

Phase 7 Watershed and Airshed Models of the Chesapeake Watershed and Bay

Water Quality Goal Implementation Team

February 23, 2026

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CBPO), and Jesse Bash (Norwegian Meteorological Institute)



Chesapeake Bay Program
Science, Restoration, Partnership



Clean Water Act as Amended Section 117 (b)(2)(B)

“(B) FUNCTION. -- The Chesapeake Bay Program Office shall ...

(i) [implement and coordinate] science, research, modeling, support services, monitoring, data collection, and other activities that support the Chesapeake Bay Program;

(iii) [assist] the signatories to the Chesapeake Bay Agreement in developing and implementing specific action plans [to]...

(I) improve the water quality and living resources in the Chesapeake Bay ecosystem;”

CBP Modeling makes the plans to “improve the water quality and living resources in the Chesapeake Bay ecosystem.” The Phase 7 Models are the latest development of a long line of watershed, airshed, and estuarine models.



Chesapeake Bay Program
Science, Restoration, Partnership



Modeling Workgroup & Modeling Team Core Values

The Modeling Workgroup and Team provides the Chesapeake Bay Program partnership state-of-the-science decision-support modeling tools that are built through community and participatory principles. The Modeling Team and Modeling Workgroup adhere to the core values of:

Integration - Integration of most recent science and knowledge in air, watershed, and coastal waters to support ecosystem modeling for restoration decision making.

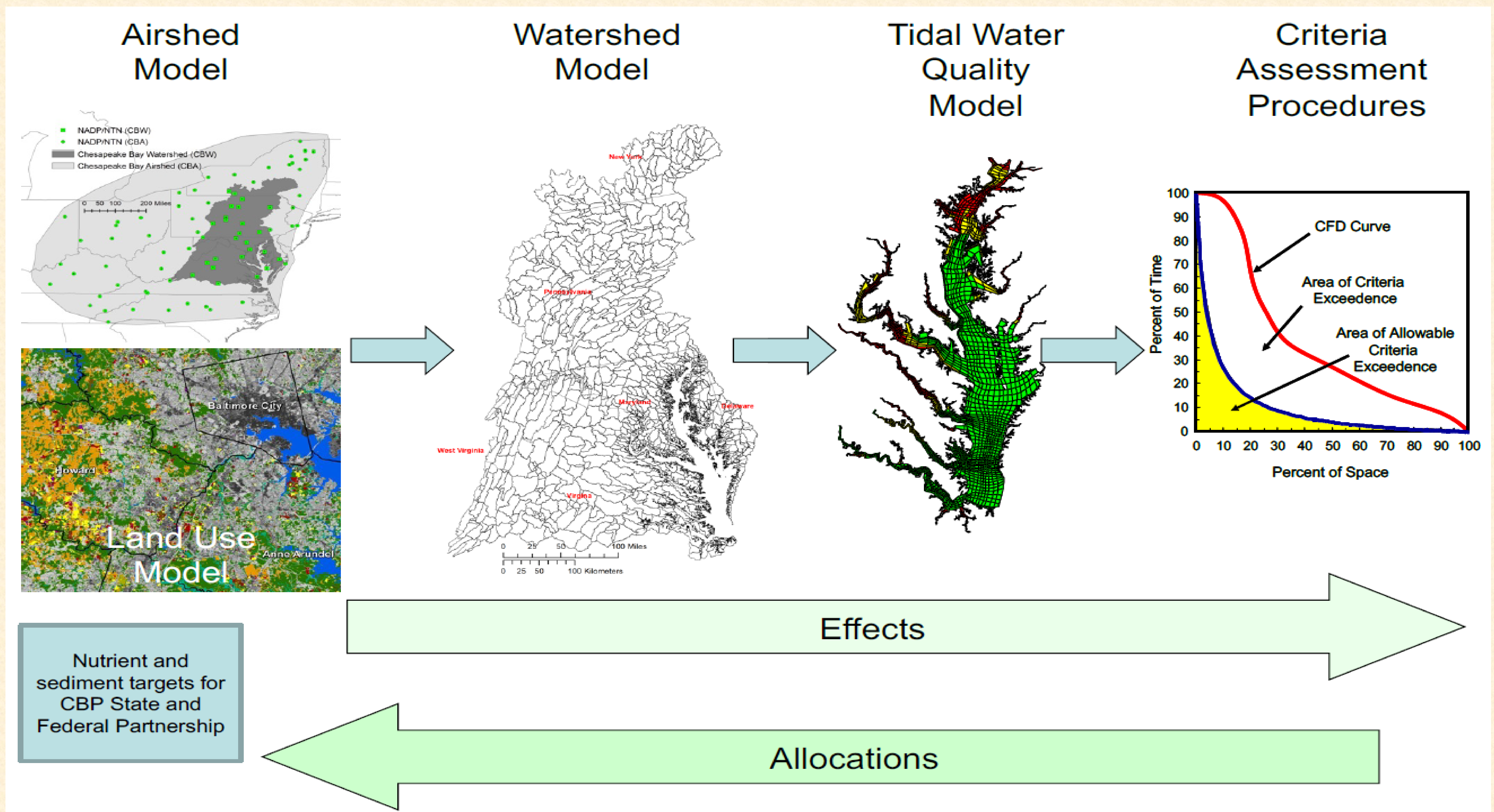
Innovation - Embracing creativity and encouraging improvement in the development and support of transparent and robust modeling tools.

Independence – Making CBP modeling decisions on the basis of best available evidence and using the most appropriate methods to produce, run, and interpret models, independent of policy considerations.

Inclusiveness - Commitment to an open and transparent process and the engagement of CBP partners that results in strengthening the Partnership's decision-making tools.



How the CBP Makes a Plan – Broad View



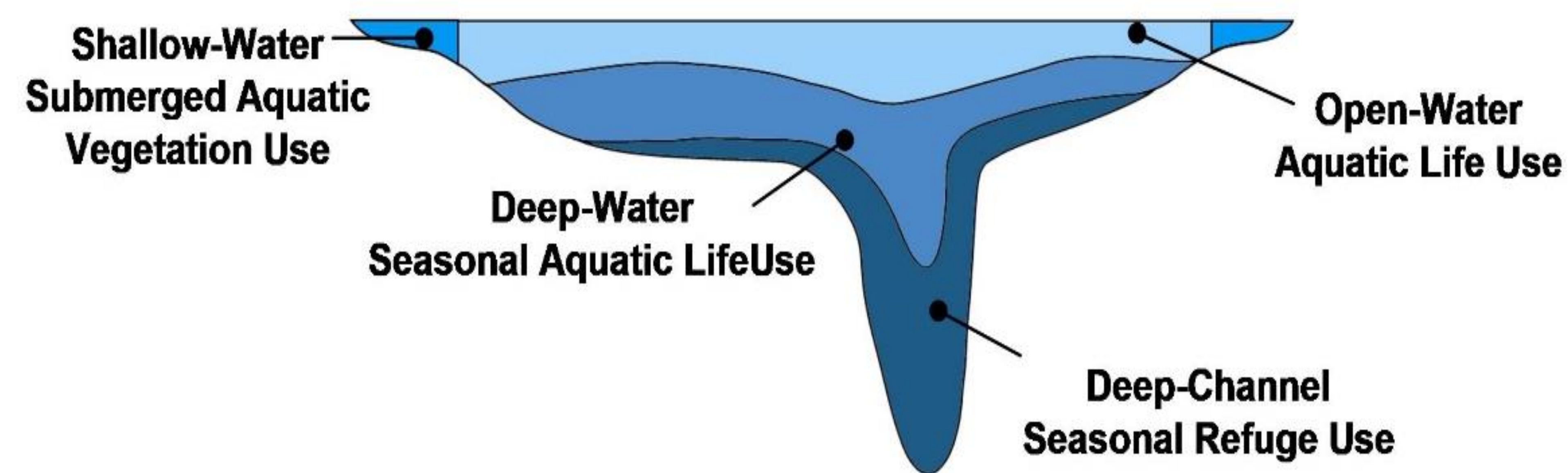
The overall Phase 7 suite of CBP is similar to the Phase 6 suite of Airshed, Land Use, Watershed and Bay models but all with refined inputs and expanded spatial and temporal scale.



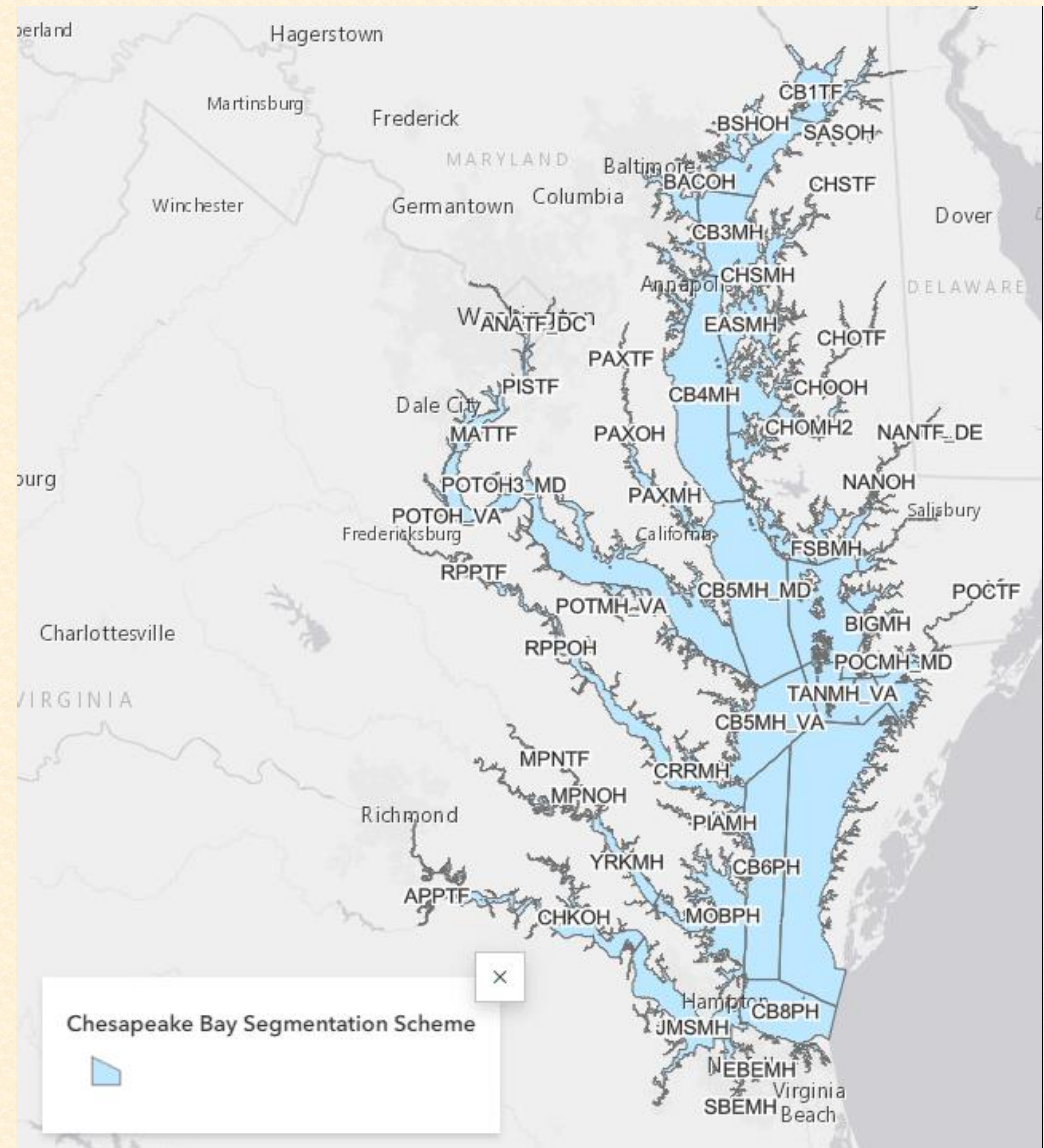
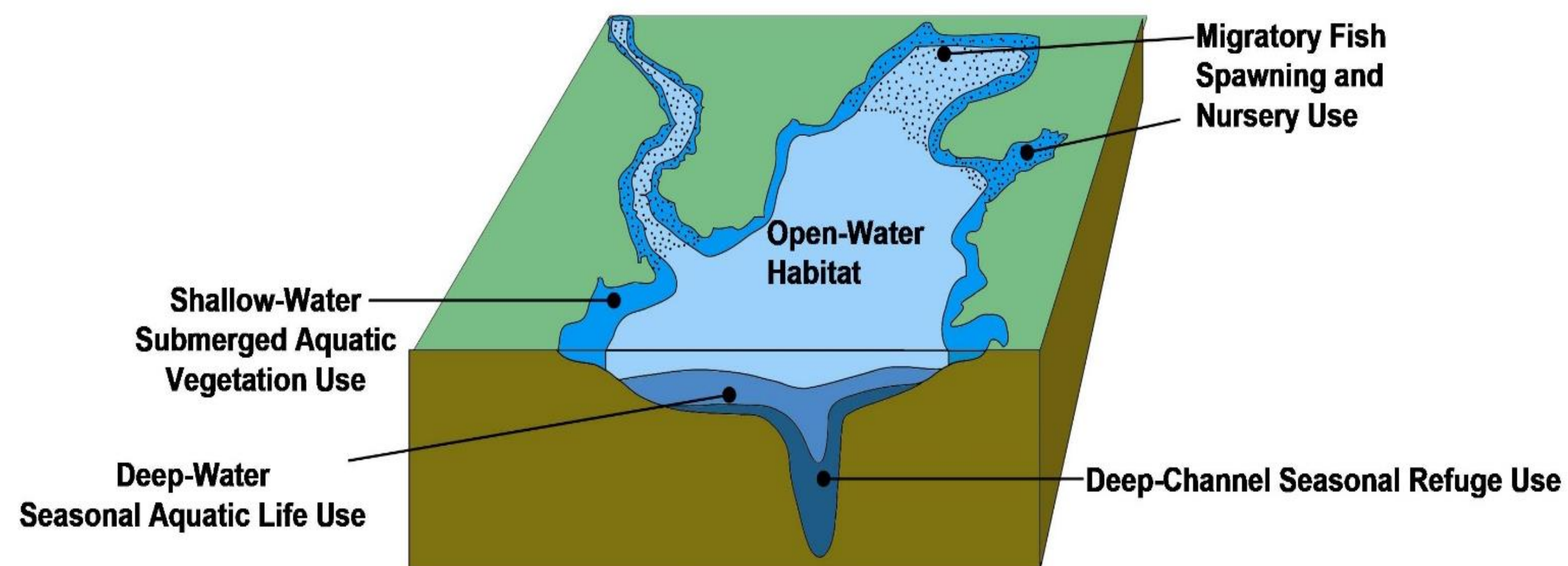
Restoring Chesapeake Water Quality & Living Resources

Goal: Meet living resource-based water quality standards in 92 segments of the tidal Chesapeake Bay.

A. Cross Section of Chesapeake Bay or Tidal Tributary



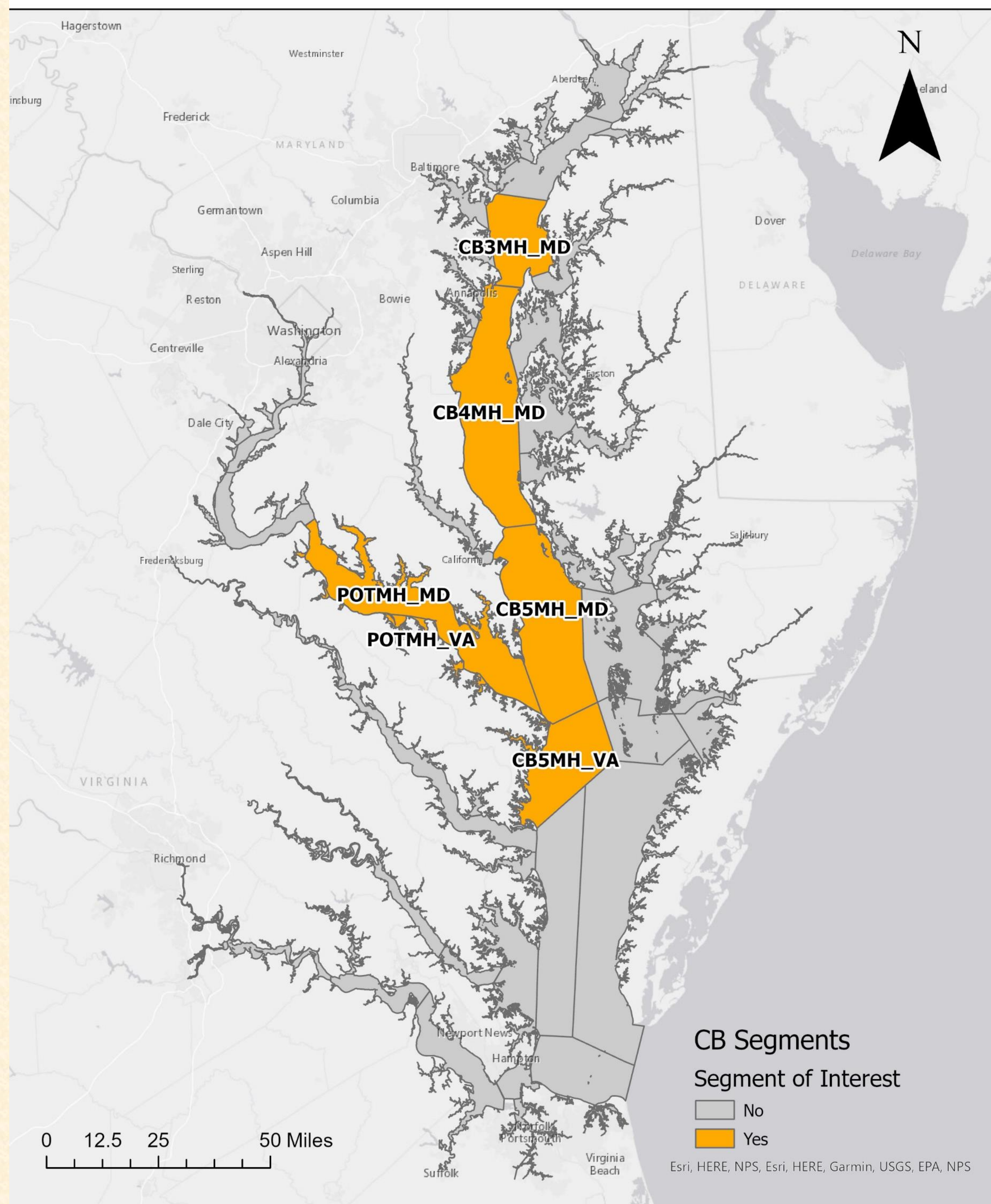
B. Oblique View of the "Chesapeake Bay" and its Tidal Tributaries





A Key 2010 TMDL Finding

Chesapeake Bay Segments 3, 4, 5, and Potomac Mesohaline



A Key 2010 TMDL Finding:
Meeting WQ Standards in
Deep-Water/Deep Channel,
meets them everywhere else.

Deep water and deep channel segments listed below were among the last to come into attainment

- Deep Channel
 - CB3MH
 - CB4MH
 - CB5MH
- Deep-Water
 - CB3MH
 - CB4MH
 - CB5MH
 - POTMH

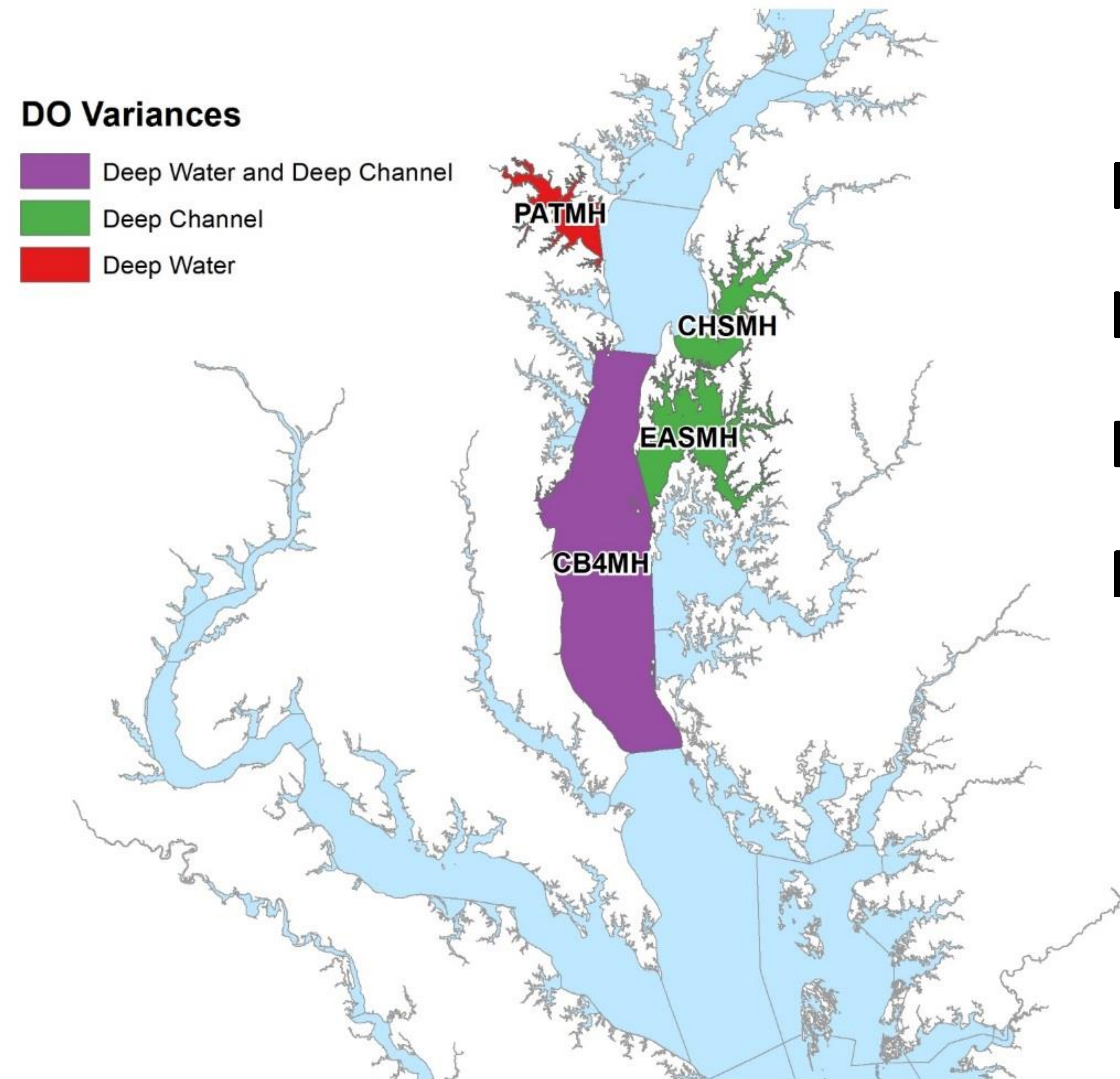
Bay TMDL, Section 6



From PSC December 19, 2017 Presentation

Maryland's Restoration Variances

Maryland's water quality standards regulations still contain restoration variances agreed to by the Partners/approved by EPA in 2010 and updated in 2012



Patapsco River Deep-water 7%

Lower Chester River Deep-channel 16%

Eastern Bay Deep-channel 2%

Middle Central Chesapeake Bay

- Deep-water 7%
- Deep-channel 2%



Open-Water - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Open-Water Use

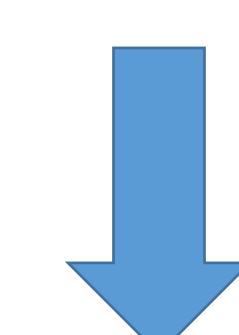
Segments NOT in Attainment

- CB2OH
- CB6PH
- CB7PH
- BSHOH
- SEVMH
- PAXOH
- PAXMH
- POTTF_DC
- POTTF_MD
- ANATF_DC
- ANATF_MD
- PISTF
- POTOH1_MD
- POTOMH_MD
- PMKOH
- YRKMH
- YRKPH
- ELIPH
- C&Dcanal
- ELKOH
- SASOH
- EASMH
- CHOTF
- CHOOH
- CHOMH2
- CHOMH1
- POCTF
- POCOH_MD
- POCOH_VA
- TANMH_VA

404 TN 41.7
TP



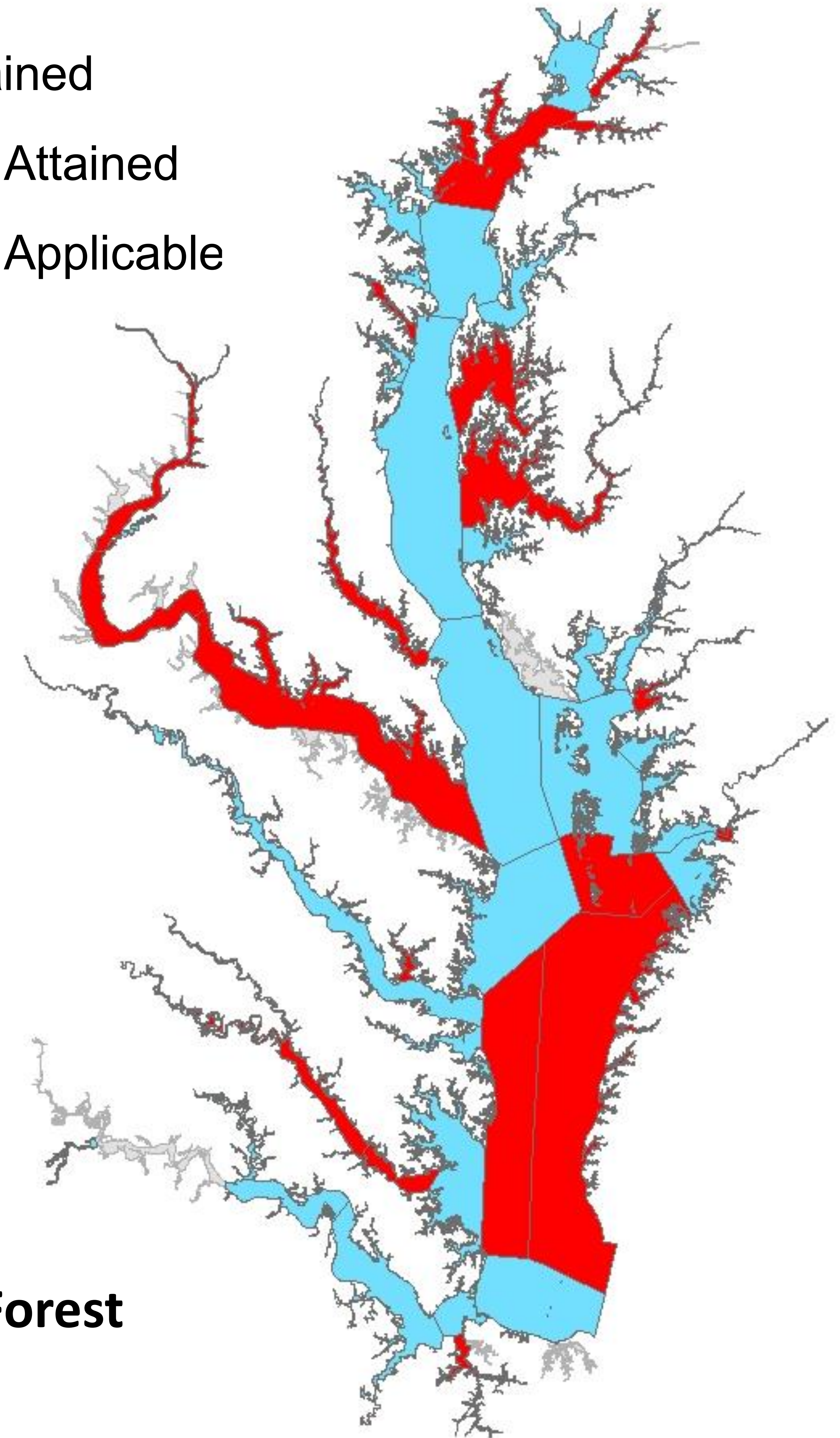
No Action



E3

All Forest

-  Attained
-  Not Attained
-  Not Applicable



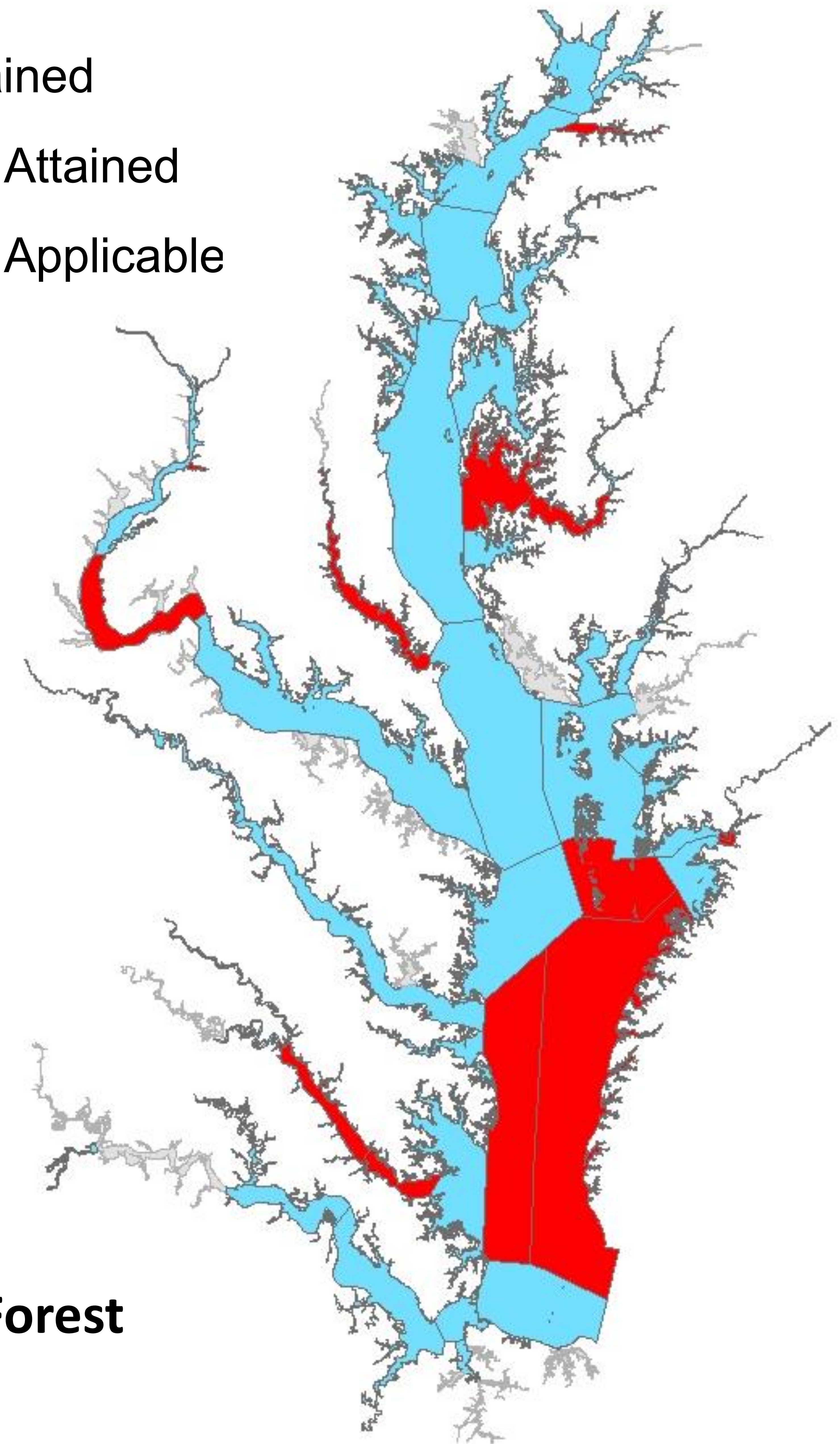
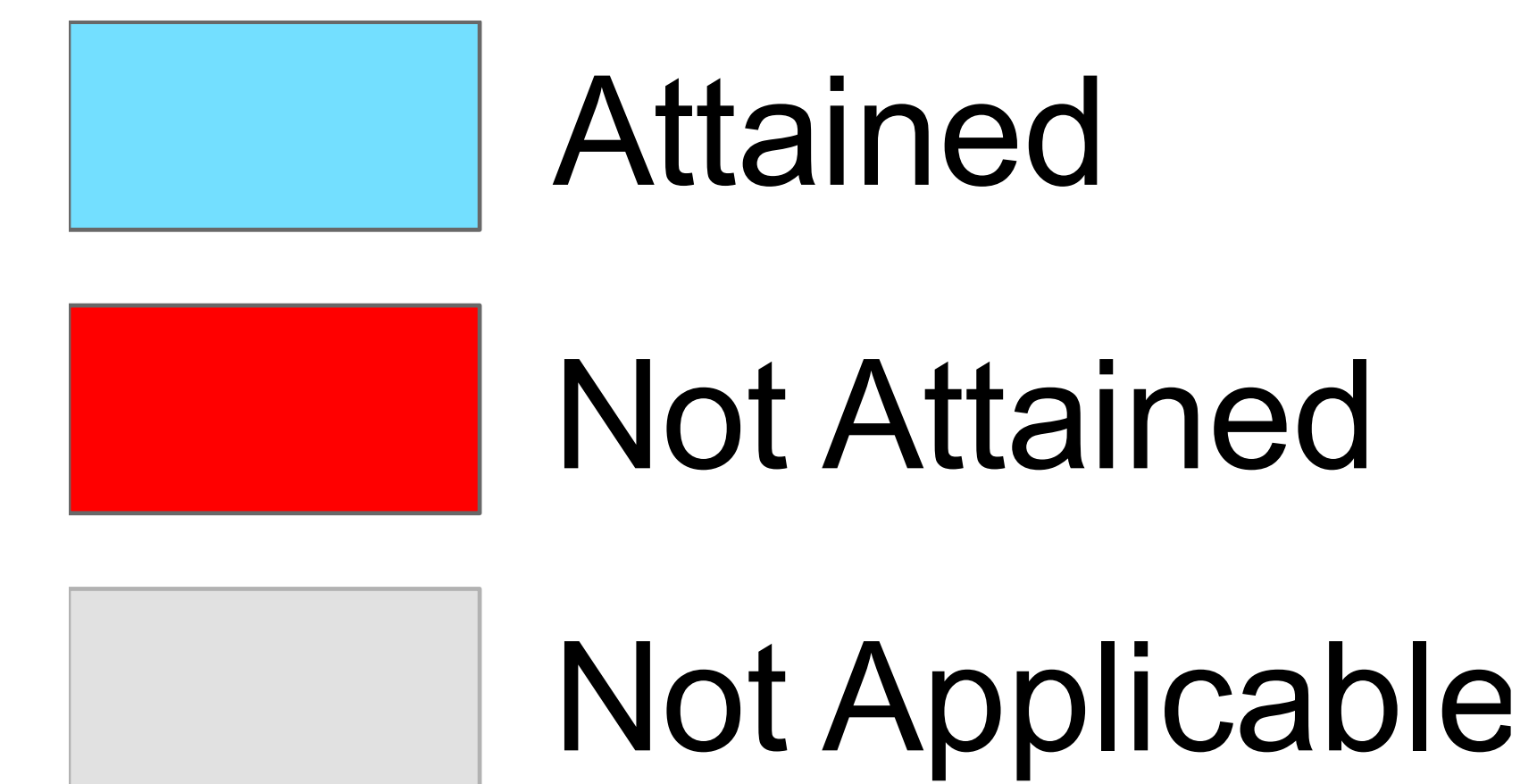


Open-Water - PSC December 19, 2017 Presentation

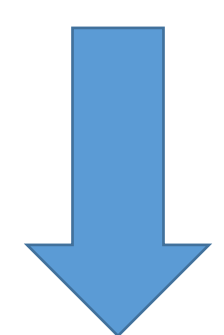
Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment

- CB6PH
- CB7PH
- PAXOH
- PAXMH
- ANATF_DC
- ANATF_MD
- PISTF
- POTOH1_MD
- YRKMH
- YRKPH
- C&Dcanal
- SASOH
- CHOMH2
- CHOMH1
- POCTF
- POCOH_MD
- POCOH_VA
- TANMH_VA



347 TN 30.4
TP



E3

All Forest

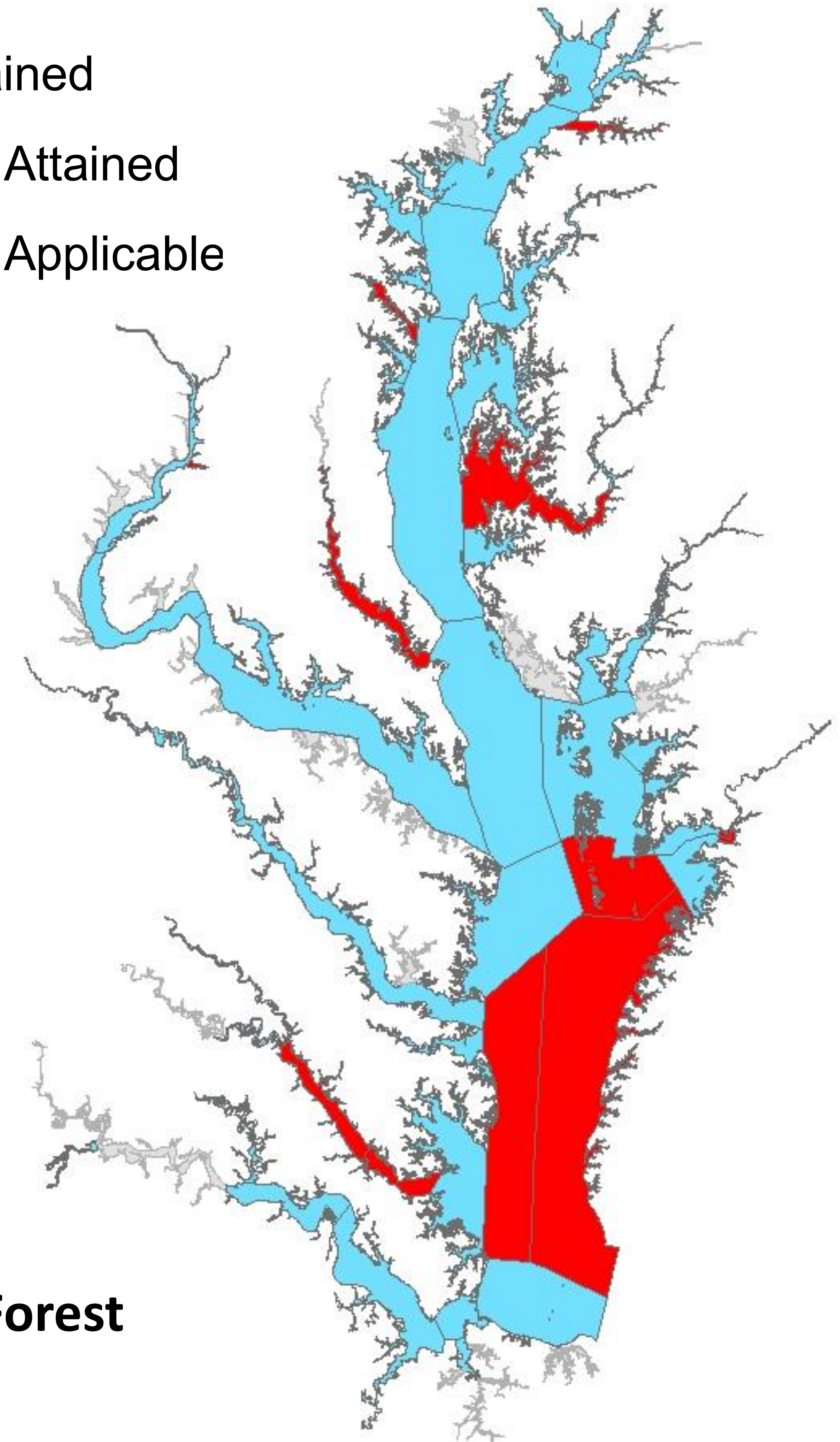
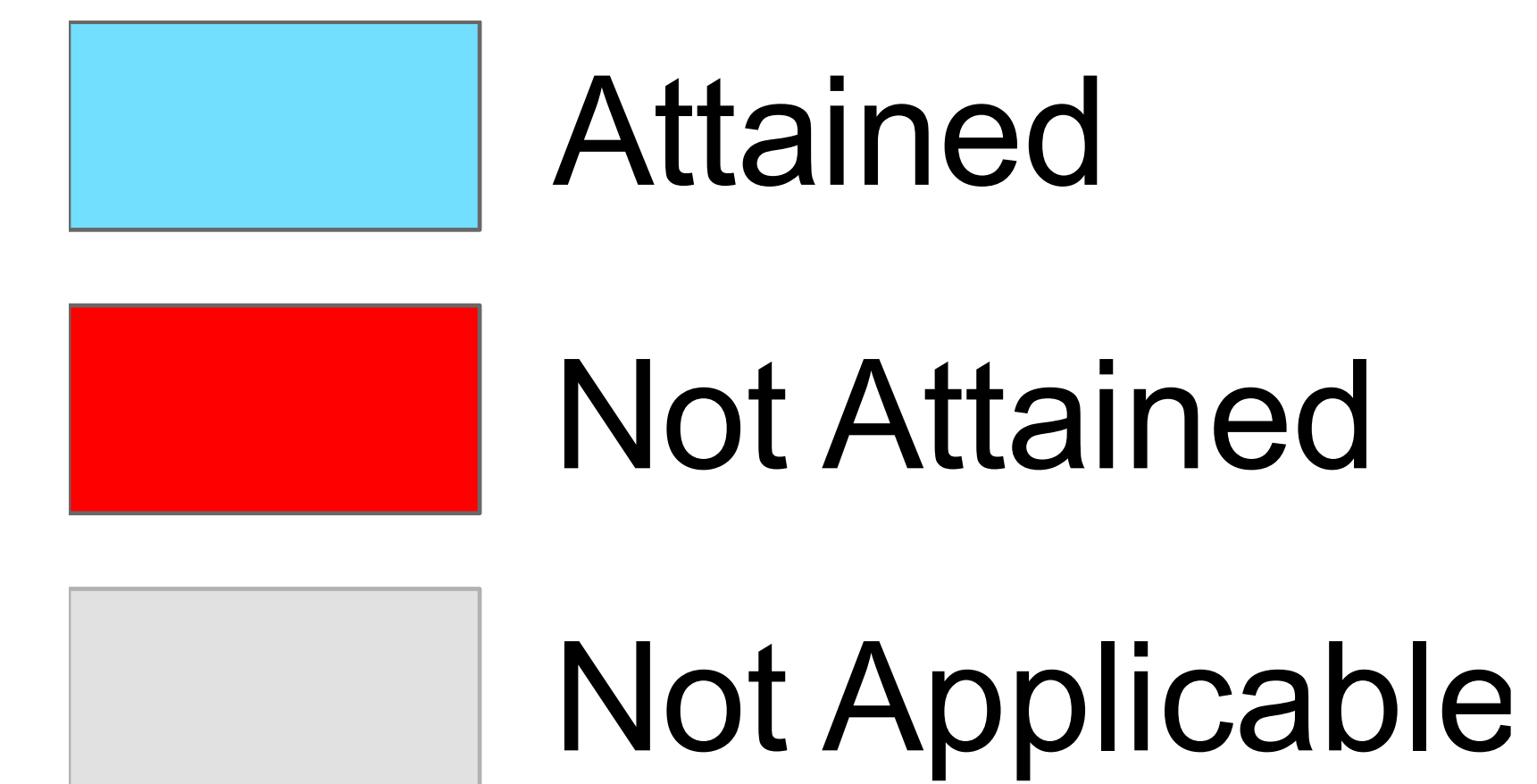


Open-Water - PSC December 19, 2017 Presentation

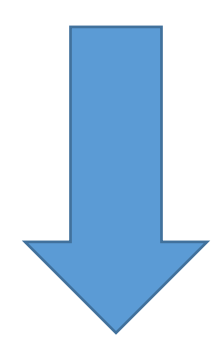
Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment

- CB6PH
- CB7PH
- PAXOH
- PAXMH
- ANATF_DC
- ANATF_MD
- PISTF
- POTOH1_MD
- YRKMH
- YRKPH
- C&Dcanal
- SASOH
- CHOMH2
- CHOMH1
- POCTF
- POCOH_MD
- POCOH_VA
- TANMH_VA



337 TN
23.7 TP



E3

All Forest

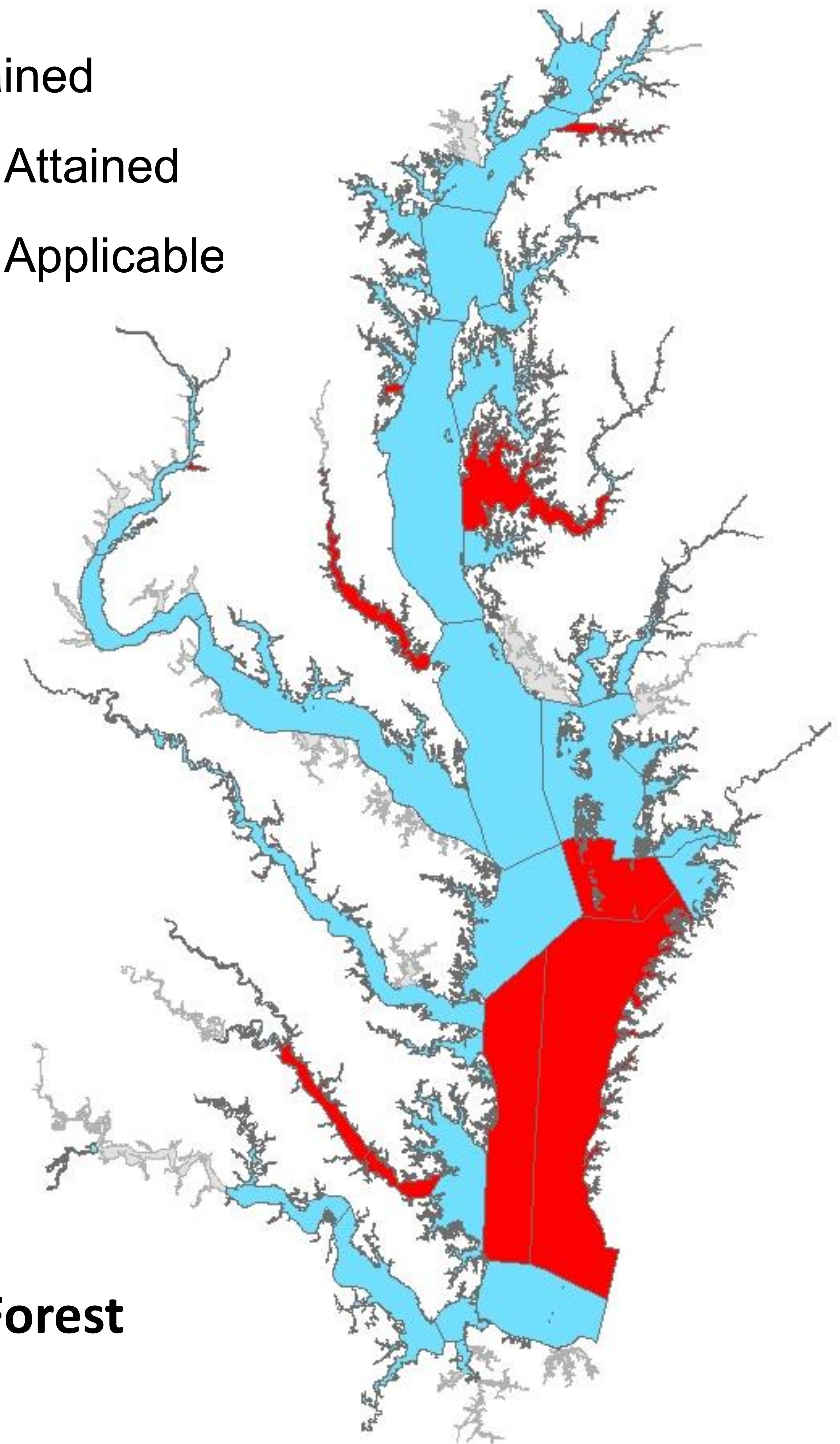
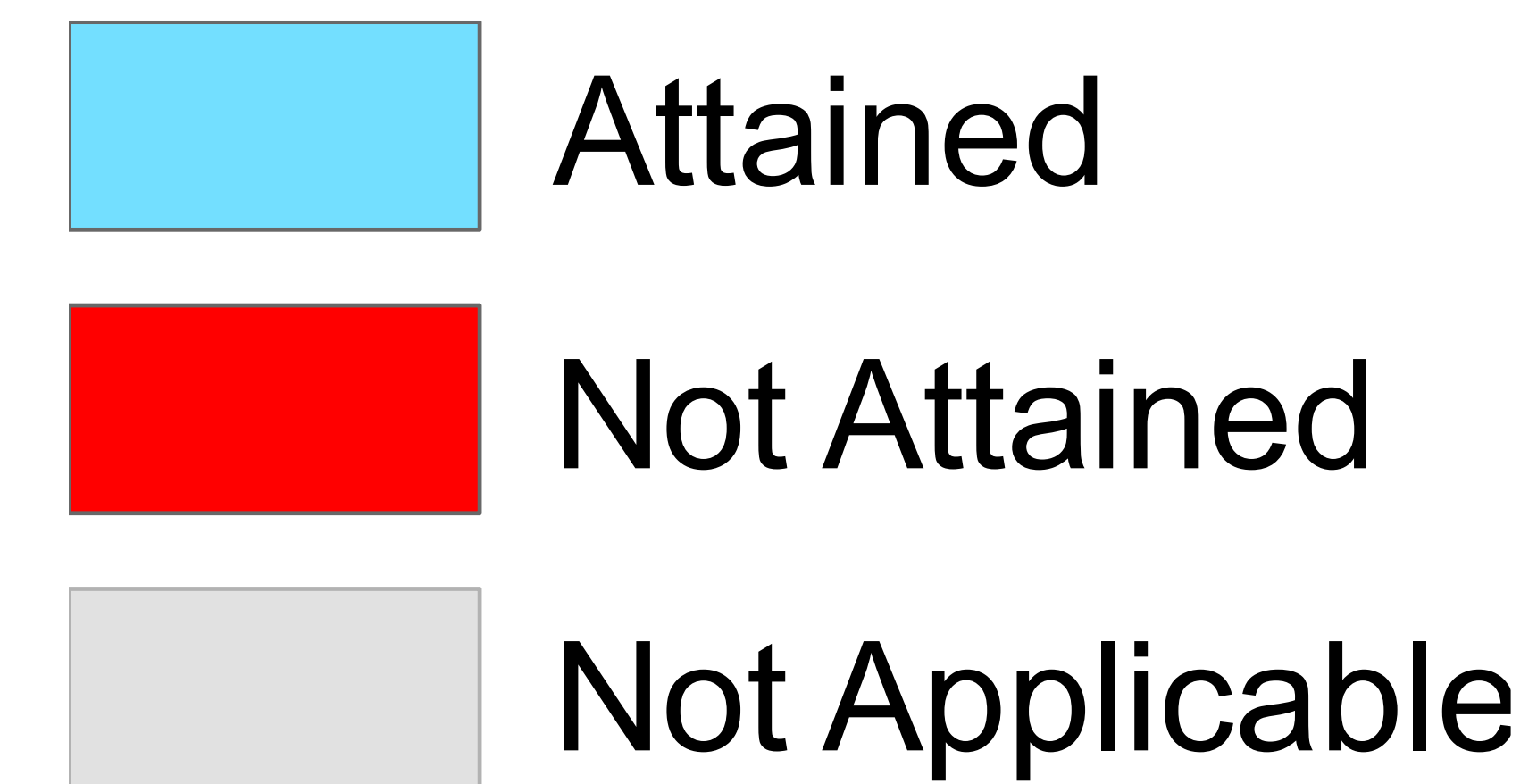


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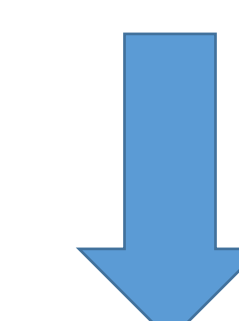
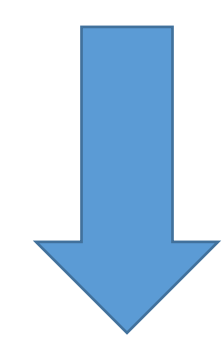
Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment

- CB6PH
- CB7PH
- WSTMH
- PAXOH
- PAXMH
- ANATF_DC
- ANATF_MD
- PISTF
- YRKMH
- YRKPH
- SASOH
- CHOMH2
- CHOMH1
- TANMH_VA



337 TN
23.7 TP



E3

All Forest

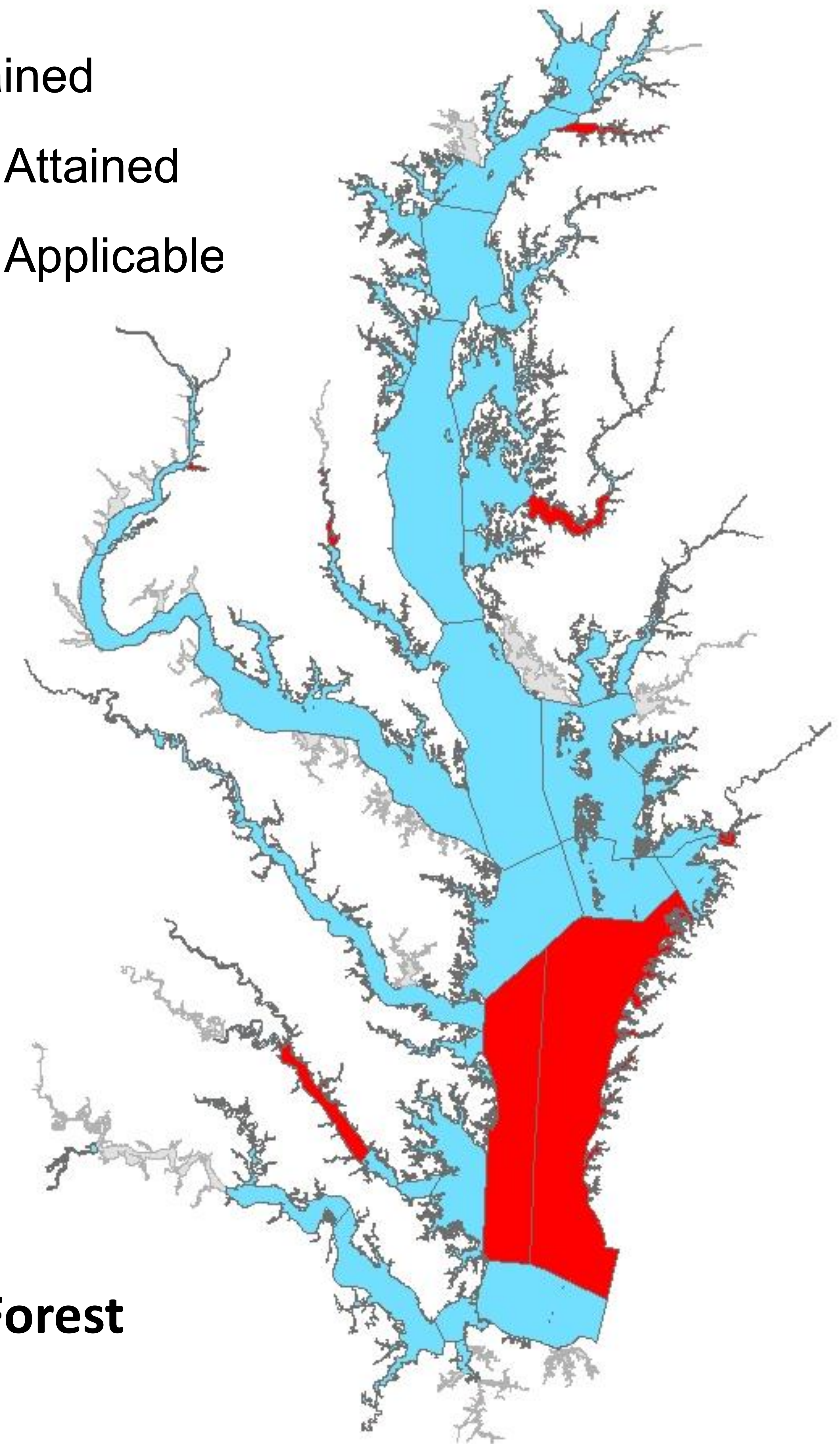
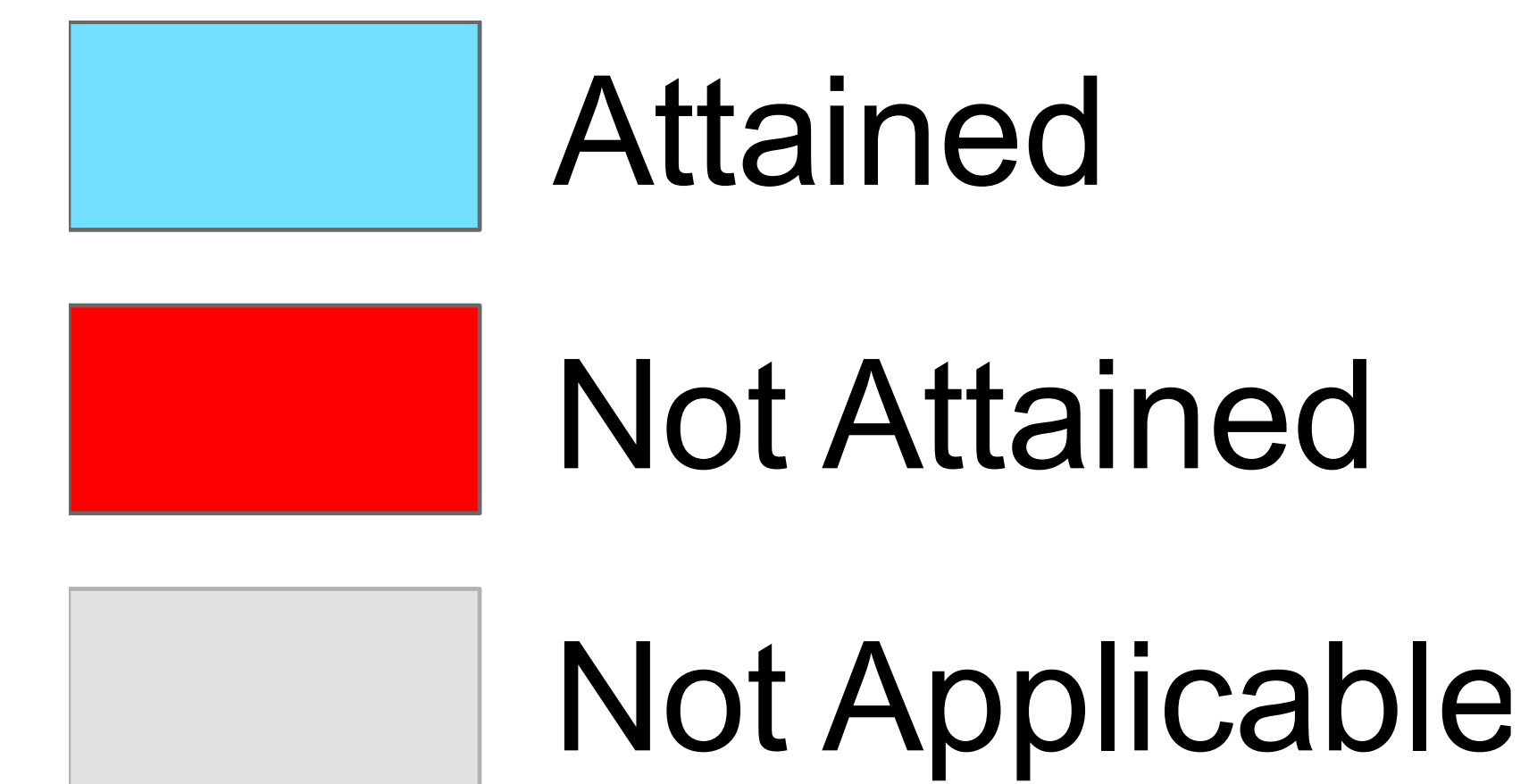


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Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment

- CB6PH
- CB7PH
- PAXOH
- ANATF_DC
- ANATF_MD
- PISTF
- YRKMH
- SASOH
- CHOMH2
- POCTF
- POCOH_MD
- POCOH_VA



317 TN 21.9

TP



E3

All Forest



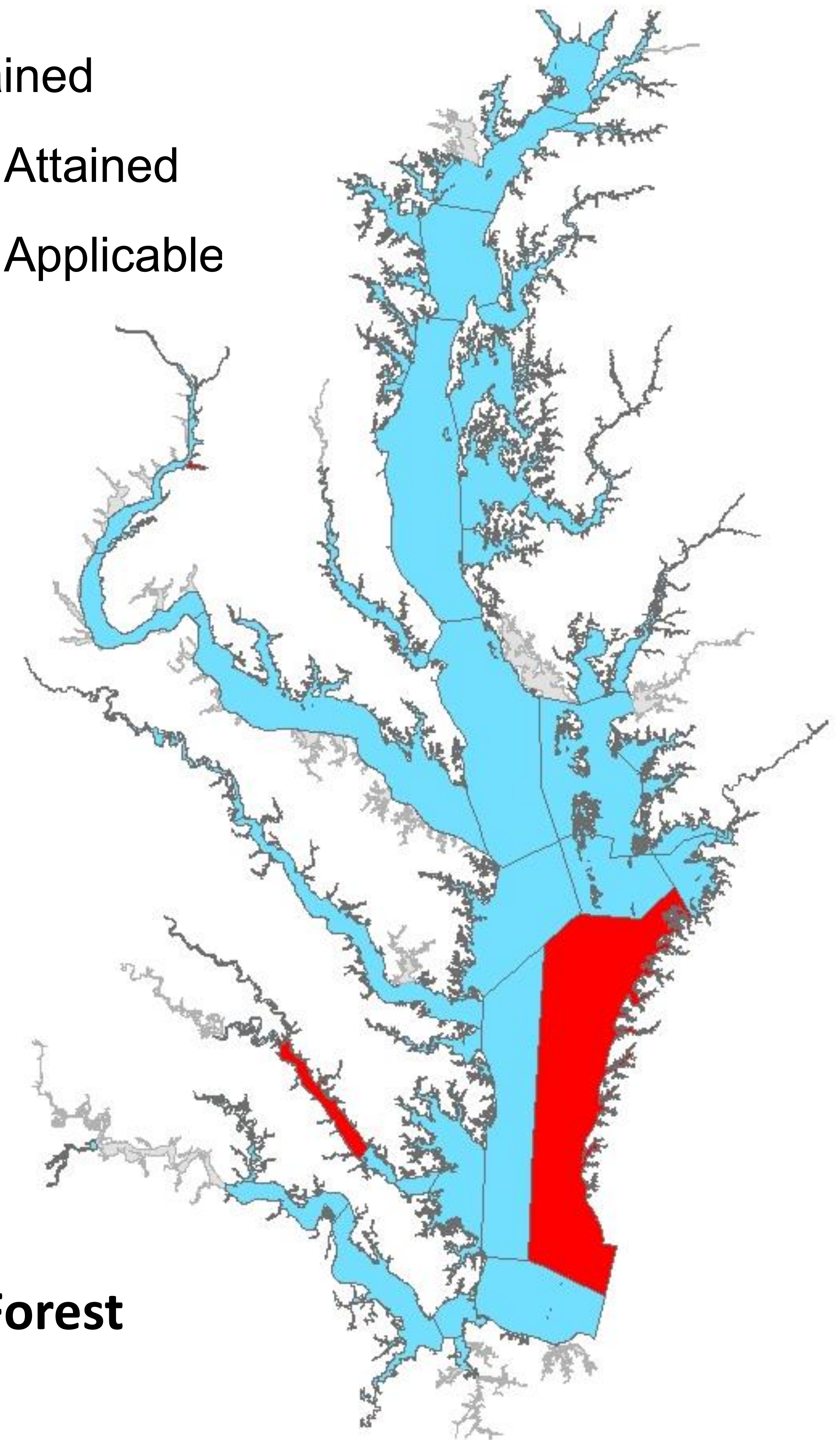
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Segments Attaining Oxygen Standards: Open-Water Use

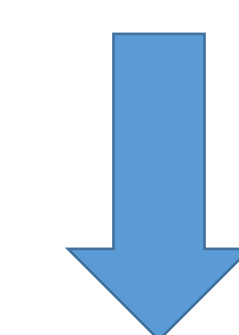
Segments NOT in Attainment

- CB6PH
- CB7PH
- PAXOH
- ANATF_DC
- ANATF_MD
- PISTF
- YRKMH
- SASOH
- CHOMH2
- POCTF
- POCOH_MD
- POCOH_VA

-  Attained
-  Not Attained
-  Not Applicable



266 TN 16.9
TP



E3

All Forest

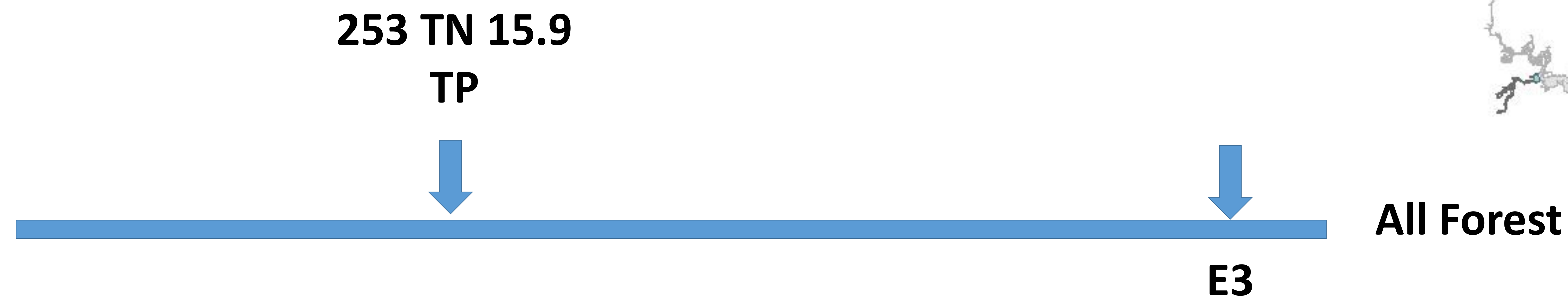
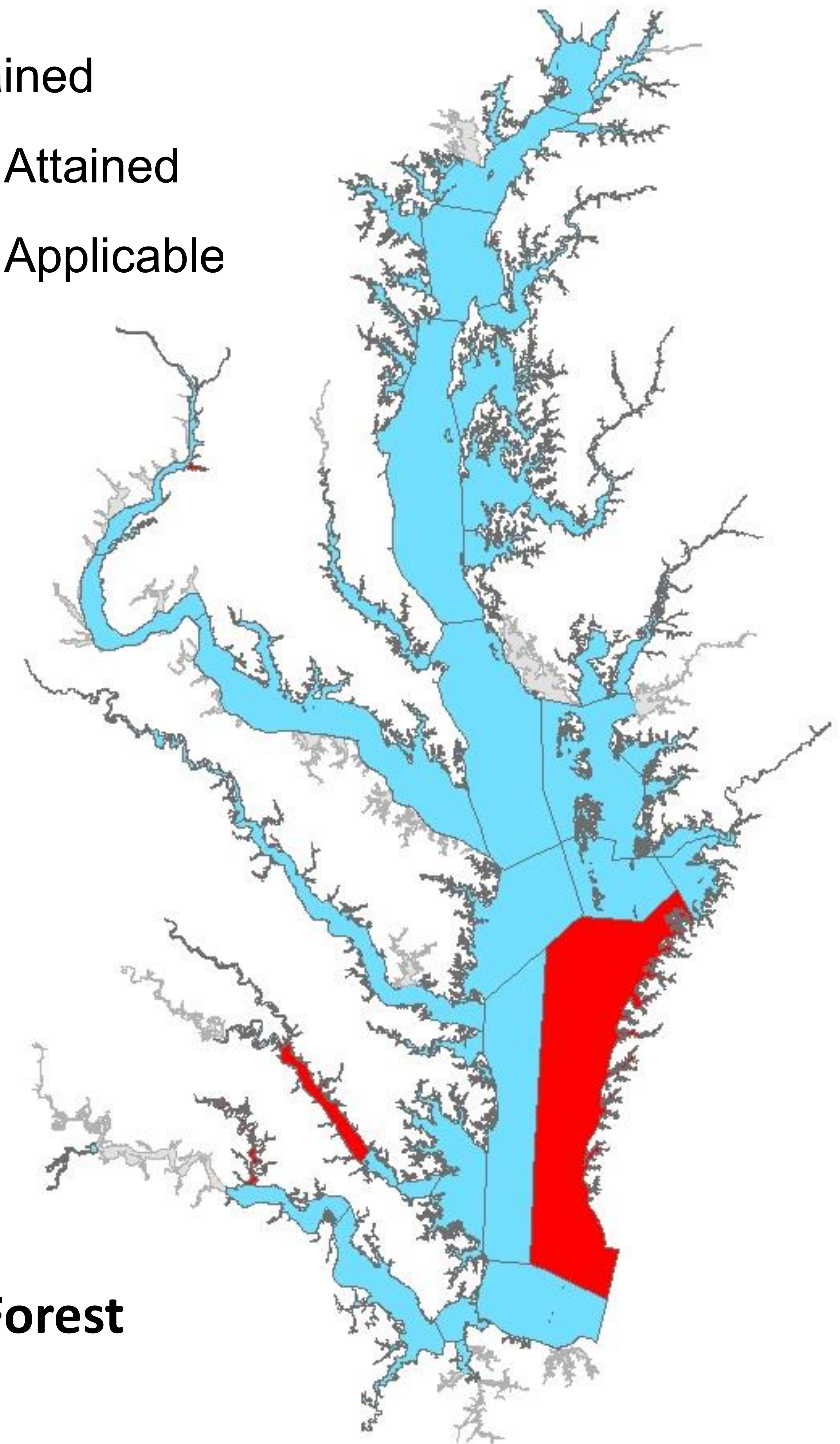
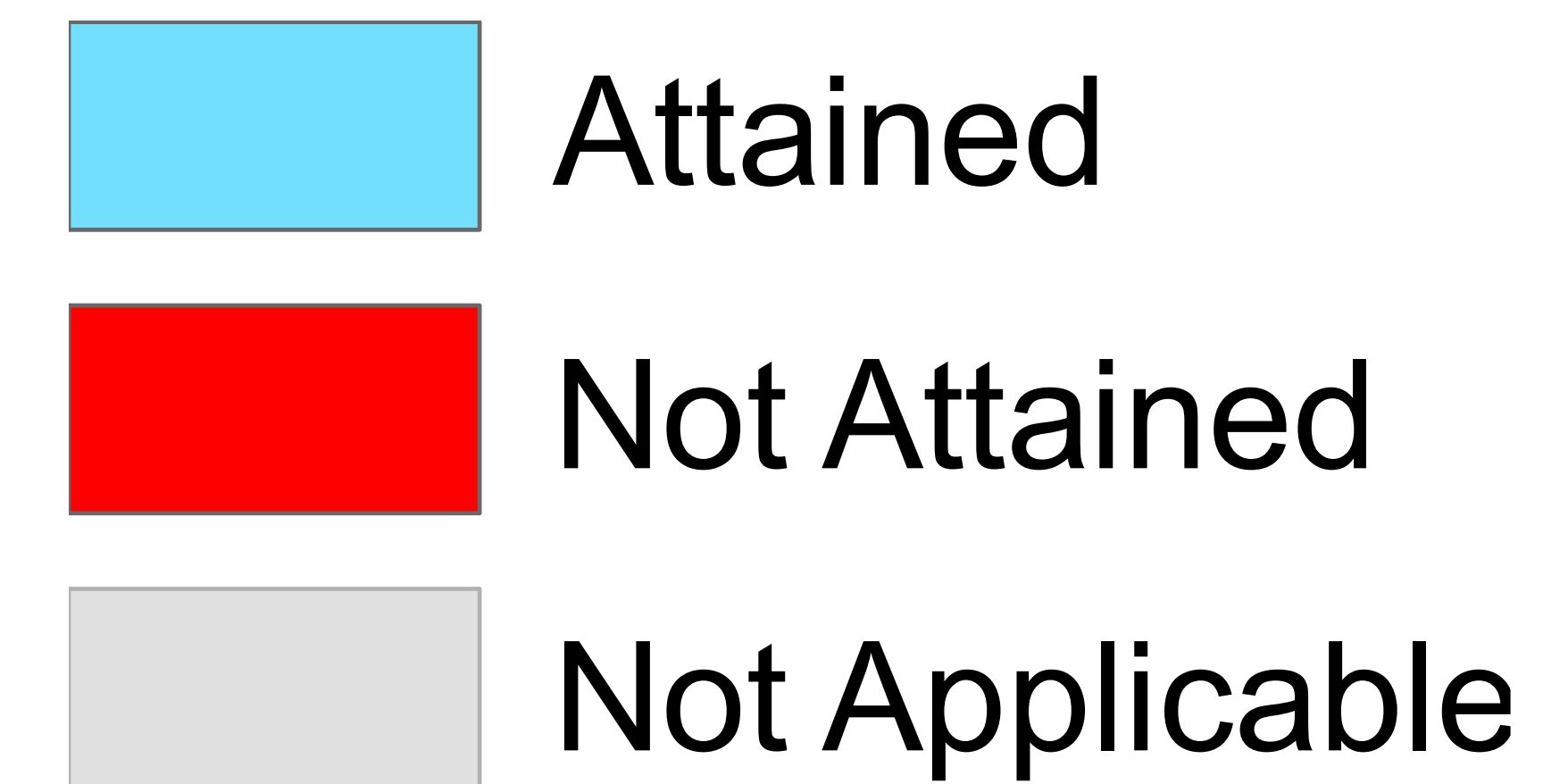


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Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment

- CB7PH
- ANATF_DC
- ANATF_MD
- PISTF
- YRKMH
- CHKOH



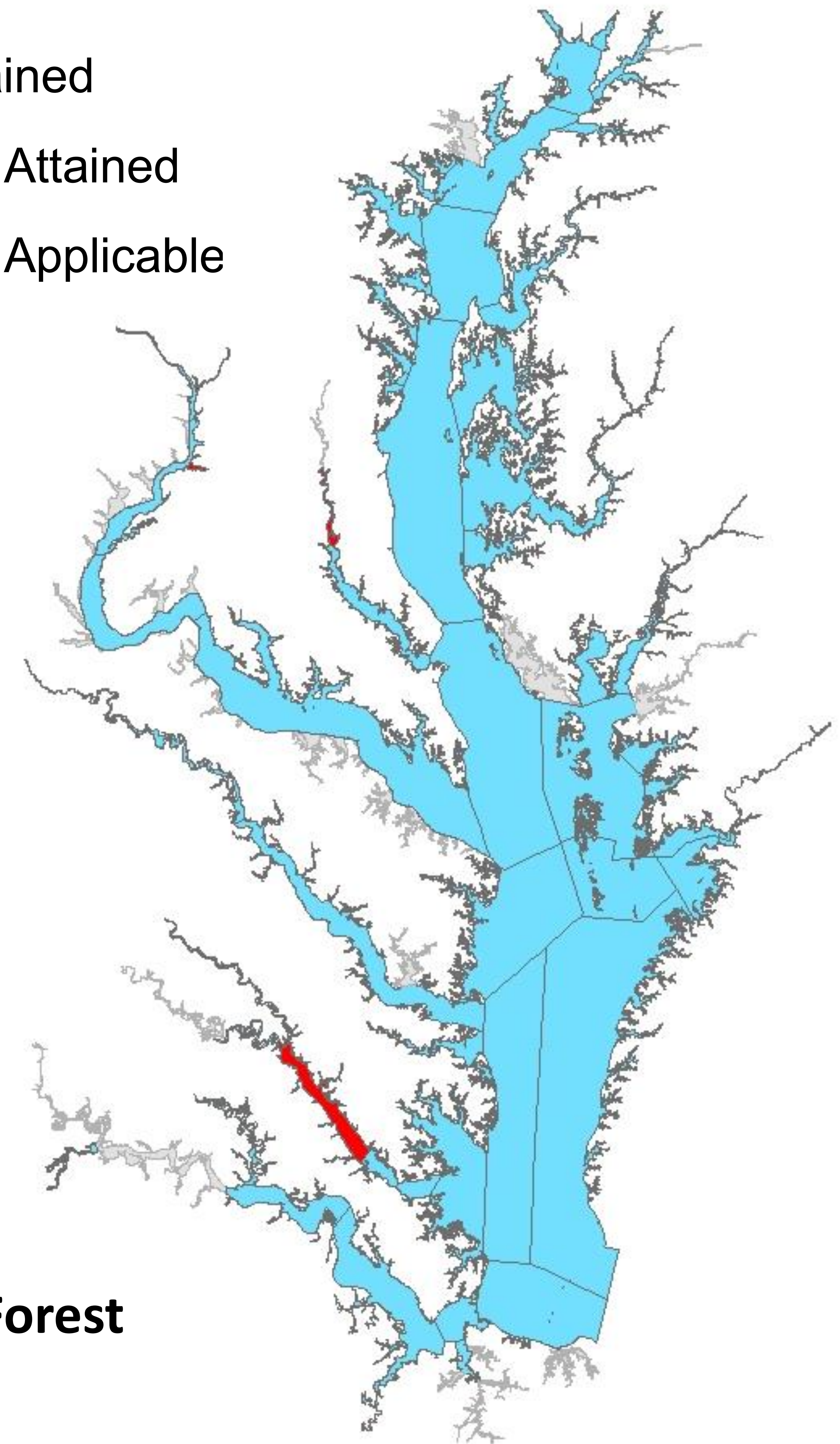
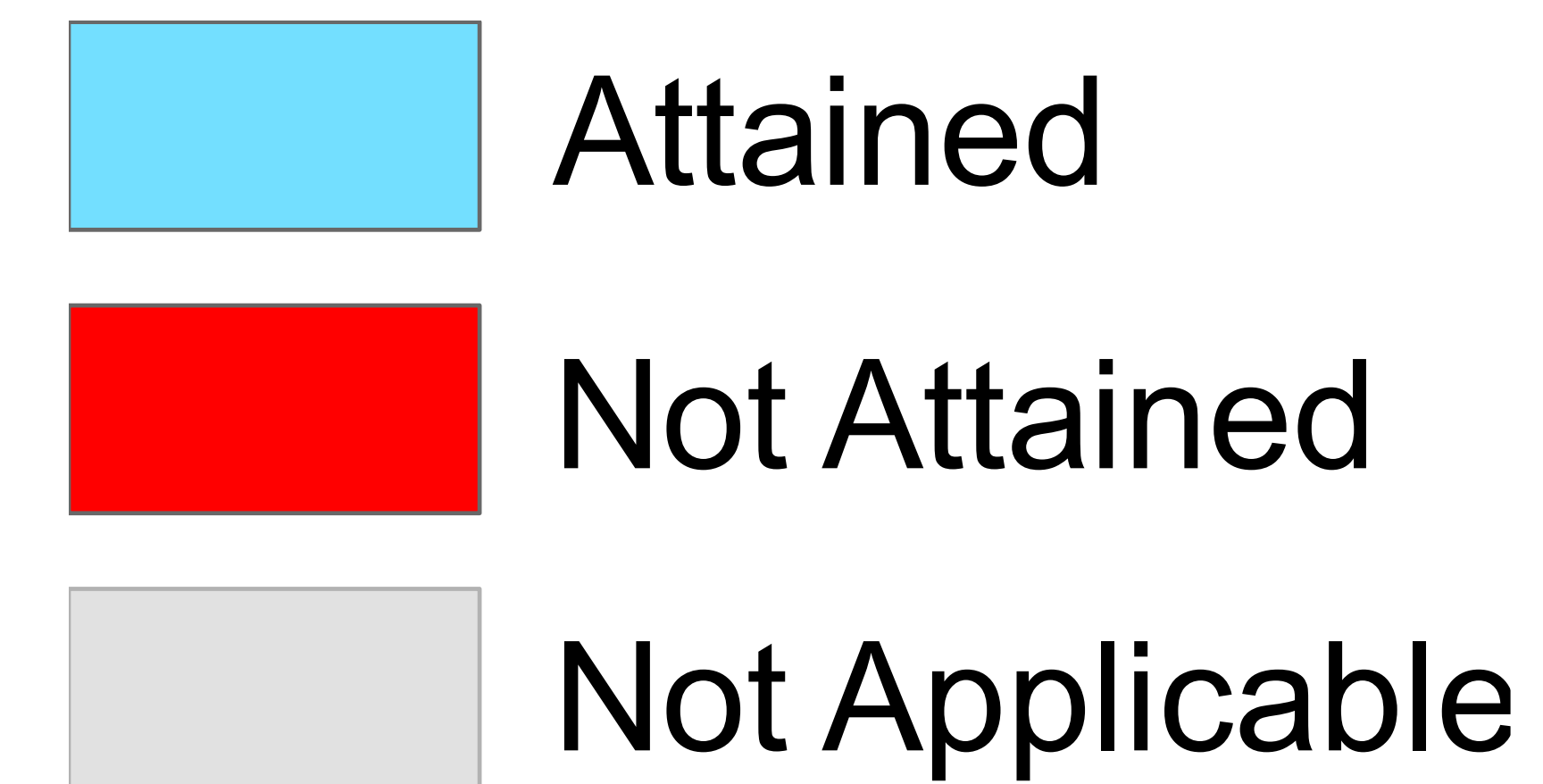


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Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment

- PAXOH
- ANATF_DC
- ANATF_MD
- PISTF
- YRKMH



224 TN 14.8
TP



E3

All Forest

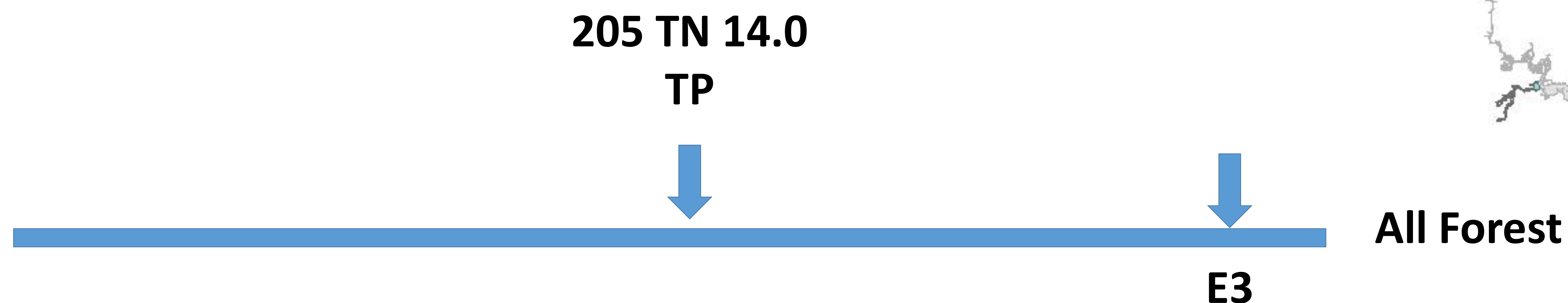
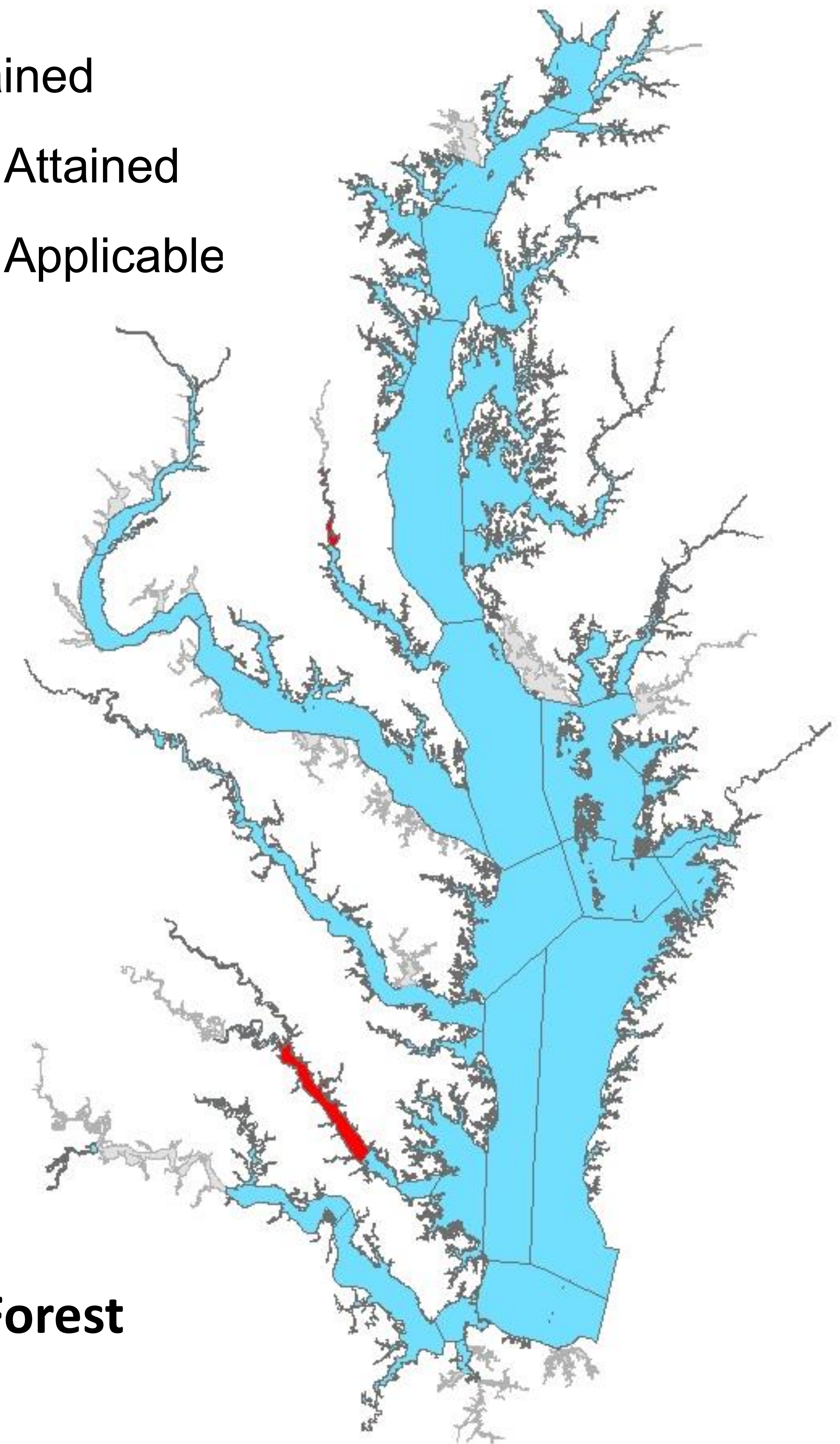
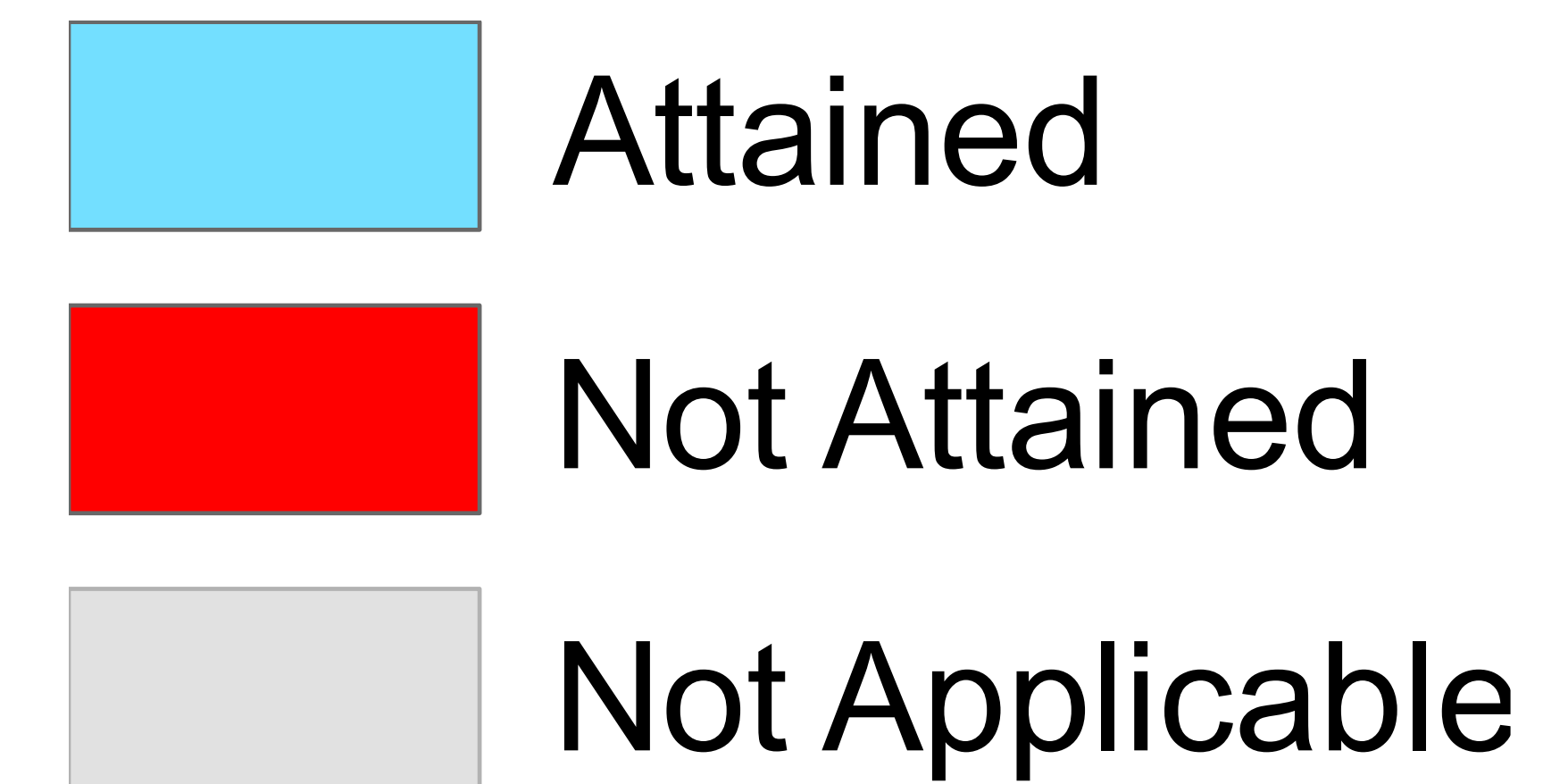


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Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment

- ANATF_MD
- YRKMH

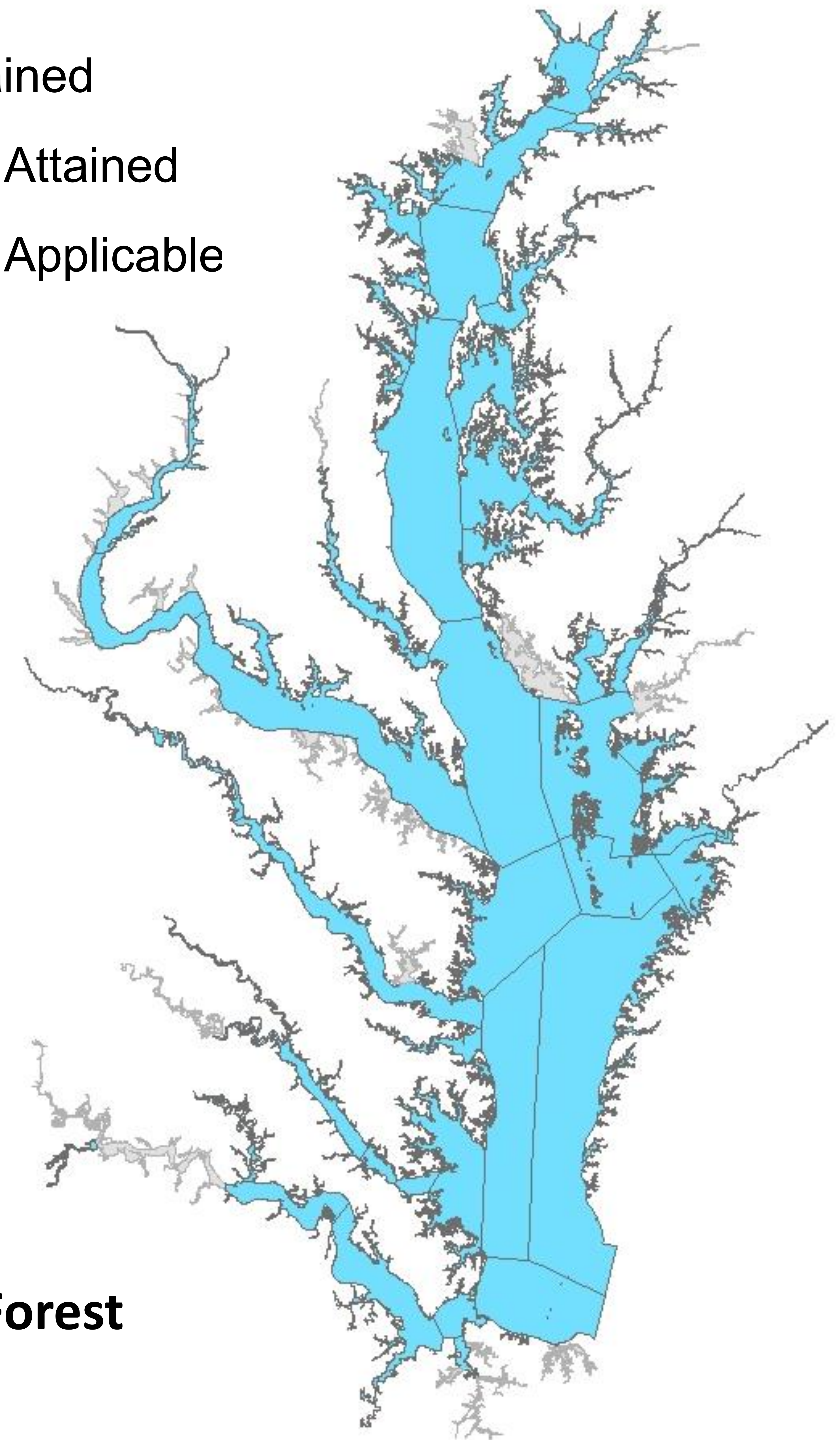
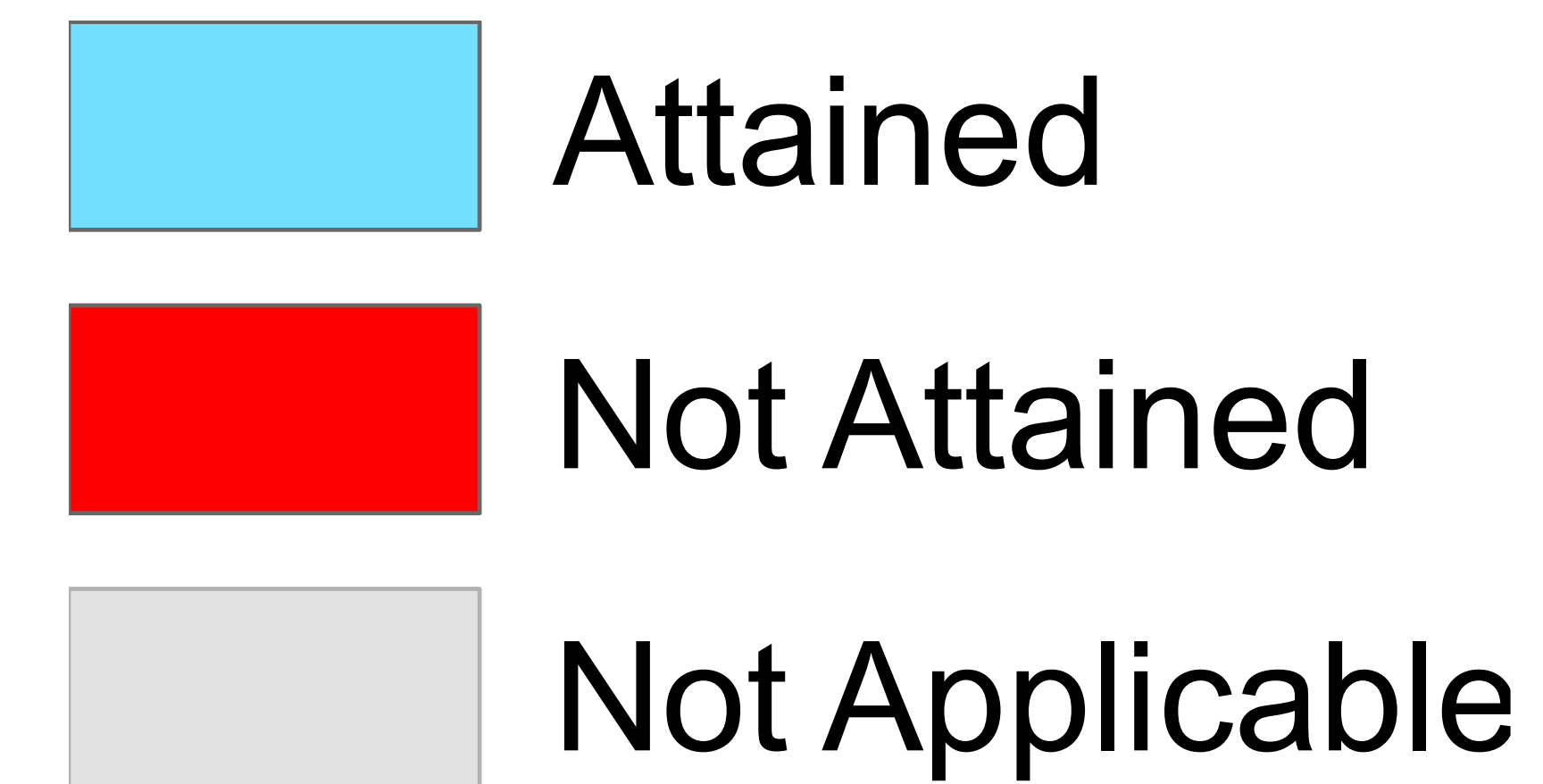




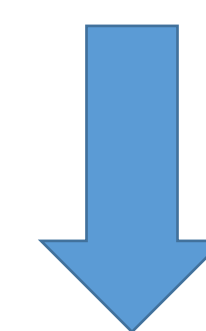
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Segments Attaining Oxygen Standards: Open-Water Use

Segments NOT in Attainment



195 TN 13.7
TP



E3

All Forest



Deep-Water - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

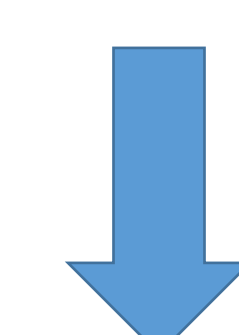
- CB3MH
- CB4MH
- CB5MH_MD
- PATMH
- MAGMH
- SEVMH
- PAXMH
- POTMH
- RPPMH
- CHSMH
- EASMH

404 TN 41.7

TP

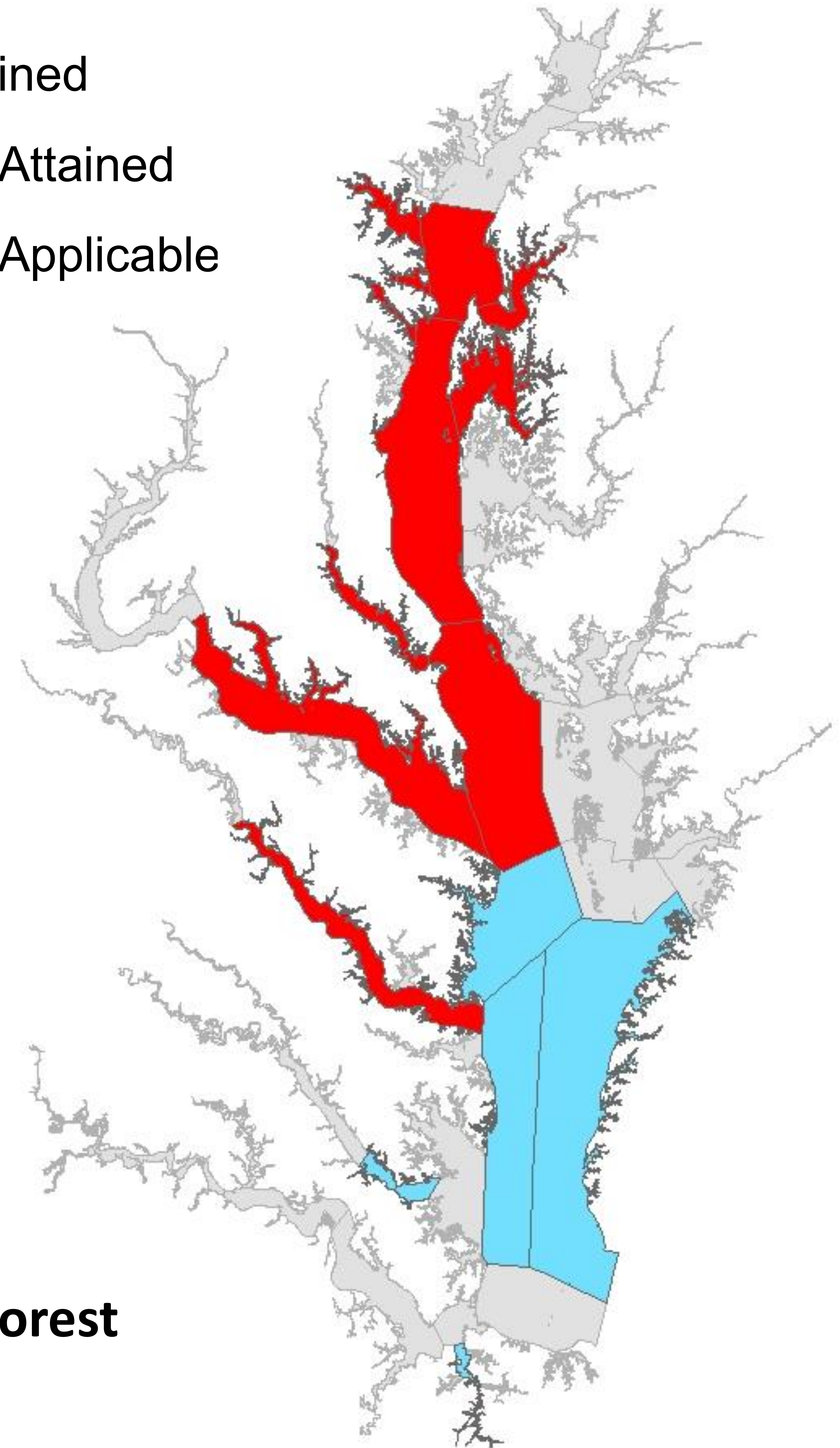
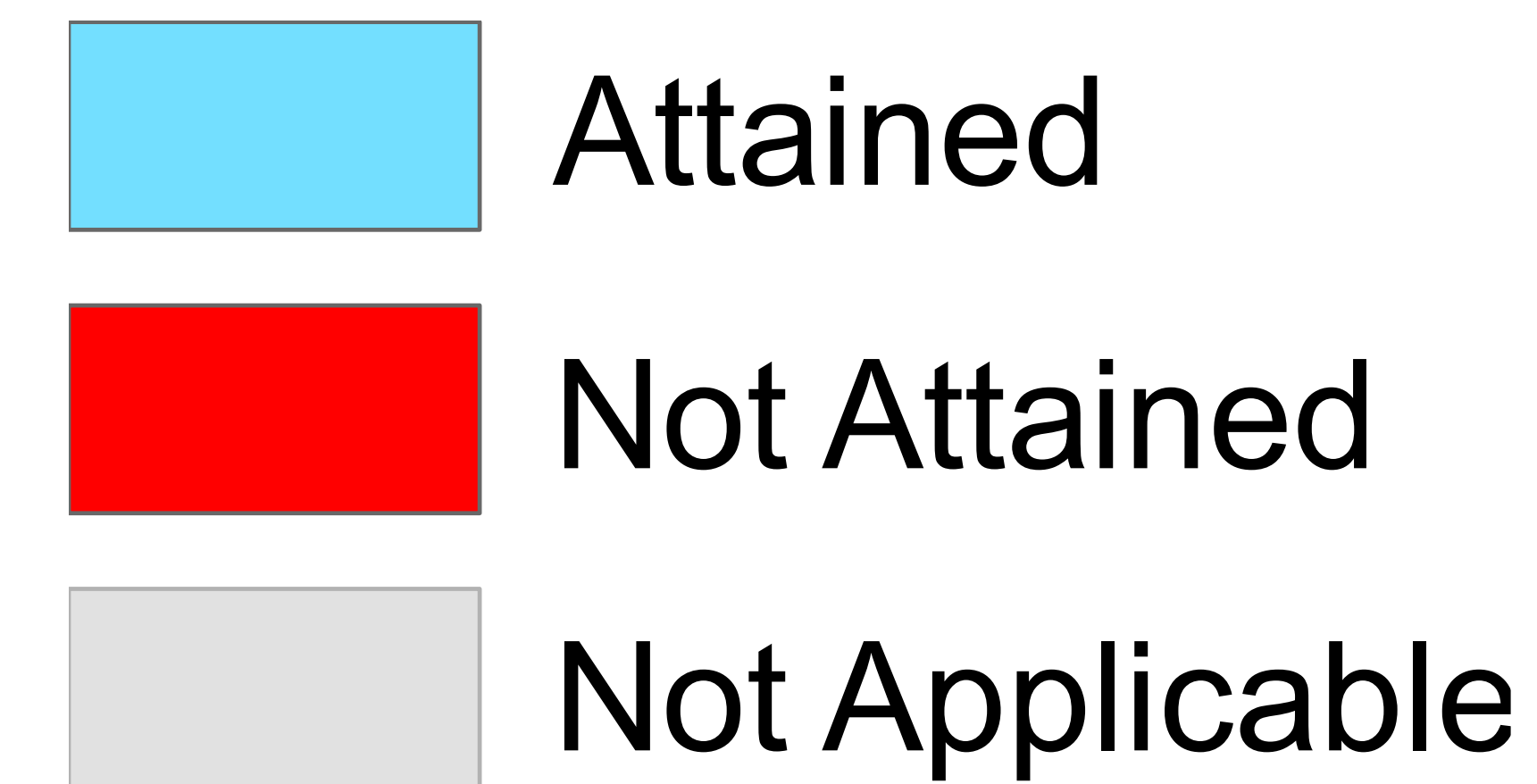


No Action



E3

All Forest



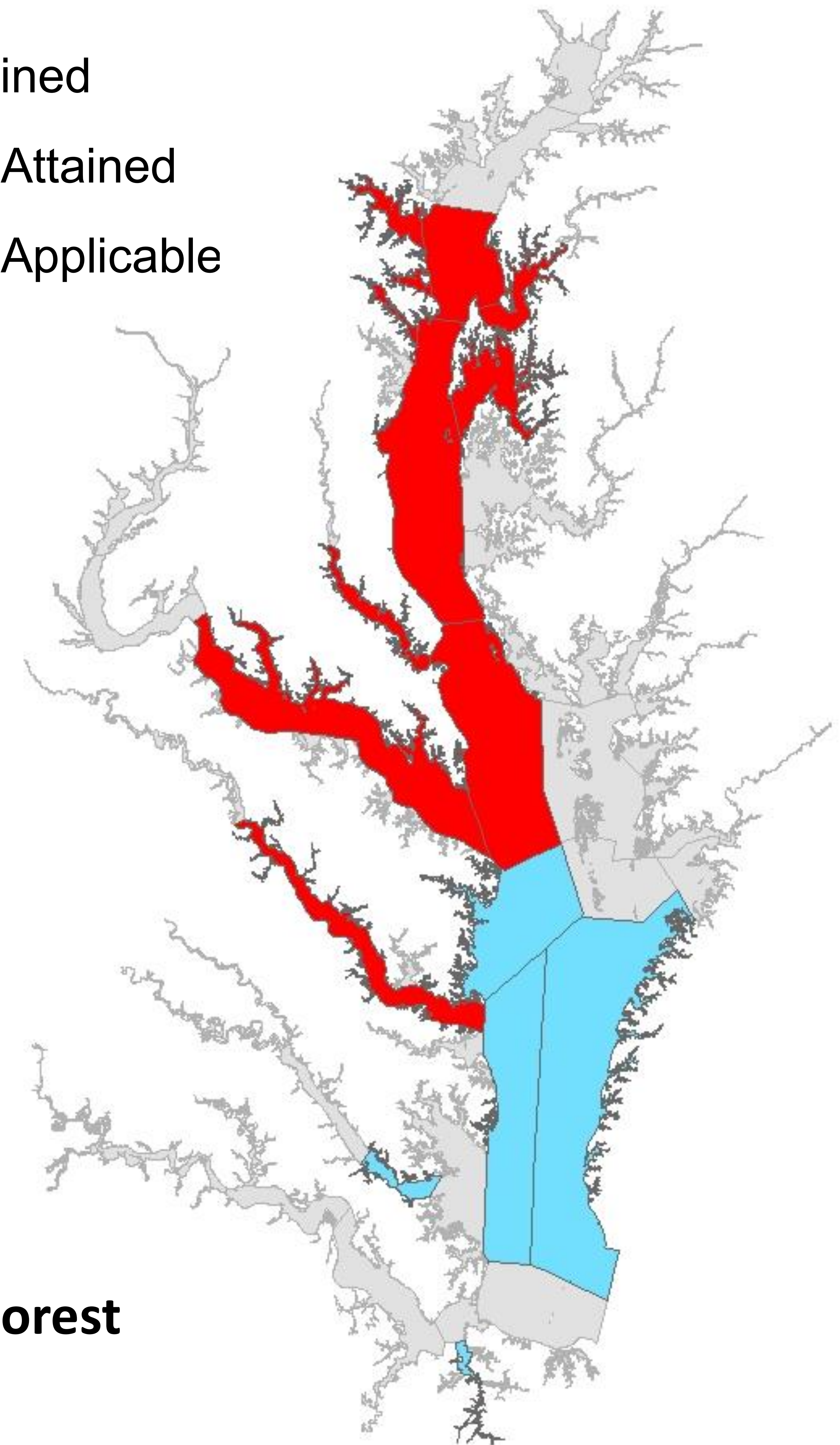
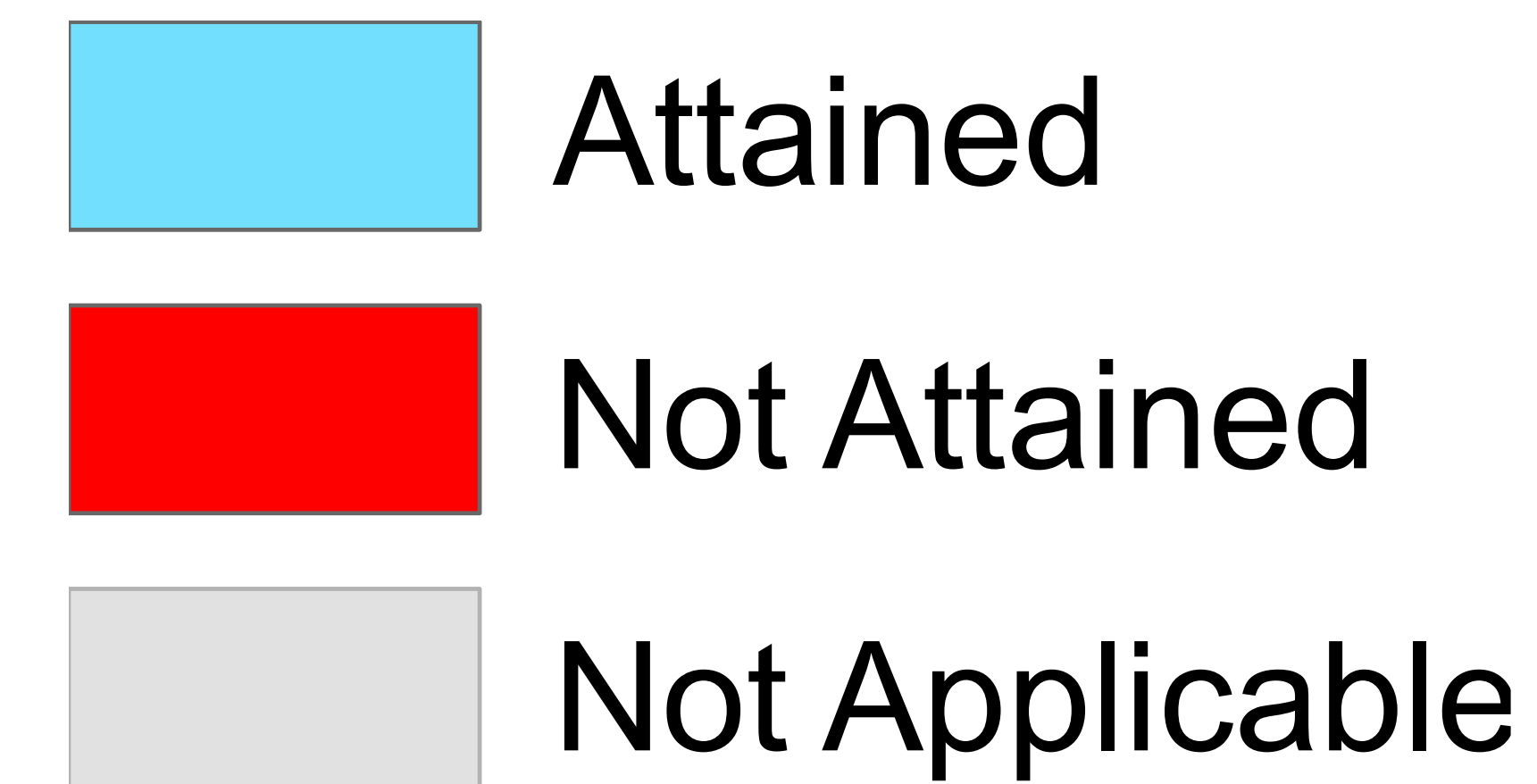


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Segments Attaining Oxygen Standards: Deep-Water Use

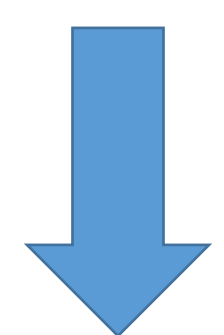
Segments NOT in Attainment

- CB3MH
- CB4MH
- CB5MH_MD
- PATMH
- MAGMH
- SEVMH
- PAXMH
- POTMH
- RPPMH
- CHSMH
- EASMH



347 TN 30.4

TP



E3

All Forest

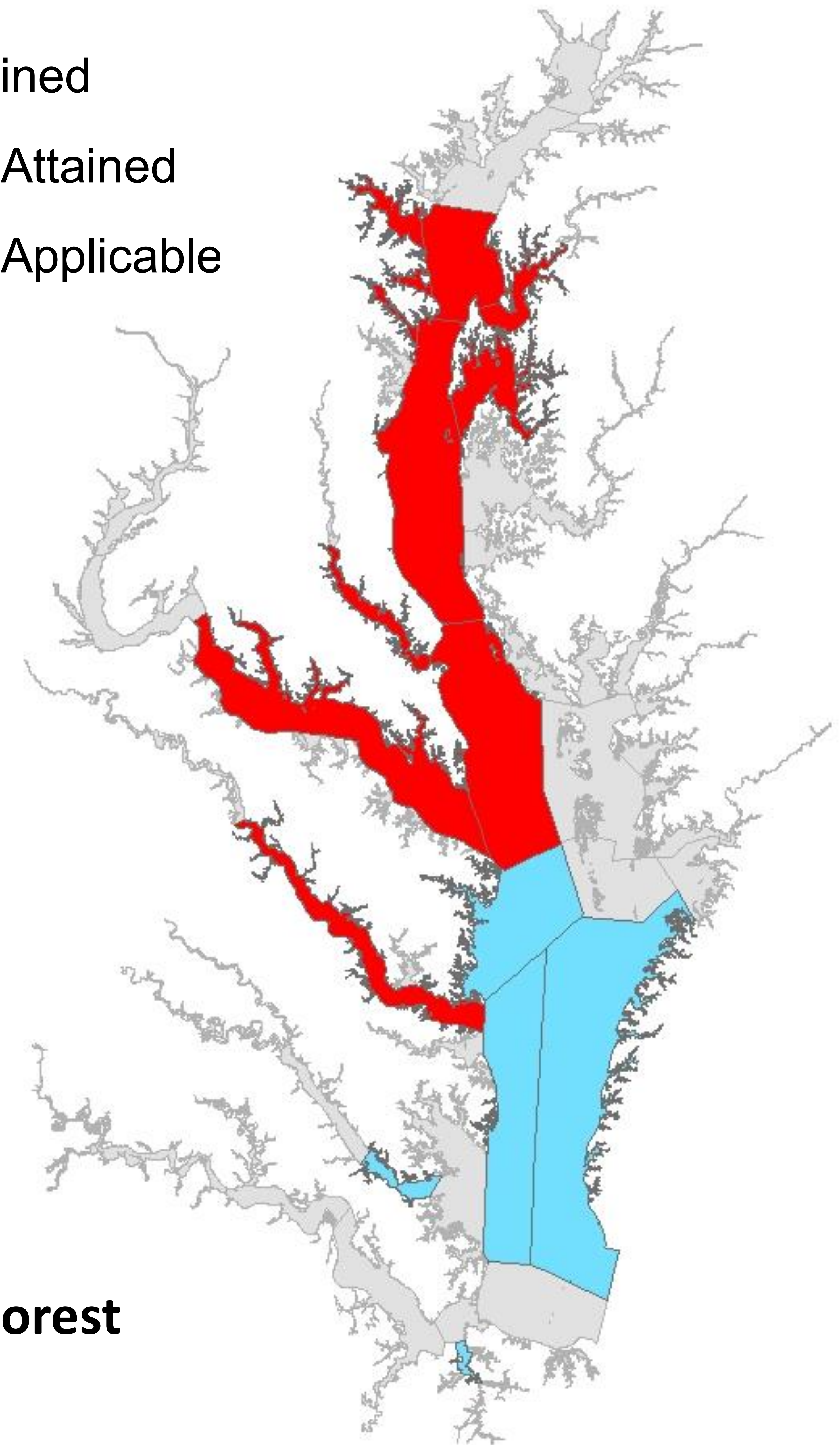
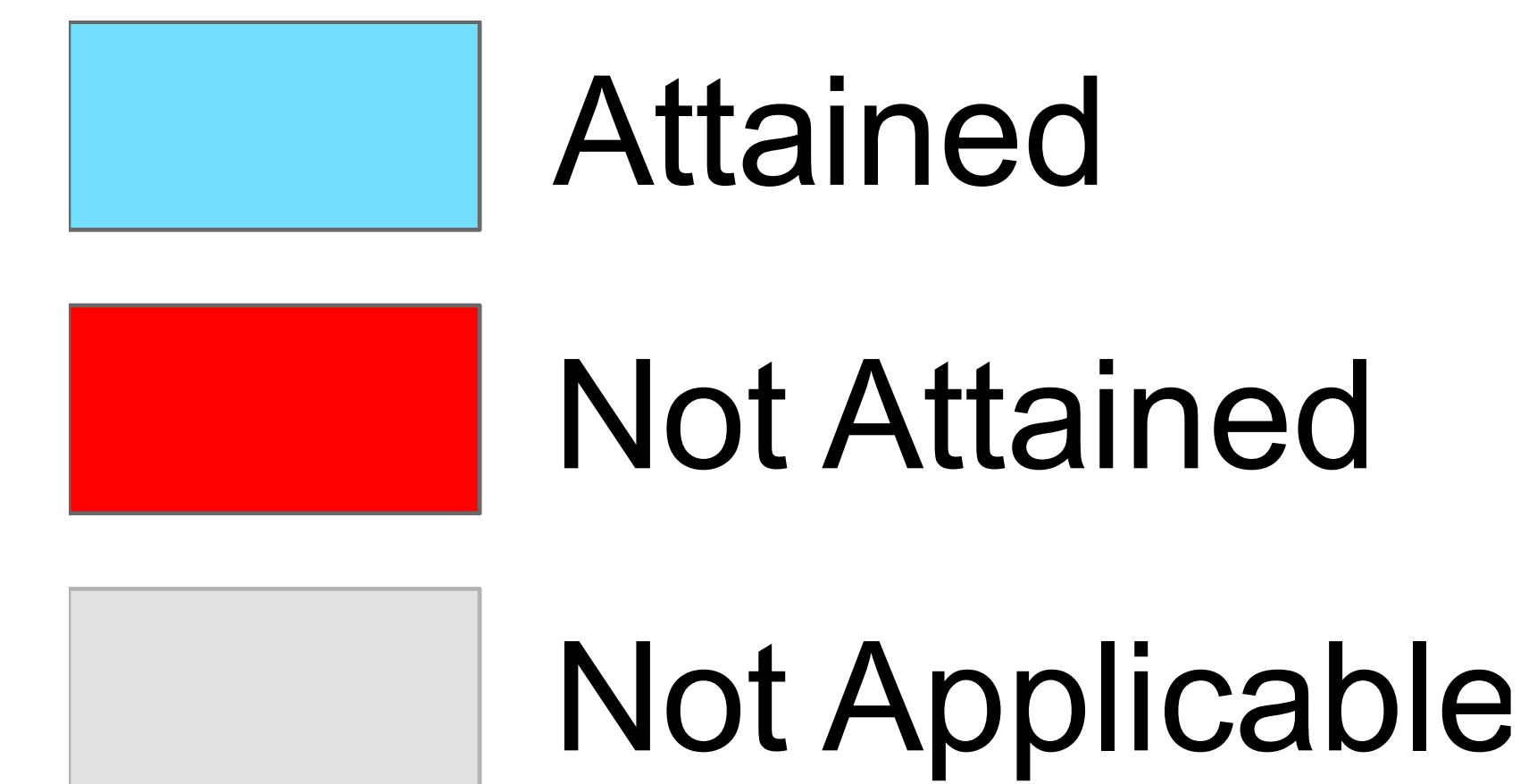


Deep-Water - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

- CB3MH
- CB4MH
- CB5MH_MD
- PATMH
- MAGMH
- SEVMH
- PAXMH
- POTMH
- RPPMH
- CHSMH
- EASMH



338 TN 27.7

TP



E3

All Forest



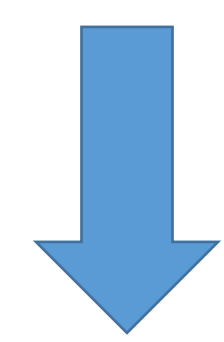
Deep-Water - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

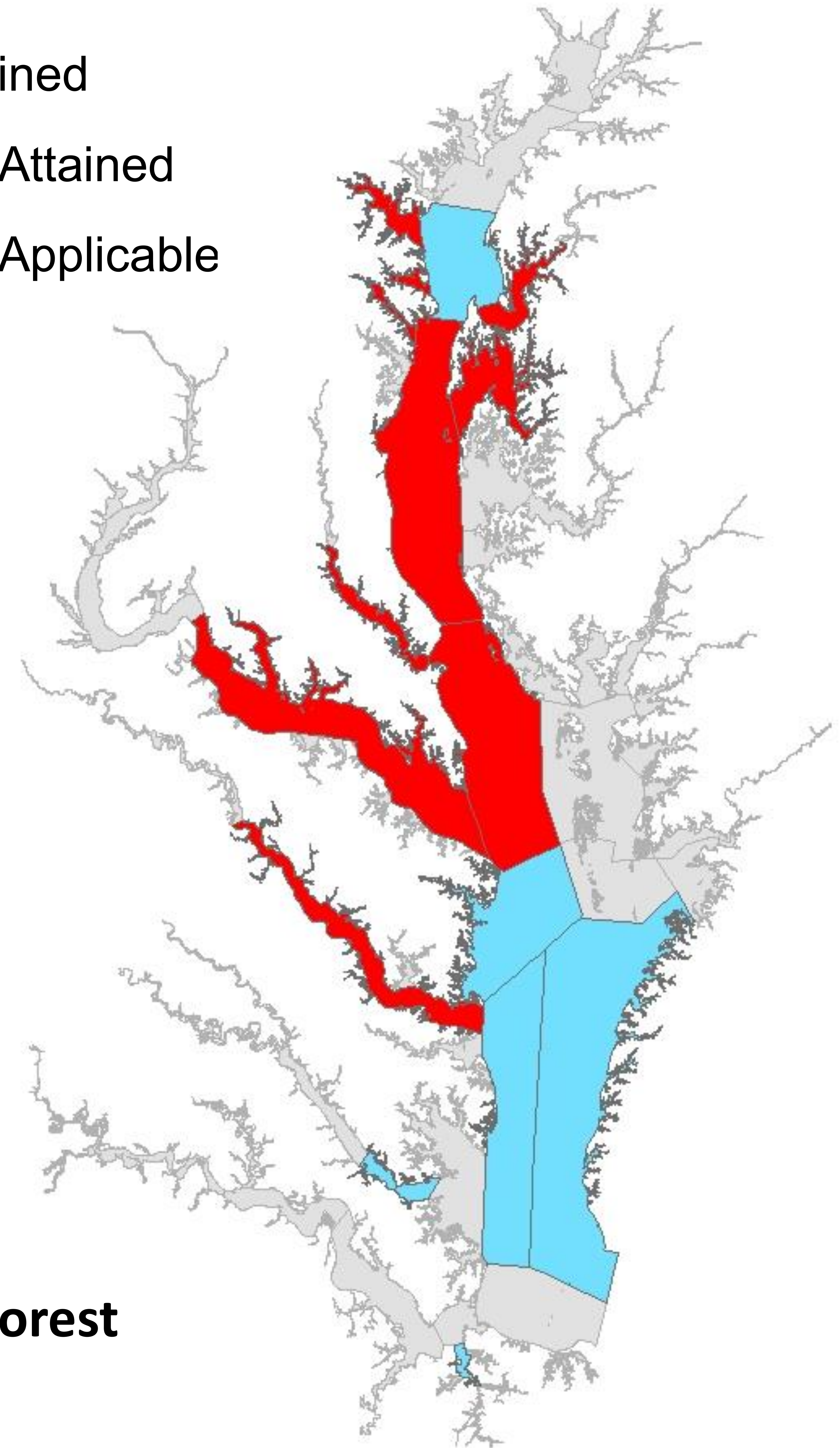
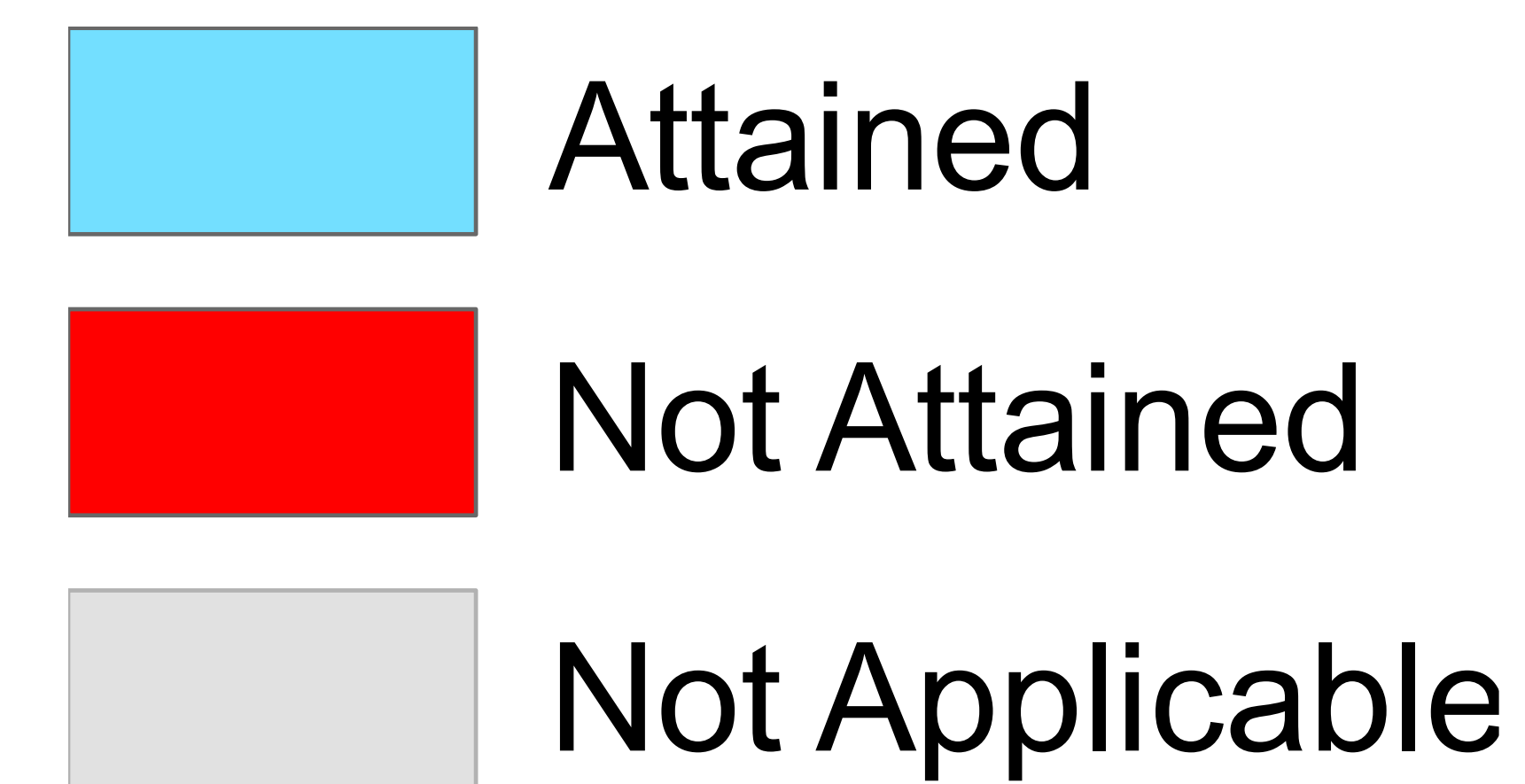
- CB4MH
- CB5MH_MD
- PATMH
- MAGMH
- SEVMH
- PAXMH
- POTMH
- RPPMH
- CHSMH
- EASMH

337 TN
23.7 TP



E3

All Forest



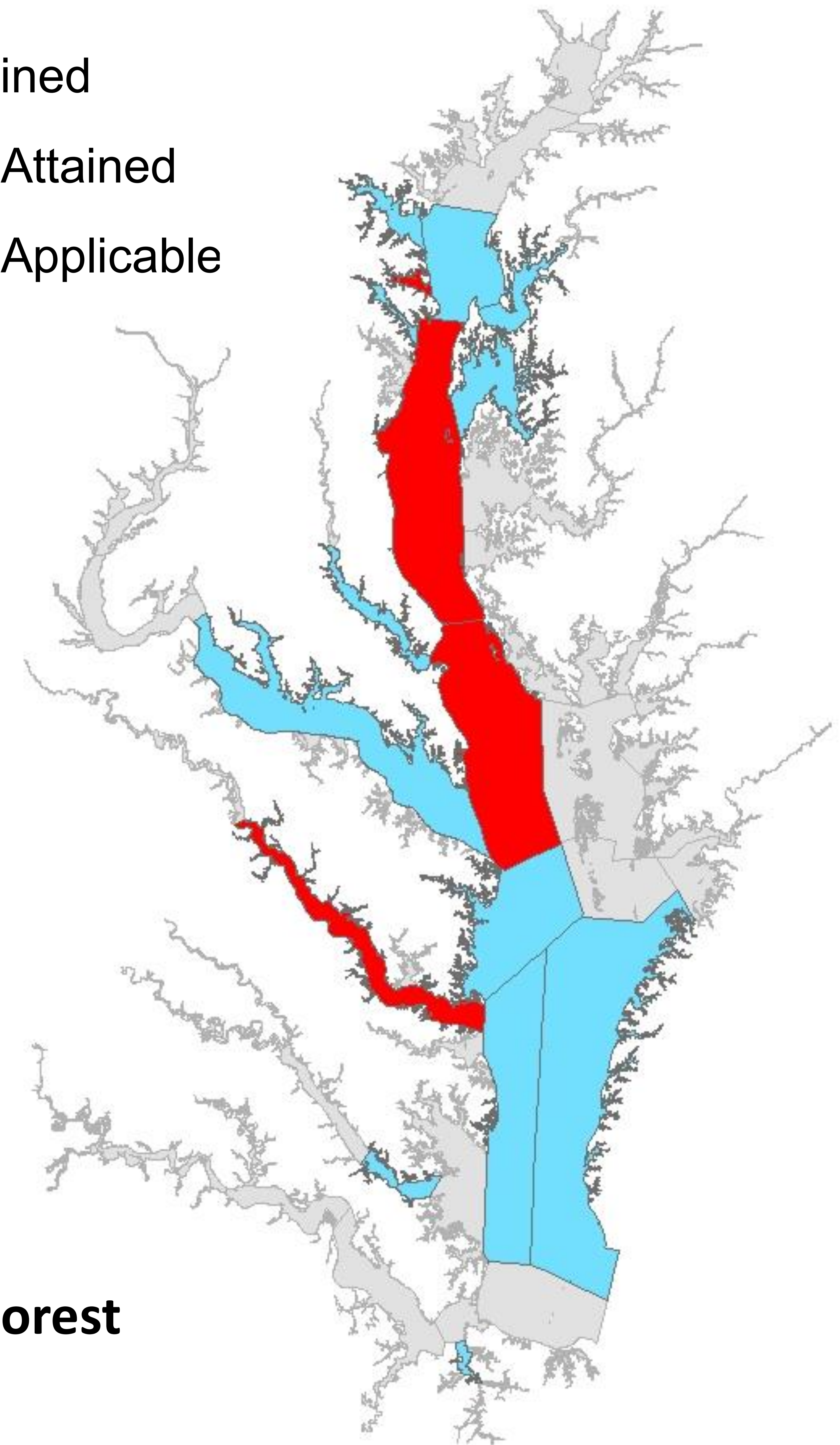
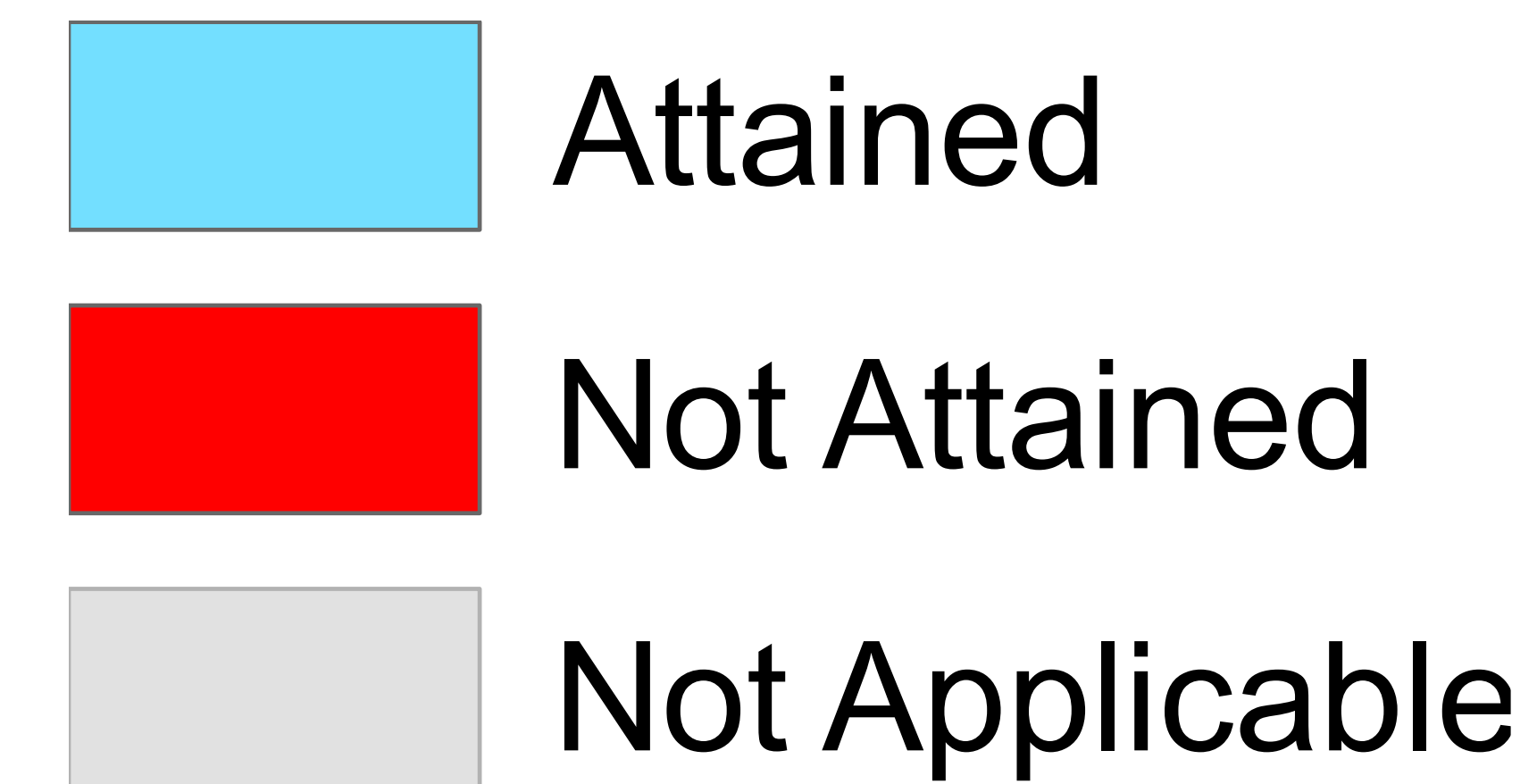


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Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

- CB4MH
- CB5MH_MD
- PATMH
- MAGMH
- PAXMH
- POTMH
- RPPMH
- CHSMH



317 TN 21.9

TP



E3

All Forest

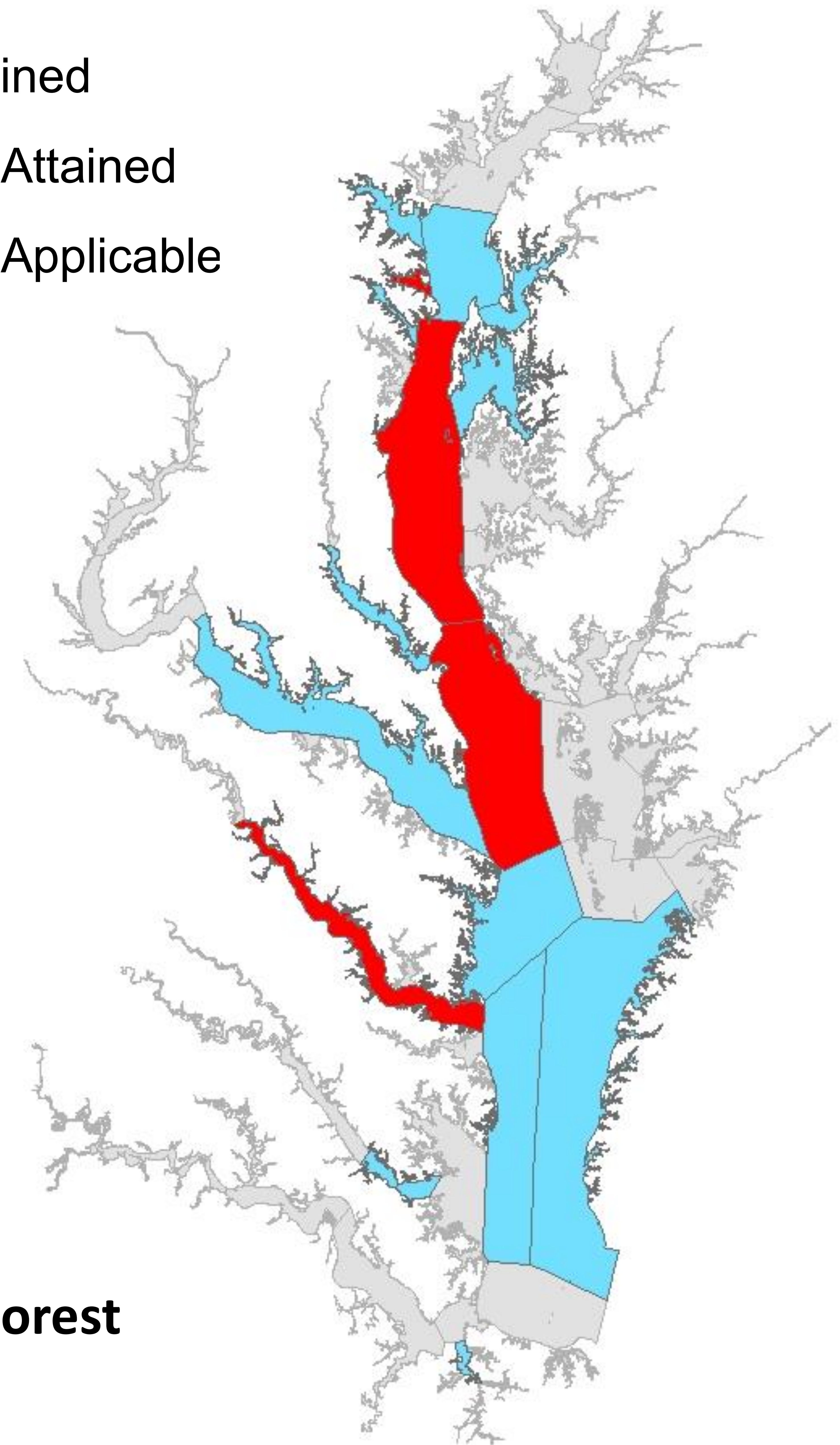
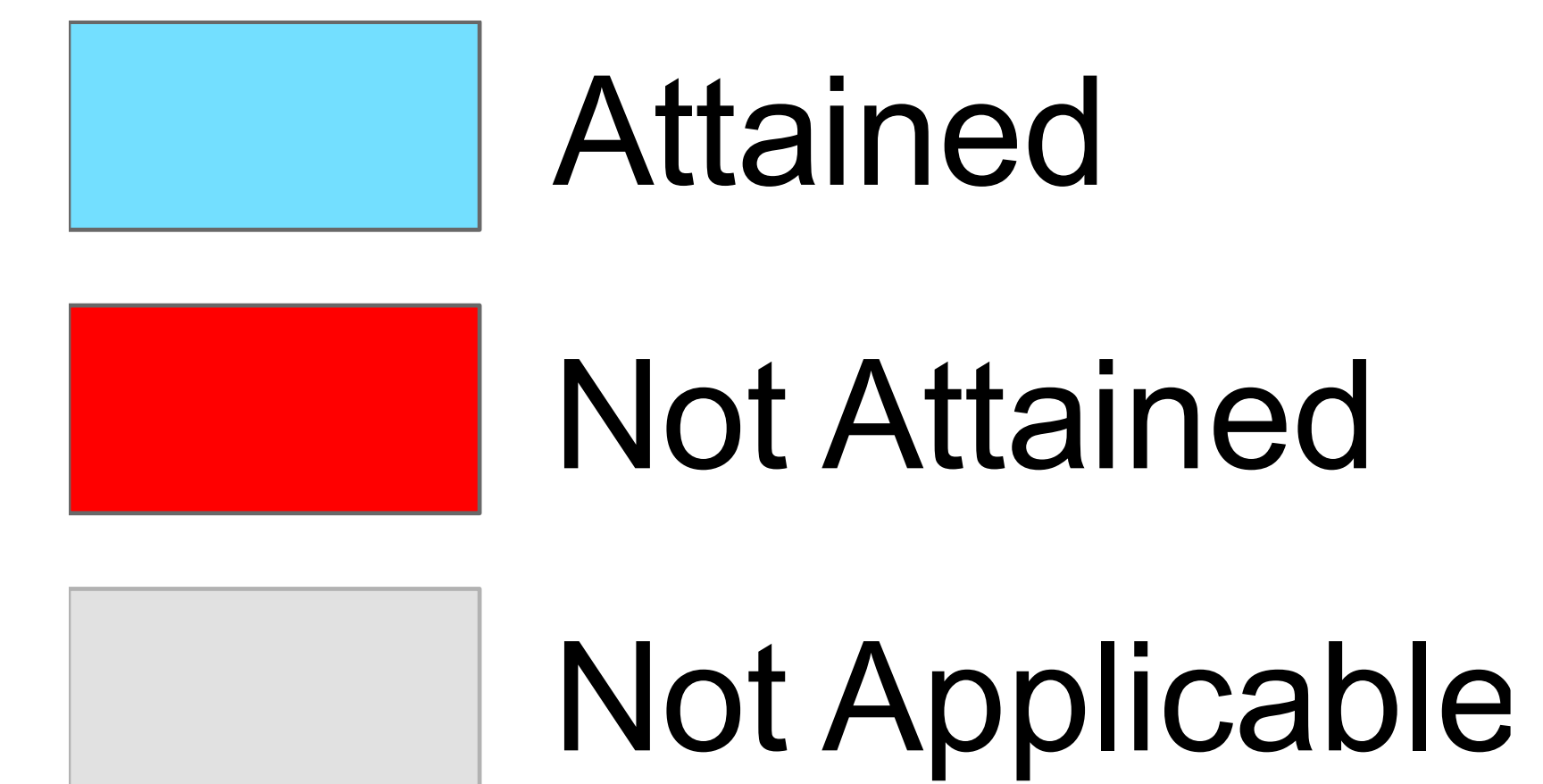


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Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

- CB4MH
- CB5MH_MD
- MAGMH
- RPPMH



317 TN 21.9
TP



E3

All Forest

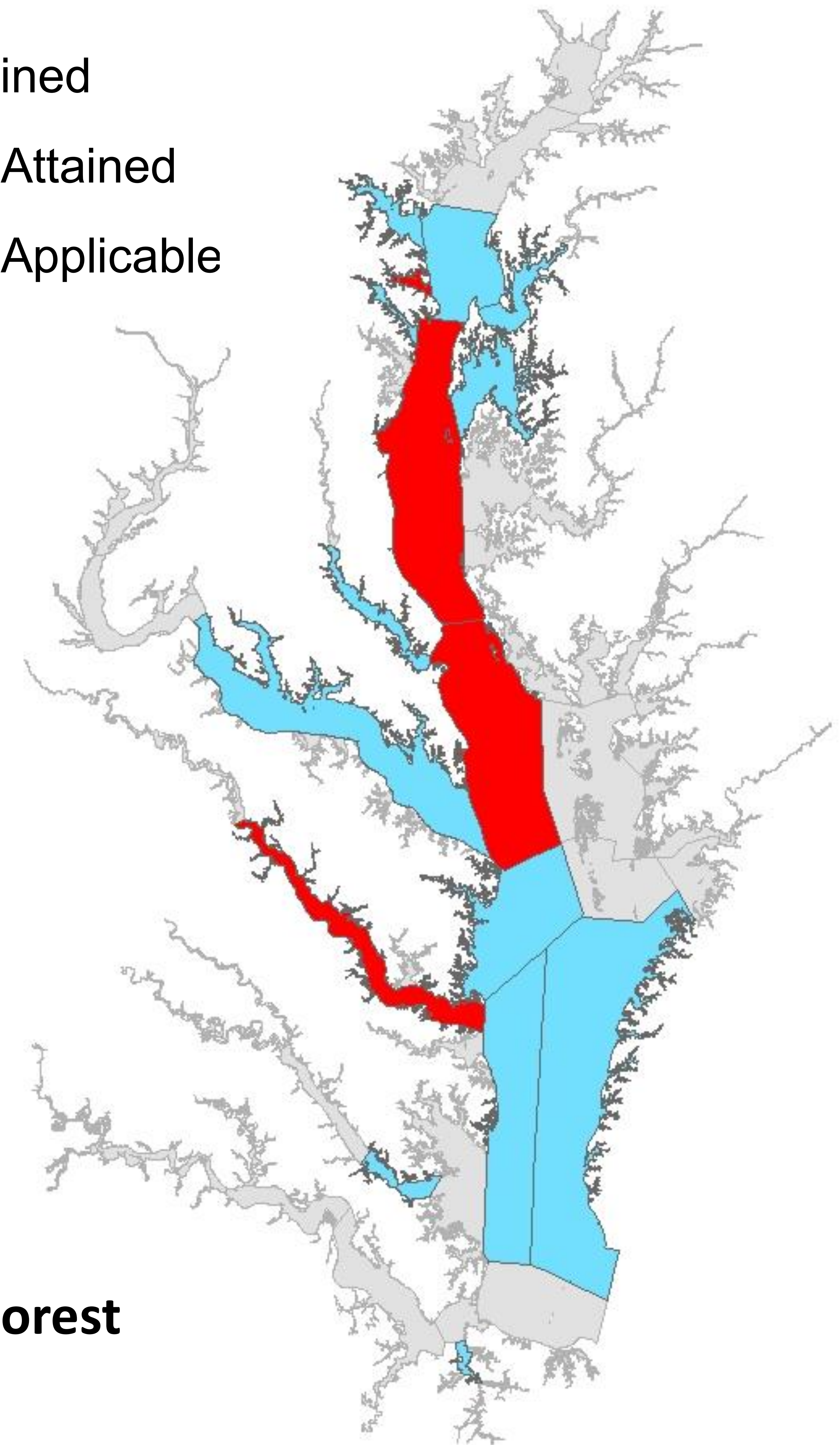
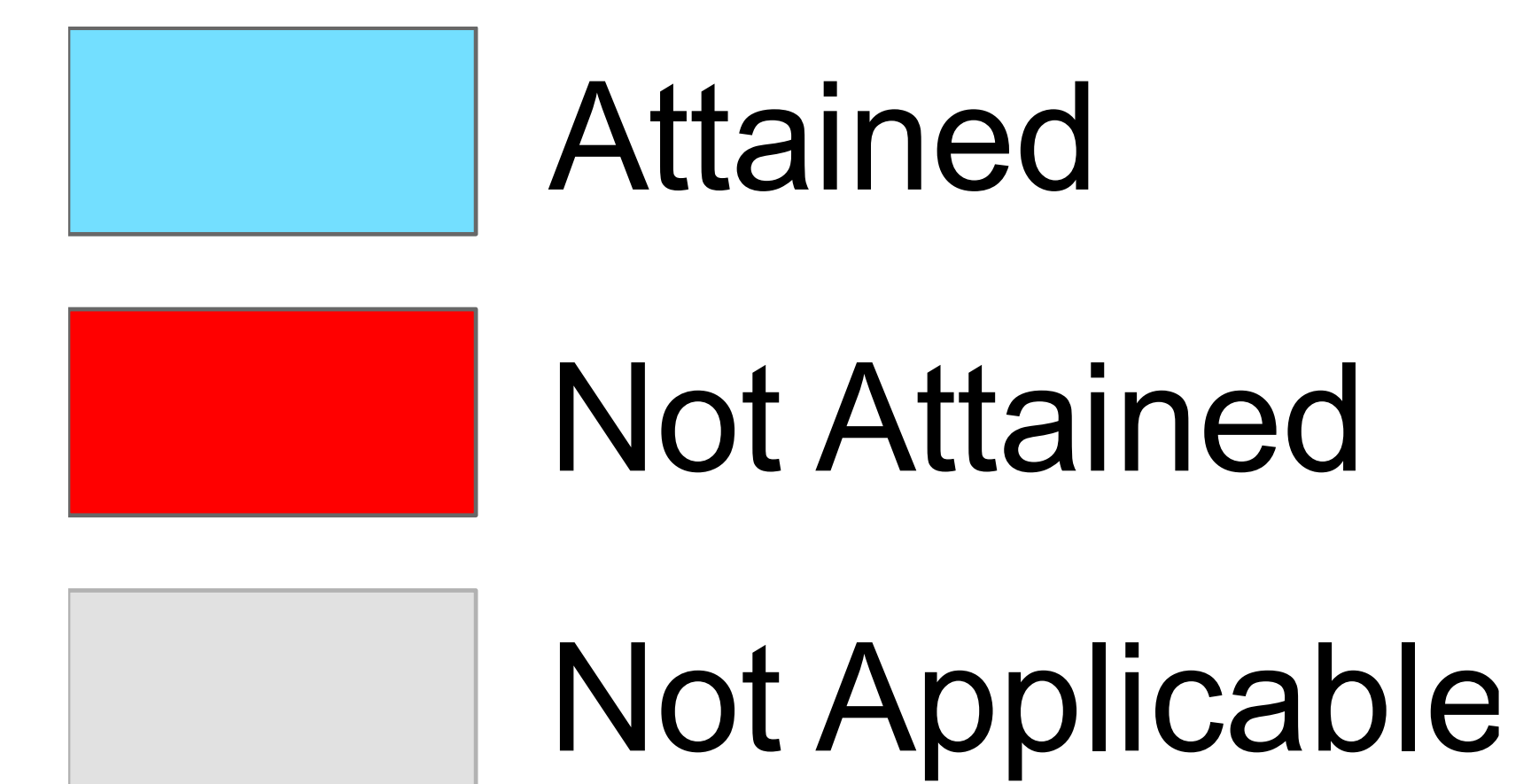


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Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

- CB4MH
- CB5MH_MD
- MAGMH
- RPPMH



253 TN 15.9
TP



E3

All Forest

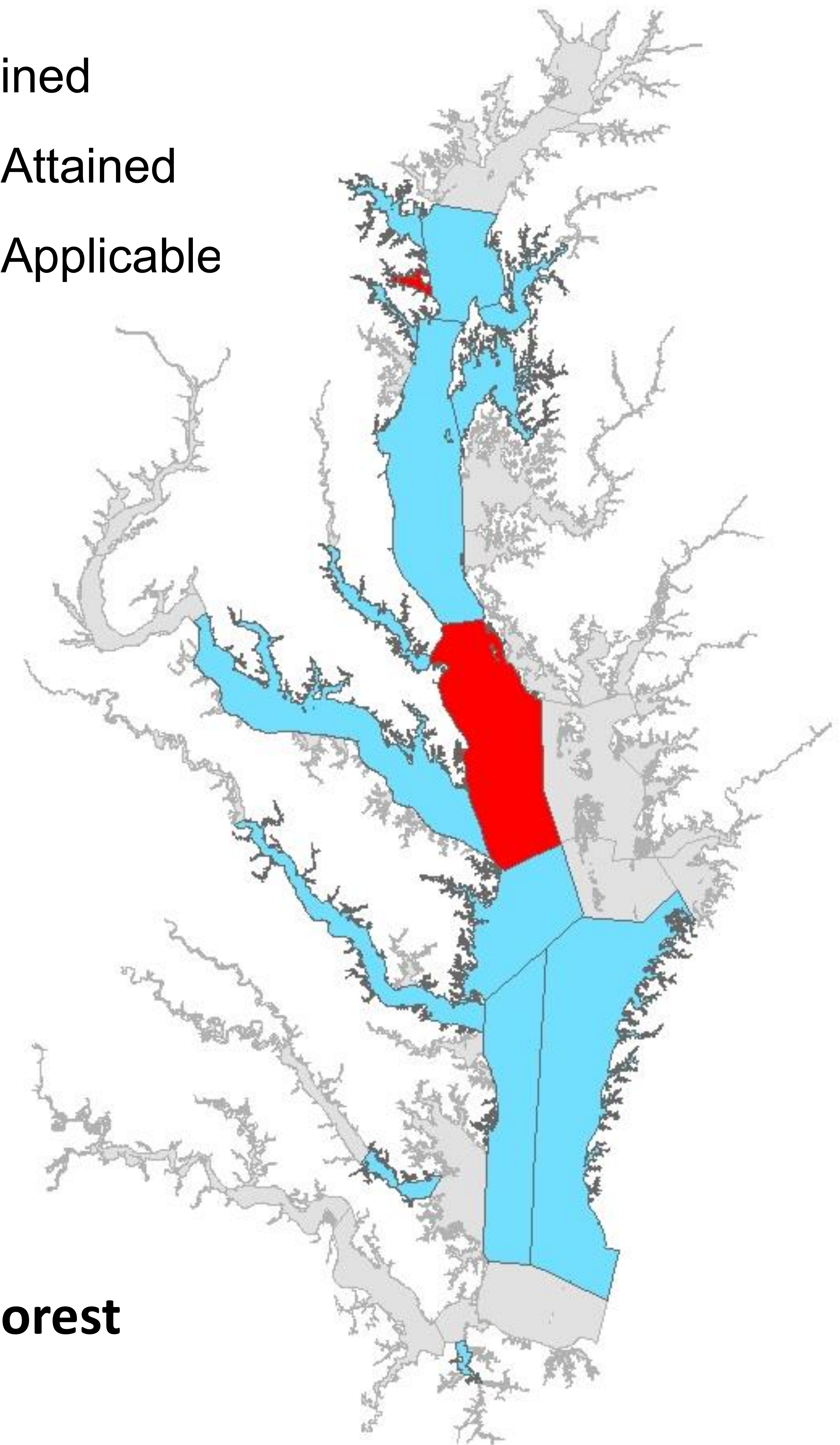
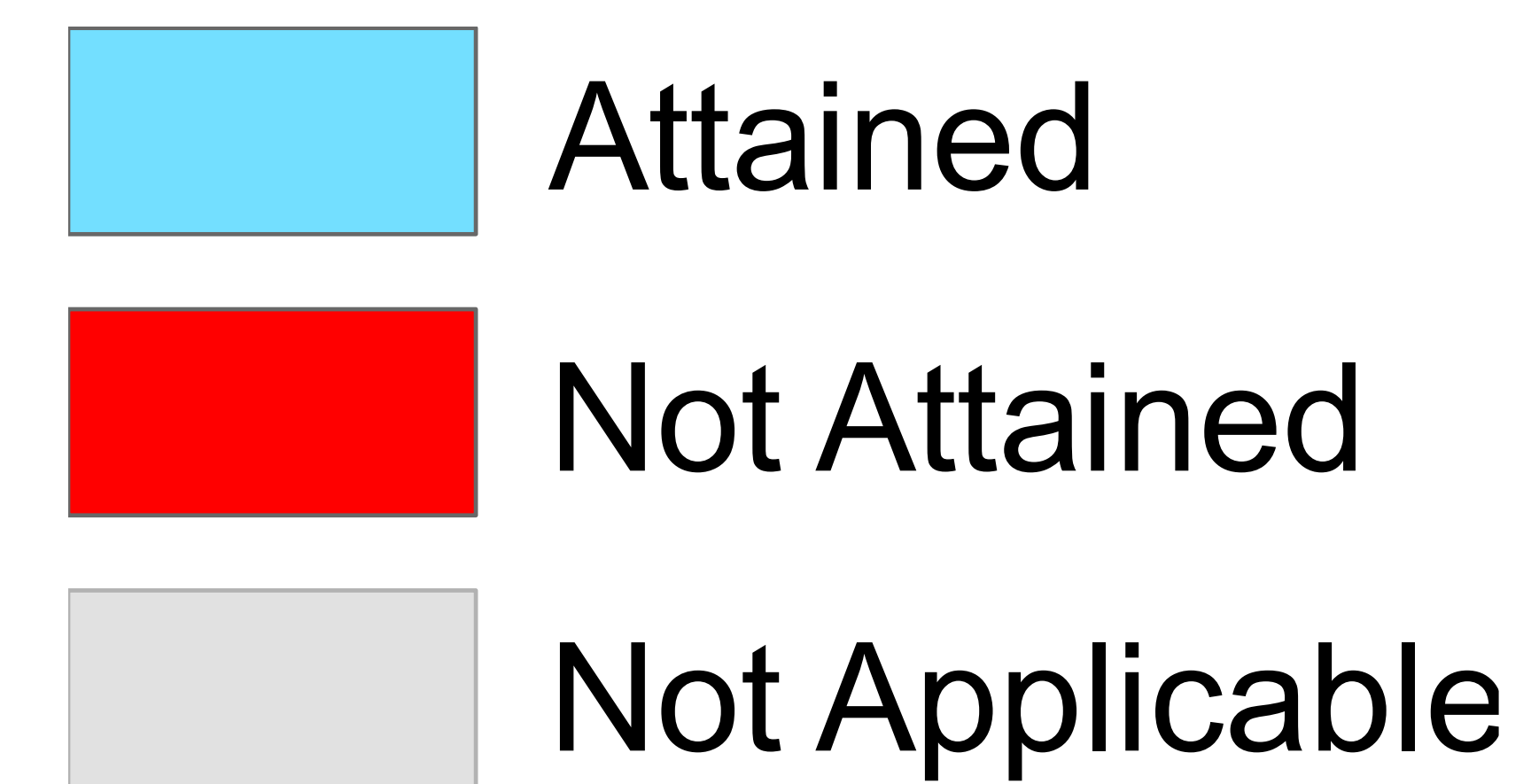


Deep-Water - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

- CB5MH_MD
- MAGMH



224 TN 14.8
TP



E3

All Forest

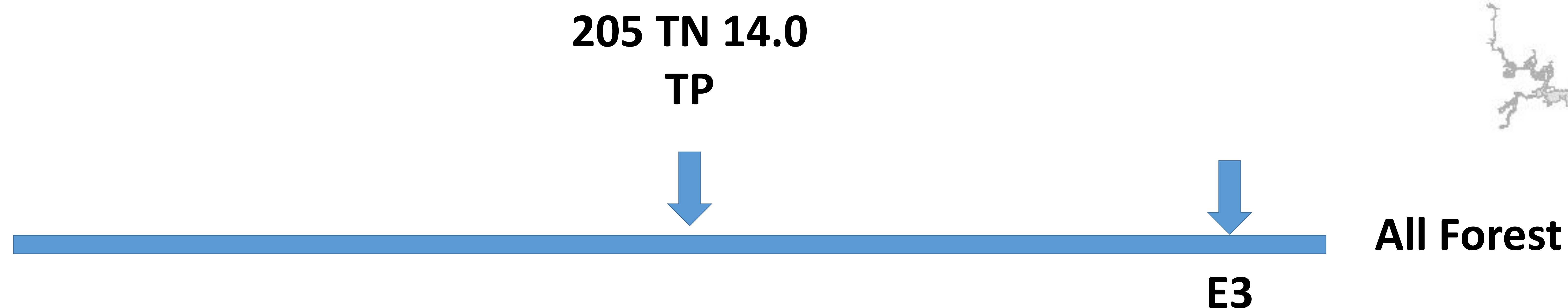
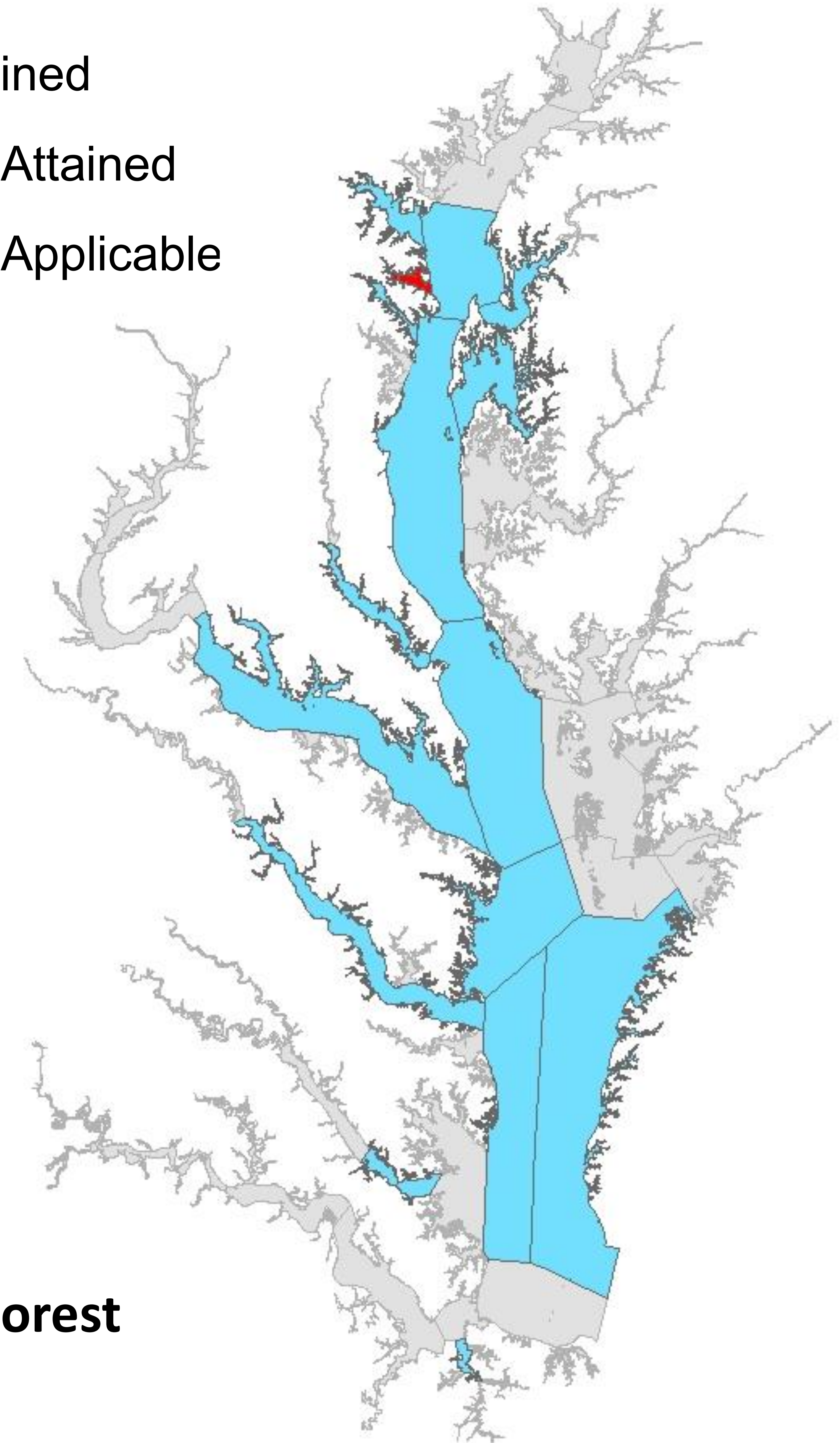
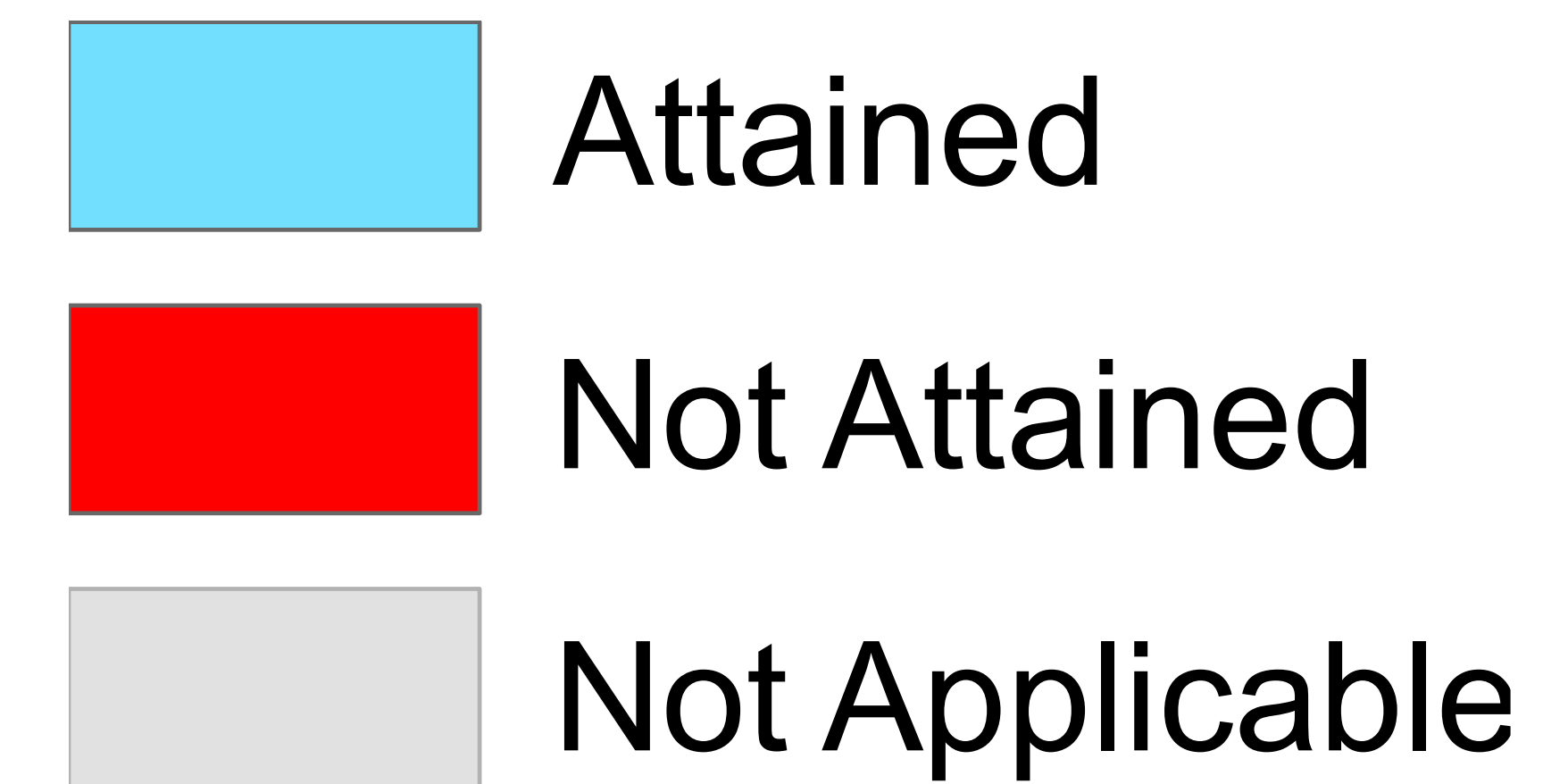


Deep-Water - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment

- MAGMH

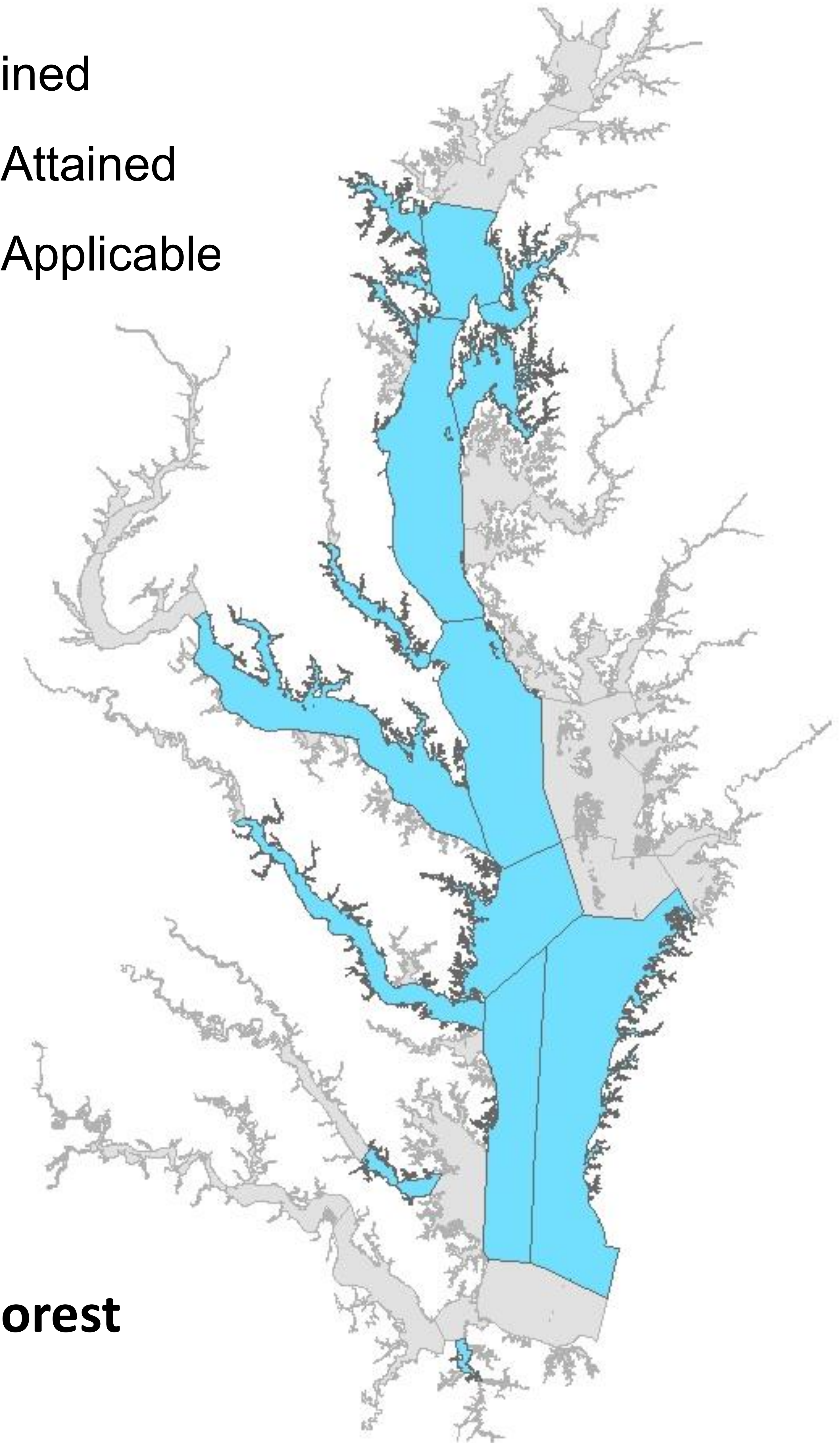
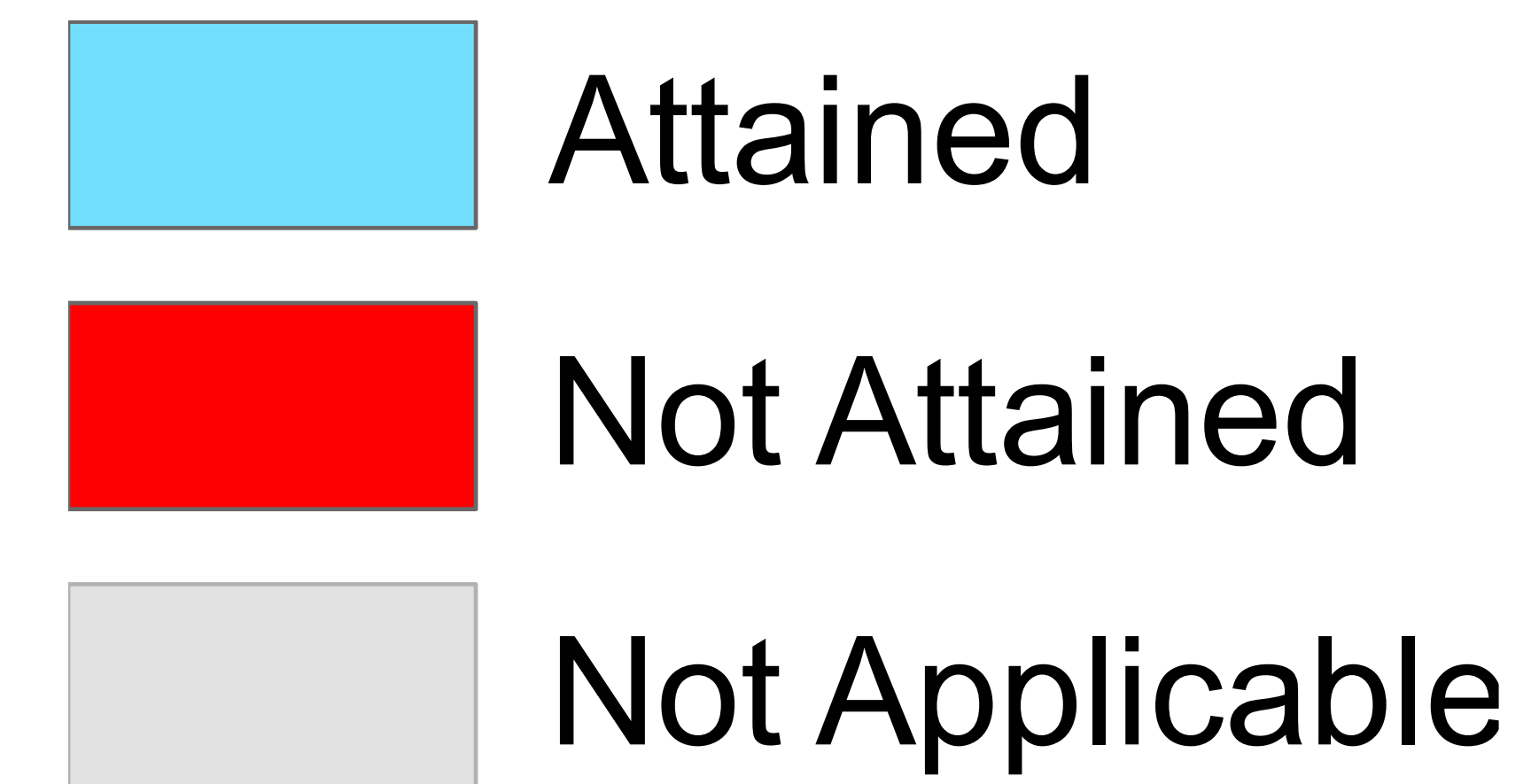




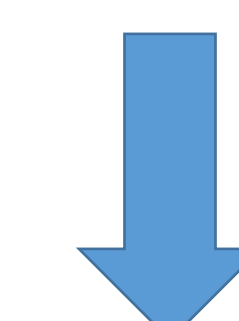
Deep-Water - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Water Use

Segments NOT in Attainment



195 TN 13.7
TP



E3

All Forest

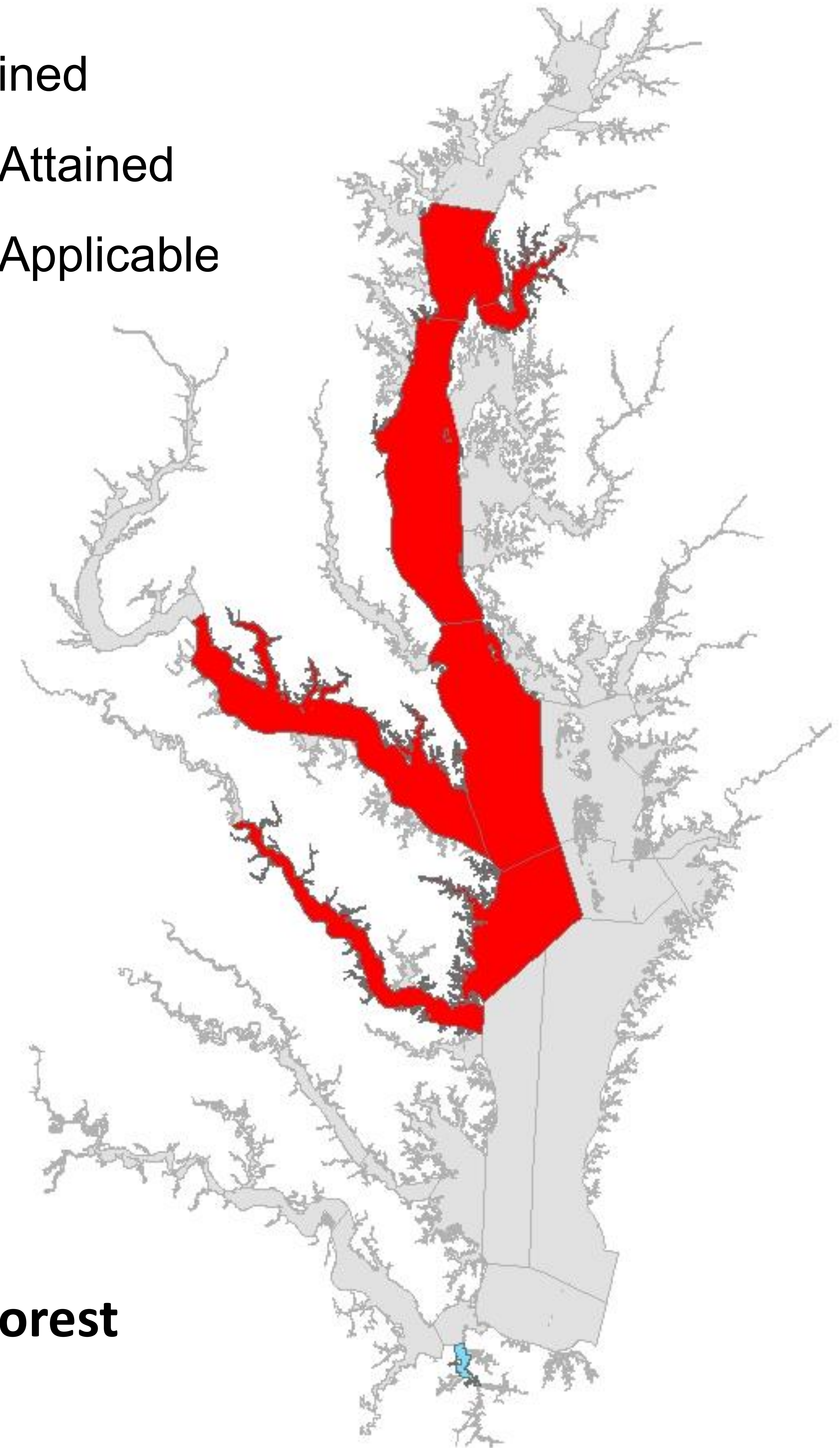
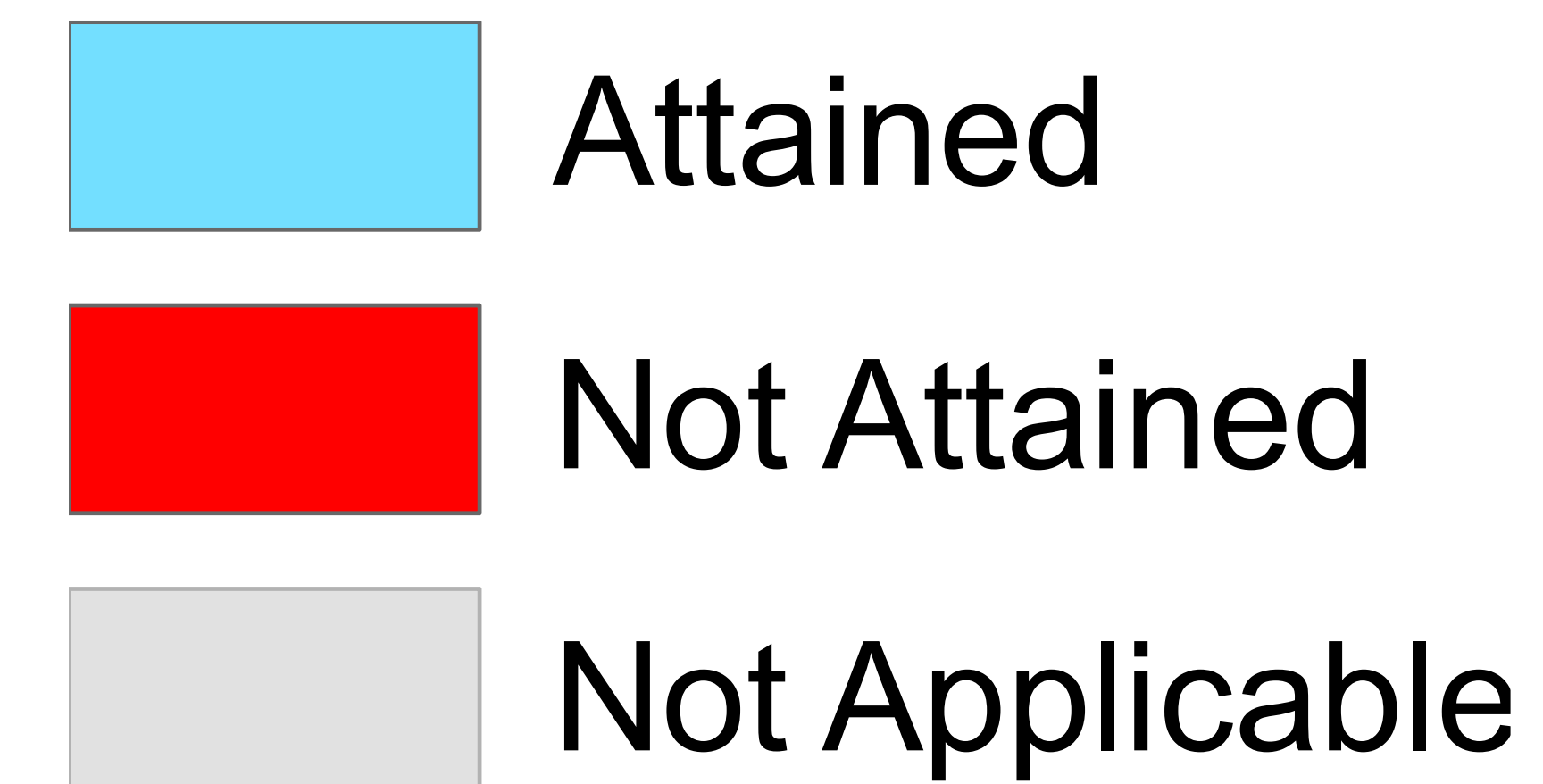


Deep-Channel - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment

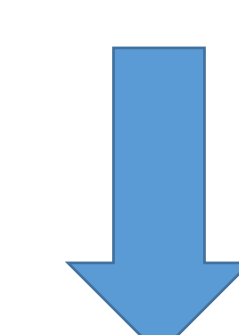
- CB3MH
- CB4MH
- CB5MH_MD
- CB5MH_VA
- PATMH
- POTMH
- RPPMH
- CHSMH



404 TN 41.7
TP



No Action



E3

All Forest

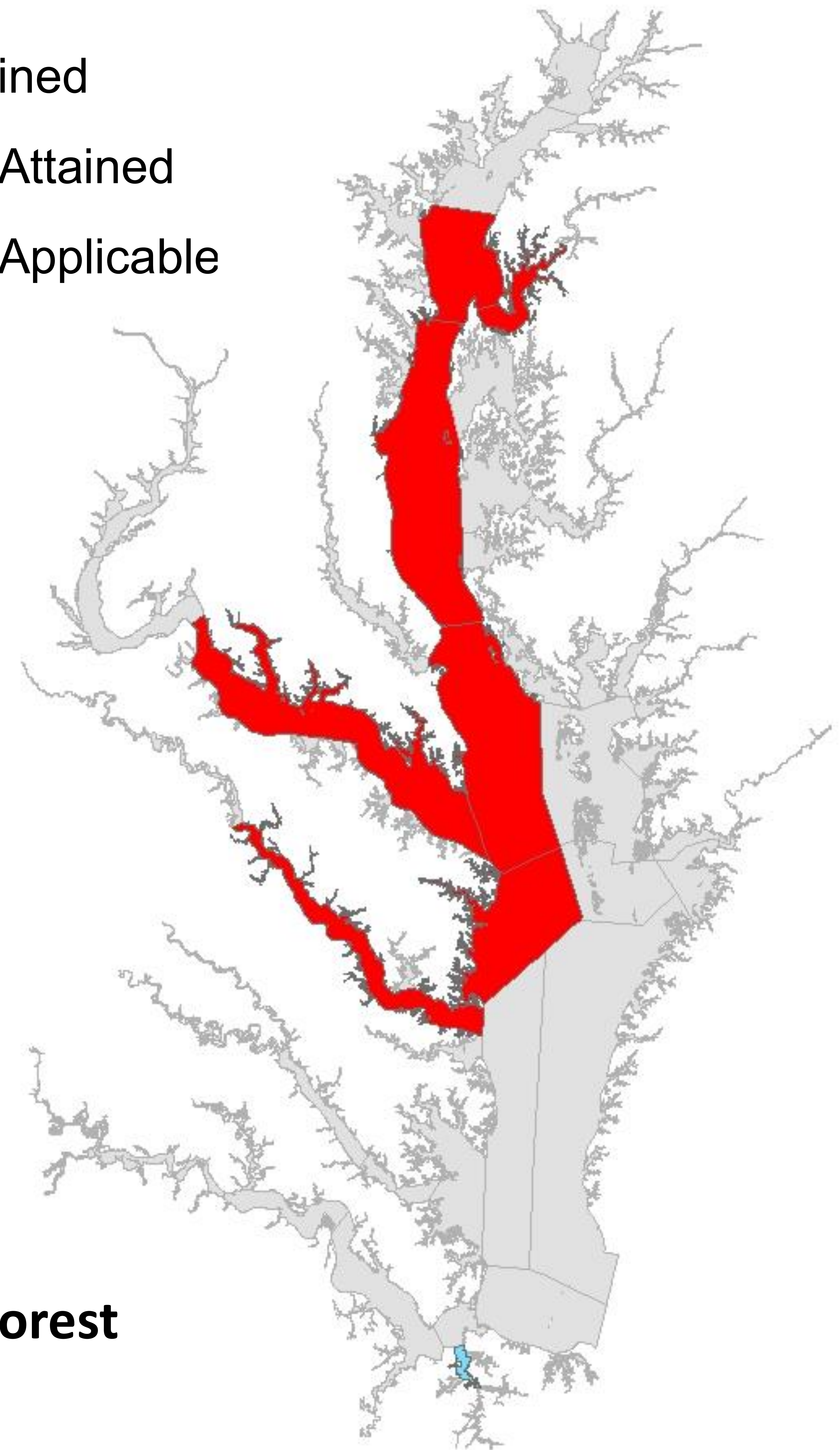
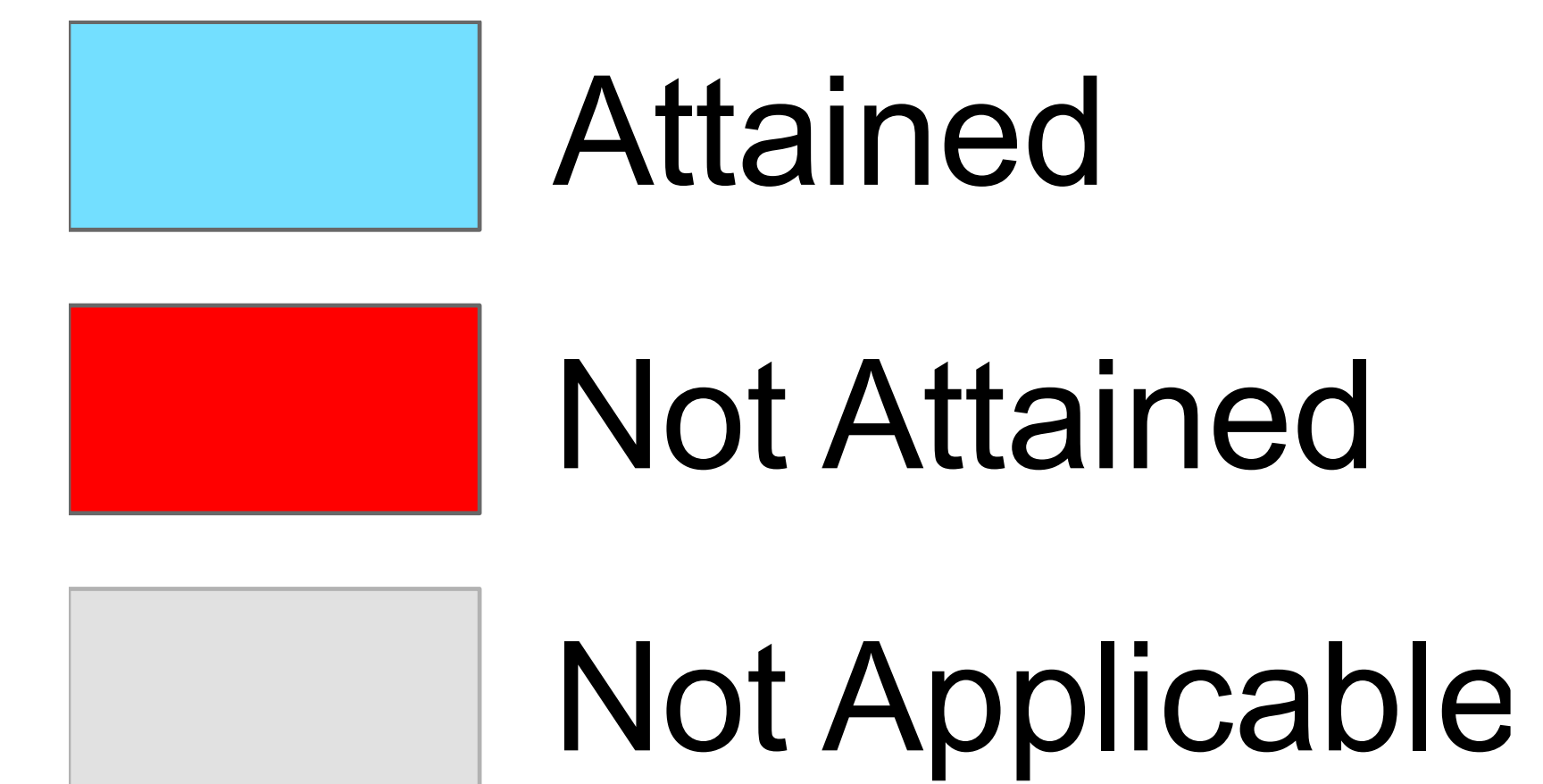


Deep-Channel - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Channel Use

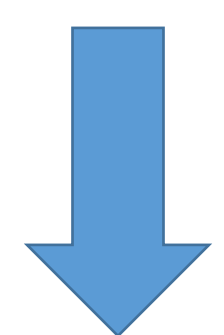
Segments NOT in Attainment

- CB3MH
- CB4MH
- CB5MH_MD
- CB5MH_VA
- PATMH
- POTMH
- RPPMH
- CHSMH



347 TN 30.4

TP



E3

All Forest

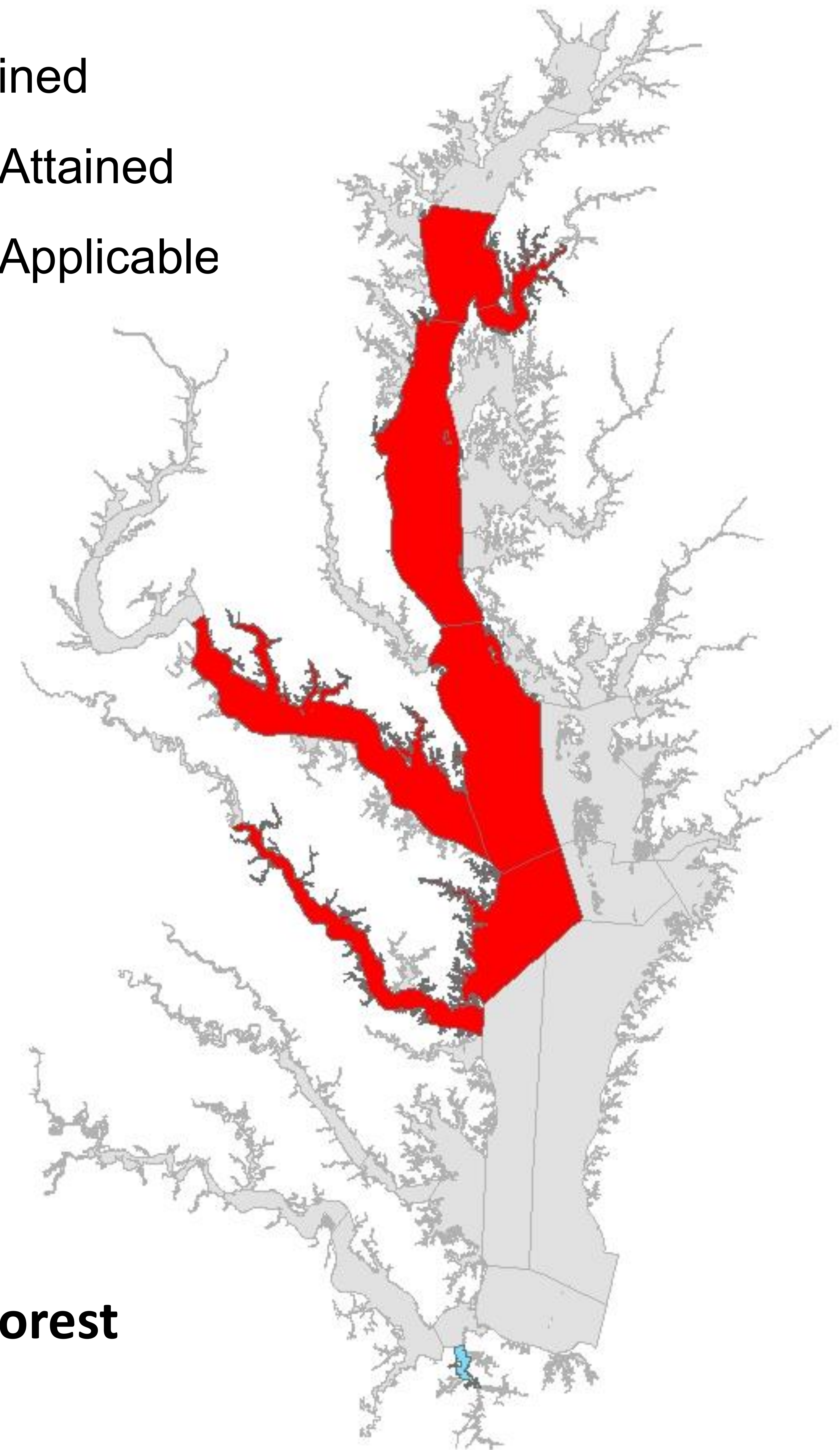
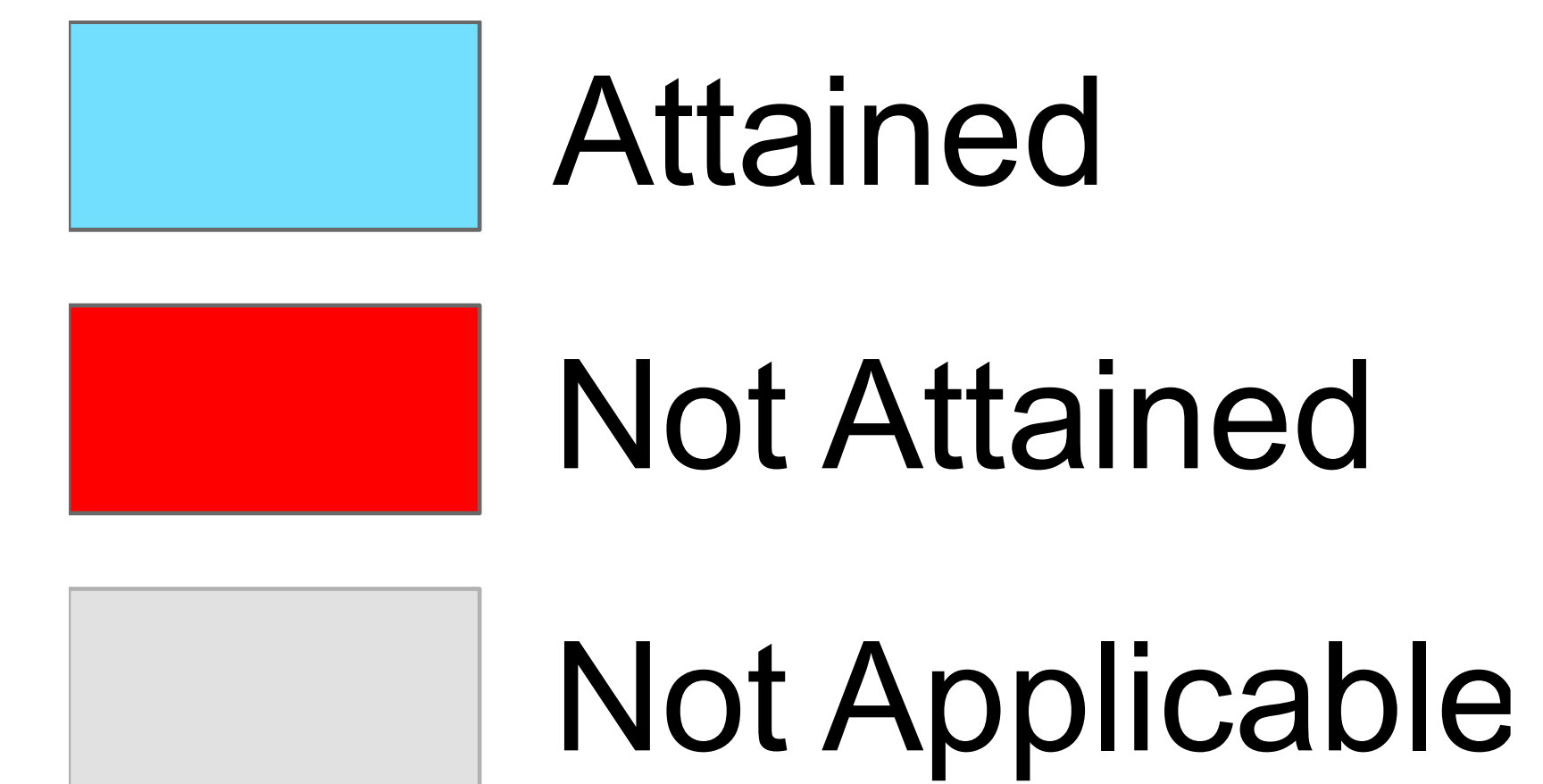


Deep-Channel - PSC December 19, 2017 Presentation

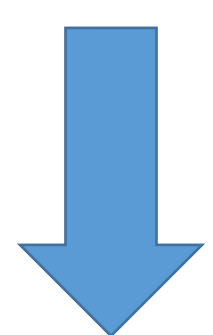
Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment

- CB3MH
- CB4MH
- CB5MH_MD
- CB5MH_VA
- PATMH
- POTMH
- RPPMH
- CHSMH



338 TN 27.7
TP



E3

All Forest

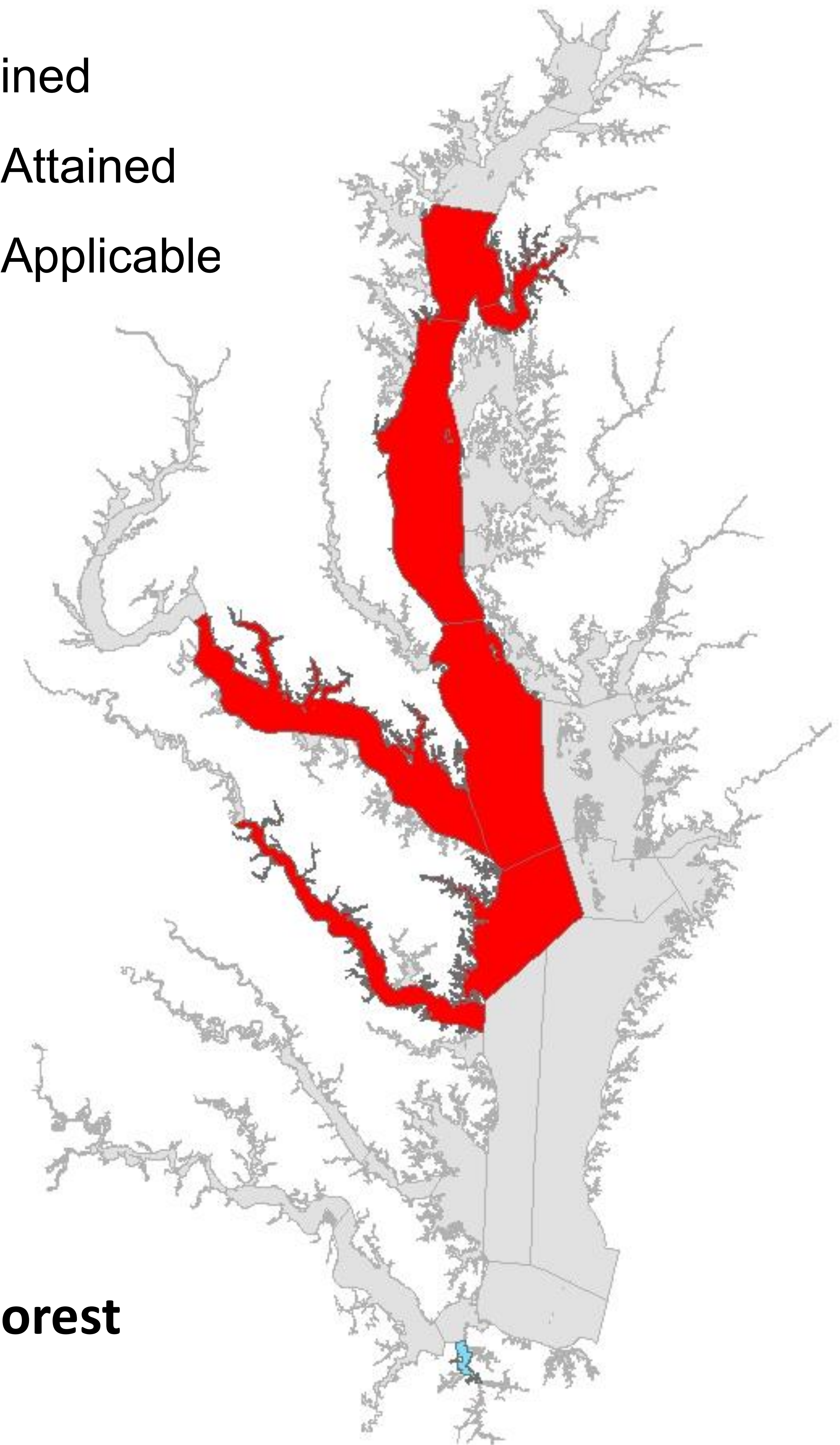
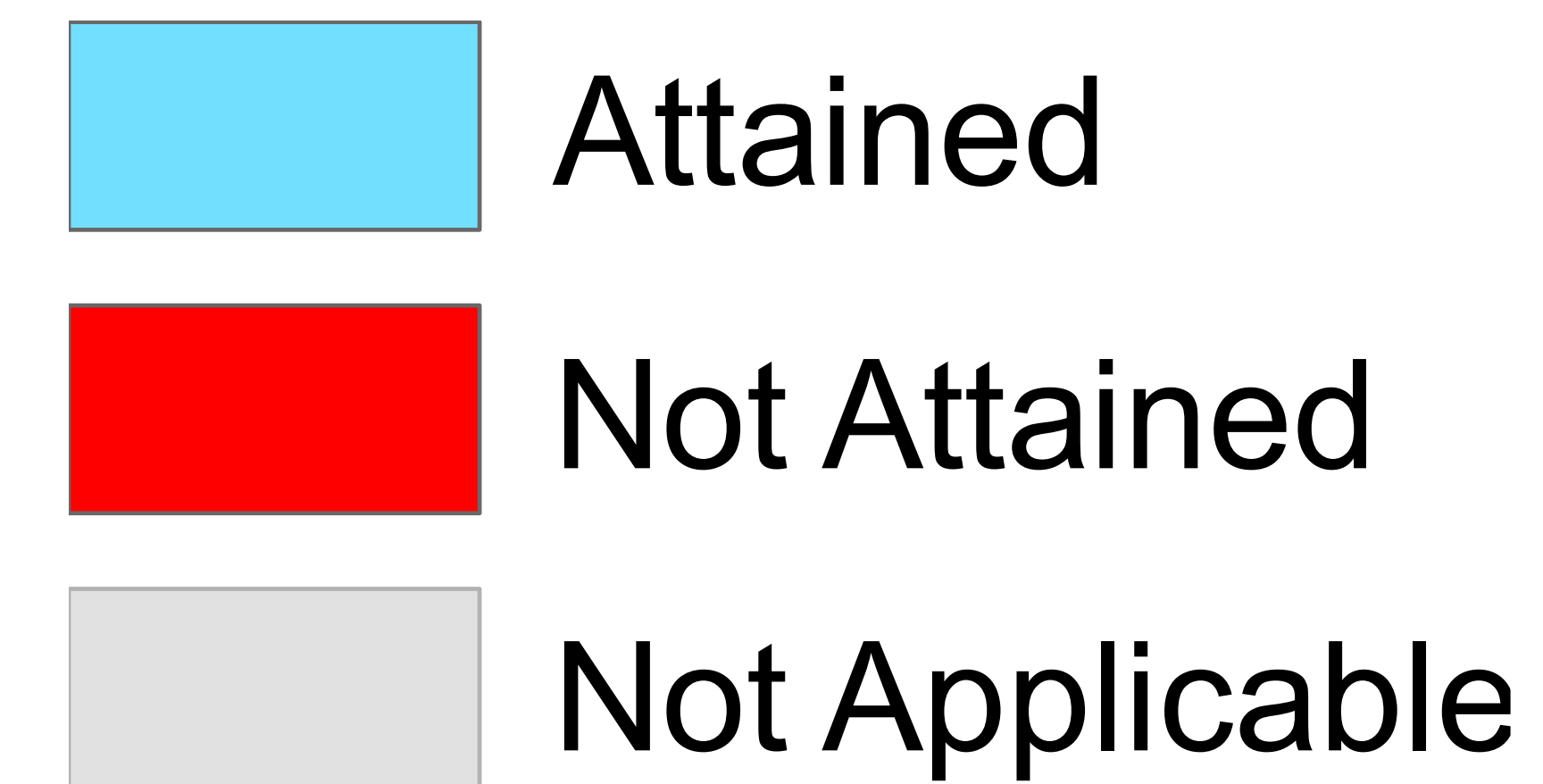


Deep-Channel - PSC December 19, 2017 Presentation

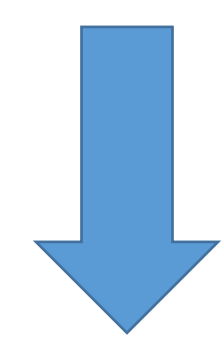
Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment

- CB3MH
- CB4MH
- CB5MH_MD
- CB5MH_VA
- POTMH
- RPPMH
- CHSMH



337 TN
23.7 TP



E3

All Forest

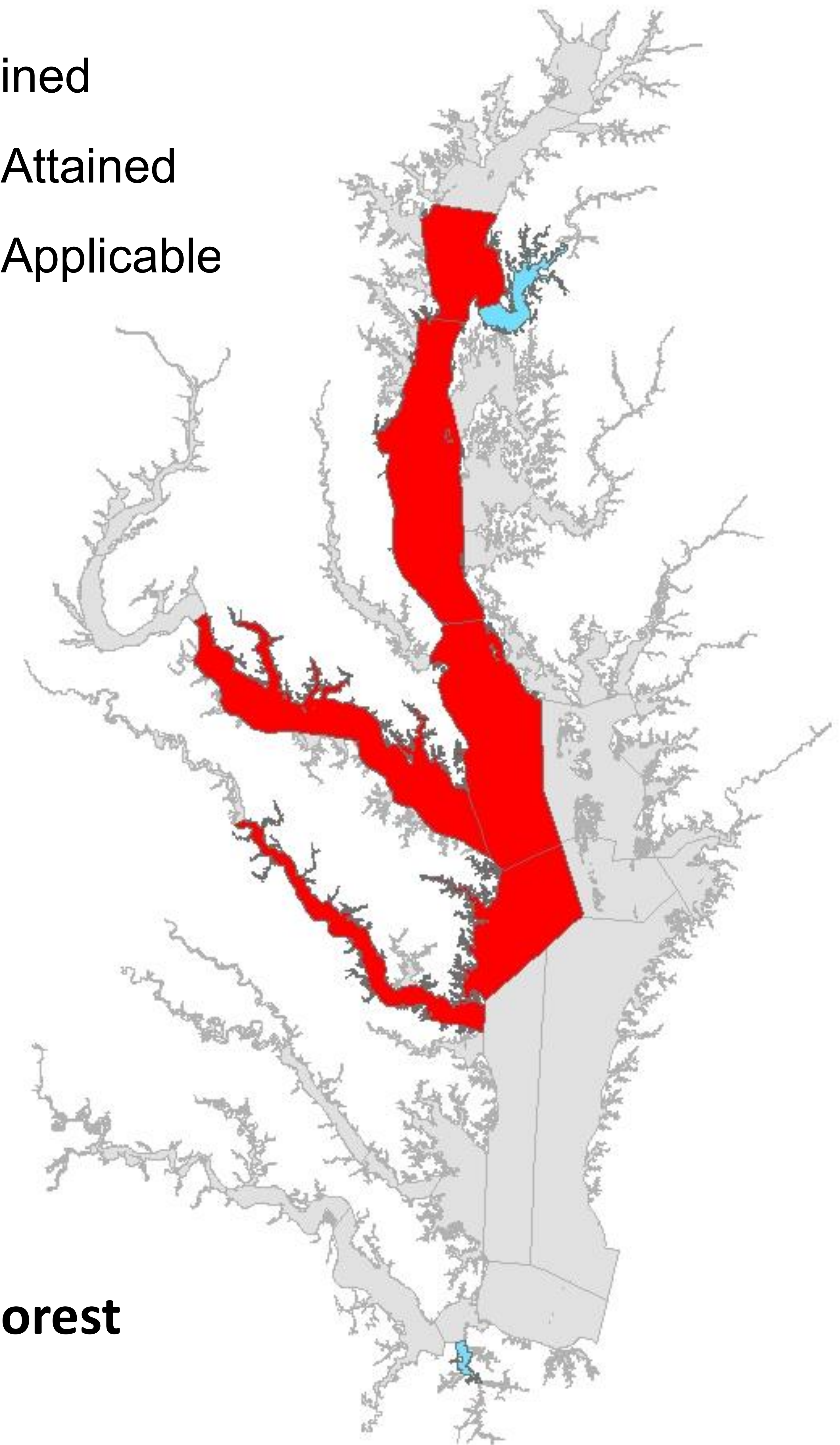
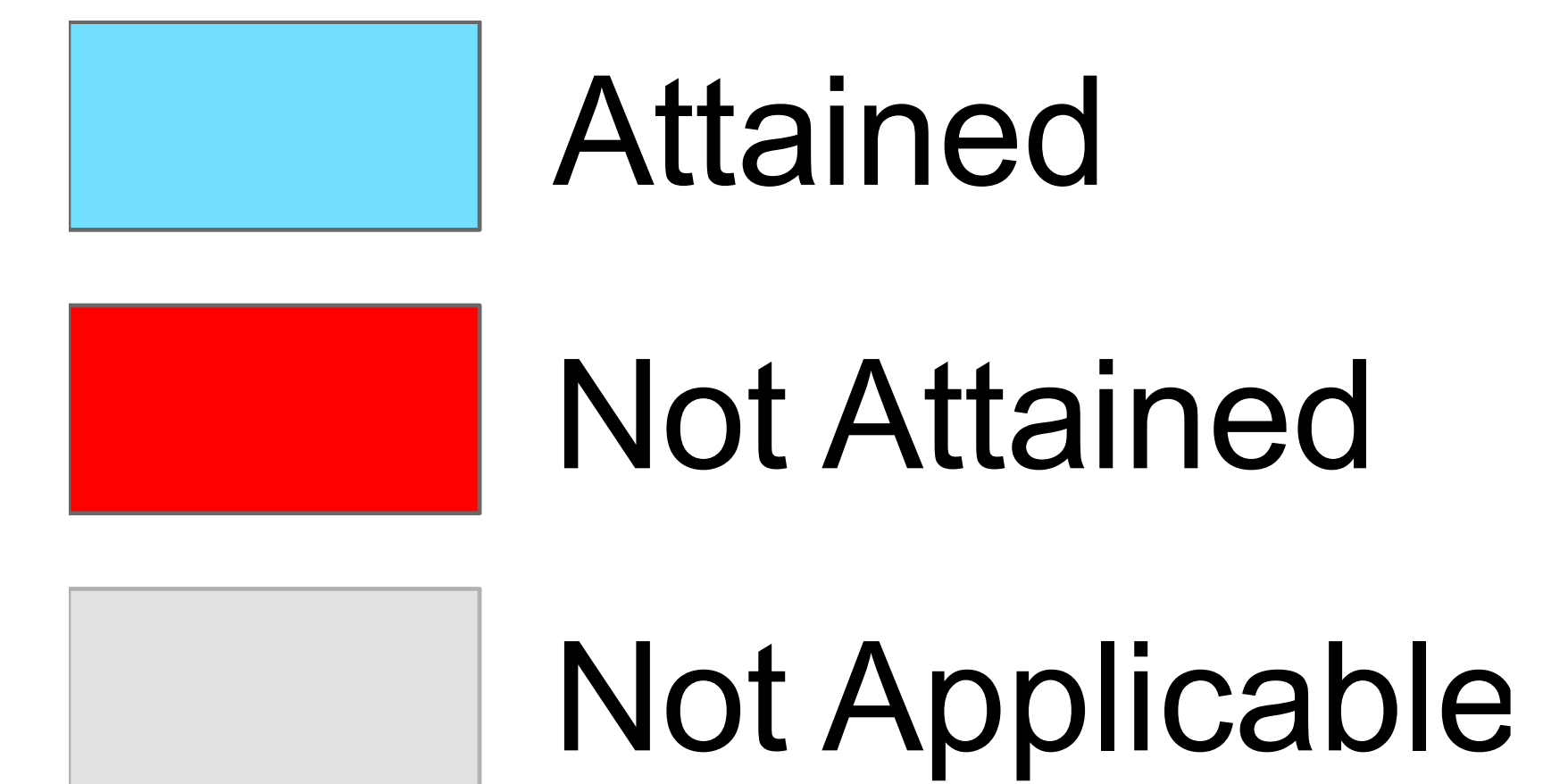


Deep-Channel - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment

- CB3MH
- CB4MH
- CB5MH_MD
- CHSMH
- POTMH
- RPPMH



317 TN 21.9
TP



E3

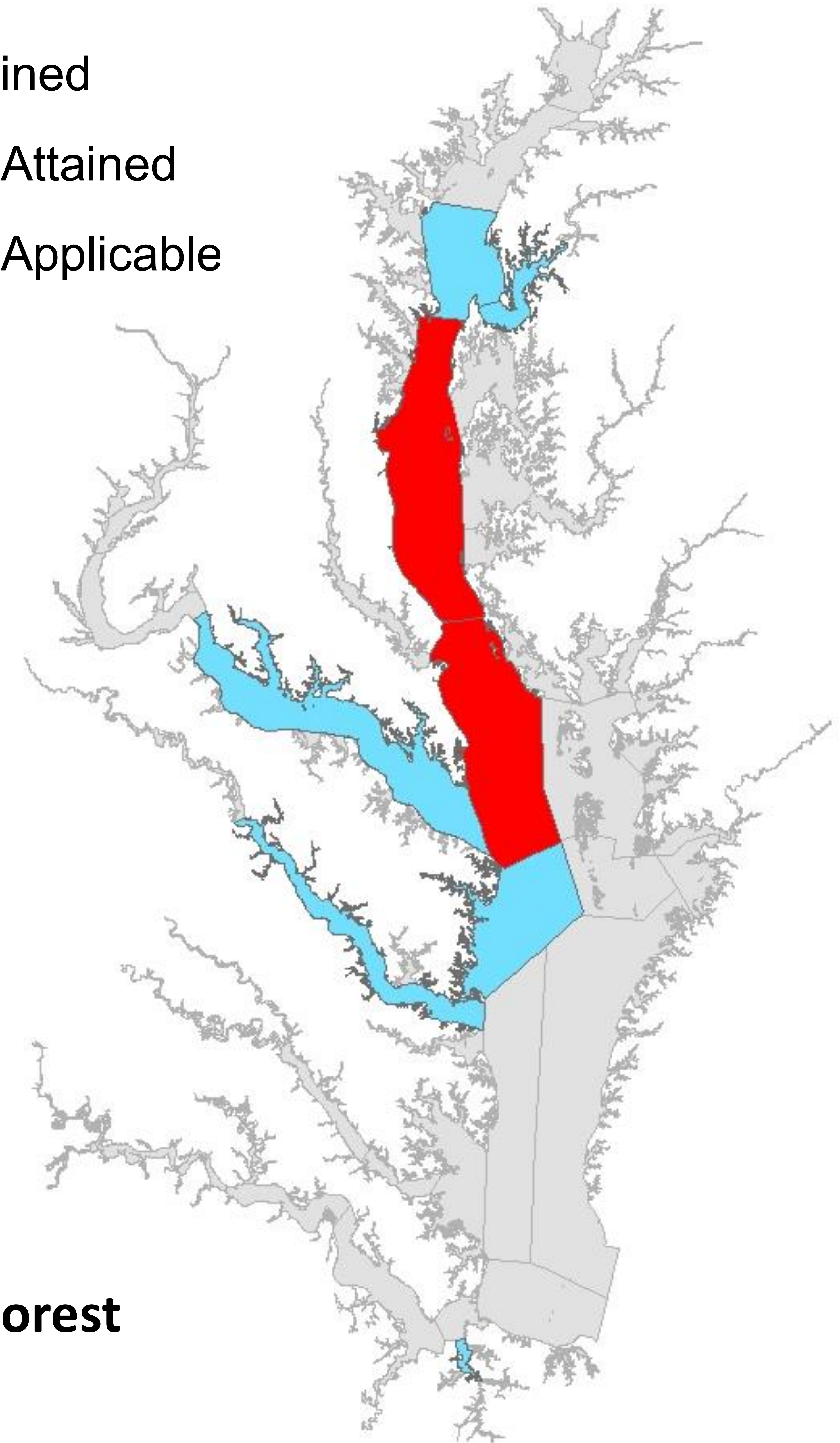
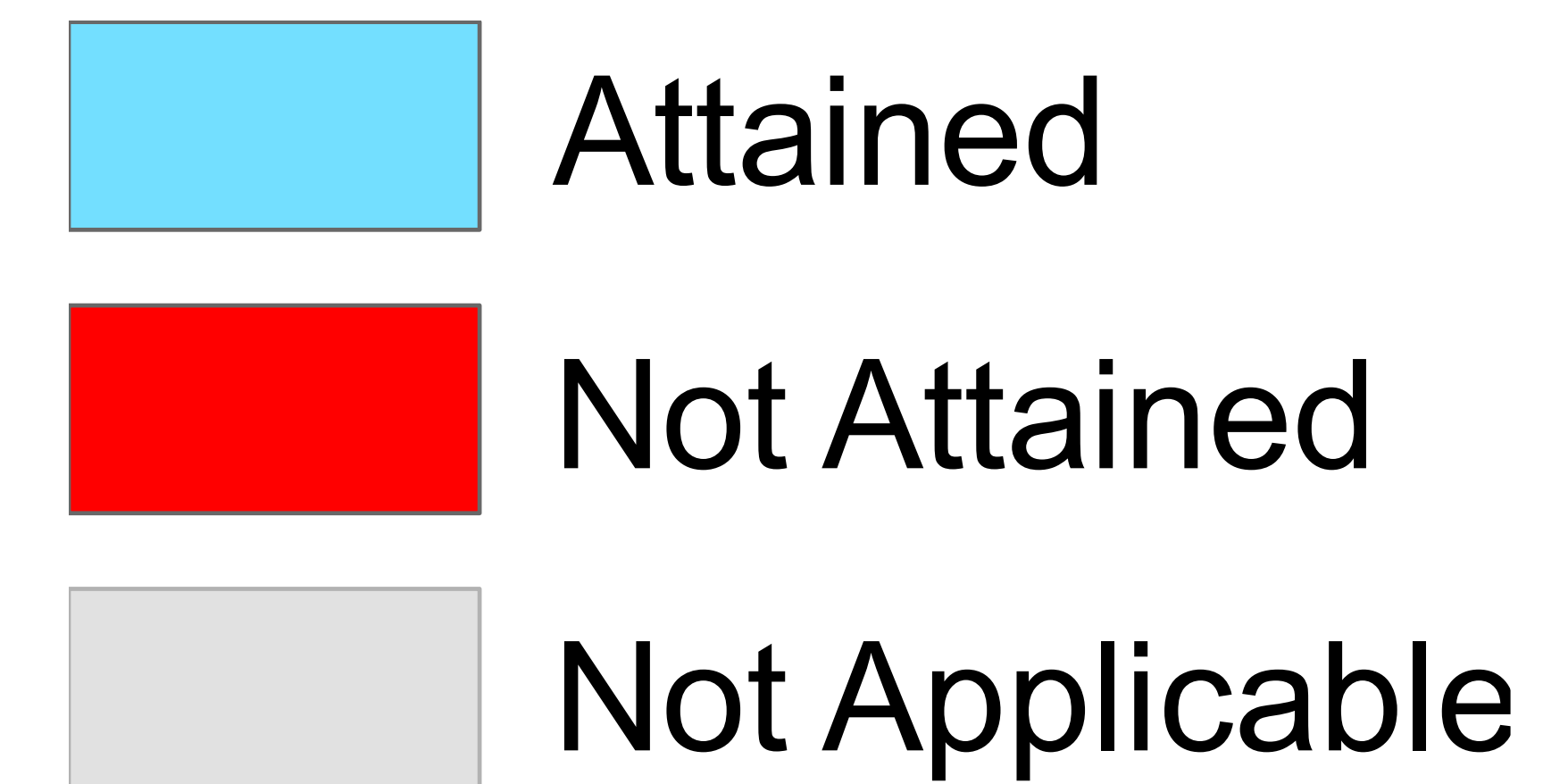
All Forest

Deep-Channel - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment

- CB4MH
- CB5MH_MD



253 TN 15.9
TP



E3

All Forest

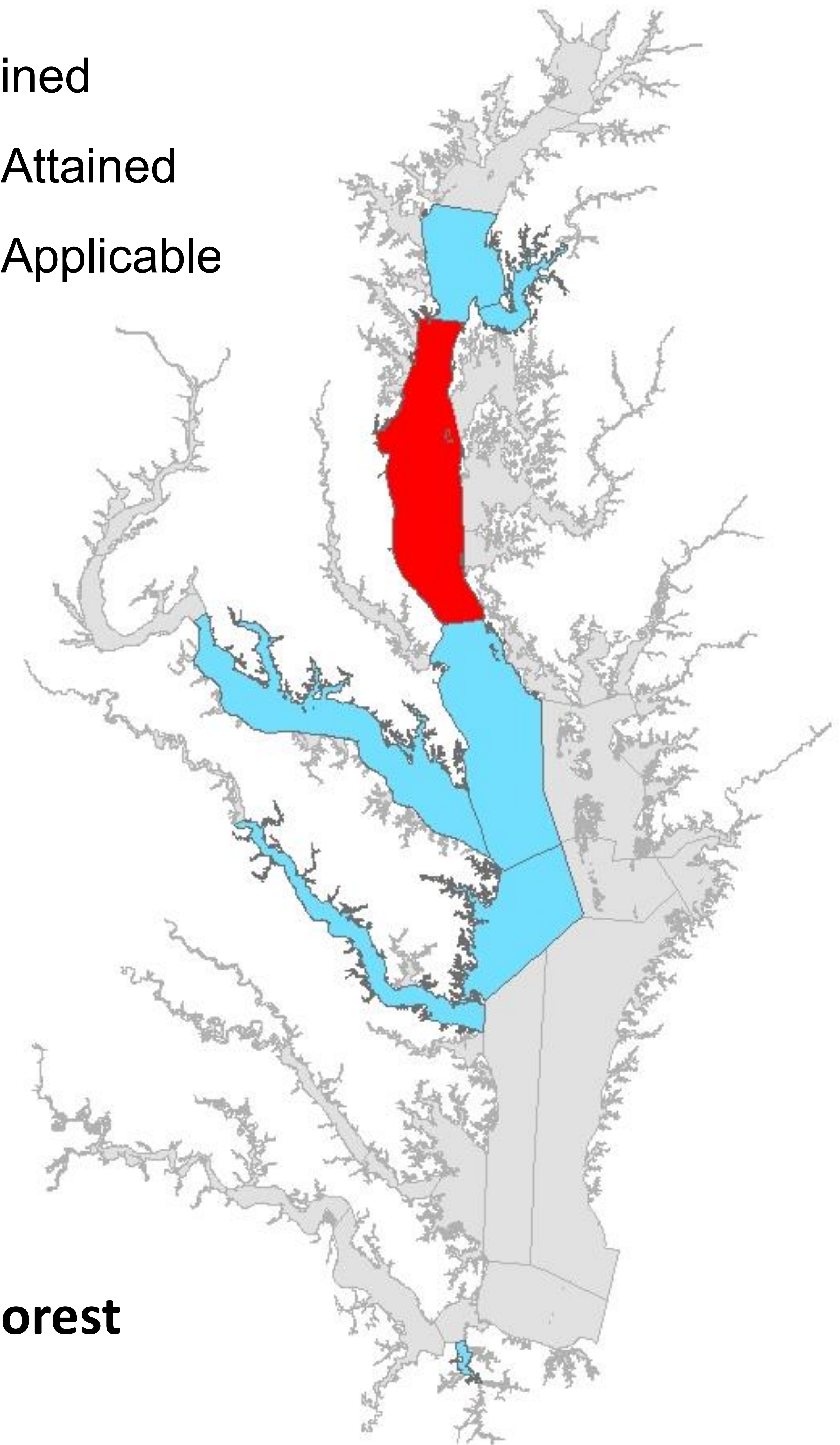
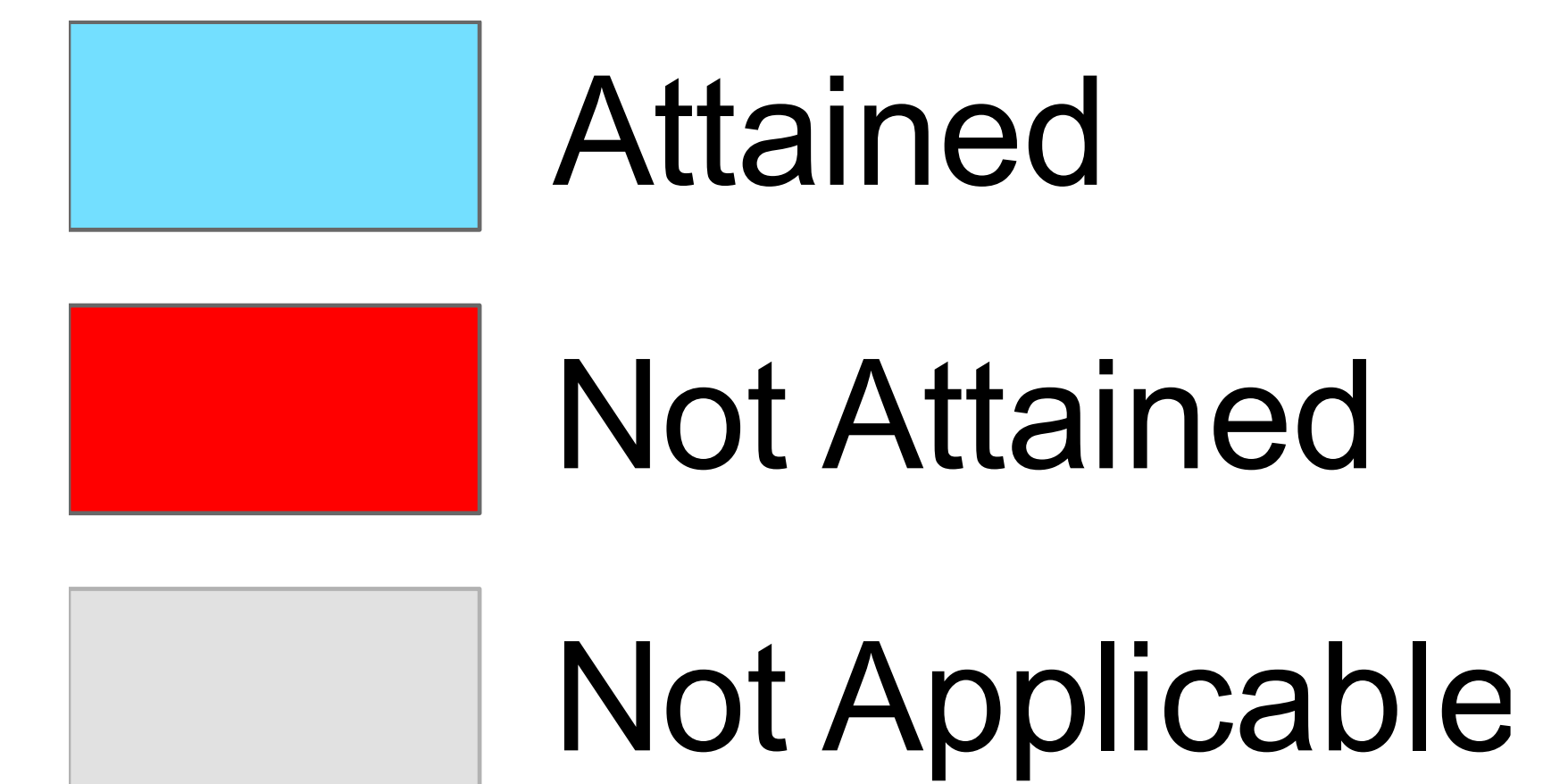


Deep-Channel - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment

- CB4MH



224 TN 14.8
TP



E3

All Forest

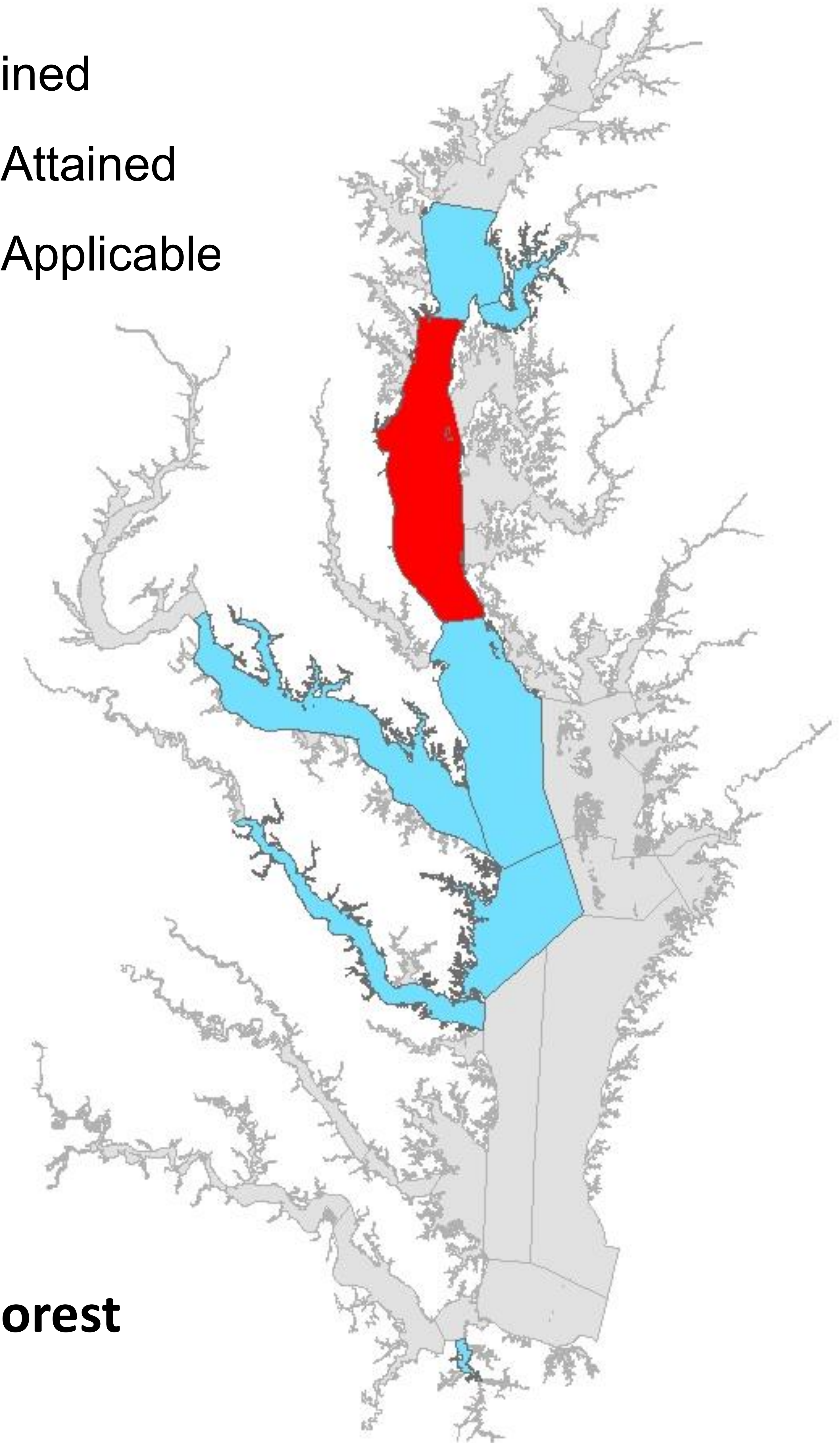
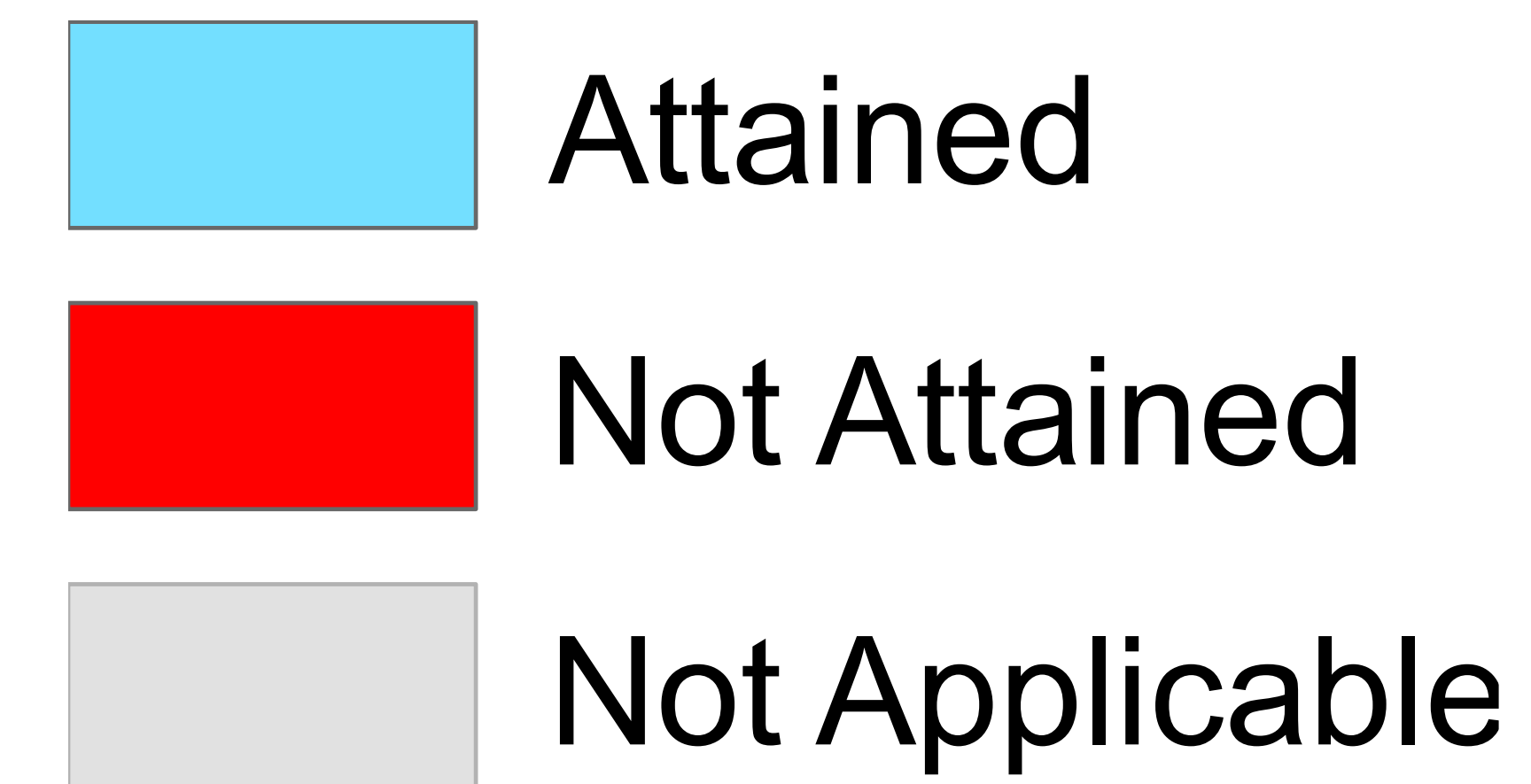


Deep-Channel - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment

- CB4MH



185 TN 12.8
TP



E3

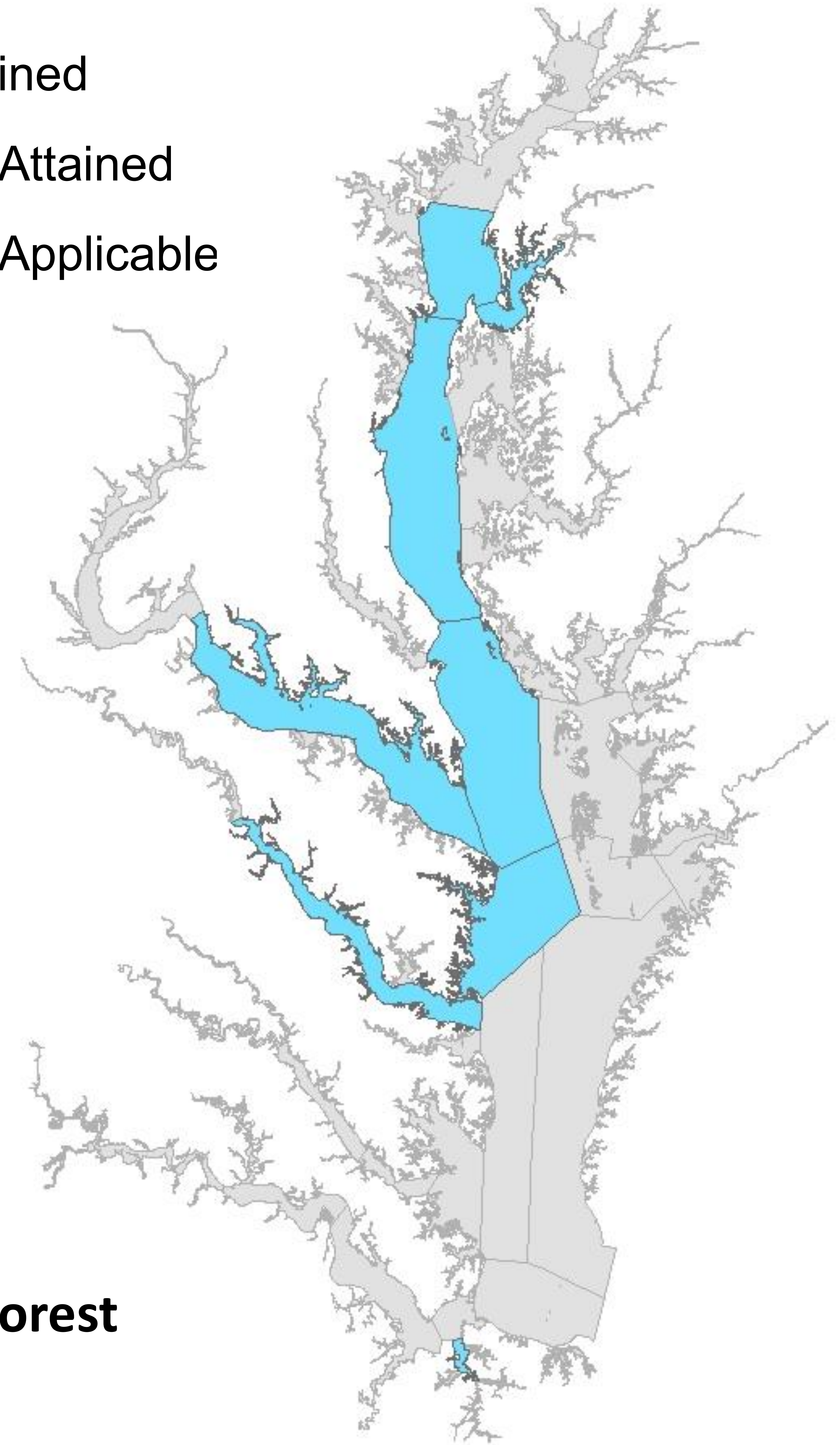
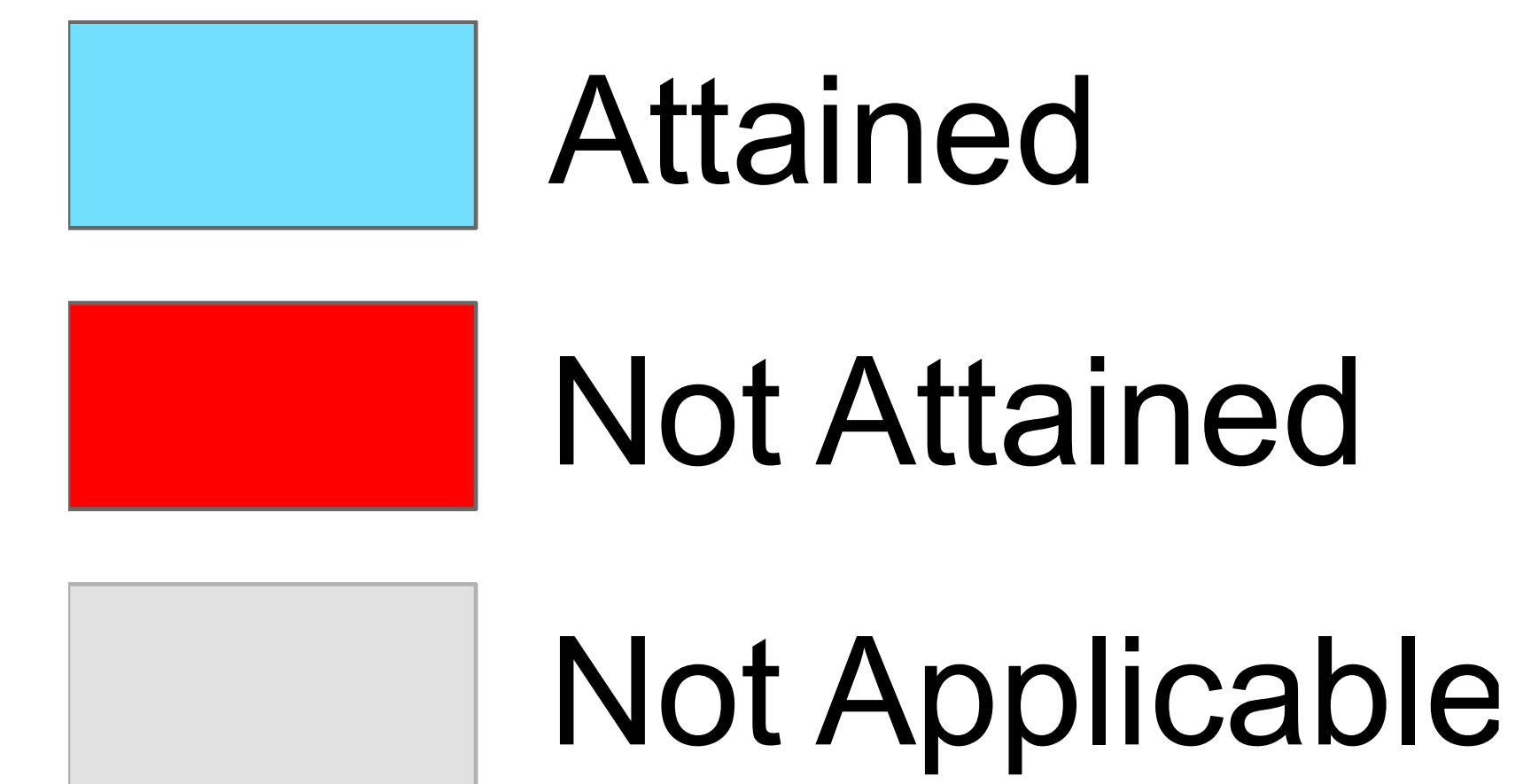
All Forest



Deep-Channel - PSC December 19, 2017 Presentation

Segments Attaining Oxygen Standards: Deep-Channel Use

Segments NOT in Attainment



174 TN 11.9
TP



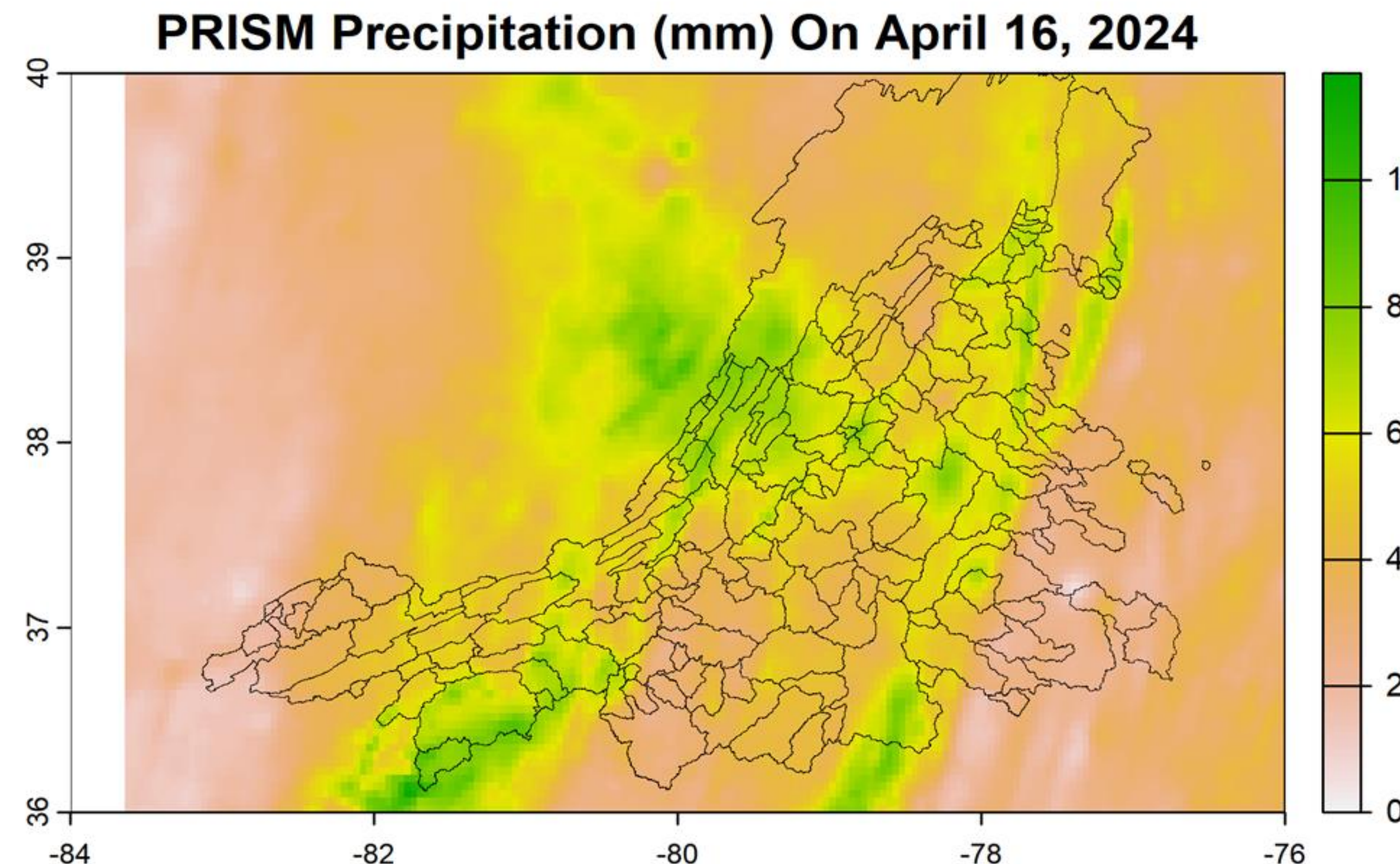
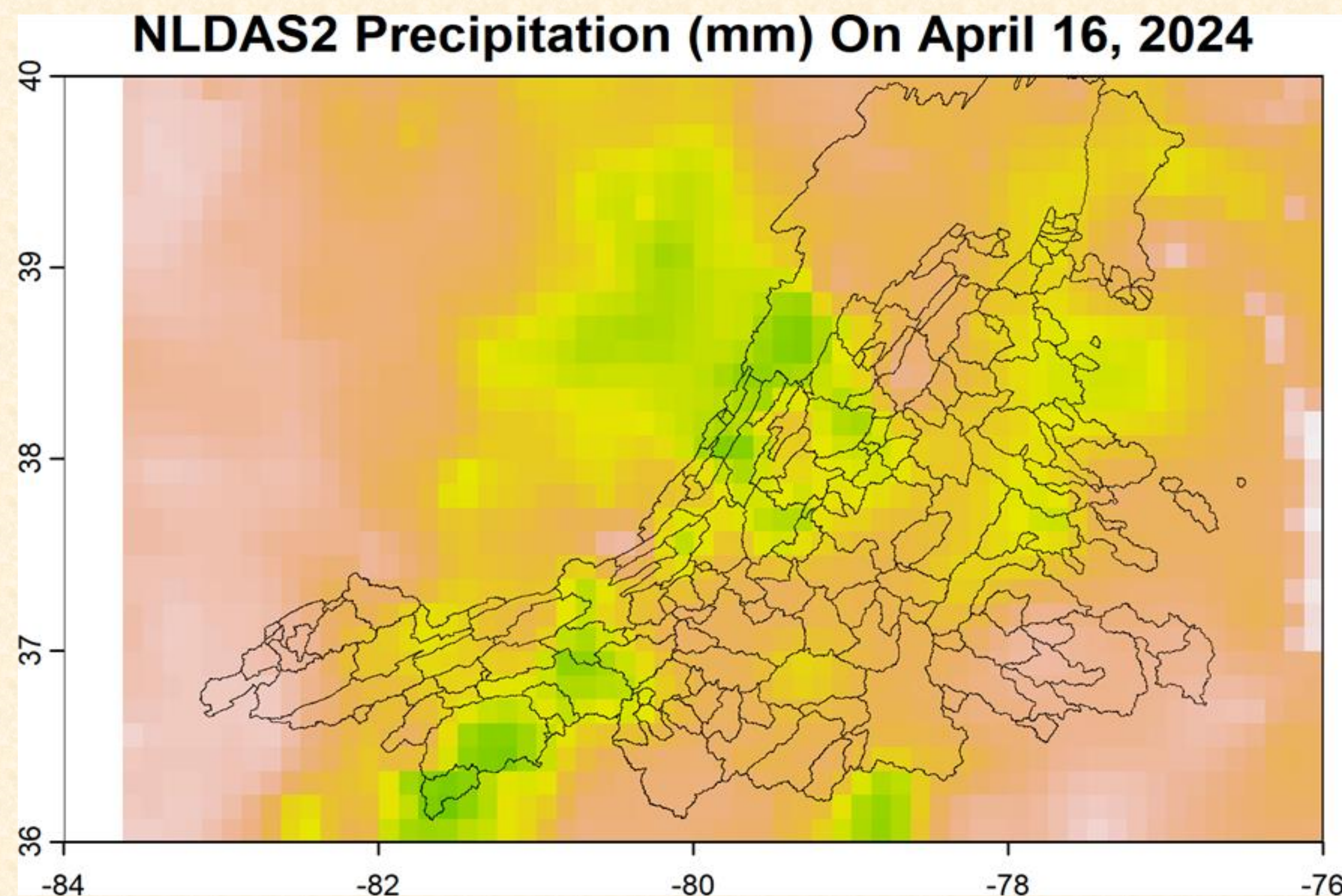
E3

All Forest



Phase 7 Watershed Model Refinements

Better simulation of flows, nutrients, and sediment through use of daily precipitation from PRISM with NLDAS hourly adjustments. Particularly improves high flows and recent years largely due to the finer resolution of the PRISM data set of 4km x 4km resolution compared to NLDAS resolution of 14km x 14km. The PRISM 4km x 4km precipitation grid is disaggregated to hourly time steps based on NLDAS-2 14km x 14km grid with meteorological data (air temperature, potential evapotranspiration, wind speed, solar radiation, dew point temperature, and cloud cover) based on NLDAS-2.



Working in collaboration with Robert Burgholzer and Connor Brogan (VA DEQ)



Phase 7 Watershed Model Refinements

Longer 40-year period of model simulation in Phase 7 (1985 – 2024) compared to the 30-year simulation period of Phase 6 (1985 – 2014) providing for an improved calibration with an additional decade of flow and concentrations of nutrients and sediment.

Phase 1 Watershed Model (1987) Steady state summer average loads for 1965, 1984, and 1985: zero years of simulation.

Phase 2 Watershed Model (1992) 1984 – 1987: 4 years of simulation.

Phase 4 Watershed Model (2002) 1985-2000: 16 years of simulation.

Phase 5 Watershed Model (2010) 1985-2002: 18 years of simulation.

Phase 6 Watershed Model (2017) 1985-2014: 30 years of simulation.

Phase 7 Watershed Model (current) 1985-2024: 40 years of simulation.



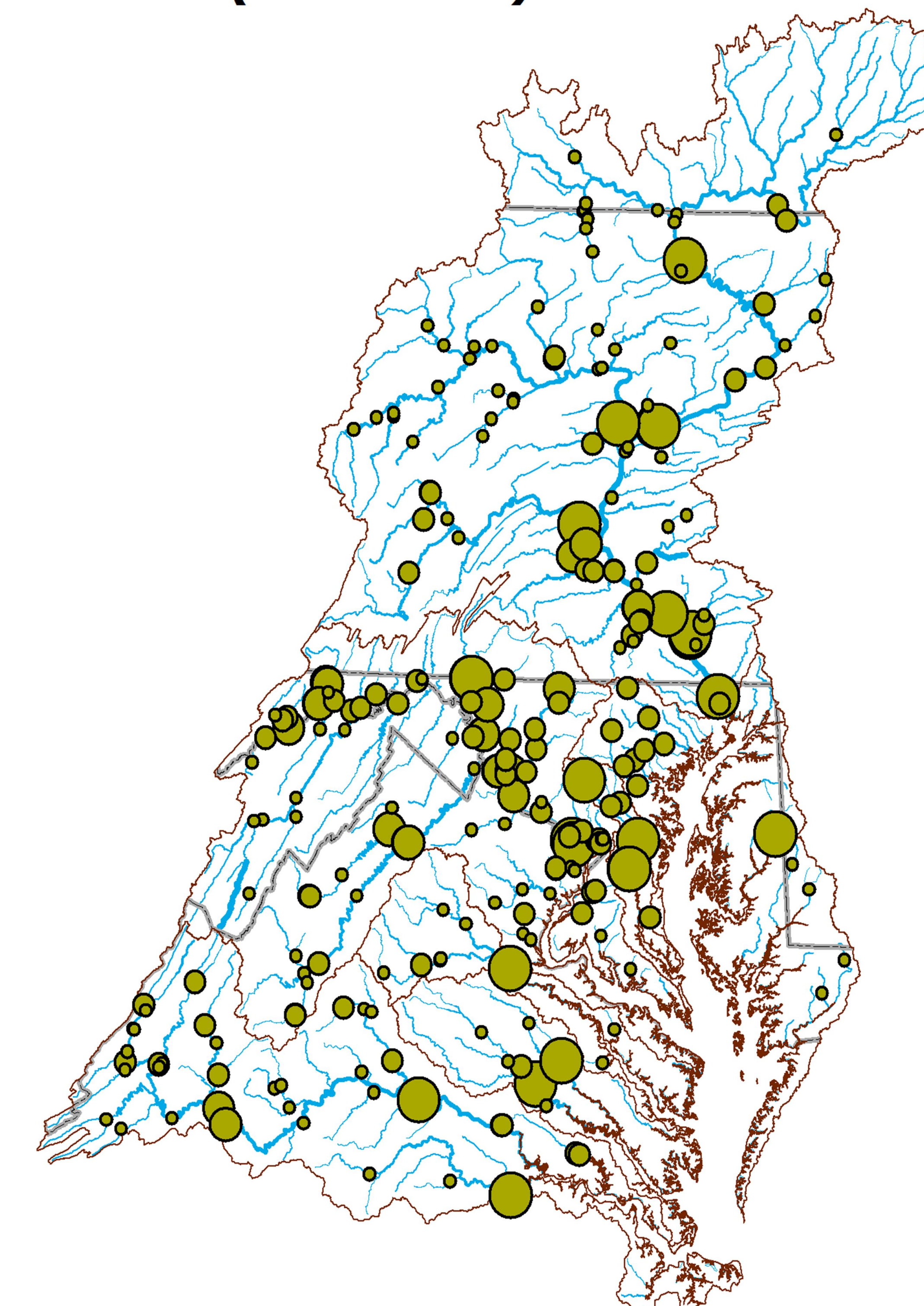
Phase 7 Watershed Model Refinements

The Phase 7 Model is calibrated with four decades of monitoring data and hundreds of thousands of water quality monitoring data points.

1) The Watershed Model Phase 7 riverine simulation uses from 14% (nitrate) to 33% (suspended sediment) more monitoring observations than Phase 6.

DWSM Variable	#Stations in P6	#Stations in P7	#Observations in P6	#Observations in P7	Δ Observations
Streamflow	249	266	2,749,709	3,245,529	18%
Nitrogen	184	211	48,634	64,671	33%
Phosphorus	211	221	55,115	63,969	16%
Nitrate	217	225	56,514	64,178	14%
Ammonia	212	224	54,904	64,117	17%
Dissolve Phosphate	172	175	43,777	56,640	29%
Suspended Sediment	164	216	57,814	67,558	17%

Phase 6 (1984-2014)



2) The new **Generalized Stream Network (GSN) simulation** uses monitoring observations organized with Random Forest Models of flow and seasonal beta parameters:

GSN β parameter stations for Nitrogen = 216

GSN β parameter stations for Phosphorus = 196

GSN β parameter stations for Suspended Sediment = 146

3) The new **Coastal Plain tidal monitoring** for 16 stations, 40 years, 21 collection periods/year, and observations of Ammonia, Nitrate, Phosphate, TN, TP, and TSS = 80,600.

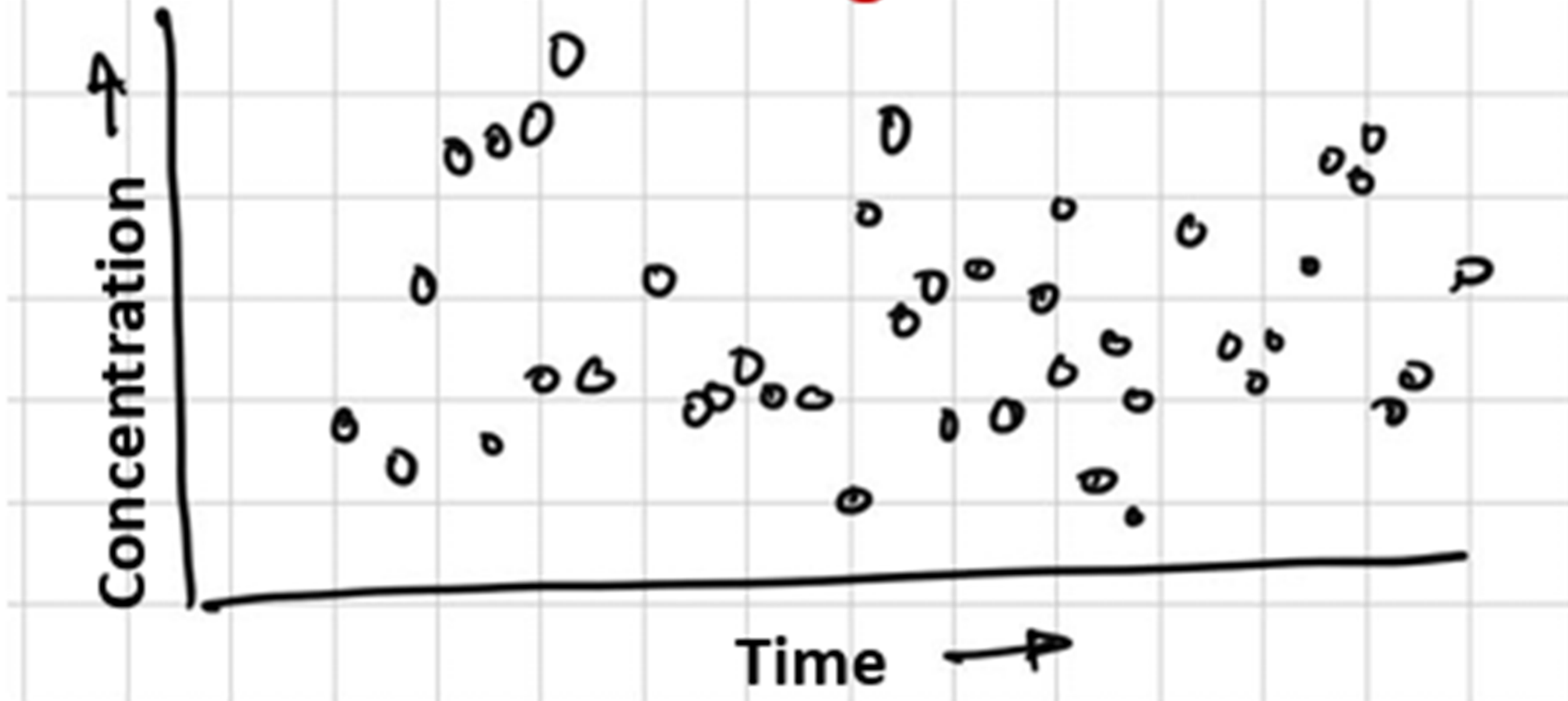
4) For **WRTDS TN and TP use in CalCAST** we apply 216 stations and 182 stations, respectively.



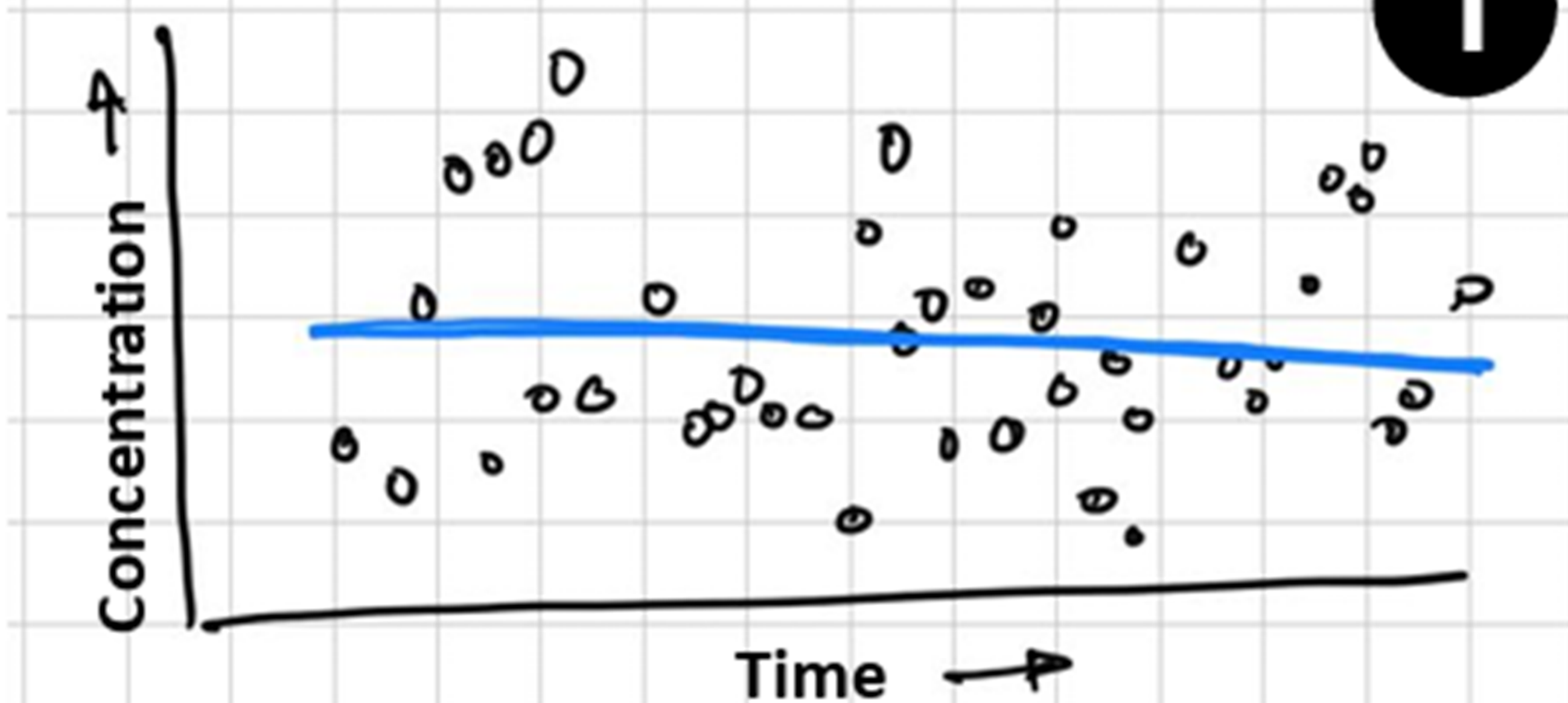
Phase 7 Watershed Model Refinements

First time application in the CBP Watershed Model of a Generalized Stream Network (GSN) simulation allowing use of a greater number of calibration stations, improved simulation of stream network attenuation, and quantifiably better load assessment throughout the watershed.

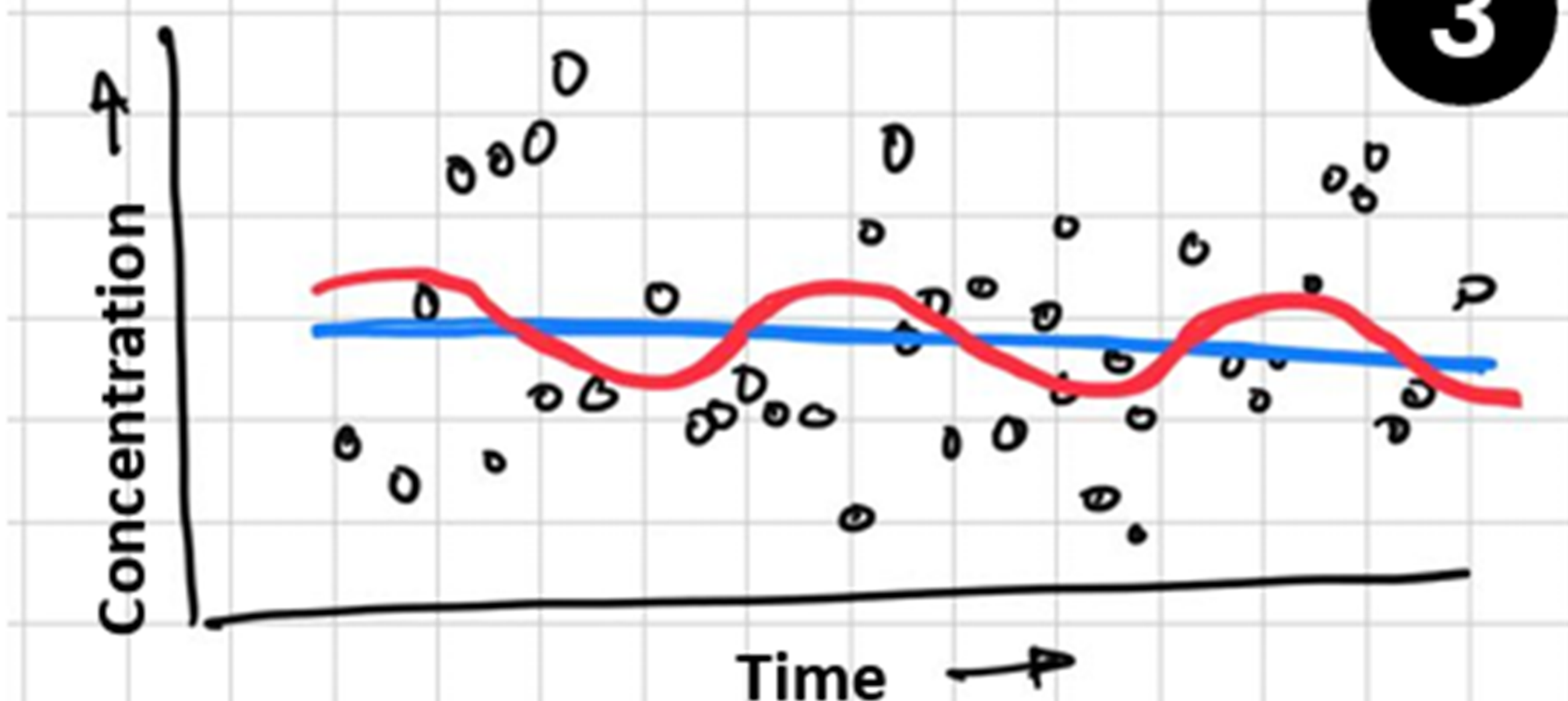
> data at a monitoring station



$$\ln(c_{trend}) = \beta_x + \beta_1 t$$



$$\ln(c_{season}) = \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t)$$



$$\ln(c) = \beta_o + \underbrace{\beta_1 t}_{1} + \underbrace{\beta_2 \ln(Q)}_{2} + \underbrace{\beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t)}_{3} + \varepsilon$$

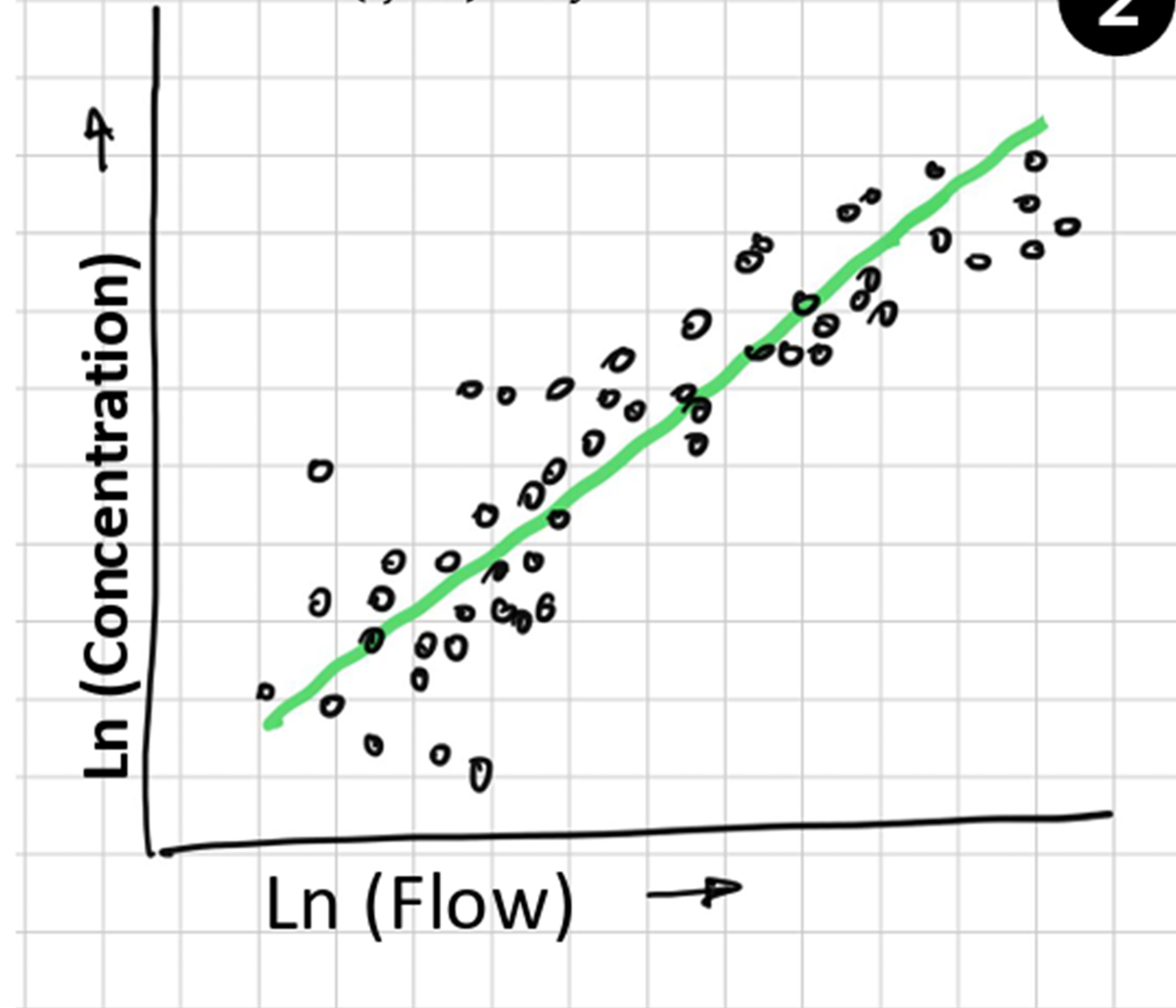
[FluxMaster]

trend

flow
variability

seasonal
variability

$$\ln(c_{flow}) = \beta_y + \beta_2 \ln(Q)$$



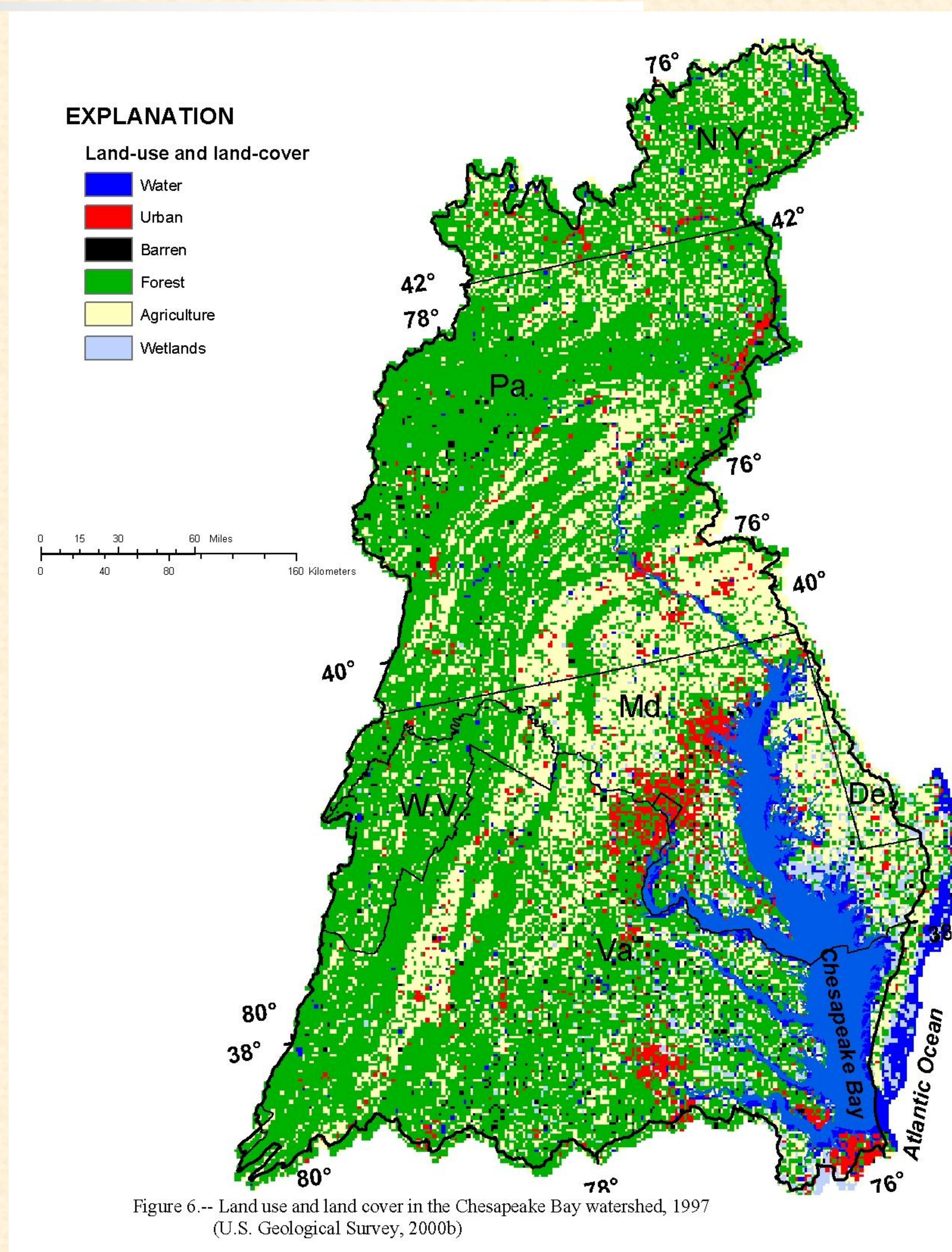
Random Forest models were developed for explaining variability in β_2 , β_2 and β_3 parameters of the monitoring stations and for estimating the same for all NHD streams.



Phase 7 Watershed Model Refinements

The Generalized Stream Network (GSN) simulation is of particular importance in the calibration from the Coastal Plain. Although the Coastal Plain physiographic region is only 14% of the watershed and adds only 14% of flow to the Chesapeake it also adds 32% of the nitrogen, 33% of the phosphorus, and 52% of the sediment loads*. The relatively high loads are from the diminished nutrient attenuation close to the Bay, high proportions of urban and cropland loads, and tidal shoreline erosion.

*Source: Phase 6 separation of 1991-2000 average of delivered loads from point source, non-point source, and tidal shoreline erosion loads.



Coastal Plain flow & loads without shoreline erosion:

Flow	Nitrogen	Phosphorus	Sediment	Acres
14%	32%	27%	11%	13%



Phase 7 Watershed Model Refinements

Better simulation and calibration of coastal plain nitrogen, phosphorus, and sediment loads to Chesapeake tidal embayments through the first-time assessment of coastal plain loads with tidal monitoring station information.

- **Zhengui Wang (VIMS), Wenfan Wu (VIMS), and Gopal Bhatt (Penn State)** have developed tools for assessing and tracking watershed model outputs and estuarine model performance.

Table: Comparison of Phase 6 and Phase 7 watershed loads in small embayments. Data in parenthesis show RMSD of watershed model loads (Phase 6, Phase 7) as compared to that of immediately downstream tidal monitoring stations.

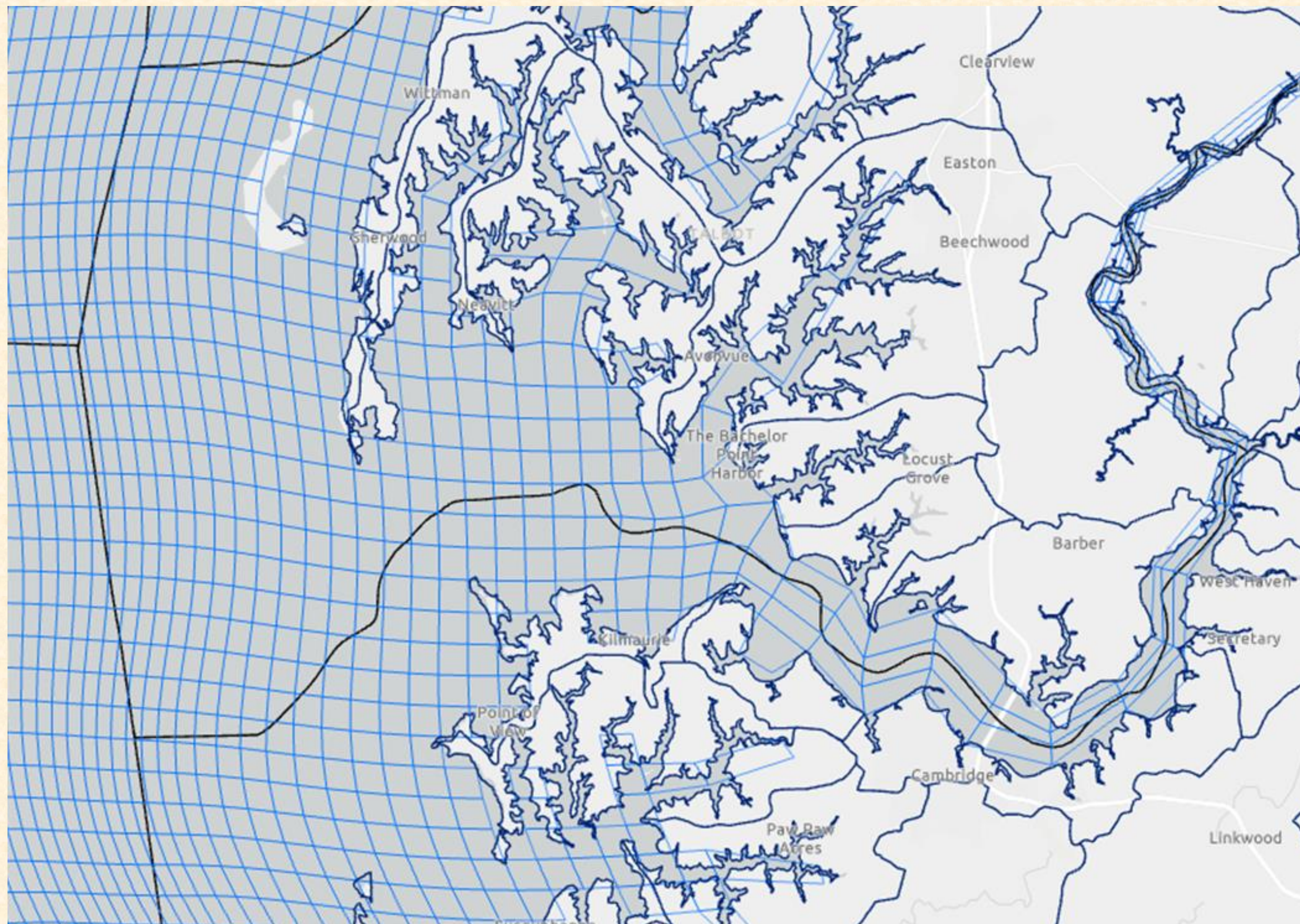
Embayments	River Impact	Salinity	Ammonia	Nitrate	Phosphate	TN	TP	Sediment
Sassafrass R.	99.5%	1.91	(0.1553, 0.1724)	(2.1799, 1.5663)	(0.0506, 0.0303)	(2.1749, 2.2918)	(0.1157, 0.0708)	(83.4010, 64.0950)
Bush R.	95.9%	0.84	(1.5825, 0.8445)	(2.4744, 2.0285)	(0.1267, 0.1176)	(3.0666, 2.1254)	(0.1737, 0.1249)	(59.0322, 53.9453)
Gunpowder R.	94.7%	1.63	(0.0774, 0.0722)	(1.0177, 0.4990)	(0.0122, 0.0164)	(0.8905, 0.4488)	(0.0471, 0.0442)	(41.6804, 37.5875)
South R.	69.1%	9.84	(0.1297, 0.1260)	(3.9673, 1.0413)	(0.0467, 0.0570)	(3.8474, 0.8997)	(0.0784, 0.0691)	(72.0014, 40.8683)
Piscataway R.	100.0%	0.00	(0.3453, 0.3234)	(5.3081, 3.5262)	(0.0381, 0.0407)	(5.3026, 3.7516)	(0.0702, 0.0805)	(50.1494, 36.6836)
Mattawoman C.	100.0%	0.02	(0.2073, 0.1016)	(4.8008, 1.8416)	(0.4483, 0.1060)	(5.5305, 1.7449)	(0.7417, 0.1505)	(57.9953, 37.4156)
Corrotoman R.	56.6%	14.53	(0.1101, 0.0573)	(1.8100, 0.7028)	(0.0223, 0.0406)	(1.8435, 0.5316)	(0.0785, 0.0431)	(61.3329, 12.5883)
Chickahominy R.	99.7%	1.18	(0.9466, 0.0622)	(5.4596, 0.1991)	(0.0683, 0.0370)	(7.2374, 0.3392)	(0.1628, 0.0585)	(59.5836, 49.2633)
Nanticoke R.	99.8%	0.19	(0.1803, 0.1174)	(2.9407, 1.4765)	(0.0436, 0.0748)	(2.8671, 1.2300)	(0.0962, 0.0807)	(35.9075, 35.1593)
Manokin R.	49.0%	13.87	(1.1536, 0.1188)	(3.7258, 1.3950)	(0.0762, 0.1538)	(4.8577, 1.6415)	(0.1603, 0.1767)	(43.1494, 30.3107)
Big Annemessix R.	47.8%	15.41	(10.0068, 0.2549)	(17.8570, 1.7639)	(0.4463, 0.1978)	(25.9882, 2.5115)	(0.8129, 0.2395)	(85.0987, 19.1356)
Patapsco R.	80.8%	10.42	(3.5302, 3.2289)	(2.9920, 2.4831)	(0.2444, 0.2266)	(6.6460, 5.9269)	(0.3410, 0.3307)	(55.0892, 39.3605)
Anacostia R.	100.0%	0.17	(0.2177, 0.2341)	(2.7501, 0.3297)	(0.0824, 0.0522)	(1.7004, 0.8990)	(0.0571, 0.0756)	(95.3317, 80.2096)
Elizabeth S.	46.9%	19.08	(1.8986, 0.4678)	(4.3389, 1.0248)	(0.8990, 0.2319)	(7.6235, 1.3427)	(1.2829, 0.3256)	(14.6792, 13.5410)
Chester R.	99.3%	0.49	(0.1221, 0.1062)	(1.0766, 1.2225)	(0.0301, 0.0733)	(0.9874, 1.1437)	(0.1563, 0.1110)	(87.0498, 91.7857)
Pocomoke R.	100.0%	0.20	(0.2716, 0.0722)	(0.7283, 0.6284)	(0.0953, 0.0869)	(1.1926, 0.6074)	(0.1445, 0.1108)	(30.9019, 23.7107)

Source: April 2025 Quarterly Review Gopal Bhatt presentation.

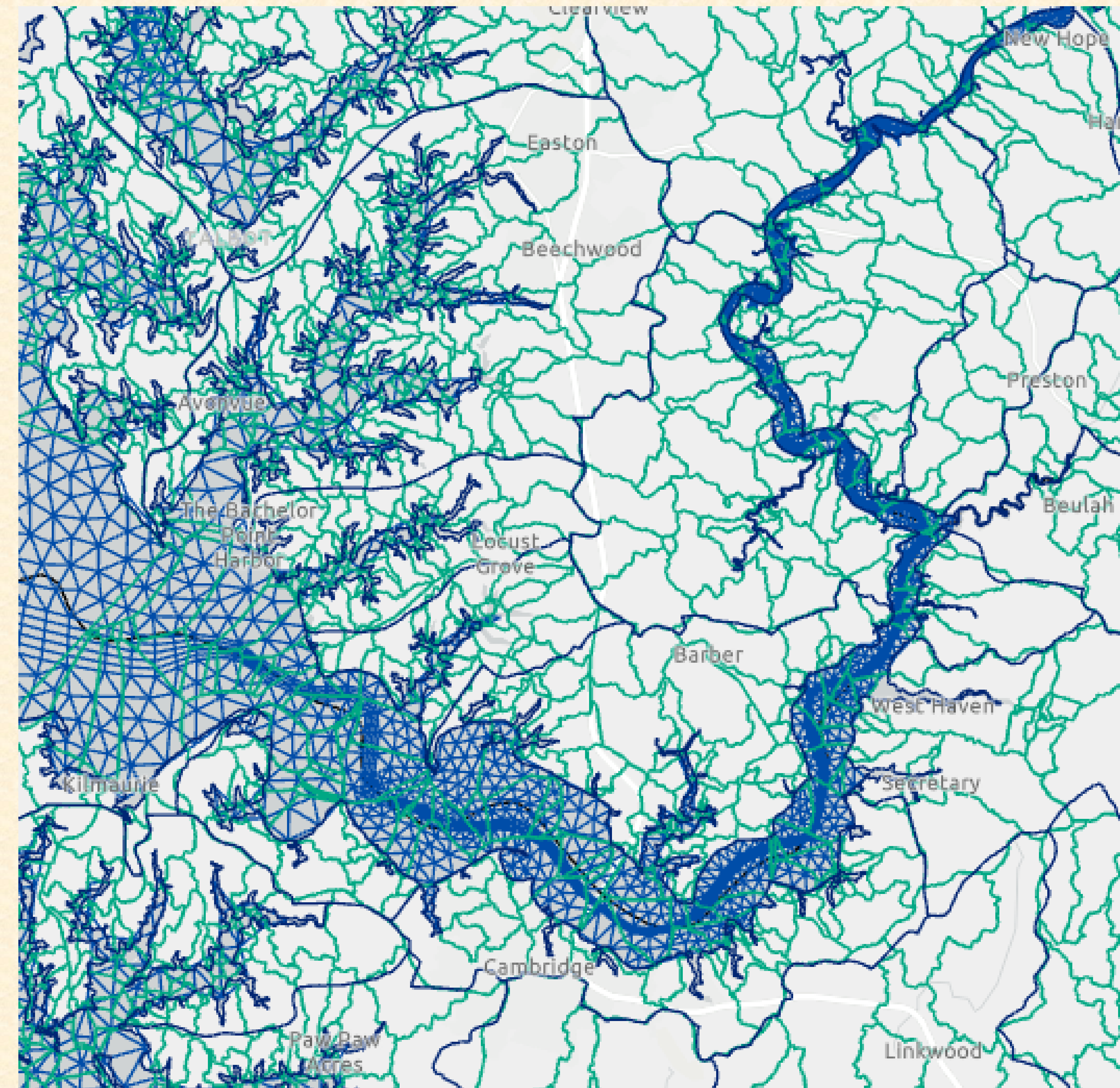


Phase 7 Watershed Model Refinements

Finer segmentation of broad land use categories at an NHD level of about one square mile in Phase 7 compared to the approximate 50 square mile segments of Phase 6.



Showing the Phase 6 Watershed Model finest level grid, the land-river segments and the Phase 6 Bay Model grid.

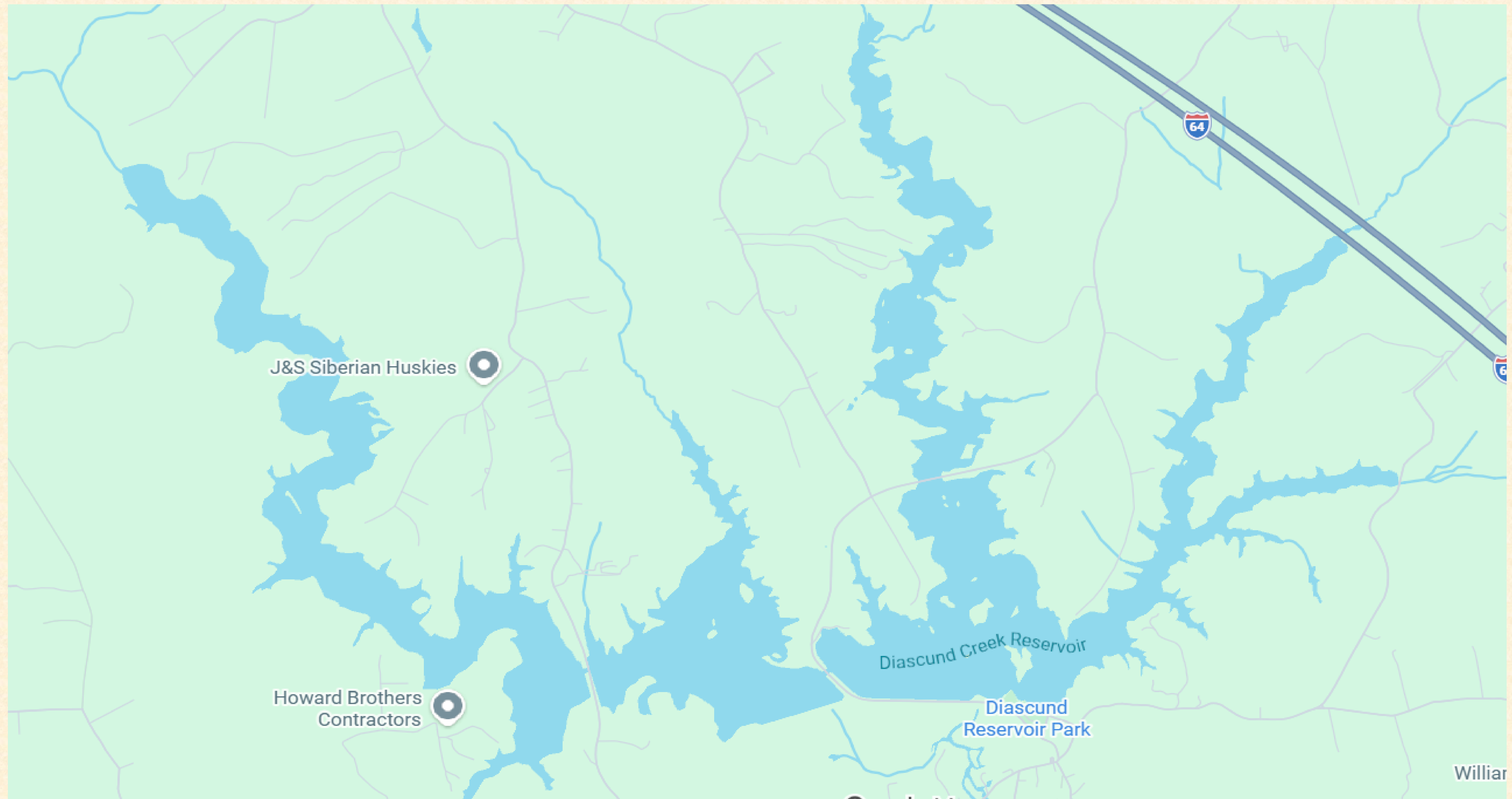


Showing the Phase 7 Watershed Model finest level grid of NHD+ segments and the Phase 7 Bay Model grid.



Phase 7 Watershed Model Refinements

Inclusion of coastal plain reservoirs and their attenuation capability which were not previously represented in Phase 6.



In collaboration with Robert Burgholzer, DEQ.



Phase 7 Watershed Model Refinements

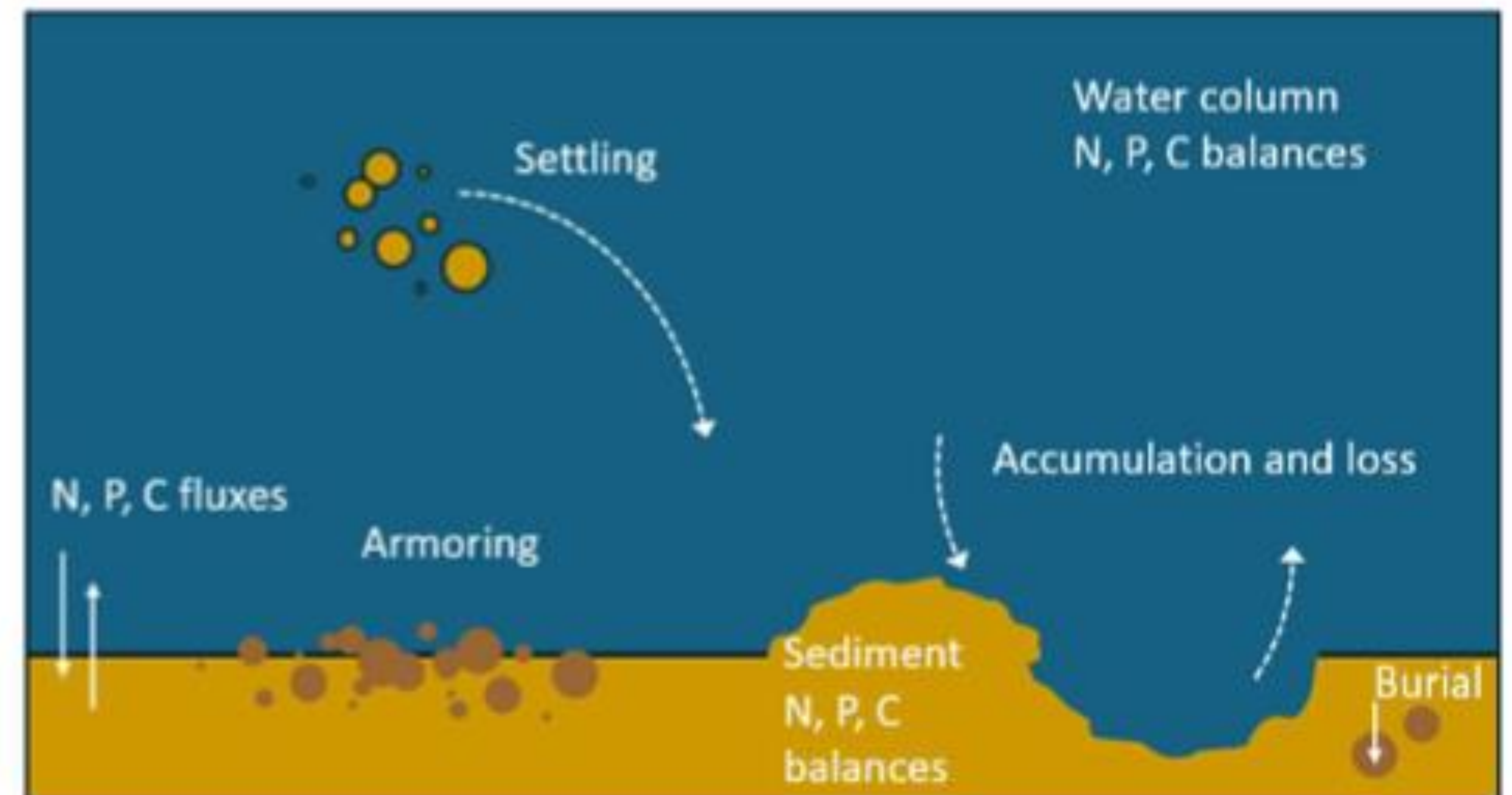
Improved simulation of Conowingo infill in the Dynamic Watershed Model and through the CoE-ERDC 2027 Conowingo Model.



MODEL REQUIREMENTS



- Continuous simulation of the reservoir pool including selected hydrometeorological events; (1991-2000)
- Change in hydrodynamics from reservoir infill of sediments from the CR watershed, and removal of material through dredging
- Biogeochemistry in the reservoir pool, responding to the amount and speciation of nitrogen, phosphorus, and sediment inputs from upstream and bottom sediment
- Biogeochemical changes in sediments, including burial, species changes, and water column exchanges
- Physical changes in sediment characteristics due to erosion, bed armoring, and deposition of sediment and the resulting morphological changes in the reservoir
- Dredging of the reservoir.

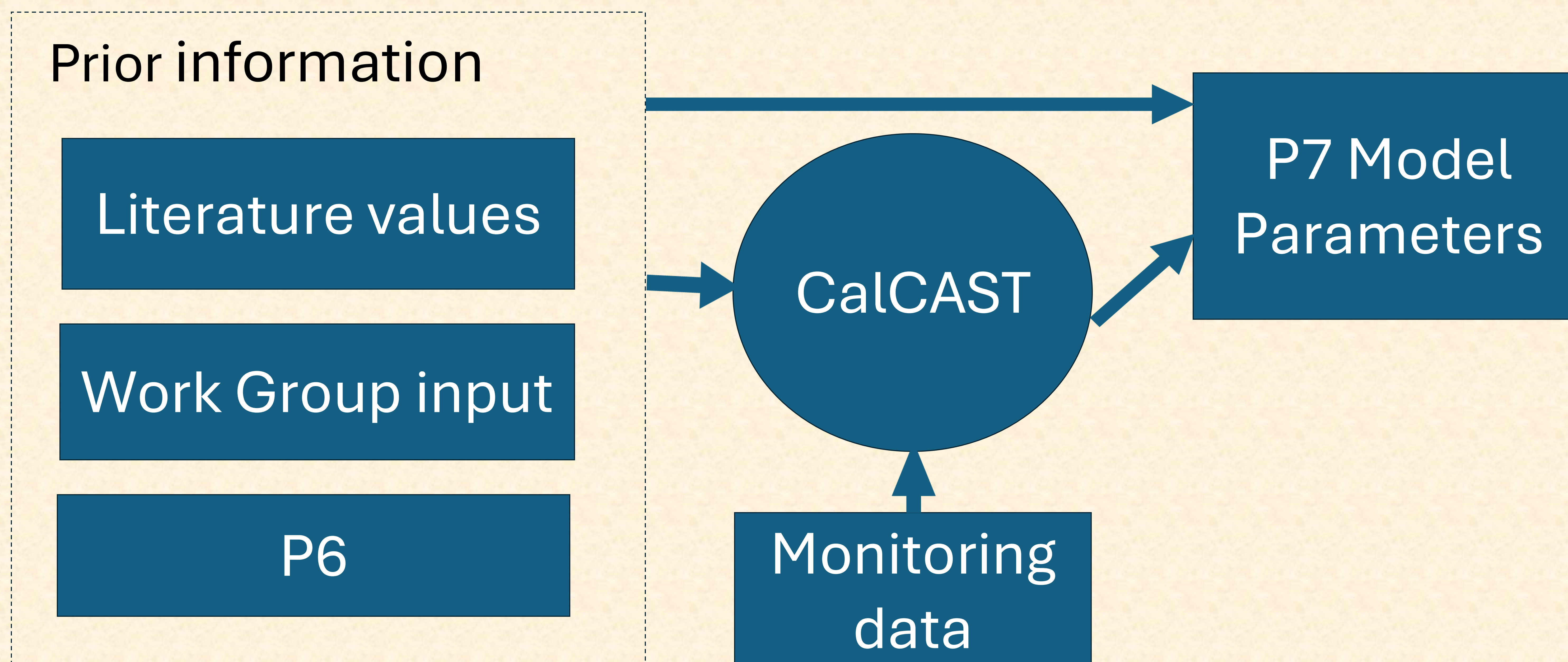




Phase 7 Watershed Model Refinements - CalCAST

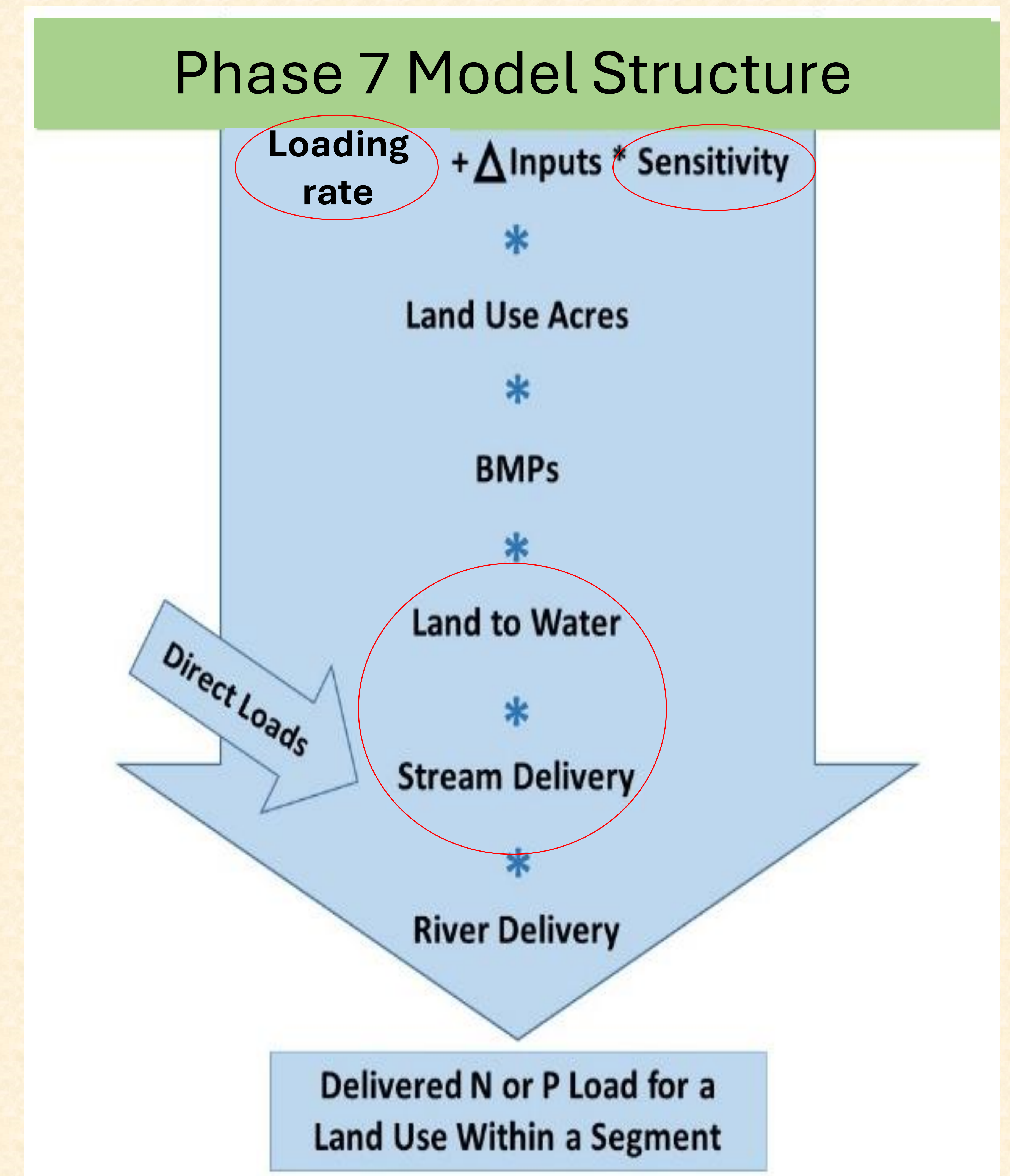
Better estimates of land use loading rates, input sensitivities, and transfer factors through CalCAST.

Incorporate data-driven lines of evidence into modeling approach



CalCAST: CAST represented in a framework for statistical calibration to monitoring data.

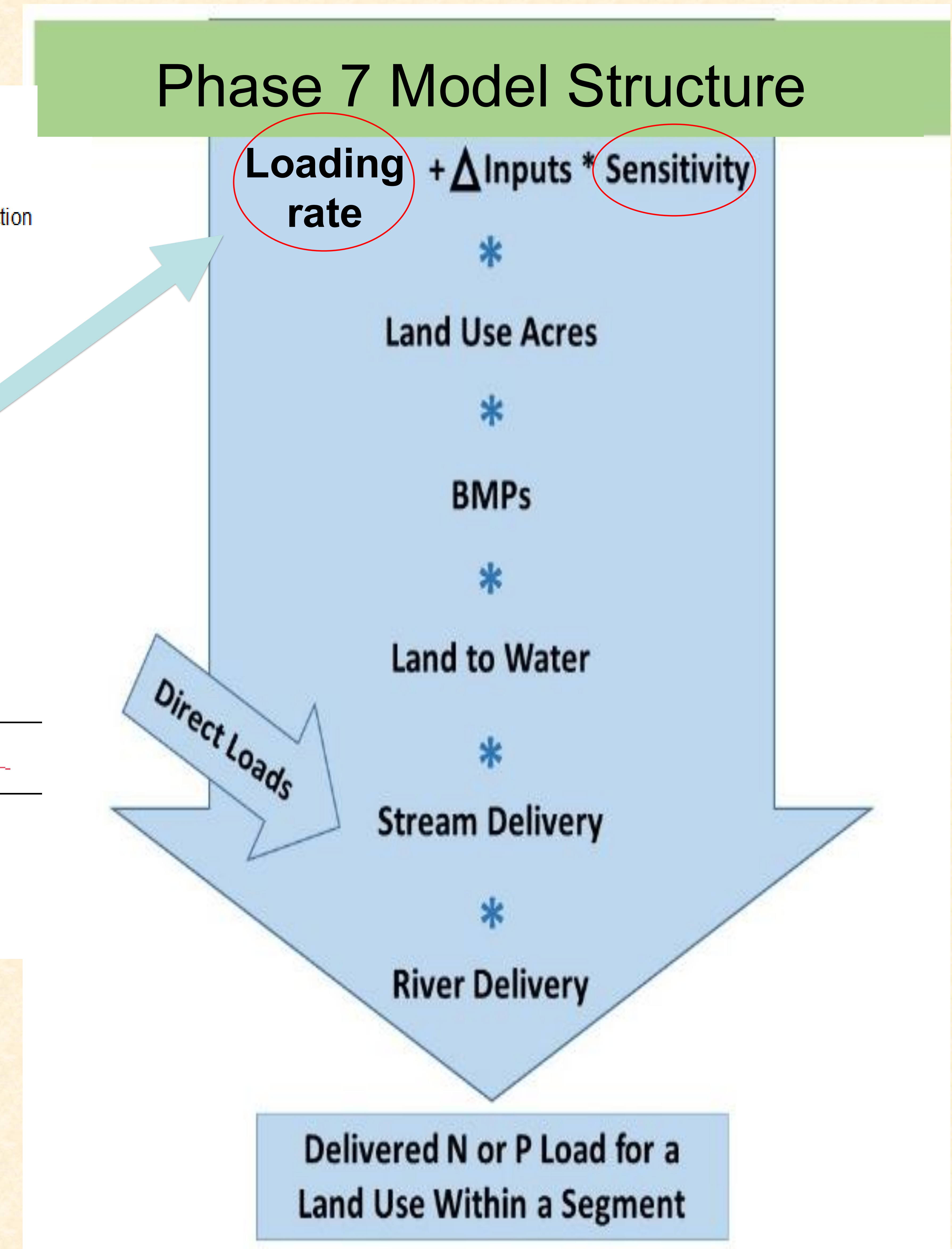
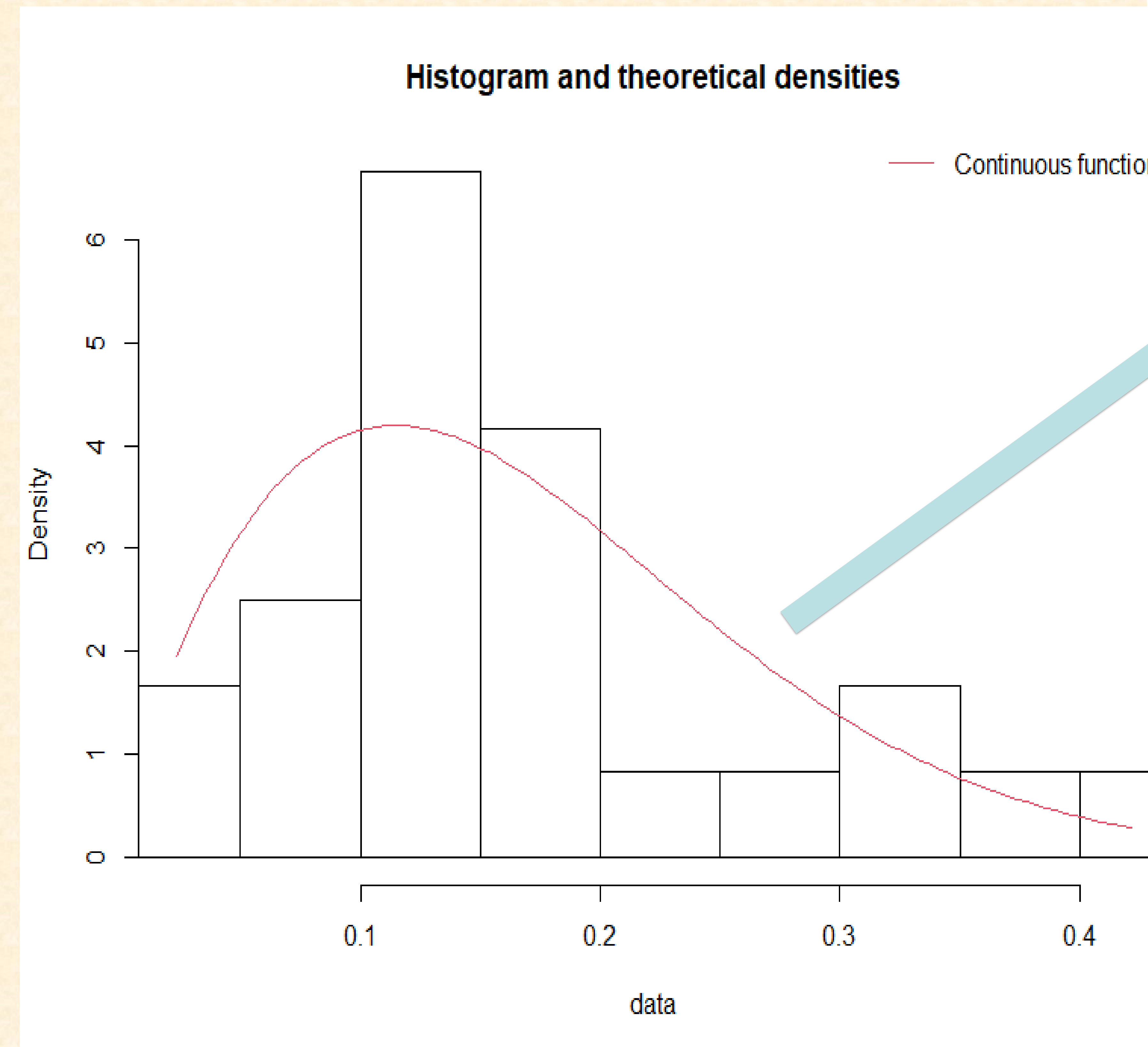
Calibrate loading rates, select sensitivities, and coefficients of delivery factors.





CalCAST: Utilizes All Available Prior Information

- Literature and modeled parameter values are summarized as a probability distribution.
- The distribution of values is randomly sampled hundreds of times to select values to run through CAST.
- How well each of these values describes the observed monitoring data is defined and a final parameter value is selected.





Example: Test of Land Use Total Nitrogen Average Loads

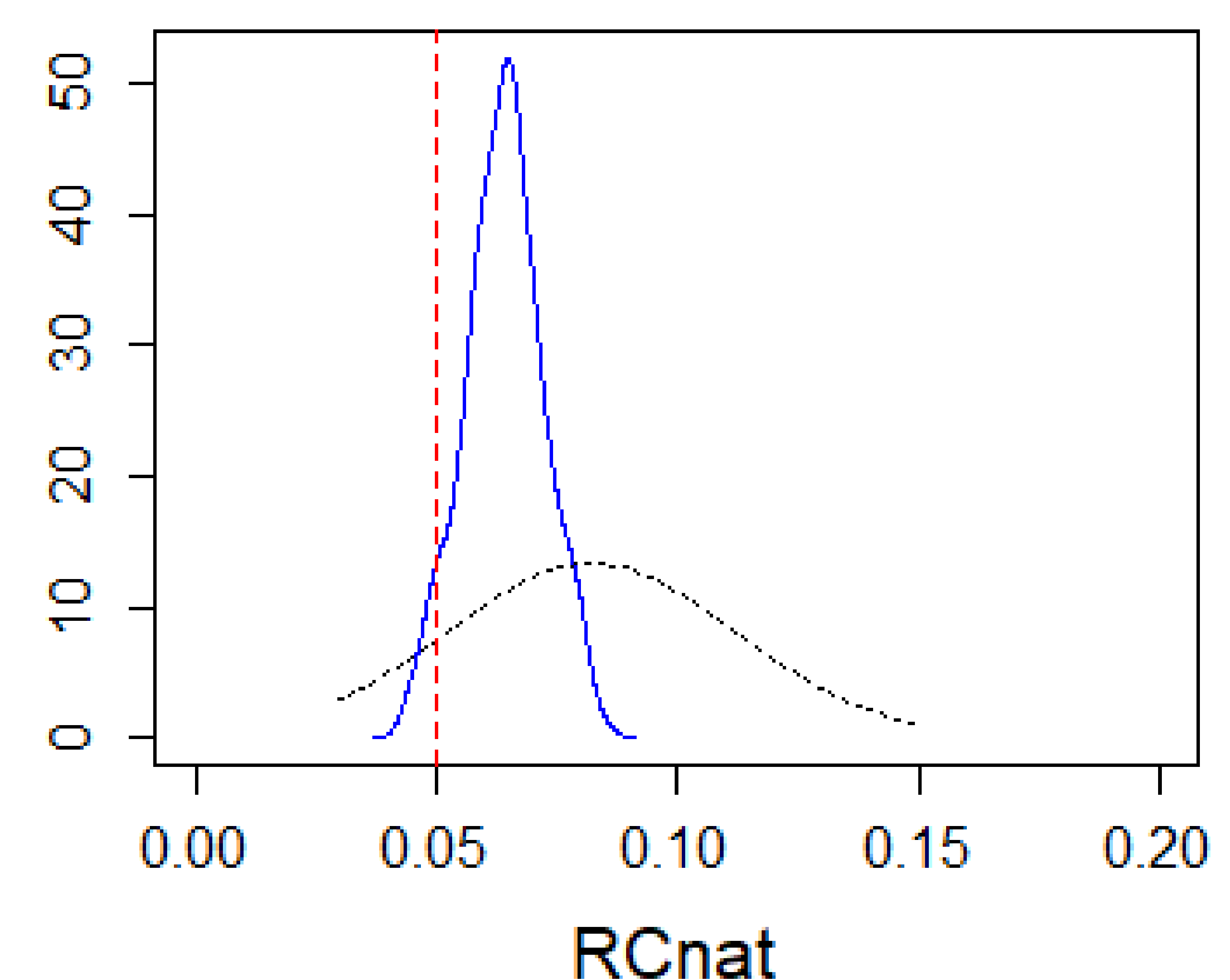
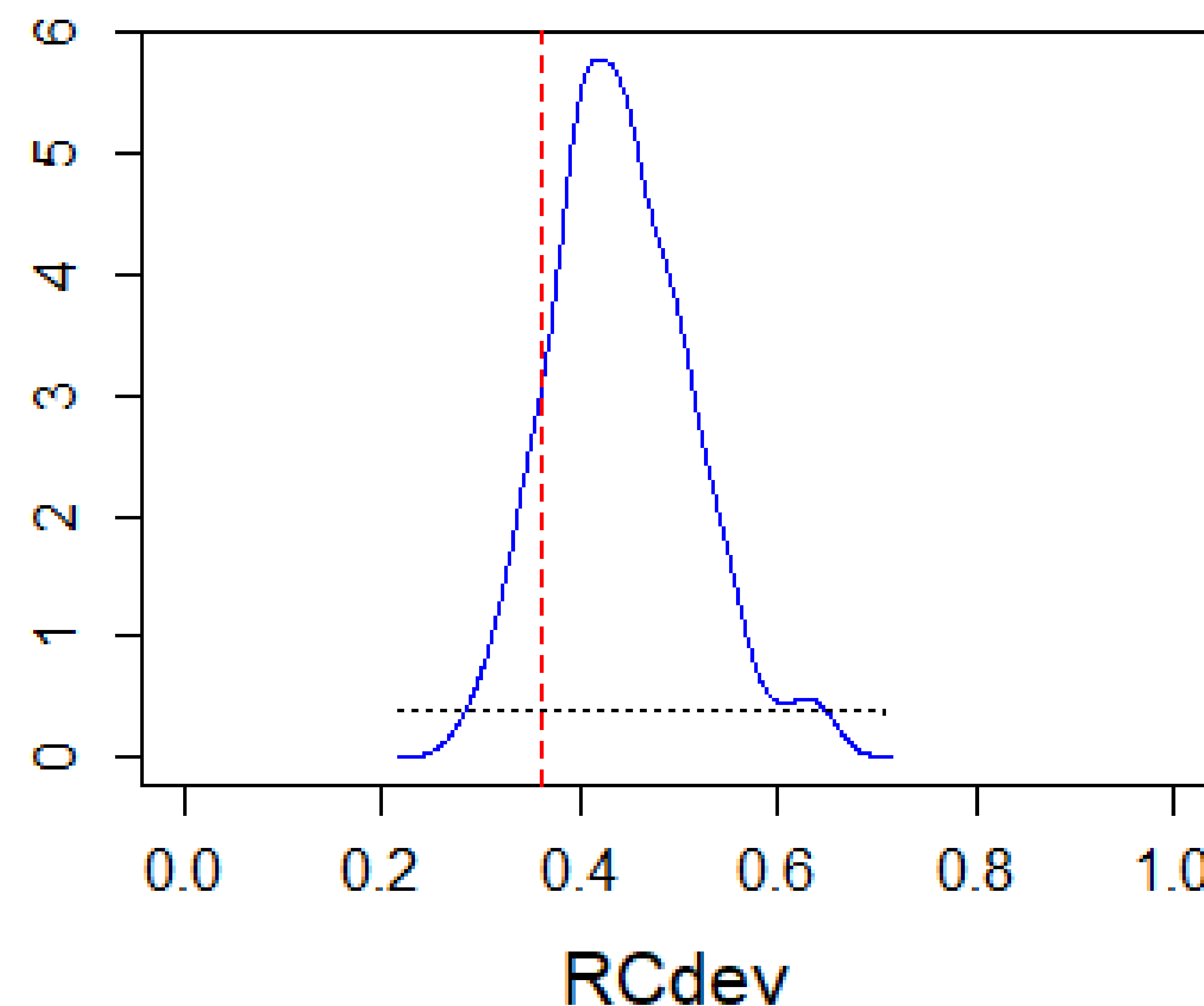
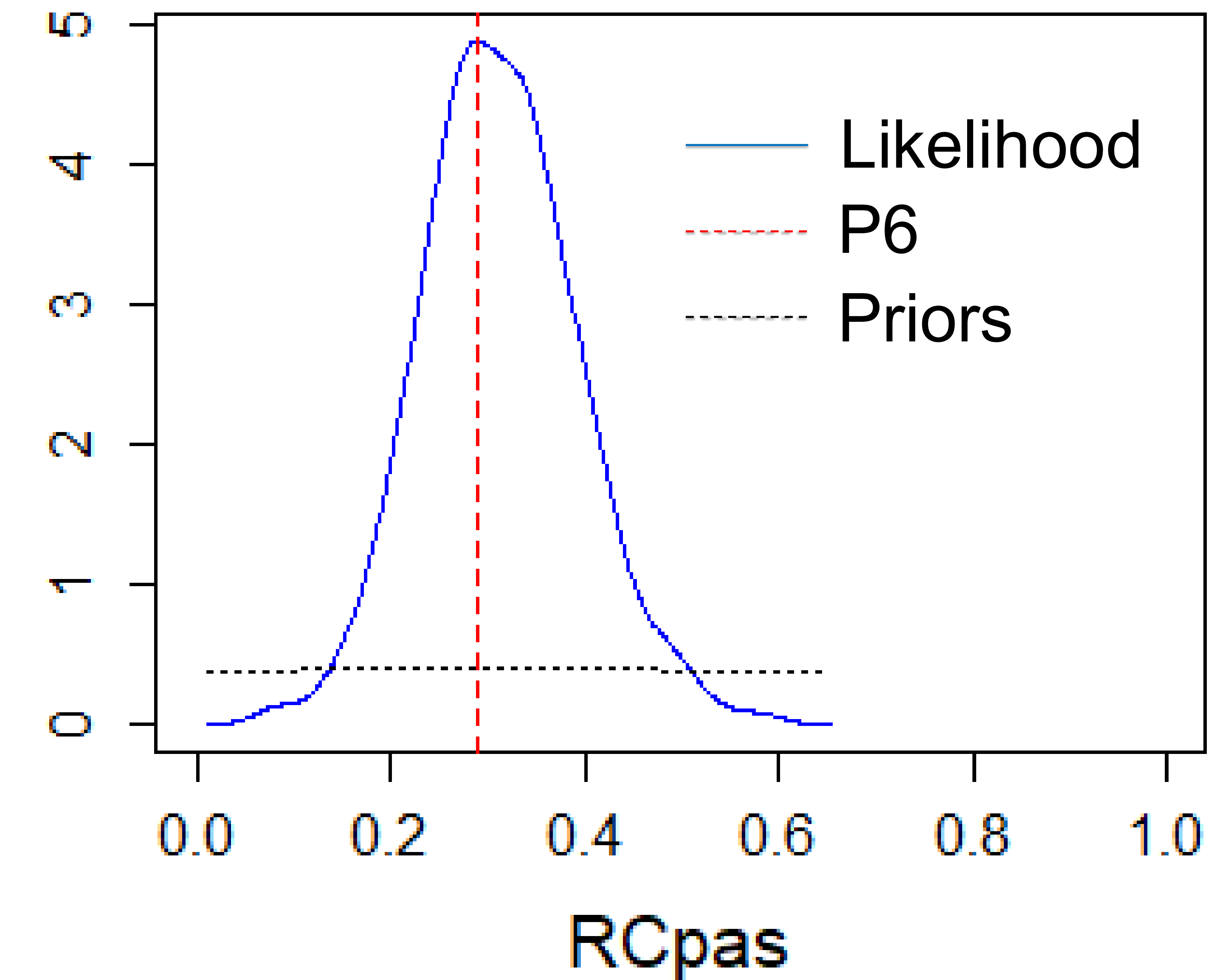
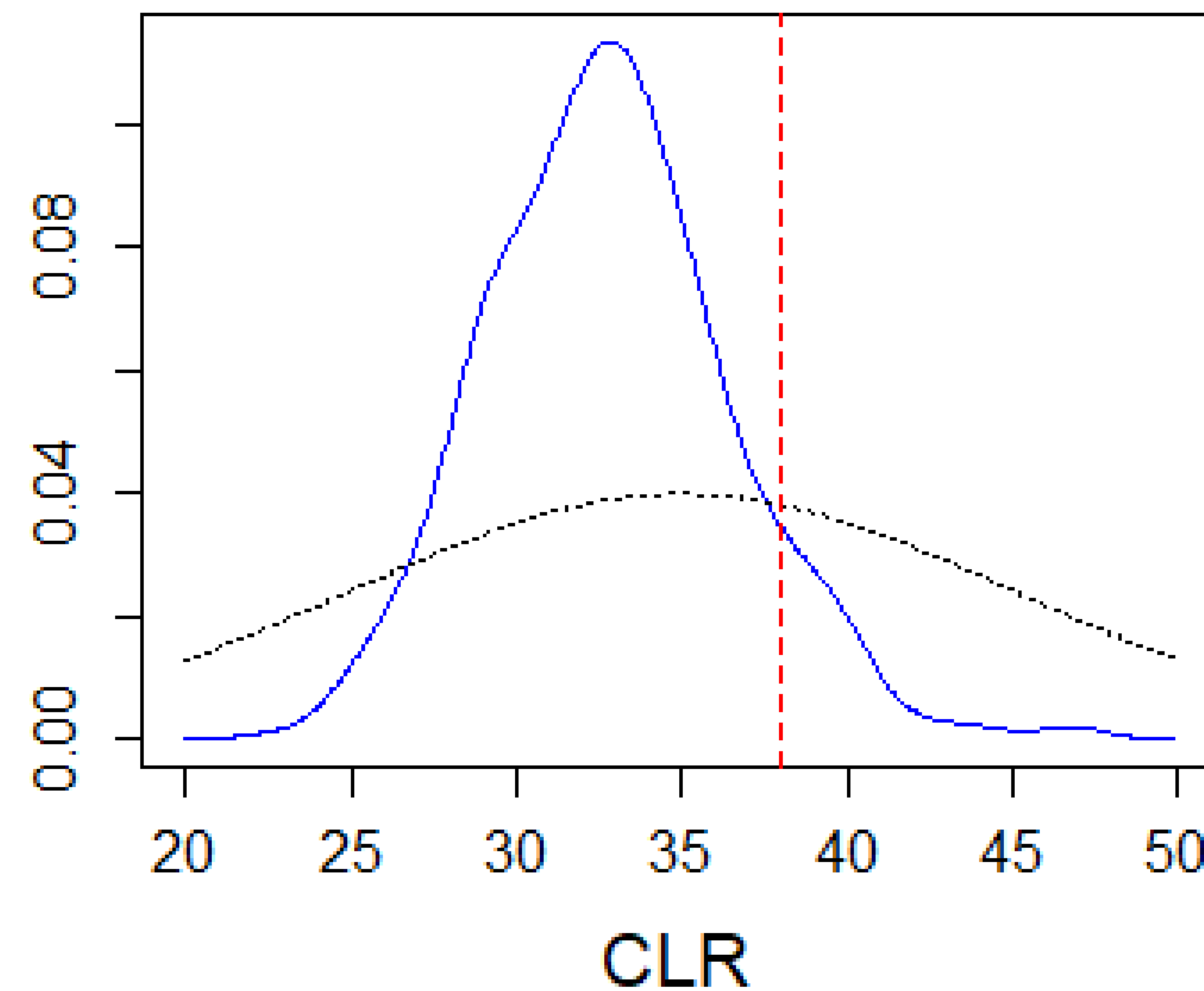
CLR = Average CROP
loading rate (lbs/ac)

RCpas = Ratio of PASTURE
loading rate to CROP
loading Rate

RCdev = Ratio of
DEVELOPED loading rate to
CROP loading Rate

RCnat = Ratio of NATURAL
loading rate to CROP
loading Rate

Red dashed line = P6
Black dashed lines =
P532, SPARROW, CEAP



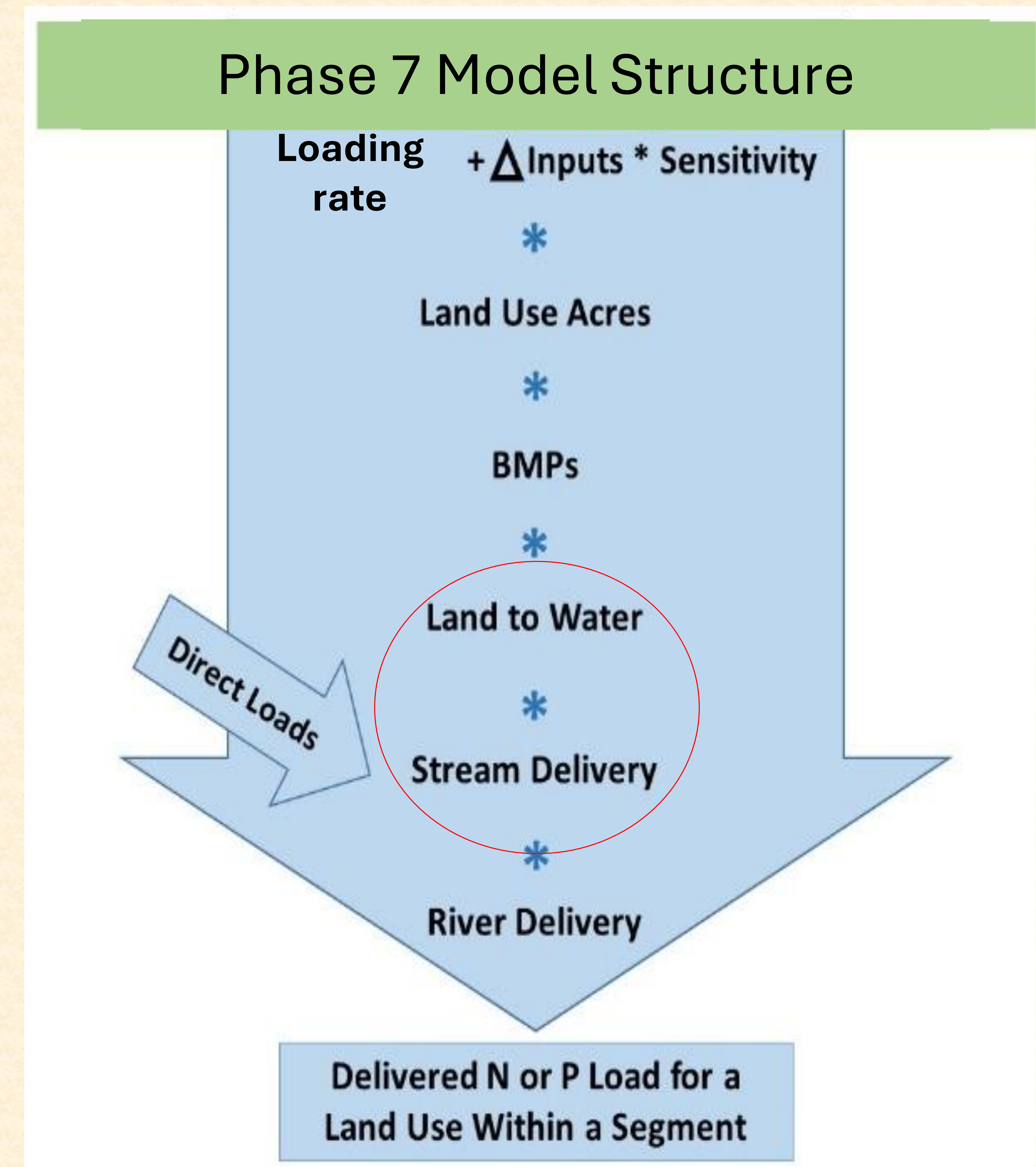
These values will change as CAST and inputs are updated.



Use of CalCAST to Improve Delivery Factors

Delivery factors describe the transport and attenuation of nutrients and sediment from the edge of field to the stream, rivers and Bay.

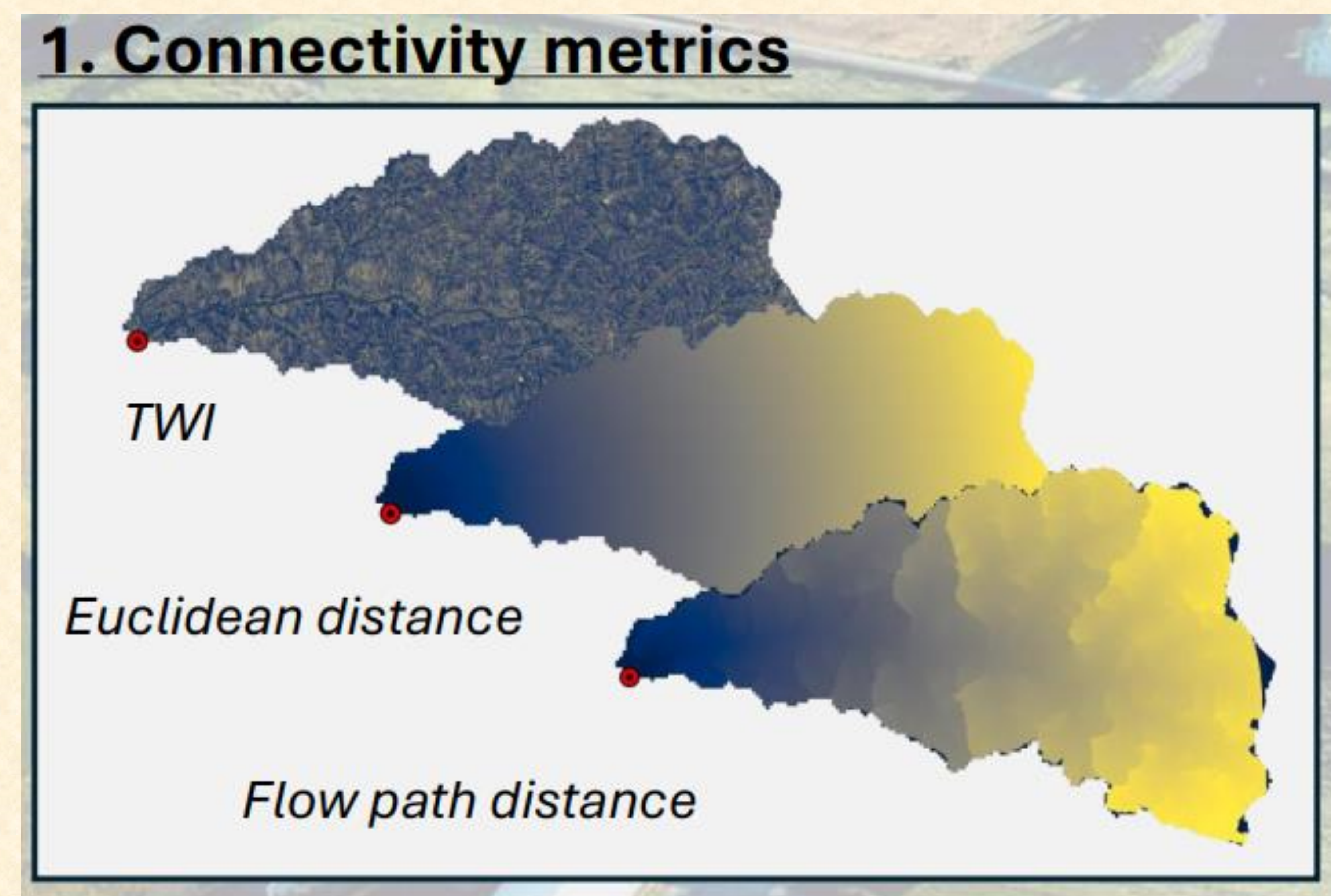
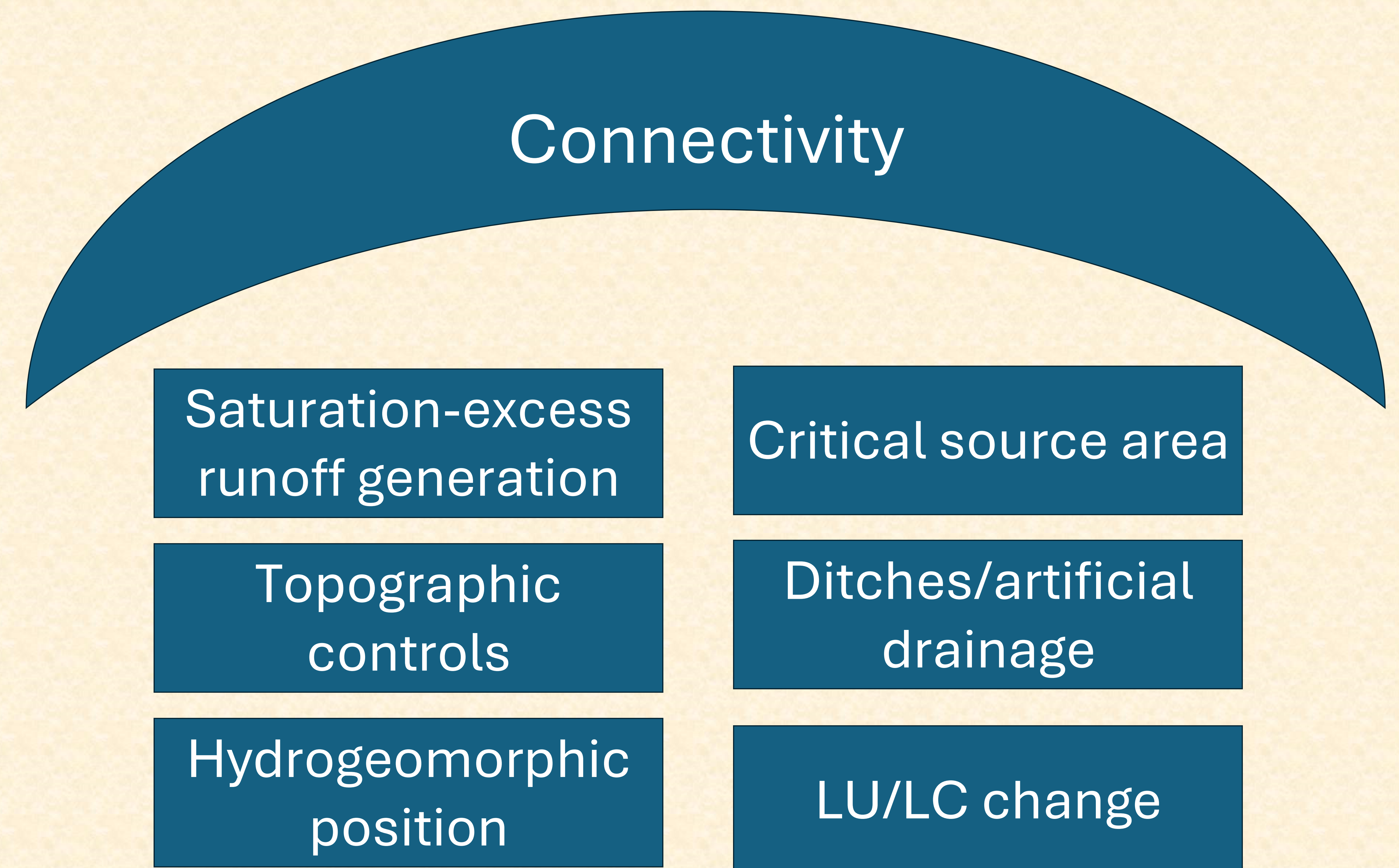
- Phase 6 delivery factors for land-to-water and stream-to-river were largely selected and parameterized by other models (SPARROW).
- In Phase 7, CalCAST will allow us to directly test and parameterize delivery factors in CAST.
- This will allow more comprehensive, consistent, and optimized representation of transport and attenuation.
- We have incorporated inputs from work groups, model review, STAC, and the literature to establish an expansive set of factors to test.





Use of CalCAST Example: Landscape Connectivity

- Model review, STAC, and literature review have identified several processes related to landscape connectivity of nutrient and sediment source loads to streams.
- Michelle Katoski (USGS) put together a dataset to better capture landscape connectivity in the model.

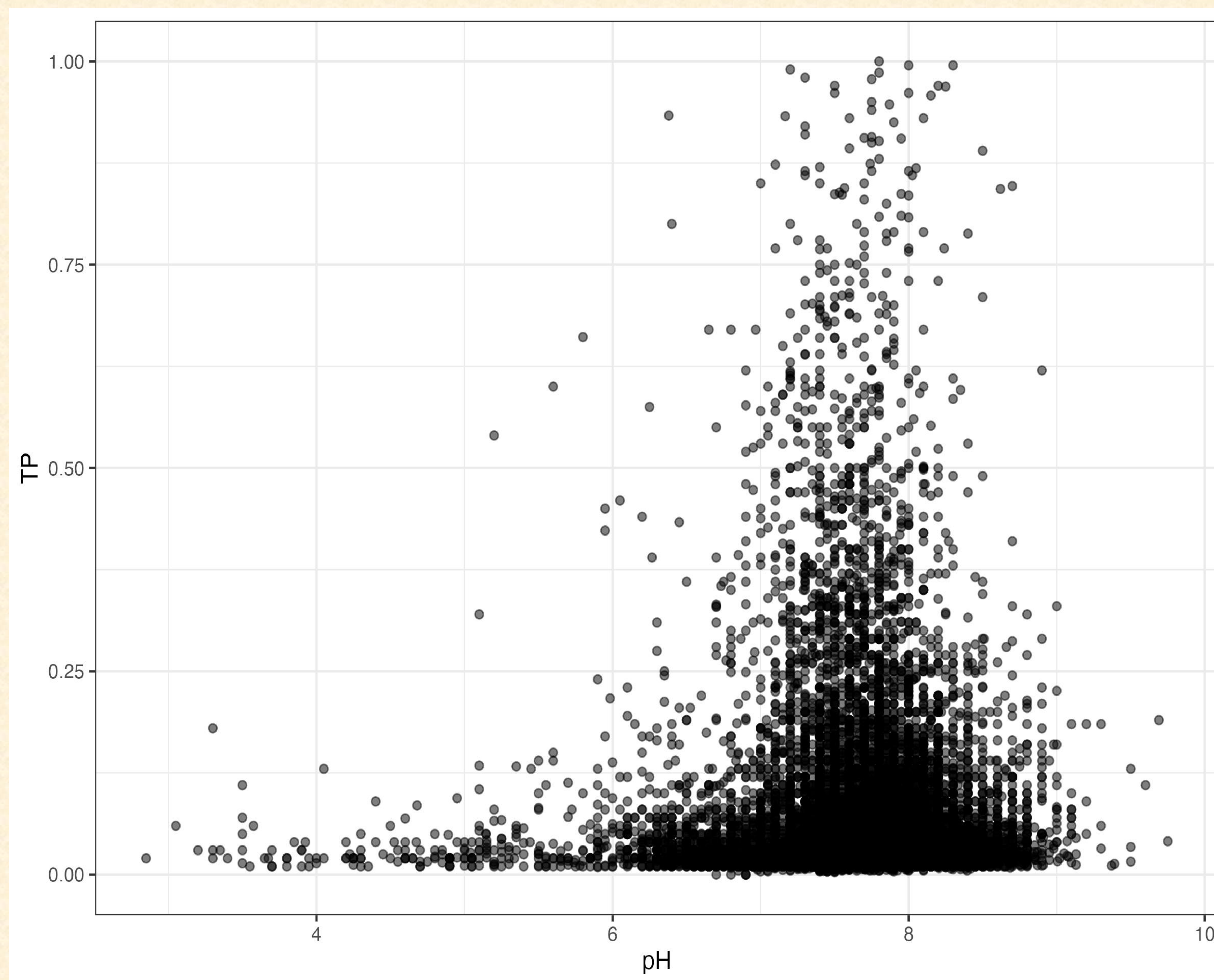




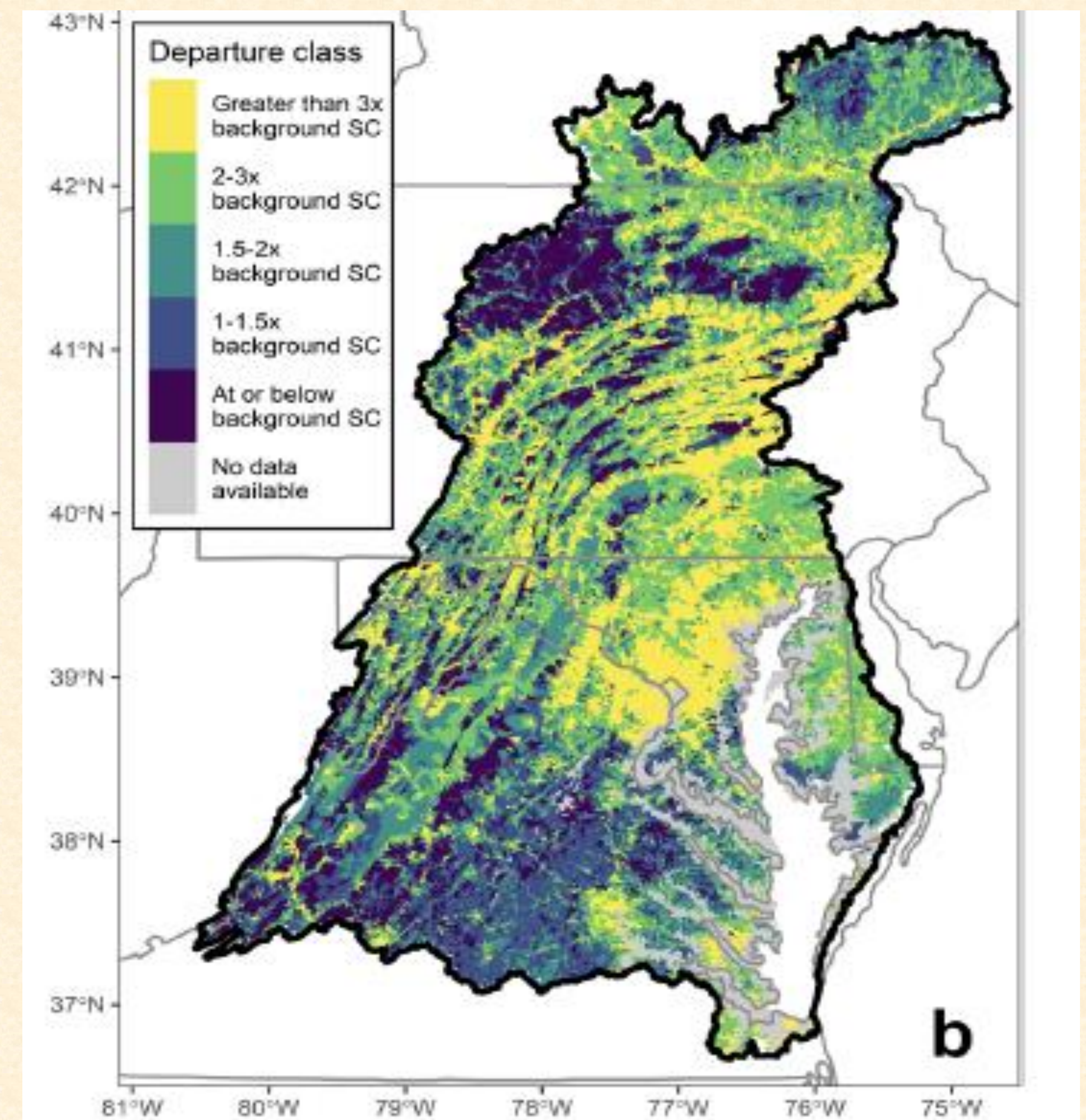
Phase 7 Watershed Model Refinements

Working to better represent P through representation of pH and ionic strength P dissociation curves.

pH Mediated P Sorption/Desorption



Ionic Strength Mediated P Sorption/Desorption



Predictions from a random forest model show that elevated conductivity levels are widespread in the watershed (Fanelli et al. 2024)

In Collaboration with Conor Keitzer, UMCES



Phase 7 Watershed Model Refinements

Working to better represent P through representation of geogenic phosphorus.

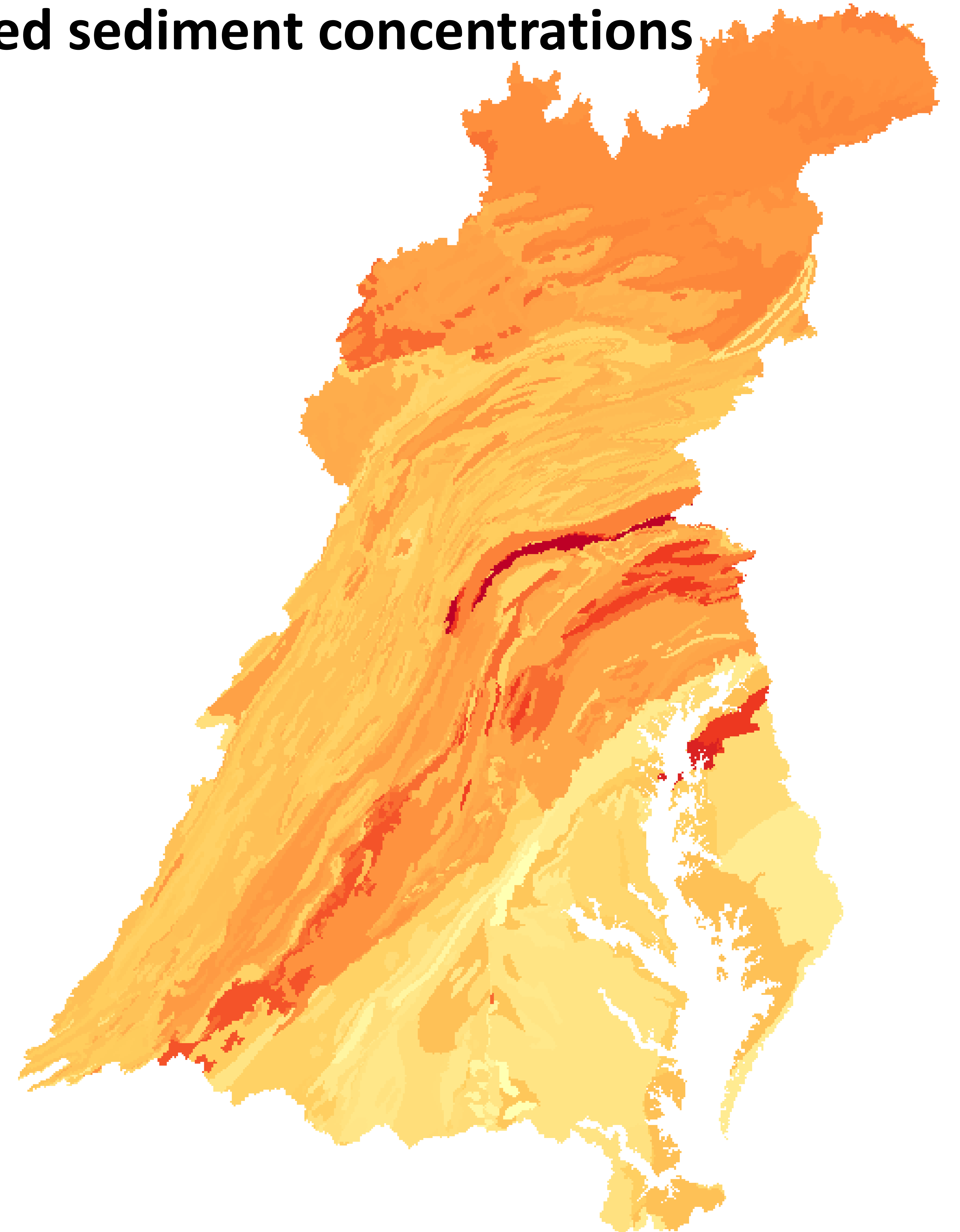
Upland Geologic Approach

([Wise 2020](#), [Nardi 2014](#),
[Smith 1979](#))

Geogenic P is characterized by summarizing geochemical data from bed-sediment samples collected from first-order streams in relatively undisturbed watersheds to geologic mapping units.

In Collaboration with Conor Keitzer, UMCES

Bed sediment concentrations



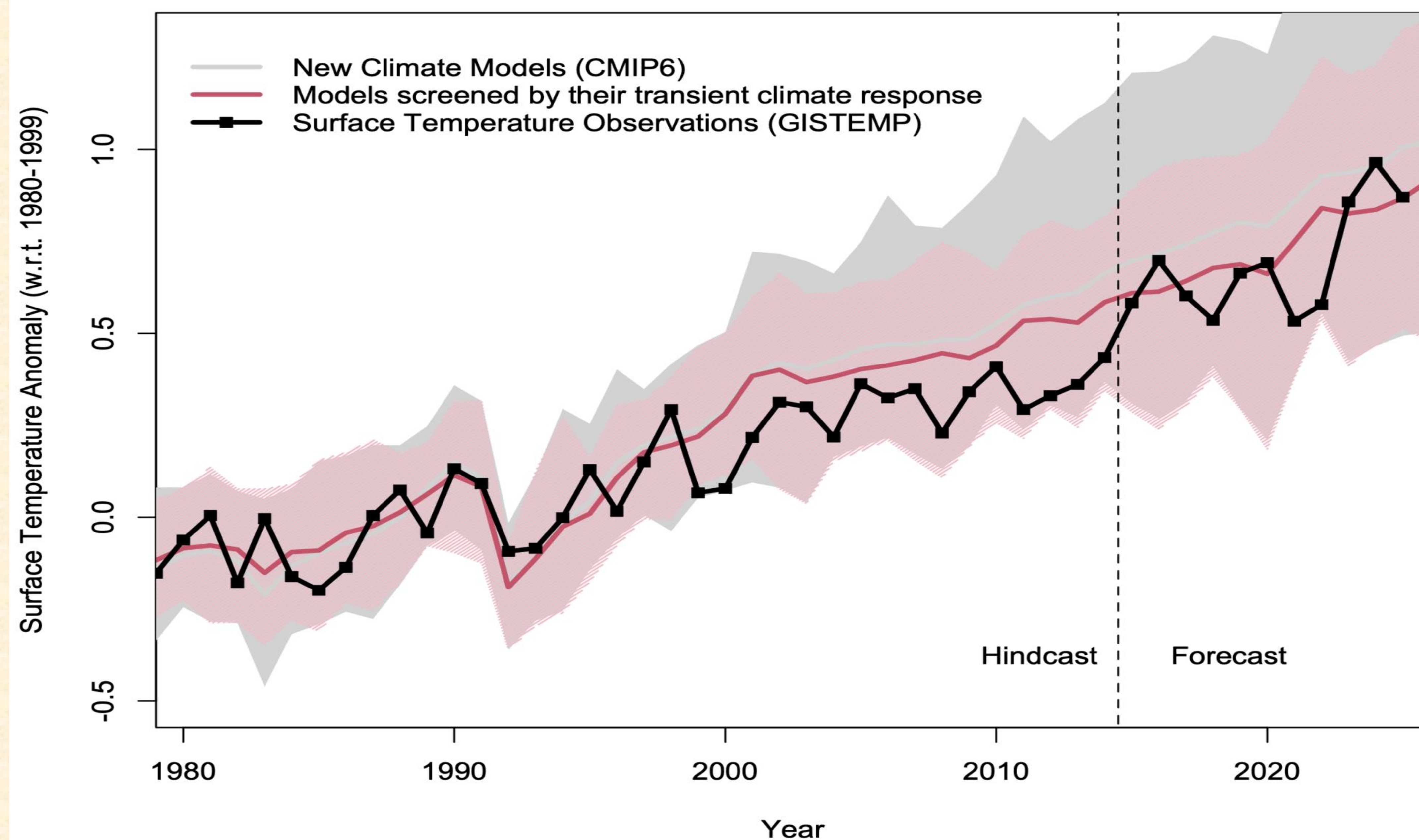
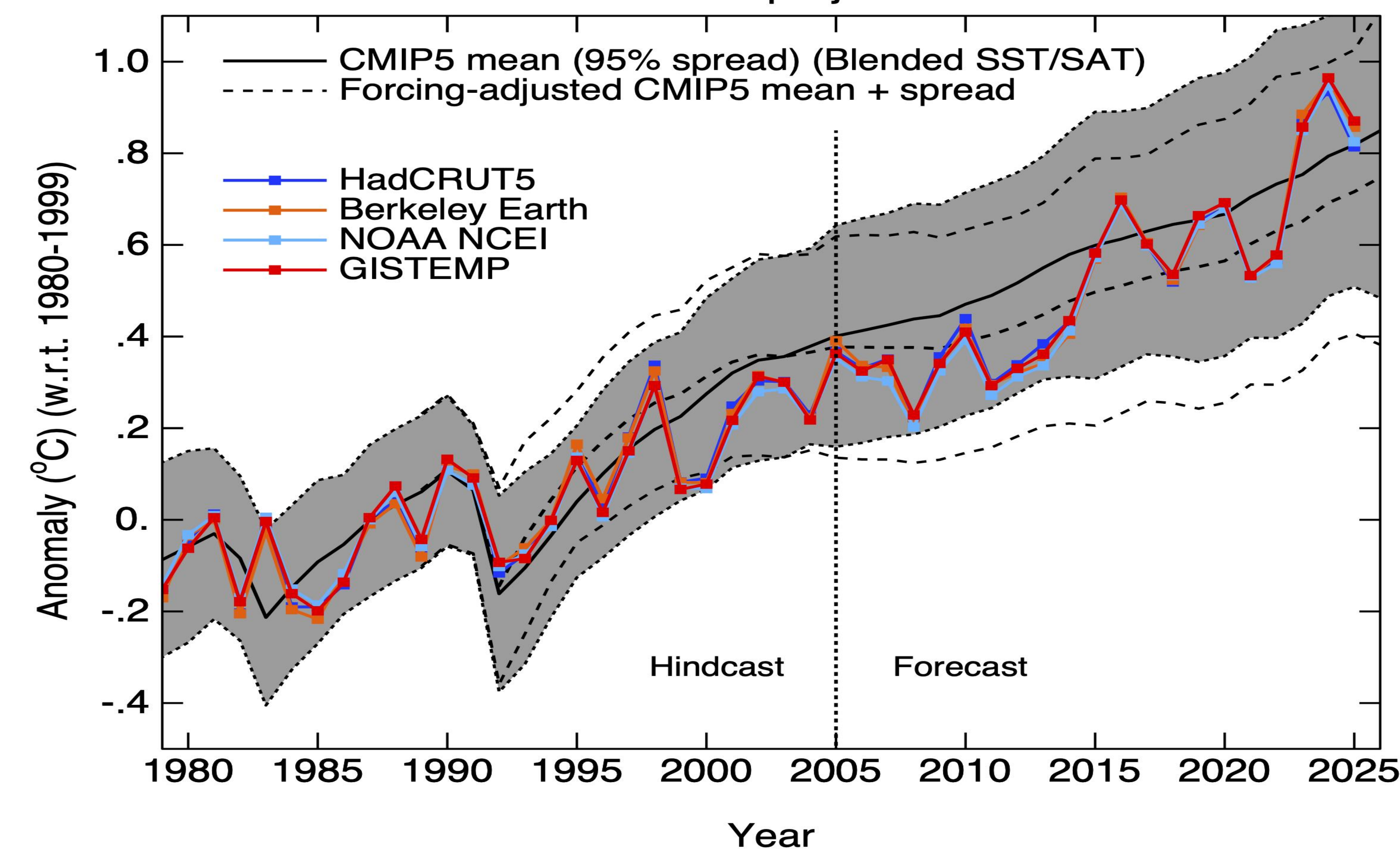


Phase 7 Watershed Model Refinements

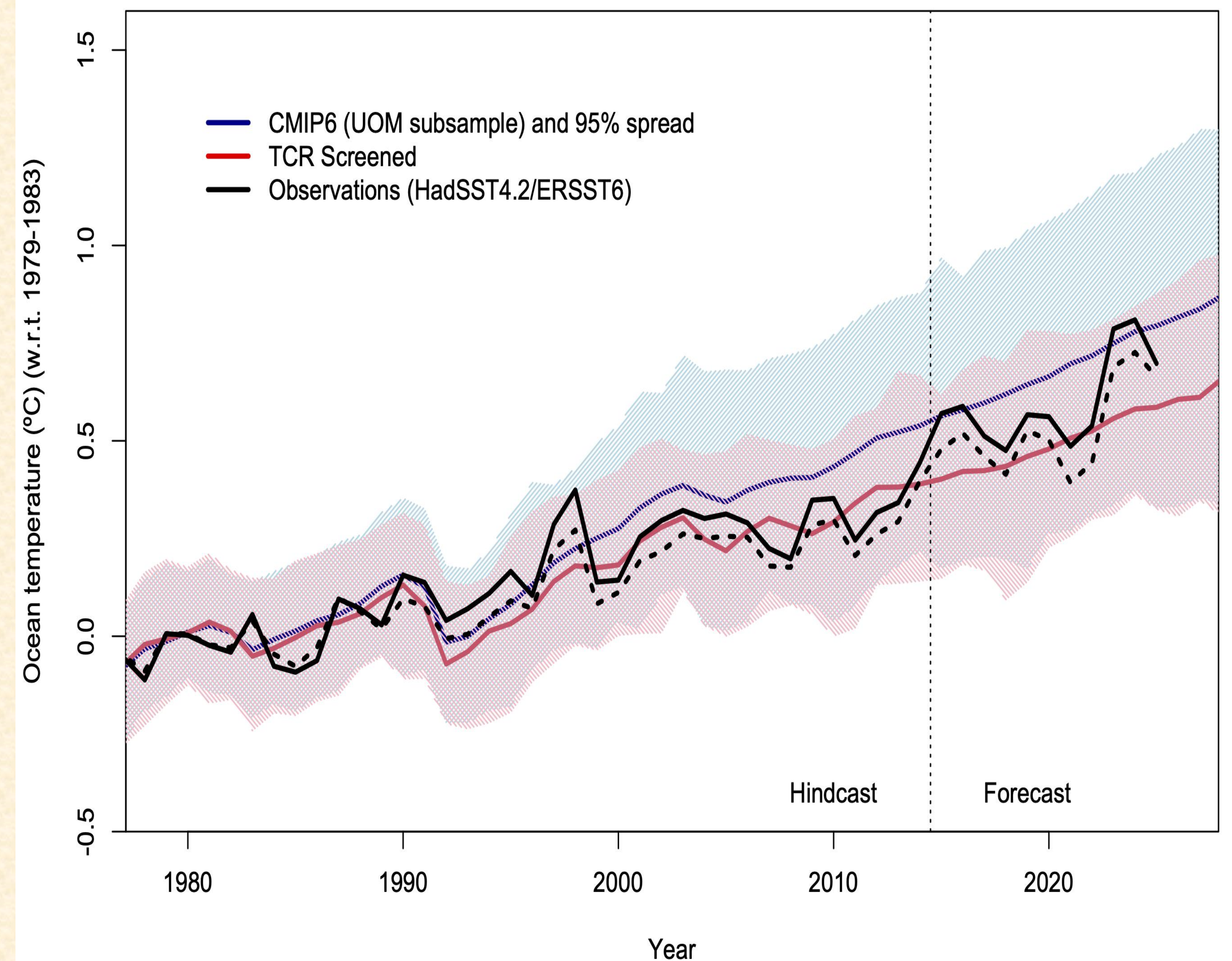
An updated representation of future environmental conditions of increased temperatures and rainfall volumes and intensities through application of CMIP6 in Phase 7 compared to CMIP5 used in Phase 6

CMIP5 Blended SST and SAT

How have model projections done?



CMIP6 Global SST



CMIP6 Global Sea Surface Temperature.



Phase 7 Watershed Model Refinements

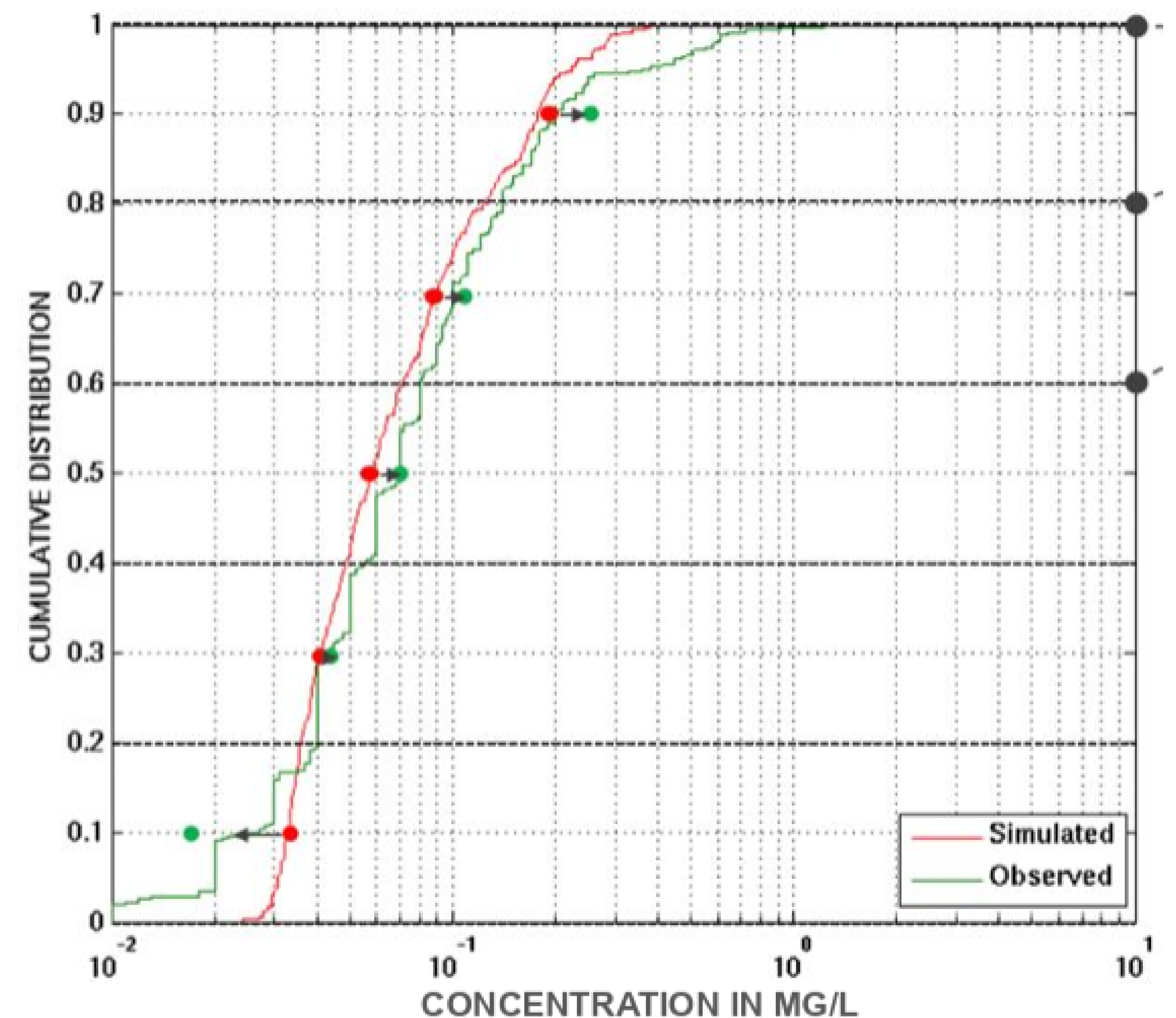
High flow particulate organic nitrogen and phosphorus scour in rivers stoichiometrically balanced

We implemented an organic source module within P7 DWSM water quality calibration framework to improve agreement in cumulative frequency distribution (CFD) of observed and simulated high flow concentrations.

→ The module includes 2 parameters for concentrations of organic N and organic P in the scoured sediment:

- HSPF estimated net hourly scoured sediment flux is used
- Calibration v1: organic N and organic P scour model parameters are independently calibrated
- **Calibration v2:** organic N is calibrated and Redfield N:P ratio is maintained

Figure: Cumulative distribution of concentrations at a monitoring station



Also improved the simulation of N speciation under different flow conditions.



Additional Phase 7 Watershed Model Refinements

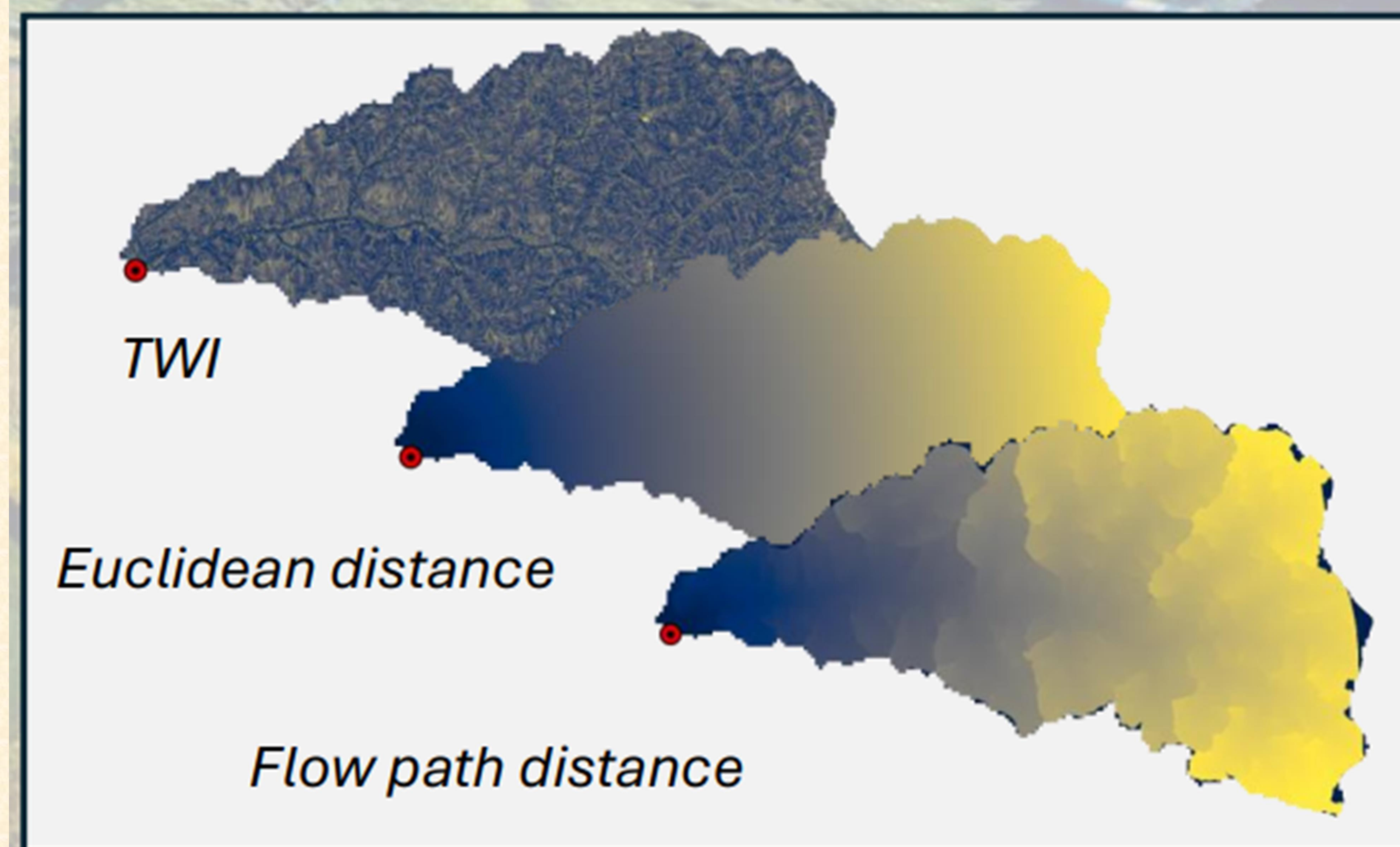
- Improvement of major input estimates of fertilizers, manures, atmospheric deposition, nitrogen fixation, and crop uptake.
- Better forecasted and backcasted land use data from 1985 to 2022 and improved assessment of future growth to 2075 through a refined land use model.
- Septic system location in the simulation improved.
- Sewershed service area delineation improved.



Additional Phase 7 Model Refinements

- Additional CBP land uses for better management.
- Incorporation of new agricultural and stormwater BMPs.
- Working to better represent P sources and transport.

1. Connectivity metrics



Suite of connectivity metrics (processed at 1m, 10m)

- Index of Sediment Connectivity (SedIC)
- Inverse distance to Stream:
 - Euclidean distance
 - Flow path distance
- Topographic Wetness Index



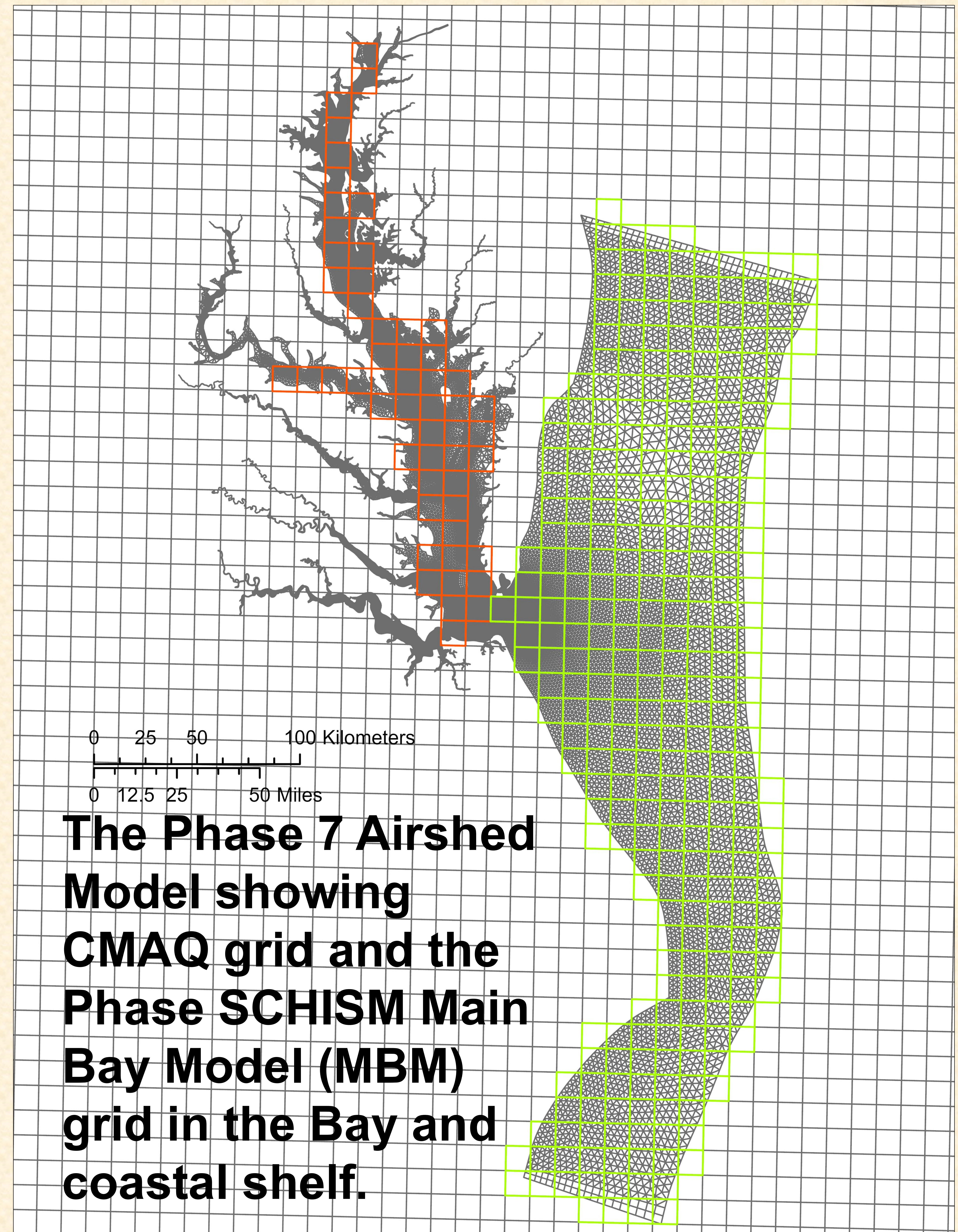
Ancillary or Additional Phase 7 Model Refinements

- Improved scenario handling through “one file” NetCDF linkage of DWSM to MBM, MTMs, and other PI models for faster, more efficient scenario and other file passing procedures to aid in collaboration with the Chesapeake scientific community.
- Inclusion of a RAND-Carnegie Mellon assessment of the effectiveness of BMPs under future climate hydrologies.
- Refined location of point source discharges in the GSN resulting in improved stream attenuation rates of nutrients.



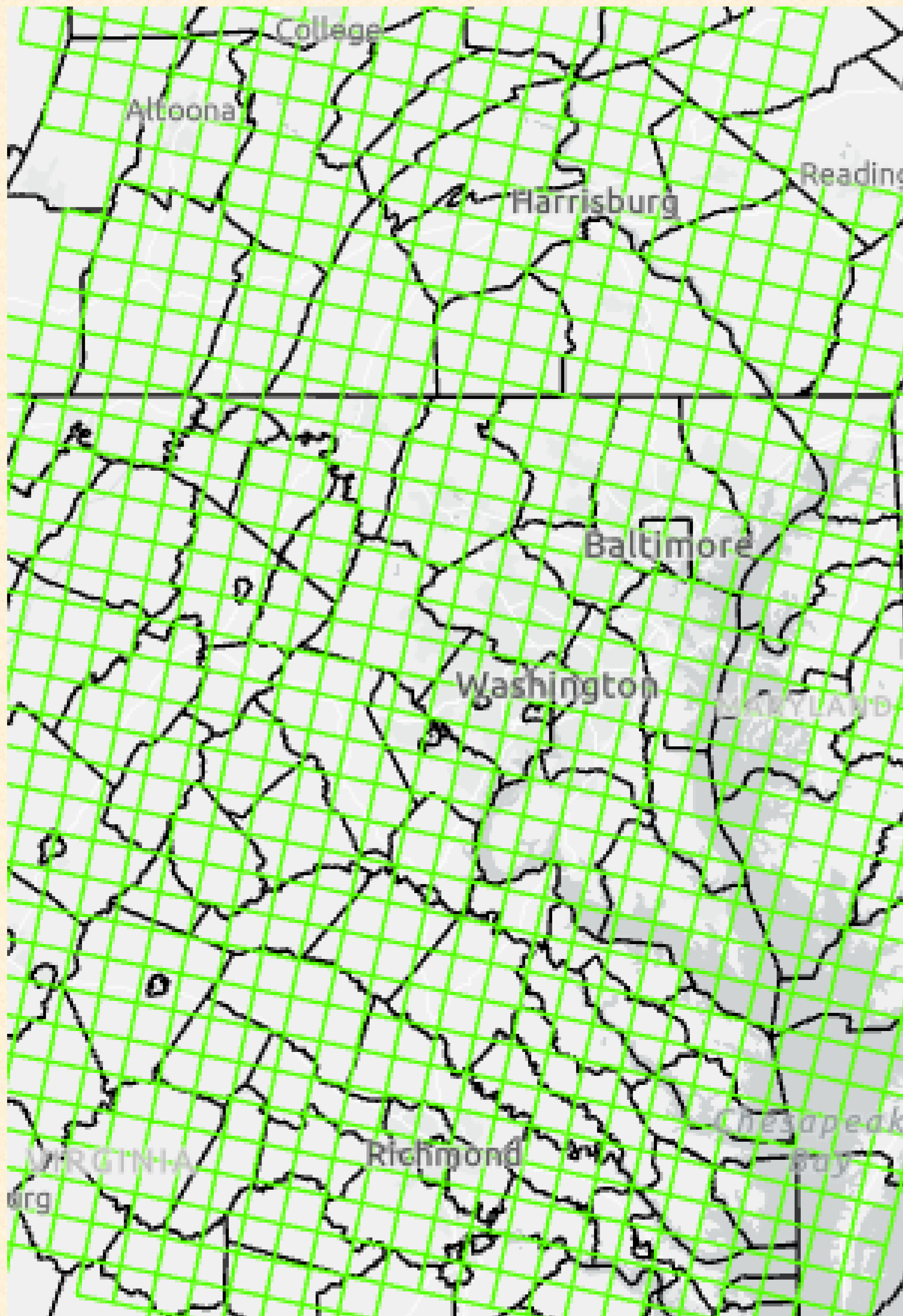
Phase 7 Airshed Model Refinements

Better estimates of atmospheric deposition loads to the watershed, tidal Bay, and coastal ocean, particularly for more recent years with improved atmospheric deposition load estimates from 1985 to 2024 compared to the 1985 to 2014 airshed loads in Phase 6.





The Phase 7 Airshed Model - CMAQ

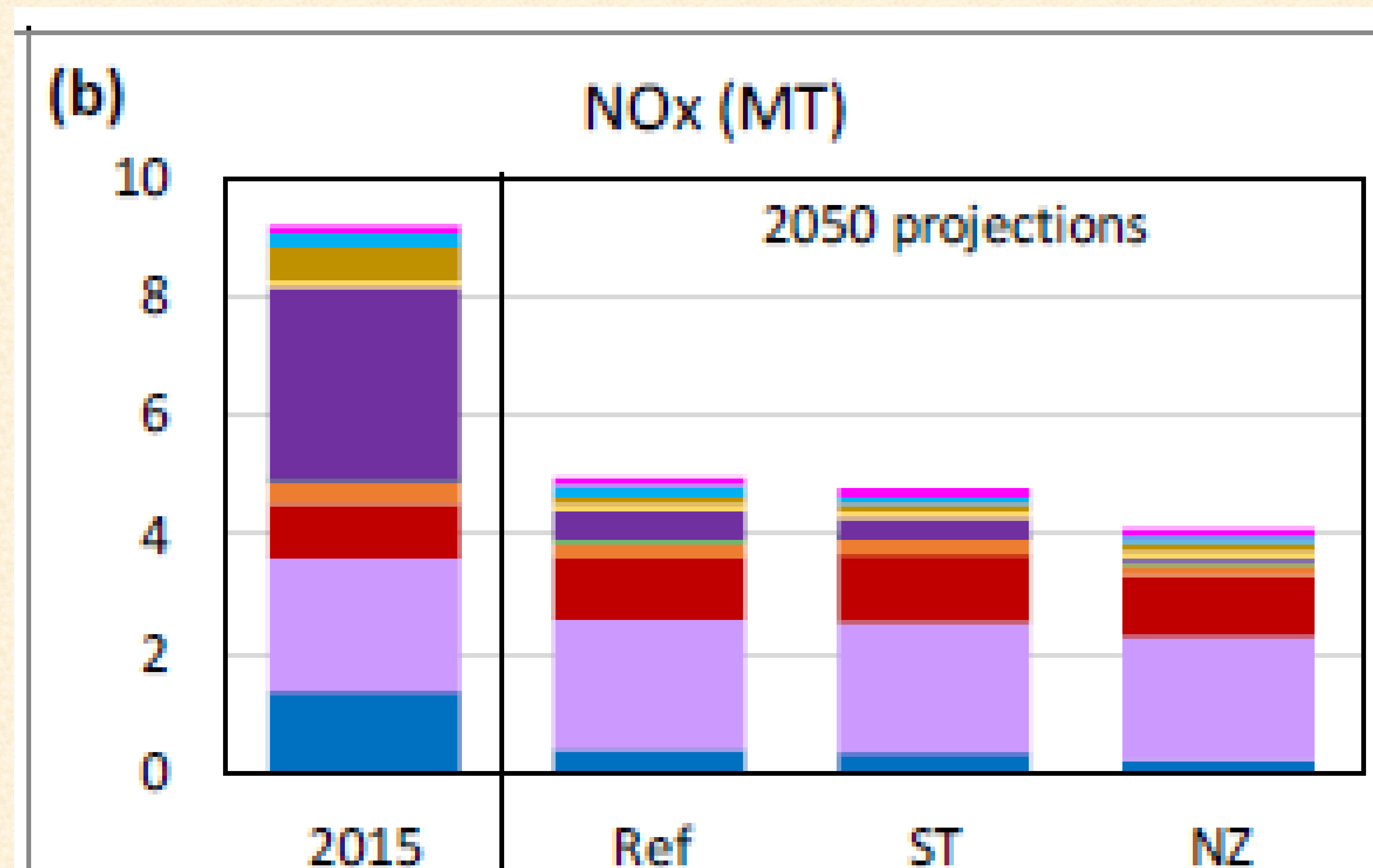
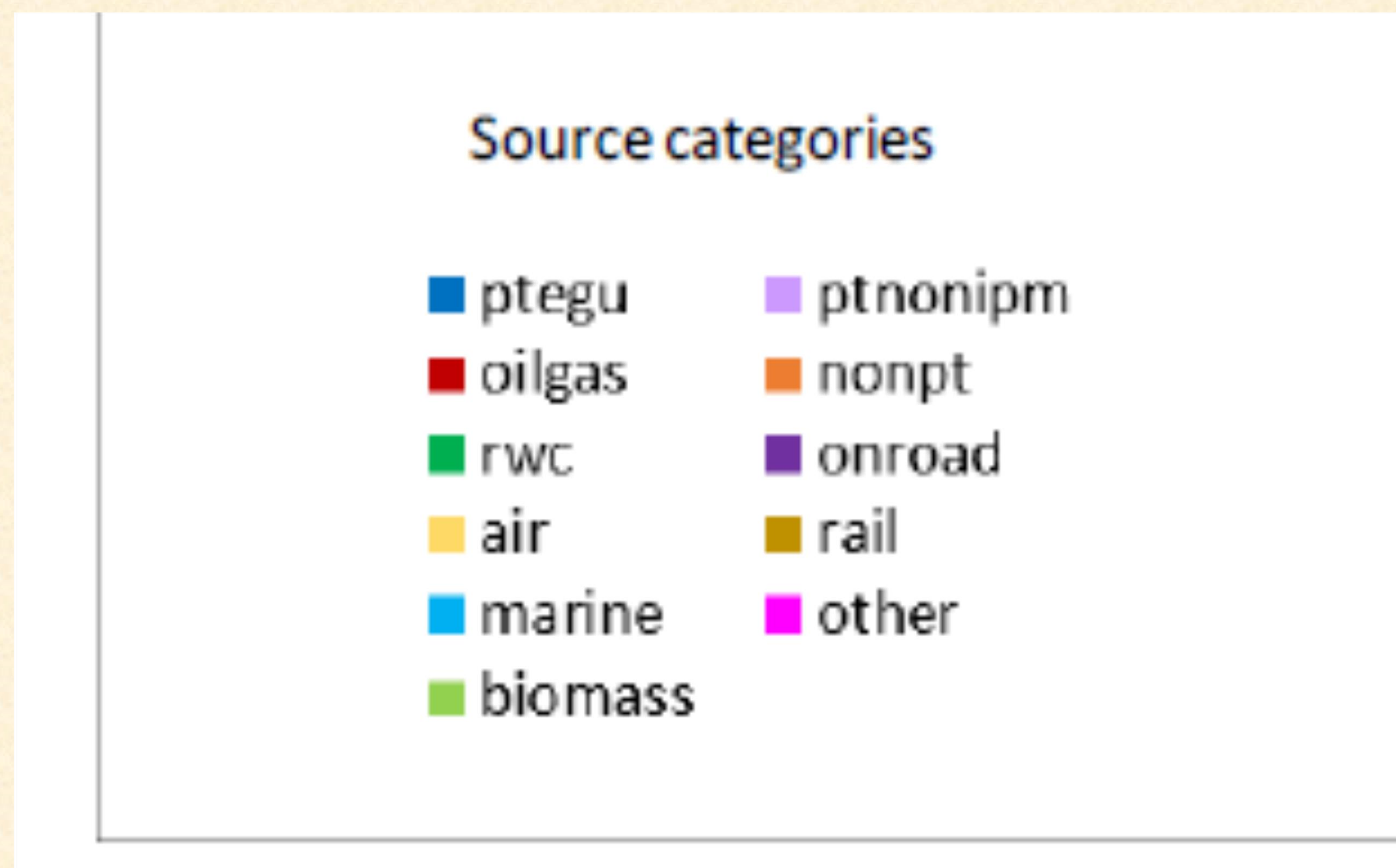


- Refined simulation of deposition to the watershed, tidal Bay, and for the first time, to coastal shelf waters.
- Deposition time series expanded to a continuous 40-year period (1985 - 2024) for the watershed, Bay, and coastal ocean.
- Improved ammonia simulation and dry deposition.
- Better source – deposition tracking of NO_x and ammonia (ISAM).



The Phase 7 Airshed Model - CMAQ

Our Phase 7 Airshed Model includes a new 2015 Base, a Reference Scenario which represents current laws and statutes, State Targets which are a further slight reduction in emissions, and finally a 2050 Zet Zero emission of GHGs. We have these CMAQ scenarios for 2035, 2045, and 2050. Unfortunately we no longer have our airshed modeler, Jesse Bash. Any additional analyses on the scenarios we have or any additional Airshed Model scenarios that may be requested may be unlikely given the loss of our Airshed Modeling Team and Jesse Bash.

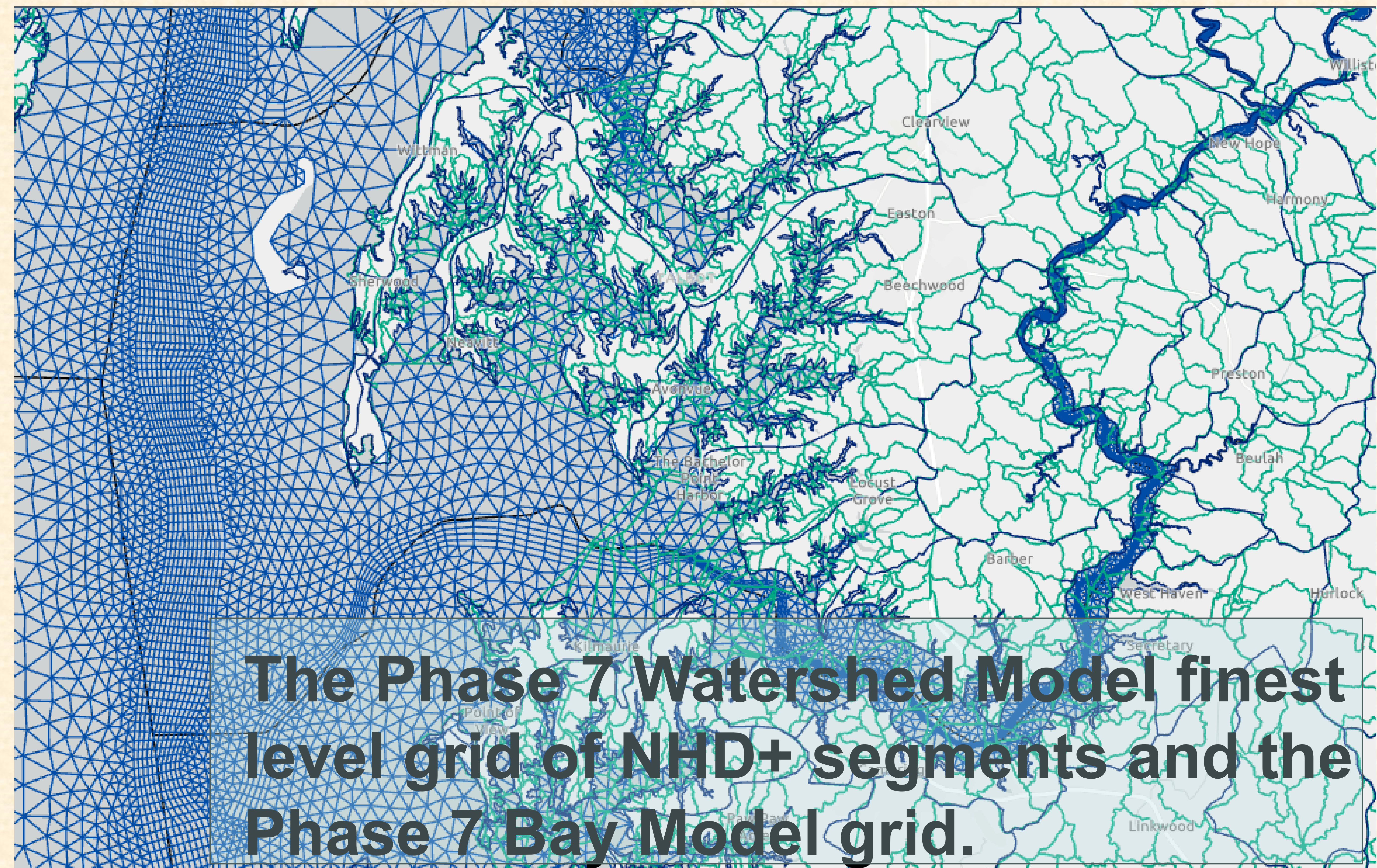


Source: Shankar, Uma, Benjamin N. Murphy, Maridee A. Weber, Yang Ou, Steven J. Smith, Daniel H. Loughlin, and Christopher G. Nolte. "Modeling the Air Quality Impacts of Future Energy Scenarios." ACS ES&T Air 2, no. 11 (2025): 2433-2444.



The Phase 7 Watershed Model Summary

- Expanded 1985 – 2024 continuous simulation period, Generalized Stream Network (GSN) simulation, and use of nearshore tidal stations increases calibration observations many fold.
- Finer scale PRISM precipitation data improves simulated hydrology.
- Improved land use/land cover overall with scale improvements at NHD+ level.
- CalCAST provides an improved assessment of loads and nutrient processes.
- Improvement of major input estimates of fertilizers, manures, atmospheric deposition, nitrogen fixation, and crop uptake.





Key Guidance From PSC and STAC

Completed the PSC directive of being able to represent future (2035 and beyond) environmental conditions on Bay water quality.

2020 PSC Guidance to CBP:

Understand the Science: Continue efforts to improve understanding of science and refine estimates of pollutant load changes due to 2035 changing environmental conditions ... [and] update targets (if warranted).

Followed STAC technical guidance as closely as possible:

STAC Guidance to Modeling Workgroup:

Shenk, G., M. Bennett, Z. Easton, M. Friedrichs, R. Hood, J. Keisman, L. Linker, R. Najjar, R. Sabo, and C. Stock.. (2025). [*A Path Forward in Considering Future Environmental Scenarios in Chesapeake Bay Restoration Efforts*](#)

Shenk, G., M. Bennett, D. Boesch, L. Currey, M. Friedrichs, M. Herrmann, R. Hood, T. Johnson, L. Linker, A. Miller, and D. Montali. (2021). [*Chesapeake Bay Program Climate Change Modeling 2.0*](#).

Hood, R.R., G. Shenk, R. Dixon, W. Ball, J. Bash, C. Cerco, P. Claggett, L. Harris, T.F. Ihde, L. Linker, C. Sherwood, and L. Wainger. (2019). [*Chesapeake Bay Program Modeling in 2025 and Beyond: A Proactive Visioning Workshop*](#)



Conclusions

- The CBP Modeling develops and applies state-of-the science integrated environmental models to “improve the water quality and living resources in the Chesapeake Bay ecosystem.”
- The CBP models combine modeling, research, and monitoring to support CBP implementation of environmental management that is environmentally protective and cost effective.
- The CBP modeling tools and analyses are deeply collaborative by design and extensively used in the CBP policy and scientific communities of the Chesapeake watershed and Bay.





Conclusions *(continued)*

- The Phase 7 modes are on track for completion of model development in 2026 and the start of the year of review in 2027.
- The Dynamic Watershed Model will be largely complete by the July Modeling Quarterly Review and ready for Modeling Workgroup final review at our October Quarterly.
- The Main Bay Model and Multiple Tributary Models will be completed and ready for Modeling Workgroup review at the January 2027 Quarterly.

