WIP2 Non-Attaining Segments:
monitored water quality conditions and simulated responses to load reductions

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With thanks to Rebecca Murphy and Renee Karrh (wq trends), Qian Zhang (attainment trends), and Mike Mallonnee (data)

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WIP2 Non-Attaining Segments

Background:

- At N and P load reductions established in the CBP "WIP2" allocation scenario, several segment-designated use combinations fail to attain applicable DO standards for the 1993-1995 assessment period.

Questions:

- What is the current state of water quality conditions in these segments?
- How has their water quality changed over time?
- What are the WQSTM-simulated patterns of response to load reductions in these segments?

Purposes:

- To illustrate the process that we're using to answer these questions
- To show examples of the insights that are developing as we move through this process

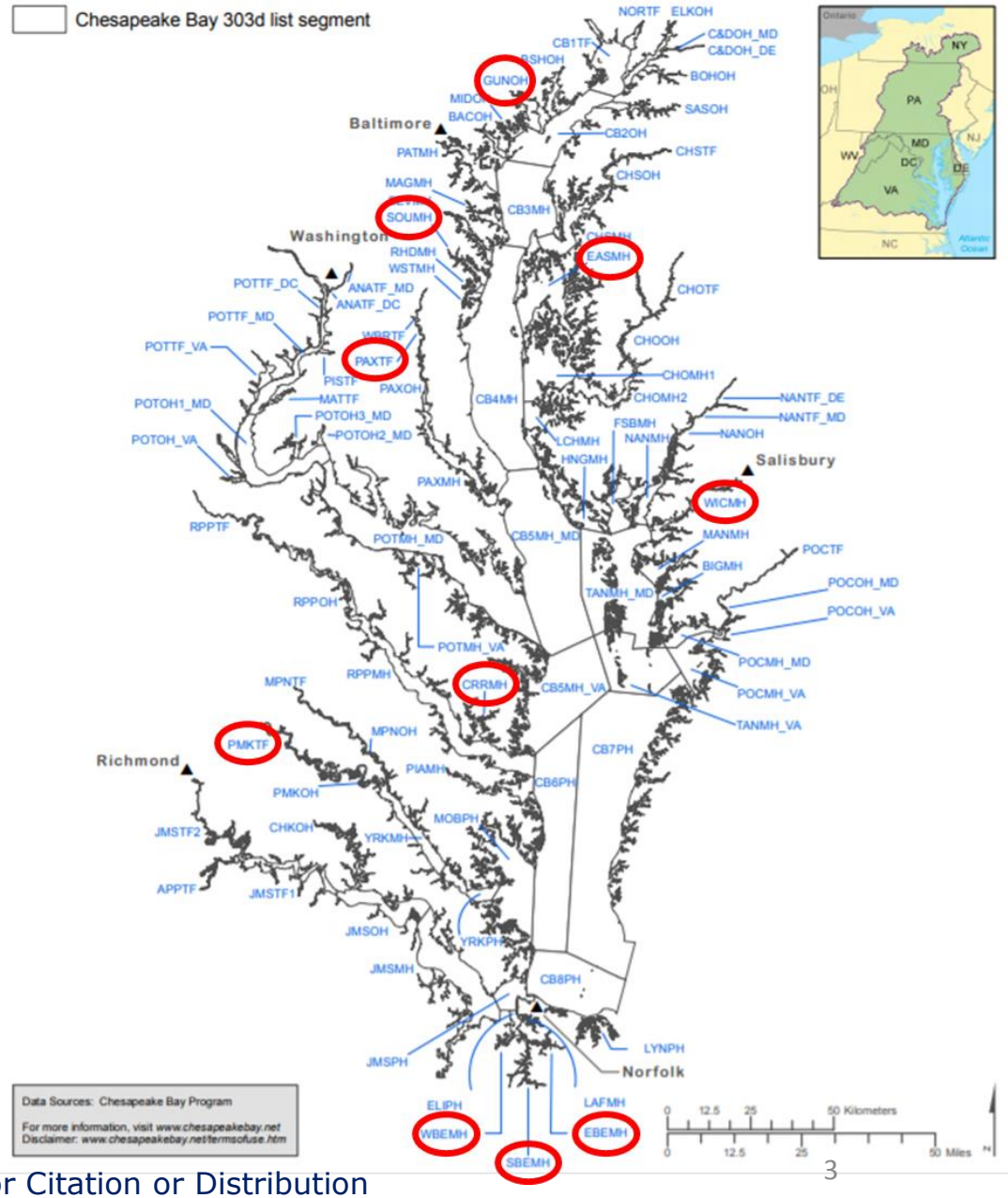
Caveats:

- Modeling and monitoring information on non-attaining segments is being provided to support decision-making by the Chesapeake Bay watershed jurisdictions and EPA.
- No inferences are made regarding expected attainment of these segments under TMDL.

WIP2 Non-Attaining Segments

Non-attaining Segments

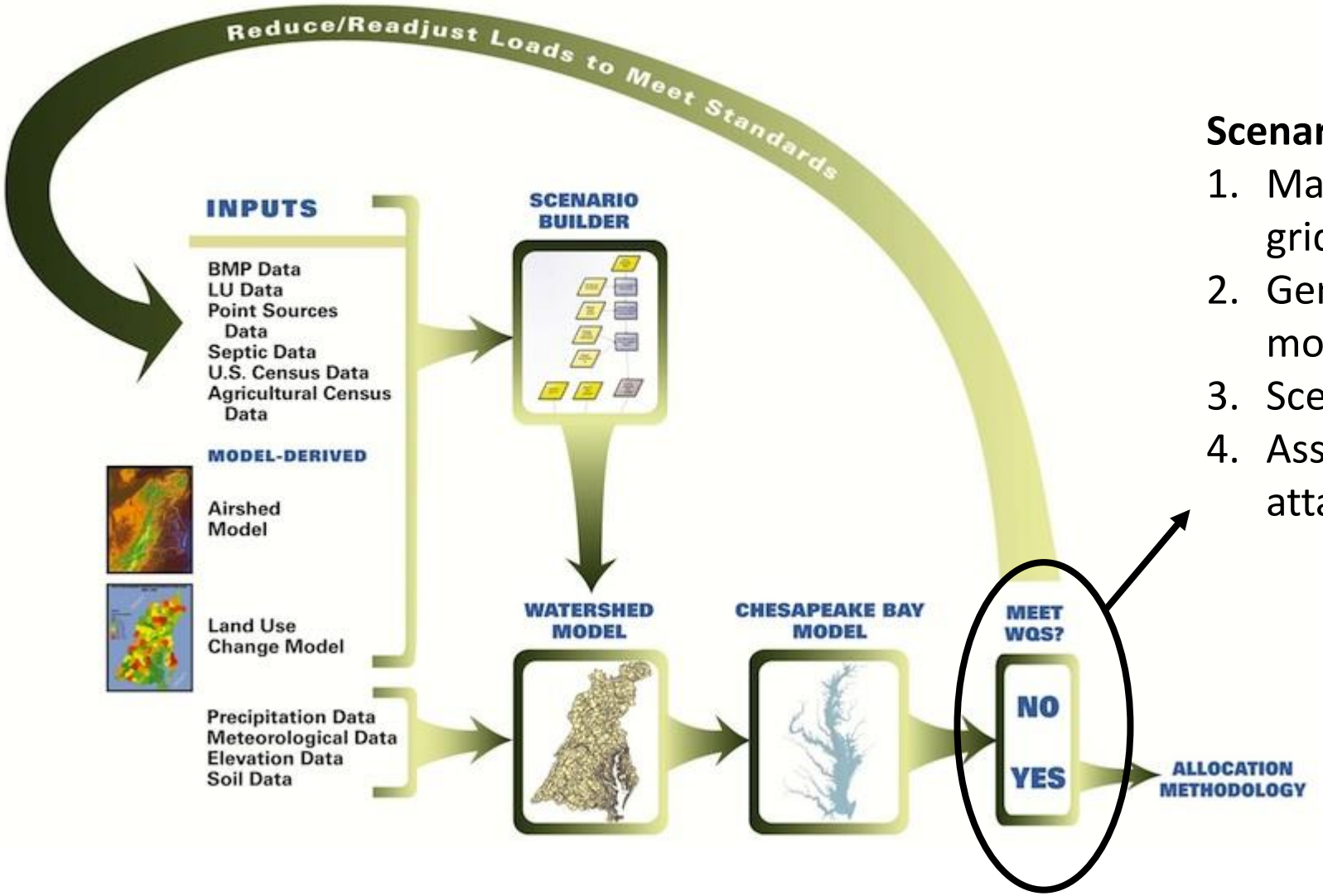
Designated Use	CBSeg	1985Progress 347TN 30.4TP	2013Progress 253TN 15.9TP	WIP2 195TN 13.7TP	E3 133TN 8.6TP	All_Forest 40TN 3.9TP
Open Water	GUNOH	5%	5%	5%	0%	0%
	PAXTF	9%	3%	8%	0%	0%
	CRRMH	25%	16%	5%	2%	0%
	PMKTF	9%	9%	9%	5%	0%
	WBEMH	8%	8%	8%	3%	0%
	SBEMH	48%	34%	26%	12%	3%
	EBEMH	23%	18%	8%	0%	0%
	WICMH	11%	11%	5%	5%	1%
Deep Water	SOUMH	20%	3%	3%	0%	0%
Deep Channel	EASMH	21%	13%	6%	0%	0%



Characterization of WIP2 Non-Attaining Segments

- Historical record of observed dissolved oxygen (DO) and chlorophyll-*a* (chla) concentrations
- Historical record of dissolved oxygen criteria attainment
- CBP Watershed Model (WSM) estimated load reductions to non-attaining segments
- CBP Water Quality Sediment Transport Model (WQSTM) simulated response to estimated load reductions in non-attaining segments
- Combination of 1993-1995 historical observations and WQSTM results driving non-attainment

Scenario Attainment Assessment Methods



Scenario assessment process:

1. Match monitoring stations to WQSTM grid cells
2. Generate linear regressions representing modeled response to load reductions
3. Scenario-modify the monitoring data
4. Assess the monitoring data for criteria attainment

Source: 2010 Chesapeake Bay TMDL report

Scenario-Modification of Dissolved Oxygen Data for TMDL Assessment

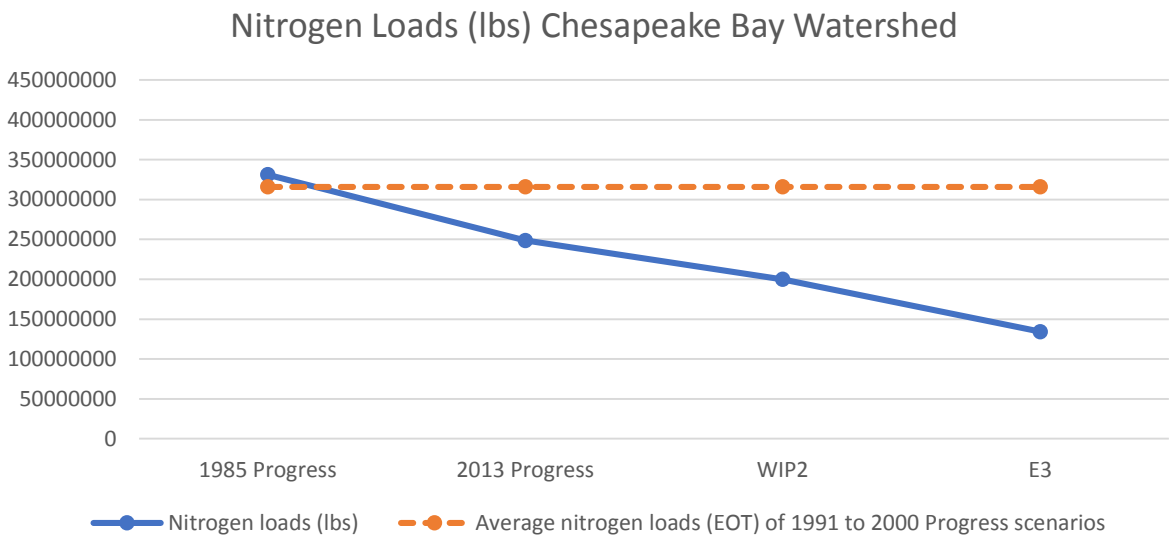
1. Watershed Model provides a load reduction scenario to the estuarine model (WQSTM).

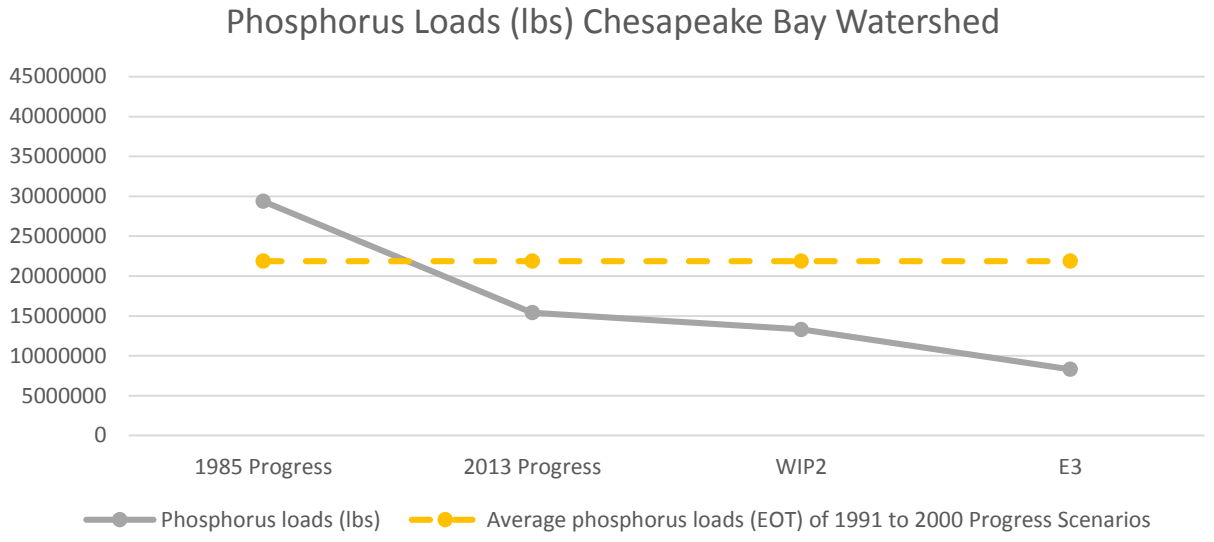
2. The WQSTM provides an expectation of improvement in DO concentrations for a given load reduction scenario.

3. This WQSTM “expected degree of response” is applied to actual DO monitoring data for the 1993-1995 critical assessment period in order to generate a modified dataset.

4. These “scenario-modified” DO concentrations are assessed for attainment of water quality standards.

1) WSM Load Reductions to WQSTM





1985-2013: N loads declined by **83M lbs (25%)**

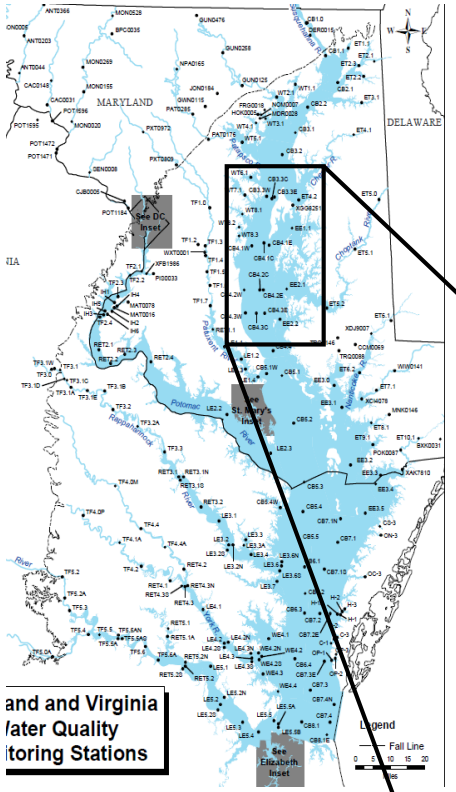
2013 – WIP2: N loads declined by **49M lbs (20%)**

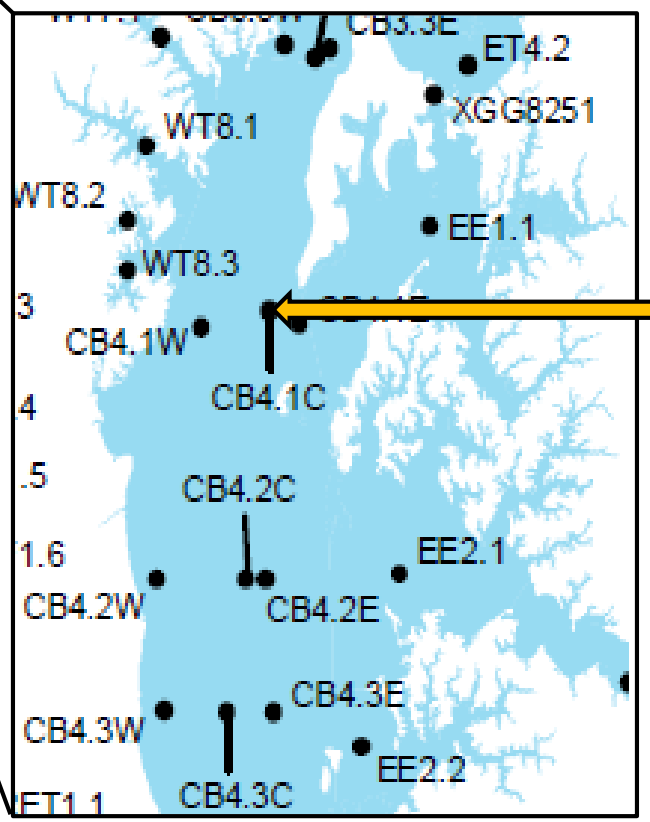
1985-2013: P loads declined by **14M lbs (48%)**

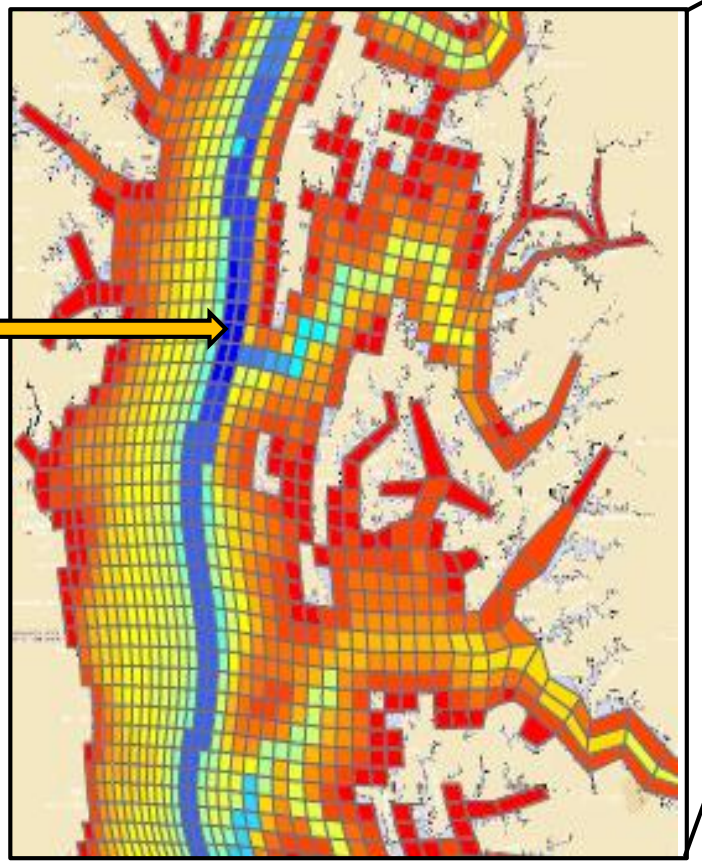
2013 – WIP2: P loads declined by **2M lbs (14%)**

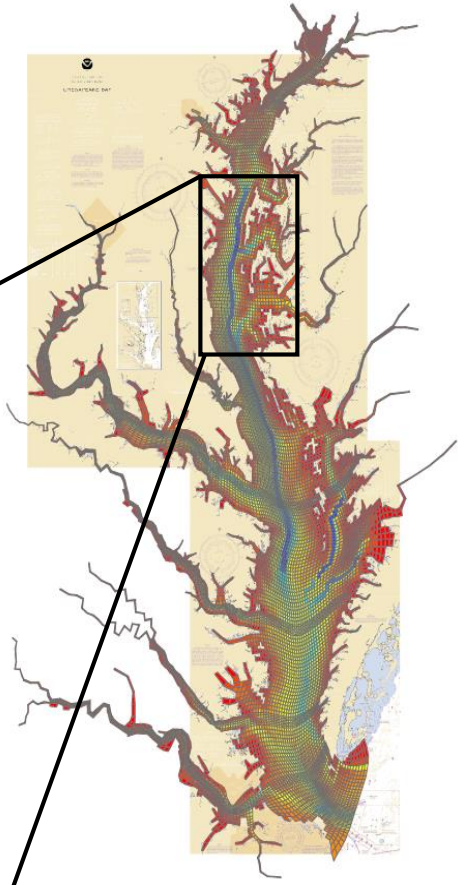
2) WQSTM response

Match monitoring stations to WQSTM grid cells



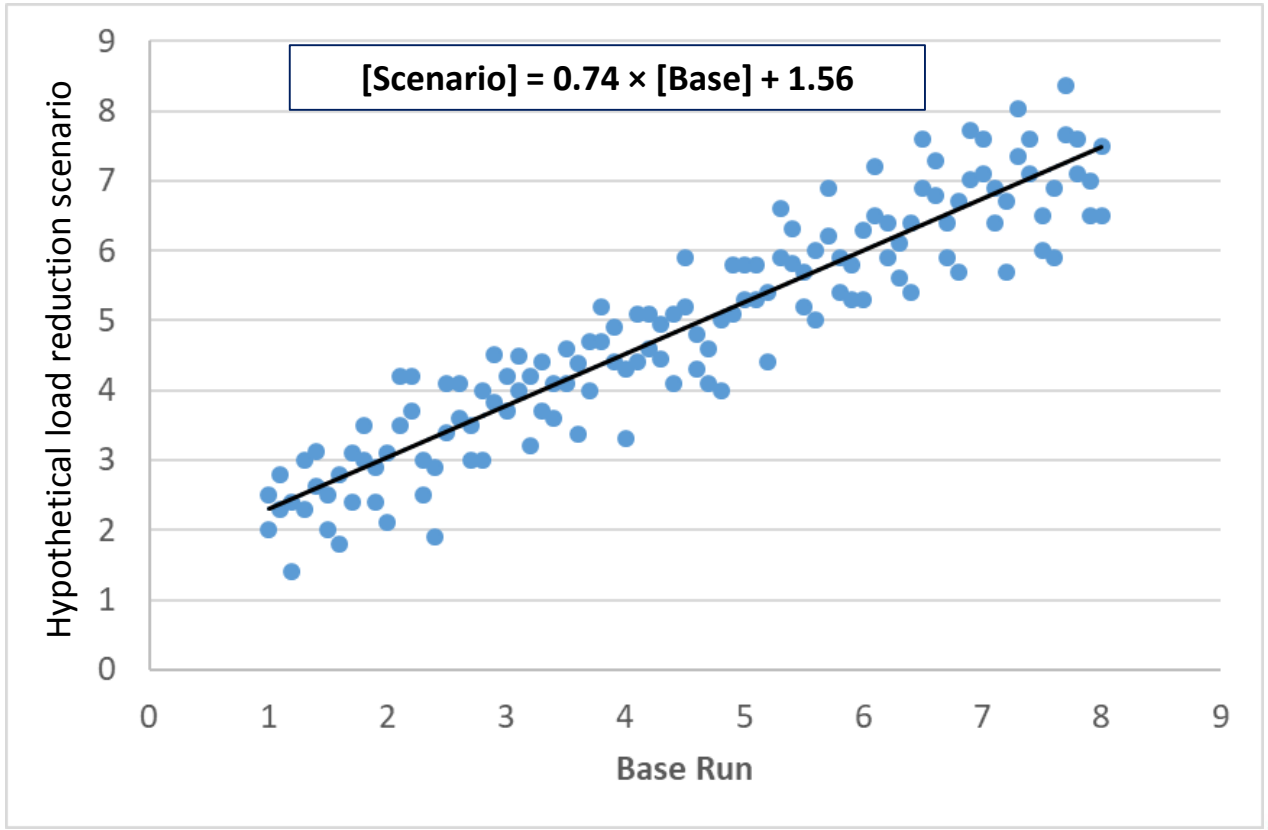




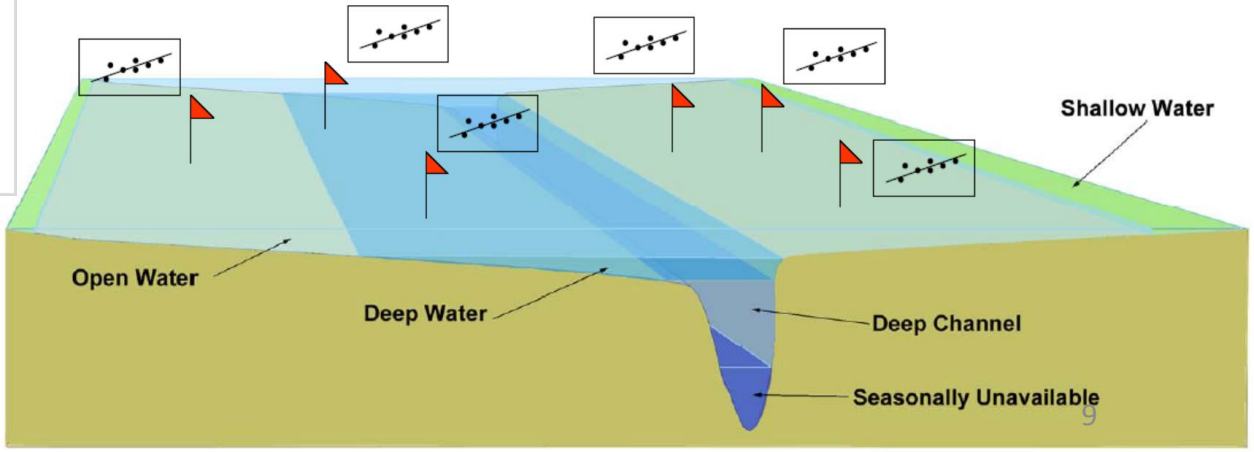


2) Translate WQSTM response into a linear regression

For each corresponding WQSTM cell, regress modeled data from the load reduction scenario against the base run.

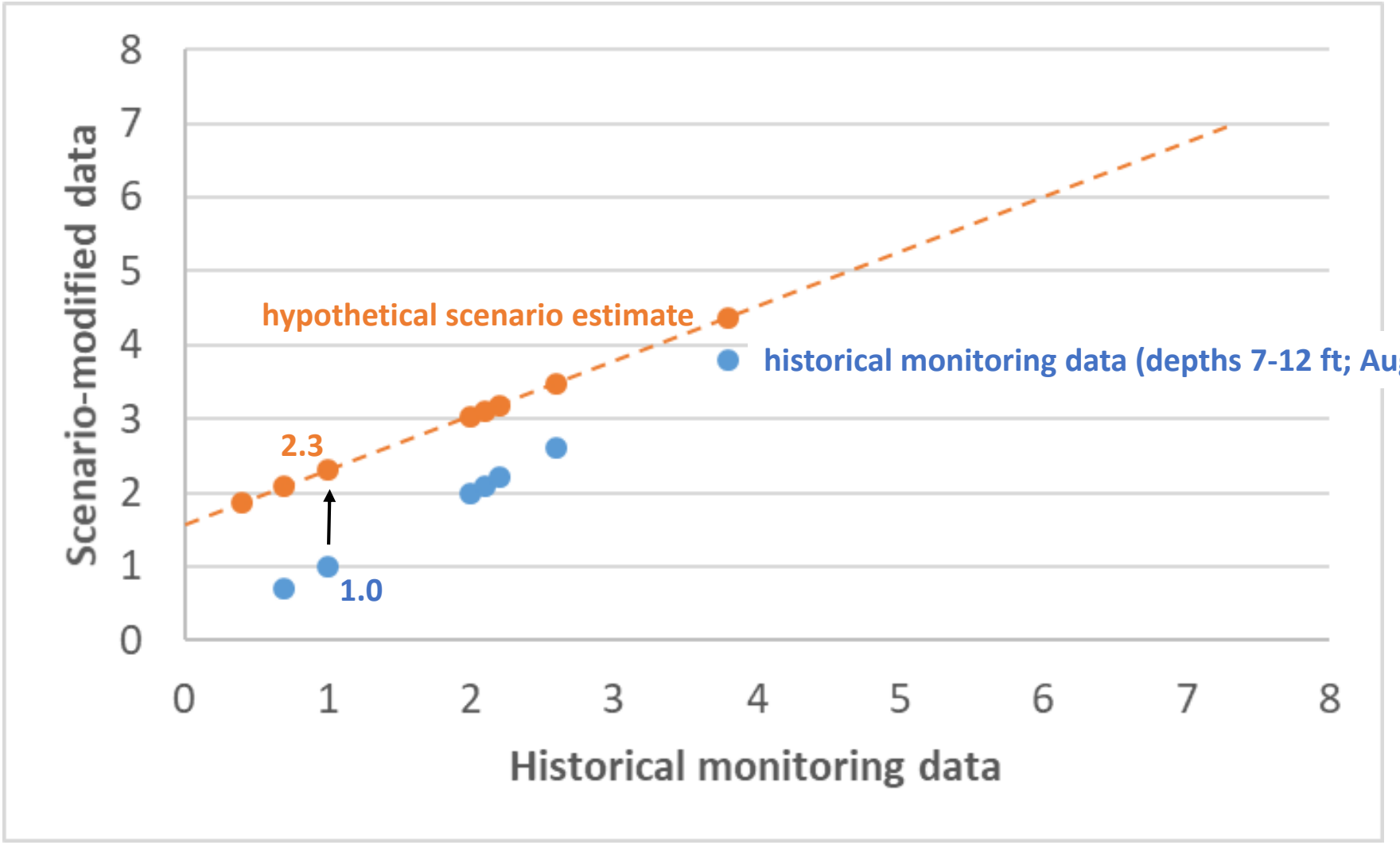


A unique regression equation is generated for each monitoring station



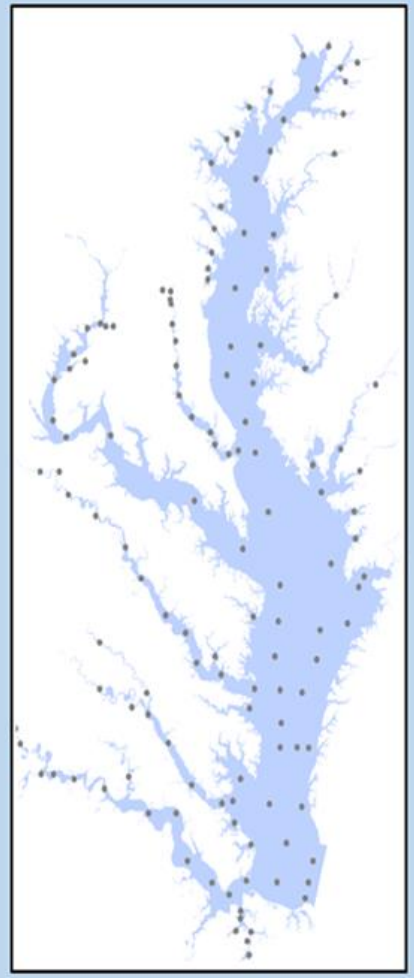
3) Apply regression to historical monitoring data

[Scenario] = 0.74 × [Base] + 1.56

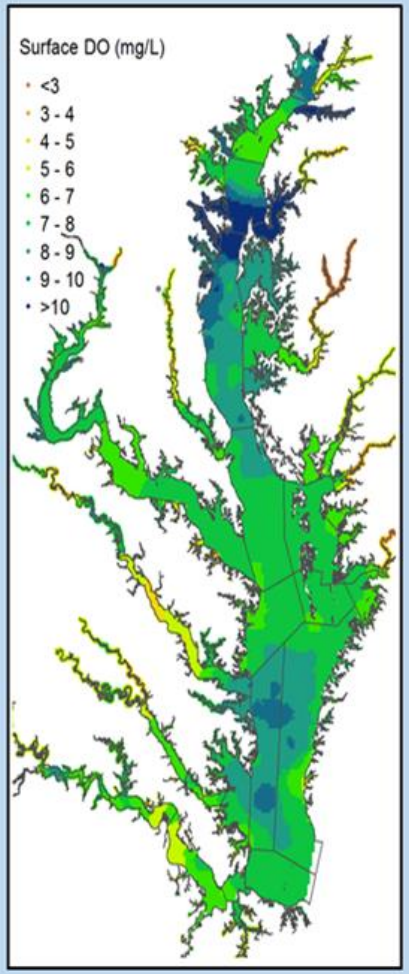


4) Assess scenario-modified data for criteria attainment

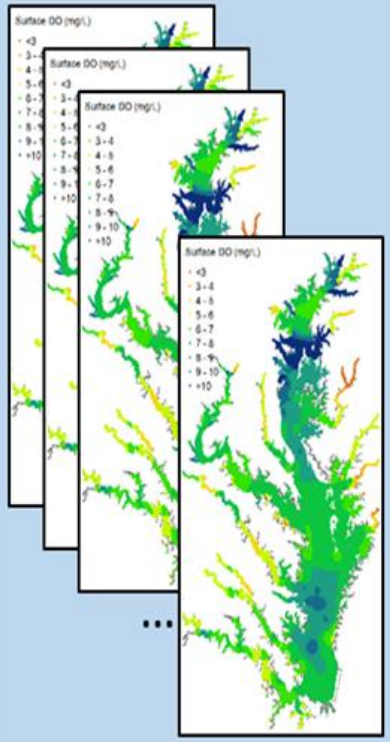
Bi-weekly to Monthly observations



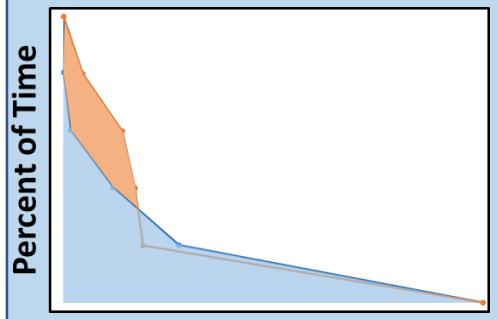
Monthly interpolations



Combine interpolations for a specific season, over 3-year period (DO and Chl-a)



Assess violation rates against a reference curve of allowable criteria exceedance



Yes/no each segment in this 3-year period

Documentation of WIP2 Non-Attaining Segments

Historical monitoring data

- Water quality conditions for the non-attaining segments
- Changes in those conditions over time

CBP WSM and WQSTM estimates:

- Estimated loads to each segment for a range of WSM scenarios (1985 Progress, 2013 progress, WIP2, E3)
- WQSTM response to progressively changing loads
- Identify the 1993-1995 sampling events violating criteria, and
- Show estimated changes in criteria violation at reduced loads

Documentation will inform jurisdictions' environmental planning

- Inform Watershed Implementation Plan III
- Discuss the possibility of restoration variances

Documentation of WIP2 Non-Attaining Segments

Characterizes water quality conditions:

- A segment may show a clear history of sufficient dissolved oxygen conditions;
- A segment may have a consistent history of degraded DO conditions;
- Water quality conditions may be mixed and vary over time.

Characterizes response to CBP model scenarios:

- Observed responses to load changes may be evident. These responses may be as expected, or mixed;
- WQSTM results may show varying degree and direction of response to load reductions.

Documentation of WIP2 Non-Attaining Segments

Examples

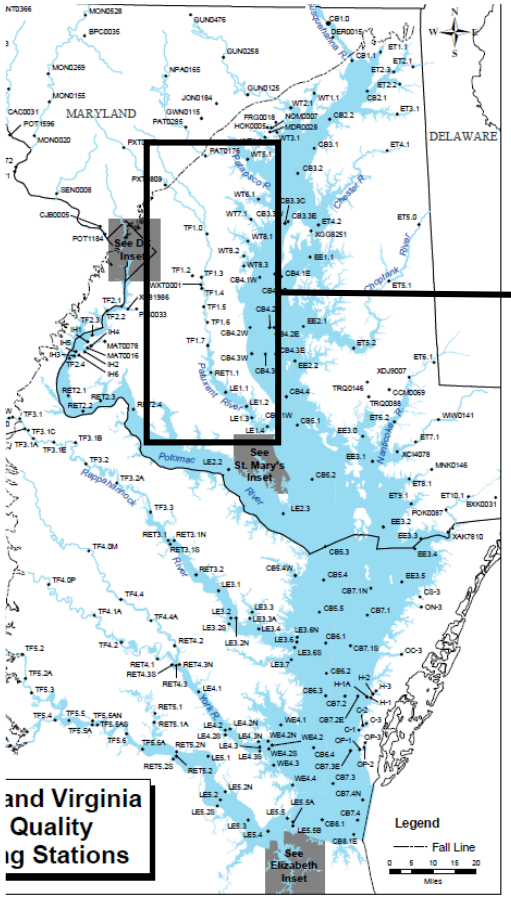
Southern Branch Elizabeth Mesohaline Open Water:

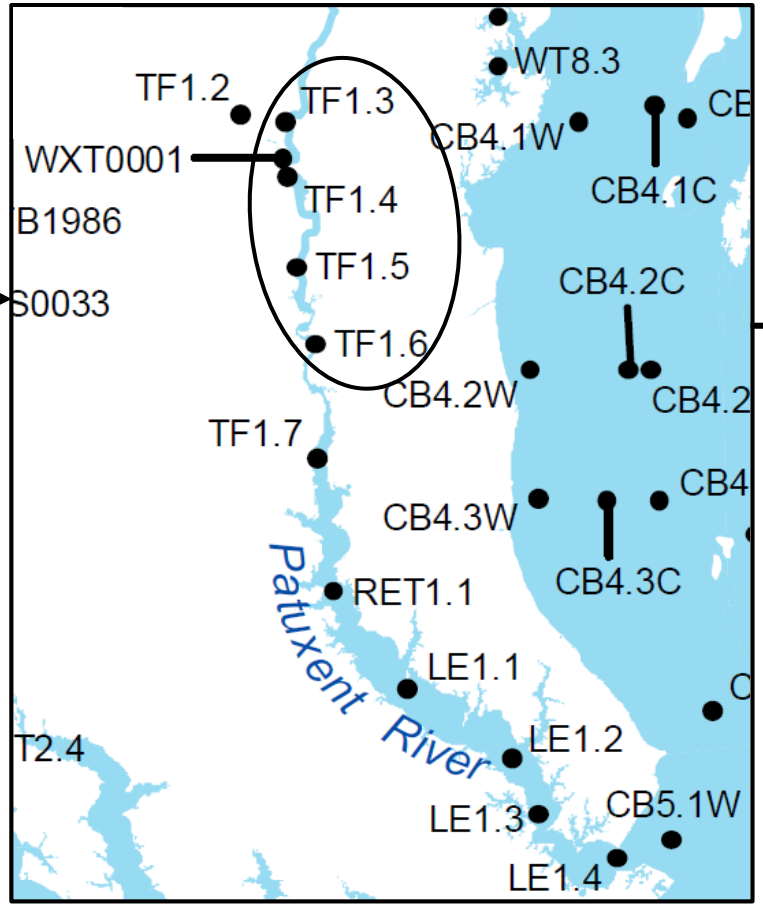
- multiple stations;
- consistent history of degraded conditions;
- Observed responses to load changes are evident and clear; varying WQSTM-simulated responses.

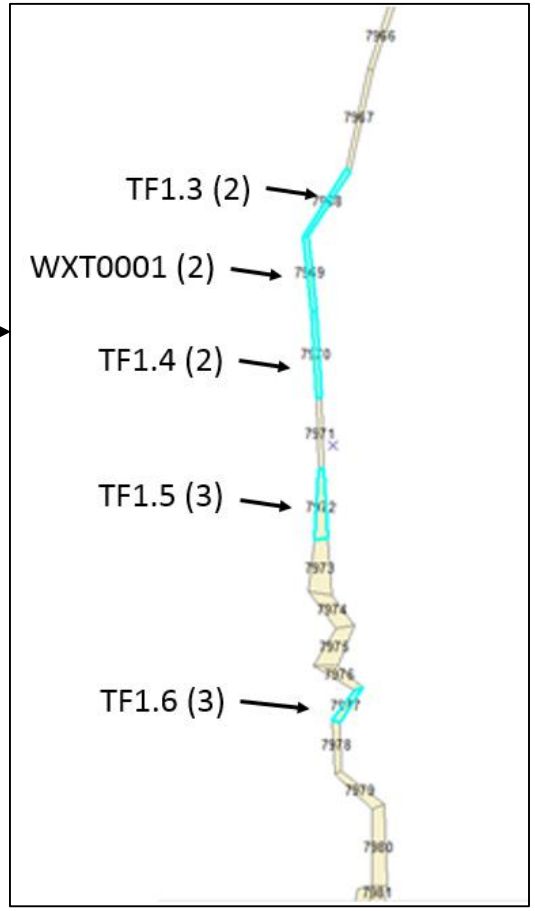
Patuxent Tidal Fresh Open Water:

- multiple stations;
- water quality conditions vary over time;
- observed responses to load reductions are evident but mixed; WQSTM-simulated responses vary.

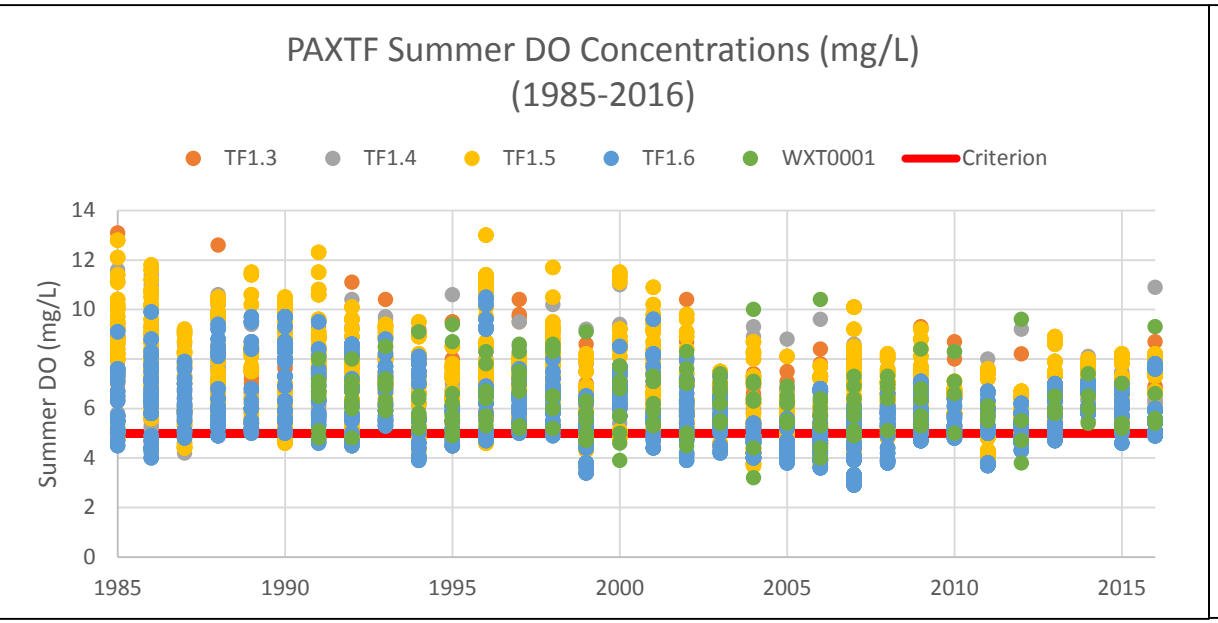
Patuxent Tidal Fresh Diagnostics

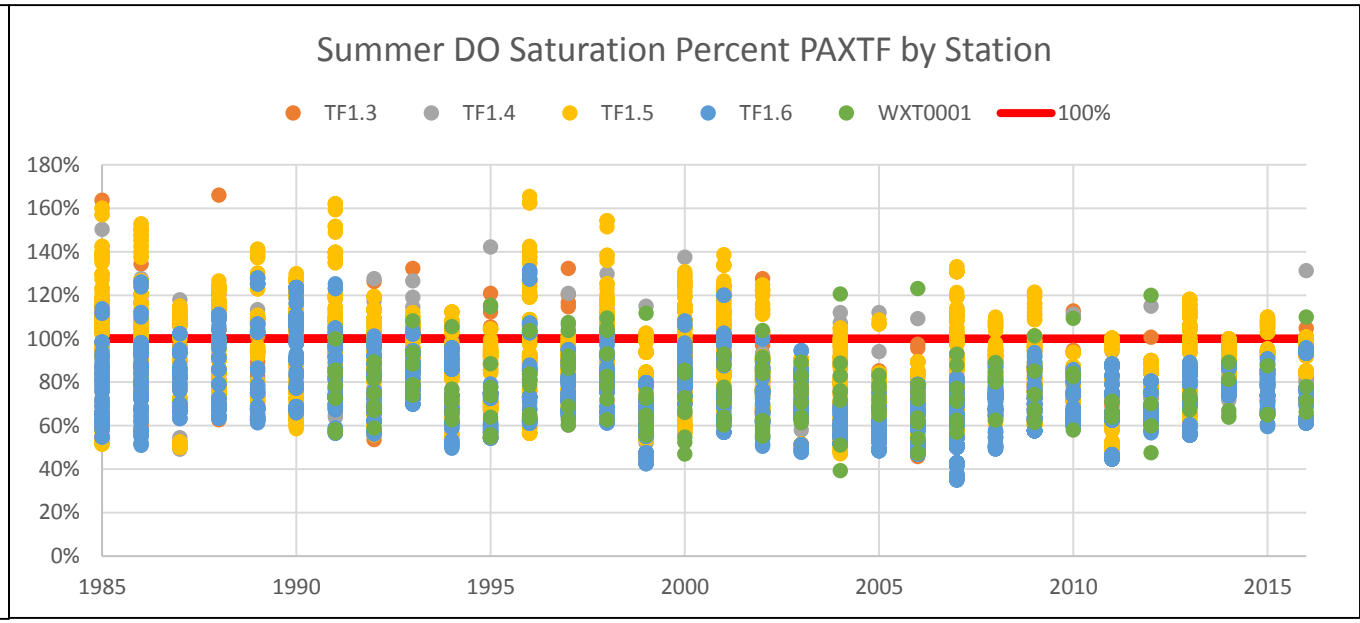


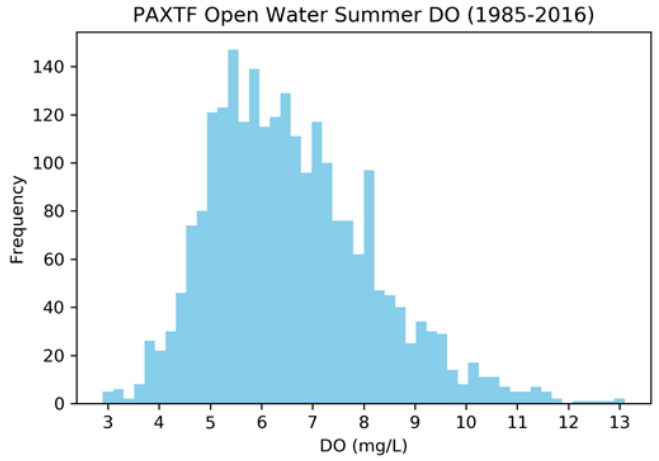




How is the Tidal Fresh Patuxent doing?







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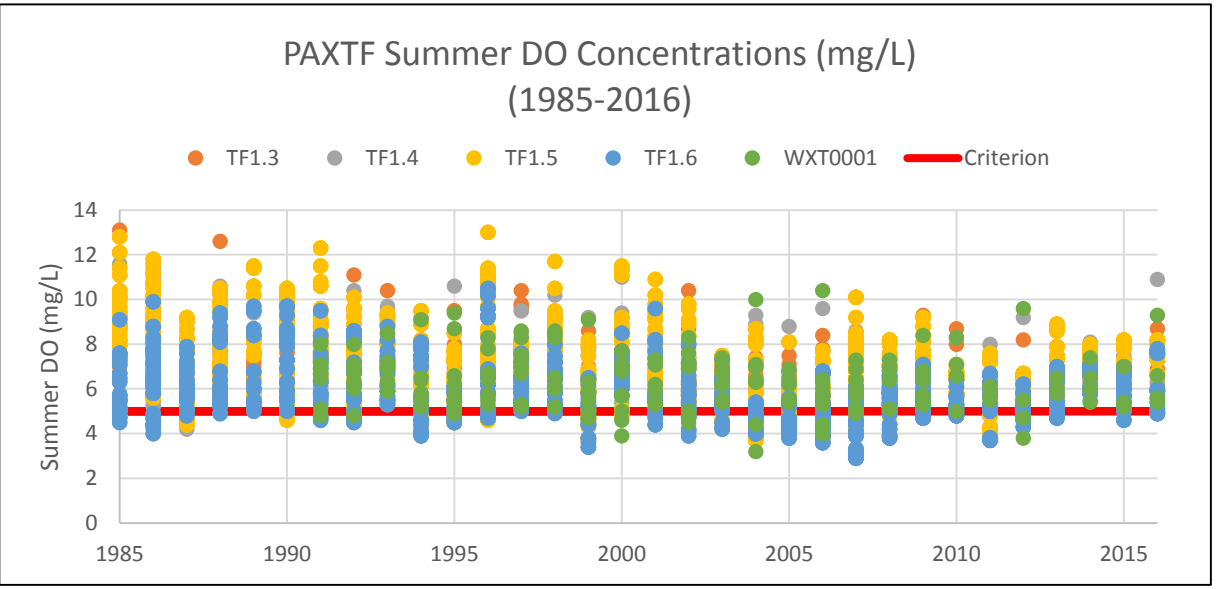
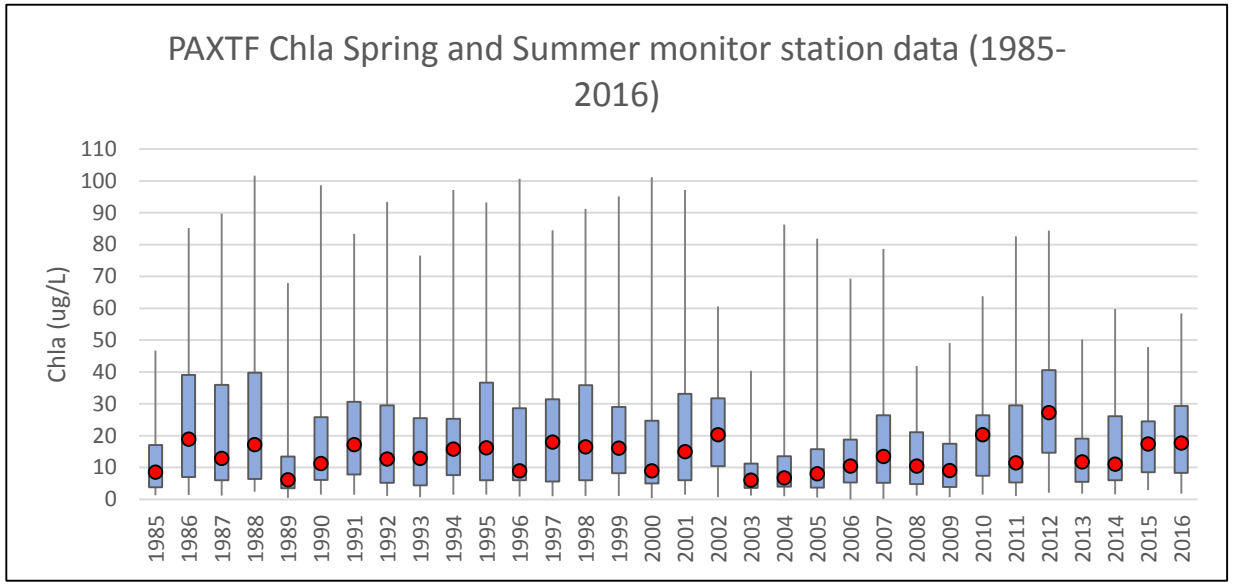
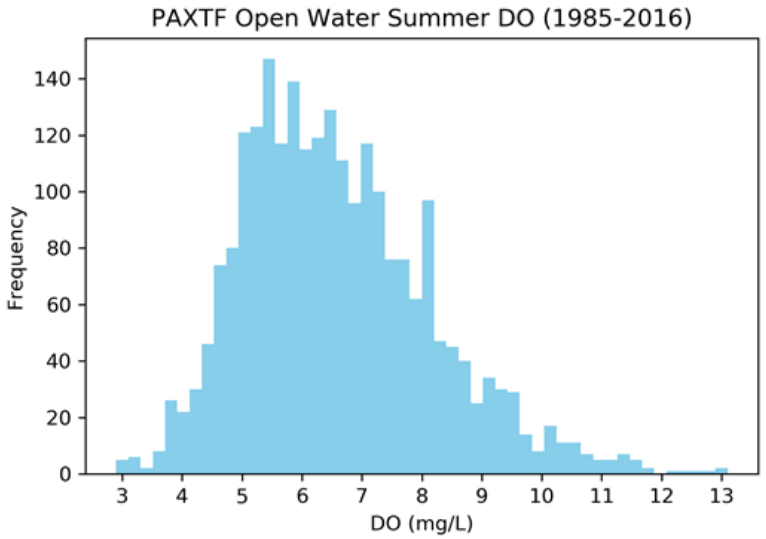
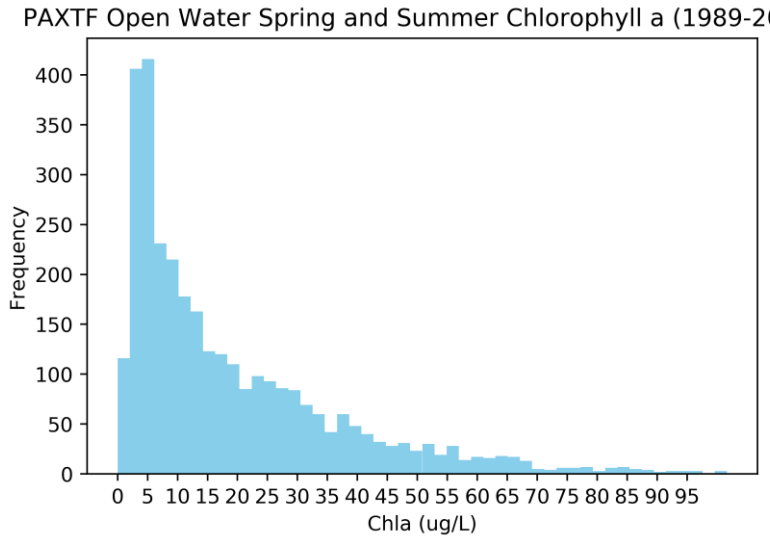




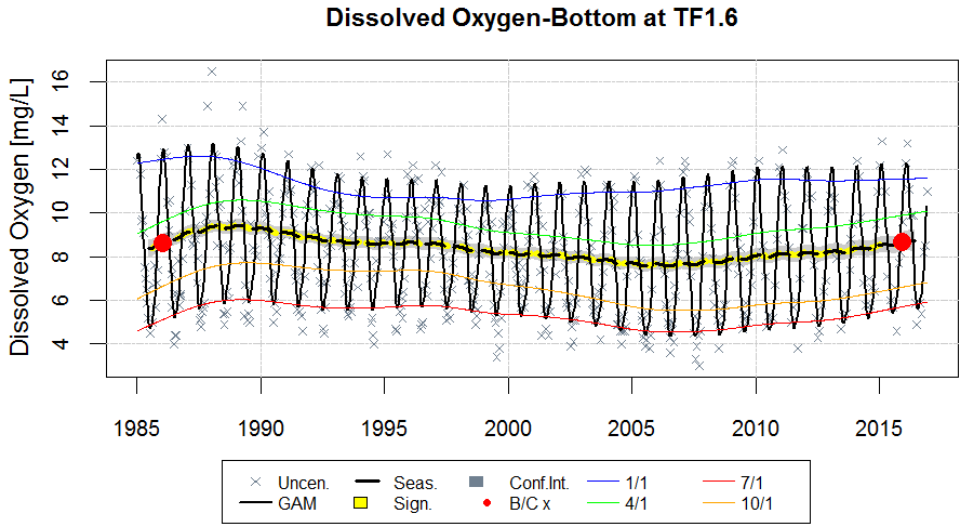




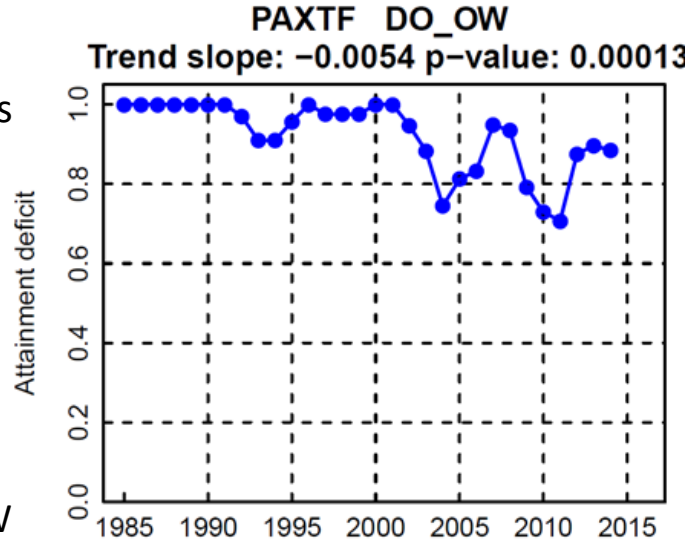
How is the Tidal Fresh Patuxent doing? Water Quality Trends

	Parameters	Period Start	Percent Change	p value
Station TF1.3	TN (surface)	1999	-23.38	p < 0.0001
	TN (surface)	2007	-16.28	p < 0.0001
	TP (surface)	1999	-33.51	p < 0.0001
Station TF1.4	TN (surface)	1999	-28.58	p < 0.0001
	TN (surface)	2007	-9.72	p<0.01
	TP (surface)	1999	-28.98	p < 0.0001
Station TF1.5	Chla (surface)	2007	46.23	0.01
	TN (surface)	1999	-22.99	p < 0.0001
	TN (surface)	2007	-8.19	0.02
	TP (surface)	1999	-16.47	p<0.001
	DO (Summer bottom)	1985	-12.20	0.02
	DO (Summer bottom)	2007	13.07	0.04
Station TF1.6	Chla (surface)	2007	125.12	p < 0.0001
	TN (surface)	1999	-17.99	p < 0.0001
	TN (surface)	2007	-7.14	0.05
	TP (surface)	1999	-10.40	0.02
	DO (Summer bottom)	2007	24.27	p<0.01
Station WXT0001	Chla (surface)	2007	37.61	0.04
	TN (surface)	1999	-43.08	p < 0.0001
	TP (surface)	1999	-33.14	p < 0.0001
	TP (surface)	2007	-25.15	p<0.01

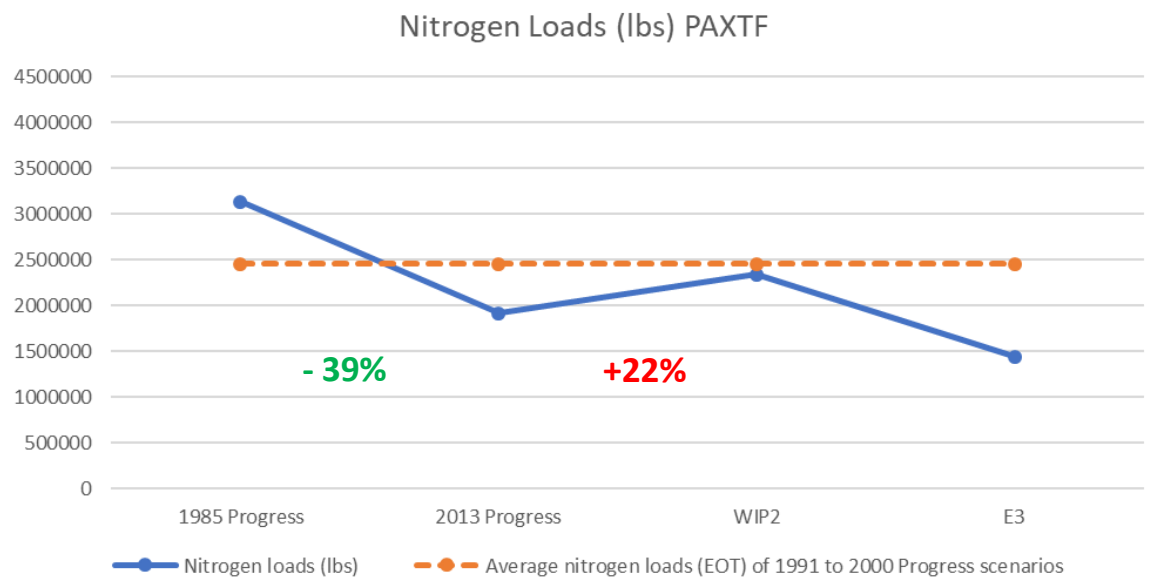
- Surface TN and TP concentrations **declined** at all stations in PAXTF from 1999-2016
- Surface chlorophyll-*a* concentrations **increased** or showed no change.
- DO concentrations have **improving** at the lowest tidal fresh station in the past 10 years.

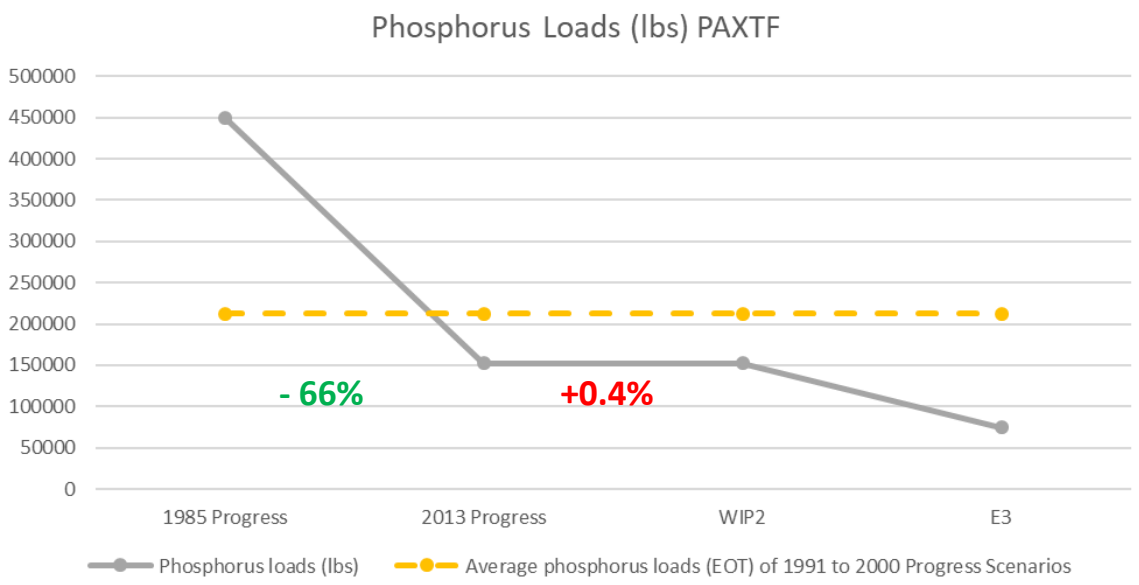


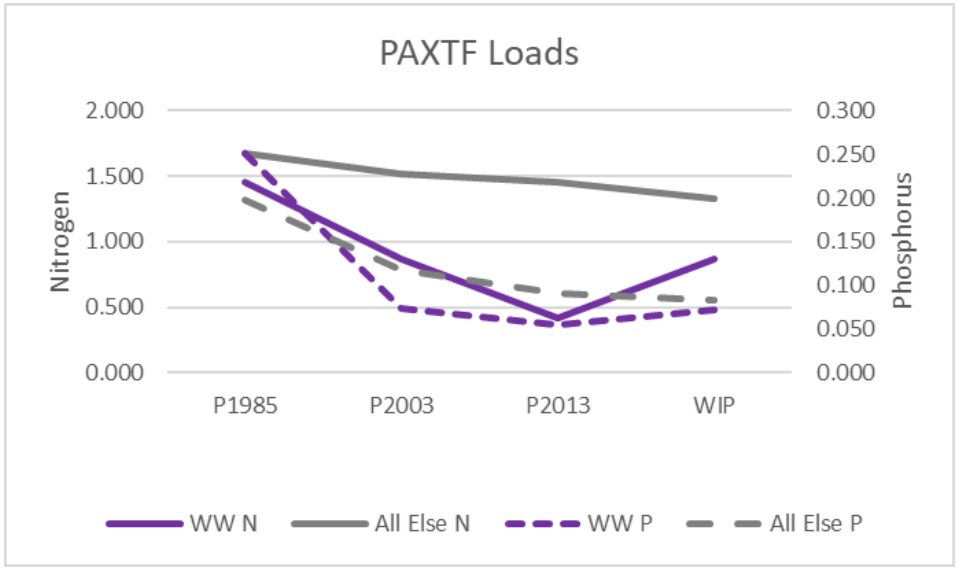
- Percent attainment of the OW summer 30-day mean criterion has declined over the 30 assessment periods between 1985 and 2016 (p< 0.001).
- 7 of the 10 attaining periods were prior to 1992.
- PAXTF has not attained the DO OW summer 30-day mean since 2002.



Do model scenarios allocate reductions to PAXTF?





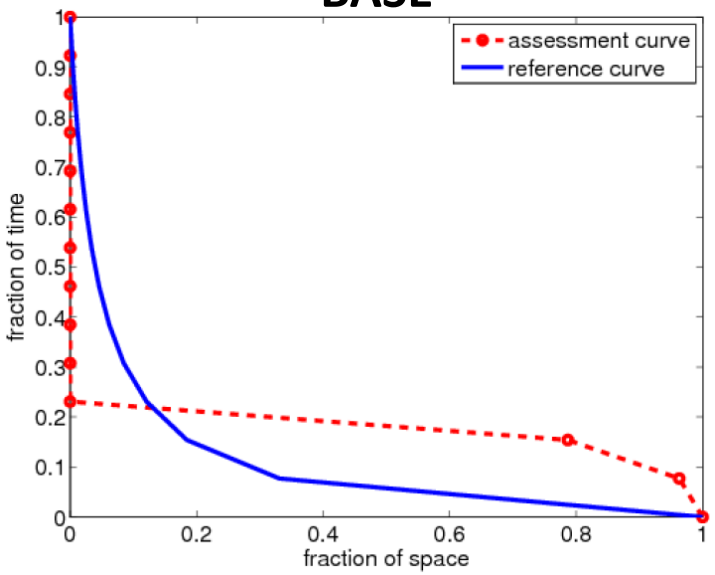


- Increasing nutrient loads to PAXTF under the WIP2 scenario are driven by WWTP estimates.
- Flow estimates increased from 56.3 MGD for 2013 to 85.4 MGD for WIP2.

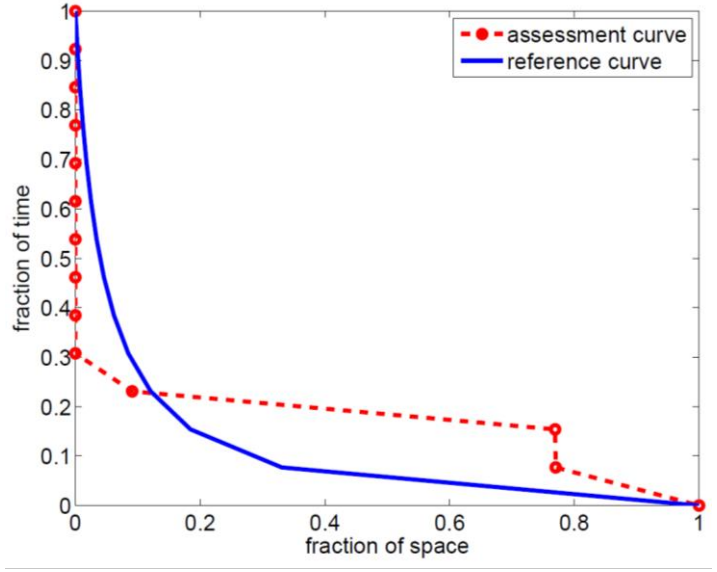
PAXTF: How much violation was there, and when did it occur?

	1985Progress	2013Progress	WIP2	E3	All_Forest
CBSeg	347TN	253TN	195TN	133TN	40TN
	30.4TP	15.9TP	13.7TP	8.6TP	3.9TP
PAXTF	9%	3%	8%	0%	0%

BASE



WIP2



Year	Month	Violation Rate	
		Calibration	WIP2
1993	6	0%	0%
1993	7	0%	0%
1993	8	0%	0%
1993	9	0%	0%
1994	6	0%	0%
1994	7	0%	9%
1994	8	79%	77%
1994	9	0%	0%
1995	6	96%	77%
1995	7	0%	0%
1995	8	0%	0%
1995	9	0%	0%

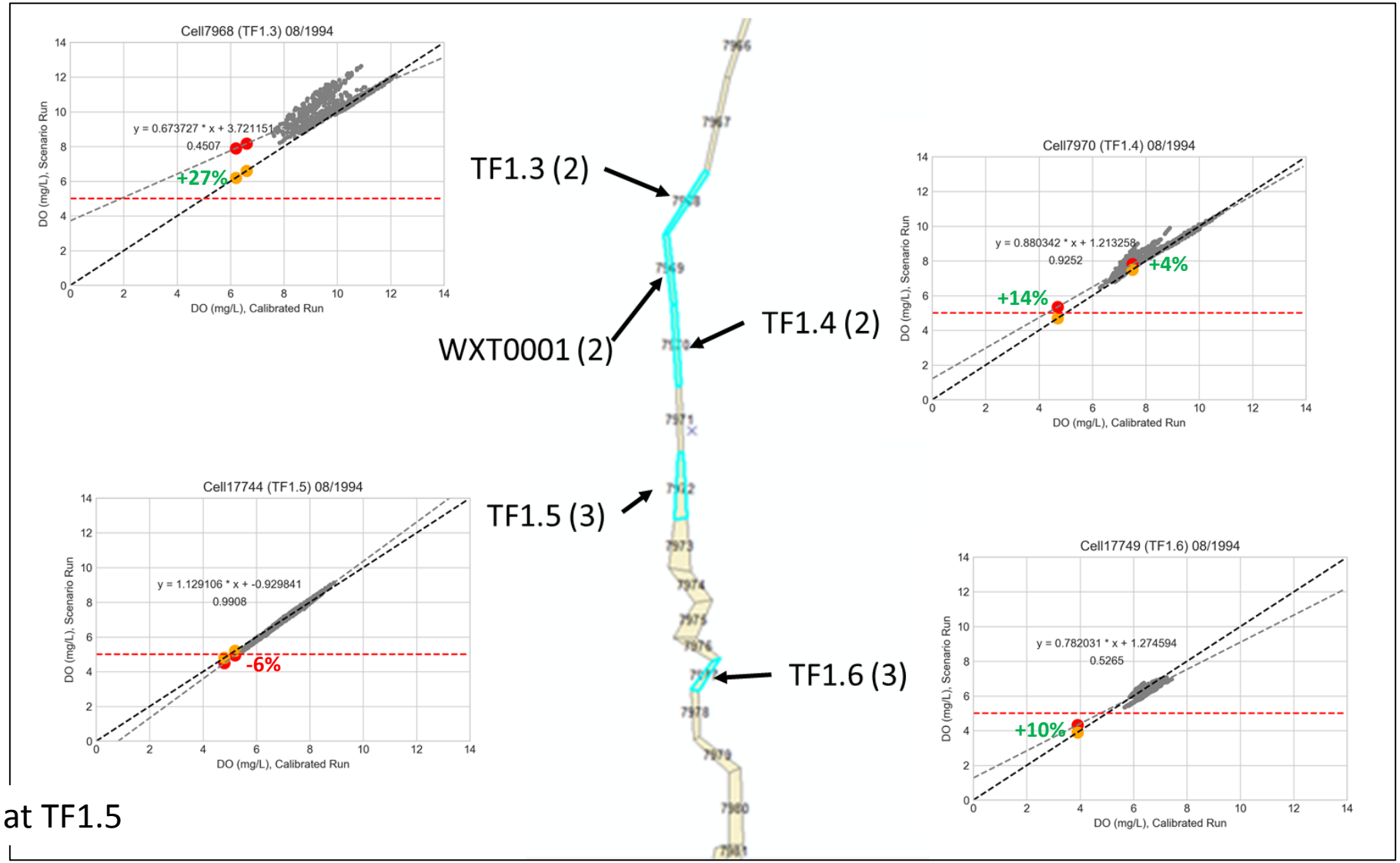
2 out of the 12 summer months in the 1993-1995 period failed the criterion.

The violation rate decreased slightly at the WIP2 scenario compared to the base scenario

Violations occurred in August 1994 and June 1995

PAXTF: Scenario-simulated responses (August 1994)

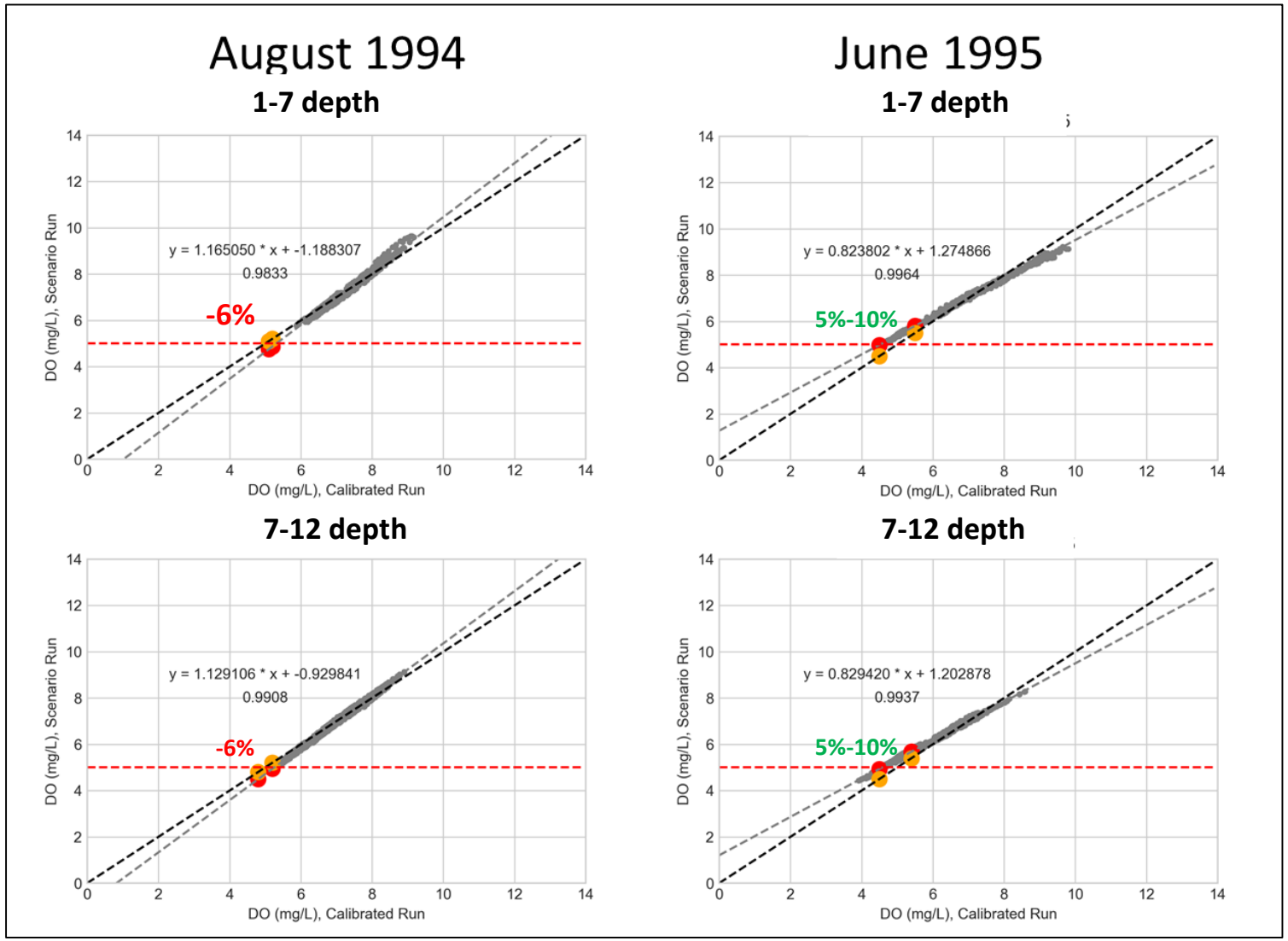
degree of response varies across stations



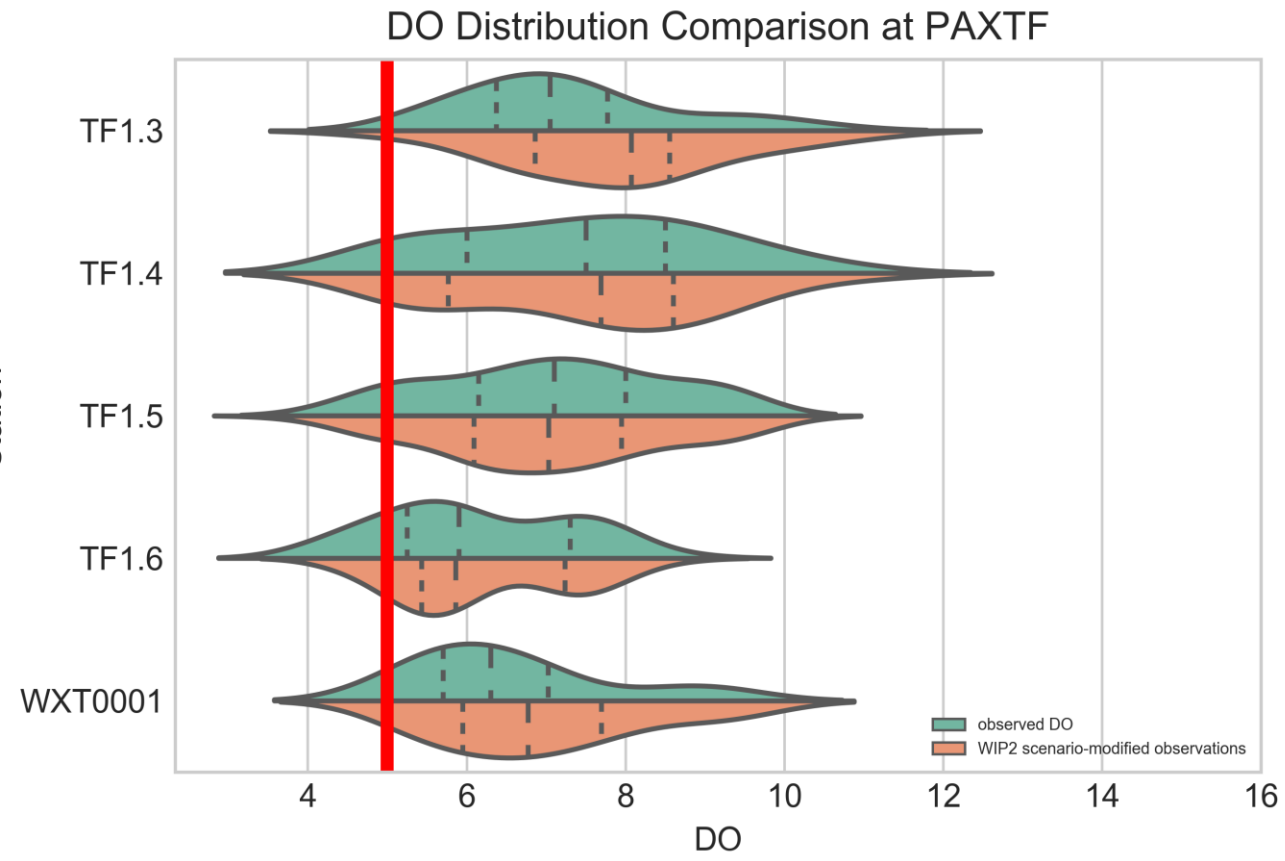
DO decreased at TF1.5

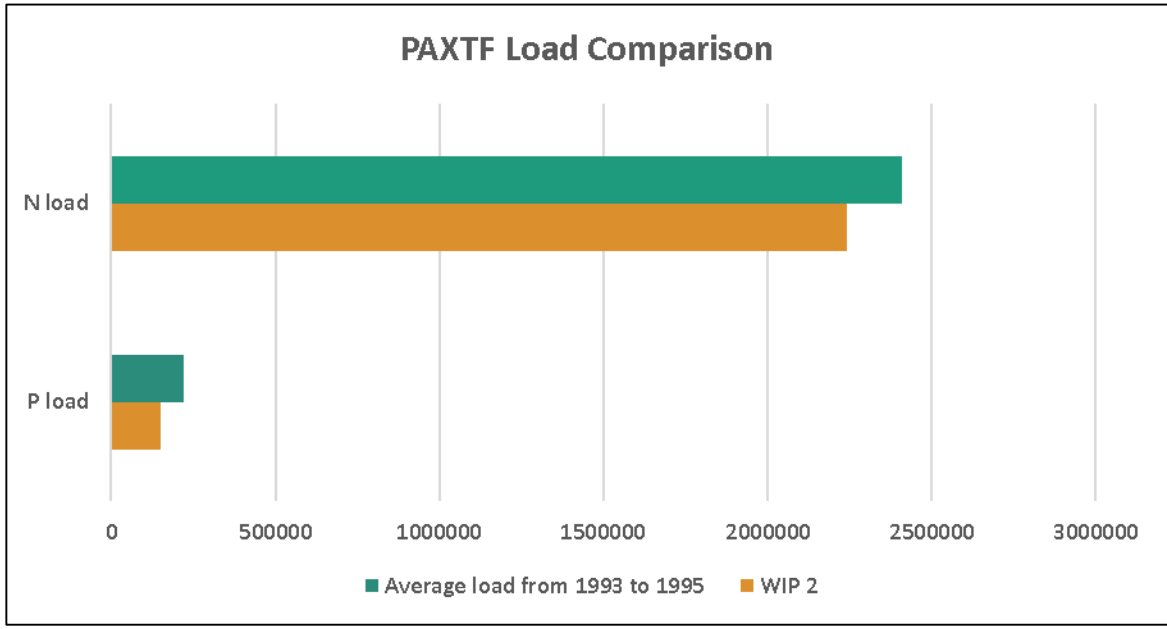
PAXTF: scenarios simulated response (TF1.5)

Expected response varies over time



PAXTF: Scenario-simulated responses



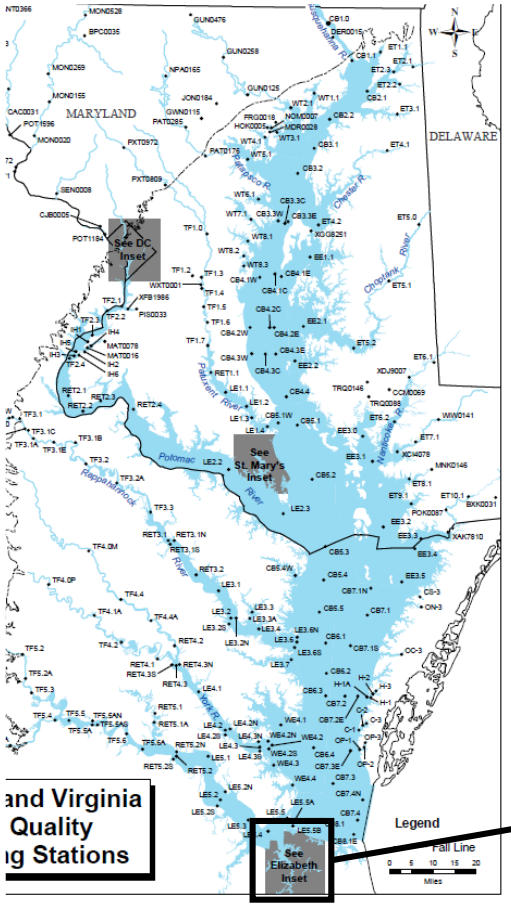


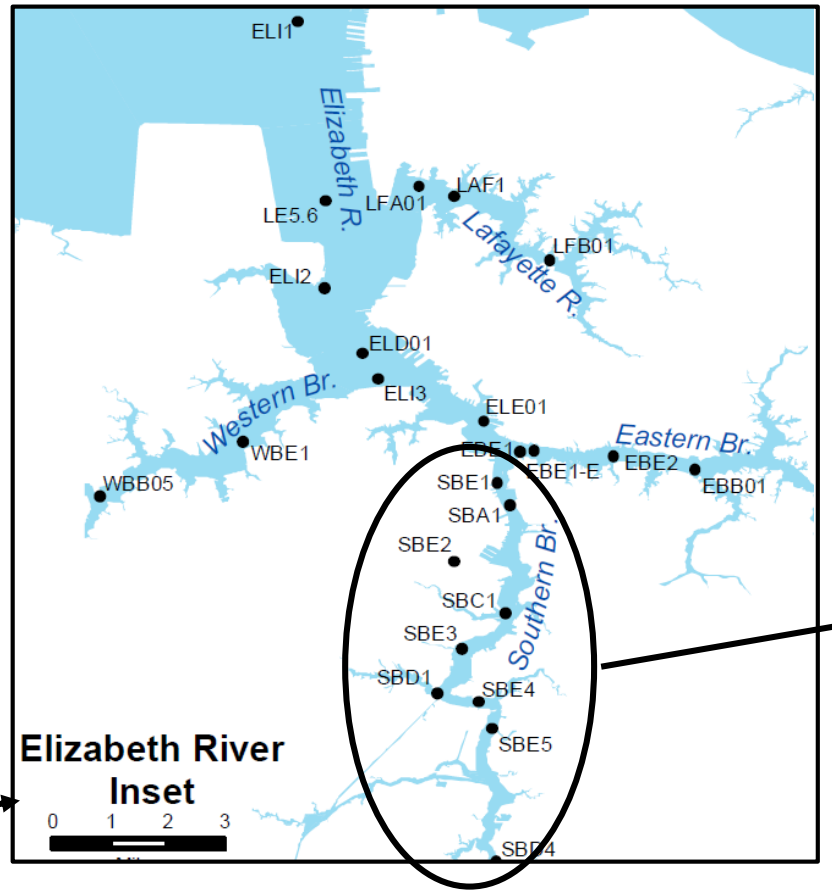
How is the Tidal Fresh Patuxent doing? Water Quality Trends

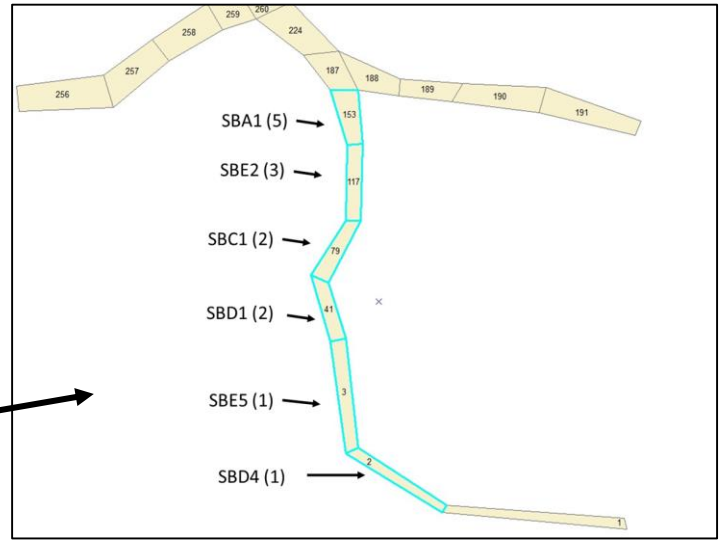
- Nitrogen and Phosphorous concentrations are improving, consistent with waste water load reductions into the Patuxent
- Other water quality response is mixed with some degradation in chlorophyll-*a* and DO, but less super-saturation and fewer very high chlorophyll-*a* values

→ This is an area of active research, water quality response can be complex with multiple physical and biological factors at play as well

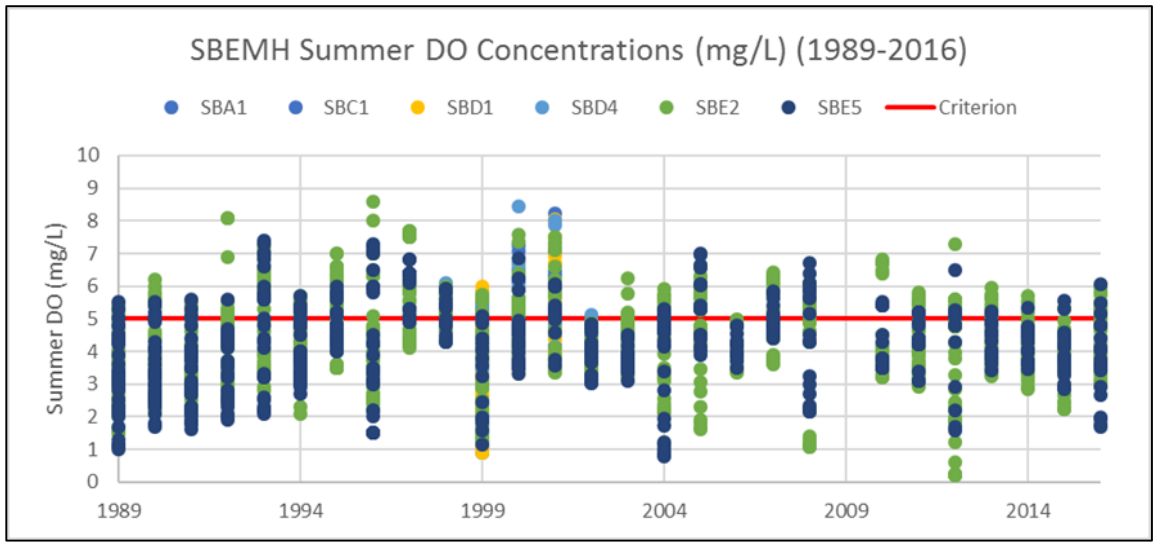
Southern Branch Elizabeth Diagnostics

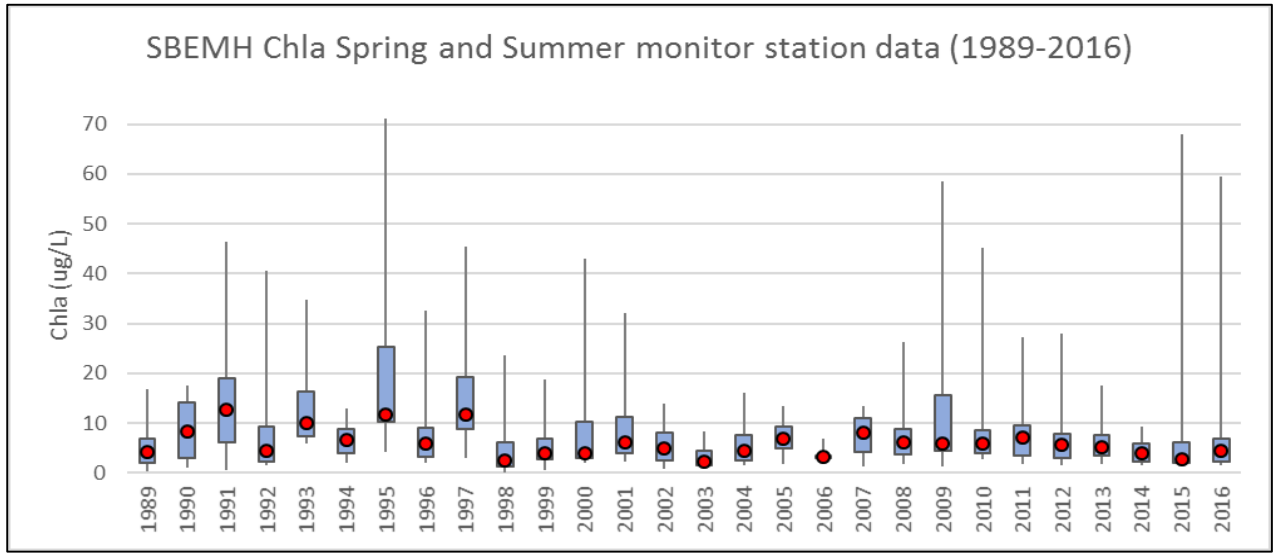


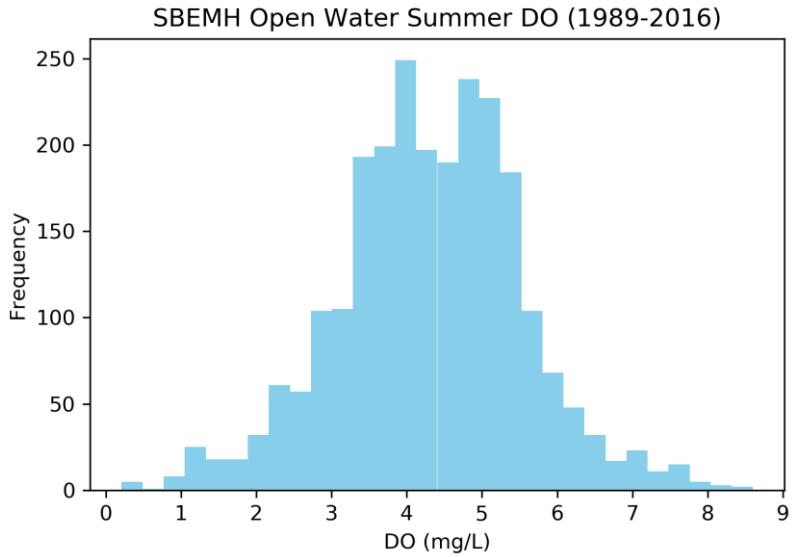


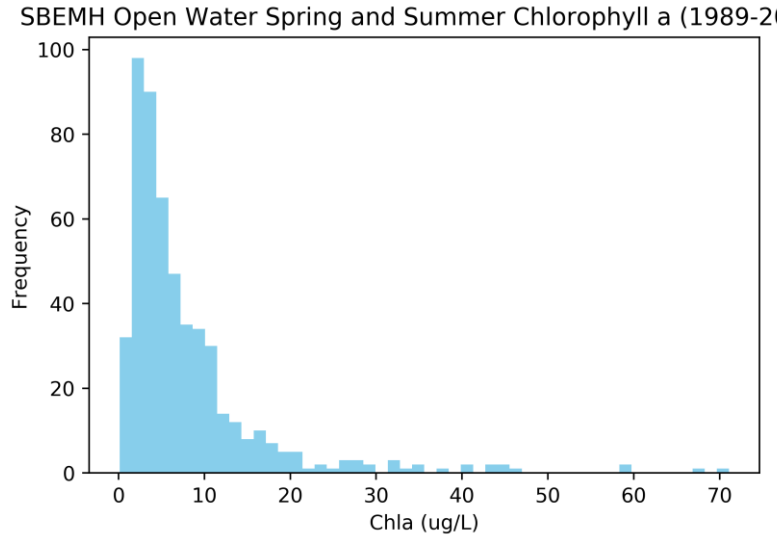


How is the Southern Branch Elizabeth doing?





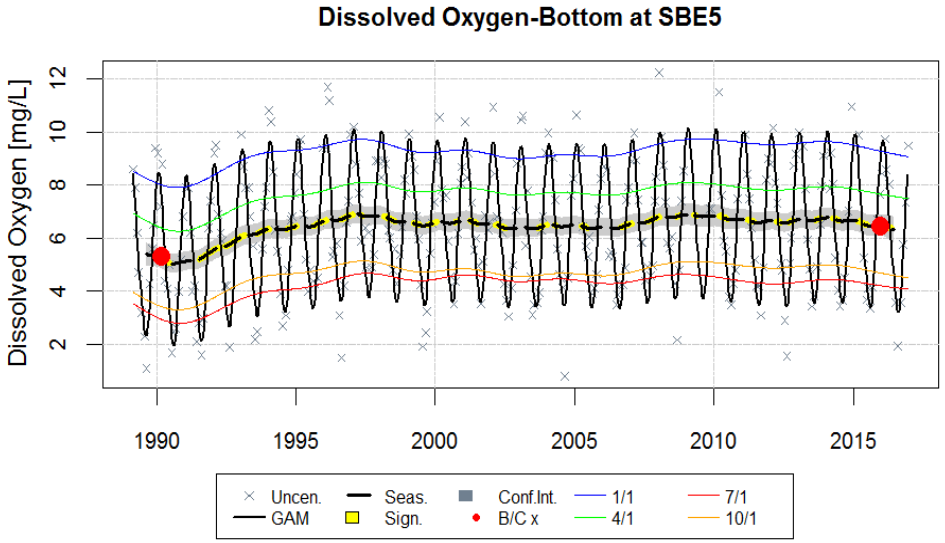




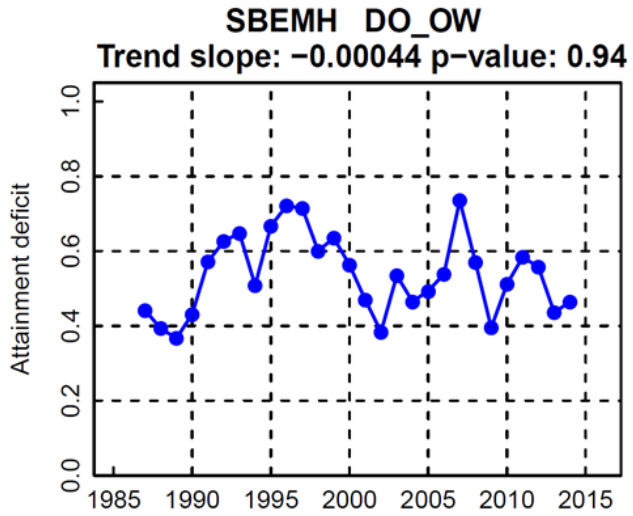
How is the Southern Branch Elizabeth doing? Water Quality Trends

- Surface TN concentrations **declined** at all stations in SBEMH from 1999-2016
- Surface chlorophyll-*a* concentrations have been **declining** since 2007 at all stations.
- DO concentrations have been **increasing** since 1989 at all stations.

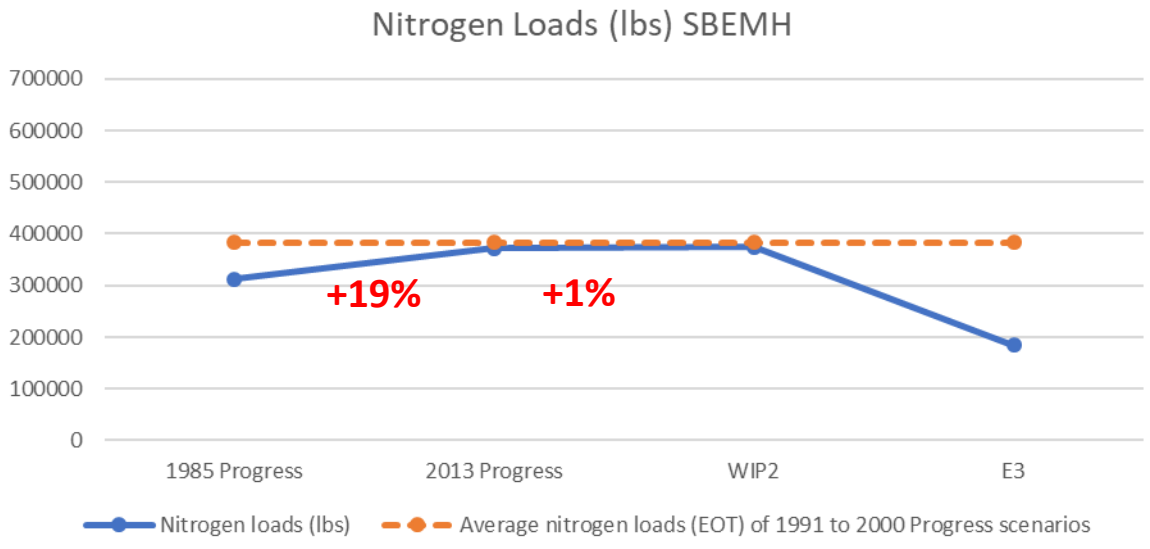
	Parameters	Period Start	Percent Change	p value
Station SBE2	Chla (surface)	2007	-40.50	p<0.01
	TN (surface)	2007	-15.62	0.01
	TN (surface)	1999	-26.43	p < 0.0001
	DO (Summer bottom)	1989	23.40	p<0.01
Station SBE5	Chla (surface)	2007	-48.52	p<0.001
	TN (surface)	1999	-20.88	p<0.001
	DO (Summer bottom)	1989	41.60	p < 0.0001

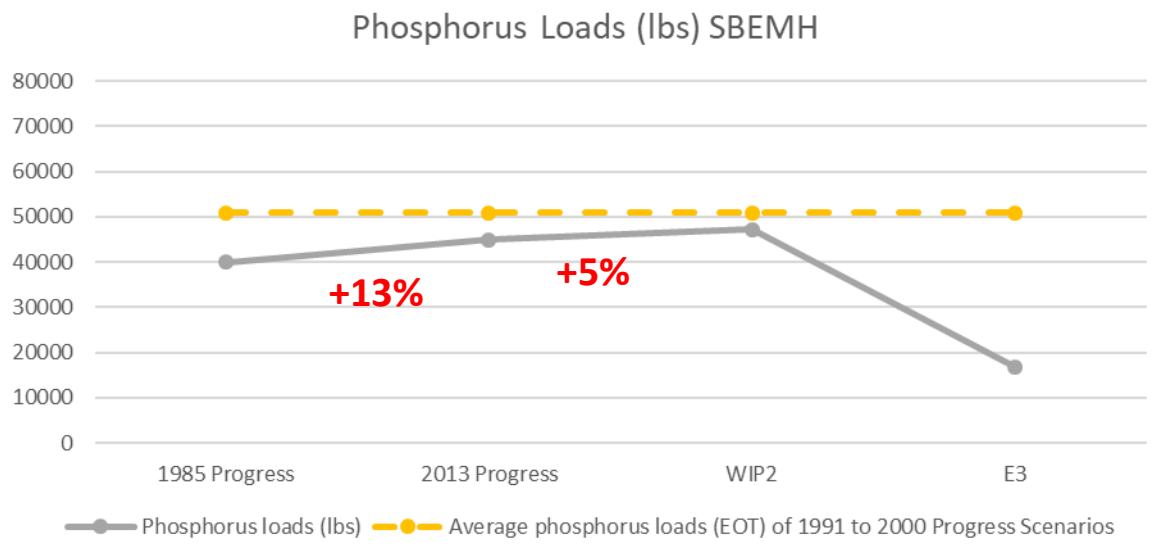


- Percent attainment of the OW summer 30-day mean criterion has no significant change from 1985 to 2016 (p = 0.94)
- SBEMH has not attained the DO OW summer 30-day mean since 1985.



Do model scenarios allocate reductions to SBEMH?





1985-2013: **60K** lbs N (**19%**) load increase

2013-WIP2: additional **1%** N increase

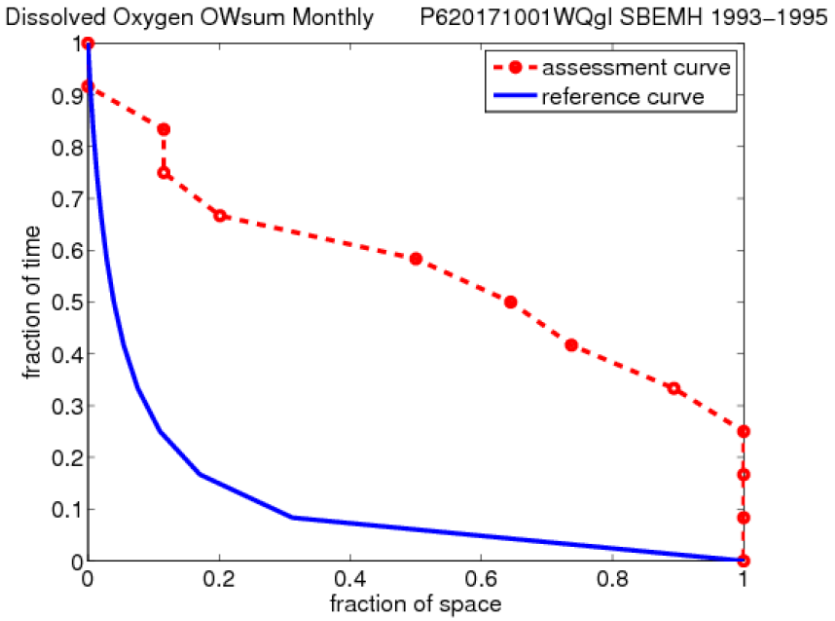
1985-2013: **5K** lbs (**13%**) P load increase

2013-WIP2: additional **5%** P load increase

SBEMH: How much violation was there, and when did it occur?

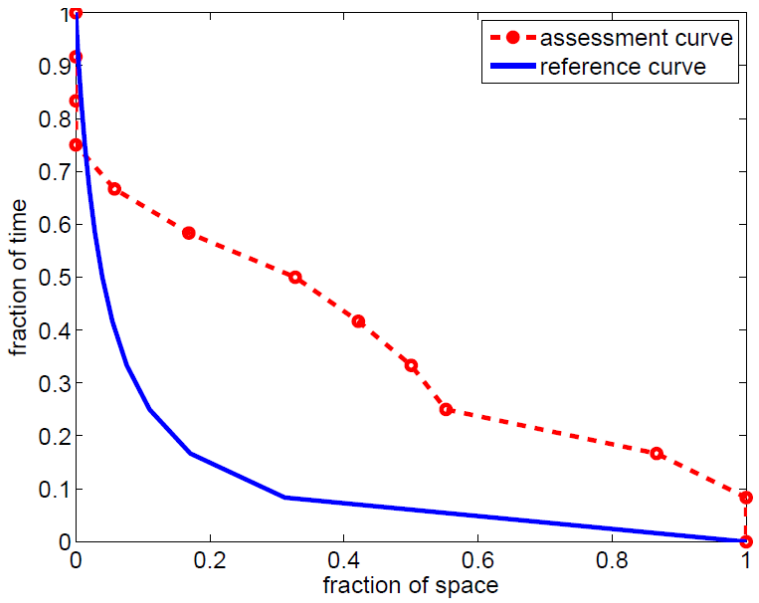
	1985Progress	2013Progress	WIP2	E3	All_Forest
CBSeg	347TN	253TN	195TN	133TN	40TN
	30.4TP	15.9TP	13.7TP	8.6TP	3.9TP
SBEMH	48%	34%	26%	12%	3%

BASE



10 out of the 12 summer months in the 1993-1995 period failed the criterion.

WIP2



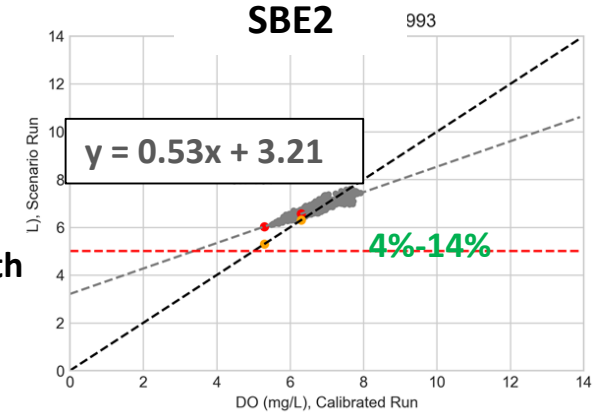
The violation rate decreased at the WIP2 scenario compared to the base scenario

Year	Month	Violation Rate	
		Calibration	WIP2
1993	6	0%	0%
1993	7	74%	50%
1993	8	50%	33%
1994	6	64%	17%
1994	7	100%	87%
1994	8	100%	42%
1994	9	12%	0%
1995	6	20%	0%
1995	7	12%	6%
1995	8	89%	55%
1995	9	100%	100%
1995	9	0%	0%

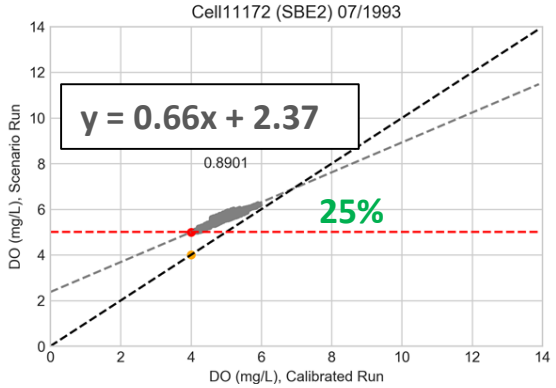
8 violations occurred between 1993 to 1995

SBEMH: Scenario-simulated response varies in space (July 1993)

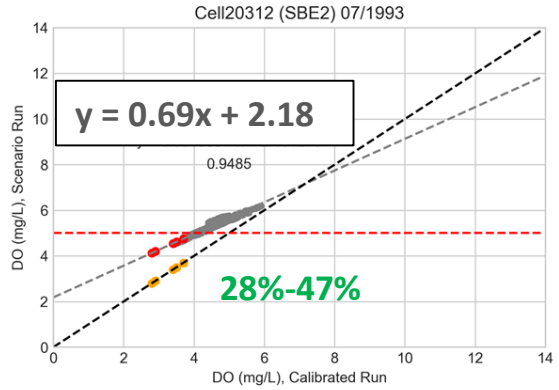
0-7 ft depth

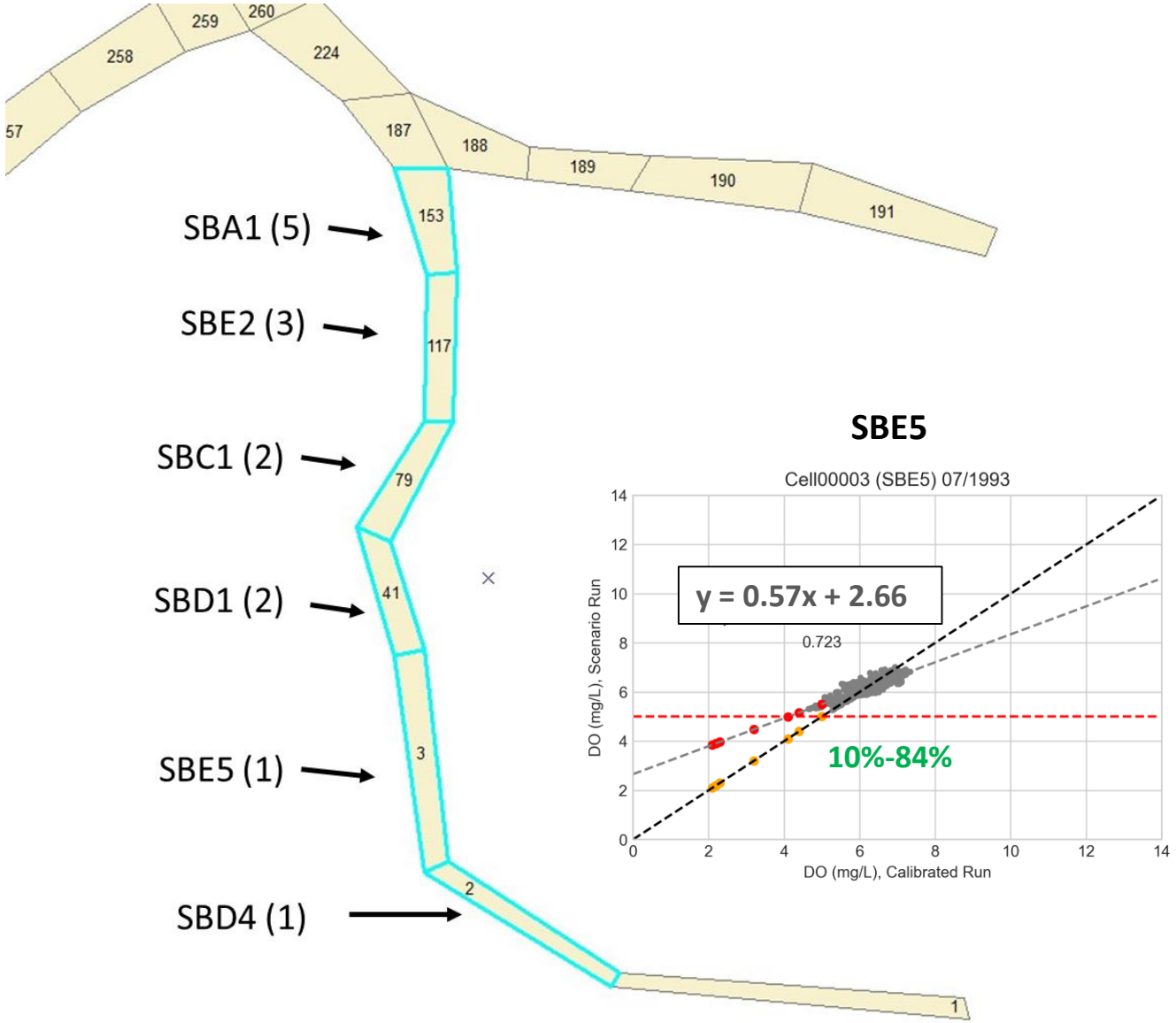


7 -12 ft depth



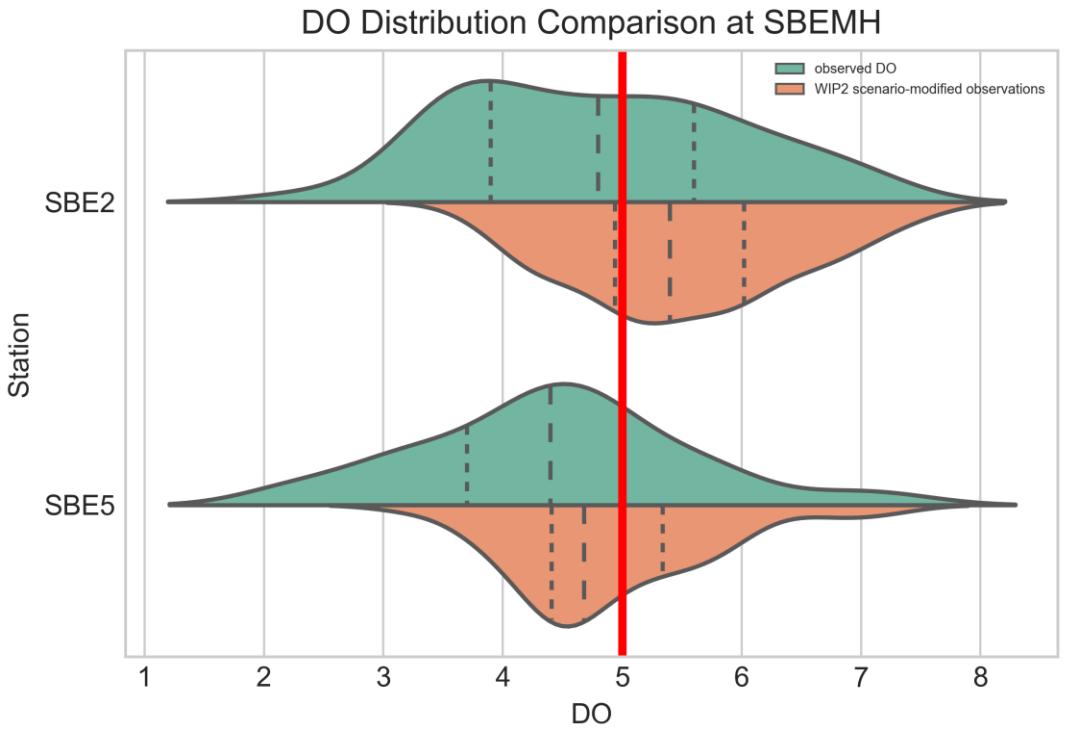
12-17 ft depth

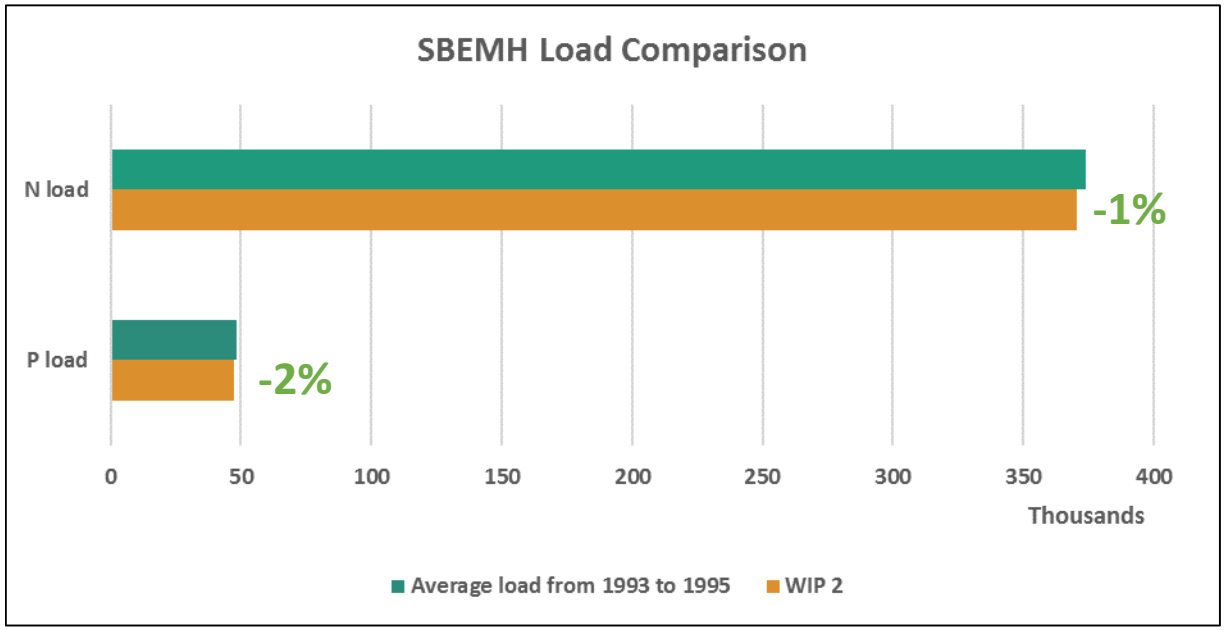




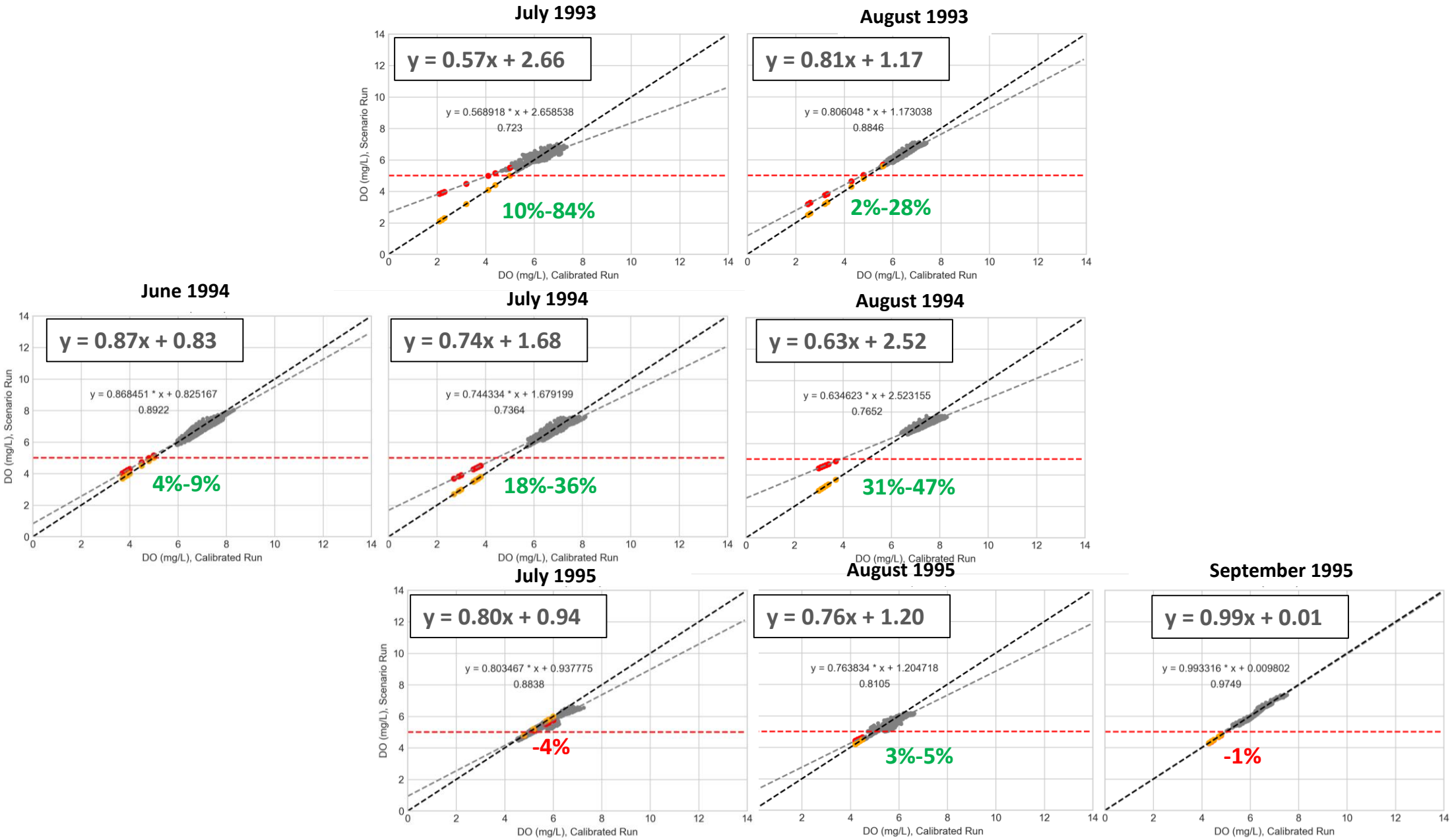
SBE5

SBEMH: Scenario-simulated response varies in space (July 1993)





SBE5: scenario-simulated response varies over time



How is the Southern Branch Elizabeth doing? Water Quality Trends

- Nitrogen concentrations have improved significantly in recent years, but there has been little change in phosphorus
- DO trends are improving, but concentrations still below 5 mg/L frequently
- Impacted by the mainstem of the Bay, but not expected to attain by 2025

→ Trends are in the right direction, but significant progress is still needed