A New Tool for Communicating Dissolved Oxygen Concentrations in Virginia's Chesapeake Bay

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Water Quality Standards Scientist
Virginia Department of Environmental Quality -- Office of Ecology
November 12, 2025

VIRGINIA MERCURY

After a less rainy spring, the Chesapeake Bay may see smaller dead zone than normal

BALTIMORE FISHBOWL

The Chesapeake's Dead Zone Less Bad than Normal

CHESAPEAKE BAY FOUNDATION
Saving a National Treasure

Bay Dead Zone: What's It Like This Summer?

MARYLAND MATTERS

The Bay's 'dead zone' was near average in 2024, sort of

Where we can do better with communication

1. The dead zone is only one facet of the Chesapeake Bay dissolved oxygen story. And it isn't the most interesting facet.

VIRGINIA'S 2024 305(b)/303(d) Water Quality Assessment Integrated Report

Submitted in accordance with Sections 303(d) and 305(b) of the Clean Water Act, and the Virginia Water Quality Monitoring, Information, and Restoration Act

March 2025

4.6.2 Chesapeake Bay and Tidal Tributaries Aquatic Life Uses and Criteria

The Chesapeake Bay specific aquatic life uses described below reflect the different aquatic living resource communities living in the different areas of the Bay. Impairment of any of these sub-categories of aquatic life use is also considered an impairment of the overall aquatic life use. The overall aquatic life use also exists as a distinct designated use (i.e., distinct from the Chesapeake Bay specific aquatic life uses) and is assessed with other protocols including benthic Indices of Biological Integrity (IBI), ammonia criteria, and toxicity bioassays.

Designated Uses

Multiple designated uses exist in waters in the Chesapeake Bay and its tidal tributaries. Figure 4.6-2 illustrates these designated uses. Detailed descriptions are available in Virginia's WQS and the *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability 2004 Addendum Chesapeake Bay Program Office, Annapolis, Maryland.*

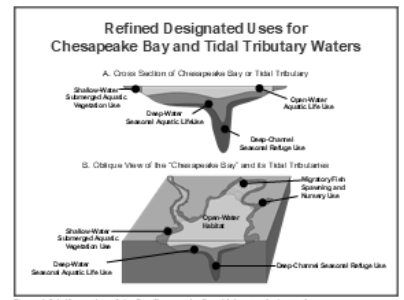

Figure 4.6-1. Illustration of the five Chesapeake Bay tidal water designated use zones.

Migratory Fish Spawning and Nursery (MSN) Designated Use

This use exists in waters in the Chesapeake Bay and its tidal tributaries that protect the survival, growth, and propagation of the early life stages of a balanced, indigenous population of anadromous, semi-anadromous, catadromous[13] and tidal-fresh resident fish species inhabiting spawning and nursery grounds. The designated use extends from the beginning of tidal waters to the downriver end of spawning and nursery habitats, as determined through a composite of all targeted anadromous and semi-anadromous fish species' spawning and nursery habitats. The designated use extends horizontally from the shoreline of the body of water to the adjacent shoreline and extends down through the water column to the bottom water-sediment interface. This use applies February 1 through May 31 and exists concurrently with the open-water use.

Shallow Water Submerged Aquatic Vegetation (SWSAV) Designated Use

This use exists in waters in the Chesapeake Bay and its tidal tributaries that support the survival, growth, and propagation of submerged aquatic vegetation (rooted, underwater bay grasses).

Open Water (OW) Aquatic Life Designated Use

This use exists in waters in the Chesapeake Bay and its tidal tributaries that protect the survival, growth, and propagation of a balanced, indigenous population of aquatic life inhabiting open water habitats.

Deep Water (DW) Aquatic Life Designated Use

This use exists in waters in the Chesapeake Bay and its tidal tributaries that protect the survival and growth of a balanced, indigenous population of aquatic life inhabiting deep water habitats.

Deep Channel (DC) Seasonal Refuge Designated Use

This use exists in waters in the Chesapeake Bay and its tidal tributaries that protect the survival of a balanced, indigenous population of benthic infauna and epifauna inhabiting deep channel habitats.

[13] An anadromous fish, born in fresh water, spends most of its life in the sea and returns to fresh water to spawn. Salmon, smelt, shad, striped bass, and sturgeon are common examples. A catadromous fish does the opposite – lives in fresh water and enters salt water to spawn.

Applicable Criteria

Dissolved oxygen (DO) criteria protecting the described uses are shown in Table 4.6-1. The methodology for assessing monitoring data against these criteria involves spatial interpolation of fixed site monitoring results to create a 3-D picture of DO conditions in thousands of individual grid cells throughout the Bay. Each individual grid cell is then assessed against the criteria. In this way, the volume of water in attainment is calculated for each data collection cruise, allowing for an assessment of criteria on a spatial scale. To account for natural fluctuations over seasons and years, the individual monthly spatial assessments of a three-year period are aggregated, allowing for an estimate of the frequency of violations. (Note that this contrasts with the six-year period used in the assessment of DO for non-Bay waters.) The frequency and spatial extent of violations are combined to create a cumulative frequency diagram (CFD) curve, which is examined against an established reference curve.
The DO assessment is based on stations monitored by DEQ, Old Dominion University, Virginia Institute of Marine Science, municipalities, and citizens groups. Details of the assessment procedure can be found in guidance manuals from EPA and DEQ (*Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity, and Chlorophyll a for the Chesapeake Bay and its Tidal Tributaries (EPA 903-R-03-002, April 2003), the 2004 (EPA 903-R-002, October 2004), 2007 (CBP/TRS 285-07, EPA 903-R-07-003), 2007 (CBP/TRS 288/07, EPA 903-R-005), 2008 (CBP/TRS 290-08, EPA 903-R-08-001), 2010 (CBP/TRS 301-10, EPA 903-R-10-002), 2017 (CBP/TRS 320-17, EPA 903-R-17-002) addenda and the Final 2024 Water Quality Assessment Guidance Manual, November, 2023*).

Table 4.6-1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean ≥ 6 mg/L (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 ≥ 5 mg/L	Survival/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[1]	30-day mean ≥ 5.5 mg/L (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile/adult fish; protective of threatened/endangered species.	Year-round
	30-day mean ≥ 5 mg/L (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile, and adult fish/shellfish; protective of threatened/endangered species.	
	7-day mean ≥ 4 mg/L	Survival of open-water fish larvae.	
	Instantaneous minimum ≥ 3.2 mg/L	Survival of threatened/endangered sturgeon species.[2]	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg/L	Survival/recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean ≥ 2.3 mg/L	Survival of open-water juvenile/adult fish.	
	Instantaneous minimum ≥ 1.7 mg/L	Survival of bay anchovy eggs/larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg/L	Survival of bottom-dwelling worms/clams.	June 1 - September 30
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[1] Special criteria for the Mattaponi and Pamunkey rivers are 30-day mean > 4.0 mg/L; Instantaneous minimum > 3.2 mg/L at temperatures < 29°C; Instantaneous minimum > 4.3 mg/L at temperatures > 29°C.
[2] At temperatures considered stressful to shortnose sturgeon (> 29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg/L will protect survival of this listed sturgeon species.

impairment

designated uses

criteria

attainment

violations

reference curve

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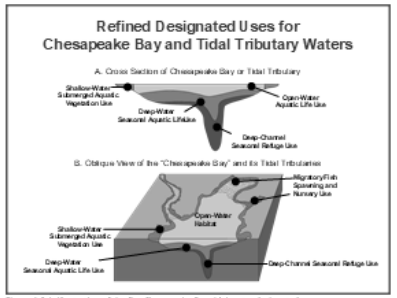

Figure 4.6-1. Illustration of the five Chesapeake Bay tidal water designated use zones.

Final 2024

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Where we can do better with communication

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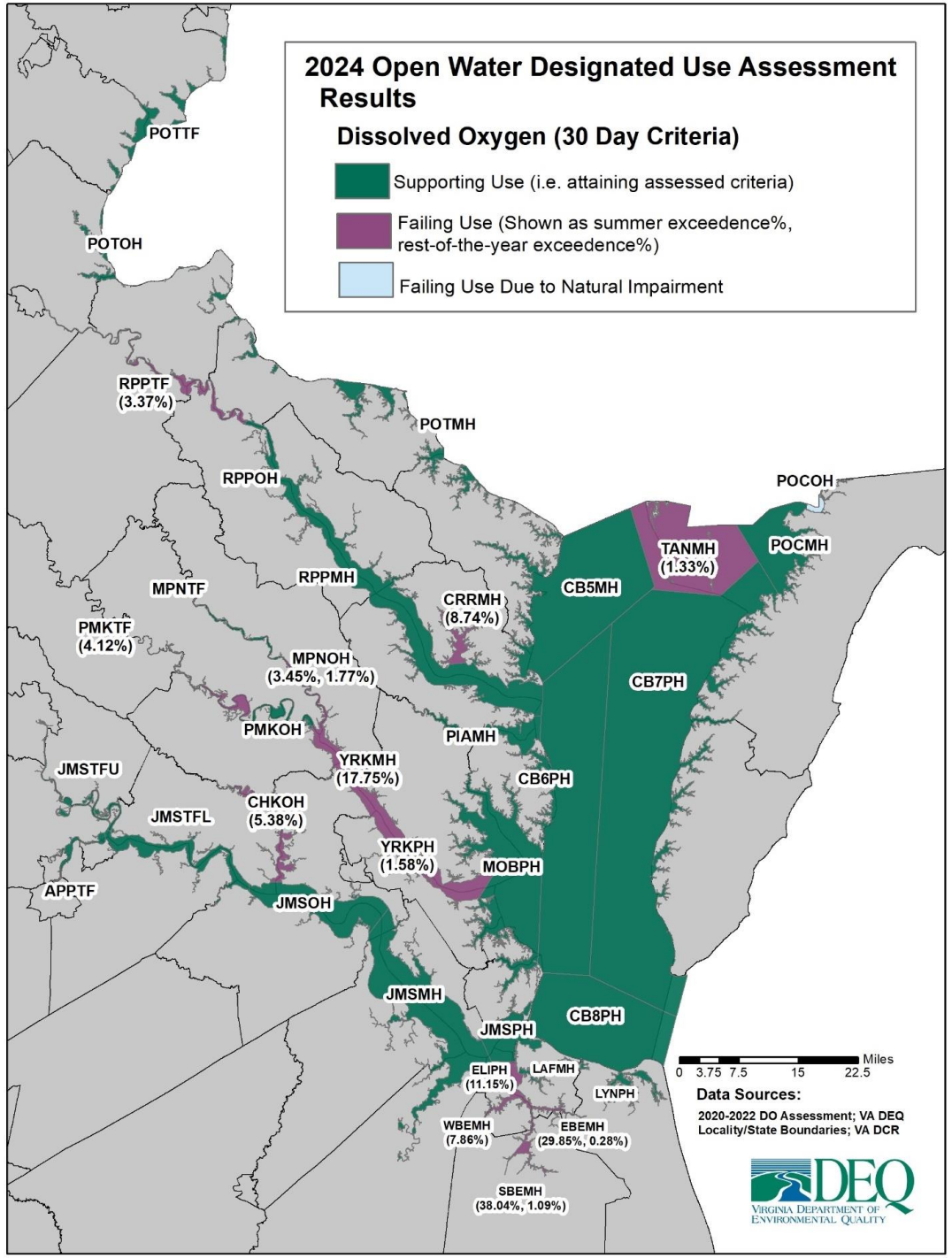
2024 Open Water Designated Use Assessment Results
Dissolved Oxygen (30 Day Criteria)
Supporting Use (i.e. attaining assessed criteria)
Failing Use (Shown as summer exceedence%, rest-of-the-year exceedence%)
Failing Use Due to Natural Impairment
POTTF
POTOH
RPPTF (3.37%)
POTMH
RPPOH
POCOH
TANMH (1.33%)
POCMH
MPNTF
RPPMH
CB5MH
CRRMH (8.74%)
PMKTF (4.12%)
MPNOH (3.45%, 1.77%)
CB7PH
PMKOH
PIAMH
YRKMH (17.75%)
JMSTFU
CB6PH
CHKOH (5.38%)
JMSTFL
YRKPH (1.58%)
MOBPH
APPTF
JMSOH
JMSMH
CB8PH
JMSPH
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LAFMH
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EBEMH (29.85%, 0.28%)
SBEMH (38.04%, 1.09%)
0 3.75 7.5 15 22.5 Miles
Data Sources:
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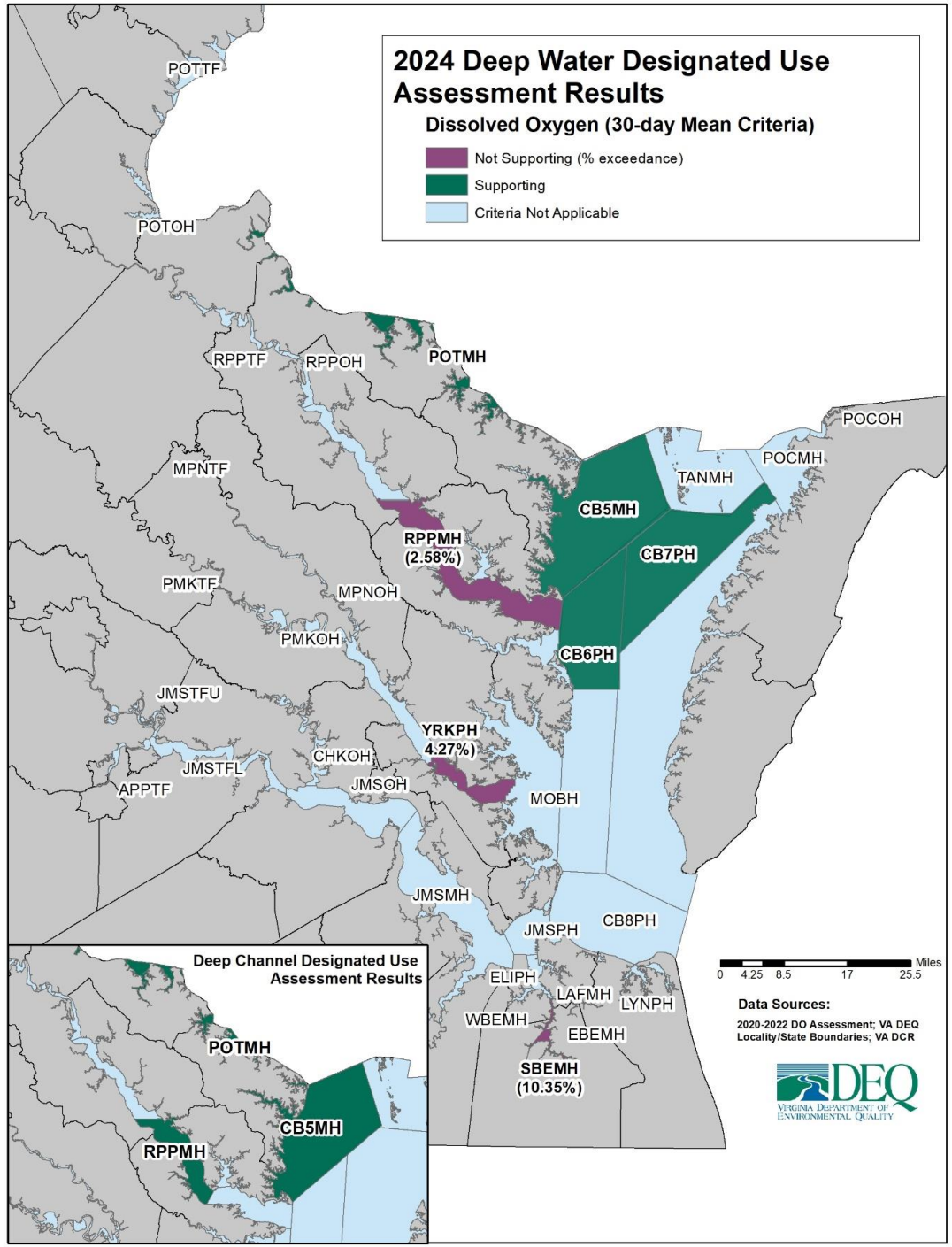
2024 Deep Water Designated Use Assessment Results
Dissolved Oxygen (30-day Mean Criteria)
Not Supporting (% exceedance)
Supporting
Criteria Not Applicable
POTTF
POTOH
RPPTF
RPPOH
POTMH
POCOH
MPNTF
TANMH
POCMH
CB5MH
RPPMH (2.58%)
CB7PH
PMKTF
MPNOH
PMKOH
CB6PH
JMSTFU
YRKPH (4.27%)
CHKOH
JMSTFL
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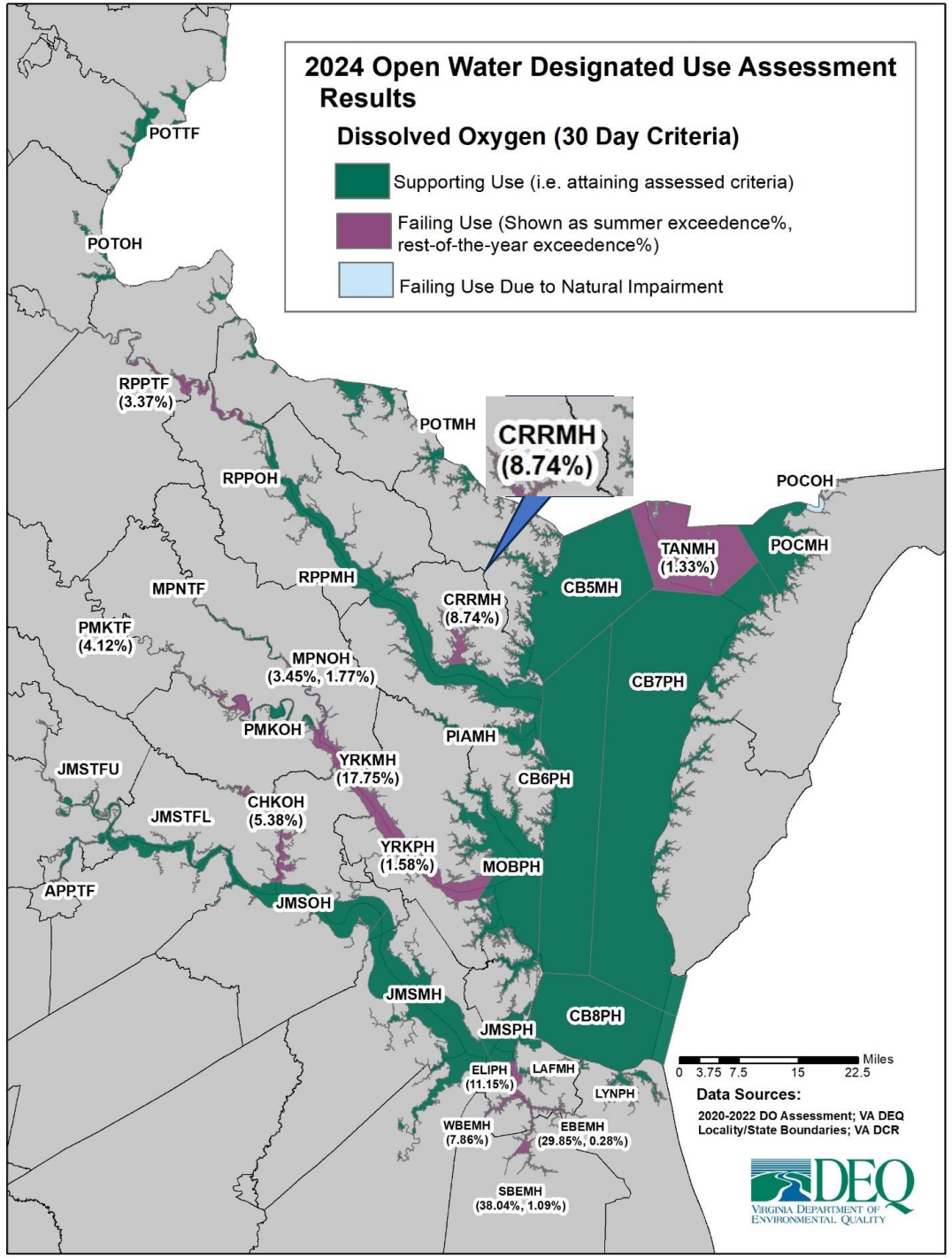
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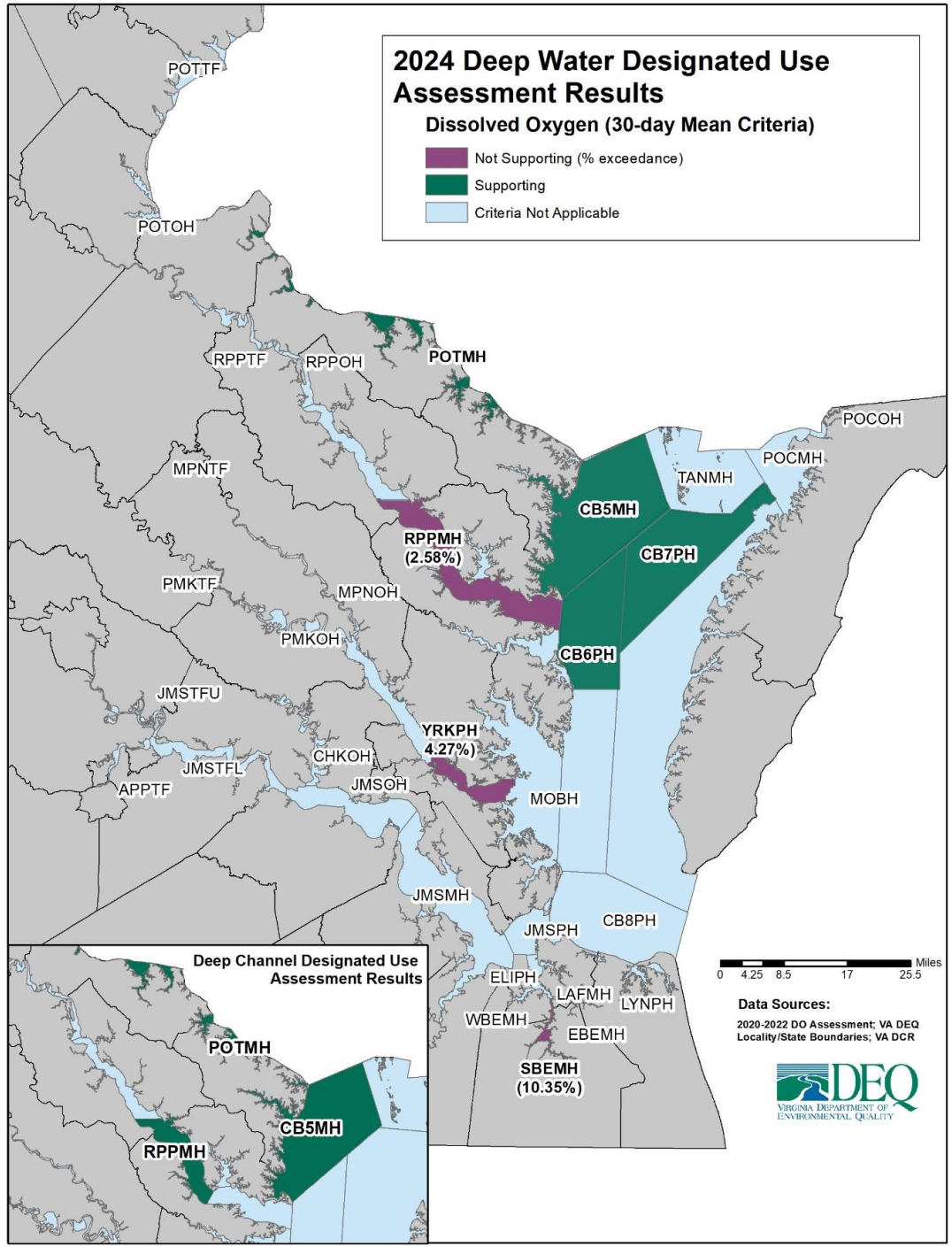
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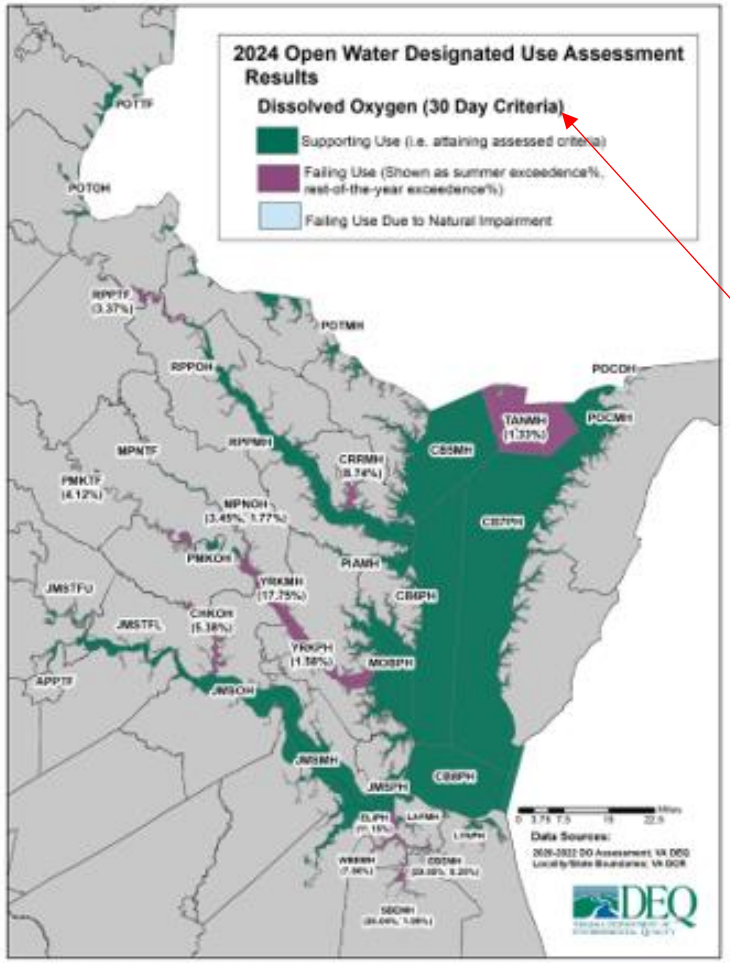

Figure 4.6-4. Attainment of the Open-Water designated use (dissolved oxygen criteria).

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
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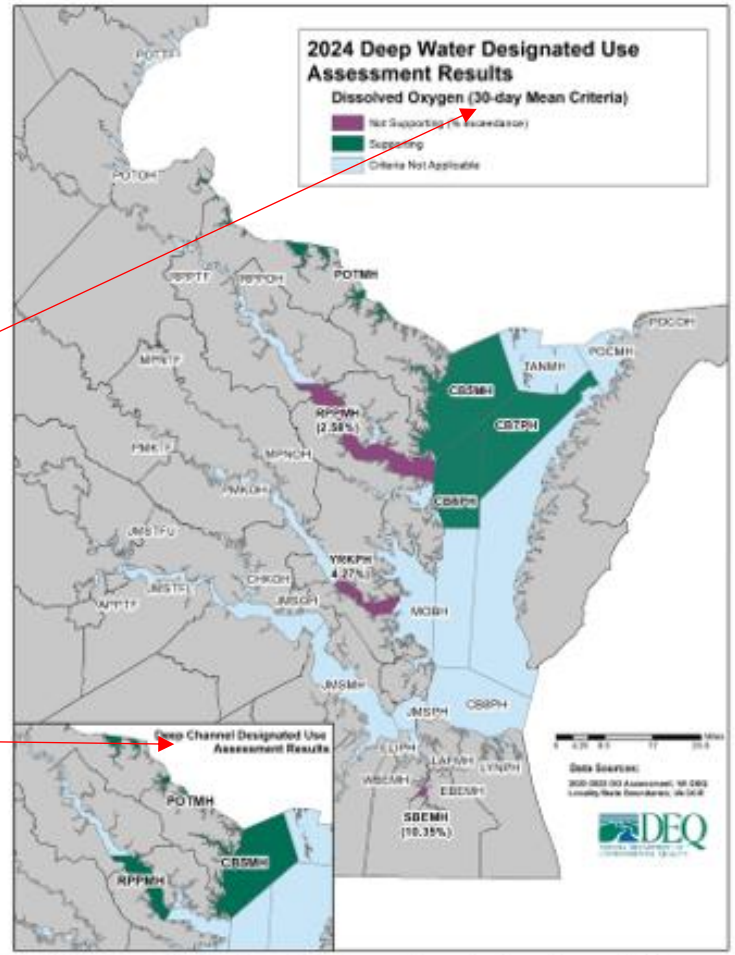

Figure 4.6-6. Attainment of the Deep-Water and Deep-Channel designated use (dissolved oxygen criteria).

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4. The current reporting is limited to only a few of the dissolved oxygen habitat goals (i.e., water quality criteria).

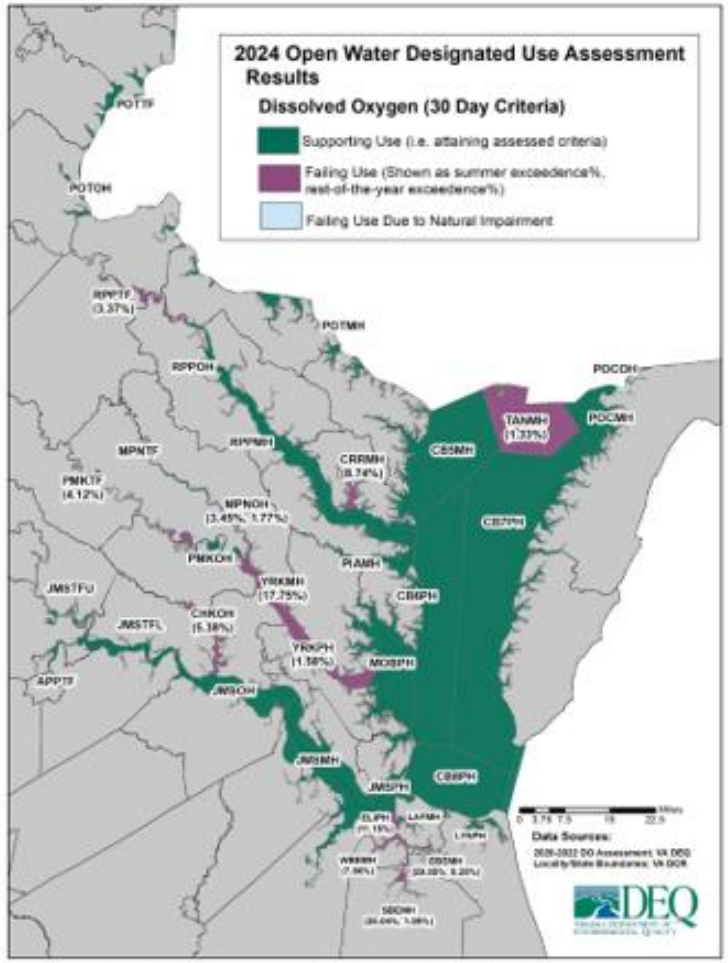
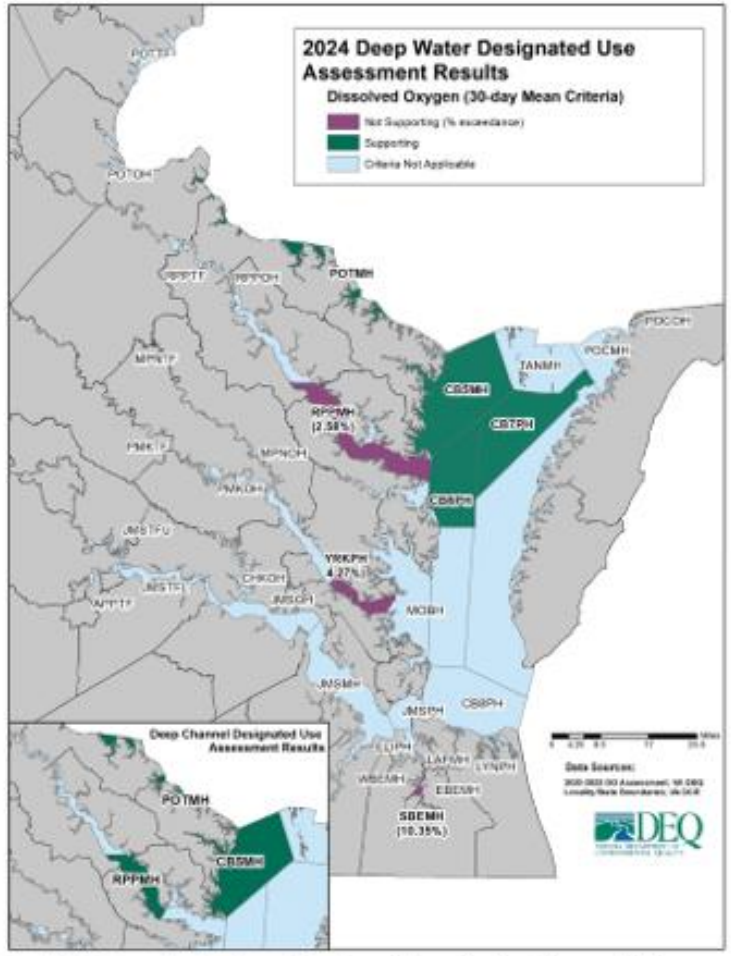


Figure 4.6-4. Attainment of the Open-Water designated use (dissolved oxygen criteria).

The results shown in these maps are based on a considerable amount of monitoring data, but this is not being communicated.



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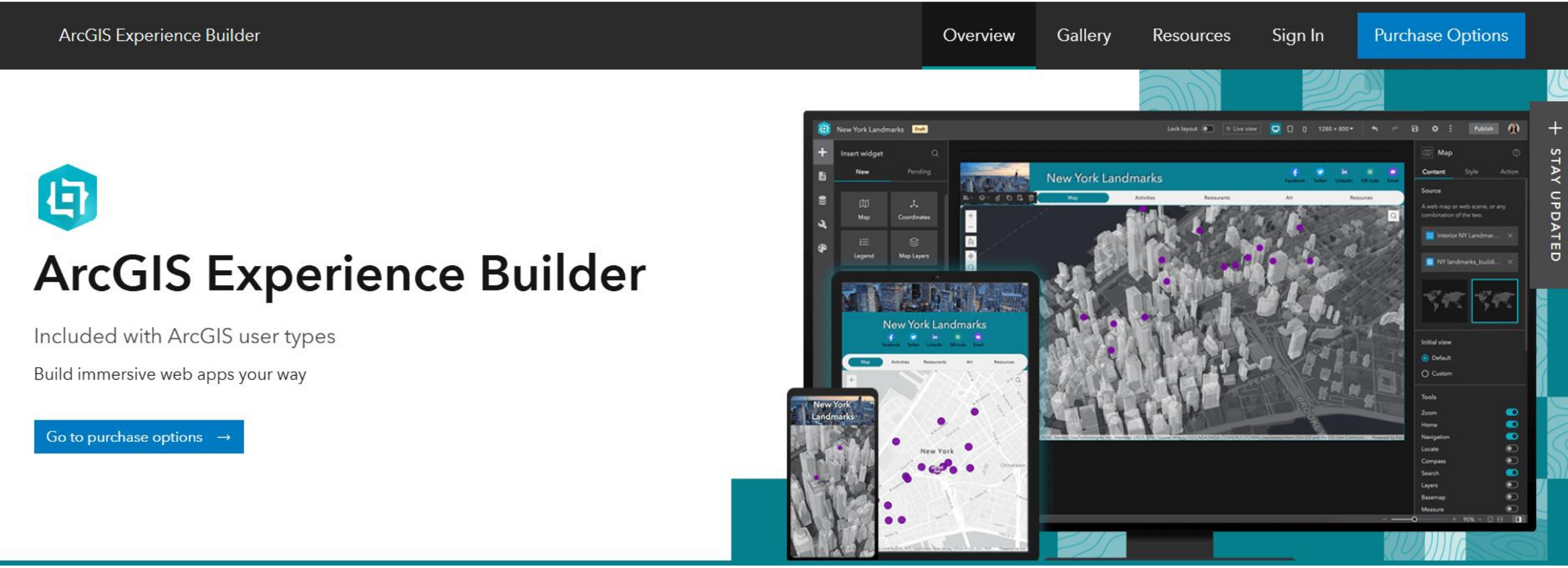
5. We should highlight the data being collected. Everyone—not just nerds—loves data.

DEQ's New Communication Tool



Virginia's Chesapeake Bay Dissolved Oxygen Explorer

DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

This is an interactive exploratory tool that is intended to help the public, stakeholders, researchers, resource managers, and decision-makers understand the problem of low dissolved oxygen in the Chesapeake Bay and the work being done to remedy it. Click on any of the links below to get started on this exploration.

- Learn About Chesapeake Bay Dissolved Oxygen
- Dissolved Oxygen Monitoring in Virginia's Chesapeake Bay
- Where's the Low Dissolved Oxygen in Virginia's Chesapeake Bay?
- Our Approach to Interpreting the Data
- Resources

Dissolved Oxygen and the Chesapeake Bay

Dissolved oxygen (DO) is the substance of life for the Chesapeake Bay. It is critical for the survival and growth of the smallest baby oyster to the most impressive Atlantic sturgeon. Unfortunately, DO concentrations have been depressed in the Chesapeake Bay for the past several decades due to nutrient pollution. Excessive nitrogen and phosphorus levels promote the excessive growth of algae, or algae blooms. Algal blooms can lead to decreased DO levels as they die off and are consumed by microorganisms. Nutrients can come from agricultural and garden fertilizers that are washed into streams and rivers by stormwater. Human and animal wastes that are not properly disposed of can also be a significant source of nutrient pollution. Many of the restoration activities taking place in the Chesapeake Bay watershed are focused on the control of nutrient pollution, with the ultimate goal of restoring Bay DO to the levels needed to support healthy aquatic life.

An algal bloom like this is not only unpleasant to the senses, but it can also result in low dissolved oxygen concentrations.

DO is most vital in four habitats in the Chesapeake Bay. These habitats have their own unique set of critters, all which have have their own specific tolerance levels to low DO.

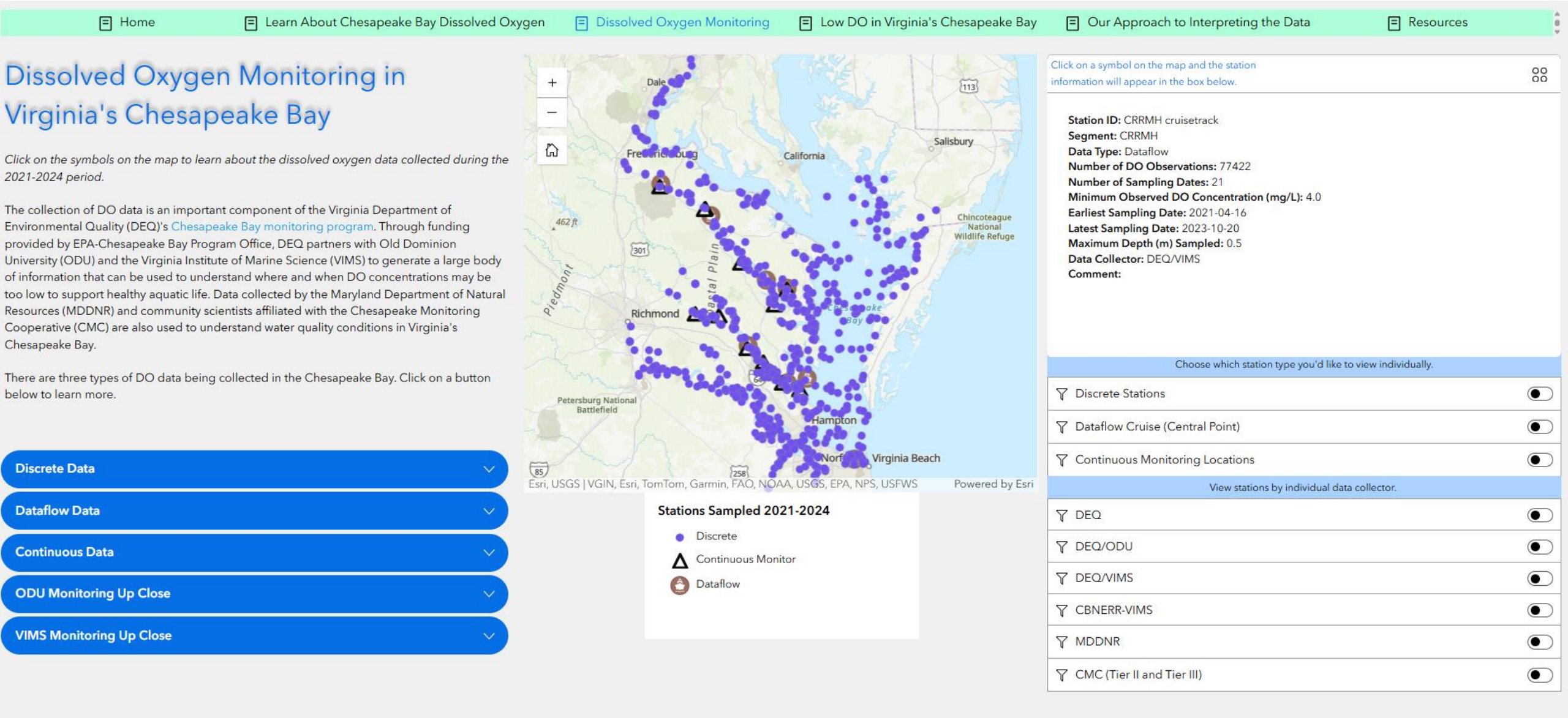
The Migratory Fish Spawning and Nursery habitat is where you can find critters that are the most sensitive to low DO. During the spring, anadromous species, which spend most of their lifespan in the ocean, return to the fresh and brackish waters of the Bay watershed to mate and lay eggs. DO levels greater than equal to 6.0 mg/L are critical for both adults and offspring during this period.

Check out the EPA-Chesapeake Bay Program's photographic field guide of migratory fish.

The Open Water habitat is where you can find the critters that are the most charismatic representatives of the Chesapeake Bay. Atlantic menhaden, the Virginia oyster, the loggerhead sea turtle, the cownose ray, and the Atlantic sturgeon dwell in this habitat year-round. The survival of these critters is reduced when DO levels are frequently below 4.0 mg/L. Their growth may be reduced when DO levels are frequently less than 5.0 mg/L. While they are not as sensitive to low DO as the critters in the Migratory Fish Spawning and Nursery habitat, they are more sensitive than the critters that hang out in deeper waters.

Check out the EPA-Chesapeake Bay Program's photographic field guide of aquatic life inhabiting the open and shallow waters.

Goal of this page: Educate the general public about Bay DO in a concise, friendly way.



Goals of this page: 1) Highlight DEQ's Chesapeake Bay monitoring program and partners
2) Educate the public about DO monitoring
3) Engage the data nerds!

Home | Learn About Chesapeake Bay Dissolved Oxygen | Dissolved Oxygen Monitoring | Low DO in Virginia's Chesapeake Bay | Our Approach to Interpreting the Data | Resources

Dissolved Oxygen Monitoring in Virginia's Chesapeake Bay

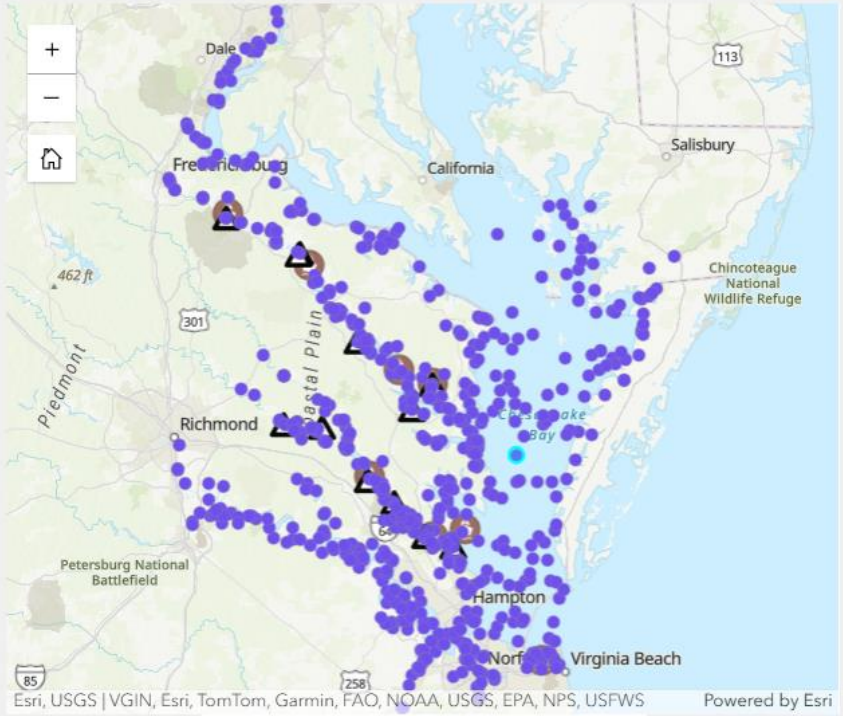
Click on the symbols on the map to learn about the dissolved oxygen data collected during the 2021-2024 period.

The collection of DO data is an important component of the Virginia Department of Environmental Quality (DEQ)'s Chesapeake Bay monitoring program. Through funding provided by EPA-Chesapeake Bay Program Office, DEQ partners with Old Dominion University (ODU) and the Virginia Institute of Marine Science (VIMS) to generate a large body of information that can be used to understand where and when DO concentrations may be too low to support healthy aquatic life. Data collected by the Maryland Department of Natural Resources (MDDNR) and community scientists affiliated with the Chesapeake Monitoring Cooperative (CMC) are also used to understand water quality conditions in Virginia's Chesapeake Bay.

There are three types of DO data being collected in the Chesapeake Bay. Click on a button below to learn more.

Discrete Data

Discrete data, also known as "grab samples". Discrete data are the most common type of water quality data. They are manually collected at a specific point in time at a specific location using an electronic device called a water quality sonde. At many of the discrete stations in the Bay, dissolved oxygen measurements are collected as a vertical profile--where measurements are taken at 1-meter increments from the surface to the bottom. This allows for a complete evaluation of habitat water quality. However, some discrete stations are only sampled at the surface, particularly in shallow waters.



Stations Sampled 2021-2024

- Discrete
- Continuous Monitor
- Dataflow

Click on a symbol on the map and the station information will appear in the box below.

Station ID: CB6.2
Segment: CB6PH
Data Type: Discrete
Number of DO Observations: 515
Number of Sampling Dates: 55
Minimum Observed DO Concentration (mg/L): 1.2
Earliest Sampling Date: 2021-01-25
Latest Sampling Date: 2024-11-11
Maximum Depth (m) Sampled: 10
Data Collector: DEQ/ODU
Comment:

Choose which station type you'd like to view individually.

- Discrete Stations
- Dataflow Cruise (Central Point)
- Continuous Monitoring Locations

View stations by individual data collector.

- DEQ
- DEQ/ODU
- DEQ/VIMS
- CBNERR-VIMS
- MDDNR
- CMC (Tier II and Tier III)

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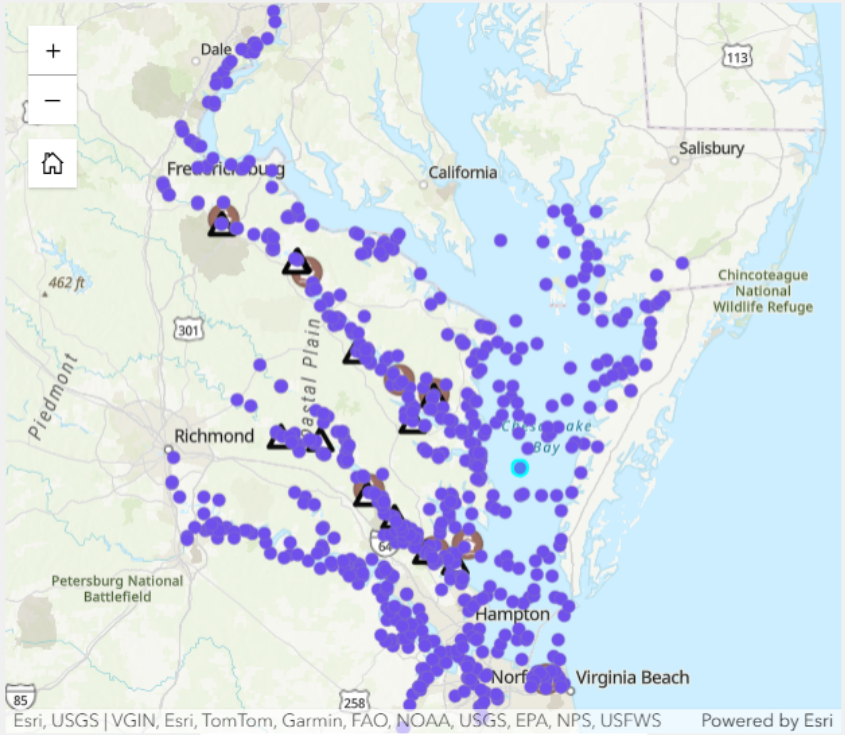
- Dataflow Data
- Continuous Data
- ODU Monitoring Up Close
- VIMS Monitoring Up Close



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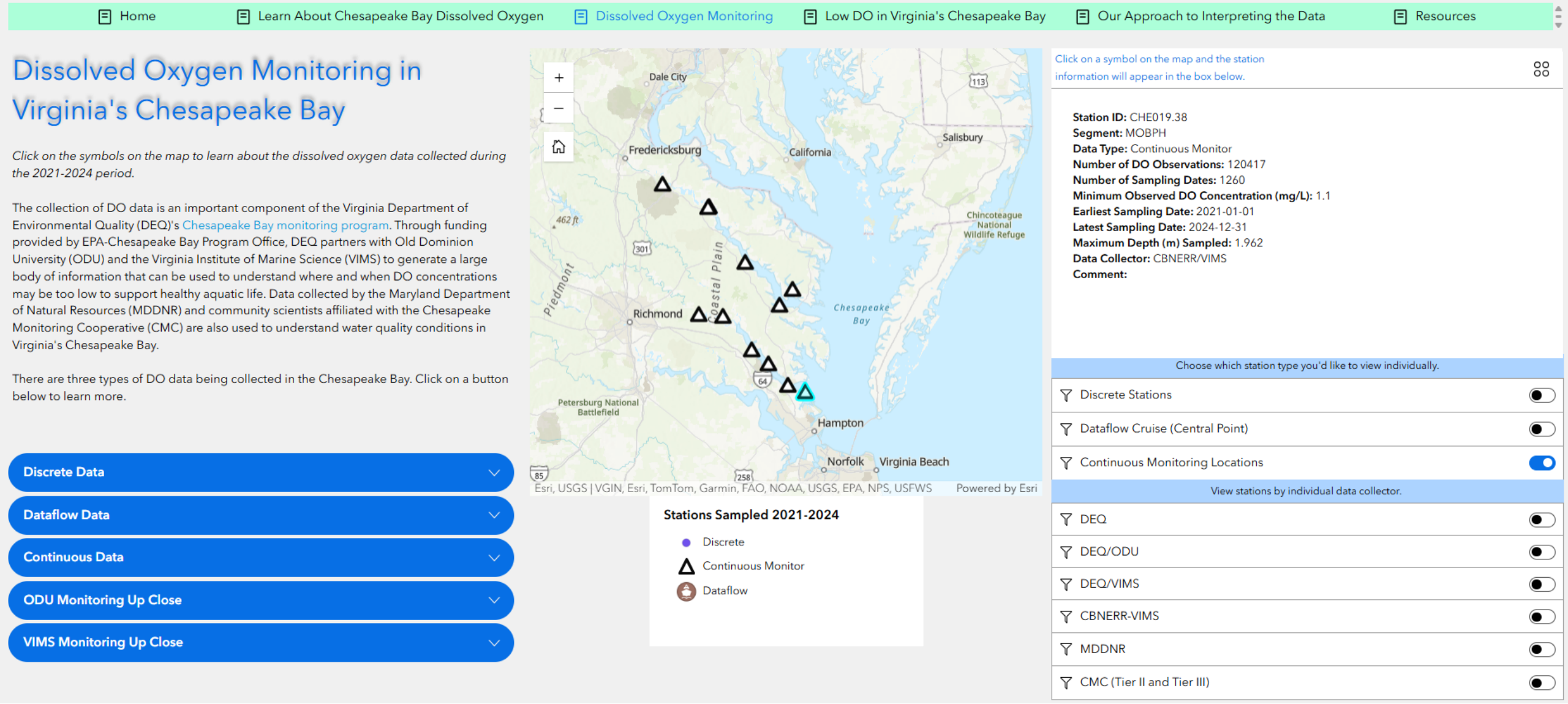

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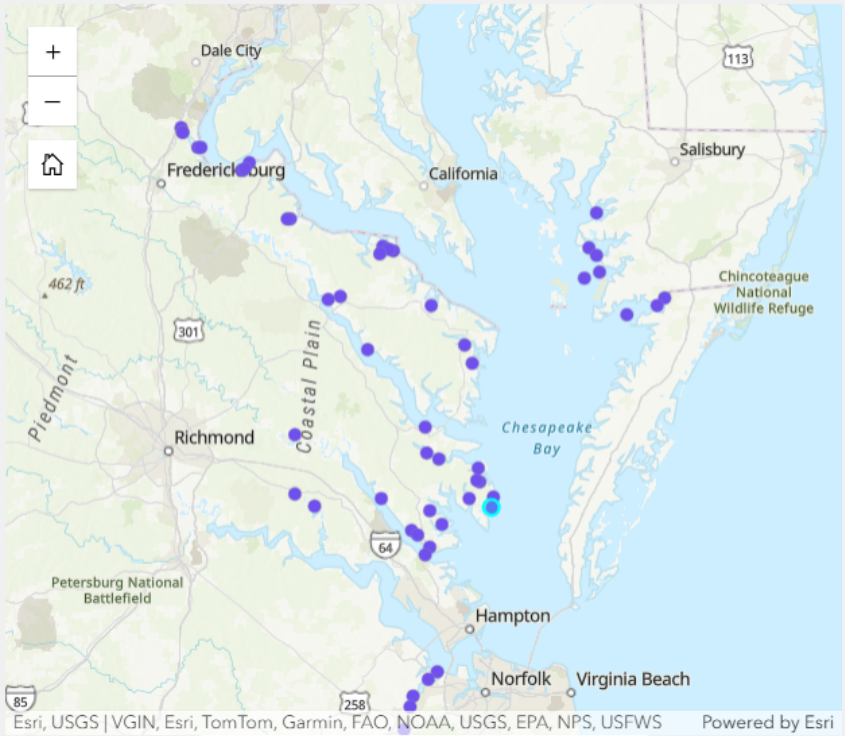

Stations Sampled 2021-2024

- Discrete
- Continuous Monitor
- Dataflow

Click on a symbol on the map and the station information will appear in the box below.

Station ID: ACB.WINHAR0.8
Segment: CB6PH
Data Type: Discrete
Number of DO Observations: 23
Number of Sampling Dates: 23
Minimum Observed DO Concentration (mg/L): 5.0
Earliest Sampling Date: 2021-01-19
Latest Sampling Date: 2022-12-29
Maximum Depth (m) Sampled: 0.3
Data Collector: Chesapeake Monitoring Cooperative
Comment:

Choose which station type you'd like to view individually.

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- Dataflow Cruise (Central Point)
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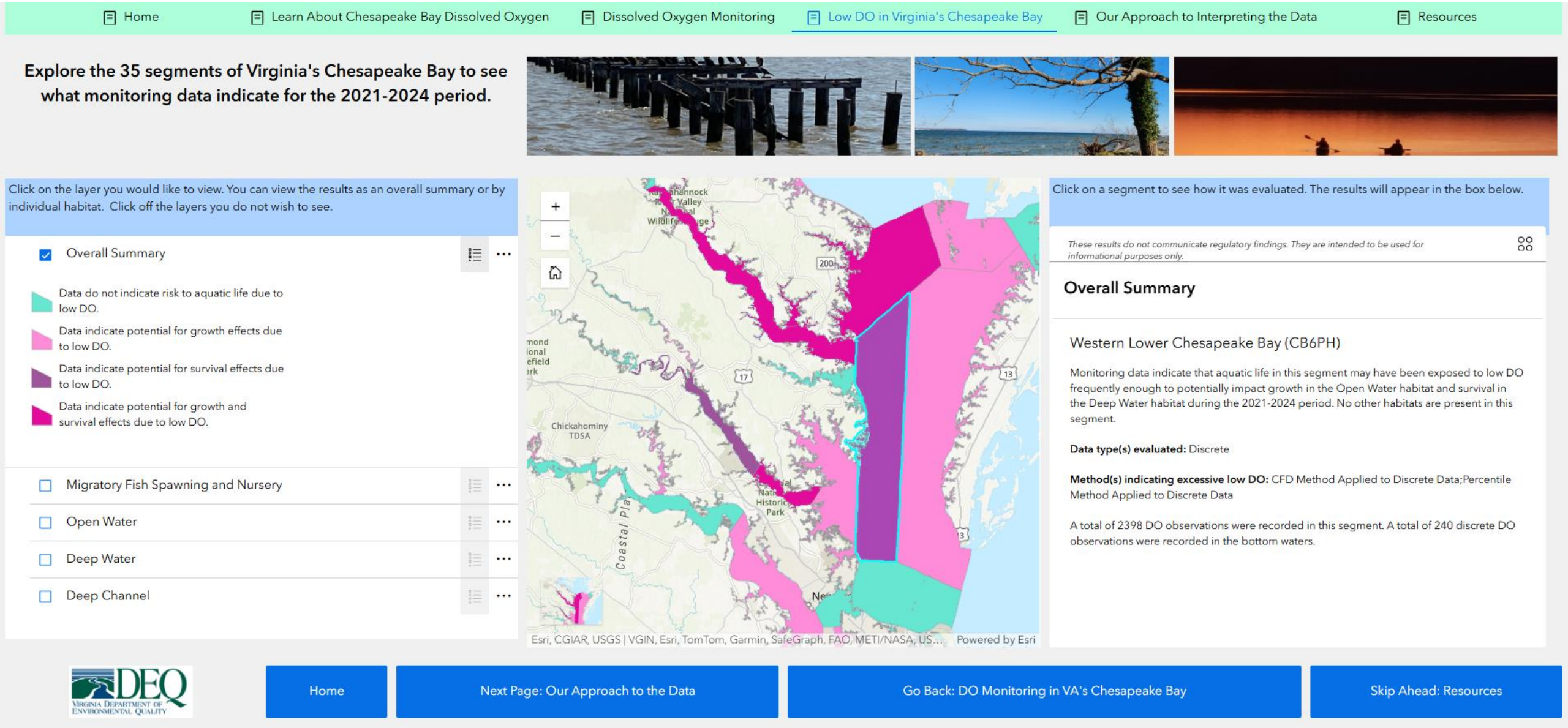

Goal of this page: Inform the public about what the data indicate in an easy-to-digest way

Our Approach to Interpreting the Data

For over 40 years, DEQ and its partners have collected a considerable amount of DO data in Virginia's Chesapeake Bay and its tidal tributaries. These data are diverse, representing different scales in time and space. For instance, while discrete sampling is conducted monthly at many stations, some may be sampled less frequently or only once. This is in contrast to the continuous monitors, which take water quality measurements every 15 minutes. However, collectively the discrete samples create a snapshot of water quality conditions for the whole Bay, while continuous monitors can only paint a picture for a single site. The diversity of the DO datasets necessitates a tailored approach that considers the strengths and weaknesses of each data type. Collectively, these different datasets can tell us whether the target DO concentrations in the table to the right are being met in the four Chesapeake Bay habitats where DO is most vital.

The approach we used to produce the results shown here is described below. It is our goal to continue refining this approach in collaboration with the federal-interstate Chesapeake Bay Partnership, with the ultimate goal of communicating the story of DO in a clear, consistent way across the entire Chesapeake Bay.

Habitat	Dissolved Oxygen Threshold and Duration	Protection Provided	Period When Habitat is Used
Migratory Fish Spawning and Nursery	7-day mean > 6.0 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 > 5.0 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
Open Water	30-day mean > 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 > 5.0 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 > 4.0 mg liter^{-1}	Survival of open-water fish larvae.	
	Instantaneous minimum > 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.	
Deep Water	30-day mean > 3.0 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean > 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum > 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
Deep Channel	Instantaneous minimum > 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30

Adapted from USEPA (2003)

Our approach combines two methods that are recommended by the United States Environmental Protection Agency for evaluating DO datasets.

The **cumulative frequency distribution method** has been used by the Chesapeake Bay Program Office since the early 2000. The method relies on a model that generates thousands of DO estimates from a much smaller discrete DO dataset. The model results allow low DO to be quantified in both space and time. If low DO occurs in a large area within a segment more than once or occurs in a small space many times during an evaluation period, then the segment is determined to have excessive low DO. The method is described in USEPA (2003).

The **percentile method** is used by DEQ and many other state regulatory agencies to determine when low DO in a waterbody is excessive. When more than 10% of a dataset's observations are less than a DO concentration deemed necessary for aquatic life, a conclusion is made that the aquatic life in that waterbody are at-risk. The percentile method is used by DEQ to identify impaired streams, rivers, lakes/reservoirs, and tidal waters that are not in the Chesapeake Bay. This method is described in USEPA (2002).

We combined the results of the CFD method applied to discrete data with the results of the percentile method applied to discrete, Dataflow, and continuous data to evaluate the risk of low DO in each of the 35 segments in Virginia's Chesapeake Bay.

For the CFD method, the thresholds shown in blue in the table above were used for evaluating the Open Water, Deep Water, and Deep Channel habitats. All the values in the table were compared to the data using the percentile method. This method was applied individually to the three data types. However, for the discrete and Dataflow data, the averages (for instance, the 30-day mean) were not calculated because these data types are collected at intervals that are not ideal for calculating averages.

Goal of this page: Provide a high-level description of DEQ's approach for interpreting the DO data presented in this exploratory tool.

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Resources

Learn About DEQ's Chesapeake Bay Monitoring

- DEQ's Chesapeake Bay Monitoring Program Webpage
- DEQ's Chesapeake Bay Monitoring Program on YouTube

Explore Monitoring Data

- The discrete datasets funded by the EPA-Chesapeake Bay Program, including data collected by members of the Chesapeake Monitoring Cooperative
- Discrete datasets generated by DEQ (use Organization ID "21VASWB")
- Dataflow and continuous monitoring datasets collected by VIMS

Become a Data Collector

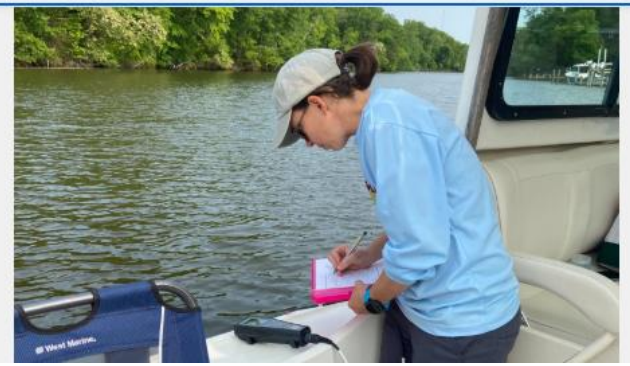
- Learn about DEQ's Volunteer Monitoring Program.

Learn About the Efforts to Restore the Chesapeake Bay

- Chesapeake Bay Program Partnership

Explore Other Chesapeake Bay Data Explorers

- Virginia Estuarine and Coastal Observatory System
- Maryland's Eyes on the Bay
- Chesapeake Monitoring Cooperative Data Explorer



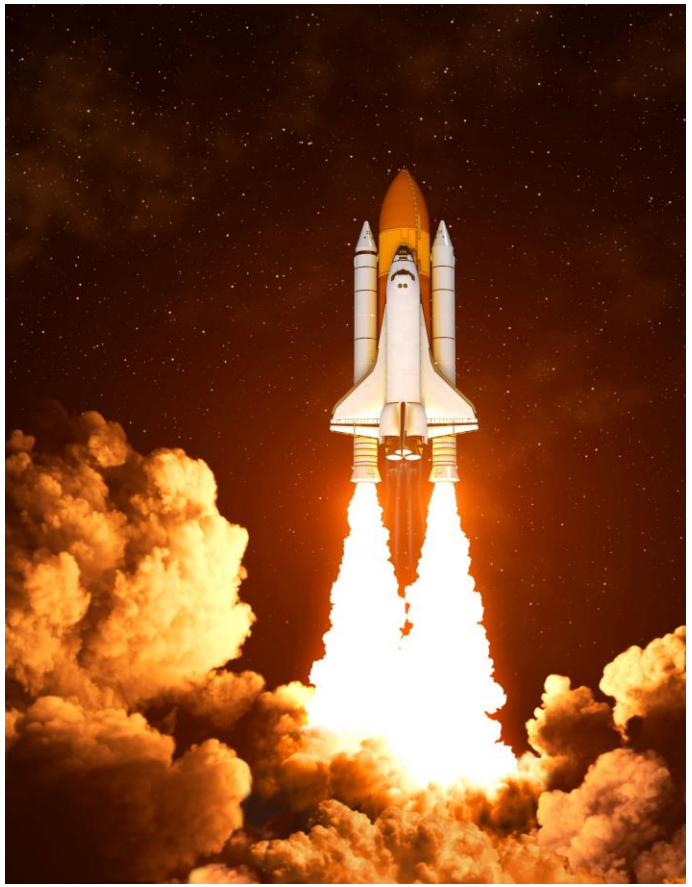
This beautiful landscape feature is designed to capture stormwater. Stormwater can carry nutrients into nearby streams and rivers that flow into the Chesapeake Bay. A garden like this one acts like a filter by absorbing stormwater and the pollutants in it. The stormwater that flows out will be cleaner than it would be if the garden was not present. Best management practices like this one are being constructed all over the Bay watershed.

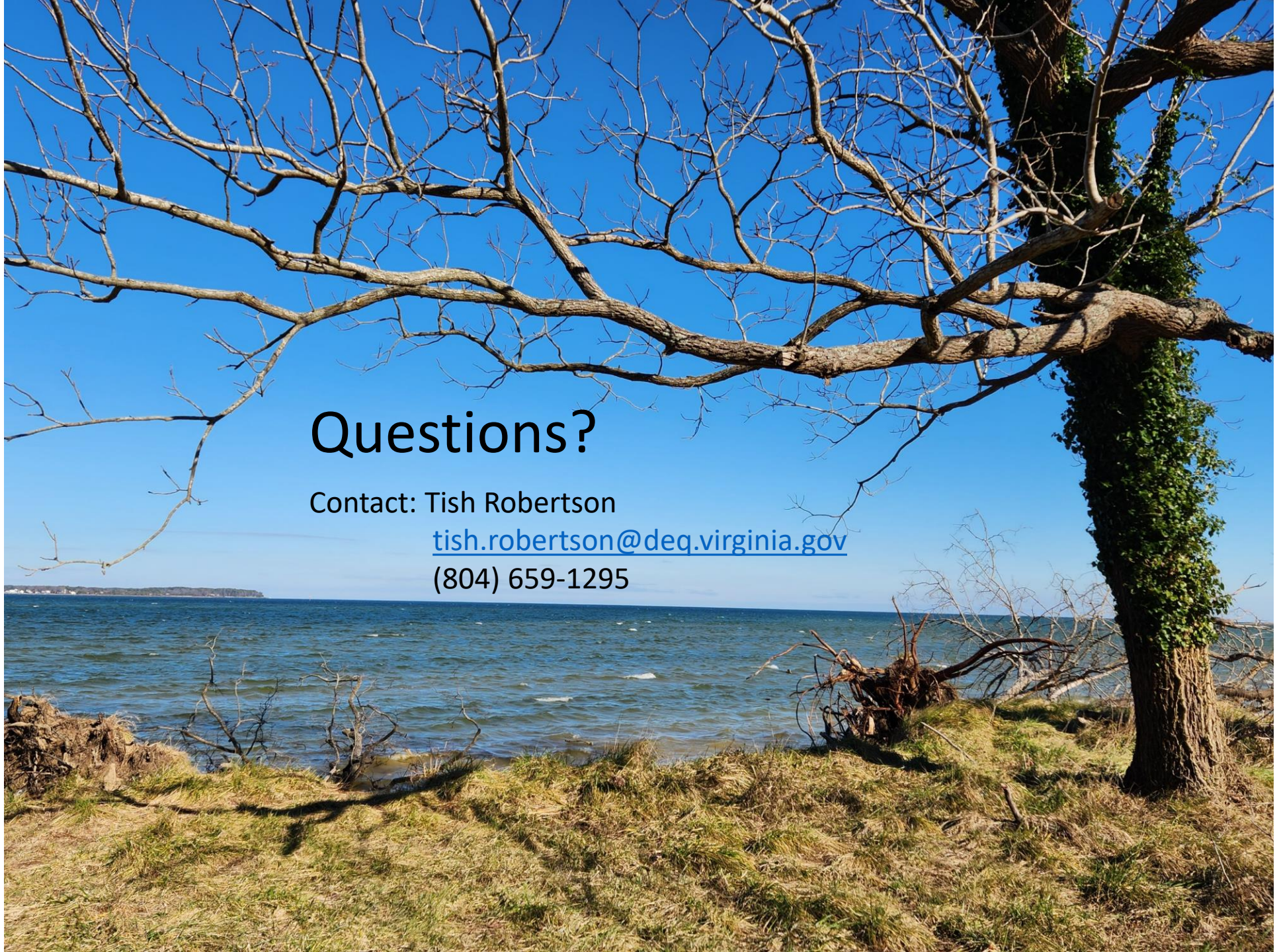
Help Virginia's Chesapeake Bay Water Quality

- Guide to Rain Gardens - Virginia Department of Forestry
- Adopt-a-Storm-Drain Program - Interstate Commission on the Potomac River Basin
- Financial assistance for the installation of urban best management practices - Virginia

Goal of this page: Empower the public to get involved

Stay tuned for the Explorer’s launch date!




Questions?
Contact: Tish Robertson
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(804) 659-1295