THE STATE OF YOUR CREEK

Herring and Guinea Creeks on Rehoboth Bay

DELAWARE CENTER FOR THE
INLAND BAYS
Research. Educate. Restore.

The State of Your Creek:
Herring and Guinea Creeks on Rehoboth Bay

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The Delaware Center for the Inland Bays is a nonprofit organization and a National Estuary Program. It was created to promote the wise use and enhancement of the Inland Bays watershed by conducting public outreach and education, developing and implementing restoration projects, encouraging scientific inquiry and sponsoring needed research, and establishing a long-term process for the protection and preservation of the Inland Bays watershed.

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STATE OF THE INLAND BAYS

The Inland Bays are coastal lagoons—bays that lie behind a narrow barrier island that separates them from the Atlantic Ocean (Figure 1). Travelling down Coastal Highway, through Dewey Beach, Bethany Beach and Fenwick, the Inland Bays lie to the west.

They are unique places where 'the rivers meet the sea' …where freshwater flowing off the land and down rivers and creeks mixes with seawater that enters through inlets from the ocean.

The Bays are ringed with salt marshes and tidal flats and for thousands of years have supported an abundance of wildlife. People have always been drawn to these shores: first the Native Americans, then Dutch and English colonists and most recently in this century, a huge influx of retirees and second-home owners that have settled here and urbanized the areas around the Bays.

Over fifty years ago, the Bays were thought to be generally healthy: clear waters with plentiful seagrass meadows, productive oyster reefs, and oxygen concentrations that supported diverse and plentiful fish populations.

But years of accumulated nutrient pollution from human activities, and the loss of forests and wetlands, have left our Bays and creeks polluted.

Seagrass beds and oyster reefs have largely disappeared, and algae blooms are frequent in the poorly flushed areas of the Bays. Oxygen concentrations frequently are too low and bacteria concentrations too high, especially in the upper creeks and canals during the warmer months.

Changes in the landscape, including conversion of land from forests and wetlands to agriculture and development, have taken a toll on the Bays. However, results from the 2016 State of the Delaware Inland Bays report indicate that some areas of the Bays are seeing improvements in water quality —demonstrating that actions taken over the past two decades are beginning to pay off.

The Inland Bays and their creeks can be healthy again, but it will take people, towns, and communities working together as our quality of life depends on them.

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This *State of Herring and Guinea Creeks Report* is a compilation of environmental data about Herring and Guinea Creeks and their watershed.

Eight environmental indicators were selected to provide a snapshot of the State of Herring and Guinea Creeks using the most recent data available. These indicators are:

1. Land use change
2. Septic system permits
3. Inputs of nutrient pollution
4. Concentrations of nitrogen and phosphorus
5. Dissolved oxygen concentrations
6. Bacteria concentrations
7. Water clarity
8. Algae concentrations

Additional relevant environmental information is included in the report narrative and appendix.

This report is a product of the Delaware Center for the Inland Bays' (CIB) **'Your Creek'** initiative, a project to introduce residents and property owners to their local creek and to the CIB as a resource of data and support for their creek. By empowering these residents and property owners with data on water quality in the tributary and with information on land use and practices that can affect water quality, those who use and value Herring and Guinea Creeks can better advocate for protection and restoration of the waterways.

HERRING AND GUINEA CREEK WATERSHED

The Herring and Guinea Creek watershed occupies the central portion of the Rehoboth Bay drainage area in the Inland Bays (Figure 2). The watershed drains nearly 34 square miles of land and is characterized by a network of minor arterial roadways and secondary roads, resulting in many stream crossings.

Herring Creek flows into the western side of Rehoboth Bay, and the watershed is roughly bisected in the north-south direction by Route 24 (Figure 3). Guinea Creek, a smaller tributary, joins the system from the south, about a mile from the mouth of Herring Creek. Further upstream, Herring Creek divides into two smaller branches, Burton Prong and Hopkins Prong. Route 24 defines the approximate extent of tidal influence in both tributaries. A headwater stream, Chapel Branch, flows into Burton Pond, a 35-acre, privately-owned reservoir created by a dam at the Route 24 crossing. Hopkins Prong is formed by the confluence of Phillips Branch and Unity Branch.

The Herring Creek watershed includes the northern half of the Long Neck peninsula, north of Long Neck Road, and headwater areas west of Route 24. The state-owned Angola Neck Preserve borders Herring Creek on the north side, near the mouth of the creek. The watershed is characterized by development to the east, with agriculture and patches of forest toward the west. It includes some of the more densely populated areas of the Inland Bays. Recent development of agricultural land to suburban residential and commercial land uses has occurred throughout the watershed.

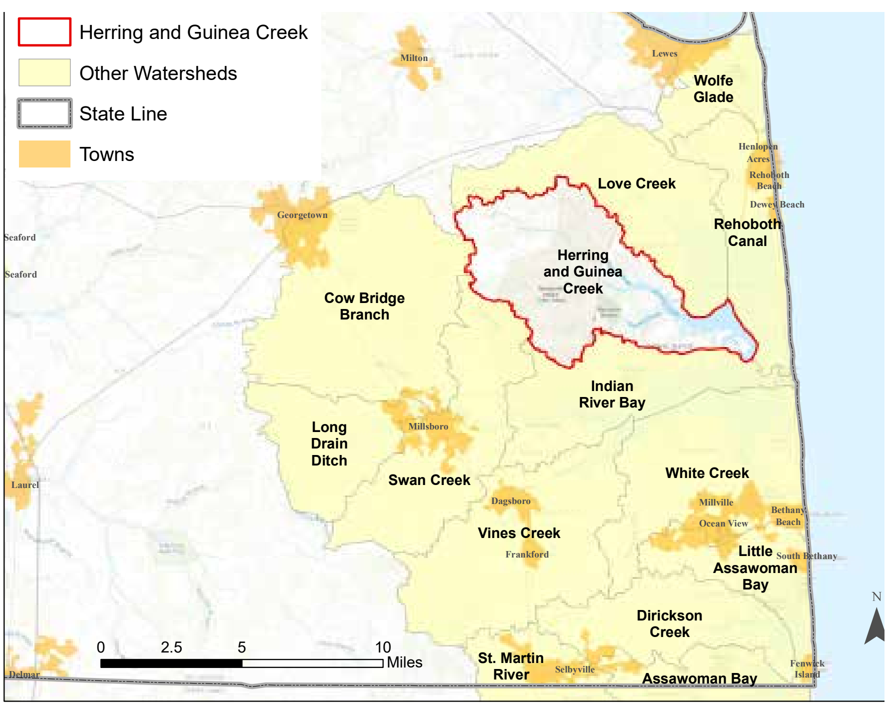


Figure 2. Figure 2. Location of Herring and Guinea Creek watershed within the Inland Bays watershed.

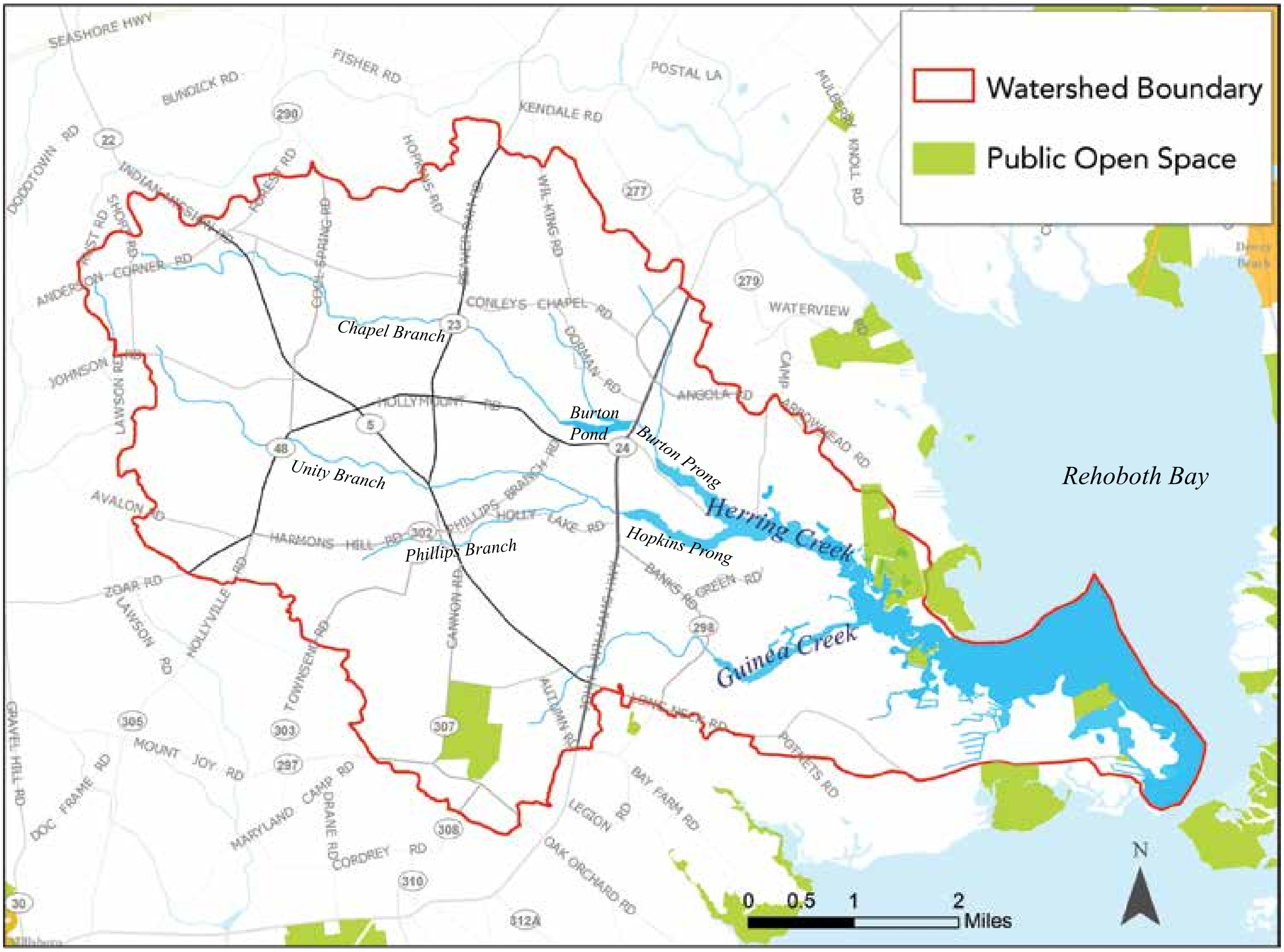


Figure 3. Map of Herring and Guinea Creek watershed showing the location of roadways, towns and public open space areas that are in the watershed.

POLLUTION IN THE CREEKS—WHERE DOES IT COME FROM?

There are many sources of pollution to Herring and Guinea Creeks including legacy contaminants (contaminants that entered the watershed during an earlier period and are still there) from agricultural fertilizers and animal farming. The transport of these legacy nutrients through groundwater to creeks and bays may happen quickly, or may take a decade or more, depending upon the location and soil types. Therefore, some improvements to fertilizer management will take time to show results in water quality. Fortunately, there are no significant 'point sources' of pollution entering these creeks (i.e. industrial or wastewater outfalls discharging directly into the water). 'Nonpoint source' pollution from both agricultural and developed areas, however, is an ongoing issue in the watershed.

Farming continues in much of the western portion of the watershed through which the fresh, headwater streams (Chapel Branch, Unity Branch, and Phillips Branch) flow. The Inland Bays Wastewater Treatment Facility, located near Guinea Creek, disposes of treated wastewater through spray irrigation on adjacent cropland. Guinea Creek also flows through the Baywood Greens Golf Course, which is irrigated with treated water from its community wastewater system. In addition, sources of pollutants related to residential development and stormwater runoff exist in the heavily developed eastern portion of the watershed (Figure 4).

Figure 4. Aerial image of Herring and Guinea Creek Watershed, showing the location of communities and other features of interest.

Different types of land uses contribute differing amounts of nitrogen and phosphorus pollution to creeks and bays. Forests and wetlands contribute very few nutrients to waterways; fertilized croplands contribute the most. In recent years, forests and farmland have increasingly been converted to residential development in western areas of the Herring and Guinea Creek watershed. As agricultural land is converted to residential and commercial developments, the increase in impervious cover (i.e., roads, parking lots, roofs, and driveways) creates new pollution challenges. Rainwater flowing across these hard surfaces picks up and carries pollutants into nearby waterbodies through storm drain systems. Nutrients from lawn fertilizers and septic systems on developed land also can find their way into the creeks and, eventually, into Rehoboth Bay. However, developed lands still generate less nitrogen and phosphorus pollution on average than agricultural lands.

Herring and Guinea Creeks and their tributaries currently are listed as 'impaired' under the federal Clean Water Act for bacteria, nutrients, and dissolved oxygen. The Rehoboth Bay watershed as a whole has a Total Maximum Daily Load (TMDL) regulation that requires a 40% reduction in nitrogen and phosphorus, and a 40% reduction in freshwater bacteria from nonpoint sources. More information on this can be found at inlandbays.org.

SUMMARY OF THE FINDINGS IN THIS REPORT

- Herring and Guinea Creeks are highly impaired by nutrient pollution. **Average concentrations of nitrogen measured in the creeks are ten to twelve times the healthy limit.** Since 2006, annual total nitrogen inputs to Herring and Guinea Creeks have exceeded water quality standards about 40% of the time, with no consistent trend. Phosphorus concentrations also exceed healthy limits and seem to be increasing in Guinea Creek, despite much work over the years to remove pollution sources. Water clarity has significantly decreased in Herring Creek.

- Data collected by the University of Delaware's Citizen Monitoring Program indicate that **dissolved oxygen in Guinea Creek frequently falls to very low concentrations on summer nights and early mornings**, creating conditions that can harm fish, shellfish, and other aquatic life.

- Land use has a direct impact on water quality in the creeks. While conversion of more farmland to development in the western portion of the watershed reduces inputs of pollution from agricultural fertilizers, the loss of forests and wetlands to residential and commercial use may increase nutrient inputs. Intensive development has occurred in the Herring and Guinea Creek watershed east of Route 24, closest to the Bay, over the past couple of decades. **Between 1992 and 2012, nearly four square miles of agricultural land and forest have been developed.**

- While the Herring and Guinea Creek watershed still has one of the highest densities of active septic systems in the Inland Bays, **nearly 100% of properties along waterways east of Route 24 are converted or have plans to convert to central sewer service.** This eventually should mean fewer nutrients entering the creeks and Rehoboth Bay.
- **In the tidal portion of upper Guinea Creek, summertime concentrations of fecal indicator bacteria failed to meet the single-sample safe swimming standard 83% of the time.** Since 2003, average annual concentrations of *Enterococcus* bacteria at this location also have consistently remained above the long-term safe swimming standard. A preliminary study conducted by DNREC in Guinea Creek suggests that most of the bacteria are coming from wildlife, rather than human, sources.

SOURCES OF WATER QUALITY DATA

To assess the health of Herring and Guinea Creeks, a suite of environmental indicators were selected. These are specific conditions that are measured over time to determine how the creeks are changing and how much progress has been made toward restoration goals.

To assess the current status and trends in the overall health of Herring and Guinea Creeks and their watersheds, it is helpful to examine a variety of water quality- and landscape-related indicators. The data presented in this report reflect some of the key conditions that are monitored by scientists to understand the health of the creeks.

Water quality data from several long-term monitoring locations were used to develop this report - two stations maintained by the Delaware Department of Environmental Resources and Environmental Control (DNREC) in Herring and Guinea Creeks, and two stations maintained by the University of Delaware Citizen's Monitoring Program in Guinea Creek (Figure 5).

Details of data sources and analyses used in developing this report can be found in the Appendix. A more comprehensive report, *2016 State of the Delaware Inland Bays*, assessed the health of the entire Inland Bays estuary. That report is available on the CIB's website, inlandbays.org.

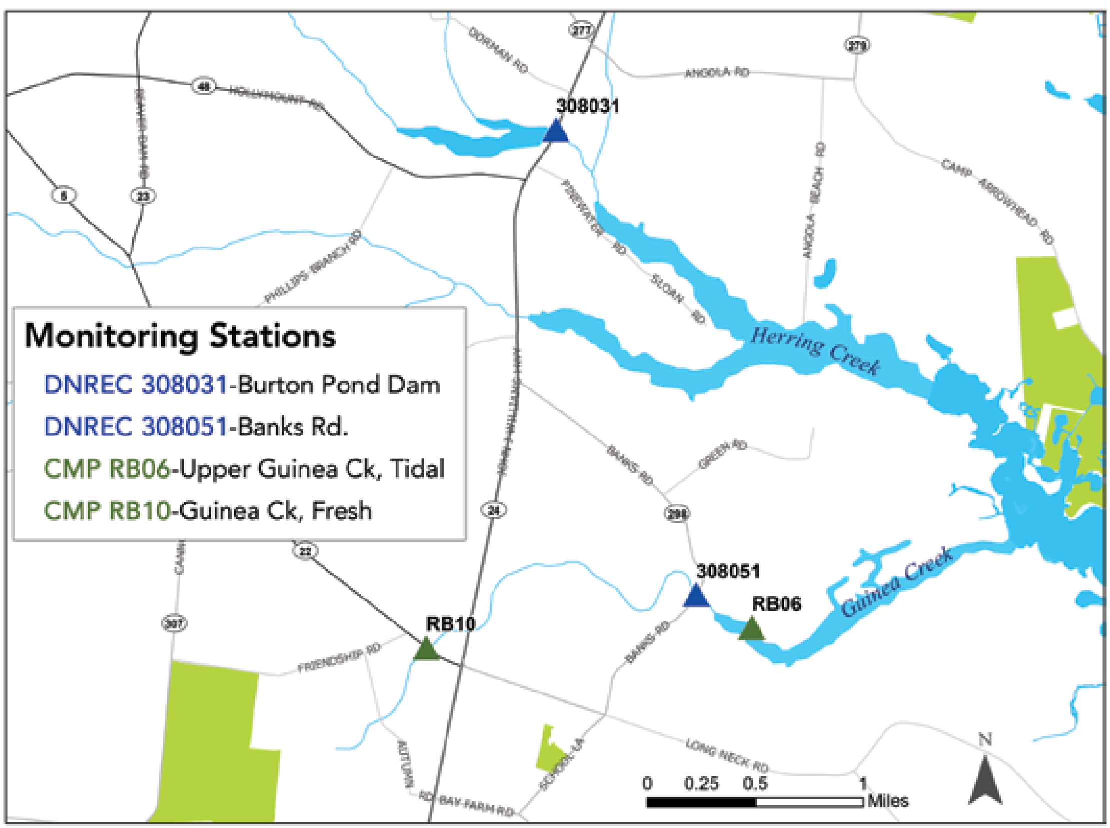


Figure 5. Map showing the locations of Herring and Guinea Creek water quality monitoring stations maintained by the state (DNREC) and the University of Delaware's Citizen Monitoring Program (UDCMP). These stations provided data used to develop this report.

INDICATOR: LAND USE CHANGE

The Herring and Guinea Creek watershed has seen considerable land use changes in the past several decades. Increasing development pressure has occurred as agricultural and forested lands are converted to residential and commercial development.

Between 1992 and 2012 (the most recent year for which data were available) there was a 68.3% increase in developed land (3.9 square miles). Most of this development has occurred in the eastern half of the watershed near Rehoboth Bay (Figure 6). These areas also are the most environmentally sensitive because of their proximity to wetlands and forests that fringe the Creeks and the Bay. The areas of agricultural and forested land use declined by 18.4% and 15.0%, respectively, over the 20-year period (Figure 7). Loss of forested buffers along waterways is particularly concerning, because these buffers can intercept and remove nutrient pollution before it enters creeks and bays. Buffers also provide important habitat for life in the estuary.

The third map in Figure 6 shows in red properties with applications (as of 2012) to the Preliminary Land Use Service (PLUS) of the Delaware Office of State Planning Coordination. PLUS applications are submitted early in the development process for major projects, and thus are a useful indicator of future development. Based on this, further

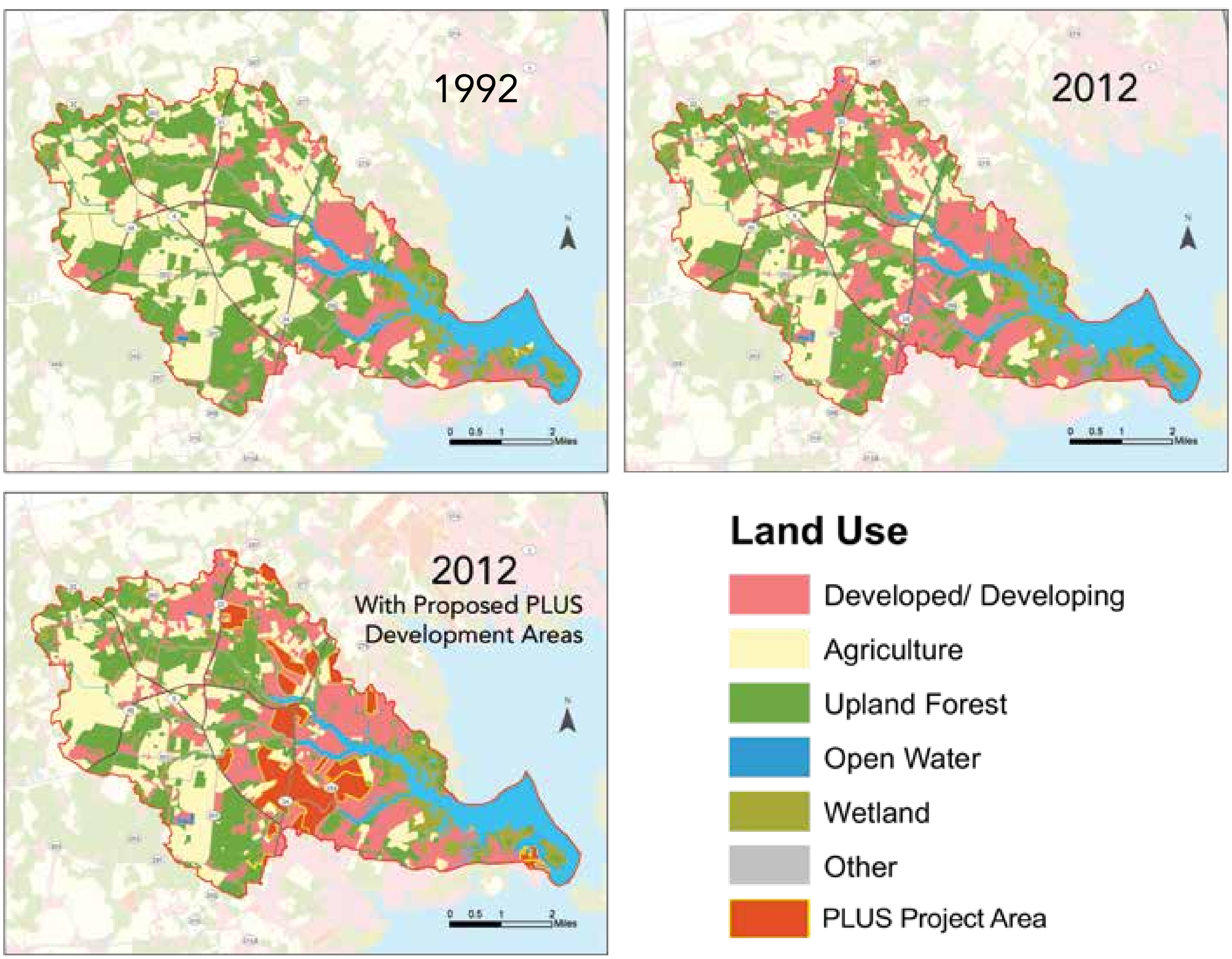
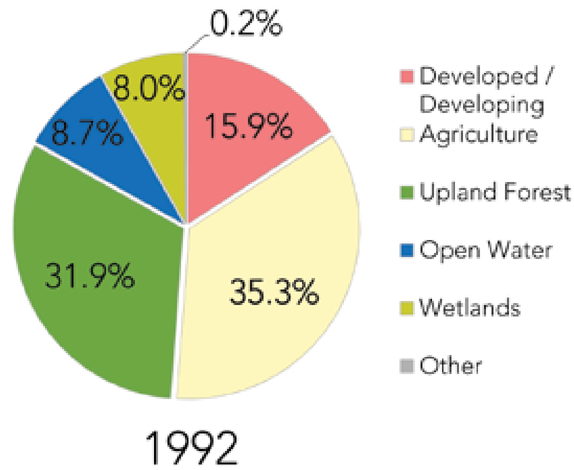


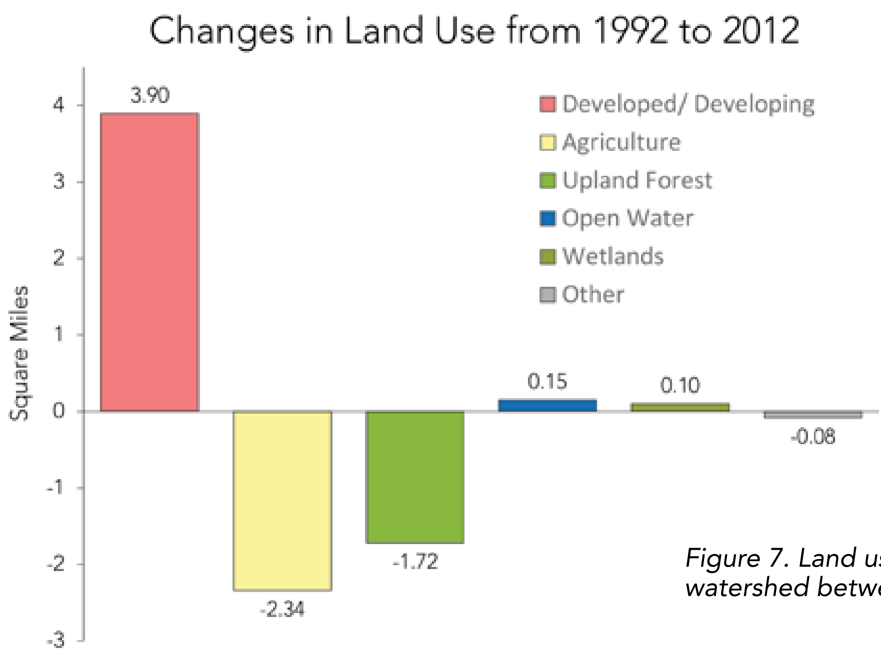
Figure 6. Maps showing changes in land use over time in the Herring and Guinea Creek watershed, including proposed development projects (Preliminary Land Use Service, or PLUS) as of 2012. Note that proposed development projects represent full project areas, which may include some areas left as undeveloped forest, water, or wetland.

development in the watershed can be expected along the Route 24 corridor and in proximity to the major tributaries.

How humans use the land directly affects water quality in creeks and rivers that flow into the Inland Bays. Different types of land uses, including development, agriculture, and forests, each have a characteristic contribution of pollutants to waters.

Per acre of land, cropland tends to contribute the highest loads of nutrient pollution to waters, followed by developed areas. Forests contribute few nutrients, and healthy wetlands can actually remove nutrients from waters that flow to the Bays.





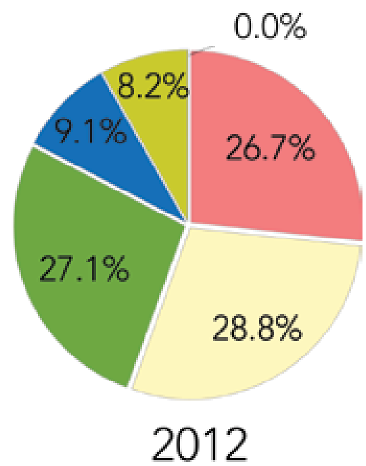


Figure 7. Land use changes in the Herring and Guinea Creek watershed between 1992 and 2012.

LOOKING AHEAD—WHAT CAN BE DONE?

- Because cropland tends to contribute the most nutrients to waterways, the conversion of croplands to development may actually result in gradually reduced nutrient loads to Herring and Guinea Creeks over time - but only if communities manage residential fertilization and stormwater effectively. Increased impervious surfaces in developed areas - such as roads, driveways, roofs, etc. - tend to speed the delivery of pollutants (nutrients, toxins, bacteria, sediment, etc.) to the creeks via stormwater runoff. Thus, developers and communities should adopt green infrastructure practices that limit impervious surfaces.
- Alternately, the conversion of forests and wetlands to development will result in increased nutrient inputs to the Creeks. Protecting forest buffers along shorelines can help mitigate impacts from development by filtering runoff and taking up excess nitrogen and phosphorus. Protection of forested areas also benefits native wildlife.
- The location of new developments near marshes and streams along Herring Creek, will degrade the natural function of wetlands and shorelines unless communities protect wetland areas, opt for 'living shorelines' to manage erosion, and maintain vegetated buffers to protect waterways from runoff. Data from the State of Delaware Preliminary Land Use Service (PLUS), indicates that rapid development along the shores of Herring Creek, its marshes and streams is intended. The only way to protect the quality of life that clean water affords a community is to design and build to protect water quality.

INDICATOR: SEPTIC SYSTEM PERMITS

Septic systems are a significant source of nutrients to nearby waterbodies.

Conventional septic systems can leach up to 23.2 pounds of nitrogen into the groundwater each year (Maryland Department of the Environment information). More advanced, high-efficiency septic systems are now required for any new or replacement installations in the Inland Bays watershed; these provide much higher removal of nitrogen from wastes than conventional systems. In addition to nutrient pollution, septic systems that are not properly designed, constructed, or maintained can also contribute bacteria to the creek if untreated waste enters surface runoff or groundwater.

Based upon 2016 septic permit data obtained from Sussex County, a total of 5,664 septic systems were believed to be actively in use that year within the watersheds of the Inland Bays. The relative densities of systems within each watershed are shown in Figure 8. The Herring and Guinea Creek watershed has both a higher number and higher density of active septic permits than most other watersheds on the Inland Bays. This is not surprising given that it is currently and historically an area of relatively dense residential development.

However, Sussex County is actively working to provide central sewer service to many of the homes in the area surrounding Herring and Guinea Creeks. The focus of this conversion has been in and environmentally sensitive region east of Route 24 along the waterways (Figure 9). In fact, in July 2016 the Sussex County Engineering Department approved two new sewer districts, Herring Creek and Chapel Branch, which will convert more than 1,250 homes to central sewer. When all construction is complete, nearly 100% of the homes east of Route 24 will have sewer connections made available. While active septic permits still exist in some of these communities, it is anticipated that most septics will be abandoned as sewer service is provided.

This is important for the creeks and for Rehoboth Bay. Central sewer service allows a higher level of sewage treatment and eliminates much of the pollution from septic systems.

LOOKING AHEAD—CHOICES WE CAN MAKE FOR CLEANER WATER

- Sussex County and private wastewater utilities are working to expand sewer service to more communities in the Herring and Guinea Creek watershed, including about 550 acres in the Burton Pond, Hollymount and Robinson Road areas. By supporting these new sewer districts, property owners in these communities will have the opportunity to vote for cleaner water in their creeks. Central sewer provides a much higher level of sewage treatment compared to existing septic systems, and even properly maintained septic systems leach nutrients into groundwater. Over time, conversion of most existing septic systems to public sewer will result in cleaner water. However, increased availability of central sewer service may also increase development potential in areas that might not have been approved for septic system installations.
- For properties maintaining or installing septic systems—proper siting and regular pump outs and maintenance, as required by the Inland Bays Pollution Control Strategy (PCS), will reduce the risk of pollution to the Bays. New and replacement septic systems must now provide advanced waste treatment. This regulation went into effect January 2009 for sites close to tidal waters and wetlands and extended to the entire Inland Bays watershed in 2015.

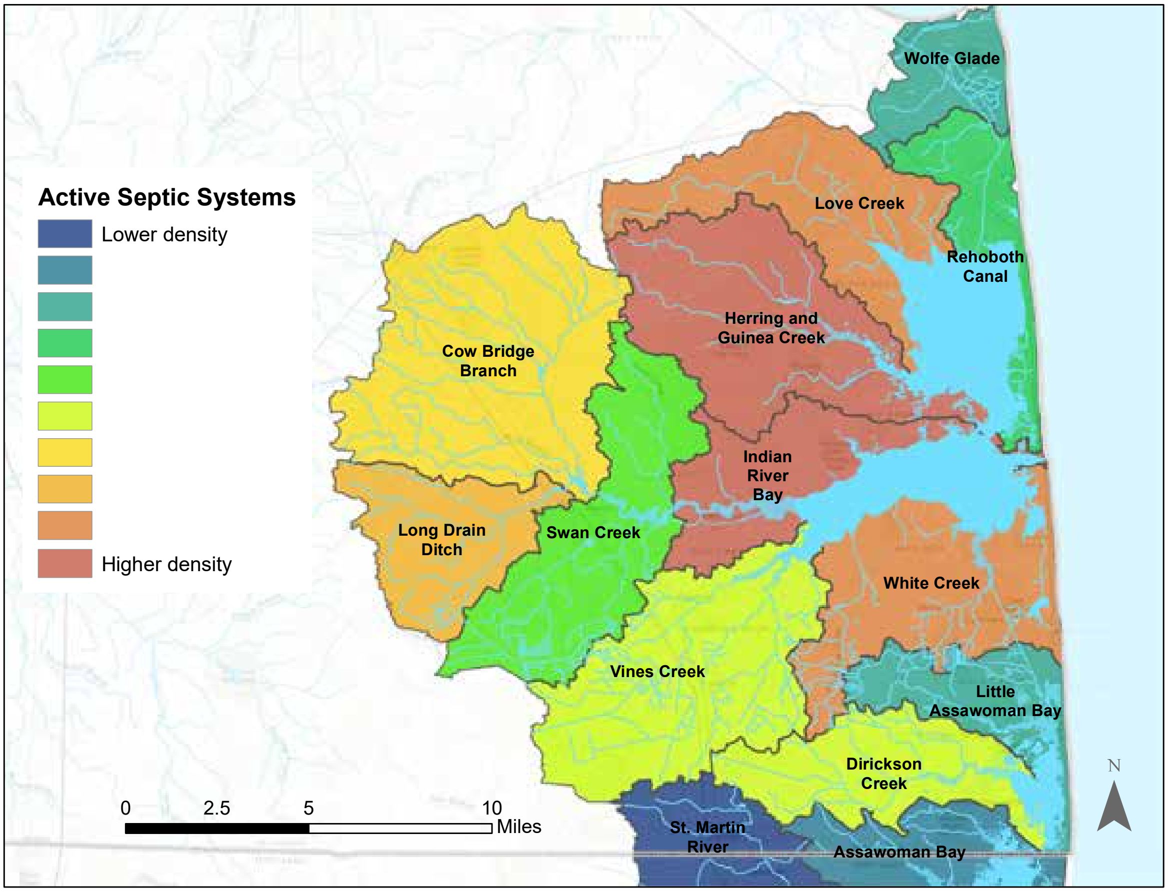


Figure 8. Relative density of septic system permits in watersheds of the Inland Bays, as of 2016.

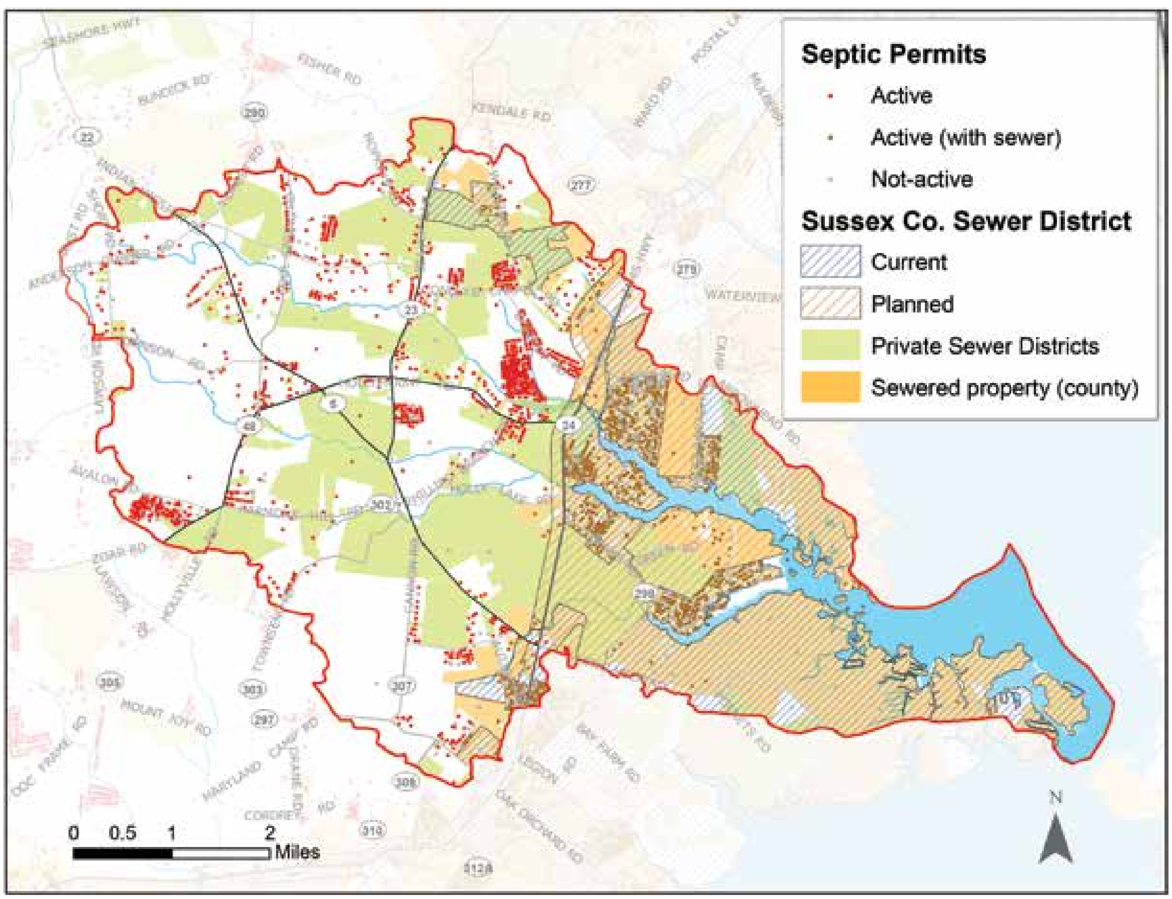


Figure 9. Map showing locations of permitted septic systems and sewer districts within the Herring and Guinea Creek watershed, as of 2019.

INDICATOR: INPUTS OF NUTRIENT POLLUTION

Nutrients are necessary for the growth of beneficial grasses and algae in tidal creeks. However, excessive amounts of nitrogen and phosphorus in the water cause an overabundance of algae, cloudy waters, and unhealthy dissolved oxygen concentrations. This can inhibit the growth of underwater baygrasses and lead to deaths of fish and shellfish.

Nutrient pollution—in particular, an excess of nitrogen—is the largest water quality problem facing Herring and Guinea Creeks and Rehoboth Bay. Nitrogen and phosphorus found in the waters of the Creeks come primarily from fertilizers, stormwater runoff, wastewater, septic systems, and natural sources. These nutrient loads vary with the different ways that land in the watershed is used; farms, developments, and even forests to some extent, contribute nutrients to Herring and Guinea Creeks.

"Nutrient load" refers to the total amount of nitrogen or phosphorus entering the water during a given time, such as "pounds of nitrogen per day." Nutrient loads are calculated from measurements of nitrogen and phosphorus taken over time in the creeks—basically concentration multiplied by volume of stream flow. The estimated nitrogen and phosphorus loads are compared with the allowable Total Maximum Daily Load (TMDL) of nutrients that a creek may receive and still remain healthy for human use and aquatic life.

The variation in nutrient loads from year to year is related to stream flow, which is in turn related to the amount of precipitation in a year. During wetter years, the increase in precipitation will cause an increase in runoff from the land. This runoff carries nutrients from farms and residential lawns, bacteria and toxins from developments, and sediment from eroding stream banks and construction sites, and delivers them to the creeks.

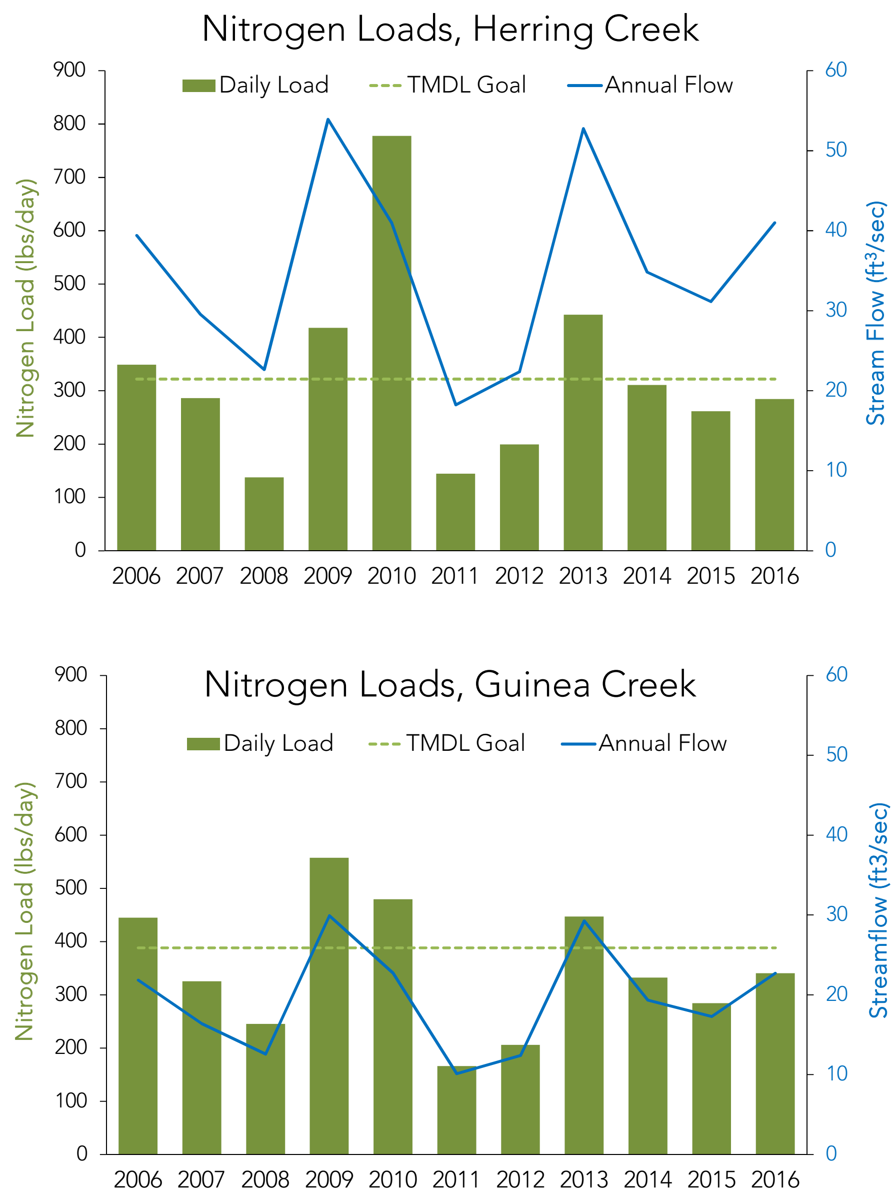


Figure 10. Annual inputs of nitrogen to Herring and Guinea Creeks, with mean annual streamflow for comparison. The Total Maximum Daily Load (TMDL) goal for nitrogen in each creek is indicated by the dashed lines. For the creeks to remain healthy,loads should be below the TMDL goal.

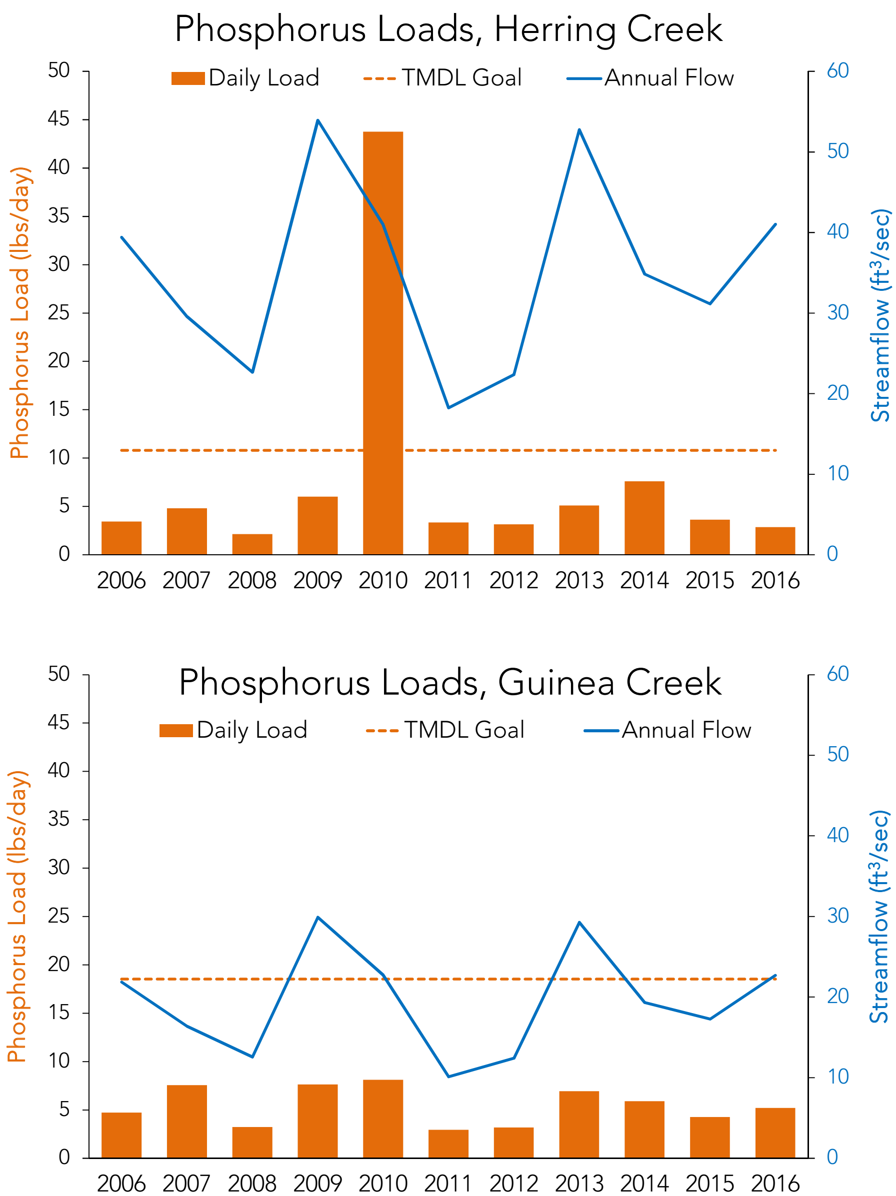


Figure 11. Annual inputs of phosphorus to Herring and Guinea Creeks, with mean annual streamflow for comparison. The Total Maximum Daily Load (TMDL) goal for nitrogen in each creek is indicated by the dashed lines. For the creeks to remain healthy,loads should be below the TMDL goal.

These impacts can be lessened. If developments are built with protective buffers and stormwater control structures, farms and residential lawns apply nutrients only when necessary and in the correct quantity, and shorelines are stabilized in a natural way, then runoff from these areas will be less harmful to the bays.

INPUTS OF NITROGEN

Since 2006, annual nitrogen loads to Herring and Guinea Creeks have exceeded water quality standards about 40% of the time. In 2010, nitrogen inputs to Herring Creek were more than double the healthy limit (i.e., the TMDL goal), while in other years the exceedances were not as great (Figure 10). The variation in nutrient loads from year to year is related to stream flow, which is a function of the amount of precipitation in a year. More precipitation means more runoff and groundwater flow, which means more pollutants entering waterways.

There has been no consistent increasing or decreasing trend in nitrogen loads. Nitrogen has been and continues to be the major pollutant of concern for both Herring and Guinea Creeks, as well as for Rehoboth Bay into which they flow.

INPUTS OF PHOSPHORUS

Phosphorus loads to Herring and Guinea Creeks have been well within healthy limits, with the exception of 2010, when average daily loads in Herring Creek were four times the standard (Figure 11). As with nitrogen, phosphorus loads vary from year to year, mostly due to changes in precipitation and streamflow. There is no overall trend of increase or decrease in phosphorus loads, indicating no significant increase or decrease in sources.

INDICATOR: CONCENTRATIONS OF NITROGEN AND PHOSPHOROUS

The 'loads' (or inputs) of nitrogen and phosphorus are a measure of pollution entering the creek and can change depending on how the land is managed and used. 'Concentration,' on the other hand, is the amount of a dissolved pollutant actually measured in a certain volume of water (for example, milligrams of dissolved nitrogen per liter of water).

The concentrations of nutrients in Herring and Guinea Creeks reflect the loads to the Creeks, but they also are affected by other factors such as use by plants and algae and release of nutrients stored in creek sediments.

Annual median concentrations of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) were determined from water samples collected at one monitoring station in Herring Creek (DNREC Station 308031, at the Burton Pond dam spillway) and two stations in Guinea Creek (DNREC Station 308051 and CMP Station RB06). Refer to Figure 3 for the locations of these stations. The inorganic forms of these nutrients are measured because they are most readily used as food by algae.

With a goal of reducing nutrients to concentrations at which baygrasses can re-establish in our Bays, the State has established water quality standards for dissolved inorganic nitrogen and phosphorus in tidal waters of the Inland Bays (0.14 mg/L and 0.01 mg/L, respectively). Concentrations of nitrogen and phosphorus measured in the Creeks are compared against these goals. While a certain level of nutrients is essential to the growth of beneficial grasses and algae in tidal creeks, an excess of nutrients can lead to an overabundance of algae and eventually to low levels of dissolved oxygen in the water.

NITROGEN CONCENTRATIONS

Even though the loads, or inputs, of nitrogen into Herring and Guinea Creeks have largely met state standards, concentrations of nitrogen measured in the water are extremely high in both creeks, consistently far exceeding the healthy limit for tidal waters of 0.14 mg/L (Figure 12). Herring Creek Station 308031 is in Burton Pond , above, the dam, and thus a freshwater site. However, there is no numerical criteria for nitrogen in freshwater ponds in the state. While there has been no clear overall trend in nitrogen concentrations at the Herring

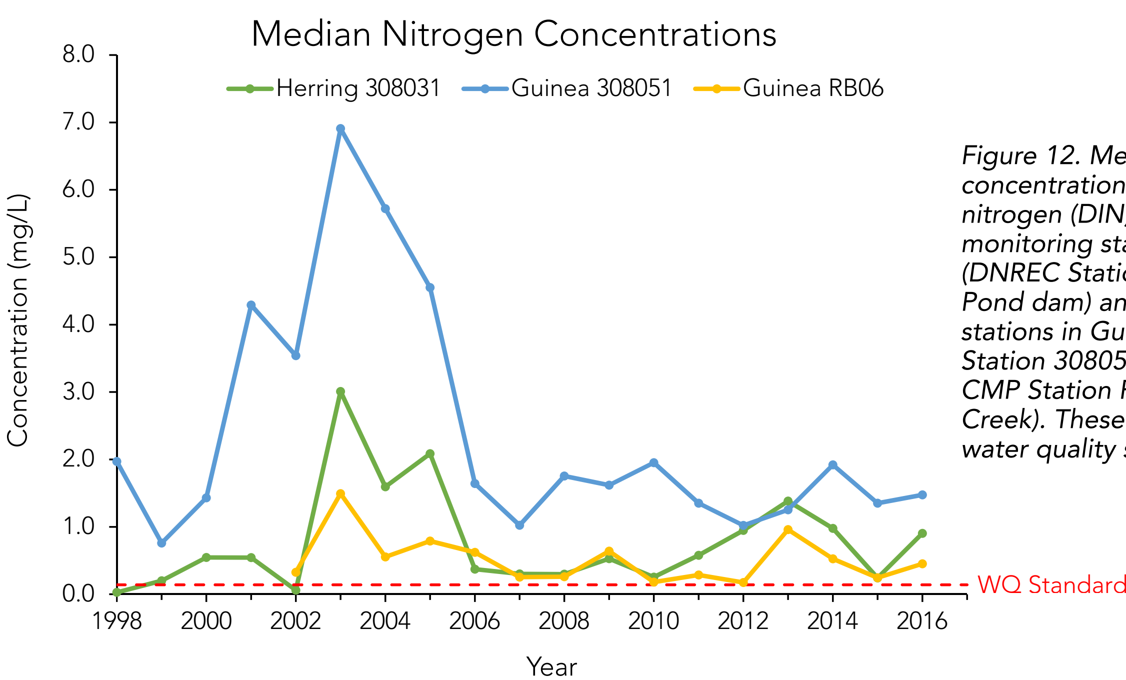


Figure 12. Median annual concentrations of dissolved inorganic nitrogen (DIN) measured at one monitoring station in Herring Creek (DNREC Station 308031 at Burton Pond dam) and two monitoring stations in Guinea Creek (DNREC Station 308051 at Banks Rd. and CMP Station RB06 in upper Guinea Creek). These are compared to a water quality standard of 0.14 mg/L.

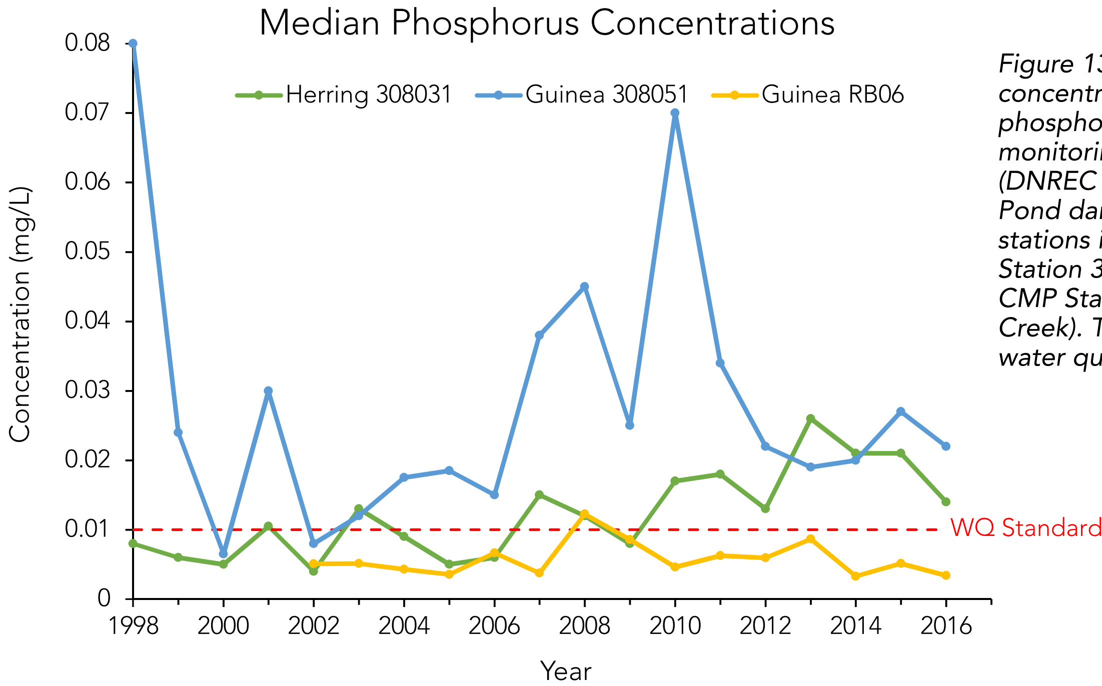


Figure 13. Median annual concentrations of dissolved inorganic phosphorus (DIP) measured at one monitoring station in Herring Creek (DNREC Station 308031 at Burton Pond dam) and two monitoring stations in Guinea Creek (DNREC Station 308051 at Banks Rd. and CMP Station RB06 in upper Guinea Creek). These are compared to a water quality standard of 0.01 mg/L.

Creek monitoring station over the years, there are some signs of improvement in Guinea Creek. Nonetheless, nitrogen concentrations remain at up to ten times the healthy limit. Among Inland Bays tributaries, Guinea Creek is one of the most polluted by nitrogen; only the upper Indian River has similarly high concentrations. This is a major driver of excess algae growth and low dissolved oxygen conditions in the Creek.

PHOSPHORUS CONCENTRATIONS

Since 2007, concentrations of dissolved inorganic phosphorus measured at the Burton Pond dam in Herring Creek have shown a steady and concerning trend upwards. The reasons for this increase are unknown, but it could be related to the significant amount of development that has occurred upstream of Burton Pond in the last decade.

In Guinea Creek, concentrations of phosphorus in samples collected at Banks Road (Station 308051) are even higher, with no apparent trend either upward or downward. Further downstream, where the Creek is better flushed, phosphorus concentrations are lower.

LOOKING AHEAD

- Herring and Guinea Creeks remain highly polluted by nutrients, despite many years of work to remove nitrogen and phosphorus inputs to them. There can be a lag time between removal of pollution sources and visible improvements in water quality, because polluted groundwater may take some years to actually reach creeks and bays. Yet the trend in phosphorus, at least, seems to be degrading rather than improving.
- Loads of both nitrogen and phosphorus to Herring Creek will be affected by the projected changes in land use in the watershed. The net effect of conversion of crop lands and forests to housing is not completely clear and should be closely monitored.
- In December 2018, the Sussex County Council approved an ordinance that changes the method of calculation for permitted housing density on parcels that contain wetlands. The Council is also considering more protective buffer regulations. Both actions could provide significant water quality benefits.
- Conversion of communities from septic systems to central sewer should have a positive long-term impact on nutrient loads to the Creek from groundwater. But increased stormwater runoff from development and roads may have a negative impact unless communities and residents work together to protect against runoff into waterways.

INDICATOR: DISSOLVED OXYGEN CONCENTRATION

All aquatic life needs healthy concentrations of oxygen in the water (Figure 14). Healthy, stable concentrations of oxygen are especially important in tidal creek nursery grounds where young fish, crabs, and shellfish are found.

Delaware has a minimum standard of 4 milligrams of dissolved oxygen per liter of water (mg/L) for both freshwater and tidal creeks to be considered healthy. If the minimum daily concentration falls below this standard too often, water quality is considered impaired, and aquatic life may be harmed.

Excess algal growth fueled by nitrogen and phosphorus creates high concentrations of oxygen during the day (while the algae photosynthesizes), but also causes oxygen to plummet during the night and early mornings (when the algae stops photosynthesizing and consumes oxygen during respiration). Decomposition of dead algae by naturally occurring bacteria further reduces oxygen in the water. These swings in dissolved oxygen are characteristic of waters which have unhealthy amounts of algae. Eventually, the algae blooms die and decompose, which consumes even more of the dissolved oxygen in the water.

It is important to collect dissolved oxygen (DO) concentration measurements in summer months (June through September) and in the early morning (before photosynthesis by algae begins to raise oxygen concentrations). These measurements are most likely to show periods of low oxygen conditions in the creeks. Even temporary drops in oxygen levels in the water can be harmful to aquatic life.

DO has been monitored on summer mornings by Citizen Monitoring Program (CMP) volunteers at two stations in Guinea Creek (RB06 and RB10). No similar long-term record of summer morning DO concentrations exists for Herring Creek.

Prior to 2007, nearly all samples collected at Station RB06 in the upper tidal portion of Guinea Creek had healthy levels of dissolved oxygen (greater than 4 milligrams per liter). Since 2007, however, 22% of measurements made at that station on summer mornings had DO values below the water quality standard of 4 mg/L (Figure 15). 34% of measurements made at Station RB10 in the freshwater portion of the creek above Route 24 (Station RB10) had unhealthy oxygen concentrations.

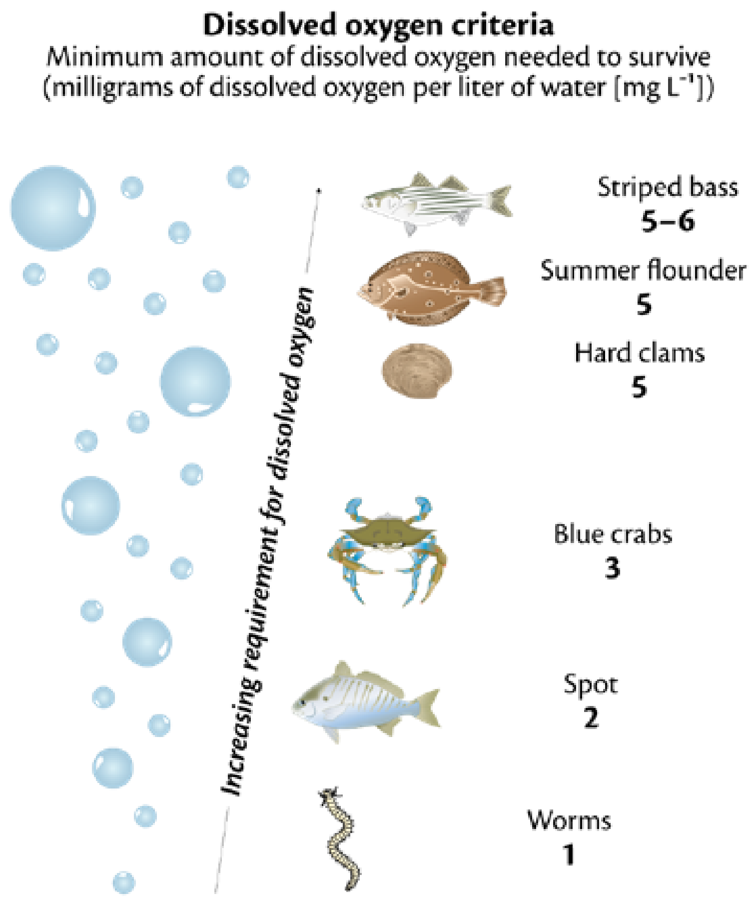


Figure 14. Different organisms require different levels of dissolved oxygen in the water to survive. Dissolved oxygen is a useful indicator of water quality. Diagram courtesy of the Integration and Application Network, ian.umces.edu.

LOOKING AHEAD—DISSOLVED OXYGEN

- Low dissolved oxygen is directly tied to excess nutrients and water clarity, so control of nitrogen and phosphorus inputs to Herring and Guinea Creeks will continue to be critical for the survival and health of aquatic life there.
- Continuous (i.e., automated, high-frequency) monitoring of dissolved oxygen in both creeks would be helpful to provide a more accurate picture of the daily cycling of low and high oxygen levels that typically occurs in summer months.

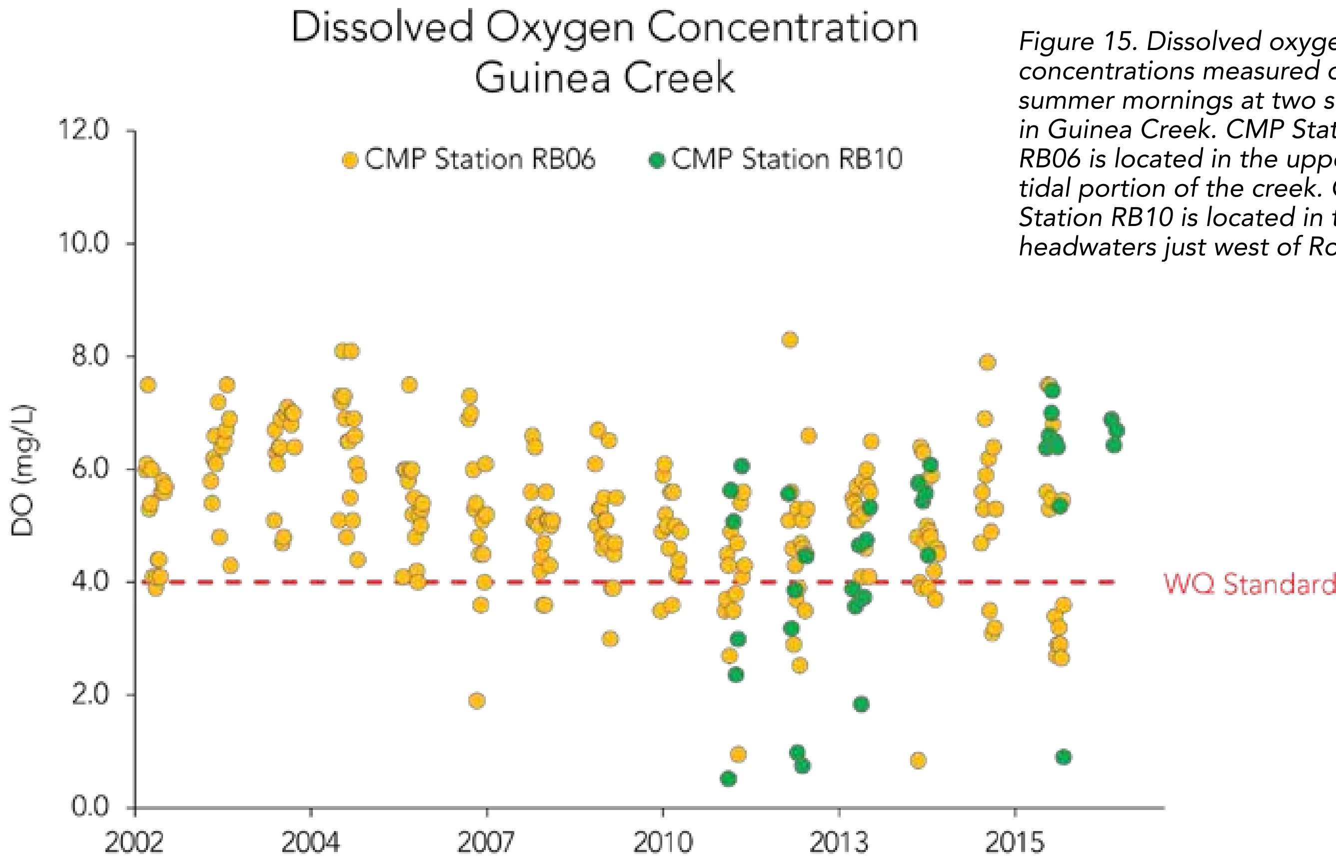


Figure 15. Dissolved oxygen concentrations measured on summer mornings at two stations in Guinea Creek. CMP Station RB06 is located in the upper tidal portion of the creek. CMP Station RB10 is located in the fresh headwaters just west of Route 24.

INDICATOR: BACTERIA CONCENTRATIONS

Recreational use of the waters of the Inland Bays is a primary attraction for coastal residents and visitors who love boating, fishing, swimming, and other water activities. Unfortunately, concentrations of indicator *Enterococcus* bacteria often exceed the safe swimming standards in the Bays' creeks and canals.

Potentially harmful waterborne pathogens can enter waterways from many sources, including waste from wildlife, pets, septic systems, manure, and marine sanitation devices (MSDs) Impervious surfaces such as roofs, roads, and parking lots in developed areas can accumulate bacteria that wash into creeks and the Bays with stormwater runoff. With more impervious surface comes more bacteria. In Herring and Guinea Creeks, monitoring of recreational water quality is conducted by the University of Delaware Citizen Monitoring Program (CMP). They measure concentrations of *Enterococcus*, a type of bacteria that can indicate the presence of other harmful bacteria and pathogens. While *Enterococcus* is not usually harmful to humans, it does indicate that sources of fecal matter are present, and therefore more harmful pathogenic bacteria and viruses may be present as well.

Different bacteria standards are set for freshwater and saltwater. In freshwater areas, a maximum standard of 104 colonies (CFUs) of *Enterococcus* bacteria in a single 100 milliliter sample of water is used to assess the health of individual water samples and to close waters for swimming. The long-term average must be less than 35 CFUs of *Enterococcus* per 100 milliliters of water. In freshwater portions of creeks, the single sample limit is 185 CFU per 100 milliliters, and the long-term average limit is 100 CFU per 100 milliliters. Varying advisory standards are provided to prevent unnecessary beach closures due to variation from a single sample.

Bacteria concentrations can vary by location within a tributary, typically increasing upstream and decreasing downstream where there is more mixing and dilution with saltier bay water. Bacteria counts also generally are higher following heavy rain events.

Guinea Creek has consistently had extremely high levels of *Enterococcus* bacteria, indicating that there are sources of fecal pollution in the watershed. Since at least 2003, average annual

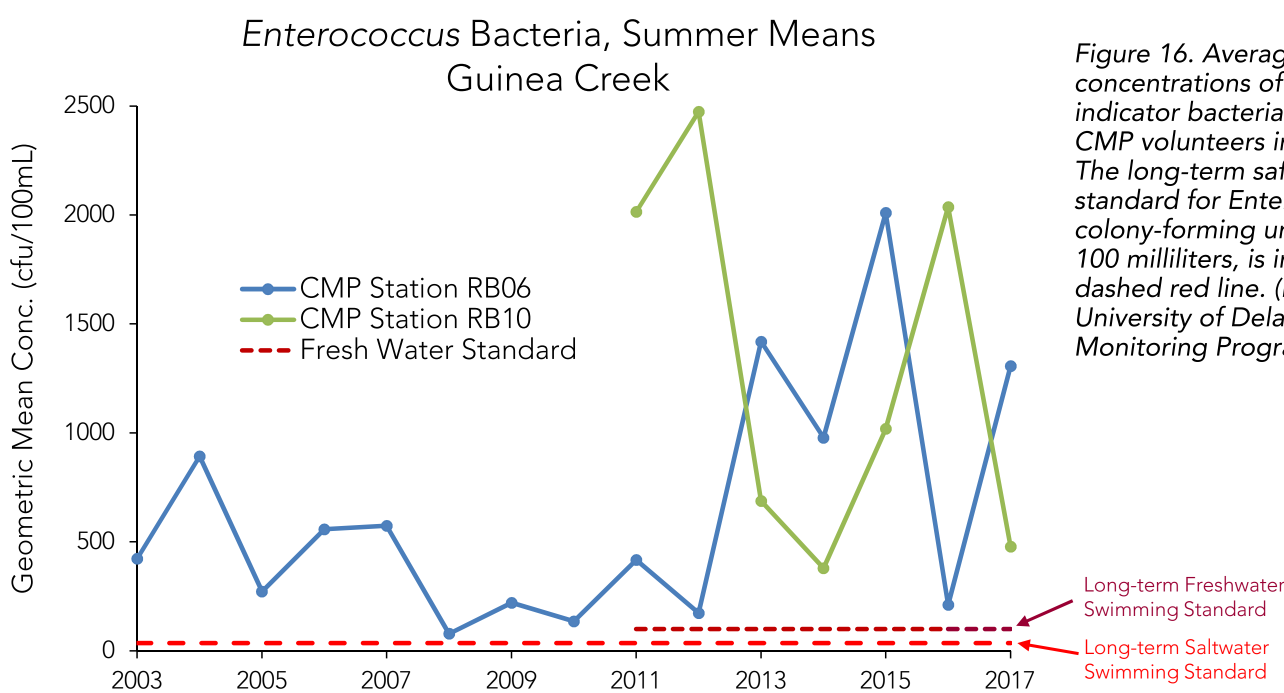


Figure 16. Average summertime concentrations of Enterococcus indicator bacteria measured by CMP volunteers in Guinea Creek. The long-term safe swimming standard for Enterococcus, 35 colony-forming units (cfu) per 100 milliliters, is indicated by the dashed red line. (Data source: University of Delaware Citizen Monitoring Program)

concentrations of *Enterococcus* bacteria at the station also have remained well above the long-term safe swimming standard (Figure 16). In fact, at all three Guinea Creek monitoring stations, summertime *Enterococcus* concentrations failed to meet the single-sample safe swimming standard 69-95% of the time. Less long-term bacteria data is available for Herring Creek.

There are many potential sources of fecal pollution—human sources, domestic animals, and wildlife. Bacteria from non-human sources are much less likely to cause human illness. But determining the main source(s) of Enterococcus bacteria in creeks can be challenging. The consistently high concentrations of bacteria in Guinea Creek recently prompted DNREC to partner with Salisbury University on a study to determine whether the primary source of these bacteria might be human waste (Frana, 2016). This type of study is called "microbial source tracking" and is based on detection of genetic markers found in fecal bacteria that come from a particular host animal.

Samples of water collected in the creek at Banks Road were tested for the presence of genetic markers designed to specifically detect human fecal sources. The Baywood Country Club surrounds this portion of Guinea Creek, and there was concern that some of the fecal bacteria contamination might be of human origin due to the close proximity of Baywood's wastewater lagoon and septic systems in the nearby residential areas. None of the twelve water samples collected between December 2015 and November 2016, however, showed evidence of human fecal sources. An earlier study conducted by the University of Delaware in 2012-2013 showed a human signal in 18% of the samples collected in Guinea Creek.

The implication is that most of the fecal bacteria detected in Guinea Creek come from non-human sources. These could include wildlife, animal agriculture, or domestic pets. Further studies are recommended to determine with more certainty what the primary sources of fecal bacteria are in the creek.

LOOKING AHEAD—BACTERIA

- Herring and Guinea Creeks have many potential human and animal sources of fecal bacteria. Additional studies may provide a better understanding of the specific sources responsible for the high concentrations seen in summer months in the mid- to upper portions of the tributaries.
- The County's work to convert septic systems to central sewer service in the watershed has the potential to reduce the amount of fecal bacteria entering the creeks.
- Communities on Herring and Guinea Creeks could reduce their input of bacteria in the water through improved stormwater management and planting or protection of forested buffers near the water.

photo credit: Driscoll Drones

INDICATOR: WATER CLARITY

Because all plants need sunlight to grow, clear water is essential for underwater bay grasses to grow. Algae blooms and/or suspended sediments can reduce clarity and prevent sunlight from reaching the bottom of creeks and bays to support plant life and associated habitats. Thus water clarity is a good indicator of water quality.

Water clarity is often measured by lowering a black and white Secchi disk into the water until its markings can no longer be seen. An average Secchi depth of at least 0.67 meters is generally needed for bay grasses to grow in shallow tidal waters. Secchi depth values below 0.67 meters indicate water that is too cloudy for underwater grasses to grow well.

Water clarity measurements are available for both DNREC monitoring stations in Herring and Guinea Creeks - Stations 308031 (Burton Pond) and 308051, respectively - and for CMP station RB06 in the tidal portion of upper Guinea Creek (Figure 17).

Over the long term, there has been little change in the overall clarity of water in Guinea Creek. Measured clarity often fails to meet the water quality standard. Although the Secchi depth standard of 0.67 meters does not apply to freshwater sites such as Burton Pond, water clarity data collected there has shown a significant gradual degrading trend; eight of the last nine years have seen the lowest median clarity measurements across the period of record. The reason for this is unclear.

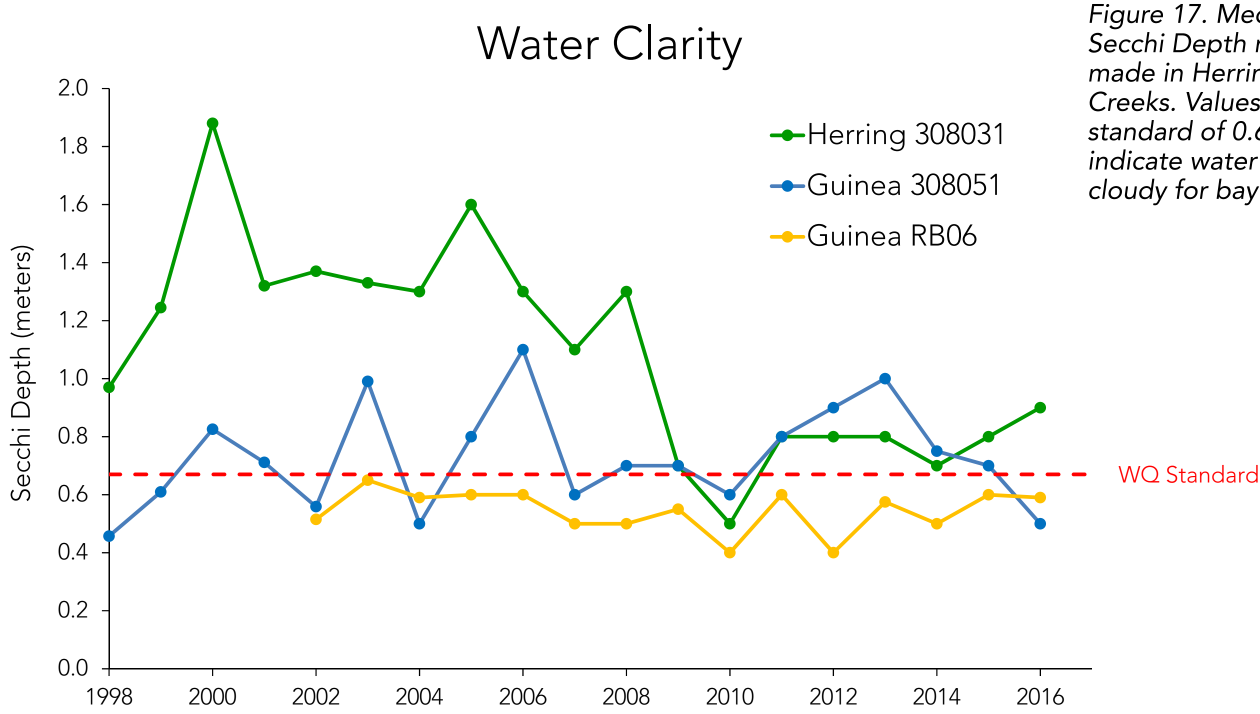


Figure 17. Median annual Secchi Depth measurements made in Herring and Guinea Creeks. Values below a standard of 0.67 meters indicate water that is too cloudy for bay grasses to grow.

INDICATOR: ALGAE CONCENTRATION

In healthy bay waters, floating microscopic algae provide food for fish, shellfish, and other invertebrates. In waters with excessive concentrations of nutrients, however, algae grow out of control and blooms occur. If the blooms persist, waters become too cloudy for bay grasses to grow, and dissolved oxygen concentrations may plummet.

Algae abundance is indicated by measurements of the concentration of green pigment (known as chlorophyll *a*) in water samples. Concentrations below 15 micrograms per liter of water (μg/L) are considered healthy in tidal waters. No numerical standard exists for fresh, non-tidal waters.

Median annual algae concentrations in samples collected since 1998 from the monitoring station at the Burton Pond dam in Herring Creek have not fluctuated greatly, and they consistently have been relatively low (Figure 18). This is a bit surprising given the high concentrations of nitrogen and phosphorus at this location, but other factors in the pond may influence the algae abundance there.

Concentrations of algae in Guinea Creek, however, often fail to meet the water quality standard. There does appear to be a slight downward trend in algae concentration at the Guinea Creek monitoring stations, though, and median values are approaching healthy levels. This is a good sign if it continues.

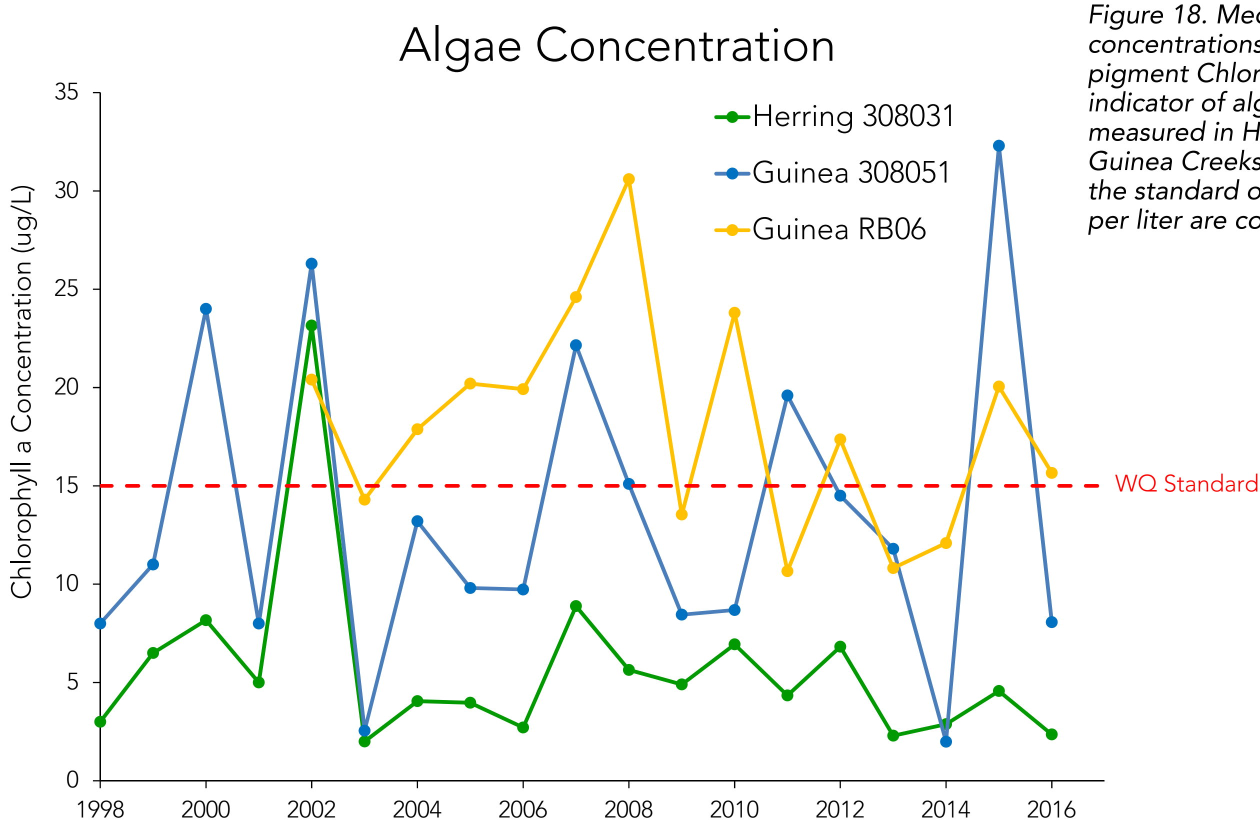


Figure 18. Median annual concentrations of the algal pigment Chlorophyll-a (an indicator of algae abundance) measured in Herring and Guinea Creeks. Values below the standard of 15 micrograms per liter are considered healthy.

CONCLUSIONS

Like many other areas of the Inland Bays watershed, the landscape of the Herring and Guinea Creek watershed is becoming urbanized as forested and agricultural lands are converted to development. Nutrient pollution from development generally is less than that from fertilized agricultural lands, but urbanization presents stormwater runoff and wastewater challenges. Loss of wetlands and forested buffers that filter water, provide habitat for native plants and animals, and help prevent flooding is also of concern.

In positive trends, nutrient inputs from septic systems will lessen as even more communities in the watershed are converted to central sewer service. One hundred percent of the homes located along the waterways on Burton Pond, Hopkins Prong, Herring Creek and Guinea Creek either currently have, or are planned for, available sanitary sewer infrastructure. Additional sewer districts west of Route 24 continue to be annexed to the county sewer system.

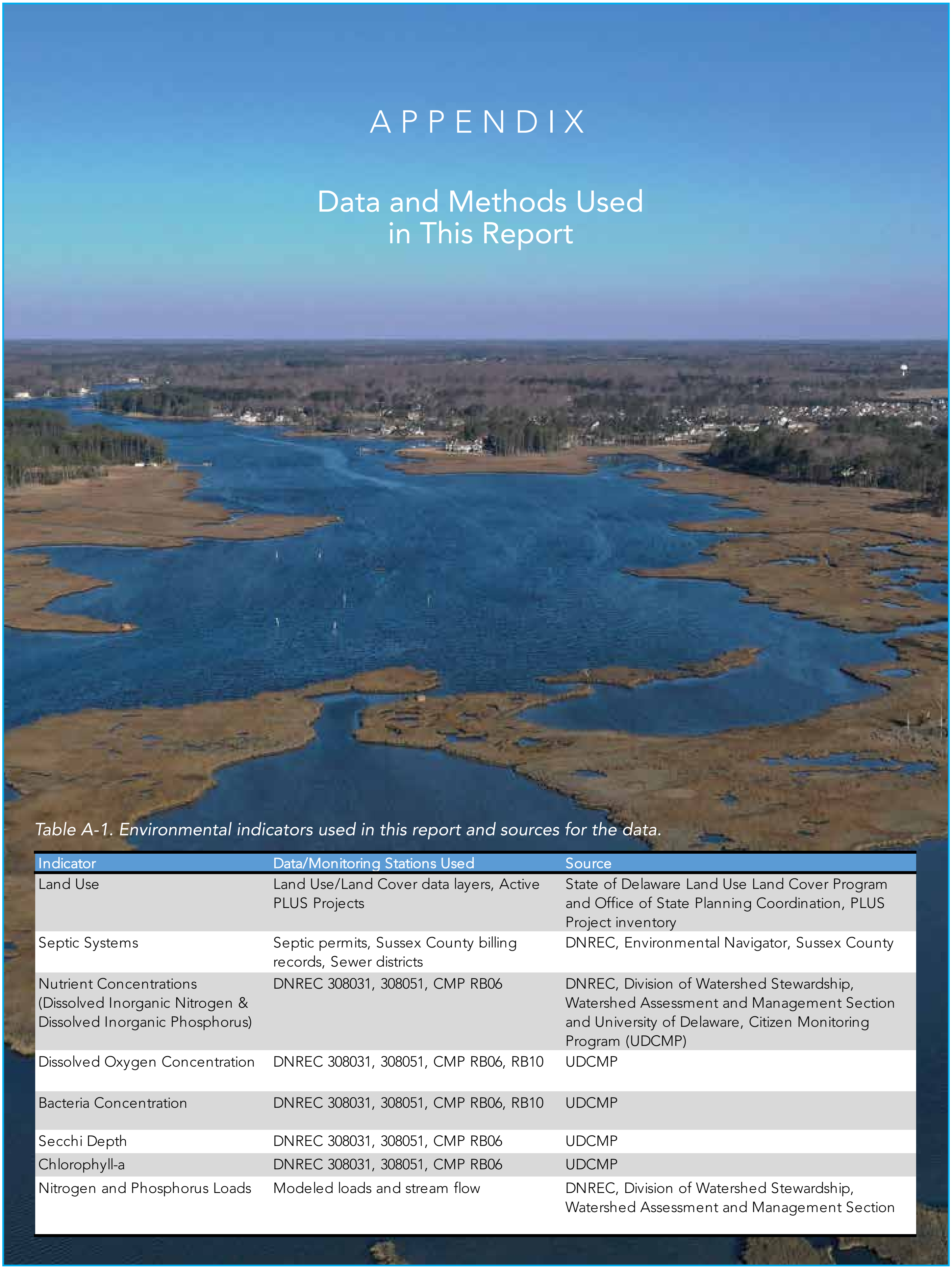
Nitrogen and phosphorus inputs to Herring and Guinea Creeks, as measured by the state, are largely meeting the standards set by Total Maximum Daily Load (TMDL) regulations. Despite this, however, both creeks remain highly polluted by excess nitrogen and phosphorus. Annual median concentrations of nitrogen exceed healthy limits by as much as ten to twelve times. Water quality does not appear to be improving, despite many years of effort to remove sources of nutrient inputs. The result is excessive algae growth, murky water, and low dissolved oxygen that is harmful to fish and other aquatic life. Dissolved oxygen measurements made in Guinea Creek during early morning hours of the summer have increasingly fallen to unhealthy levels in recent years.

Concentrations of fecal indicator bacteria in upper portions of Guinea Creek far exceed standards for safe swimming and shell fishing. However, preliminary studies indicate that wildlife (rather than humans or domestic animals) may be the source of much of the fecal bacteria load.

RECOMMENDATIONS FOR CLEANER CREEKS

Much work clearly remains to reduce or eliminate sources of nutrient pollution to Herring and Guinea Creeks. That nitrogen and phosphorus concentrations remain extremely high, despite the work that has already been done to reduce pollutant loads, suggests that some major pollution sources are not being captured by current monitoring efforts. The number of locations and frequency of monitoring of nutrients, dissolved oxygen, and algae abundance should be expanded in order to better understand degrading water quality trends.

Developed and developing land use is increasing dramatically in the watershed. Thus it is crucial that the water quality impacts of this development be mitigated through control and treatment of stormwater runoff and continued improvements in treatment of wastewater. Sustainable financing for clean water projects in the watershed is critically needed to support these efforts. Developers and communities must do more to preserve or restore buffers along waterways and to adopt best practices for stormwater management, lawn care, and control of pet wastes in order to reduce inputs of nutrients and bacteria to the waterway.



APPENDIX

Data and Methods Used in This Report

Table A-1. Environmental indicators used in this report and sources for the data.

Indicator	Data/Monitoring Stations Used	Source
Land Use	Land Use/Land Cover data layers, Active PLUS Projects	State of Delaware Land Use Land Cover Program and Office of State Planning Coordination, PLUS Project inventory
Septic Systems	Septic permits, Sussex County billing records, Sewer districts	DNREC, Environmental Navigator, Sussex County
Nutrient Concentrations (Dissolved Inorganic Nitrogen & Dissolved Inorganic Phosphorus)	DNREC 308031, 308051, CMP RB06	DNREC, Division of Watershed Stewardship, Watershed Assessment and Management Section and University of Delaware, Citizen Monitoring Program (UDCMP)
Dissolved Oxygen Concentration	DNREC 308031, 308051, CMP RB06, RB10	UDCMP
Bacteria Concentration	DNREC 308031, 308051, CMP RB06, RB10	UDCMP
Secchi Depth	DNREC 308031, 308051, CMP RB06	UDCMP
Chlorophyll-a	DNREC 308031, 308051, CMP RB06	UDCMP
Nitrogen and Phosphorus Loads	Modeled loads and stream flow	DNREC, Division of Watershed Stewardship, Watershed Assessment and Management Section

LAND USE DATA

Land use data for the Herring and Guinea Creek watershed were obtained from the State of Delaware, Office of State Planning Coordination, which sponsors development of land use/land cover information derived from aerial photography acquired every five years (the program began in 1992), during early spring/late winter, leaf-off season. 2012 data were the most recently available at the time this report was written.

The land use data are broken into 56 categories based on the Anderson 3-digit classification code. For purposes of the Herrin/Guinea Creek analysis, these were simplified into six generalized categories, which match categories used in previous "Your Creek" studies (Figure A-1).

Figure A-1. Correspondence of Anderson Land Use Code to simplified land cover class.

LULC Category	
Airports	Developed
Communication - antennas	Developed
Highways/Roads/Access roads/Freeways	Developed
Industrial	Developed
Institutional/Governmental	Developed
Junk/Salvage Yards	Developed
Marinas/Port Facilities/Docks	Developed
Mixed Residential	Developed
Mixed Urban or Built-up Land	Developed
Mobile home Parks/Courts	Developed
Multi Family Dwellings	Developed
Other Commercial	Developed
Other Urban or Built-up Land	Developed
Parking Lots	Developed
Railroads	Developed
Recreational	Developed
Retail Sales/Wholesale/Professional Serv	Developed
Single Family Dwellings	Developed
Transitional (incl. cleared, filled, and grad	Developed
Utilities	Developed
Vehicle Related Activities	Developed
Warehouses and Temporary Storage	Developed
Total Developed	Developed
Confined Feeding Operations/Feedlots/H	Agriculture
Cropland	Agriculture
Farmsteads and Farm Related Buildings	Agriculture
Herbaceous Rangeland	Agriculture
Idle Fields	Agriculture
Mixed Rangeland	Agriculture
Orchards/Nurseries/Horticulture	Agriculture
Other Agriculture	Agriculture
Pasture	Agriculture
Shrub/Brush Rangeland	Agriculture
Total Agriculture	Agriculture
Clear-cut	Upland Forest
Deciduous Forest	Upland Forest
Evergreen Forest	Upland Forest
Mixed Forest	Upland Forest
Total Upland Forest	Upland Forest
Bays and Coves	Water
Man-made Reservoirs and Impoundment	Water
Natural Lakes and Ponds	Water
Non-tidal Open Water	Water
Waterways/Streams/Canals	Water
Total Water	Water
Non-tidal Emergent Wetland	Wetland
Non-tidal Forested Wetland	Wetland
Non-tidal Scrub/Shrub Wetland	Wetland
Tidal Emergent Wetland	Wetland
Tidal Forested Wetland	Wetland
Tidal Scrub/Shrub Wetland	Wetland
Tidal Shoreline	Wetland
Total Wetland	Wetland
Beaches and River Banks	Other
Extraction	Other
Inland Natural Sandy Areas	Other
Total Other	Other

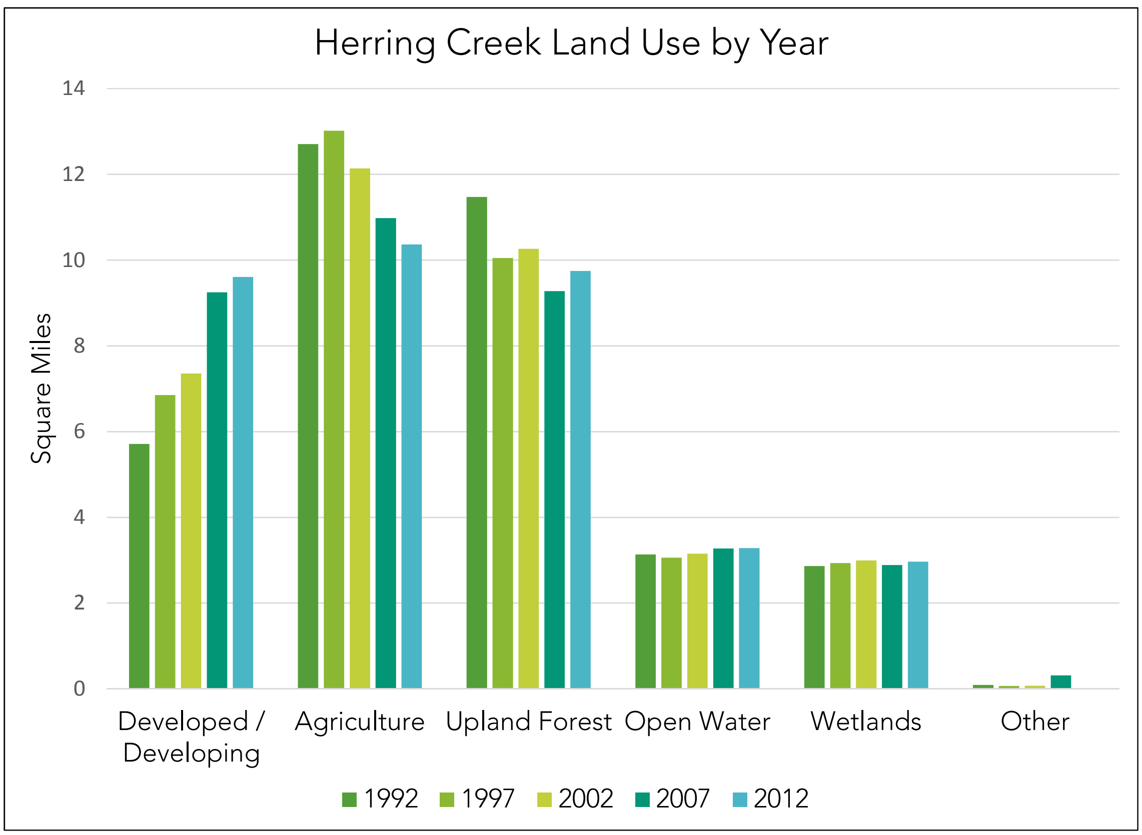
Figure A-2 summarizes the changes across the six categories, within the Herring and Guinea Creek watershed, for each of the five year periods. The percent of land use for each broad category from 1992 was compared to the current percent in the 2012 land use data.

ADDITION OF DEVELOPMENT PROJECT AREAS

Polygon shapefiles of development projects proposed to the State of Delaware Office of Planning's Preliminary Landuse Service from 2007 to 2012 were obtained from Delaware First Map (http://firstmap.delaware.gov). Project areas were clipped to the Herring and Guinea Creek watershed outline. Developed & Developing land uses from the 2012 land use layer were then erased from the proposed development layer to exclude proposed developments that were already built or under construction. This resulted in proposed projects intended for construction.

Project areas are the entire outline of the parcels to be developed. They include lands to be developed as well as lands to be left in the existing land use as open space. The percentage of open space for a proposed development is variable depending on a number of factors. Therefore, project areas cannot be used as an accurate estimate of land use conversion to development. However, they can be used as a more general approximation of the level of intended development intended in the watershed.

Figure A-2. Land use change in the Herring and Guinea Creek watershed, 1992-2012.



SEPTIC SYSTEM PERMIT DATA

On-site septic systems are a significant source of pollution in the Inland Bays. Septic information was acquired from the DNREC and from Sussex County.

Septic permit data were downloaded on August 28th, 2017 from Delaware First Map. Parcels in the sewer billing database as well as current delineation of Sussex County Sewer district boundaries were obtained from Sussex County GIS Department. Other sewer districts, including municipal and private districts, had previously been acquired from the Delaware Public Service Commission.

The numbers of septic permit points that are active, and that do not fall within an existing sewered area, were used to calculate the number of actively-used septic systems (i.e., those that are not also in the process of being abandoned). The maps of the entire Inland Bays watershed showed the density of active permits (current) based on this analysis. The change in number of permits is based on previous work (in 2014) of the number of active septic, compared with the current numbers.

Table A-2 summarizes the number of active Inland Bays septic permits in 2016 by watershed, along with the density, in number of septic permits per square mile. Net change in septic permits between 2014 and 2016 was calculated from the total number of permits minus the number of septic permits on properties with sewer service provided by Sussex County (based on Sussex County billing records).

Table A-2. 2016 septic permit summary for watersheds in the Inland Bays.

Watershed	Land Area, Sq. Mi.	Active Septic Permits	Active in Non-sewered Parcels	Acitive in Sewered Parcels	Permit Density (per sq. mi.)	Change in Active Permits 2014-2016
Assawoman Bay	6.8	177	15	162	2	-71
Cow Bridge Branch-Indian River	44.8	2,061	1,818	243	41	369
Dirickson Creek-Little Assawoman Bay	18.9	636	271	365	14	-131
Herring Creek-Rehoboth Bay	33.8	2,557	1,365	1,192	40	-219
Indian River Bay-Indian River Inlet	17.6	1,276	84	1,192	5	-585
Little Assawoman Bay	13.1	244	69	175	5	-61
Long Drain Ditch-Betts Pond	17.6	1,018	878	140	50	128
Love Creek-Rehoboth Bay	24.2	1,684	289	1,395	12	-565
Rehoboth Canal-Rehoboth Bay	11.4	312	9	303	1	9
St. Martin River	7.8	61	13	48	2	-45
Swan Creek-Indian River	29.4	958	482	476	16	-290
Vines Creek-Indian River	35.7	1,238	237	1,001	7	-818
White Creek-Indian River Bay	26.9	1,793	125	1,668	5	-720
Wolfe Glade-Rehoboth Canal	10	224	9	215	1	3
TOTAL	298	14,239	5,664	8,575	19	(2,996)

NUTRIENT LOADS FROM NONPOINT SOURCES

Data for nonpoint source loads of total nitrogen and total phosphorus to the Inland Bays were provided by DNREC's Division of Watershed Stewardship. Annual loading data were available for the years from 2006 through 2015. Prior to 2006, the state's monitoring focused on TMDL development; hence, they many more stations were monitored, but with less frequency. The low frequency of monitoring in those periods did not allow calculation of annual loads with sufficient confidence.

The loads are provided in pounds per year for total nitrogen (TN) and total phosphorus (TP), as well as loading rate per acre of watershed area. Flow information is provided based on the annual mean flow in cubic feet per second at the Millsboro Pond Outlet at Millsboro (USGS 01484525). The daily mean was obtained for each day between 2006 and 2015, and then the yearly mean was calculated using each year's daily mean data.

DISSOLVED NUTRIENT CONCENTRATION DATA

To assess the status and trends of water quality in the Herring and Guinea Creek tributaries, dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) trends were considered using data both from DNREC long-term monitoring stations and the University of Delaware Citizen Monitoring Program (CMP) stations. Elevated levels of DIN and DIP lead to the potential for eutrophication in bodies of water.

DNREC maintains one monitoring station in Herring Creek (308031) and one in Guinea Creek (308051), both of which lie at the approximate location of the head-of-tide. Two long-term CMP stations, RB06 and RB10, are located in Guinea Creek, the former in the tidal portion, and the latter in the non-tidal, freshwater portion.

DNREC station data were available from 1998 to the present, and CMP data were available from 2003 to 2016 (for RB06) and 2010 to 2017 (for RB10). DNREC monitoring data were accessed from the U.S. EPA STORET data archive, and CMP data were received from program personnel.

DNREC monitoring stations are generally sampled approximately once per month, and assess a variety of constituents. DIN levels, in mg/L, were obtained by adding Nitrate and Nitrite, plus Ammonia, and DIP was determined based on orthophosphate as P-dissolved. CMP sites are sampled regularly for a variety of parameters, including DIN and DIP. Concentrations were reported in μM and converted to mg/L for comparison.

Data for both stations were subdivided by year, and annual medians calculated and graphed, to assess the status over time relative to state standards (0.14 mg/L for DIN and 0.01 for DIP). Only data collected March through November (the putative eelgrass growing season) were used for this indicator (Valdes-Murtha 1997, Batiuk et al. 2000).

The Inland Bays has a current Total Maximum Daily Load (TMDL) allocation for Enterococcus bacteria and nutrients (nitrogen and phosphorus). Table A-3 shows nonpoint source load allocations and required reductions for nutrients (based on the 1998 TMDL).

Table A-3. Nonpoint source load allocations, Inland Bays TMDL.

<table>
<tr><th rowspan="2">Nonpoint Source Category</th><th colspan="2">Nitrogen</th><th colspan="2">Phosphorus</th></tr>
<tr><th>Load Allocation (kg/d)</th><th>Percentage reduction (%)</th><th>Load Allocation (kg/d)</th><th>Percentage reduction (%)</th></tr>
<tr><td>Agriculture</td><td rowspan="4">1393</td><td rowspan="4">40-85</td><td rowspan="4">78</td><td rowspan="4">40-65</td></tr>
<tr><td>Unsewered Urban</td></tr>
<tr><td>Septic tanks</td></tr>
<tr><td>Others</td></tr>
</table>

DISSOLVED OXYGEN DATA

Dissolved Oxygen (DO) concentrations were obtained at DNREC monitoring stations 308031 (Herring Creek) and 308051 (Guinea Creek), and from CMP stations RB06 and RB10 (in Guinea Creek). DNREC data were available from 2003 through 2016, and CMP data from 2003 (for RB06) and 2010 (for RB10) to 2017.

CMP data were filtered to include only morning readings, when DO levels are lowest, before 9:30 AM local time. Since DNREC samples were often collected after 9:30 AM, the DO data at Stations 308031 and 308051 were not considered in this report.

Sampling data were used from the CMP Stations RB06 (salt water tidal portion of Guinea Creek) and RB10 (fresh water, non-tidal portion of Guinea Creek). Individual grab-samples were graphed and presented in the main body of this report. The percentage of measurements with DO concentration that fell below the state standard of 4.0 mg/L (termed 'exceedances') are presented in Table A-4.

Table A-4. Percentage of morning dissolved oxygen measurements falling below the 4.0 mg/L standard.

Station	Tributary	Season	Observations	Exceedances	% Exceedances	Time of day
DNREC 308031	Herring Creek	All	240	2	0.8%	all
DNREC 308051	Guinea Creek	All	240	9	3.8%	all
CMP RB06 - since 2002	Guinea Creek	All	341	37	10.9%	before 0930
CMP RB06 - since 2002	Guinea Creek	Summer	235	35	14.9%	before 0930
CMP RB06 - since 2007	Guinea Creek	Summer	157	34	21.7%	before 0930
CMP RB10 - since 2011	Guinea Creek	Summer	35	12	34.3%	before 0930

RECREATIONAL WATER QUALITY/ BACTERIA CONCENTRATIONS

Recreational contact safety in Delaware is determined by measuring the number of colony forming units (CFUs) of Enterococcus bacteria per 100 mL of water. The EPA considers Enterococcus to be the best fecal indicator bacteria for estuarine waters; it has the strongest correlation with the risk of people acquiring gastroenteritis from inadvertent ingestion of water.

Bacteria data for CMP Station RB06 (near the head-of-tide in Guinea Creek) were available from 2003 to 2016; for CMP Station RB10 (in the freshwater, non-tidal portion of Guinea Creek) from 2010 to 2017; for DNREC Station 308031 (Burton Pond, upstream of dam) from 1998 to 2016; and for DNREC Station 308051(Guinea Creek at Banks Road) from 1998 to 2016.

Data were filtered to include the summer swimming months, from June through September, and the geometric means for each year were computed and graphed. These annual figures were compared against the long-term standards for salt and freshwater—35 CFU/100mL and 100 CFU/100mL, respectively. Both summer and year-round data also were graphed for each observation and compared against the instantaneous swimming standard—104 CFU/100mL and 185 CFU/100mL, respectively. Counts and percentages of these exceedances were presented in tabular form.

It should be noted that DNREC has a permanent swimming advisory for the entire Inland Bays estuary. Instantaneous geomeans are used by the state to issue advisories only for beaches on the Atlantic Ocean and Delaware Bay.

The following table summarizes the measured levels of enterococcus (CFU/100mL) from individual grab samples, and the number and percentage of times the levels exceeded DNREC's instantaneous swimming standard, reported for the summer swimming season and year-round. Note that the instantaneous swimming standard for salt water differs from the standard for fresh water—185 CFU/100mL versus 104 CFU/100mL, respectively.

Table A-5. Percentage of Enterococcus indicator measurements that exceed the single-sample, instantaneous safe swimming standard at each monitoring station.

Station	Tributary	Standard (CFU/100mL)	Observations	Exceedances	% Exceedances	Season
DNREC 308031	Herring Creek	185	72	9	13%	Summer
DNREC 308051	Guinea Creek	104	72	50	69%	Summer
CMP RB06	Guinea Creek	104	95	79	83%	Summer
CMP RB10	Guinea Creek	185	43	41	95%	Summer
DNREC 308031	Herring Creek	185	192	17	9%	All
DNREC 308051	Guinea Creek	104	194	89	46%	All
CMP RB06	Guinea Creek	104	190	125	66%	All
CMP RB10	Guinea Creek	185	93	62	67%	All

WATER CLARITY DATA

Secchi depth, or the depth at which a reference target (Secchi disk) is no longer visible from surface level when submerged, is a common measure of water clarity. Data from monitoring stations in Herring and Guinea Creeks were used and the annual medians graphed to help discern any trend in this metric.

The depth at which the disk is no longer visible in the water column varies according to many factors, including flow rate, recent precipitation, levels of algae or other floating particulates, and random fluctuations in water clarity, which can occur on a short-term basis. It is therefore more informative to look at annualized median trends in the data to determine if there is any systematic change over time, which could indicate watershed or water-quality degradations (or improvements). Persistent changes in the clarity of the water column can affect phytoplankton and algal levels, as well as submerged aquatic vegetation (SAV) (Valdes-Murtha, L. M., 1997), which In turn has an effect on dissolved oxygen (DO) levels and a water body's ability to support biotic diversity.

Secchi depth values collected during the eelgrass growing season (March through November) were used for analyses. Values were related to the eelgrass restoration criteria developed in the Chesapeake Bay, as refined for the Delmarva Coastal Bays (Valdes-Murtha 1997, Batiuk et al. 2000). Trends were analyzed using linear regression. A significant downward trend was detected in Secchi depth at Herring Creek Station 30831 ($p<0.03$).

CHLOROPHYLL-A CONCENTRATIONS

The level of chlorophyll a (Chl-a) in a water body is a measure of the amount of algae found there, and therefore the level of nitrification in that water body. While a certain level of algae in the water indicates a healthy level of algal activity, excessive nutrient levels can lead to unhealthy blooms followed by die off, potentially leading to low DO or even release of toxins as bacteria break down the plant material.

Chl-a data were obtained for one monitoring station in Herring Creek—DNREC station 308031—and one station in the tidal portion of Guinea Creek—CMP station RB06. Annual median values (in micrograms per liter, or ug/L) were graphed. Only data collected March through November were used for analyses. Values were related to the eelgrass restoration criteria developed in the Chesapeake Bay, as refined for the Delmarva Coastal Bays (Valdes-Murtha 1997, Batiuk et al. 2000).

Figures A-3 through A-6 present the instantaneous summer values of Enterococcus concentration (CFU/100 mL) for each monitoring station, showing the applicable instantaneous swimming standard. The Y-axis is logarithmic.

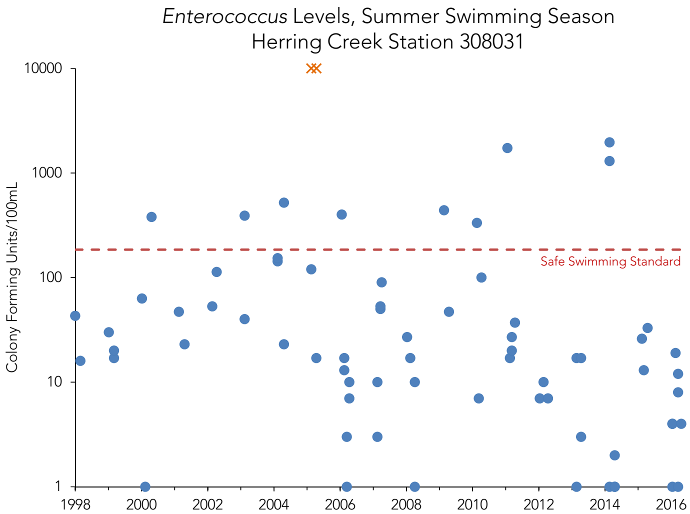


Figure A-3. Summertime Enterococcus measurements at Herring Creek Station 308031, Burton Pond dam. This station is on the upstream side of the dam. Therefore data are compared to the single-sample standard for primary contact recreation in fresh waters (185 CFU/100 mL). 13% of measurements at this station exceed the standard. Orange X's represent measurements above the upper limit of quantification.

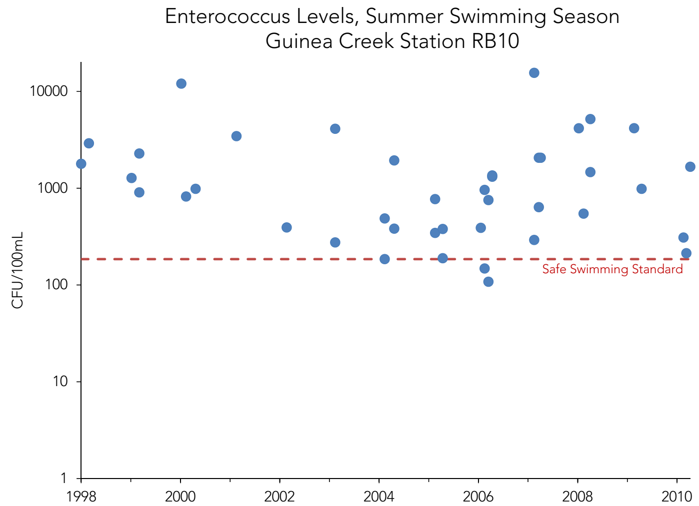


Figure A-4. Summertime Enterococcus measurements at Guinea Creek CMP Station RB10, in the fresh headwaters of the creek. Data are compared to the single-sample standard for primary contact recreation in fresh waters (185 CFU/100 mL). 95% of measurements at this station exceed the standard.

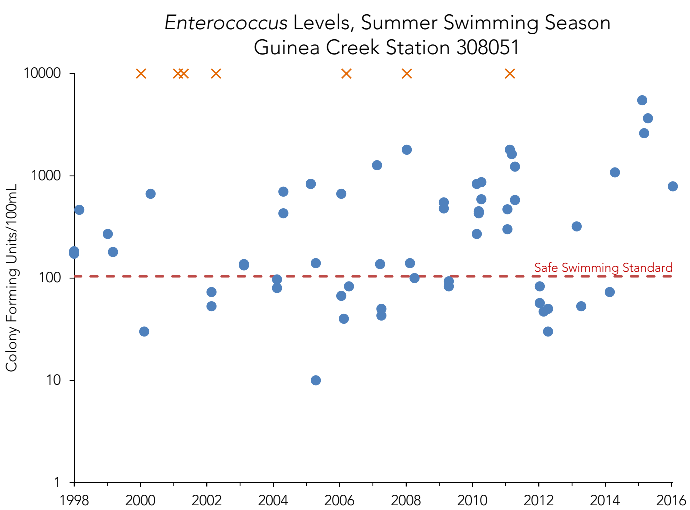


Figure A-5. Summertime Enterococcus measurements at Guinea Creek DNREC Station 308051, located at the crossing of Banks Road. Data are compared to the single-sample standard for primary contact recreation in brackish and marine waters (104 CFU/100mL). 69% of measurements at this station exceed the standard. Orange X's represent measurements above the upper limit of quantification.

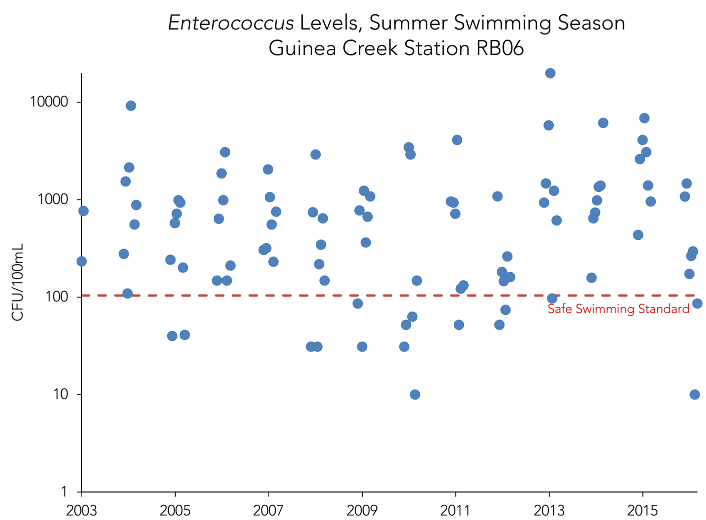


Figure A-6. Summertime Enterococcus measurements at Guinea Creek CMP Station RB06. Data are compared to the single-sample standard for primary contact recreation in brackish and marine waters (104 CFU/100mL). 83% of measurements at this station exceed the standard.

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To preserve, protect and restore Delaware's Inland Bays and their watershed.

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