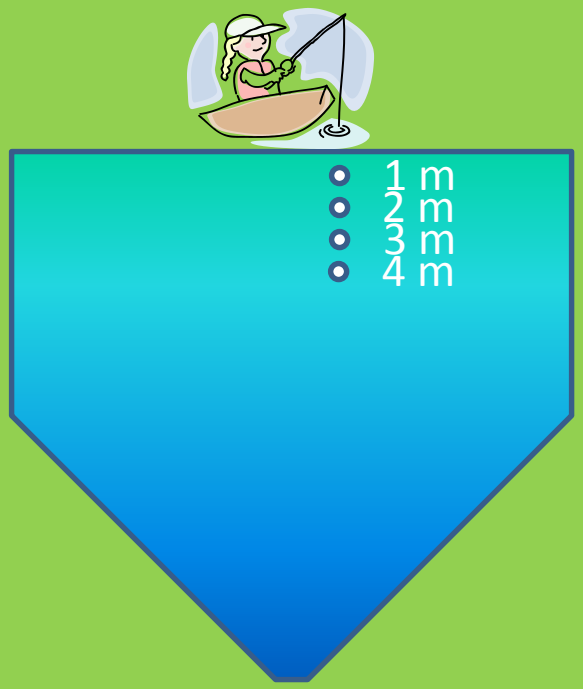
<-Select one

Can we increase accuracy by sampling differently?

Current procedure
(1 surface measurement)

Secchi Depth (2.0 m)
Photic zone (4.0 m)

Alternative procedure
(average of vertical profile)



Alternatives to Current JR Chlorophyll Assessment Procedure

Dataflow+fixed stations

Surface samples

Depth-integrated samples

<-Select one

Can we increase accuracy by changing the assessment period?

Select one

3 or 6-year assessment window

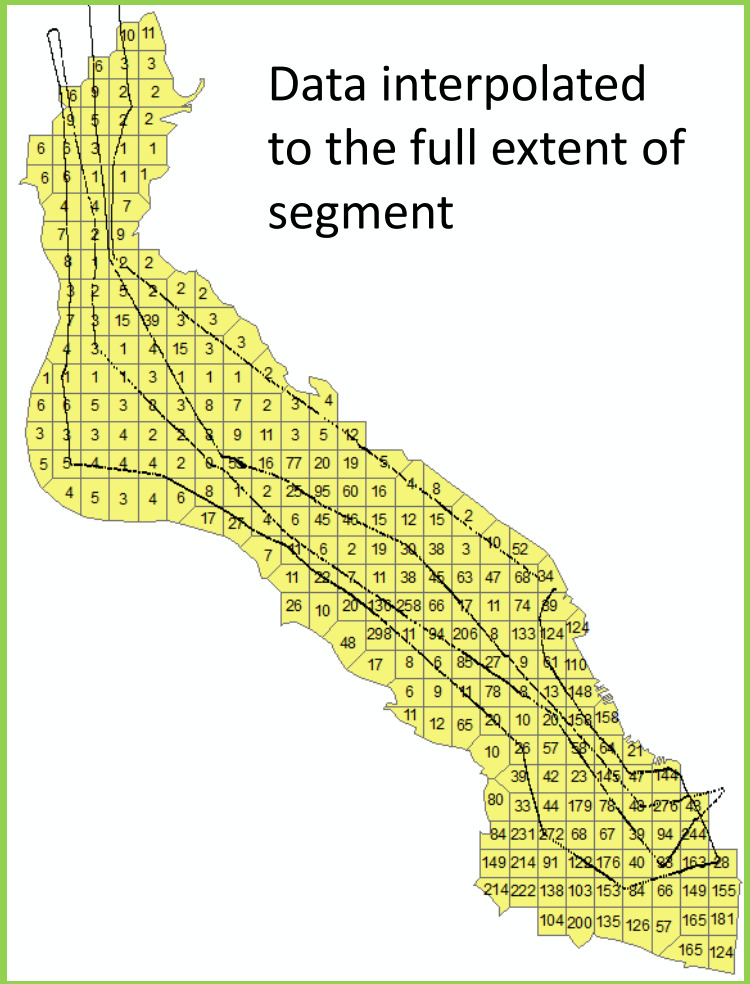
Can we increase accuracy by changing how we interpolate the data?

More conservative interpolation

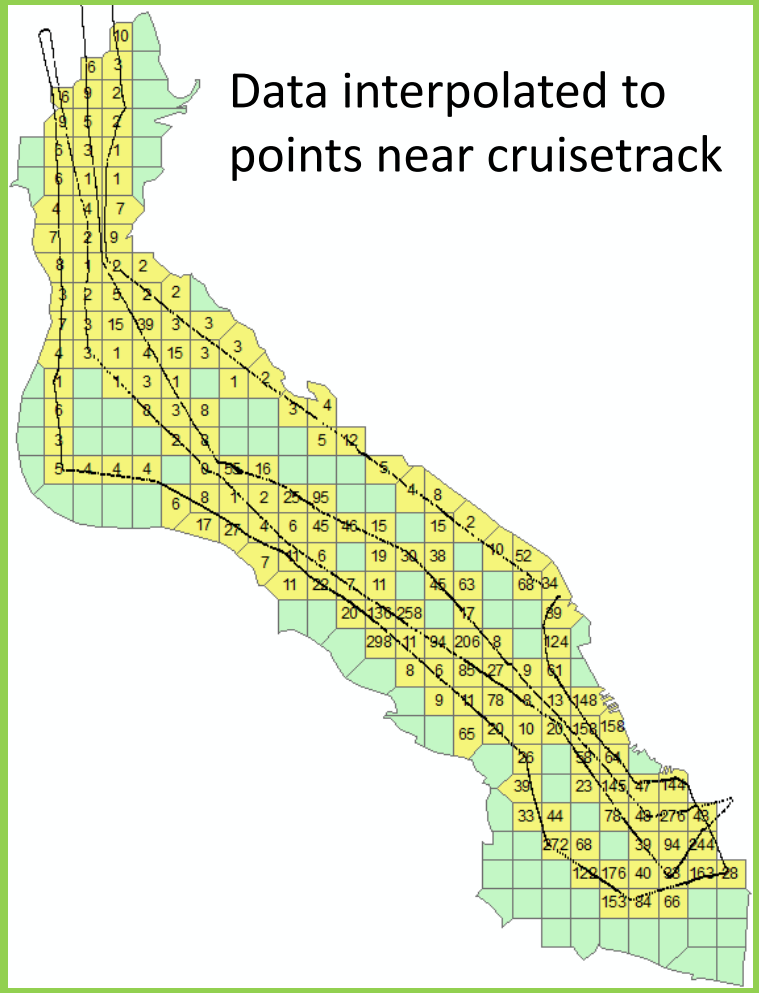
(compared to current practice)

For instance…

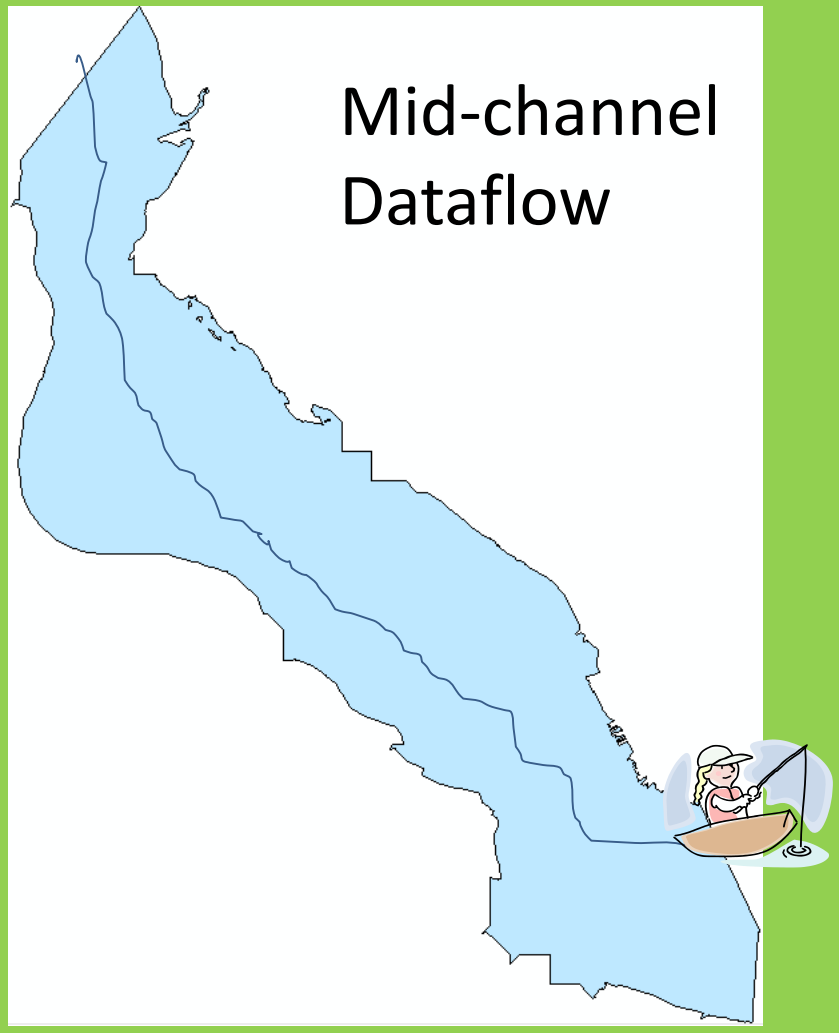
Instead of this…

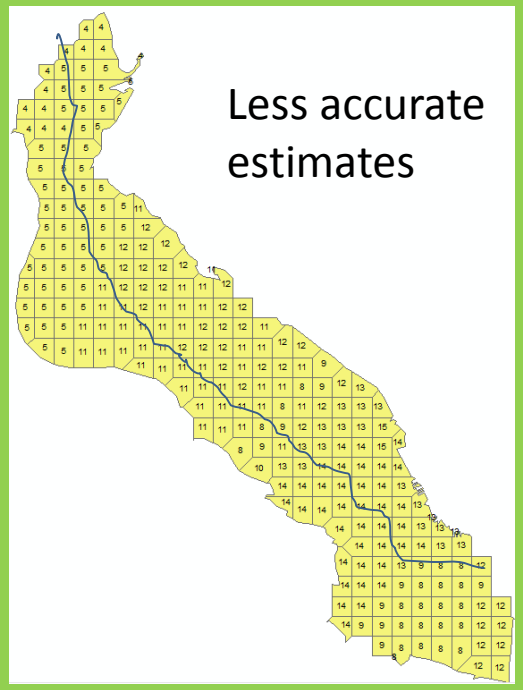


…we could do this

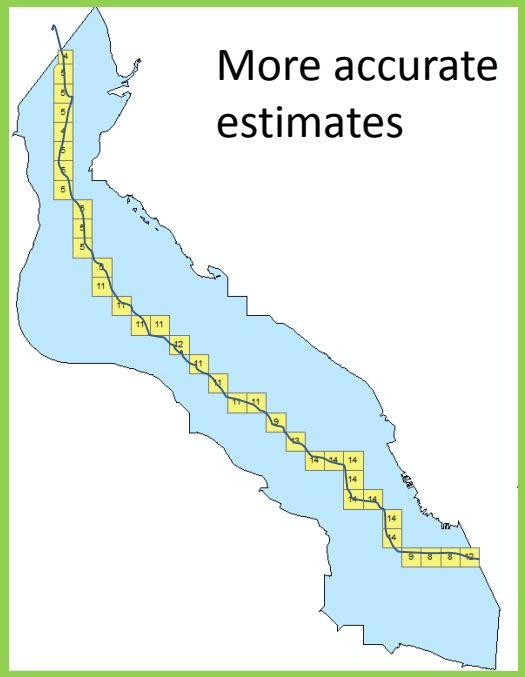


Mid-channel Dataflow



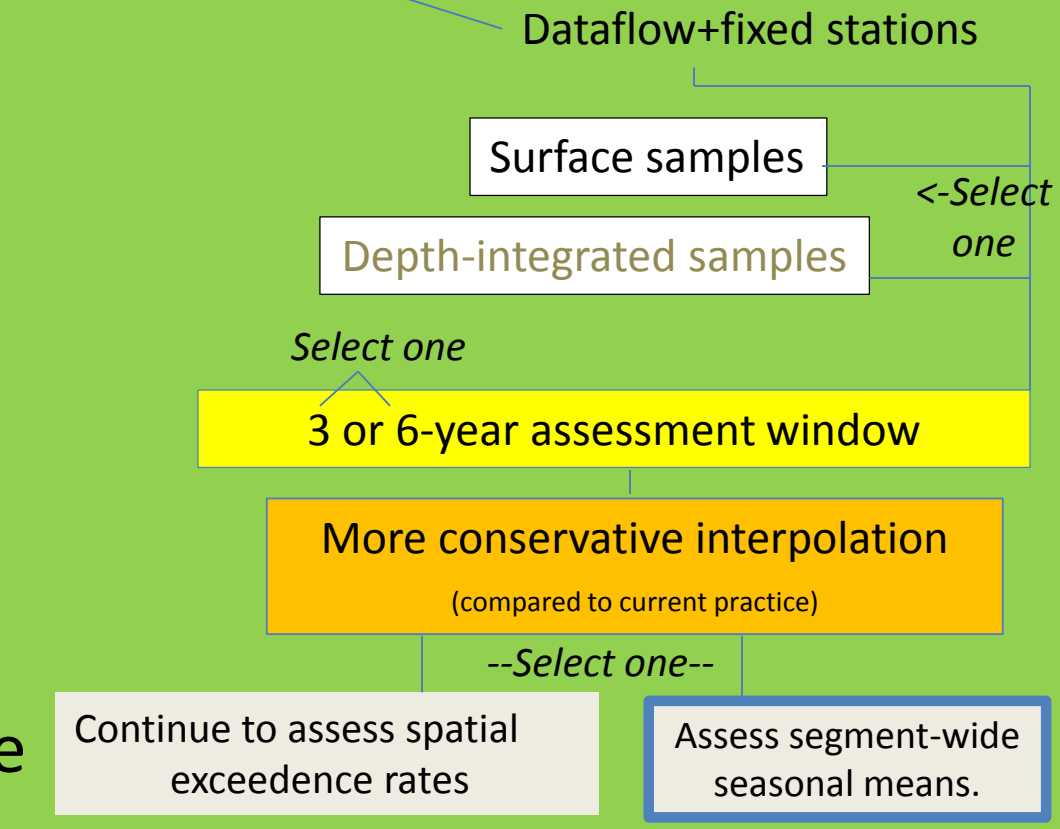


Less accurate estimates



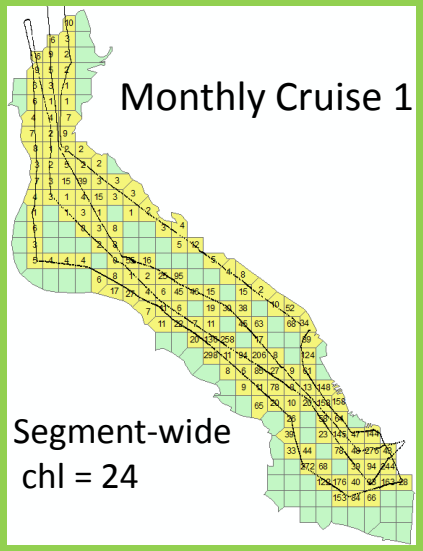
More accurate estimates

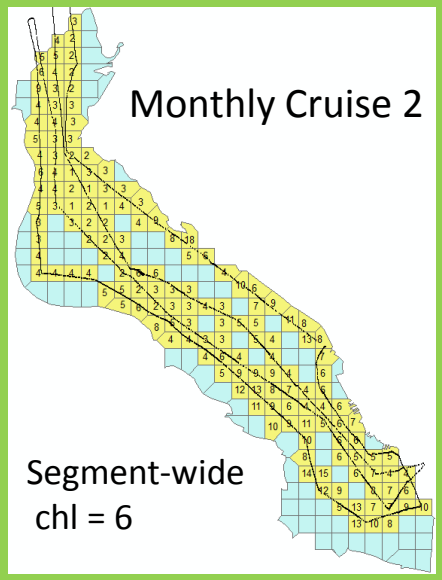
Alternatives to Current JR Chlorophyll Assessment Procedure

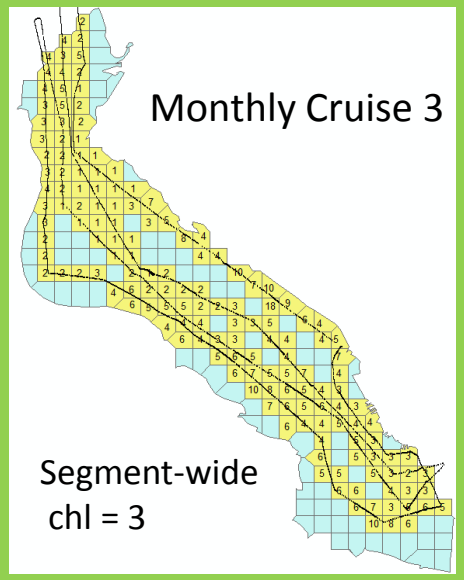


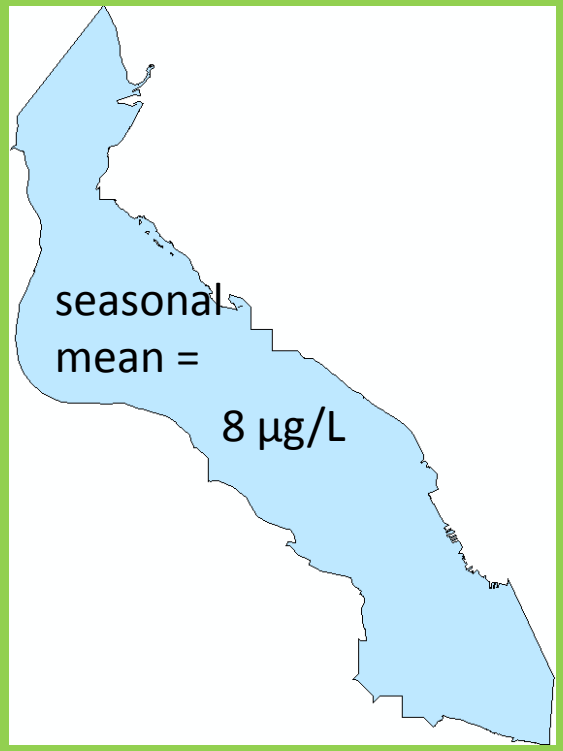
How do we can evaluate the data in a more defensible manner?

Option 1. Assess segment-wide seasonal means. One (if 3-year) or two (if 6-year) exceedences allowed.





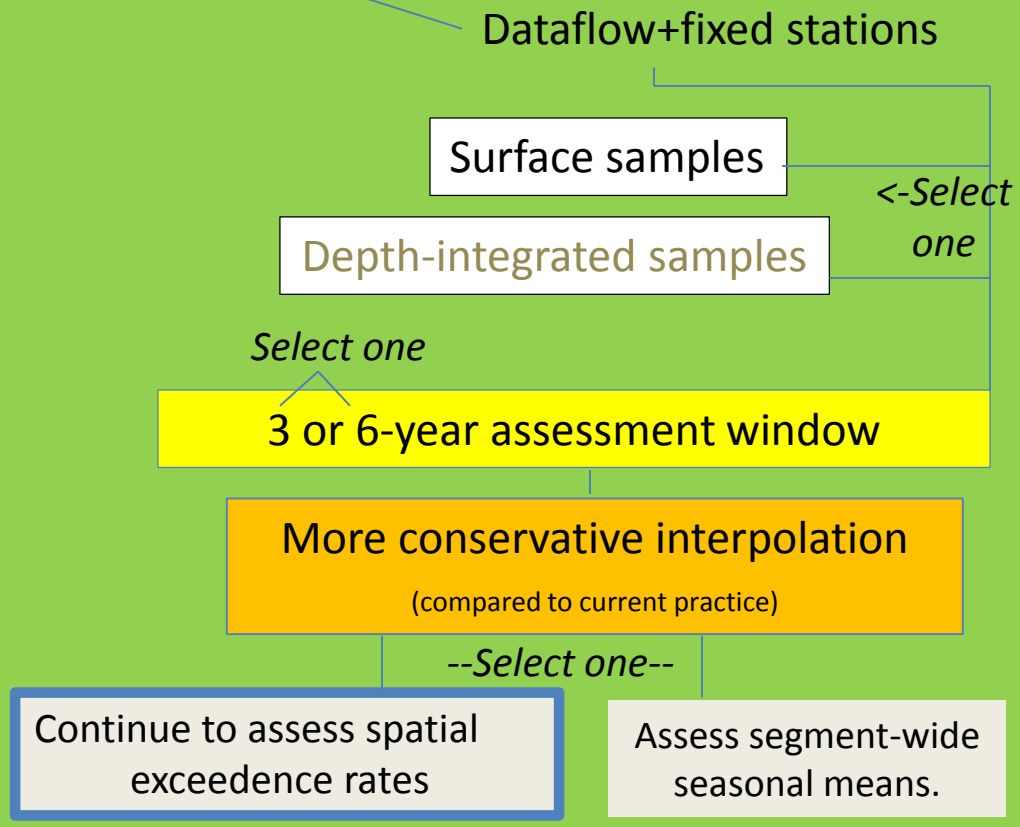




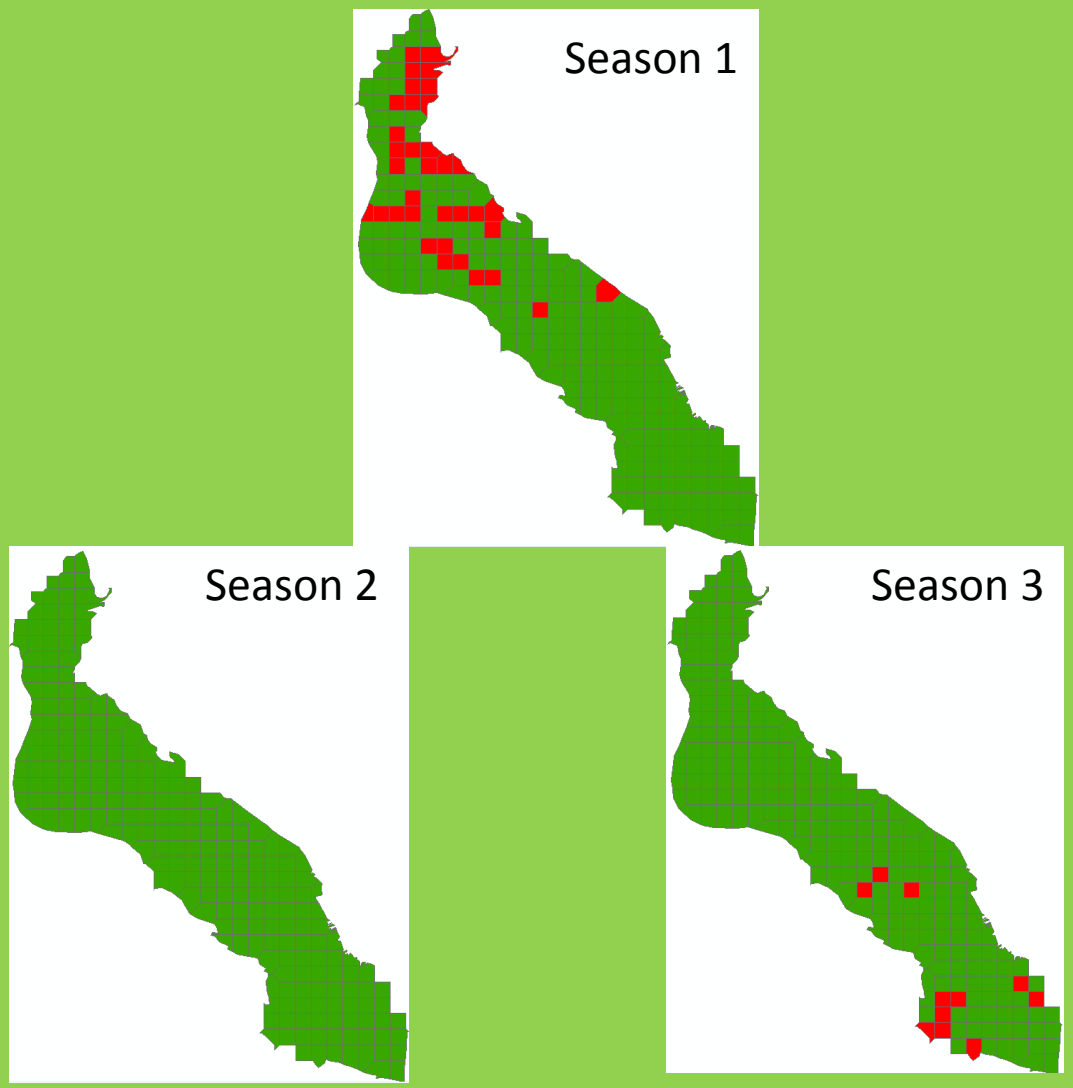
Example rule:
" Segment-wide seasonal means shall not exceed the criterion more than once in a 3-year period."

Alternative protocol

Alternatives to Current JR Chlorophyll Assessment Procedure

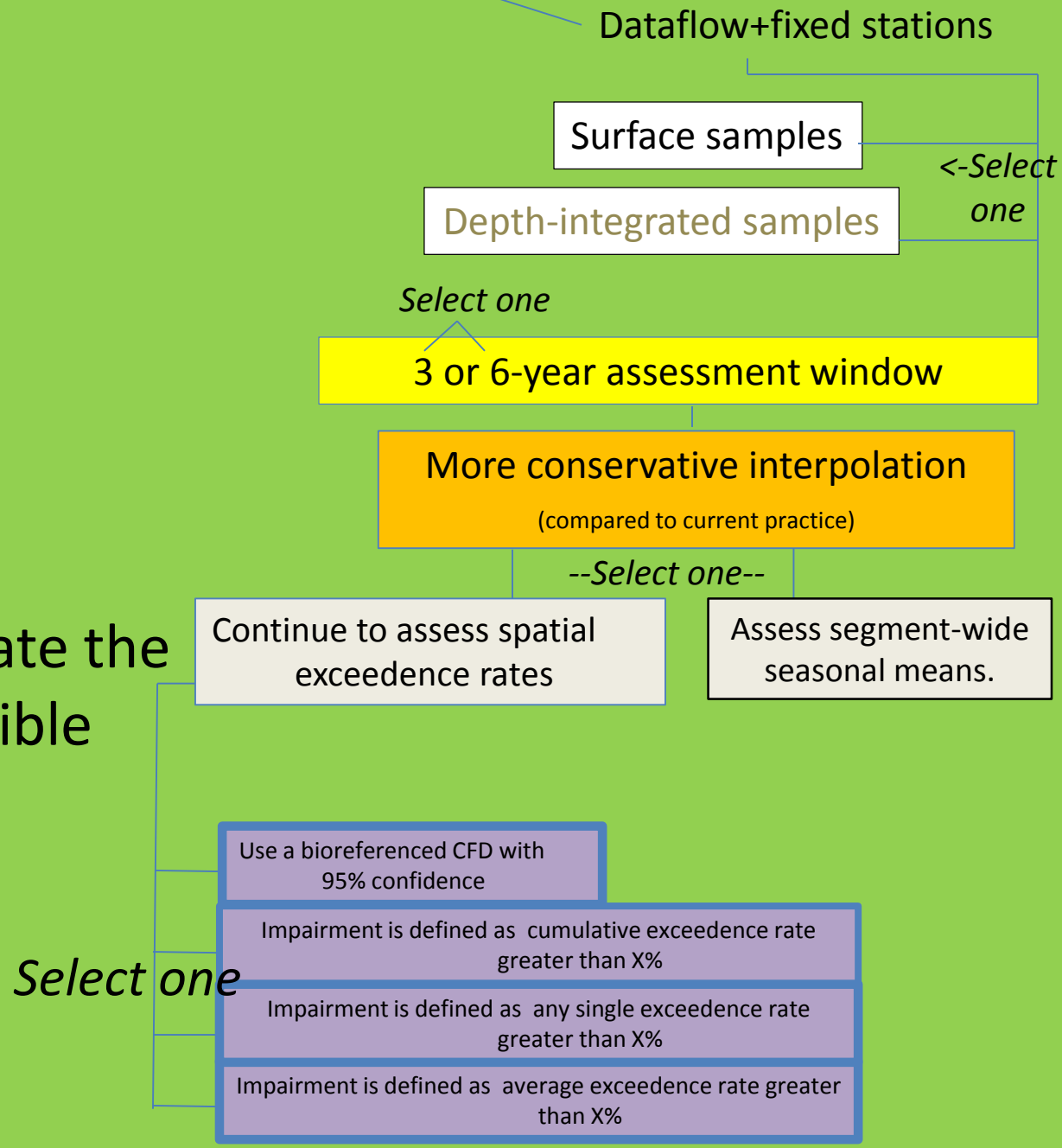


Option 2. Continue to assess spatial exceedence rates



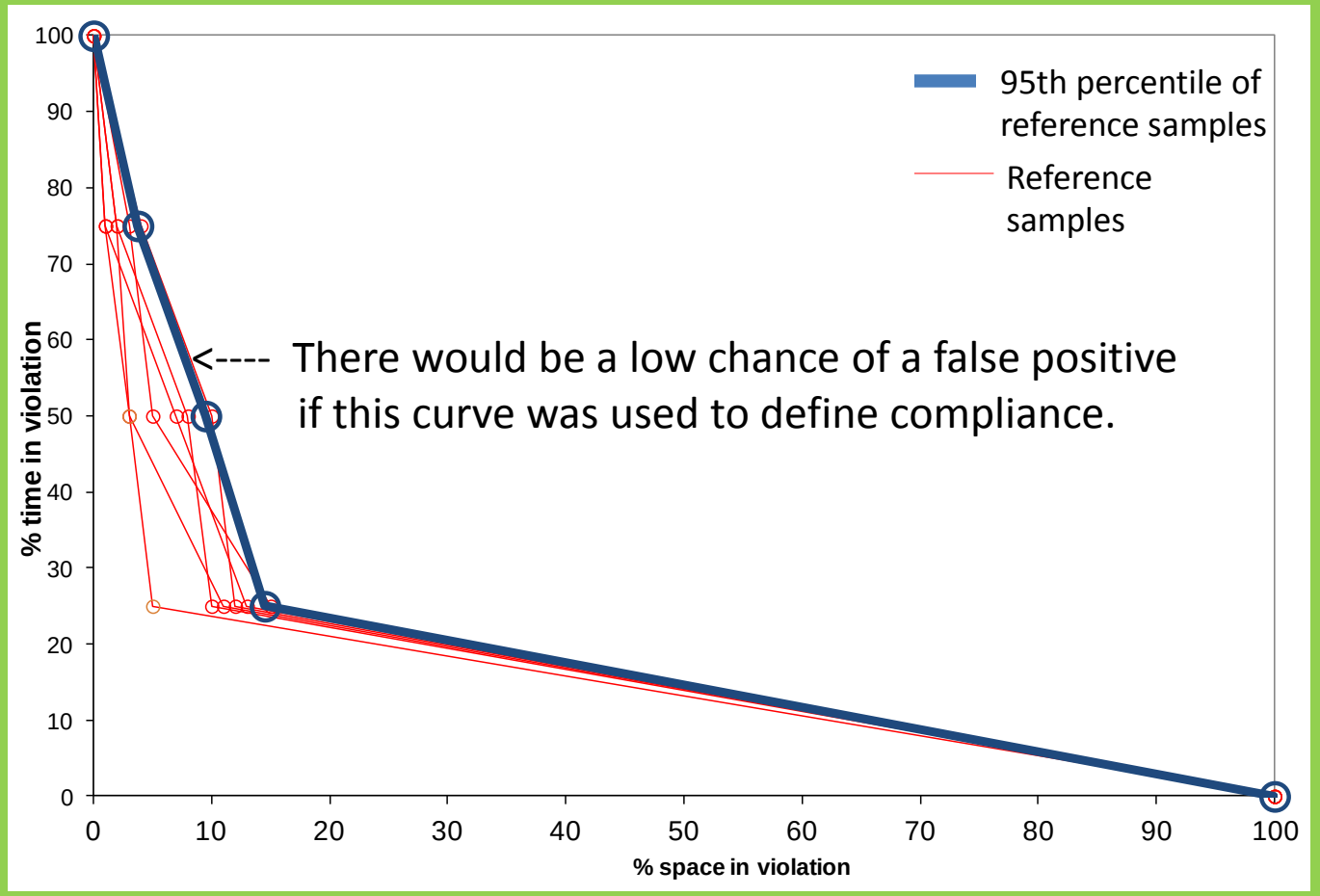
Current protocol

Alternatives to Current JR Chlorophyll Assessment Procedure



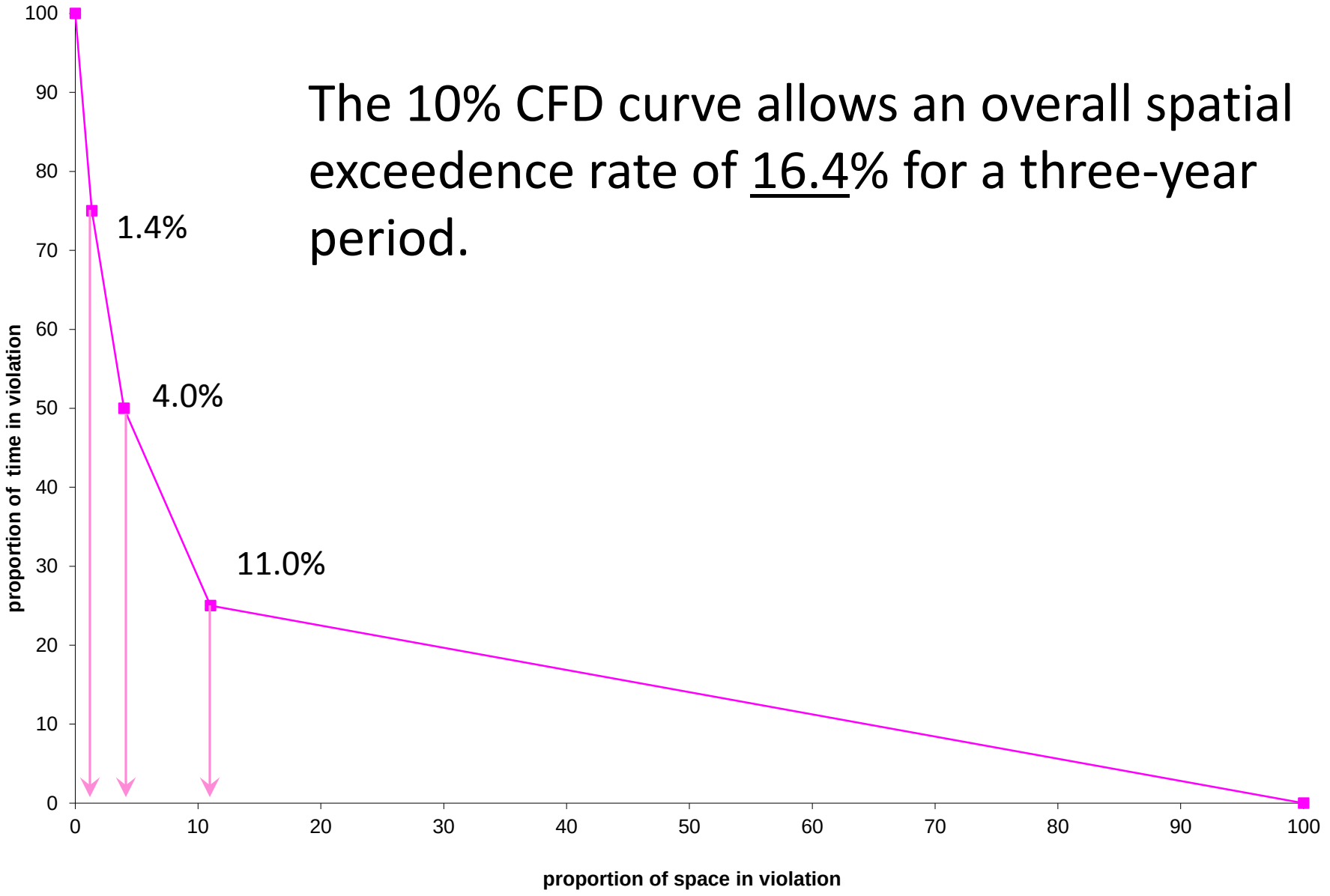
How do we can evaluate the data in a more defensible manner?

Option 1 : Use a bioreferenced CFD with 95% confidence



Option 2: Impairment is defined as cumulative exceedence rate greater than X%

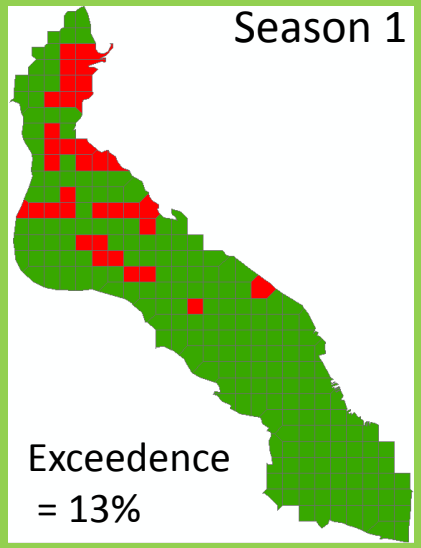
Example rule: "The sum of spatial exceedences over the assessment period shall be no greater than what the 10% CFD allows."

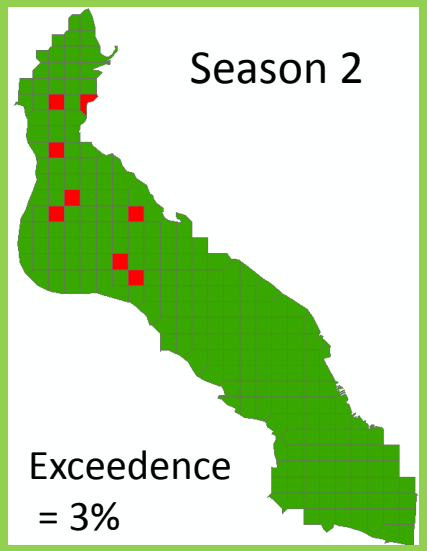

The 10% CFD curve allows an overall spatial exceedence rate of 16.4% for a three-year period.
1.4%
4.0%
11.0%
proportion of time in violation
proportion of space in violation
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100

Assessment period	Total Allowable Spatial Exceedence Rate via 10% CFD
3-year	16%
4-year	24%
5-year	32%
6-year	40%

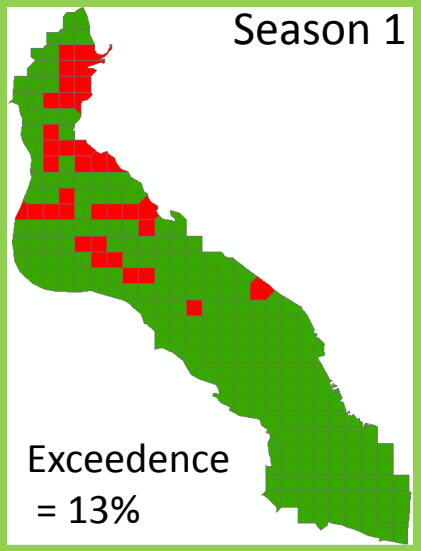
Option 2: Impairment is defined as cumulative exceedence rate greater than X%

Example rule: "The sum of spatial exceedences rates over the assessment period shall be no greater than what the 10% CFD allows."



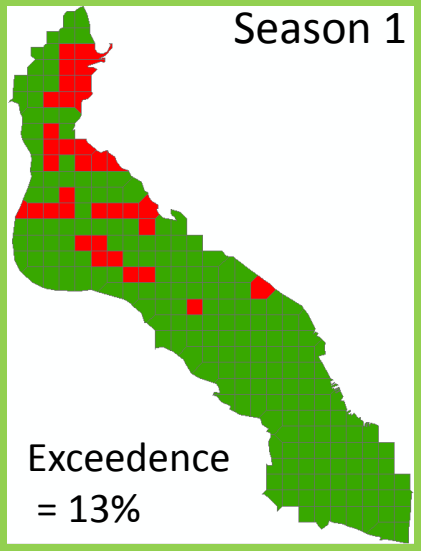


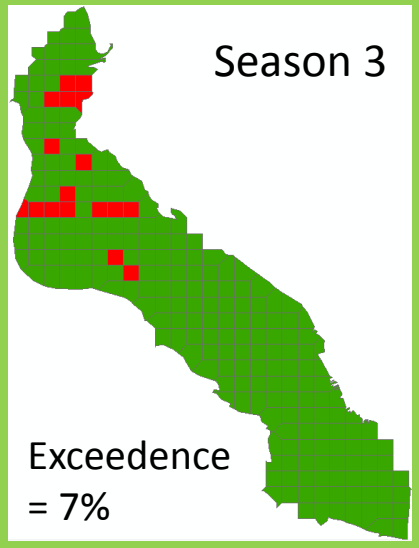
NON-IMPAIRED



IMPAIRED

Option 3: Impairment is defined as any single exceedence rate greater than X%



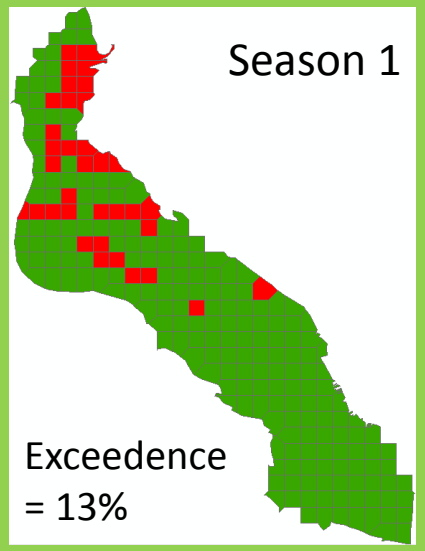


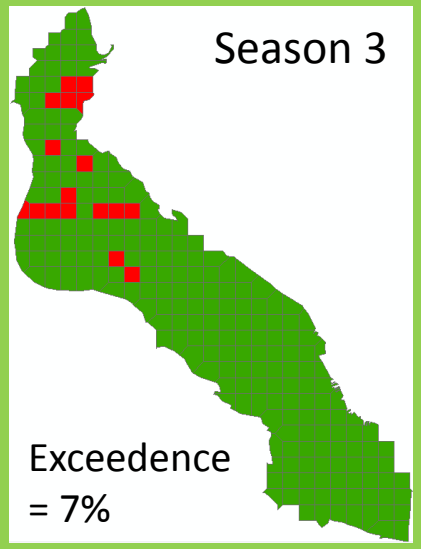
Impaired segment

Example rule: **"No more than 10% of seasonal means calculated in a segment shall exceed the criterion in a single season."**

Option 4: Impairment is defined as overall exceedence rate greater than X%

Example rule: "The average seasonal exceedence rate over the assessment period shall not exceed 10%."

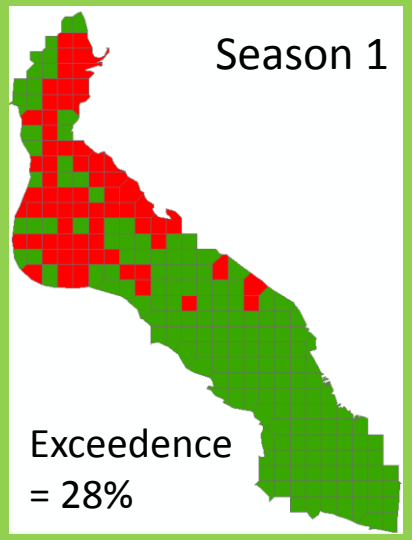




Average spatial exceedence =

8%

NON-IMPAIRED



Average spatial exceedence =

11%

IMPAIRED

Alternatives to Current JR Chlorophyll Assessment Procedure

Dataflow+fixed stations

Surface samples

Depth-integrated samples

<-Select one

Select one

3 or 6-year assessment window

More conservative interpolation

(compared to current practice)

Continue to assess spatial exceedence rates

<-Select one->

Assess segment-wide seasonal means. One (if 3-year) or two (if 6-year) exceedences allowed.

Select one

- Use a bioreferenced CFD with 95% confidence
- Impairment is defined as any single exceedence rate greater than X%
- Impairment is defined as cumulative exceedence rate greater than X%
- Impairment is defined as average exceedence rate greater than X%

Alternatives to Current JR Chlorophyll Assessment Procedure

Dataflow+fixed stations

Cons

How do we do this with Dataflow and what is the value added?

Surface samples

Depth-integrated samples

<-Select one

3 or 6-year assessment window

More conservative interpolation

(compared to current practice)

Continue to assess spatial exceedence rates

<-Select one->

Assess segment-wide seasonal means. One (if 3-year) or two (if 6-year) exceedences allowed.

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More conservative interpolation

(compared to current practice)

Continue to assess spatial exceedence rates

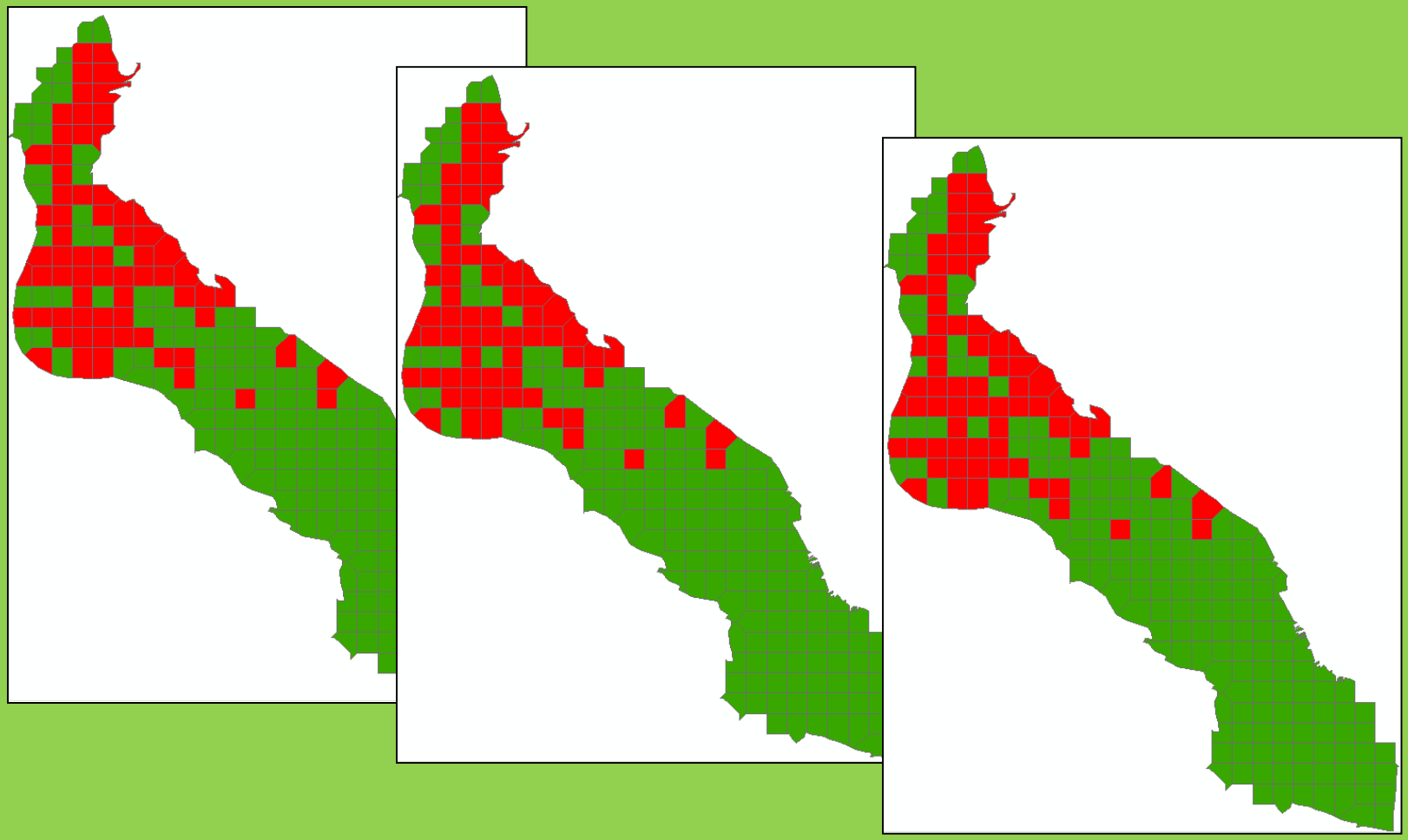
<-Select one->

Assess segment-wide seasonal means. One (if 3-year) or two (if 6-year) exceedences allowed.

Hot spots can be masked.

Select one

- Use a bioreferenced CFD with 95% confidence
- Impairment is defined as any single exceedence rate greater than X%
- Impairment is defined as cumulative exceedence rate greater than X%
- Impairment is defined as average exceedence rate greater than X%



If a segment displays this kind of exceedence pattern over the assessment period, do we want to say it is fully supporting?

Alternatives to Current JR Chlorophyll Assessment Procedure

Dataflow+fixed stations

Surface samples

<-Select one

Depth-integrated samples

Cons

How do we do this with Dataflow and what is the value added?

Select one

3 or 6-year assessment window

More conservative interpolation

(compared to current practice)

Continue to assess spatial exceedence rates

<-Select one->

Assess segment-wide seasonal means. One (if 3-year) or two (if 6-year) exceedences allowed.

Hot spots can be masked.

- What would be the reference population?
- Bioreference CFD would have to be derived from fixed station data, not Dataflow.

What X% should we choose and what would be the rationale?

Use a bioreferenced CFD with 95% confidence

Impairment is defined as any single exceedence rate greater than X%

Impairment is defined as cumulative exceedence rate greater than X%

Impairment is defined as average exceedence rate greater than X%

Alternatives to Current JR Chlorophyll Assessment Procedure

Fixed Station-Only

- Surface samples
- Depth-integrated samples

Select one

- 3-year or 6-year assessment window

No interpolation

Select one

- Assess station seasonal means. Impairment is defined as an average spatial exceedence rate greater than X%
- Assess station seasonal means. Impairment is defined as any single spatial exceedence rate greater than X%
- Assess segment-wide seasonal means (aggregated station data). One (if 3-year) or two (if 6-year) exceedences allowed.

Can we increase accuracy by sampling differently?

Can we increase accuracy by changing the assessment period?

How do we can evaluate the data in a more defensible manner?

Option 1: Assess station seasonal means.
Impairment is defined as an average spatial exceedence rate greater than X%

Six-year assessment window

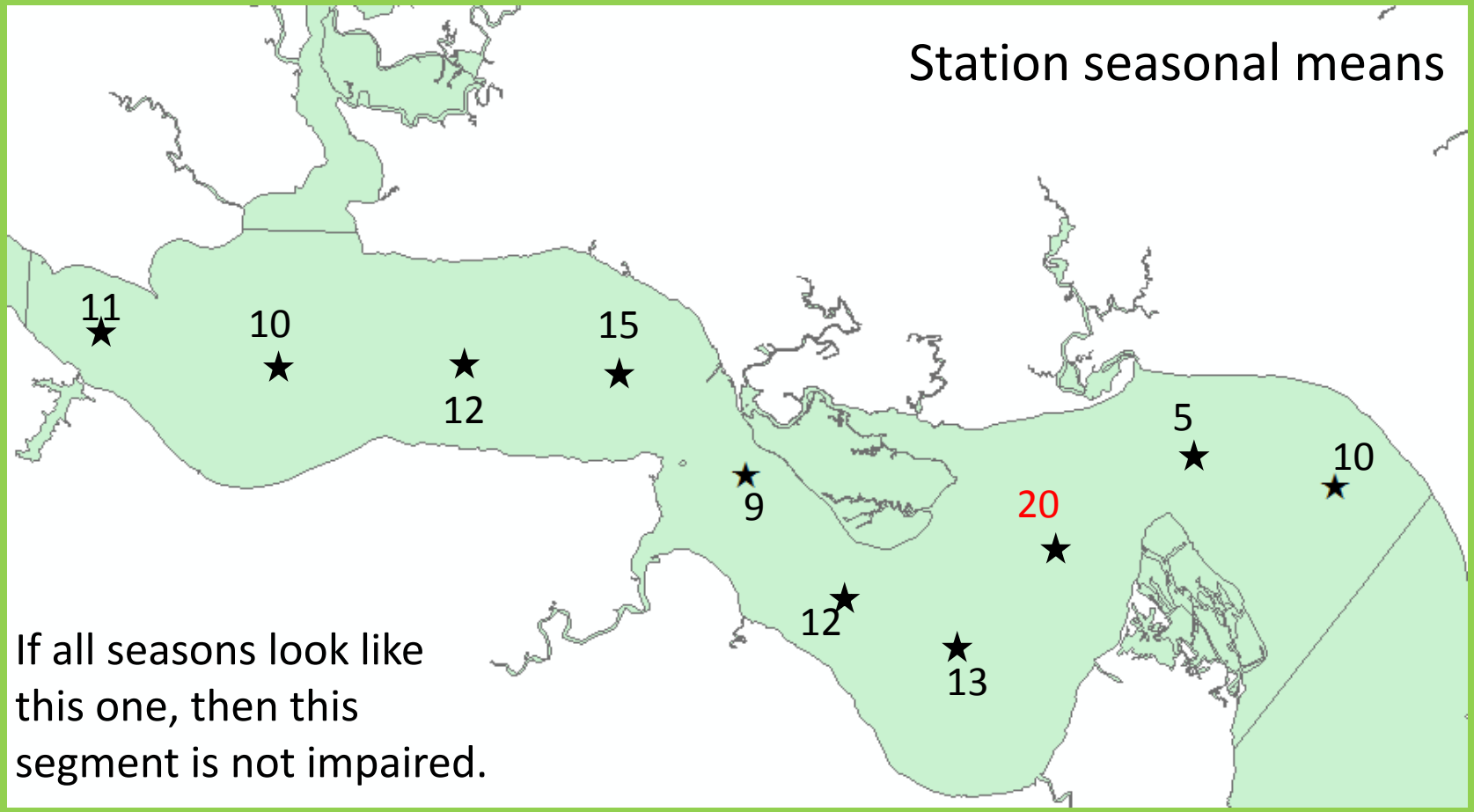
	chlorophyll seasonal means (ug/l)				
Spring-Year	**Station A**	**Station B**	**Station C**	**Station D**	**Exceedence Rate%**
2017	10	15	20	10	25%
2018	11	8	6	6	0%
2019	50	11	10	8	25%
2020	6	7	10	16	0%
2021	8	5	9	4	0%
2022	10	11	16	18	0%
				average	8%

Example rule:

"The average seasonal exceedence rate over the assessment period shall not exceed 10%."

Non-Impaired

Option 2: Assess station seasonal means.
Impairment is defined as any single spatial exceedence rate greater than X%.



Example rule: "No more than 10% of seasonal means calculated in a segment shall exceed the criterion in a single season."

Option 3: Assess **segment** seasonal means (aggregated station data).
One (if 3-year) or two (if 6-year) exceedences allowed.

Season 1	Station A	Station B	Station C	segment-wide composite
15-Jul	18	3	16	16
15-Aug	4	10	7	7
15-Sep	17	11	10	11
			seasonal mean ->	11
Season 2	**Station A**	**Station B**	**Station C**	**segment-wide composite**
15-Jul	7	3	7	7
15-Aug	6	20	10	10
15-Sep	5	11	10	10
			seasonal mean ->	9
Season 3	**Station A**	**Station B**	**Station C**	**segment-wide composite**
15-Jul	20	10	16	16
15-Aug	4	11	6	6
15-Sep	5	22	14	14
			seasonal mean ->	11

IMPAIRED

Example rule:

"Segment-wide seasonal means shall not exceed the criterion more than once in a 3-year period."

Alternatives to Current JR Chlorophyll Assessment Procedure

Fixed Station-Only

Select one

- Surface samples
- Depth-integrated samples

Select one

- 3-year or 6-year assessment window
- No interpolation

Select one

- Assess station seasonal means. Impairment is defined as an average spatial exceedence rate greater than X%
- Assess station seasonal means. Impairment is defined as any single spatial exceedence rate greater than X%.
- Assess segment-wide seasonal means (aggregated station data). One (if 3-year) or two (if 6-year) exceedences allowed.

Cons

- What is the value added?
- High uncertainty with a small window.
- Many additional fixed stations are needed.
- What threshold would we use?
- Many additional stations are needed.
- What threshold would we use?
- Some additional fixed stations are needed.
- Hot spots can be masked.

Alternatives to Current JR Chlorophyll Assessment Procedure

Fixed Station-Only

Dataflow+fixed stations

Consistent procedures

Surface samples

Depth-integrated samples

Select one

3-year or 6-year assessment window

No interpolation

Select one

Assess station seasonal means. Impairment is defined as an average spatial exceedence rate greater than X%. Slide 54

Assess station seasonal means. Impairment is defined as any single spatial exceedence rate greater than X%. Slide 55

Assess segment-wide seasonal means (aggregated station data). One (if 3-year) or two (if 6-year) exceedences allowed. Slide 56

Surface samples

Depth-integrated samples

Select one

3-year or 6-year assessment window

More conservative interpolation

(compared to current practice)

Continue to assess spatial exceedence rates

<-Select one->

Assess segment-wide seasonal means. One (if 3-year) or two (if 6-year) exceedences allowed. Slide 37

Select one

Use a bioreferenced CFD with 95% confidence

Impairment is defined as cumulative exceedence rate greater than X%

Impairment is defined as any single exceedence rate greater than X% Slide 46

Impairment is defined as average exceedence rate greater than X% Slide 47

Alternatives to Current JR Chlorophyll Assessment Procedure

Most commonly used option for implementing chlorophyll criteria nationally

Fixed Station-Only

Surface samples

Depth-integrated samples

Select one

3-year or 6-year assessment window

No interpolation

Select one

Assess station seasonal means. Impairment is defined as an average spatial exceedence rate greater than X%.

Assess station seasonal means. Impairment is defined as any single spatial exceedence rate greater than X%.

Assess segment-wide seasonal means (aggregated station data). One (if 3-year) or two (if 6-year) exceedences allowed.

Dataflow+fixed stations

Surface samples

Depth-integrated samples

Select one

3-year or 6-year assessment window

More conservative interpolation

(compared to current practice)

Continue to assess spatial exceedence rates

<-Select one->

Assess segment-wide seasonal means. One (if 3-year) or two (if 6-year) exceedences allowed.

Select one

Use a bioreferenced CFD with 95% confidence

Impairment is defined as any single exceedence rate greater than X%

Impairment is defined as cumulative exceedence rate greater than X%

Impairment is defined as average exceedence rate greater than X%

Some options for defining impairment based on the spatial aspect of James River chlorophyll

Impairment Rule	assumption level	error level for current fixed stations (n = 2 or 3)	error level with additional fixed stations (n = 5 - 10)
assessment CFD crosses bioreference CFD	very high	very high	high to very high
cumulative spatial exceedence rate exceeds X%	high	very high	high to very high
single season spatial exceedence rate exceeds X%	high	very high	high
average spatial exceedence rate exceeds X%	medium	very high	low to medium
average spatial exceedence rate exceeds X%	low	low to high	very low to medium

It is important that the new-and-improved protocol…

- produces more accurate assessment results compared to what we are currently generating.
- has fewer untested/untestable assumptions than the current framework.
- does not require a monitoring design that is especially burdensome and is compatible with EPA's "all existing and readily available water quality data" mandate.
- can be used to process model output for TMDL/ attainability analyses.

Questions and Comments?

Extra slide

monthly monitoring runs

50		

10		18

20		10

monthly interpolations

50	50	50
50	50	50
50	50	50

10	14	18
10	14	18
10	14	18

20	17	10
20	17	10
20	17	10

seasonal interpolation

22	23	21
22	23	21
22	23	21

100% spatial exceedence rate

versus

	Station A	**Station B**
Month 1	50	
Month 2	10	18
Month 3	20	10
seasonal mean	22	13
spatial exceedence rate%	50%	