A Proposal for Pycnoclines and the 4D Interpolator

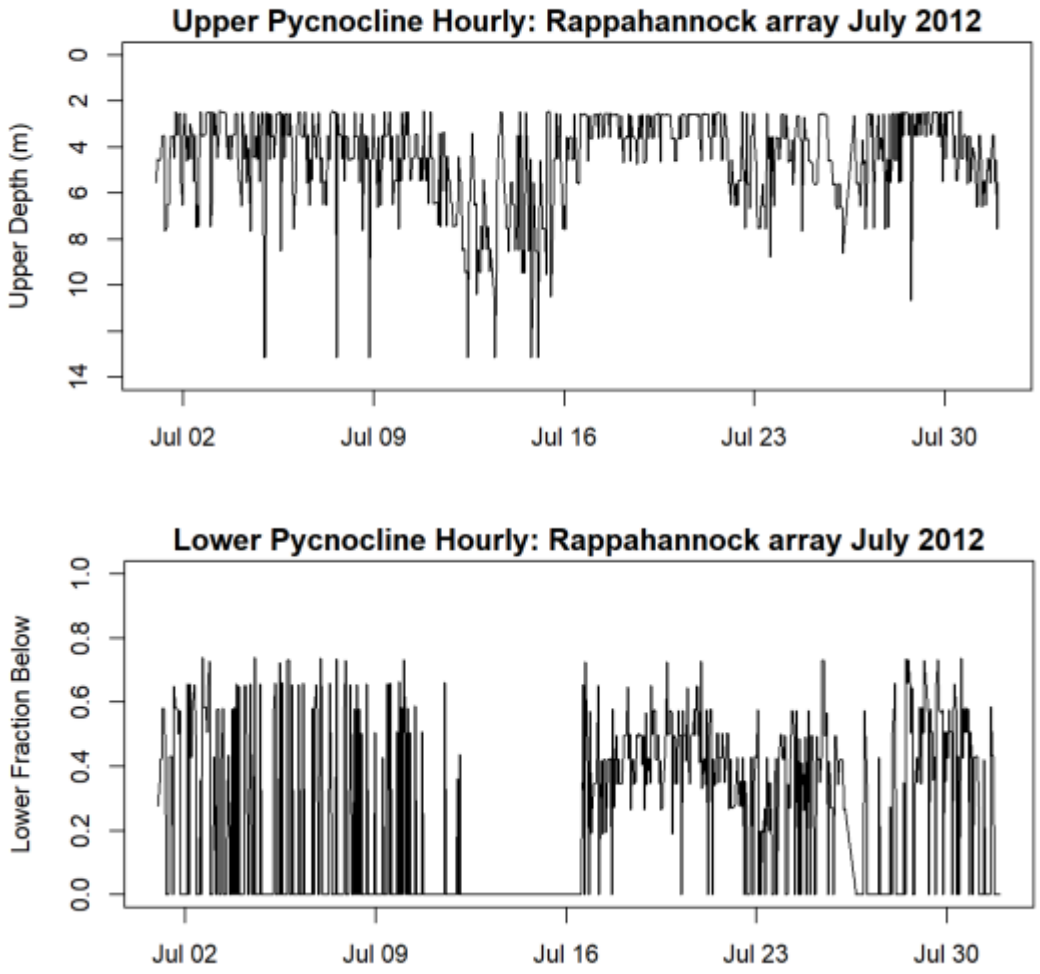
Tish Robertson
Virginia Department of Environmental Quality
July 14, 2025

Criteria Assessment Protocol Workgroup

On the last CAP call…

- We had a brief discussion about pycnoclines.
- Rebecca and Elgin have brought to our attention how variable pycnoclines can be.

Rappahannock: Full month hourly variability

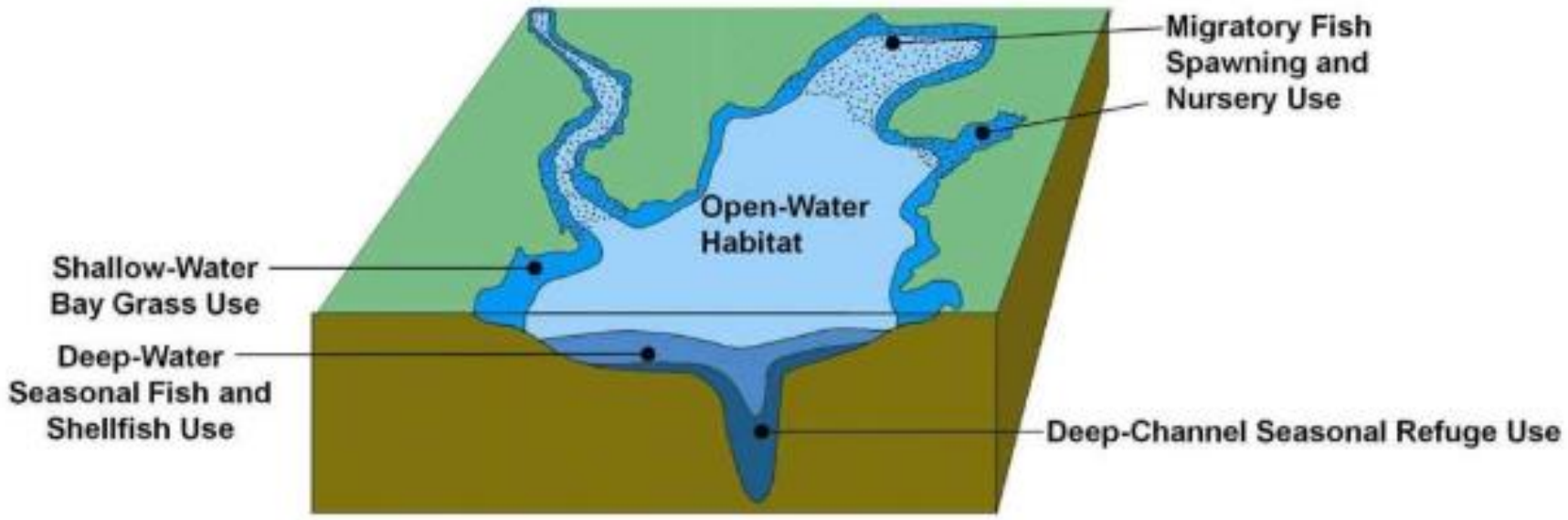


Excerpt from March 17 Bay Oxygen Research Group Development Team update

DEQ

Why are pycnoclines important to Bay DO criteria assessments?

Designated Uses Specific to the Chesapeake Bay

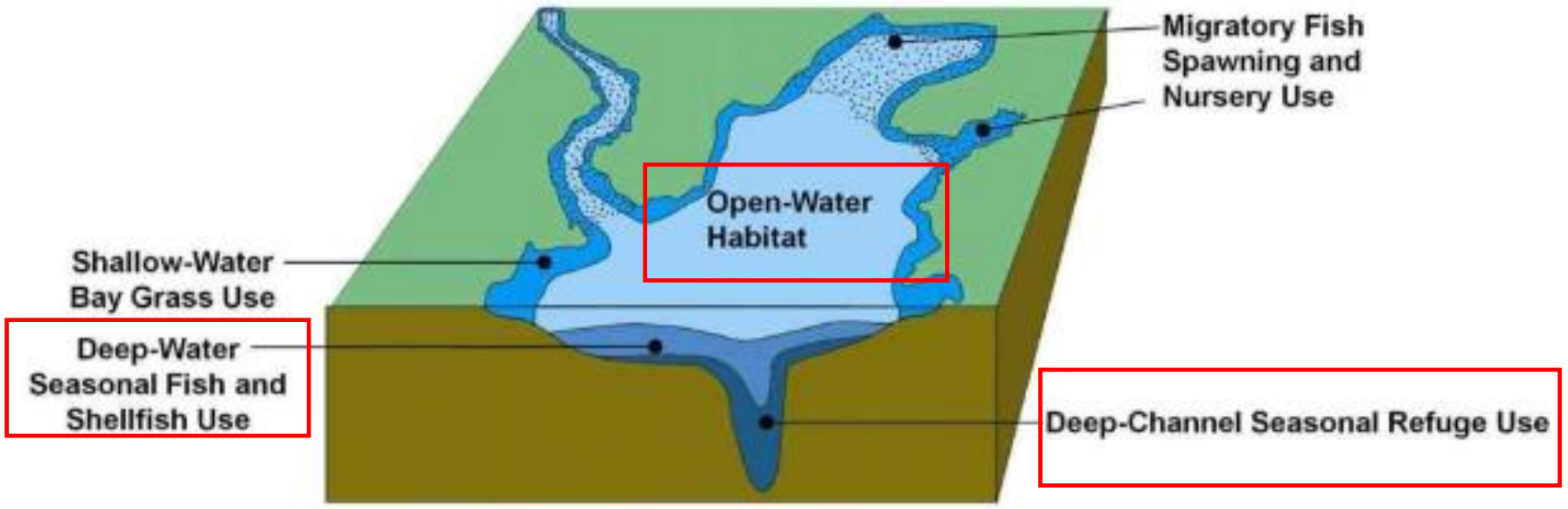


Designated Uses for Bay Tidal Waters

DEQ

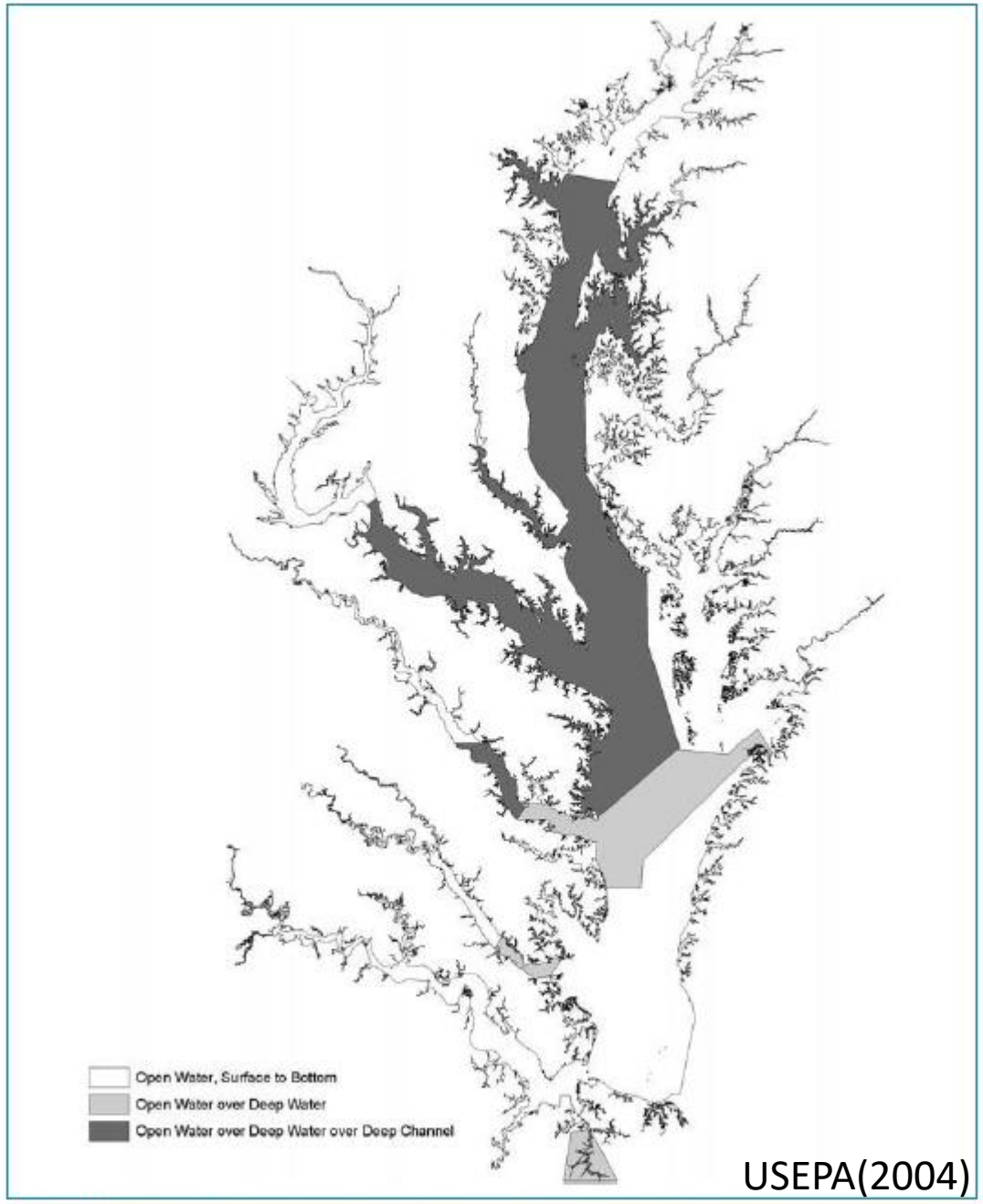
Why are pycnoclines important to Bay DO criteria assessments?

Designated Uses Specific to the Chesapeake Bay



Designated Uses for Bay Tidal Waters

DEQ



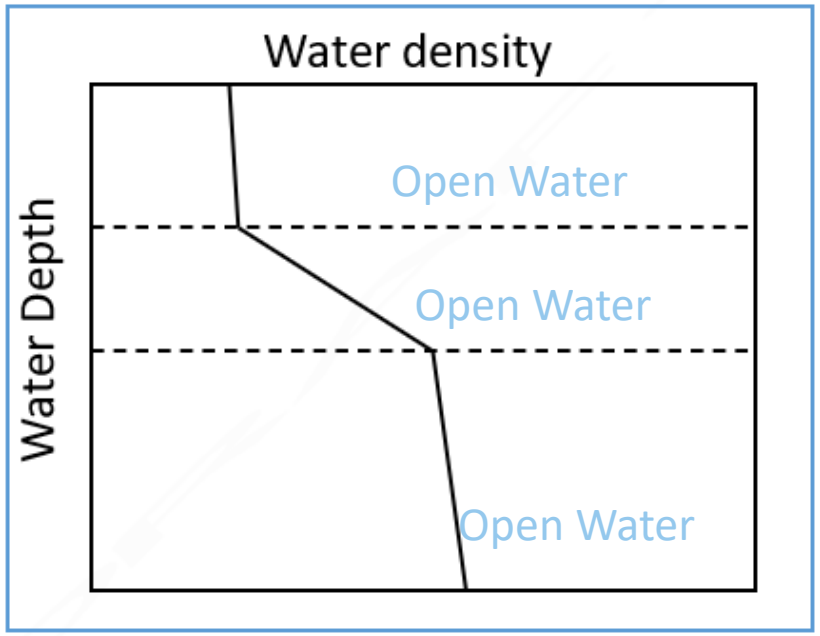
USEPA(2004)

Figure II-2. Map illustrating the refined geographic distribution of the open-water fish and shellfish, deep-water seasonal fish and shellfish and deep-channel seasonal refuge designated uses across Chesapeake Bay and its tidal tributaries.

- Only 16 segments are designated for the Deep Water use
- Only 8 segments are designated for the Deep Channel use.
- In these segments, during the summer months, the assessment of DO concentrations in the water column is dependent on the vertical position of the pycnocline.

DEQ

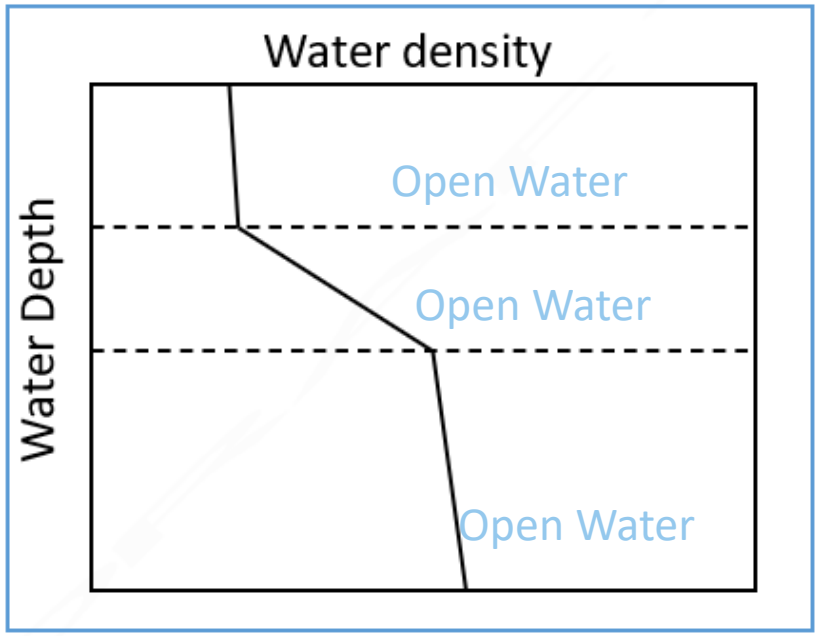
In a segment designated only for the Open Water use…..



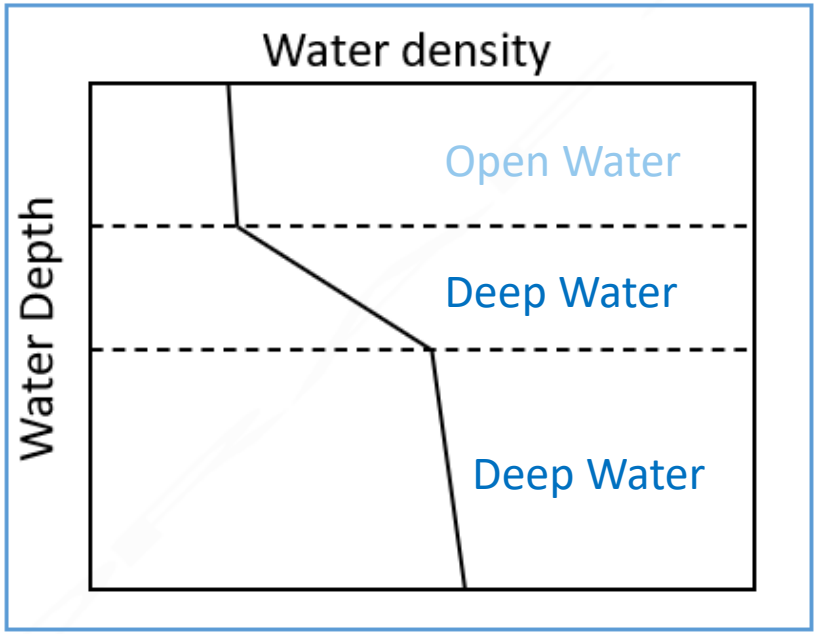
A segment can be stratified during the summer and not be designated for the DW or DC uses!

DEQ

In a segment designated only for the Open Water use…..

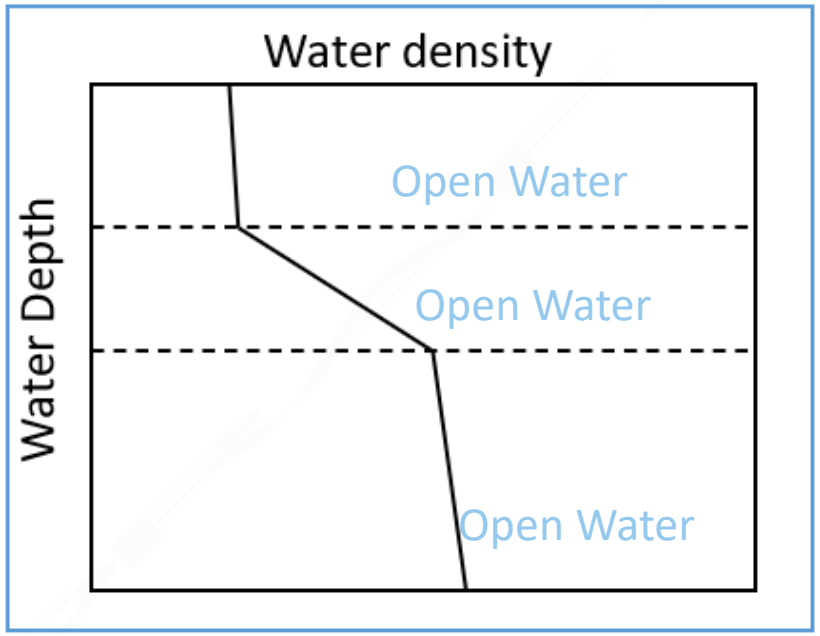


In a segment designated only for the Deep Water use…..

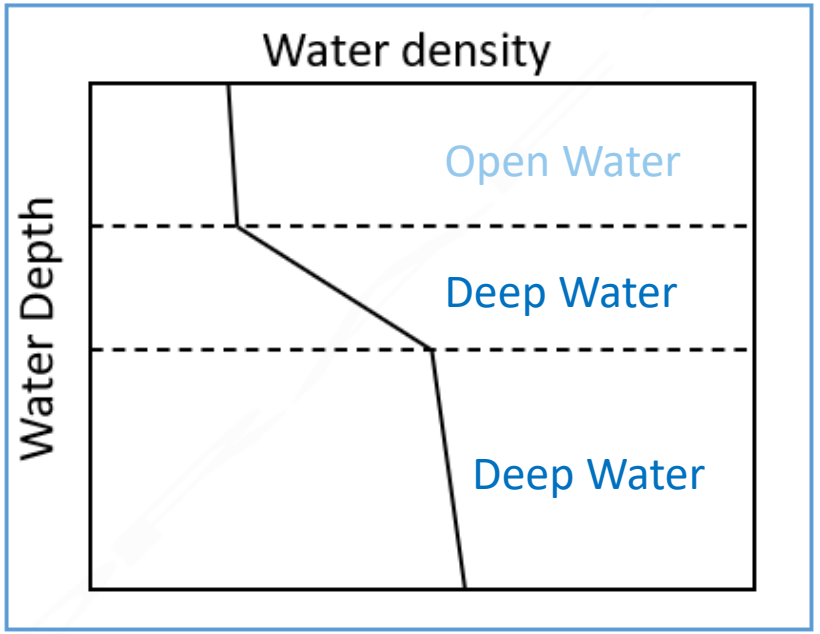


DEQ

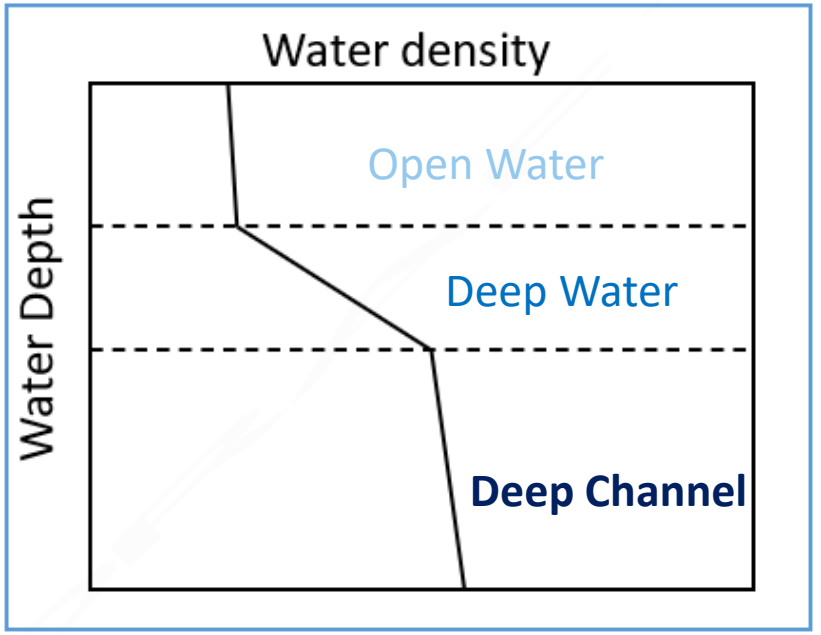
In a segment designated only for the Open Water use…..



In a segment designated only for the Deep Water use…..



In a segment designated for Deep Water and Deep Channel uses…..



DEQ

Pycnoline Boundary Determination

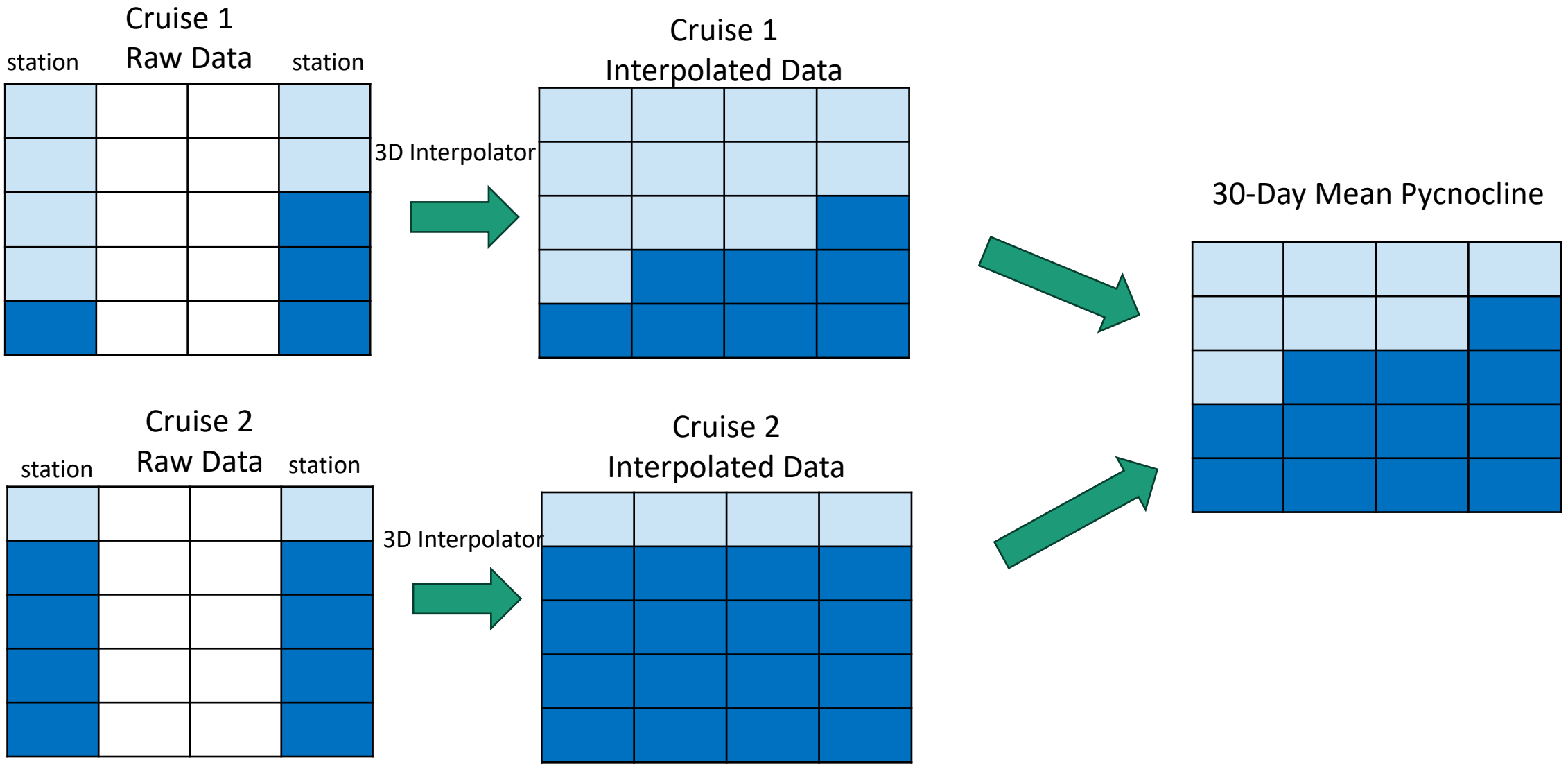
Current Procedure

- Calculate pycnocline depths using procedure in USEPA (2008) at all stations with vertical profiles.
- Aggregate pycnocline depths (upper and lower) by cruise (2-week periods)
- Spatially interpolate cruise datasets.
- Average interpolations by month.

Above Pycnocline

Below Pycnocline

Cross-sectional View of Interpolator Grid for a Hypothetical Segment



DEQ

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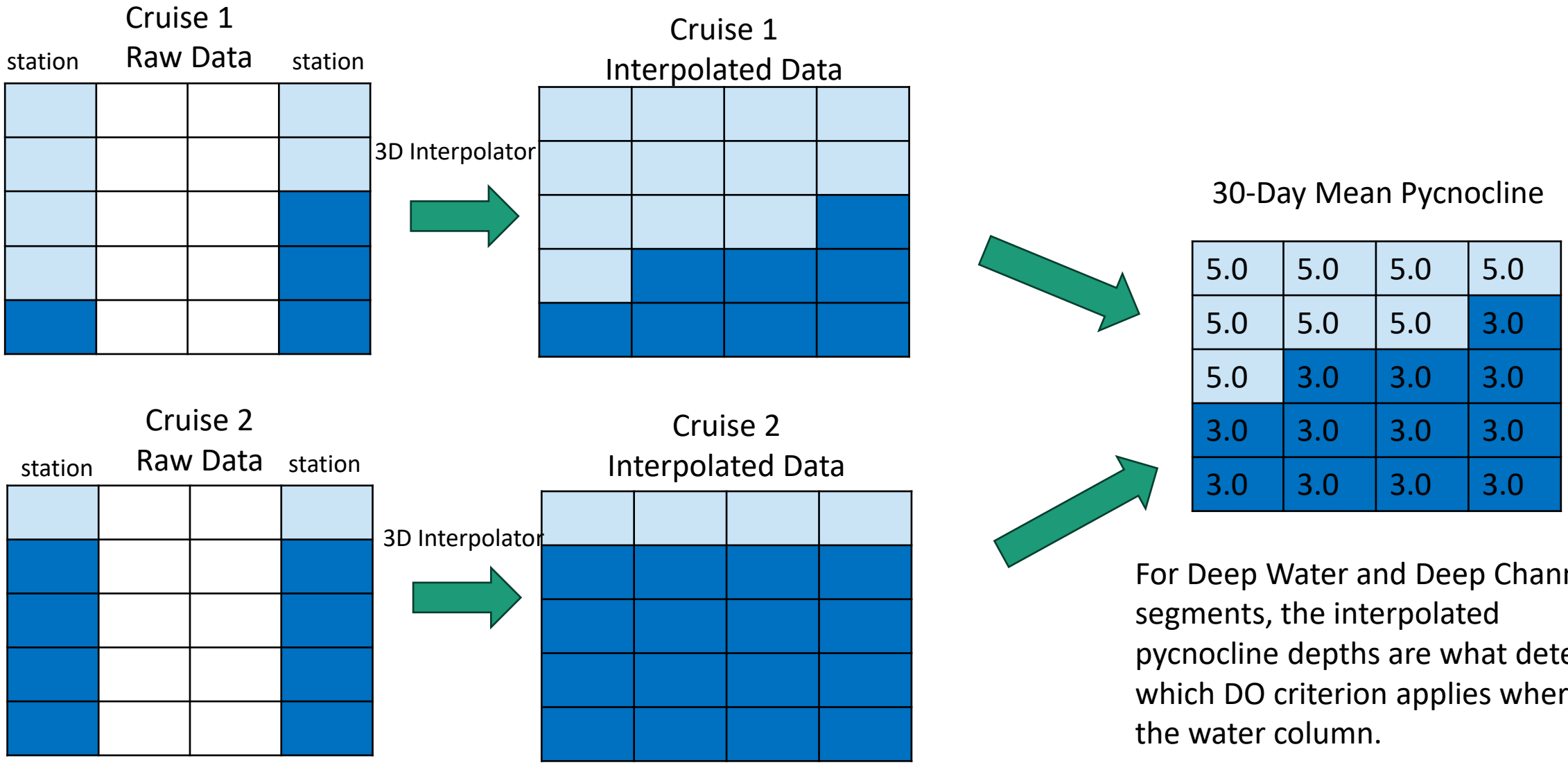
Cross-sectional View of Interpolator Grid for a Hypothetical Segment



30-Day Mean Pycnocline

5.0	5.0	5.0	5.0
5.0	5.0	5.0	3.0
5.0	3.0	3.0	3.0
3.0	3.0	3.0	3.0
3.0	3.0	3.0	3.0

For Deep Water and Deep Channel segments, the interpolated pycnocline depths are what determine which DO criterion applies where within the water column.

DEQ

What we know

- Pycnocline depths can fluctuate a lot.
- This hasn’t posed a problem for our 3-D interpolator-based assessments because of the low frequency of our monitoring data (two cruises per month) and the long duration of the criteria we have been assessing.
- But pycnocline variability is something that we have to contend with for the 4-D interpolator and the shorter duration criteria.

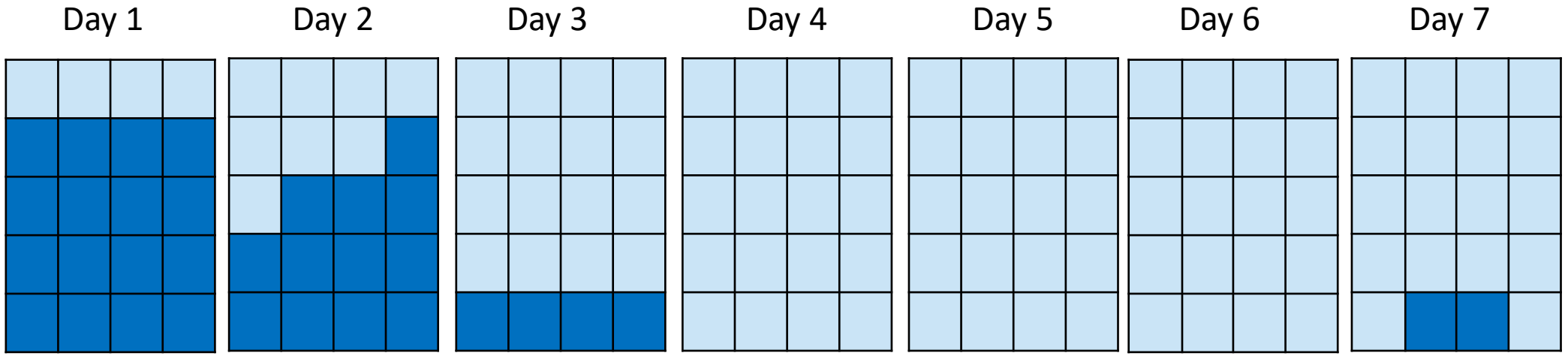
Options

1. Use spatially interpolated pycnocline depths averaged over the duration of whatever criterion is being assessed to determine the location of designation uses within the water column (status quo).

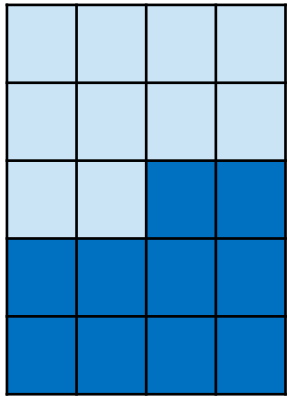
Above Pycnocline

Below Pycnocline

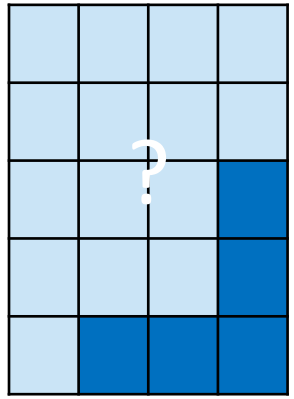
What's the average pycnocline for this 7-day period?



If we ignore the time intervals when there was no stratification….



If we include the time intervals when there was no stratification…



DEQ

Options

1. Use pycnocline depths averaged over the duration of whatever criterion is being assessed to determine the location of designation uses within the water column (status quo).

- Downside: We would be throwing more uncertainty into the assessment.

DEQ

Options

1. Use pycnocline depths averaged over the duration of whatever criterion is being assessed to determine the location of designation uses within the water column (status quo).

    - Downside: We would be throwing more uncertainty into the assessment.

2. Assign each hourly DO estimate to a designated use based on its vertical position with respect to the matched daily-average pycnocline depth. For each grid cell, average the DO estimates matched to a specific designated use, over the duration of the criterion being assessed for that designated use.

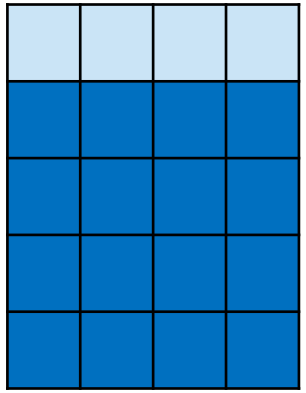
DEQ

Option 2

Depiction of the pycnocline for the July 14, 2025

Above Pycnocline

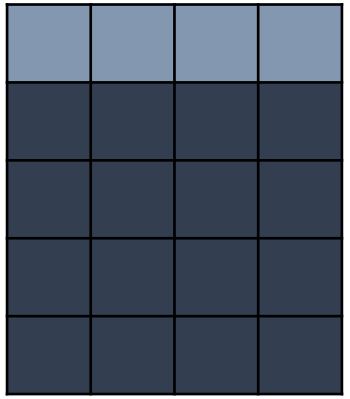
Below Pycnocline



Vertical extent of designated use for July 14, 2025

Open Water

Deep Water



Instantaneous Minimum Criteria Assessment (1-hour duration)

On this day, all the hourly DO estimates in the uppermost layer would be assessed against the Open Water instantaneous minimum criteria.

On this day, all the hourly DO estimates below the uppermost layer would be assessed against the Deep Water instantaneous minimum criteria.

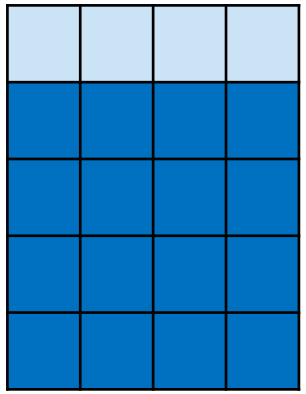
DEQ

Option 2

Depiction of the pycnocline for the July 14, 2025

Above Pycnocline

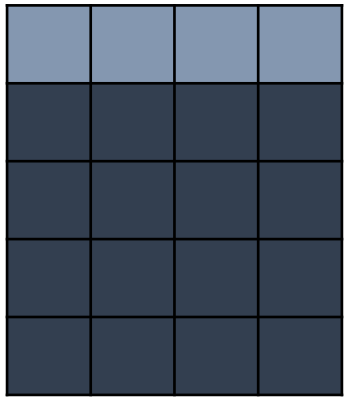
Below Pycnocline



Vertical extent of designated use for July 14, 2025

Open Water

Deep Water



1-Day Mean Criterion Assessment (Deep Water only)

On this day, none of the hourly DO estimates in the uppermost layer would be assessed against the Deep Water 1-day mean criterion.

On this day, all the hourly DO estimates below the uppermost layer would be assessed against the Deep Water 1-day mean criterion.

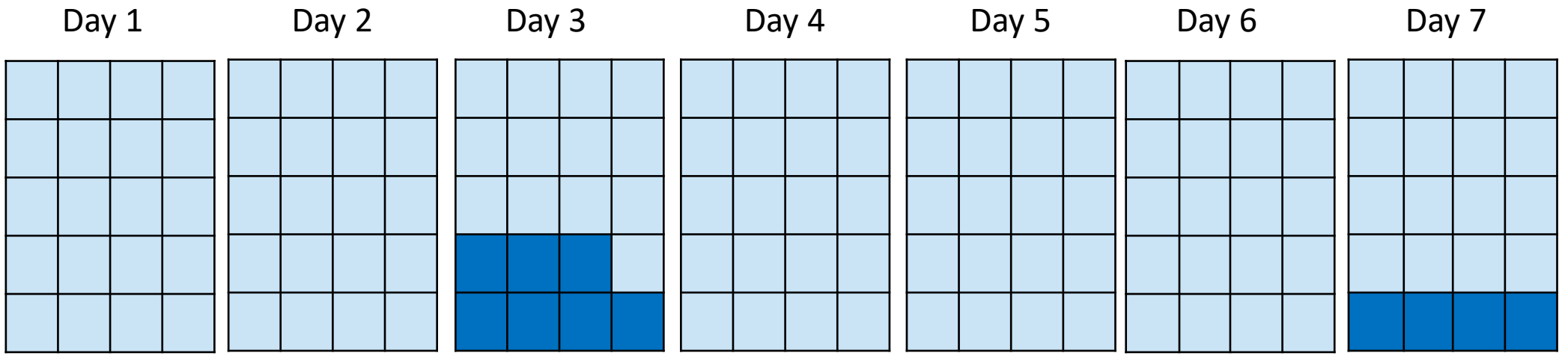
DEQ

Above Pycnocline

Below Pycnocline

Option 2

Open Water 7-Day Mean Criterion Assessment



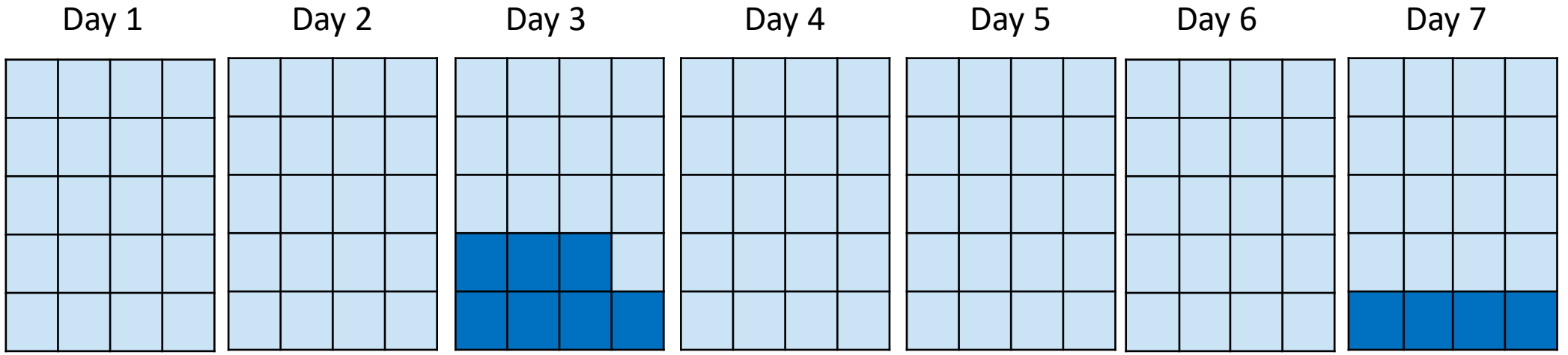
DEQ

Above Pycnocline

Below Pycnocline

Option 2

Open Water 7-Day Mean Criterion Assessment



Temporal frequency of OW use

100%	100%	100%	100%
100%	100%	100%	100%
100%	100%	100%	100%
85%	85%	85%	100%
71%	71%	71%	71%

Assessed for Open Water 7-Day Mean

Not assessed for Open Water 7-Day Mean

The Open Water use appears in all grid cells at least 50% of the time over this 7-day period. So we would use the above-pyc hourly DO estimates to calculate 7-day means for each cell. Then we would compare the means to the OW 7-day mean criterion.

DEQ

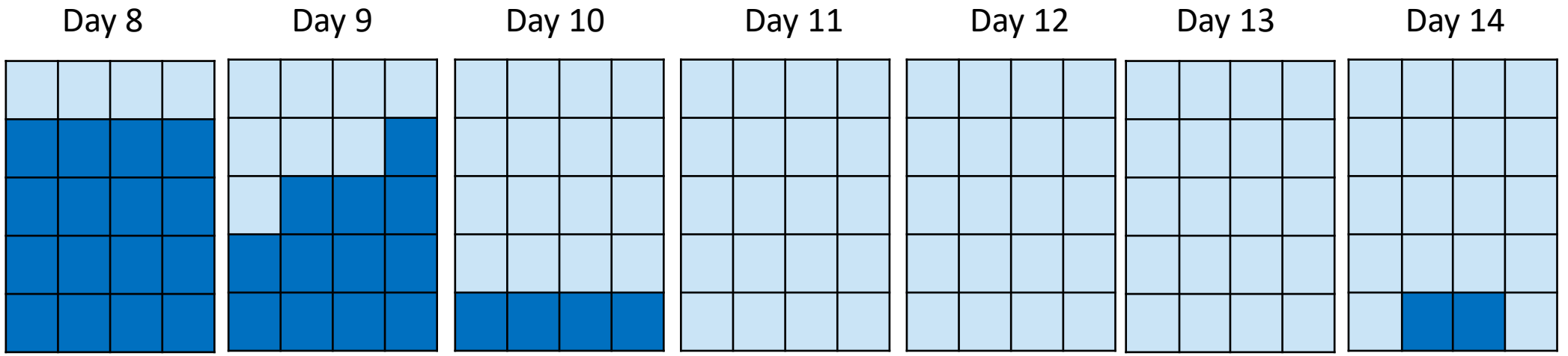
Above Pycnocline

Below Pycnocline

Option 2

THE NEXT 7-DAY PERIOD

Open Water 7-Day Mean Criterion Assessment



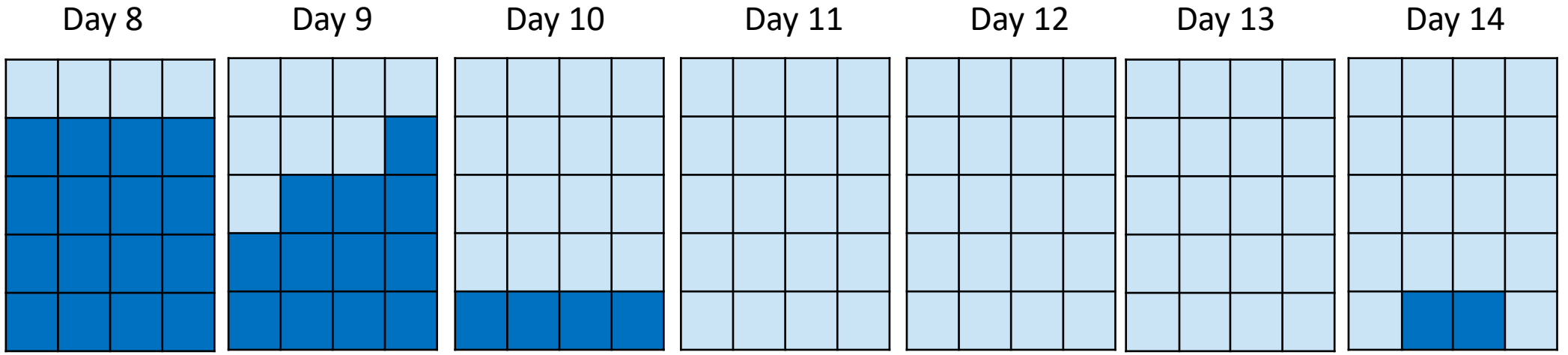
DEQ

Above Pycnocline

Below Pycnocline

Option 2

Open Water 7-Day Mean Criterion Assessment



Assessed for Open Water 7-Day Mean

Not assessed for Open Water 7-Day Mean

Temporal frequency of OW use

100%	100%	100%	100%
86%	86%	86%	71%
86%	71%	71%	71%
71%	71%	71%	71%
57%	43%	43%	57%

We could exclude the red cells from the assessment of the OW 7-day mean criterion for this 7-day period because the Open Water use appears infrequently over this period in those cells.

However, the above-pyc hourly DO estimates in the red cells would still be subject to the Open Water IM criterion.

DEQ

Options

1. Use pycnocline depths averaged over the duration of whatever criterion is being assessed to determine the location of designation uses within the water column (status quo).

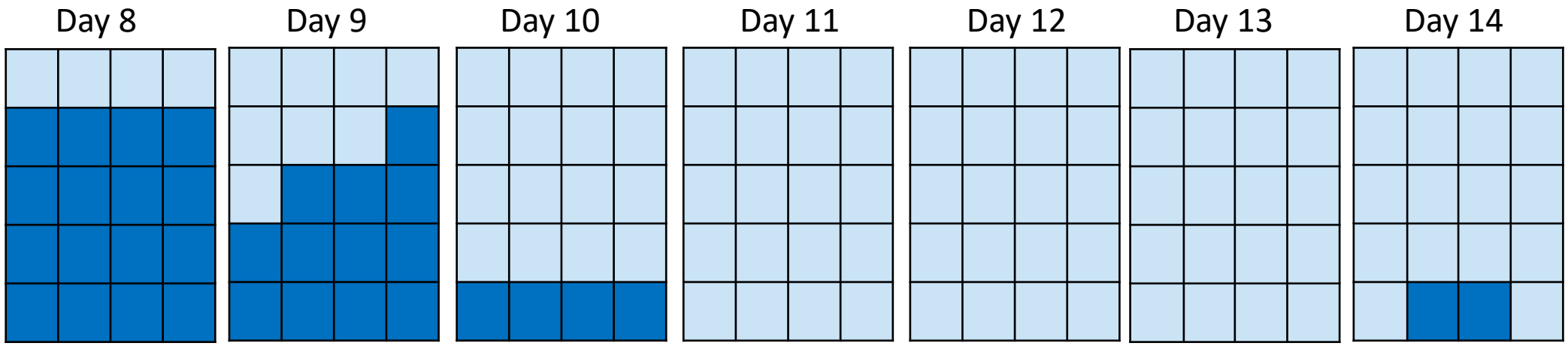
- Downside: We would be throwing more uncertainty into the assessment.

2. Assign each hourly DO estimate to a designated use based on its vertical position with respect to the concurrently estimated pycnocline depth. For each grid cell, average the DO estimates matched to a specific designated use, over the duration of the criterion being assessed for that designated use.

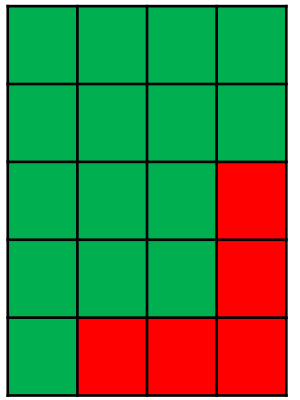
- Downside: Computationally intensive but without the uncertainty of Option 1#.

DEQ

7-Day Assessment Summary

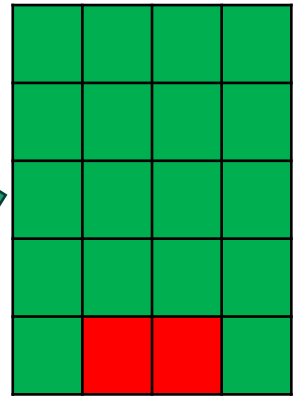


Option 1#



Averaged pycnocline depth determines volume of the Open Water use.

Option 2#



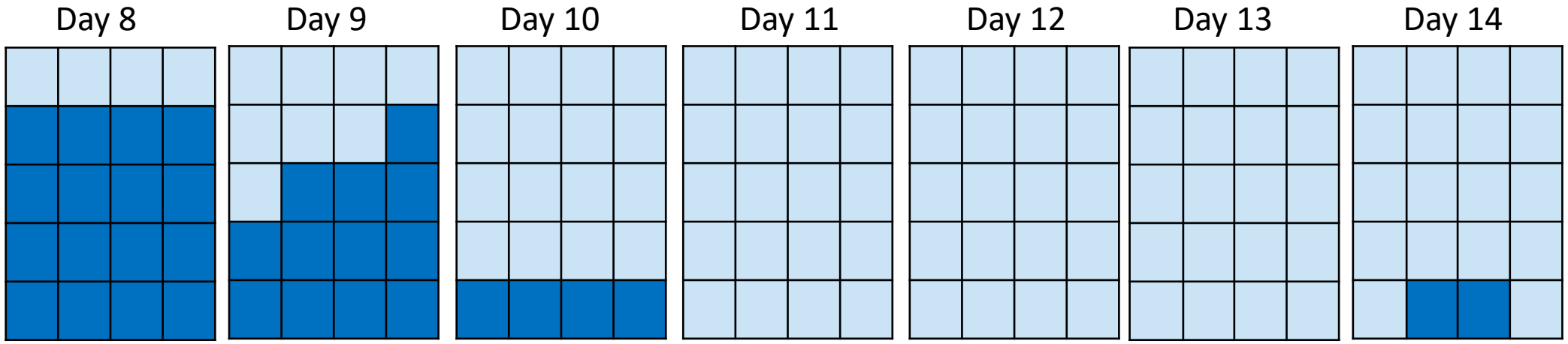
The temporal frequency of hourly DO above the pycnocline determines the volume of the Open Water use.

Assessed for Open Water 7-Day Mean

Not assessed for Open Water 7-Day Mean

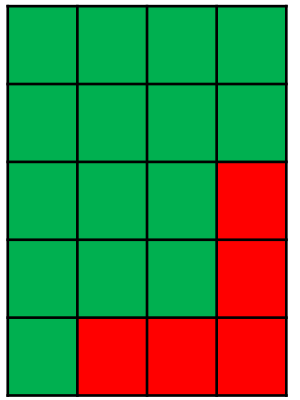
DEQ

7-Day Assessment Summary

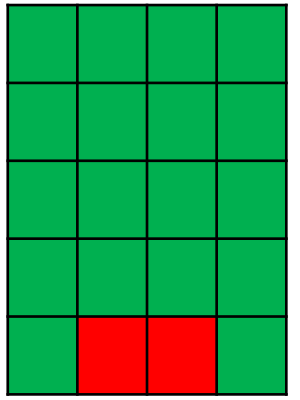


- Under Option 1#, we would be excluding a lot of DO concentrations that were technically representing conditions of Open Water habitat.
- Under Option 2#, we would be able to optimize our ability to assess all of the Open Water habitat while minimizing classification errors.

Option 1#



Option 2#



Assessed for Open Water 7-Day Mean

Not assessed for Open Water 7-Day Mean

DEQ

Questions?