State of the Elizabeth River

Scorecard 2014

November 17, 2014

Scientific data compiled & analyzed by:
Elizabeth River State of the River Steering Committee 2014,
Convened by Virginia Department of Environmental Quality and The Elizabeth River Project

DEQ
Virginia Department of Environmental Quality

Summarized and interpreted for the public by:

Elizabeth River Project
Making restoration a reality

Summary:

From Almost Dead to an Average Score of C

And Most Notorious Branch is Now the Most Improved

Parents might not think a C is too hot, if your kid brings it home from school. But when one of the three most toxic rivers on the Chesapeake Bay brings home a C, that's reason to celebrate. The Elizabeth River was commonly presumed dead when The Elizabeth River Project entered the picture in 1993. Fast forward to 2014. Area scientists have scored each of the branches of the Elizabeth for an average overall health of C for this urban river. Better news yet: **The notoriously polluted Southern Branch of the Elizabeth River shows the most improving trends**. This is the long stretch of the river that has been industrialized since before the Revolution; the branch too often in the past was described as devoid of life. For this report, area scientists found improving trends for bacteria, nitrogen, bottom health, and contaminants on the bottom of the Southern Branch.

Before cleanup, scientists found only 4 species of fish at Money Point on the Southern Branch. This speckled trout is one of 26 species now found in this improving branch.

A committee of local, state and regional scientists prepared this State of the River report for The Elizabeth River Project and VA Department of Environmental Quality to determine changes since the last comprehensive scorecard for the Elizabeth River, issued by the same partners in 2008, and to identify trends over the last 10 years.

Also heartening are improving trends for nitrogen through much of the Elizabeth River. Excess nitrogen is one of the top causes of dead zones throughout the Chesapeake Bay. Although the Elizabeth traditionally has been one of the bay's most degraded tributaries, nitrogen levels are dropping steadily not only in the Elizabeth's Southern Branch, but also its Western Branch, Eastern Branch and Main Stem. Not a freshwater river but an estuary of the bay, the Elizabeth spreads into five fingers, or branches. For this report, each branch was analyzed separately to help guide restoration planning, including an anticipated 2015 update of a watershed action plan for the Elizabeth River.

Of concern, however, are poor scores reflecting high levels of PCBs (polychlorinated biphenyl) contamination in fish and crabs in much of the river. PCBs were used in electrical equipment and other applications until the compounds were banned in 1979. Although in general, edible fish have lower concentrations of PCBs than non-edible fish, the VA Department of Health has issued fish consumption advisories for the lower James and Elizabeth Rivers based on PCB levels in fish. The Dept. of Health offers a tiered hierarchy of consumption limitations for the Elizabeth River, varying among fish species. PCB contamination is a complicated problem to address, since the compound persists in the environment and moves through the food chain. VA Department of Environmental Quality is working to address PCB contamination in the James and Elizabeth. The Elizabeth River Project is working with Duke University to measure PCB levels in red drum and speckled trout caught by anglers throughout the Elizabeth River.

While scientists have worked with The Elizabeth River Project and the state to prepare State of the River reports periodically since the 1990s, this is the first year that area scientists agreed on letter grades for scoring the Elizabeth River. Averaged across branches, the Elizabeth River earns an **overall grade of C.**

Looking at the river branch by branch:

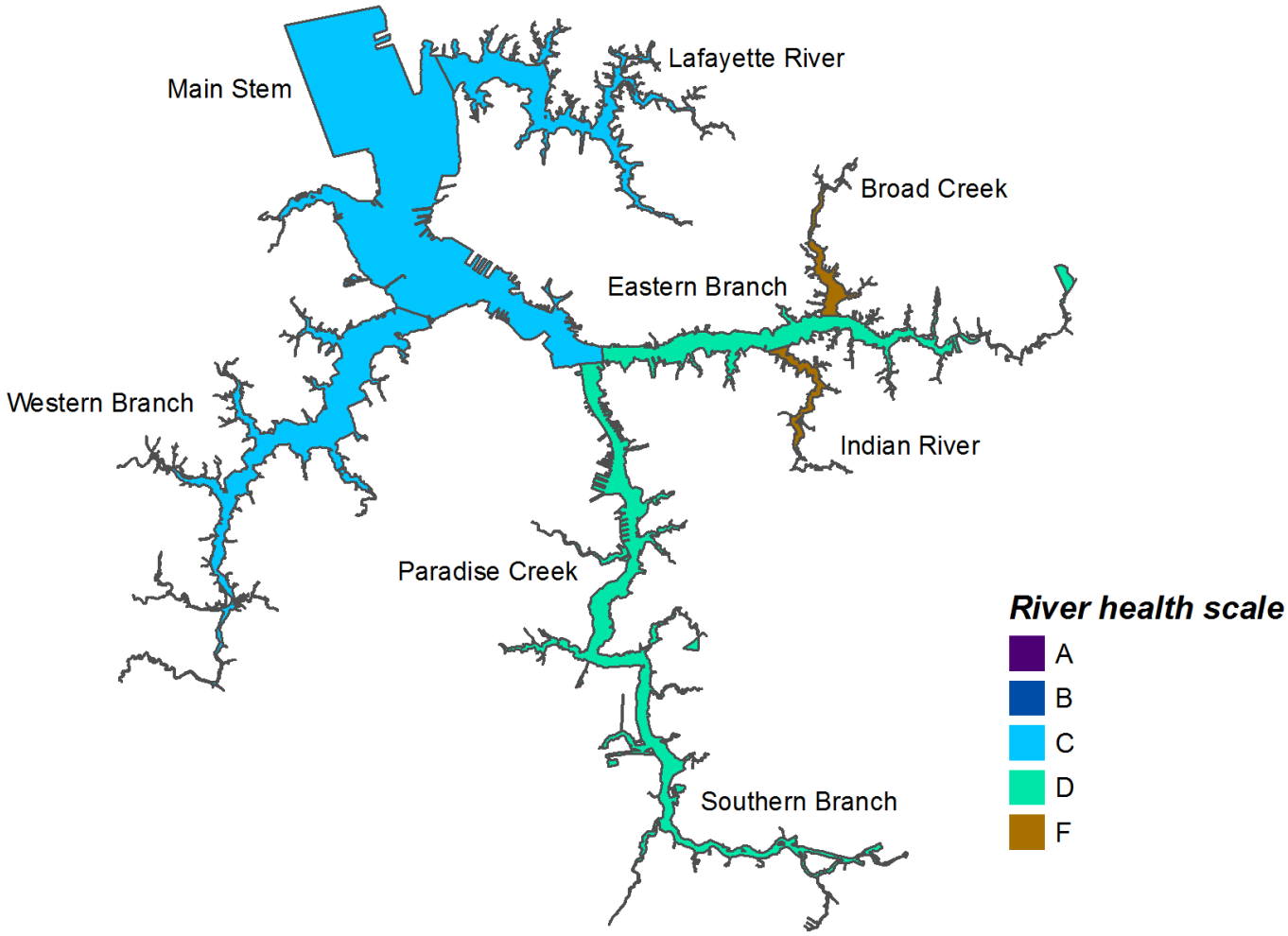
- **The Southern Branch, while improving, still earns only a D**, with much left to do. Contamination on the river bottom has been cleaned up or improvement and efforts are underway at key sites, including Money Point and Atlantic Wood, but more contaminated sites remain. Extra heartening: Paradise Creek, a long-time focus area of The Elizabeth River Project on the Southern Branch, shows improving trends across all areas examined, except for one!
- **The Lafayette River, which forms the Elizabeth's northern branch, lands a C.** This branch is anticipated to be "de-listed" this year by the Virginia Department of Environmental Quality's report of waters impaired for recreational contact due to bacteria (the draft report is still pending, however). The Elizabeth River Project and Chesapeake Bay Foundation in 2011 introduced a community-wide plan to improve the Lafayette, with a key goal to remove the Lafayette from the state's impaired list by 2014. Another goal was to meet Virginia Department of Health – Shellfish Sanitation's bacteria limits for consumption of shellfish. That goal also appears to have been met for more than 50% of the Lafayette, although the state has made no change in its prohibition of shellfish harvesting as they are evaluating other important factors, such are viruses and PCBs.
- **The Eastern Branch earns a D, indicating urgent need behind a new plan for this branch**. Scientists found disturbingly high levels of bacteria in Broad Creek and Indian River tributaries and extremely low dissolved oxygen in Broad Creek. The Elizabeth River Project has just completed a draft comprehensive strategy for community-wide efforts to improve the Eastern Branch, with a priority focus on Broad Creek and Indian River.
- **The Western Branch receives a C.** This residential portion of the river for a long time has been relatively healthy and thus has received limited restoration focus. New data, however, shows reason for attention, with declining trends in bottom health and increasing levels of phosphorous.
- **The Main Stem scores a C.** This is the wide reach at the river mouth, where strong mixing with the lower Chesapeake Bay typically provides healthier conditions than in much of the river. The Main Stem, in fact, earns an A for low levels of bacteria. Contamination in the river bottom was recently reduced when Columbia Gas (NiSource) completed a clean up project at Swimming Point in Portsmouth.

Special thanks to Roger Everton of the Virginia Department of Environmental Quality for coordinating the State of the River 2014 researchers.

Special thanks to these partners for invaluable data and analysis: VA Department of Environmental Quality, VA Department of Health – Shellfish Sanitation, Old Dominion University, the Chesapeake Bay Program, HRSD, VA Institute of Marine Science.

Special thanks to members of The Elizabeth River Project's Mummichog and River Otter donor societies and all donors to the cleanup of the Elizabeth River for progress reflected in this report.

Elizabeth River - Report Card 2014



What the Scorecard Measures

Trends were determined by statistical analysis of at least 10 years of data. Grades were determined in most cases by reviewing five years of data. The overall grade reflects averaging of the grades of the individual branches.

Bacteria (human contact criteria):
Enterococcus bacteria levels in river water, associated with animal and human waste, compared to state criteria for recreational human contact.

Dissolved Oxygen:
Amount of oxygen dissolved in the water compared to state criteria. Dissolved oxygen is an important factor for healthy marine life.

Bottom Health:
Measures the abundance and diversity of life on the river bottom (worms, clams etc) – indicates food availability for many fish. Results are based on Chesapeake Bay Program's Benthic Index of Biotic Integrity.

Contaminants on River Bottom:
Levels of polycyclic aromatic hydrocarbons (PAH) in the river sediments compared to levels having negative impacts on river life. In the Elizabeth River, PAHs are correlated with cancer in fish and are often a legacy of former wood treatment facilities.

Nutrients - Nitrogen:
Amount of nitrogen compared to the University of Maryland's EcoCheck. Excess nitrogen can lead to algal blooms and fish kills; over-fertilizing is one cause.

Nutrients - Phosphorus:
Amount of phosphorus compared to EcoCheck thresholds. Excess Phosphorus can lead to algal blooms and fish kills; over-fertilizing is one cause.

Phytoplankton/Chlorophyll:
Algae, known as phytoplankton, are vital for a productive river. But some types of algae are harmful and in excess can lead to poor water quality with impacts on fish and shellfish. Chlorophyll was compared to EcoCheck 2011 thresholds.

Contaminants in Fish:
Presence of polychlorinated biphenyls (PCBs) in fish, compared to EPA criteria from National Coastal Condition Report IV. PCBs are shown to cause human cancer above certain levels and were used in electrical & other applications until banned, 1979.

Bacteria (shellfish criteria):
Fecal coliform bacteria levels, associated with animal and human waste, compared to state criteria for shellfish harvest.

Also see Technical Appendix for how scores and trends were determined

Southern Branch: Most Improving Trends for Most Polluted Stretch of River

The Elizabeth River Project begins clean up of contamination in 2011 in the Southern Branch at Money Point (L). After 36 million lbs. of PAH contaminated sediments were removed and a new marsh created, scientists including Rebecca Walawender from Old Dominion University (R) helped to test mummichogs, an indicator fish, and found cancer had dropped from above 40% to background levels.

The heavily industrialized Southern Branch of the Elizabeth River, also known as the "cradle of maritime history," is the most notoriously polluted section of the river. The Southern Branch is also where The Elizabeth River Project has organized its largest cleanup efforts, with multiple partners. The Southern Branch is showing improving trends for bacteria; bottom health, including contamination; and nitrogen, according to scientists preparing this report.

At Money Point, a Chesapeake peninsula on the Southern Branch, The Elizabeth River Project between 2009 and 2013 removed more than 36 million pounds of sediment contaminated with polycyclic aromatic hydrocarbons (PAH) from the river bottom and restored seven acres of wetlands and oysters. Species of fish observed there have multiplied from four to 26 and the rate of cancer and pre-cancer lesions in the indicator fish, the mummichog, at Money Point has dropped from above 40 % to almost background levels. A final phase of this cleanup is now under design. Meanwhile, the US Environmental Protection Agency in 2011 began a massive, on-going cleanup of another area of contaminated river bottom on the Southern Branch, Atlantic Wood. Several other toxic hotspots still need to be addressed.

As with several other branches, PCB contamination in fish has become a concern (see summary).

Southern Branch

Bacteria (human contact criteria):	C (Improving Trend)
Enterococcus bacteria levels compared to state criteria for recreational human contact	
Dissolved Oxygen:	C (No Trend)
Amount of oxygen dissolved in the water	
Bottom Health:	D (Improving Trend)
Abundance and diversity of life on the river bottom	
Contaminants on River Bottom:	F (Improving Trend)
Levels of polycyclic aromatic hydrocarbons (PAH)	

Nutrients - Nitrogen: C (Improving Trend)
In excess can lead to algal blooms and fish kills
Nutrients - Phosphorus: C (Declining Trend)
In excess can lead to algal blooms and fish kills
Phytoplankton/Chlorophyll: B (No Trend)
Algae, known as phytoplankton is vital for a productive river.
Contaminants in Fish: F (No Trend)
Presence of ppolychlorinated biphenyls (PCBs)
Bacteria (shellfish criteria): No Data
Fecal coliform bacteria levels compared to state criteria for shellfish harvest.

Southern Branch Overall **D**
See Technical Appendix for how scores were determined

Paradise Creek, a Tributary of the Southern Branch

Memphis Peevy of Portsmouth listens to a croaker during a "bioblitz" on June 28, 2014 at Paradise Creek Nature Park. Scientists found 201 species of wildlife at the new park, celebrating revival of a creek once lined (near but not in the park) with Superfund level contamination.

Paradise Creek is also a long-running focus area of The Elizabeth River Project with broad partner involvement since 2002, and a new 40-acre park, Paradise Creek Nature Park, added by The Elizabeth River Project and City of Portsmouth in 2012. Not long ago the location of a series of "Superfund" or worst-of-the-worst contaminated sites near the park, Paradise Creek now shows improving trends in all but one area examined.

Paradise Creek

Bacteria (human contact criteria): B (Improving Trend)
Enterococcus bacteria levels compared to state criteria for recreational human contact
Amount of oxygen dissolved in the water C (No Trend)
Nutrients - Nitrogen: D (Improving Trend)
In excess can lead to algal blooms and fish kills
Nutrients - Phosphorus: F (Improving Trend)
In excess can lead to algal blooms and fish kills
Phytoplankton/Chlorophyll: B (Improving Trend)
Algae, known as phytoplankton is vital for a productive river.

Paradise Creek Overall **D**
See Technical Appendix for how scores were determined

Lafayette Branch:
Community Focus Achieves Water Quality Goal

The Lafayette forms the northernmost branch of the Elizabeth River, a residential stretch located entirely in Norfolk. The Elizabeth River Project in 2009 began organizing community-wide efforts to improve the Lafayette, introducing an action plan with community partners in 2011 with a prominent goal to "de-list" this tributary from Virginia's bi-annual report of waters impaired because of bacteria. The Elizabeth River Project's analysis of state monitoring indicates that the Lafayette now meets this goal for the first time in recent history, although state release of the report has been delayed for unrelated reasons.

Three lined seahorses found in the Lafayette have come to symbolize returning life in this branch of the Elizabeth.

Another goal in *The Plan for Restoring the Lafayette River, Strategies for Community Wide Action* (April 27, 2011, The Elizabeth River Project & Chesapeake Bay Foundation), was for a portion of the Lafayette to achieve state bacteria levels for shellfish consumption, while recognizing that urban conditions were likely to dictate that oysters still would need to be "relayed" to other waters for a short period before eating them. The VA Division of Shellfish Sanitation, participating on the scientific team for this report, indicates that more than 50% of the Lafayette may now meet state bacteria levels for shellfish consumption. However, the state cautions that it has not yet made any determination to change the current prohibition on oyster harvesting in the Lafayette and continues to analyze additional important factors.

The Lafayette, encouragingly, in this State of the River report also scores the best of any branch on the Elizabeth River for dissolved oxygen, a leading indicator for healthy conditions for fish. Scientists, in fact, gave the Lafayette an A for dissolved oxygen. Only 1 % of the time did this branch fall below the standard for healthy conditions during the five years analyzed by state scientists for this report (2009 to 2013).

While scientists did not report improving tends in the Lafayette, they looked for trends occurring over a 10-year period. The Lafayette plan, however, was introduced only four years ago, in 2011. To determine whether the plan has led to long-term trends, we will need to evaluate data in 2022.

Lafayette Branch

Bacteria (human contact criteria):	B (No Trend)**
Enterococcus bacteria levels compared to state criteria for recreational human contact	
Dissolved Oxygen:	A (Best results on river)
Amount of oxygen dissolved in the water	
Bottom Health:	C (No Trend)
Abundance and diversity of life on the river bottom	
Contaminants on River Bottom:	B (No Trend)
Levels of polycyclic aromatic hydrocarbons (PAH)	
Nutrients - Nitrogen:	B (No Trend)
In excess can lead to algal blooms and fish kills	
Nutrients - Phosphorus:	D (Declining Trend)
In excess can lead to algal blooms and fish kills	

Phytoplankton/Chlorophyll: C (No Trend)

Algae, known as phytoplankton is vital for a productive river.

Contaminants in Fish: F (No Trend)

Presence of polychlorinated biphenyls (PCBs)

Bacteria (shellfish criteria),

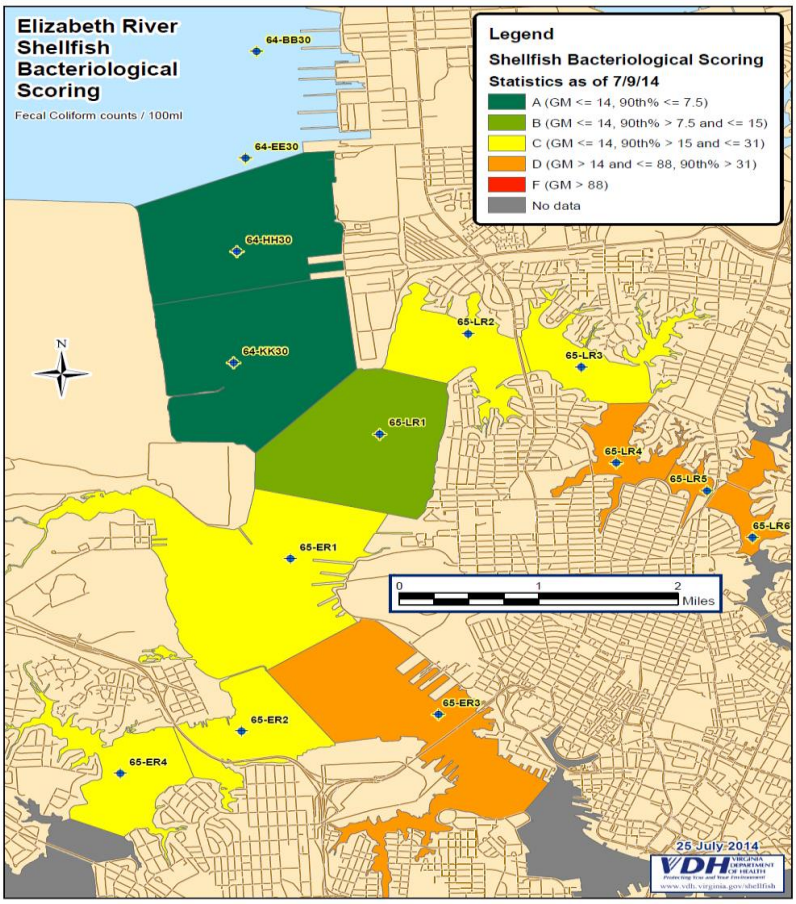
Fecal coliform bacteria levels compared to state criteria for shellfish harvest.

Area 1: Toward mouth (see map below)	B
Area 2: Middle reach (see map below)	C
Area 3: Eastern reach (see map below)	D

Lafayette Branch Overall **C**

See Technical Appendix for how scores were determined

** Removal from impaired waters list anticipated 2014. Draft report anticipated, VA Dept. of Environmental Quality



The VA Division of Shellfish Sanitation, participating on the scientific team for this report, indicates that more than 50% of the Lafayette may now meet state bacteria levels for shellfish consumption (areas graded A, B or C).

Caution: The state has not made any determination to change the current condemnation on oyster harvesting in the Lafayette and continues to analyze additional important factors affecting shellfish safety in an urban river. The Mainstem, a well-flushed area, scored even better (dark green area - see page 13), and restricted harvest with "relay" to a cleaner area before consumption is allowed from this area.

Eastern Branch:
The "Lost" Branch Needs Much Restoration

The Elizabeth River Project in 2014 engaged diverse stakeholders to complete a comprehensive action plan, *Eastern Branch Environmental Restoration Strategy*, currently in final draft form. Though this branch traverses three cities (Norfolk, Chesapeake and Virginia Beach), it has the lowest public profile and also some of the lowest scores for environmental health of any of the Elizabeth's five branches, especially with regard to troubling scores in Broad Creek and Indian River tributaries to the Eastern Branch.

Indian River and Broad Creek are typical of small, inland-reaching tributaries around the Chesapeake Bay in retaining higher levels of pollution than wide-open areas of the bay. In addition, Broad Creek's challenges include hundreds of acres of parking for older shopping centers, such as Military Circle, built before stormwater features were required to absorb runoff pollution. The new Eastern Branch strategy calls for giving highest priority attention to improving Broad Creek and Indian River.

The main channel of this branch, toward its mouth in downtown Norfolk, is the healthiest in terms of water quality. Nonetheless, partners are focusing on an area of bottom contamination there at the former location of a wood treatment facility.

Sandra Johnson of Chesterfield Heights helps restore the Eastern Branch by improving the health of her lawn as a River Star Home with The Elizabeth River Project, which also has recently developed a comprehensive new strategy for the Eastern Branch.

Special thanks to the Cities of Chesapeake and Virginia Beach for beginning to develop an implementation plan to reduce bacteria levels in the Eastern Branch, as partners to The Elizabeth River Project's new community-wide plan.

Eastern Branch (Main Channel)

Bacteria (human contact criteria):	B (No Trend)
Enterococcus bacteria levels compared to state criteria for recreational human contact	
Dissolved Oxygen:	B (No Trend)
Amount of oxygen dissolved in the water	
Bottom Health:	D (No Trend)
Abundance and diversity of life on the river bottom	
Contaminants on River Bottom:	D (No Trend)
Levels of polycyclic aromatic hydrocarbons (PAH)	
Nutrients - Nitrogen:	B (Improving Trend)
In excess can lead to algal blooms and fish kills	

Nutrients - Phosphorus: In excess can lead to algal blooms and fish kills	D (Declining Trend)
Phytoplankton/Chlorophyll: Algae, known as phytoplankton is vital for a productive river.	C (No Trend)
Contaminants in Fish: Presence of polychlorinated biphenyls (PCBs)	D (No Trend)
Bacteria (shellfish criteria): *Fecal coliform* bacteria levels compared to state criteria for shellfish harvest.	No Data

OVERALL **D**

See Technical Appendix for how scores were determined

Broad Creek, a Tributary to the Eastern Branch (Water Quality Only)

Bacteria (human contact criteria): *Enterococcus* bacteria levels compared to state criteria for recreational human contact	F (No Trend)
Dissolved Oxygen: Amount of oxygen dissolved in the water	F (Declining Trend)
Nutrients - Nitrogen: In excess can lead to algal blooms and fish kills	D (No Trend)
Nutrients - Phosphorus: In excess can lead to algal blooms and fish kills	D (No Trend)
Phytoplankton/Chlorophyll: Algae, known as phytoplankton is vital for a productive river.	D (No Trend)

OVERALL **F**

Indian River, a Tributary of the Eastern Branch (Water Quality Only)

Bacteria (human contact criteria): *Enterococcus* bacteria levels compared to state criteria for recreational human contact	F (No Trend)
Dissolved Oxygen: Amount of oxygen dissolved in the water	B (No Trend)
Nutrients - Nitrogen: In excess can lead to algal blooms and fish kills	F (No Trend)
Nutrients - Phosphorus: In excess can lead to algal blooms and fish kills	F (No Trend)
Phytoplankton/Chlorophyll: Algae, known as phytoplankton is vital for a productive river.	D (No Trend)

OVERALL **F**

See Technical Appendix for how scores were determined

Western Branch:
Relatively Healthy but Warning Signs

The Western Branch is mostly residential, extending into both Portsmouth and Chesapeake. Environmental scores have been relatively stable for some time, resulting in limited restoration efforts. Dissolved oxygen levels remain especially healthy. However, scientists report declining trends for health along the river bottom as well as some excess nutrients (phosphorous), despite improving trends for nitrogen. More effort is warranted in this branch.

Western Branch

Bacteria (human contact criteria):	B (No Trend)
Enterococcus bacteria levels compared to state criteria for recreational human contact	
Dissolved Oxygen:	A (No Trend)
Amount of oxygen dissolved in the water	
Bottom Health:	C (Declining Trend)
Abundance and diversity of life on the river bottom	
Contaminants on River Bottom:	C (No Trend)
Levels of polycyclic aromatic hydrocarbons (PAH)	
Nutrients - Nitrogen:	B (Improving Trend)
In excess can lead to algal blooms and fish kills	
Nutrients - Phosphorus:	D (Declining Trend)
In excess can lead to algal blooms and fish kills	
Phytoplankton/Chlorophyll:	C (No Trend)
Algae, known as phytoplankton is vital for a productive river.	
Contaminants in Fish:	B (No Trend)
Presence of polychlorinated biphenyls (PCBs)	
Bacteria, shellfish criteria (see map, p. 9):	C (No Trend)
Fecal coliform bacteria levels compared to state criteria for shellfish harvest.	

OVERALL **C**

See Technical Appendix for how scores were determined

Main Stem:
River Cleaner In Wide Stretch Mixing with Bay

The wide mouth of the Elizabeth River, or the "Main Stem," is what makes the Elizabeth River the largest ice-free harbor in the world. This broad reach also has the greatest mixing with the larger Chesapeake Bay, and thus has long exhibited some of the best environmental health on the Elizabeth.

Improving trends for contamination of the river bottom reflect efforts of Columbia Gas, completed in 2014, to remove PAH contamination at Swimming Point in Portsmouth. The State Division of Shellfish Sanitation actually considers the Main Stem to be clean enough for a designation of "restricted" for oyster harvesting, meaning watermen with permits may raise oysters in this area if they are then "relayed" to a cleaner area before consumption.

Main Stem

Bacteria (human contact criteria):	A (No Trend)
Enterococcus bacteria levels compared to state criteria for recreational human contact	
Dissolved Oxygen:	B (No Trend)
Amount of oxygen dissolved in the water	
Bottom Health:	C (No Trend)
Abundance and diversity of life on the river bottom	
Contaminants on River Bottom:	D (Improving Trend)
Levels of polycyclic aromatic hydrocarbons (PAH)	
Nutrients - Nitrogen:	B (Improving Trend)
In excess can lead to algal blooms and fish kills	
Nutrients - Phosphorus:	C (Declining Trend)
In excess can lead to algal blooms and fish kills	
Phytoplankton/Chlorophyll:	C (No Trend)
Algae, known as phytoplankton is vital for a productive river.	
Contaminants in Fish:	
Presence of polychlorinated biphenyls (PCBs)	D (No Trend)
Bacteria (shellfish criteria)	
Fecal coliform bacteria levels compared to state criteria for shellfish harvest.	
Area 1: Mouth (see map p. 9)	B
Area 2: Larchmont area (see map p. 9)	C
Area 3: ODU & south (see map p. 9)	D
Area 4: PMT & Scotts Creek (see map p. 9)	D

OVERALL **C**

See Technical Appendix for how scores were determined

Elizabeth River
State of the River Steering Committee 2014

Special thanks to the area scientists and organizations that gave their time, expertise and assistance to generate this report.

Kristie Britt - Virginia Department of Environmental Quality
Danny Barker - Hampton Roads Sanitation District
Daniel Dauer - Old Dominion University
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Katherine Filippino - Old Dominion University
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Donald Smith - Virginia Department of Environmental Quality
Mike Unger - Virginia Institute of Marine Science

Technical Appendix:
How Scores Were Determined

Bacteria (Human contact criteria).

Researcher: Kristie Britt (VA Dept. of Environmental Quality) and Danny Barker (Hampton Roads Sanitation District)

VA Department of Environmental Quality ambient monitoring data was used for the analysis of bacteria in the Elizabeth River. The data were analyzed for the five main segments: Eastern Branch, Western Branch, Southern Branch, Lafayette River, and Main Stem. Separate analyses were done for sub-tributaries which included Broad Creek and Indian Creek for the Eastern Branch and Paradise Creek on the Southern Branch. Sub-tributaries were evaluated separately due to poor flushing and higher land to water ratios. The data window for the status analysis was from 2009 through 2013. Trend analysis was determined on a 2003 through 2013 period. The bacteria data were assessed against the Water Quality Standard of 104 CFU/L for recreation use in estuarine waters. The grading scale uses a violation rate of the Water Quality Standard per year to rank the Elizabeth River segments. Table 1 shows the Bacteria grading scale, Table 2 shows the scores of each of the areas evaluated.

Table 1. Criteria Score Matrix

Score	Criteria
A	<5 % viol of 104 CFU
B	5 to 10 % viol of 104 CFU
C	>10 to 15% viol of 104 CFU
D	>15 to 20% viol of 104 CFU
F	>20 % viol of 104 CFU

This scale was used based on best profession judgment and is comparable to other State of the River reports performed for local waters.

Table 2. Elizabeth River Segment Scores

Entire Elizabeth (Excluding Sub-tributaries)	Lafayette	Southern	Western	Eastern	Mainstem	Broad	SBEMH Indian	Paradise
5% **B**	7% **B**	12% **C**	8% **B**	10% **B**	1% **A**	72% **F**	60% **F**	35% **F**

Trends were calculated from a regression analysis on the *Enterococci* data from 2003 to 2013 using a yearly percent violation rate for each segment and sub-tributary. The trend was determined significant if the p-value was less than 0.05 and not significant if greater than 0.05. Trends were improving if the slope was negative (decline in percent yearly violations) or declining if the slope was positive. Most *Enterococci* data showed no trend with p values greater than 0.05. Improving trends were seen in the Southern Branch and Paradise Creeks. The table below also provides the number of stations used per segment in the trend analyses. In addition to stations, the table gives an approximate number of samples used per year to determine the percent yearly violations. The sample sizes for the sub-tributaries are small and are limiting for the trend analysis. Table 3 shows the results of the regression analyses and Table 4 shows the overall grade and trend for each of the areas evaluated.

Table 3. Regression Analysis Results

	Mainstem	Western	Lafayette	Eastern	Broad	Indian	Southern	Paradise
R^2	0.335646	0.27089	0.010361	0.035464	0.182115	0.031325	0.768806	0.8337
P value	0.061248	0.099418	0.760485	0.576047	0.190546	0.611716	0.000713	0.0000868
Trend status	No trend	No trend	No trend	No trend	No trend	No trend	▲	▲
Slope	-	-	-	-	-	+	-	-
Trendline	y = -0.0087x + 0.0956	y = -0.0157x + 0.2346	y = -0.0017x + 0.0927	y = -0.0068x + 0.1578	y = -0.0201x + 0.9121	y = 0.0123x + 0.5509	y = -0.0147x + 0.2696	y = -0.058x + 0.7694
Stations	4	2	2	2	1	1	3	2
Ave Sample Size	37 per year	15 per year	22 per year	15 per year	5 per year	5 per year	15 per year	20 per year

Table 4. Summary State of the River for Bacteria

CBP Segment	**Enterococci**	
	Grade	**Trend**
EBEMH	**B**	<>
Broad	**F**	<>
Indian	**F**	<>
ELIPH	**A**	<>
LAFMH	**B**	<>
SBEMH	**C**	▲
Paradise	**F**	▲
WBEMH	**B**	<>
Elizabeth (exclude sub-tribs)	**B**	**Not calculated**

▲ Improving trend in Bacteria (decreasing % violations of the Water Quality Standard)
<> No Significant trend (p value > 0.05)

Dissolved Oxygen.

Researchers: Kristie Britt (VA Dept. of Environmental Quality) and Wick Harlan (VA Dept. of Environmental Quality)

VA Department of Environmental Quality ambient monitoring data was used for the analysis of dissolved oxygen in the Elizabeth River. The data was analyzed for the 5 main segments mentioned above. Separate analysis was done for available sub-tributaries which included Broad Creek and Indian Creek for the Eastern Branch and Paradise Creek on the Southern Branch. The sub-tributaries were evaluated separately due to poor flushing and higher land to water ratios. The data window for the status analysis was from 2009 through 2013. Trend analysis was determined on a 2003 through 2013 data window. The DO data were assessed against the Water Quality Standard of 4 mg/L for all depths and months collected. The proposed grading scale uses an annual violation rate of the Water Quality Standard to rank the Elizabeth River segments. Table 1 shows the DO grading scale and Table 2 shows the percent violation and grade for each of the areas of the river evaluated.

Table 1. Criteria Score Matrix

Score	Criteria
A	< 5% of values below 4 mg/L
B	5 to 10 % of values below 4 mg/L
C	>10 to 15 % of values below 4 mg/L
D	>15 to 20 % below 4 mg/L
F	>20 % and greater than below 4 mg/L

This scale was used based on best profession judgment and is comparable to the ranking as set by the Chesapeake Bay Scorecard.

Table 2. Elizabeth River Segment Scores

Entire Elizabeth (Excluding Sub-tributaries)	Lafayette	Southern	Western	Eastern	Mainstem	Broad - surface samples	Indian- surface samples	Paradise
5% **B**	1% **A**	12% **C**	4% **A**	6% **B**	5% **B**	43% **F**	10% **B**	12% **C**

Trends were calculated using regression analysis. The regression analyses were performed on DO from 2003 to 2013 using a yearly percent violation rate for each segment and sub-tributary. The Eastern Branch sub-tributaries had very limited data. Paradise Creek had on average 20 samples per year. The data were determined to have a significant trend if the p value was less than 0.05 and not significant if greater than 0.05 (see Table 3 below of results of analyses). Trends were improving if the slope was negative (decline in percent yearly violations) or declining if slope was positive (increase in percent yearly violations). Almost all DO data showed no trend with p values greater than 0.05. The table below also provides the number of stations used per segment in the trend analyses. In addition to stations, the table gives an approximate number of samples used per year to determine the percent yearly violations. The sample sizes for the sub-tributaries are small and are limiting for the trend analyses. Below is Table 4, which summarizes the grades and trends for dissolved oxygen in the Elizabeth River segments.

Table 3. Regression Analysis Results

	Mainstem	Western	Lafayette	Eastern	Broad	Indian	Southern	Paradise
R^2	0.11457	0.11242	0.0000023	0.04471	0.48446	0.00192	0.03212	0.009779
pvalue	0.31293	0.313457	0.99965	0.5325	0.017362	0.898129	0.820783	0.772372
Trend status	No trend	No trend	No trend	No trend	↓	No trend	No trend	No trend
slope	+	-	+	-	+	-	+	-
Trendline	y = 0.0022x + 0.0291	y = -0.0056x + 0.1003	y = 0.00002x + 0.0283	y = -0.0025x + 0.0997	y = 0.0367x + 0.097	y = -0.0015x + 0.0848	y = 0.0354x + 0.1774	y = -0.003x + 0.0981
Stations	4	2	2	2	1	1	3	2
Ave Sample Size	74 per year	31 per year	50 per year	29 per year	6 per year	5 per year	46 per year (2010-2013)	20 per year

Table 4. Summary State of the River for Dissolved Oxygen

CBP Segment	Dissolved Oxygen	
	Grade	Trend
EBEMH	**B**	<>
Broad	**F**	▼
Indian	**B**	<>
ELIPH	**B**	<>
LAFMH	**A**	<>
SBEMH	**C**	<>
Paradise	**C**	<>
WBEMH	**A**	<>
Elizabeth (exclude sub-tribs)	**B**	**Not calculated**

▼ Declining trend in Bacteria (increasing % violations of the Water Quality Standard)
<> No Significant trend (p value > 0.05)

Bottom Health.

Researcher: Dr. Daniel Dauer (Old Dominion University)

The Benthic Index of Biotic Integrity (BIBI) is a multimetric index that measures metrics such as abundance, biomass, species diversity and composition of pollution sensitive and pollution indicative species. The BIBI is scaled from 1.0 to 5.0. Sampling of the bottom occurs each year during the index period of July 15 through September 30.

Status of benthic communities is classified for the Chesapeake Bay Program as follows: (1) values less than or equal to 2 are classified as Severely Degraded; (2) values greater than 2.0 to 2.6 as Degraded; (3) values greater than 2.6 but less than 3.0 as Marginal; and (4) values of 3.0 or more are classified as Meeting Goals or similar to reference conditions. For this report the proposed grading system using the BIBI score is: A: 4.0 – 5.0, B: 3.0 – 3.9, C: 2.6 – 2.9, D: 2.1 – 2.5, F: ≤ 2.0.

Regular sampling of the benthos of the Elizabeth River is presently limited to two fixed-point stations in the Southern Branch (SBE2 and SB5) that have been sampled since 1989. Since 1996 the benthos of the Chesapeake Bay has been sampled using a stratified random sampling design. The Bay's tidal waters are divided into 10 strata with Virginia's waters containing four strata (James River, York River, Rappahannock River, and the Virginia Mainstem). Each stratum is sampled with 25 randomly allocated locations each index period. As part of the James River stratum, sites within the Elizabeth River will occasionally occur (from 0 to 3 sites per year). Table 1 below summarizes the overall BIBI scores, grades, and trends from each area of the river.

Table 1. Summary of BIBI scores, grades, and trends from the Elizabeth River

	BIBI	Grade	Trend	p	R^2
Elizabeth River	2.5	C	↑	0.058	0.249
Mainstem	2.6	C	ns	0.592	0.025
Lafayette River	2.6	C	ns	0.223	0.144
Western Branch	2.6	C	ns	0.543	0.038
Western Branch	2.6	C	↓	0.078	0.306
Eastern Branch	2.3	D	ns	0.611	0.030
Southern Branch	2.3	D	ns	0.208	0.140
Southern Branch	2.3	D	↑	0.018	0.444

Contaminants on River Bottom.

Researchers: Dr. Michael Unger (Virginia Institute of Marine Science) and Dave Koubsky (The Elizabeth River Project)

Sediment contamination throughout the river was evaluated for polycyclic aromatic hydrocarbons (PAH) because the river is known to have high levels from defunct wood treatment facilities and urban stormwater runoff. Multiple data bases were reviewed and are listed at the end of this section.

Sediment PAH data for the river was evaluated against Sediment Quality Guidelines (SQG) developed by Long et al, 1995 (NOAA EMAP). This SQG is based on toxicity data from numerous field and laboratory studies (Long et al, 1998). The SQG used in the report was the Effects Range Low (ERL) value which was the lowest concentration that produced adverse effects in 10% and the Effects Range Median (ERM) value, a concentration at which 50% of the studies reported harmful effects. The ERL used for total PAHs was 4 parts per million and the ERM value was 45 parts per million (for a total of 19 summed compounds). The grading criteria developed for each branch of the river were:

A- Total PAH < 1ppm
B- Total PAH < 4ppm in all samples
C- Total PAH > 4ppm but all samples < 45ppm
D- Total PAH any site > 45 ppm
F- Total PAH more than one site > 45 ppm

Insufficient monitoring data from fixed sediment sampling stations prevented an analysis of a comprehensive trend to establish long-term changes in sediment contamination levels. However, where direct evidence of clean-up leading to reduction in sediment contamination levels was recorded a positive trend was noted. See Table 1 for a summary of grades and trends.

Table 1. Grade and trend for PAH sediment contamination in the Elizabeth River.

Branch	Letter grade	Trend
Main Stem	D	Upward/Improved
Lafayette River	B	NA
Western Branch	C	NA
Eastern Branch	D	NA
Southern Branch	F	Upward/Improved

Data used for evaluation

NOAA Query Manager (Version 2.96)
–2012 Atlantic Creosote
–1998 AMRL VA DEQ Monitoring
–1999 ARML VADEQ Monitoring
–2000 ARML VADEQ Monitoring
–1990 to1998 VA SWCB (KY,MD,NC,TN,VA,WV)
– 2009 to 2013 DEQ – TRO sampling
– 2011 USACE Evaluation of Dredged Material Southern Branch of the Elizabeth River
– 2012 VIMS NIEHS Study-Grant RO1ESO20949

Nutrients.

Researchers: Will Hunley (HRSD) and Dr. Katherine Filippino (Old Dominion University)

Nutrient grades for Total Nitrogen (TN) and Total Phosphorus (TP) were derived using the methods of EcoCheck (2011). The specific steps involved with determining the grades are described below:

1. Water quality monitoring data from the Elizabeth River system for the past 5 years (2009-2013; April - October) were downloaded and inventoried from the Chesapeake Bay data hub https://www.chesapeakebay.net/data. Additional available data were obtained from HRSD and VADEQ sources. Refer to Figure 1 for a map of station locations used.
2. Data were assigned a salinity regime consistent with their Chesapeake Bay Program (CBP) segmentation.
3. Individual sample results were compared to EcoCheck thresholds for the respective salinity regimes. Based on those comparisons the samples were numerically scored (from 1-5).
4. Average percent numeric scores were calculated on a by station basis (e.g. 3.8/5.0)*100=76%). Surface and bottom results were averaged.
5. The average numeric scores from step #4 above were averaged by CBP segment. Only stations located in the main-stem portions of the CBP segments were used to calculate scores for those segments. Available station data from sub-tributaries were analyzed and reported separately.
6. A letter grade was assigned on the basis of a 20% scale as shown in Table 1.

Trend analysis was conducted by averaging the daily score for TN and TP in each river segment and the sub-tributaries (as described above) each year for 10 years, from 2004 to 2013. A linear regression was fit for each river segment, and the trend was either improving (positive slope), declining (negative slope), or there was no significant trend ($p > 0.1$). See Table 2 for summary.

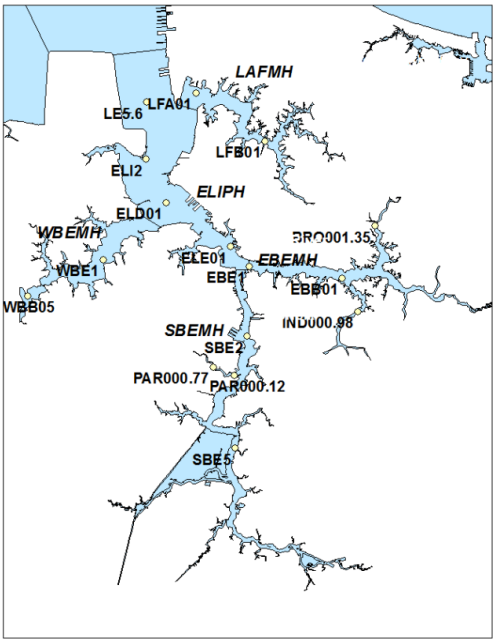

Figure 1. Map of sampling stations and river segments used for scoring (2009 – 2013) and trend analysis (2004 – 2013).

Table 1. Grading scale Source: EcoCheck (2011).

Multiple Thresholds			Grade	% Score
Measured indicator value	5	Pristine condition	A	80–100
	4		B	60–<80
	3		C	40–<60
	2		D	20–<40
	1		F	<20
	0	Impaired condition		

Table 2. Summary of grade and trends

CBP Segment	Total Nitrogen (TN)		Total Phosphorus (TP)	
	Grade	Trend	Grade	Trend
EBEMH (main-stem only)	B	↑	D	↓
EBEMH - Broad Creek	D	<>	D	<>
EBEMH - Indian River	F	<>	F	<>
ELIPH (main-stem only)	B	↑	C	↓
LAFMH (main-stem only)	B	<>	D	↓
SBEMH (main-stem only)	C	↑	C	↓
SBEMH - Paradise Creek	D	↑	F	↑
WBEMH	B	<>	D	↓

Notes:
↑ = Statistically significant positive trend (2004 – 2013); segment is improving
↓ = Statistically significant negative trend (2004 – 2013); segment is declining
trend < > = No significant trend (2004 – 2013)

Phytoplankton/Chlorophyll.

Researcher: Dr. Todd Egerton (Old Dominion University)

Algae, also known as phytoplankton, are the photosynthetic base of the aquatic food web and vital for a productive river. However, toxic species, and/or an excess of algae of any kind, can lead to reduced water clarity, low dissolved oxygen, and may harm fish and shellfish populations. Old Dominion University and Virginia DEQ have monitored the phytoplankton community in the region for over 25 years using a variety of techniques, including microscopic cell counts and chlorophyll measurements. Chlorophyll is the photosynthetic pigment found in plants and algae, and is a useful measure of phytoplankton abundance. In the Elizabeth River, high chlorophyll is strongly linked to dinoflagellate blooms, including most notably the potentially harmful species *Cochlodinium polykrikoides*. Therefore, elevated chlorophyll concentrations can be interpreted as a sign of potentially poorer environmental conditions, with a restoration goal of reduced algae and chlorophyll levels.

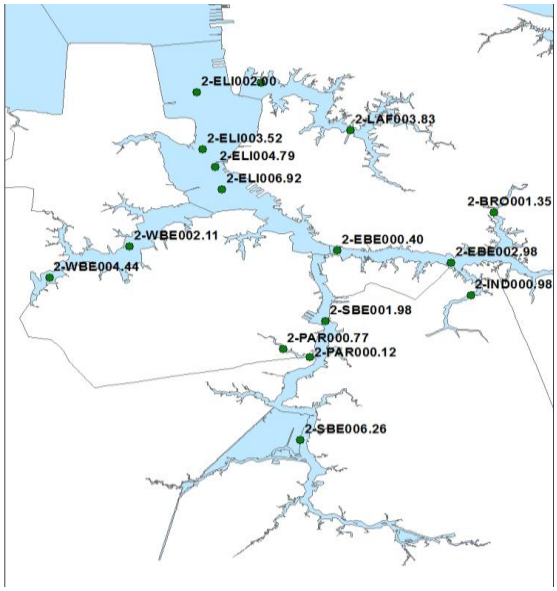

Figure 1. Virginia DEQ/ODU monitoring stations within the Elizabeth River. Chl *a* data from these stations were used to calculate scores (2009-2013) and trends (2003-2013).

Scores for chlorophyll *a* (Chl *a*) were calculated using the *Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators* (EcoCheck 2011) as described below:

1. Monthly Chl *a* data collected from the 16 stations (Figure 1) in the Elizabeth River from 2003-2013 were obtained from the Chesapeake Bay Water Quality Database (http://www.chesapeakebay.net/data/downloads/cbp_water_quality_database_1984_present), with additional data provided from the ODU water quality lab and DEQ.
2. All Chl *a* data were assigned a salinity regime, either meso or polyhaline based on matching salinity data.
3. Data were labeled seasonally based on collection date as spring (March to May) and summer (July to September). Data from other months were not used in this analysis.
4. Chlorophyll scores (0-5) were given to each collection using the thresholds listed in Table 1 for the respective season/salinity regime.
5. Average scores were calculated for each station, divided by 5 and presented as a percentage by multiplying by 100.
6. The average station percentage scores were averaged for each river segment.
7. A letter grade for each river segment was assigned based on the average percentage score as shown in Table 2.
8. Trend analysis was conducted by calculating the annual average score for each river segment for each year from 2003-2013. A linear regression analysis using an α of 0.1.was performed for each segment/sub tributary.

Table 1: Ecologically relevant thresholds for chlorophyll *a* (EcoCheck 2011)

Score	Mesohaline (>5-18ppt)		Polyhaline (>18ppt)	
	Spring (Mar-May) Thresholds (μgl^{-1})	Summer (July-Sept) Thresholds (μgl^{-1})	Spring (Mar-May) Thresholds (μgl^{-1})	Summer (July-Sept) Thresholds (μgl^{-1})
5	≤ 2.09	≤ 1.7	≤ 2.5	≤ 2.9
4	>2.09-≤ 6.2	>1.7-≤ 7.7	>2.5-≤ 2.8	>2.9-≤ 4.5
3	>6.2-≤ 11.1	>7.7-≤ 11.0	>2.8-≤ 6.9	>4.5-≤ 7.7
2	>11.1-≤ 19.1	>11.0-≤ 15.8	>6.9-≤ 12.6	>7.7-≤ 11.2
1	>19.1-≤ 49.8	>15.8-≤ 35.8	>12.6-≤ 31.7	>11.2-≤ 25.0
0	>49.8	>35.8	>31.7	>25.0

Status (average scores) and trends are summarized in Table 3. Based on the 2009-2013 time period, four of the five major river segments were scored as C (Moderate), with the Southern Branch receiving a B grade (Moderately Good). The two tributaries within the Eastern Branch (Broad Creek and Indian River) were scored the lowest grade: D (Poor), while Paradise Creek located off the Southern Branch had the highest small tributary score: B (Moderately Good).

While positive slopes (improving score, decreasing Chl *a*) were observed over the 2003-2013 time period in three of the five river segments, none of the trends were statistically significant at the α=0.1 level (Table 4). The only statistically significant regression was an improving trend (decreasing Chl *a*) in Paradise Creek. The only degrading trend (not significant) was observed in the Southern Branch (Table 4).

Table 2. Grading scale for average Chl *a* scores (Ecocheck 2011)

Average percentage score	Grade
80-100%	**A**
60-<80%	**B**
40-<60%	**C**
20-<40%	**D**
<20	**F**
Average percentage score	Grade
80-100%	**A**
60-<80%	**B**
40-<60%	**C**
20-<40%	**D**
<20	**F**

Table 3. Results summary of Chl *a* status (2009-2013) and trends (2003-2013)

River Segment	Average score	Grade	Trend
Mainstem	40%	C	no trend
Western Branch	43%	C	no trend
Southern Branch	67%	B	no trend
Eastern Branch	59%	C	no trend
Lafayette	48%	C	no trend
Broad Creek	34%	D	no trend
Indian River	38%	D	no trend
Paradise Creek	70%	B	improving

Table 4. Linear regression analysis results for 2003-2013 trends

River Segment	R^2	p value	Trend status	Slope description	Trendline	Stations	Avg. samples/yr
Mainstem	0.0008	0.935	non-sig.	flat	y = -0.0589x + 159.39	4	24
Western Branch	0.0325	0.596	non-sig.	improving	y = 0.3091x - 577.87	2	12
Southern Branch	0.1506	0.238	non-sig.	degrading	y = -0.8983x + 1873.7	2	12
Eastern Branch	0.2288	0.137	non-sig.	improving	y=1.4134x - 2784.1	2	13
Lafayette	0.1686	0.210	non-sig.	improving	y = 1.1199x -	2	12

Broad Creek	0.0059	0.823	non-sig.	flat	2200.4 y = 0.3333x - 639.64	1	3
Indian River	0.1737	0.202	non-sig.	improving	y = 1.4303x - 2835	1	4
Paradise Creek	0.6231	0.007	significant improving	improving	y = 3.0271x - 6016.1	2	11

The moderate to poor Chl *a* scores in much of the Elizabeth River may indicate the extent of nutrient inputs into the river as could be expected in a highly urbanized watershed. While there are no significant trends in any of the major river segments, the positive slopes (decreasing Chl *a*) observed in the Western and Eastern Branches and the Lafayette may be a sign of improving conditions, which could improve further in the future. There is strong correlation both locally (Egerton et al. 2012) and globally (Heisler et al. 2008) between eutrophication/higher Chl *a* and harmful algal bloom species. While Chl *a* gives a gross measure of the quantity of the algal community, species identification and counts are needed for a more complete understanding. Reduced algal densities with Chl *a* below bloom levels, such as the higher scoring values used by EcoCheck (Table 2), can be seen as a restoration goal to be accomplished by a reduction of nutrient inputs. The better scores in the Southern Branch and improving trend in Paradise Creek may be due to reduced nutrient inputs related to several restoration projects in the watershed. It should be noted that algal populations can also be limited (with low Chl *a*) even in the presence of high nutrient concentrations due to other factors, including light limitation, such as the turbid sediment filled waters of the upper Chesapeake Bay (Kemp et al. 2005). The dark tannic waters entering the Elizabeth River from the Great Dismal Swamp may also play a role in the lower Chl *a* found in the Southern Branch and Paradise Creek (Herrera-Silveira and Ramírez- Ramírez 1996).

Contamination in Fish.

Researcher: Dr. Donald Smith (VA Dept. of Environmental Quality)

The evaluation of fish tissue contamination was based upon the results from the Virginia Dept. of Environmental Quality's (DEQ) Fish Tissue and Sediment Monitoring Program. The data from which these summaries are extracted are available at: http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/FishTissueMonitoring/FishTissueResults.aspx.

Tissue sampling has been conducted on fish in the Elizabeth River system over the last two decades. Fish tissue contamination was monitored for three chemical groups: metals, pesticides, and polychlorinated biphenyls (PCBs). All three groups of contaminants were used in this evaluation, although the specific groups monitored varied among years and sites. Figure 1 illustrates the distribution of monitoring sites within the Elizabeth River and its tributaries.

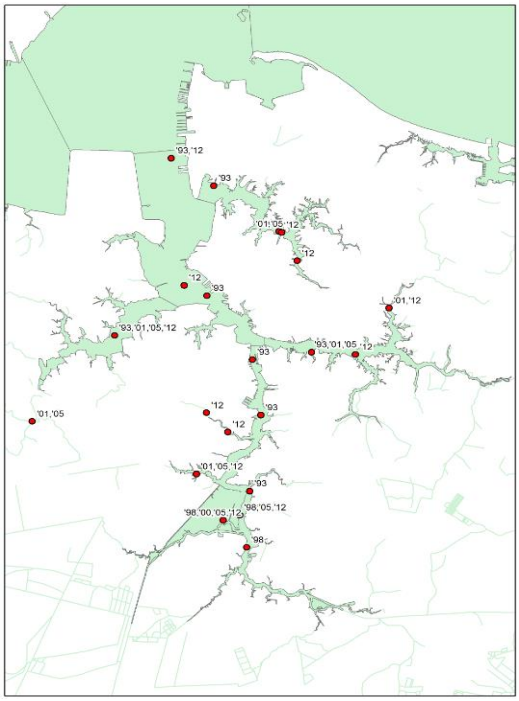

Figure 1. DEQ Fish Tissue Monitoring Sites and Years of Sampling

The criteria and thresholds used to characterize contaminant concentrations in fish tissues into five classes (Report Card format) were derived from more simple EPA criteria published in the National Coastal Condition Report IV (U.S. EPA, 2012, see also U.S. EPA, 2000). For each individual contaminant or chemical group a concentration range of Advisory Guidelines was provided. Following the original guidelines, concentrations below the specified range were characterized as "Good", concentrations above the specified range were characterized as "Poor", and values within the range were characterized as "Fair."

In adapting these criteria for the Elizabeth River five-grade Report Card format (A, B, C, D, & F), the amplitude of each guideline range was first calculated by subtracting the lesser value from the greater value. A transition range was established between the grades of "Good" and "Fair" by replacing the original lower threshold criterion with a range of values consisting of "lower limit" = original criterion – 10% of amplitude, and "upper limit" = original criterion + 10% of amplitude. A transition range between "Fair" and "Poor" was calculated in the same way, using the upper threshold criterion from the original table.

The Elizabeth River System as a whole was characterized by calculating an area-weighted arithmetic average of the numerical scores of the five major strata (mean = 1.89). This average was then evaluated to assign a final grade of "Fair to Poor", or D, for the system as a whole. The relative areas, grades and numerical scores for each major tributary and the Elizabeth River System as a whole are summarized in Table 1. No trend analyses were possible on fish tissue contaminant data because the fish species, contaminants analyzed, and sites sampled varied from year to year.

In general, it was observed the non-edible fish had higher concentrations of PCBs compared to edible fish. As a result, fish consumption advisories posted by the Virginia Department of Health provide a tiered hierarchy of consumption limitations for the Elizabeth River which vary among fish species and are based on PCB concentrations. Non-edible fish such as gizzard shad and mummichogs should not be eaten at all and should not be fed to pets. Edible fish such as American eel, striped bass, bluefish, croaker, spot, white perch, blueback herring and hickory shad should not be consumed at more than two meals per month, and other fish not listed in the advisory should not be consumed more than one meal per day.

Visit http://www.vdh.virginia.gov/Epidemiology/dee/PublicHealthToxicology/Advisories/JamesRiver.htm the Virginia Department of Health's website for the complete list and more information.

Table 1 – Grade for each branch related to contamination in fish.

Branch	Area (km^2)	Percentage	Grade	Letter Grade	Numerical Score	Trend
Elizabeth River Mainstem	20.7	44.42%	Fair - Poor	D	2	N/A
Lafayette River	5.7	12.23%	Poor	F	0*	N/A
Western Branch	6.9	14.81%	Fair - Good	B	4	N/A
Eastern Branch	5.7	12.23%	Fair - Poor	D	2	N/A
Southern Branch	7.6	16.31%	Poor	F	1	N/A
Elizabeth River System	46.6	100.00%	Fair - Poor	D	1.89**	N/A

* Score of zero given when contamination is extreme!

** Area-weighted arithmetic mean of five branch numerical scores.

Bacteria shellfish.

Researcher: Keith Skiles (VA Department of Health)

The Virginia Department of Health's Shellfish Sanitation monitors the river for fecal coliform bacteria on a monthly basis. The data are then used to determine if areas are condemned, conditionally restricted, or open for shellfish consumption. The Health Department looks at the geometric mean and the 90th percentile of the last 30 data points collected for bacteria to determine the status of a waterbody. The current grading system which is shown for the Elizabeth and Lafayette Rivers was developed by Shellfish Sanitation staff based on the 90th percentile from 2201 data points from around the state of Virginia. The grade for the river ranges from an A to D with neither the Eastern nor the Southern Branches having any data collected by the state (see Figure 1).

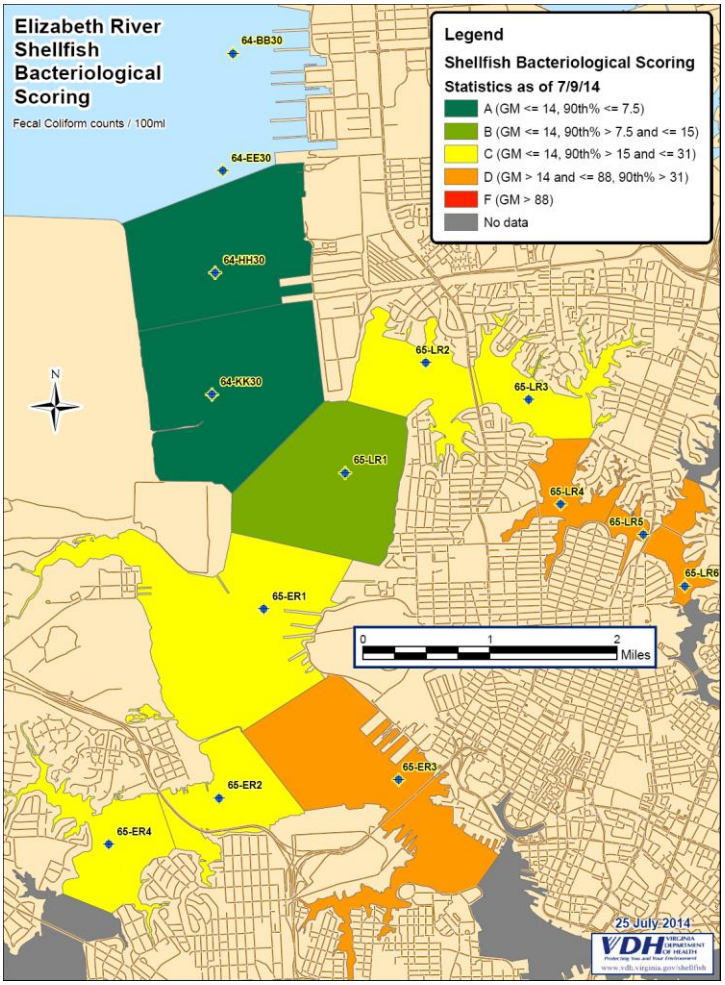

Figure 1. Grades for bacteria levels for shellfish in the Elizabeth and Lafayette Rivers.

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