Analysis of Persistent Open Water Deep Water and Deep Channel Dissolved Oxygen Impairments

Water Quality Steering Committee Conference Call

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Overview

• The new reference curves of Open Water (10%), Deep Water (refinements to curve), and Deep Channel (10%) have reduced the number of CB segments not achieving the DO WQS at the Target Scenario (175/14.1), but more needs to be done.

• Confirmation that some of the Open Water designated uses have a pycnocline with an attendant need for development of a Deep Water DU for those CB segments.

• Recommended resolution paths for DO non-attainment segments.

Comparing Persistent DO Impairments Before and After Application of the New Reference Curves

175 TN - 12.8 TP Scenario

OLD REFERENCE CURVES

Segment	Segment Name	Issue
Deep Channel		
CB3MH	Upper Central Bay	0.4% non-attainment
CHSMH	Lower Chester River	0.7% non-attainment
EASMH	Eastern Bay	2.4% non-attainment
Deep Water		
CB3MH	Upper Central Bay	0.2% non-attainment
CB4MH	Middle Central Bay	8.0% non-attainment
CB5MH	Lower Central Bay	0.6% non-attainment
EASMH	Eastern Bay	0.1% non-attainment
Open Water		
CB2OH	Upper Ches. Bay	0.2% non-attainment
CB7PH	Lower Eastern Bay	0.2% non-attainment
BSHOH	Bush River	3.6% over load range
MAGMH	Magothy River	4.3% non-attainment
SOUMH	South River	10.4% non-attainment
CHKOH	Chickahominy River	0.9% non-attainment
CHSTF	Upper Chester River	2.1% non-attainment
CHSOH	Middle Chester River	0.5% non-attainment
CHOTF	Upper Choptank River	0.5% non-attainment
CHOOH	Middle Choptank River	0.1% non-attainment
CHOMH1	Lower Choptank River	0.7% non-attainment
LCHMH	Little Choptank River	1.1% non-attainment
POCTF	Upper Pocomoke River	17.2% non-attainment
POCOH	Middle Pocomoke River	17.2% non-attainment

175 TN - 12.8 TP Scenario

NEW REFERENCE CURVES

Segment	Segment Name	Issue
Deep Channel		
CB3MH	Upper Central Bay	0.2% non-attainment
CHSMH	Lower Chester River	3.1% non-attainment
EASMH	Eastern Bay	3.2% non-attainment
Deep Water		
CB3MH	Upper Central Bay	0.1% non-attainment
CB4MH	Middle Central Bay	7.5% non-attainment
CB5MH	Lower Central Bay	0.5% non-attainment
EASMH	Eastern Bay	FULLY ATTAINED
Open Water		
CB2OH	Upper Ches. Bay	FULLY ATTAINED
CB7PH	Lower Eastern Bay	FULLY ATTAINED
BSHOH	Bush River	4.6% over load range
MAGMH	Magothy River	2.6% non-attainment
SOUMH	South River	8.4% non-attainment
CHKOH	Chickahominy River	1.8% non-attainment
CHSTF	Upper Chester River	1.4% non-attainment
CHSOH	Middle Chester River	0.2% non-attainment
CHOTF	Upper Choptank River	FULLY ATTAINED
CHOOH	Middle Choptank River	FULLY ATTAINED
CHOMH1	Lower Choptank River	FULLY ATTAINED
LCHMH	Little Choptank River	FULLY ATTAINED
POCTF	Upper Pocomoke River	17.9% non-attainment
POCOH	Middle Pocomoke River	17.9% non-attainment

Persistent DO Impairments Before and After Application of New Deep Water and Deep Channel Designated Uses

175 TN - 14.1 TP Scenario

NEW REFERENCE CURVES

Segment	Segment Name	Issue
Deep Channel		
CB3MH	Upper Central Bay	0.2% non-attainment
CHSMH	Lower Chester River	3.1% non-attainment
EASMH	Eastern Bay	3.4% non-attainment
Deep Water		
CB3MH	Upper Central Bay	0.1% non-attainment
CB4MH	Middle Central Bay	7.5% non-attainment
CB5MH	Lower Central Bay	0.5% non-attainment
EASMH	Eastern Bay	FULLY ATTAINED
Open Water		
CB2OH	Upper Ches. Bay	FULLY ATTAINED
CB7PH	Lower Eastern Bay	FULLY ATTAINED
BSHOH	Bush River	4.6% over load range
MAGMH	Magothy River	1.5% non-attainment
SOUMH	South River	8.3% non-attainment
CHKOH	Chickahominy River	1.8% non-attainment
CHSTF	Upper Chester River	1.4% non-attainment
CHSOH	Middle Chester River	FULLY ATTAINED
CHOTF	Upper Choptank River	FULLY ATTAINED
CHOOH	Middle Choptank River	FULLY ATTAINED
CHOMH1	Lower Choptank River	FULLY ATTAINED
LCHMH	Little Choptank River	FULLY ATTAINED
POCTF	Upper Pocomoke River	18.3% non-attainment
POCOH	Middle Pocomoke River	18.5% non-attainment

175 TN - 14.1 TP Scenario

NEW DEEP WATER & CHANNEL DUs

Segment	Segment Name	Issue	Solutions*
Deep Channel			
CB3MH	Upper Central Bay	0.2% non-attainment	1
CHSMH	Lower Chester River	3.1% non-attainment	6
EASMH	Eastern Bay	3.4% non-attainment	6
Deep Water			
CB3MH	Upper Central Bay	0.1% non-attainment	1
CB4MH	Middle Central Bay	7.5% non-attainment	1,2
CB5MH	Lower Central Bay	0.5% non-attainment	1
EASMH	Eastern Bay	FULLY ATTAINED	NA
Open Water			
CB2OH	Upper Ches. Bay	FULLY ATTAINED	NA/3
CB7PH	Lower Eastern Bay	FULLY ATTAINED	NA/3
BSHOH	Bush River	4.6% over load range	3
MAGMH	Magothy River	FULLY ATTAINED	3
SOUMH	South River	FULLY ATTAINED	3
CHKOH	Chickahominy River	1.8% non-attainment	4
CHSTF	Upper Chester River	1.4% non-attainment	4
CHSOH	Middle Chester River	FULLY ATTAINED	NA
CHOTF	Upper Choptank River	FULLY ATTAINED	NA
CHOOH	Middle Choptank River	FULLY ATTAINED	NA
CHOMH1	Lower Choptank River	FULLY ATTAINED	NA
LCHMH	Little Choptank River	FULLY ATTAINED	NA
POCTF	Upper Pocomoke River	18.3% non-attainment	5
POCOH	Middle Pocomoke River	18.5% non-attainment	5

*** Possible Soutions to Persistent Impairment:**

1 - Less than 1% non attainment.

2 – CB4 Deep Water has a 7% variance so only 1% of volume-time is in non-attainment under the old reference curves and 0.5% nonattainment under the new reference curves.

3 – Segments which may require a deep water DU.

4 – Segments which may require refinements to regional scale allocations to address regionally influenced water quality impairments.

5 – Segments that are entirely open water designated uses—e.g., Upper and Middle Pocomoc with extensive water column contact with bottom sediments and sediment oxygen demand which have significant influence on the water column dissolved oxygen levels.

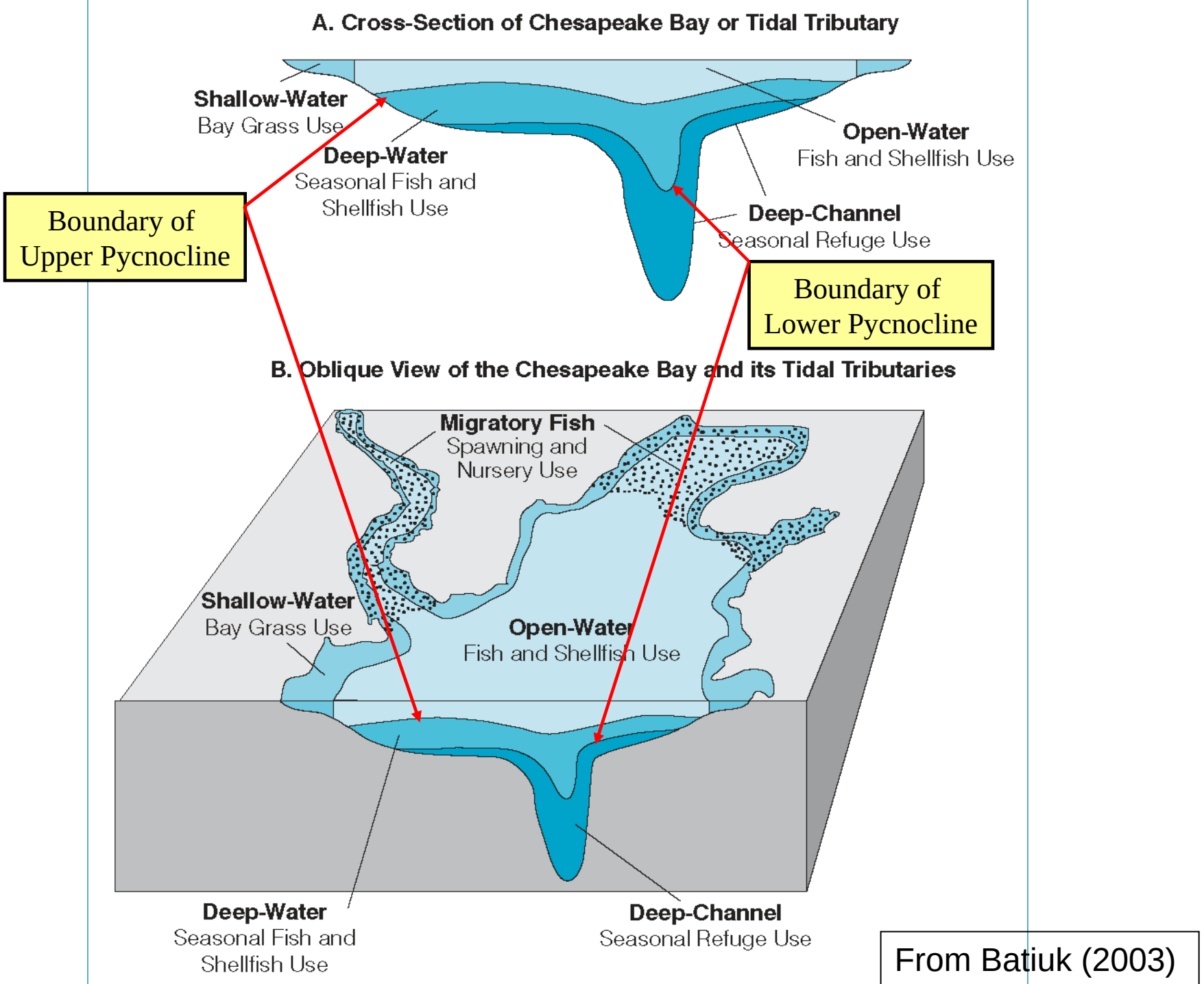
6 – Segments with a better representation of the deeper channels and holes within the new Bay water quality/sediment transport model—e.g., Eastern Bay.

Approach 1: Use of Deep Water Designated Uses in Waters Previously Only Open Water – Segments Affected MAGOH, SOUMH, BSHMH, SEVMH

• In our previous 13K cell Water Quality Model we were unable to assess CB Segments like the South River due to limited segmentation. Now, with the 57k cell Water Quality and Sediment Transport Model, we have sufficient segmentation to fully examine the South River, as well as other new CB Segments, and the question of new Open and Deep Water designated uses comes to the forefront.

• Density stratification (pycnocline) restricts the physical exchange of higher oxygenated water in the upper water column with deeper bottom water.

• The boundary between Open Water and Deep Water is based on the presence of an upper pycnocline boundary.



From Batiuk (2003)

Discussion:

- Deep Water requires a monthly mean DO > 3 mg/l.
- Open Water requires a monthly mean DO > 5 mg/l.
- Problem: Some DUs, such as MAGMH, SEVMH and SOUMH, are entirely categorized as OW. Evidence of a pycnocline that limits bottom water reaeration and causes violation of the Open Water DO standard has been demonstrated.
- Approach 1: Reassessing the occurrence of pycnoclines for these segments to create a Deep Water DU, and re-calculate DO criteria attainment.

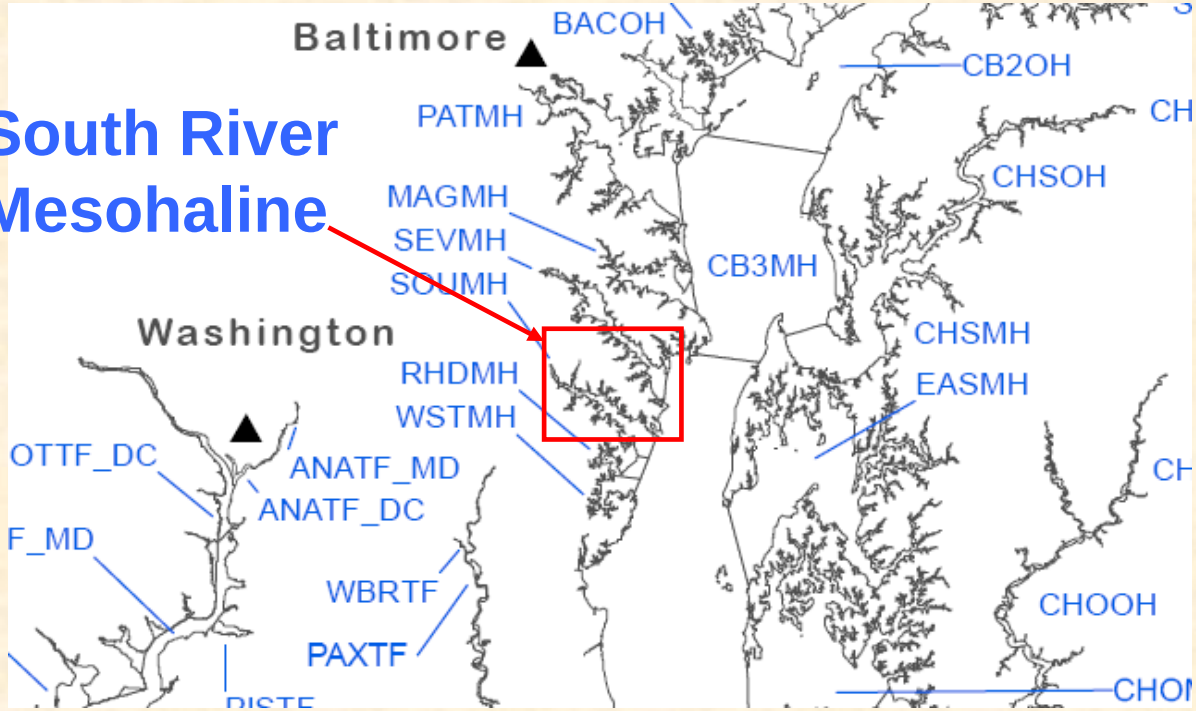
Table VI-1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean $\geq$ 6 mg liter $^{-1}$ (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum $\geq$ 5 mg liter $^{-1}$	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean $\geq$ 5.5 mg liter $^{-1}$ (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean $\geq$ 5 mg liter $^{-1}$ (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean $\geq$ 4 mg liter $^{-1}$	Survival of open-water fish larvae.	
	Instantaneous minimum $\geq$ 3.2 mg liter $^{-1}$	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean $\geq$ 3 mg liter $^{-1}$	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean $\geq$ 2.3 mg liter $^{-1}$	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum $\geq$ 1.7 mg liter $^{-1}$	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum $\geq$ 1 mg liter $^{-1}$	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

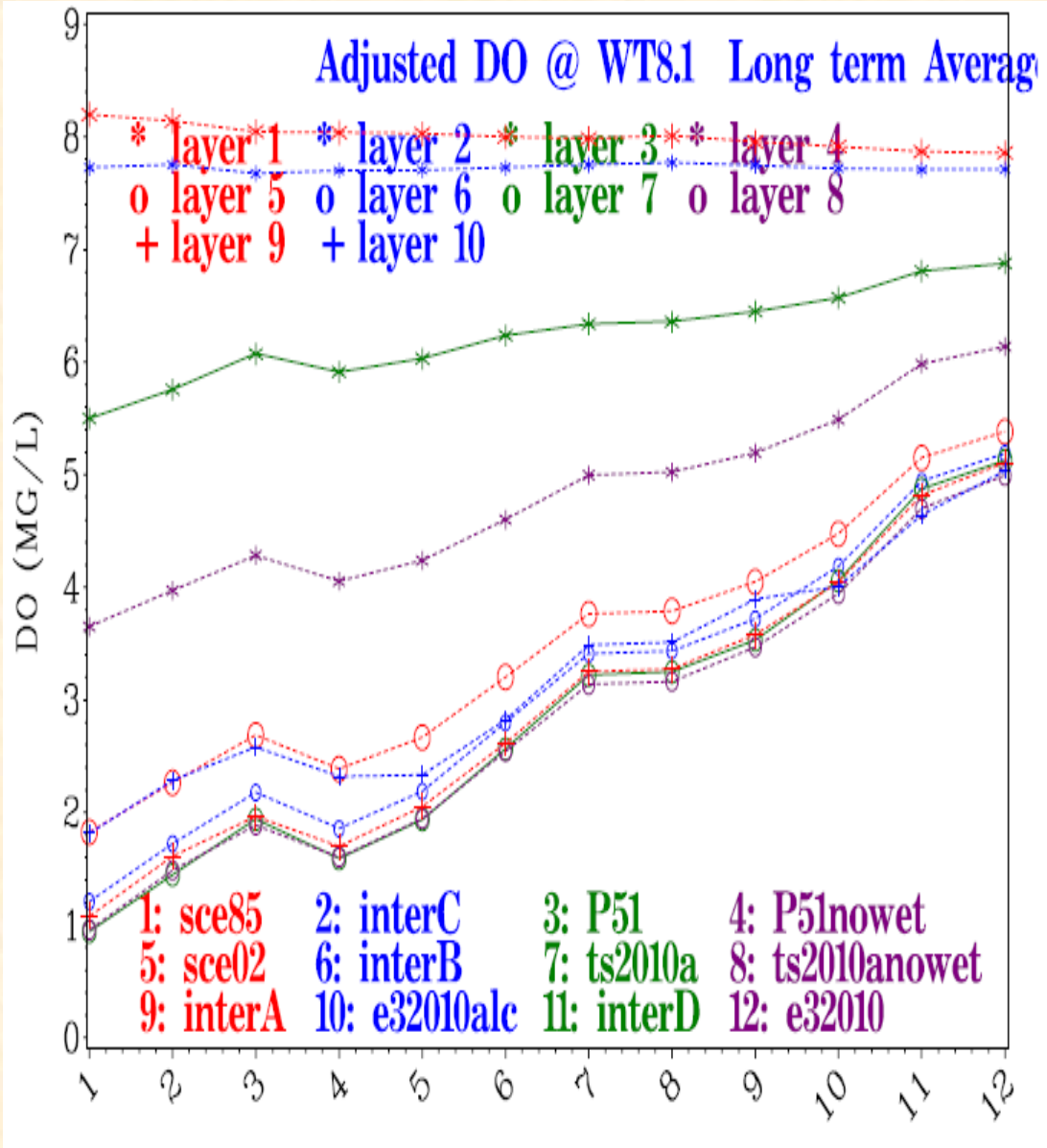
From Batiuk et al. (2003)

Location of the South River Mesohaline

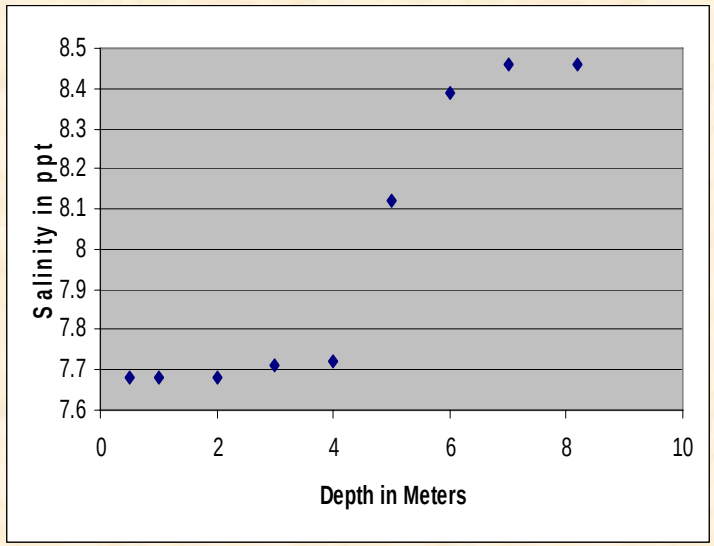


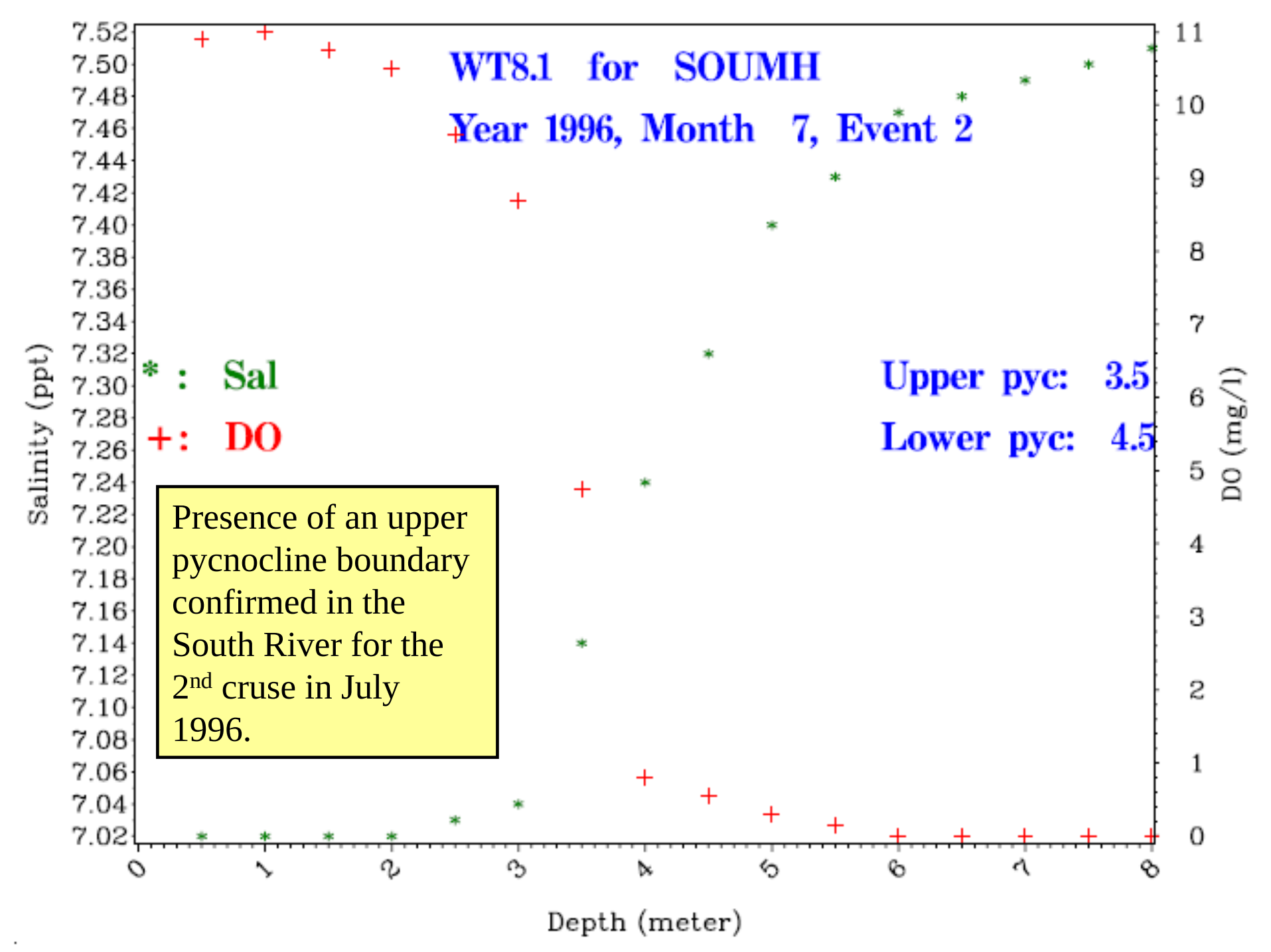
Cbseg	State	Scenario	1985 Scenario, 420TN 28.4TP	Intermediate C Scenario, 378TN 24.5TP	91 -'00 Base Scenario, 340TN 24.1TP	2002 Scenario, 333TN 20.9TP	Intermediate B Scenario, 279TN 17.2TP	Tributary Strategy 2010a Scenario, 236TN 21.1TP	Intermediate A Scenario, 209TN 13.7TP	Trial Allocation Scenario 175TN 14.1TP	2003 Allocation Scenario, 175TN 12.8TP	Intermediate D Scenario, 159TN 12.3TP	E3 2010 Scenario, 138TN 12.0TP
			DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous	DO Deep Channel Instantan-eous
SOUMH	MD		15.9%	17.1%	17.1%	16.4%	13.5%	9.8%	9.8%	8.3%	8.4%	5.7%	3.8%

South River Mesohaline Estimated DO In One Meter Depth Increments for Key CBP Scenarios

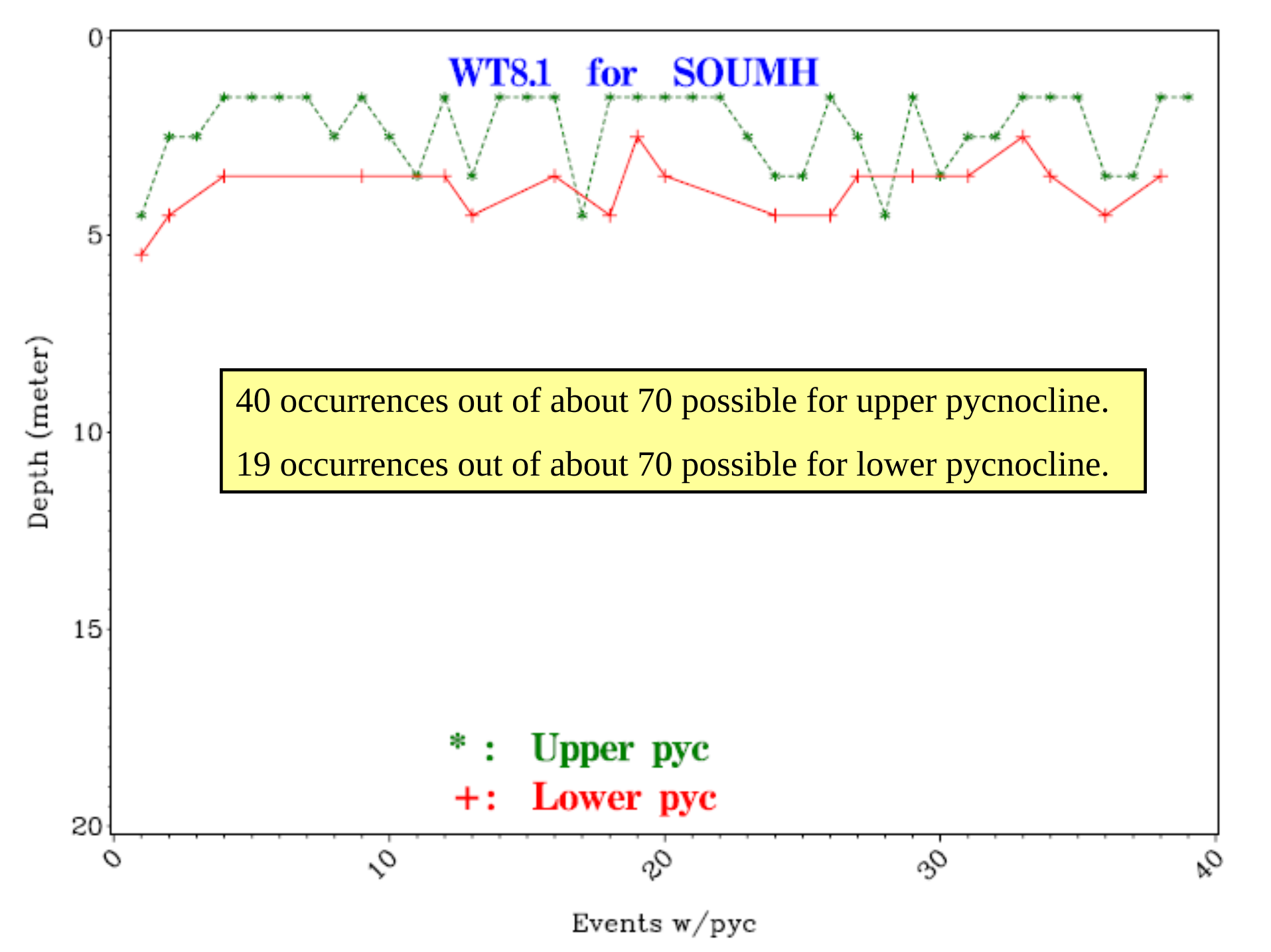


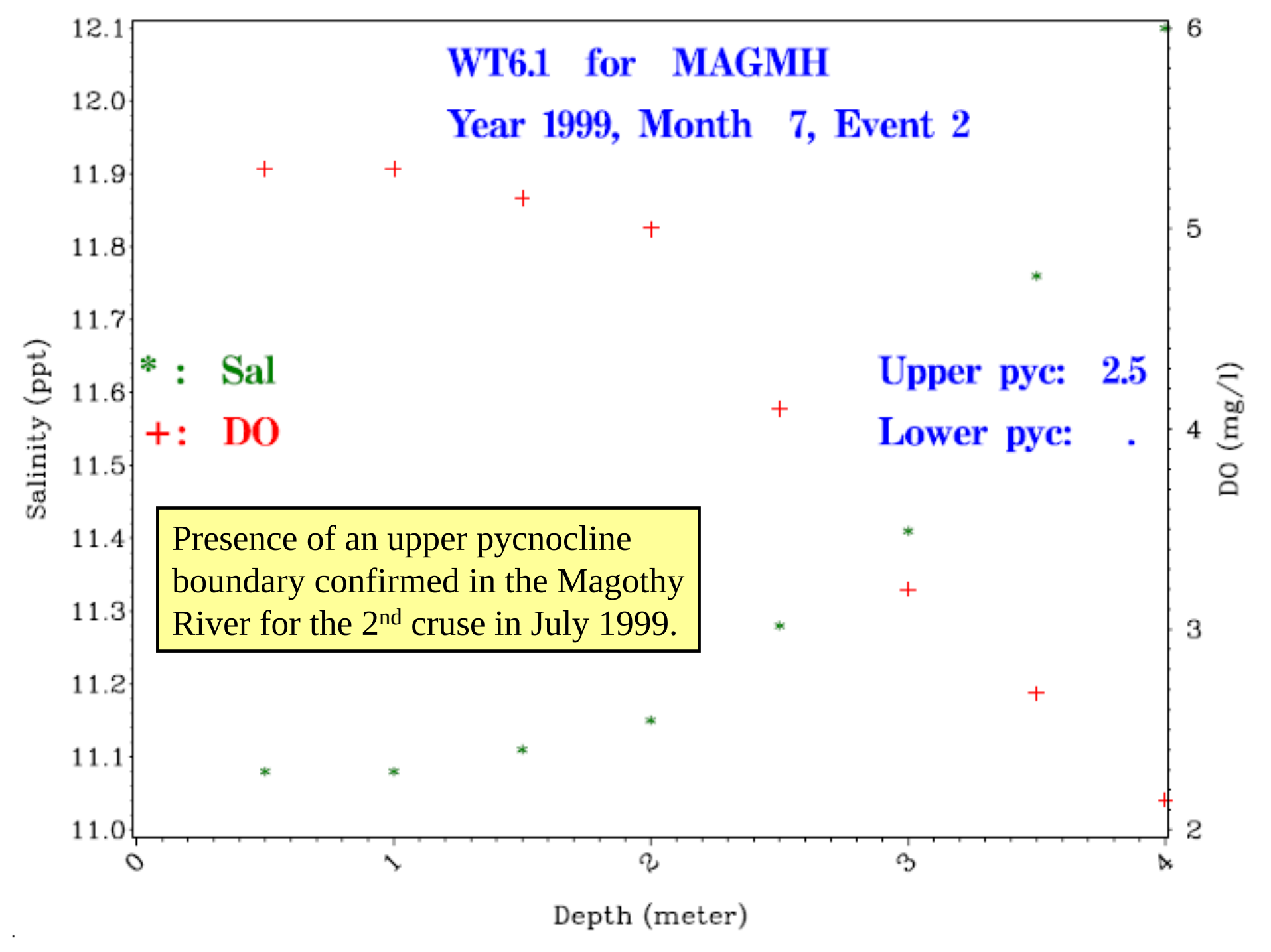
The South River (WT8.1), has a pycnocline as shown here on June 5, 1991. Evidence for pycnoclines have been found in other segments of concern including MAGMH (WT6.1), CHSOH (ET4.2), and POCOH (EE3.3).

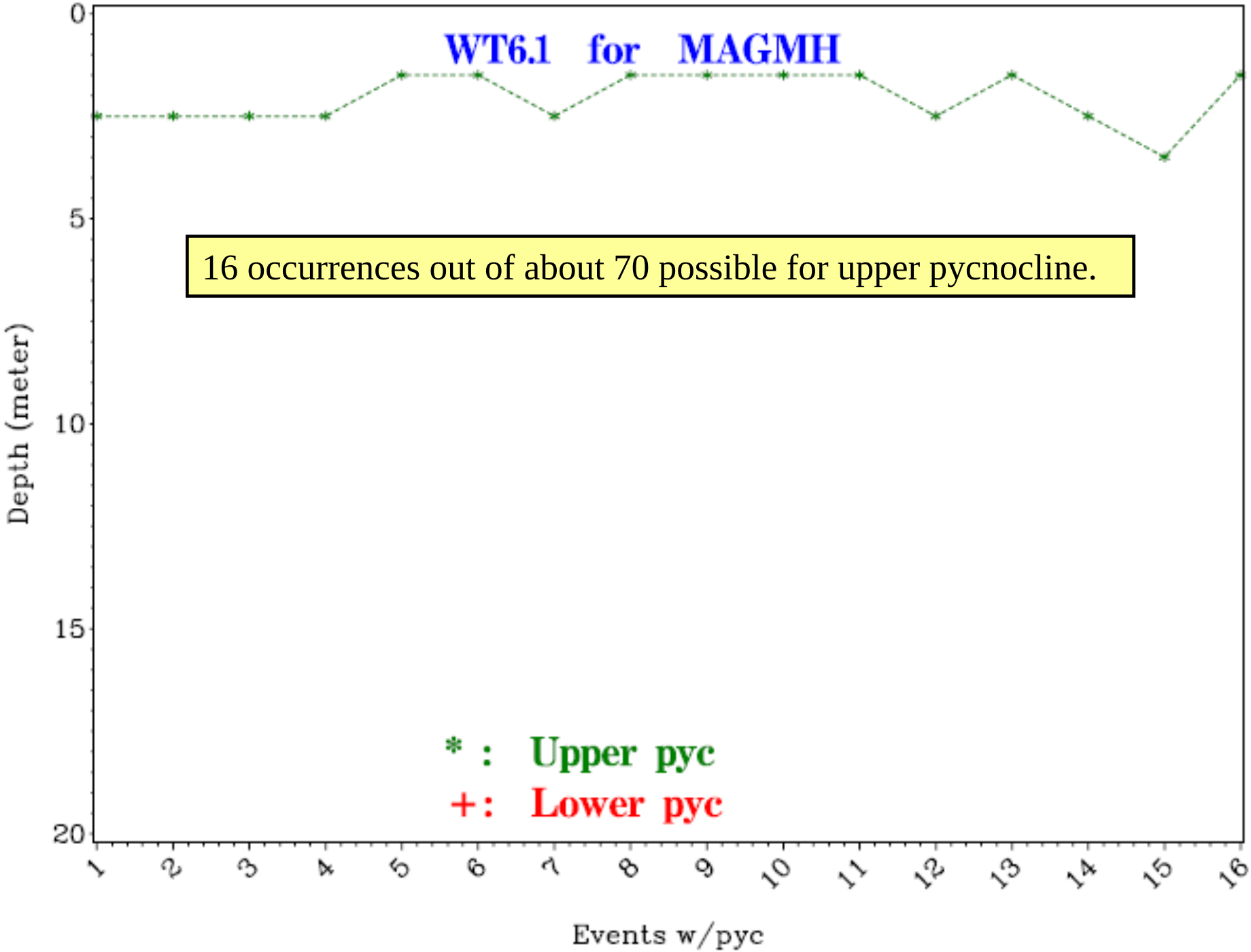


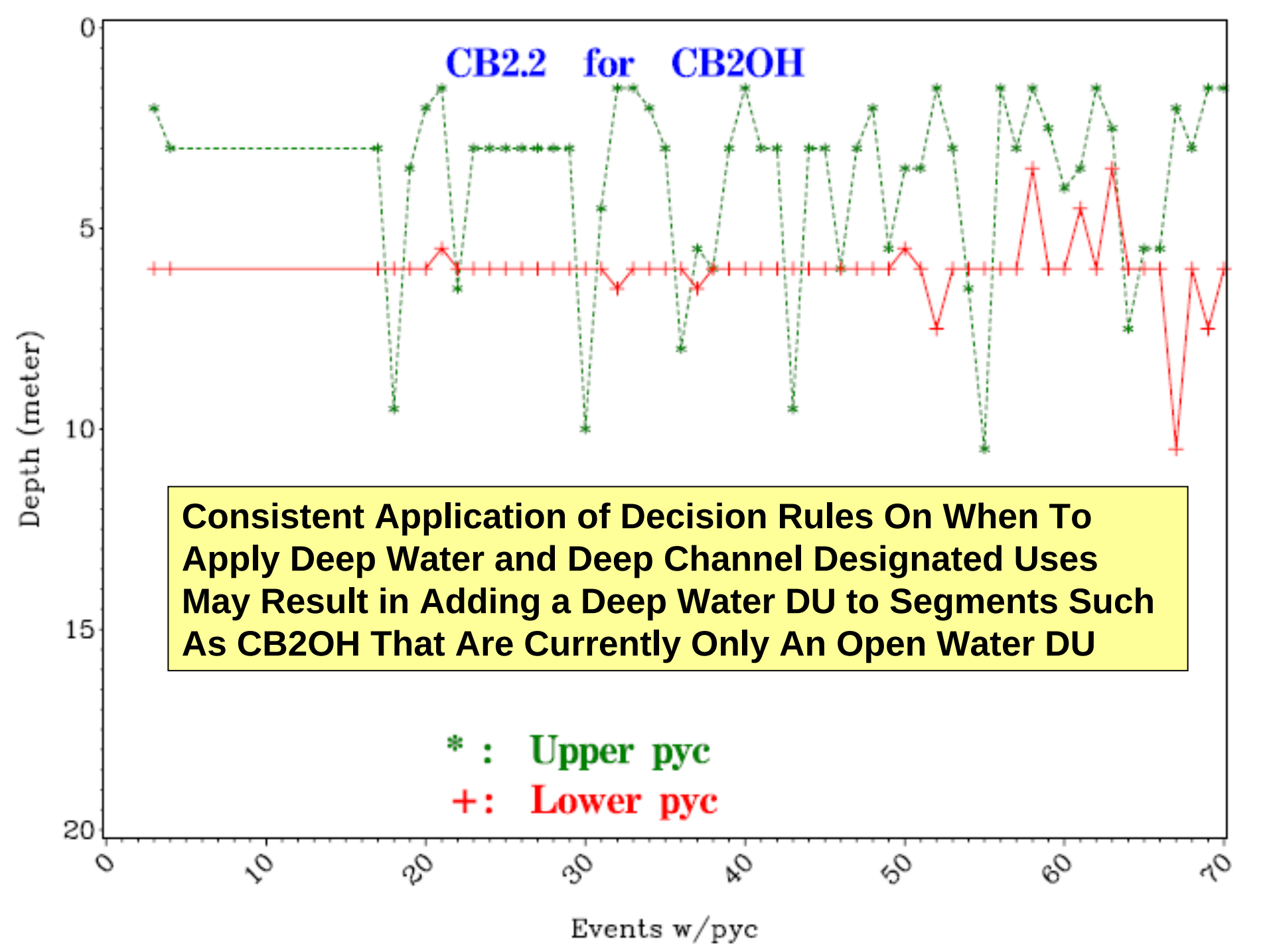


Presence of an upper pycnocline boundary confirmed in the South River for the 2nd cruse in July 1996.


WT8.1 for SOUMH
40 occurrences out of about 70 possible for upper pycnocline.
19 occurrences out of about 70 possible for lower pycnocline.
* : Upper pyc
+ : Lower pyc
Depth (meter)
Events w/pyc
0
5
10
15
20
0
10
20
30
40


WT6.1 for MAGMH
Year 1999, Month 7, Event 2
* : Sal
+: DO
Upper pyc: 2.5
Lower pyc: .
Presence of an upper pycnocline boundary confirmed in the Magothy River for the 2nd cruse in July 1999.
Salinity (ppt)
DO (mg/l)
Depth (meter)
12.1
12.0
11.9
11.8
11.7
11.6
11.5
11.4
11.3
11.2
11.1
11.0
6
5
4
3
2
0
1
2
3
4


WT6.1 for MAGMH
16 occurrences out of about 70 possible for upper pycnocline.
Depth (meter)
0
5
10
15
20
* : Upper pyc
+: Lower pyc
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Events w/pyc


CB2.2 for CB2OH
Depth (meter)
0
5
10
15
20
0
10
20
30
40
50
60
70
Events w/pyc
Consistent Application of Decision Rules On When To Apply Deep Water and Deep Channel Designated Uses May Result in Adding a Deep Water DU to Segments Such As CB2OH That Are Currently Only An Open Water DU
* : Upper pyc
+ : Lower pyc

Where we were previously before the application of new reference curves and the new Deep Water designated uses.

Cbseg	1985 Scenario, 420TN 28.4TP DO Open Water Summer Monthly '96-'98	91 -'00 Base Scenario, 340TN 24.1TP DO Open Water Summer Monthly '96-'98	2003 Allocation Scenario, 175TN 12.8TP DO Open Water Summer Monthly '96-'98	E3 2010 Scenario, 138TN 12.0TP DO Open Water Summer Monthly '96-'98
CB2OH	2.0%	1.4%	0.2%	0.1%
CB7PH	8.5%	6.3%	0.2%	0.1%
CHOMH1	5.3%	3.3%	0.7%	0.5%
LCHMH	3.3%	2.4%	1.1%	0.8%
MAGMH	11.2%	8.7%	4.3%	0.9%
SEVMH	10.0%	8.4%	0.0%	0.0%
SOUMH	16.7%	18.1%	10.4%	5.3%

Where we were after the application of new reference curves and the new Deep Water designated uses.

1996-1998	91 -'00 Base Scenario, 340TN 24.1TP			2003 Allocation Scenario 175TN 14.1 TP			E3 2010 Scenario 138TN 12.0TP		
Cbseg	DO Open Water Summer Monthly	DO Deep Water Monthly	DO Deep Channel Instantaneous	DO Open Water Summer Monthly	DO Deep Water Monthly	DO Deep Channel Instantaneous	DO Open Water Summer Monthly	DO Deep Water Monthly	DO Deep Channel Instantaneous
CB2OH	0.00%	0.00%	N/A	0.00%	0.00%	N/A	0.00%	0.00%	N/A
CB7PH	4.32%	0.00%	N/A	0.00%	0.00%	N/A	0.00%	0.00%	N/A
CHOMH1	0.00%	1.35%	N/A	0.00%	0.00%	N/A	0.00%	0.00%	N/A
LCHMH	0.00%	19.90%	N/A	0.00%	4.26%	N/A	0.00%	0.00%	N/A
MAGMH	1.27%	30.89%	N/A	0.00%	0.00%	N/A	0.00%	0.00%	N/A
SEVMH	0.50%	2.35%	N/A	0.00%	0.00%	N/A	0.00%	0.00%	N/A
SOUMH	0.00%	45.84%	N/A	0.00%	0.03%	N/A	0.00%	0.00%	N/A

Other Approaches to Address Persistent Nonattainment of DO

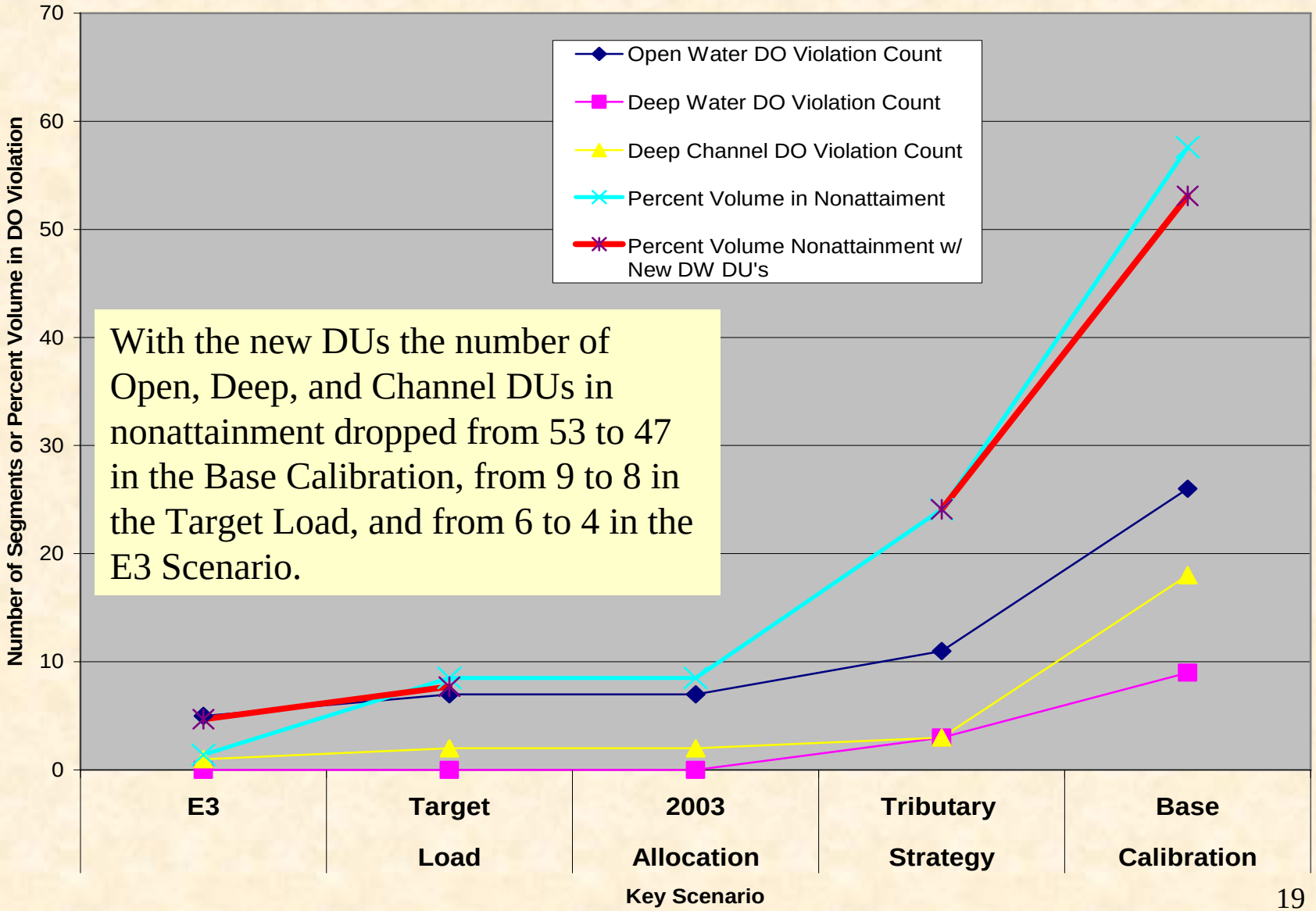
• For segments with less than 1% nonattainment at the 175/14.1 Target Scenario take no action and examine attainment with the final Phase 5.3 and WQSTM.

• For the Lower Chester River and Eastern Bay, examine WQSTM output for the reasons of persistent DO nonattainment.

• For the Chickahominy and Upper Chester River there is the possibility of either loading issues or perhaps resolution through local reductions.

• High nonattainment in the Upper and Middle Pocomoke is not yet understood. We're looking into loading issues and into the WQSTM output.

DO Stoplight Plot Summary Information



With the new DUs the number of Open, Deep, and Channel DUs in nonattainment dropped from 53 to 47 in the Base Calibration, from 9 to 8 in the Target Load, and from 6 to 4 in the E3 Scenario.

Decision Requested

Quality Steering Committee approval to move forward on the recommended resolution of Open Water segments with persistent DO impairments beyond the 175/14.1 target.