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

The State of Your Creek

Love Creek 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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Cover photo: *Love Creek,* photo by Sally Boswell

Figure 1. 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 Route 1, through Dewey Beach, Bethany Beach and Fenwick, the Inland Bays lay to the west.

They are unique places where 'the rivers meet the sea'… where freshwater flowing from the land and down tributaries mixes with seawater that flows through inlets carved into barrier islands.

A collage of saltmarshes, tidal flats, bay grass meadows, oyster reefs and winding saltwater creeks make up this environment. For thousands of years, the Bays have supported an abundance of fish and birds that come here to feed, reproduce, and grow. The beauty and productivity of this estuary now supports a thriving human culture and economy.

The Bays are dynamic, constantly changing in response to human activities and the climate.

Fifty years ago, the Bays were thought to be generally healthy: clear waters with plentiful bay grass meadows, productive oyster reefs, and oxygen levels that supported diverse and plentiful fish populations.

But years of accumulated nutrient pollution and habitat loss have changed the Bays to generally murky waters that are dominated by algae, have very few bay grasses or oysters, and do not support healthy oxygen levels in many areas. Habitat restoration and major pollution reductions are needed to restore water quality and achieve a healthy estuary once again. Since the adoption of the 1995 Inland Bays Comprehensive Conservation and Management Plan, much progress has occurred toward these goals.

Now some environmental indicators suggest that accomplishments made under the Plan are bearing fruit and may be moving the Bays back in a healthy direction

State of Love Creek Report

This *State of Love Creek* report is a compilation of environmental data about Love Creek and its watershed to provide communities and concerned citizens with information they can use to help restore and protect their creek. Seven environmental indicators, including land use, nutrient and bacteria pollution, and aquatic vegetation were selected to provide a snapshot of the *State of Love Creek*, using the most recent data available, as well as trends in condition over time.

The report is a project of the Delaware Center for the Inland Bays 'Your Creek' initiative, a multi-year project to introduce residents and property owners in the Inland Bays watershed to their local creek. *Your Creek* is community-based and seeks to empower watershed citizens by providing data on water quality conditions in their creek and land use conditions and practices that can affect water quality.

We began the initiative with Love Creek. A Love Creek Team was formed in 2013 and is working with the Center to learn about their creek, share their creek knowledge with their communities, and take steps to restore and protect their local waters that flow into the Inland Bays.

Love Creek Watershed

Love Creek is a major tributary of Rehoboth Bay that flows into the Bay from the northwest.

The watershed of Love Creek drains approximately 24 square miles of land (Figure 2), and is characterized by a network of mostly two-lane country roads. Patches of upland forest, mostly associated with streams, can be found throughout the watershed, but in recent decades, these have diminished in size and number.

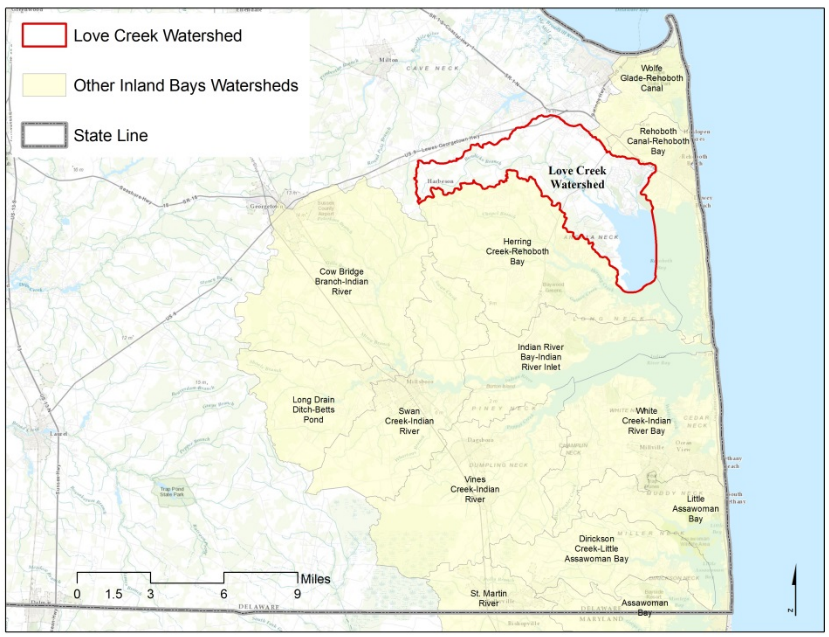


Figure 2. Watersheds of the Inland Bays, showing the location of Love Creek.

Love Creek can be viewed from the Route 24 bridge that crosses the Creek a few miles west of Route 1 Coastal Highway. Looking upstream to the north and west, the creek watershed is mostly rural, but rapidly developing. Looking downstream to the east toward Rehoboth Bay, the watershed is mostly developed with relatively older, established communities.

Love Creek is tidal up to the dam at Goslee Pond, located just upstream of the bridge where Road 277 (Robinsonville Road) crosses the creek. Below the dam, the salinity level increases toward Rehoboth Bay. Data used in this report comes primarily from two water quality monitoring stations on the creek, located near the head of tide and at the Route 24 bridge (Figure 3).

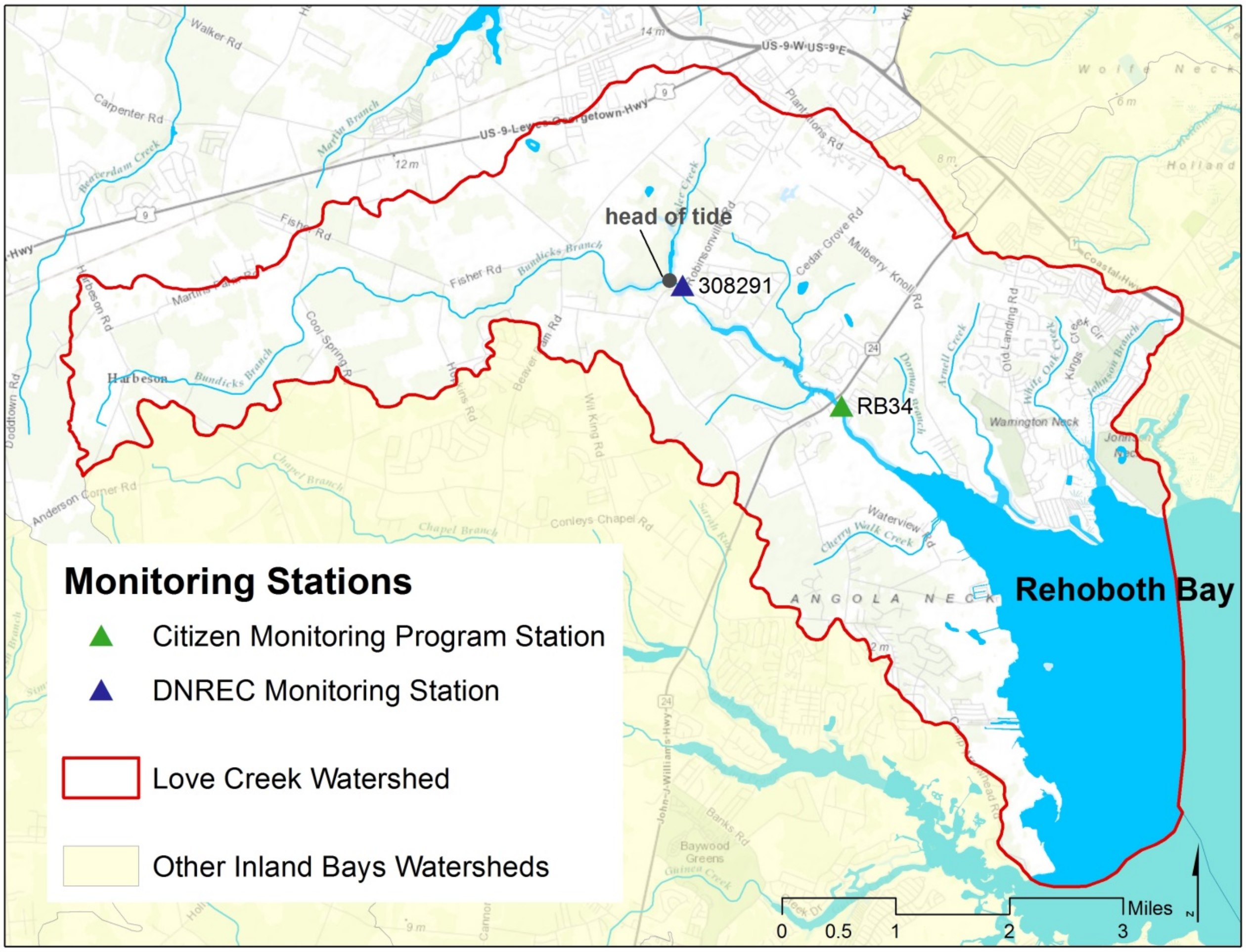


Figure 3. Map of Love Creek watershed showing the tidal area and the location of the two water quality monitoring stations that have provided data for this report.

Sources of Pollution

There are many sources of pollution to Love Creek, including legacy contaminants (contaminants that entered the watershed during an earlier period and are still there), agricultural and residential fertilizers, stormwater runoff from residential and commercial development, and wastewater disposal including septic systems.

There are no significant 'point sources' of pollution entering the Creek (i.e., industrial or wastewater discharges flowing directly into the water from pipes).

Love Creek and its tributaries are currently listed as 'impaired' under the federal Clean Water Act for bacteria and nutrients. Love Creek was removed from the list for dissolved oxygen in 2002, according to the 2012 303(d) list of impaired waters of the state, which is maintained by DNREC. The Inland Bays as a whole has a Total Maximum Daily Load (TMDL) designation for pollutants of concern. More information on this can be found at www.inlandbays.org

The Environmental Indicators Included in this Report

Environmental indicators are specific species and conditions that can be measured over time to determine change in conditions, and how much progress has been made toward restoration goals.

Table 1 below summarizes the indicators considered in assessing watershed health, monitoring stations or data sets used, and the sources of data. Details of data and analyses used in developing this report can be found in the Appendix at the end of this report. The 2011 State of the Bays Report which assessed the health of the Inland Bays can be viewed at http://www.inlandbays.org/wp-content/documents/2011-state-of-the-bays.pdf .

Table 1. Summary of the indicators and sources of data used for the State of Love Creek Report.

Indicator	Data/Stations Used	Source
Land Use	Land Use/Land Cover data layers, Active PLUS[1] 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, CPCN[2] areas	DNREC Division of Water, Sussex County, and Delaware Public Service Commission
Nutrient Loads	Modeled loading data table	DNREC Division of Watershed Stewardship, Watershed Assessment and Management Section
Dissolved Nitrogen and Phosphorus Concentrations	DNREC Station #308291, UDCMP[3] Station RB34	DNREC Division of Watershed Stewardship, Watershed Assessment and Management Section and University of Delaware, Citizen Monitoring Program
Bay Grasses	Field observations	UDCMP, Center for the Inland Bays
Dissolved Oxygen Concentration	UDCMP Station RB34	UDCMP
Recreational Water Quality (Fecal Indicator Bacteria)	UDCMP Station RB34	UDCMP

[1] Preliminary Land Use Service (PLUS)
[2] Certificate of Public Convenience and Necessity (CPCN)
[3] University of Delaware Citizen Monitoring Program (UDCMP)

Watershed Condition

Indicator: Land use

How humans use the land impacts water quality in waterways that flow into the 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 nutrients to waters, followed by development. Forests contribute few nutrients and healthy wetlands can actually remove nutrients from waters on the way to the Bays.

In 2012, agriculture was the largest use of the land (30%) followed by developed/developing land (23%), forested land (16%) and and wetlands (13%). 18% of the creek watershed was open water.

Over the past two decades, the watersheds of the Inland Bays have developed rapidly.

From 1992 to 2012, land use in the Love Creek watershed changed significantly (Figures 4 and 5).

- *An increase of 2.91 square miles of development (80% increase)*
- *A loss of 1.15 square miles of upland forest (17% decrease)*
- *A loss of 1.87 square miles of agriculture   (18% decrease)*

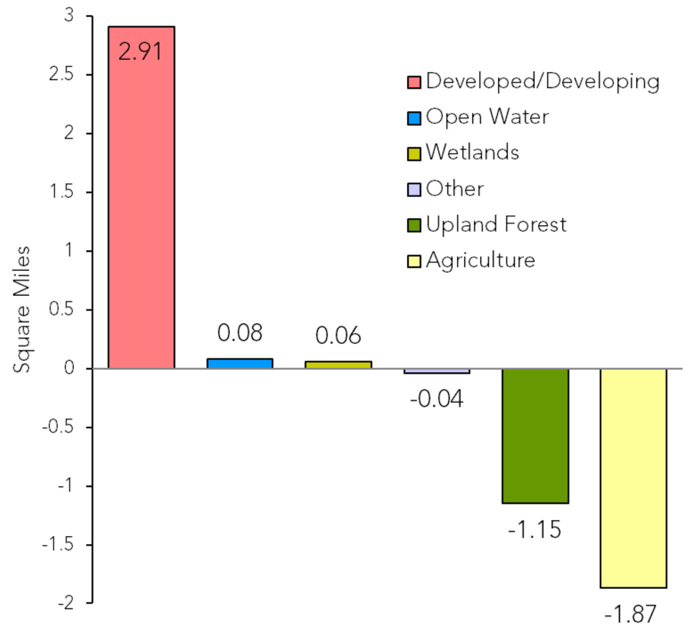


Figure 4. Changes in land use in the Love Creek watershed .between 1992 to 2012.

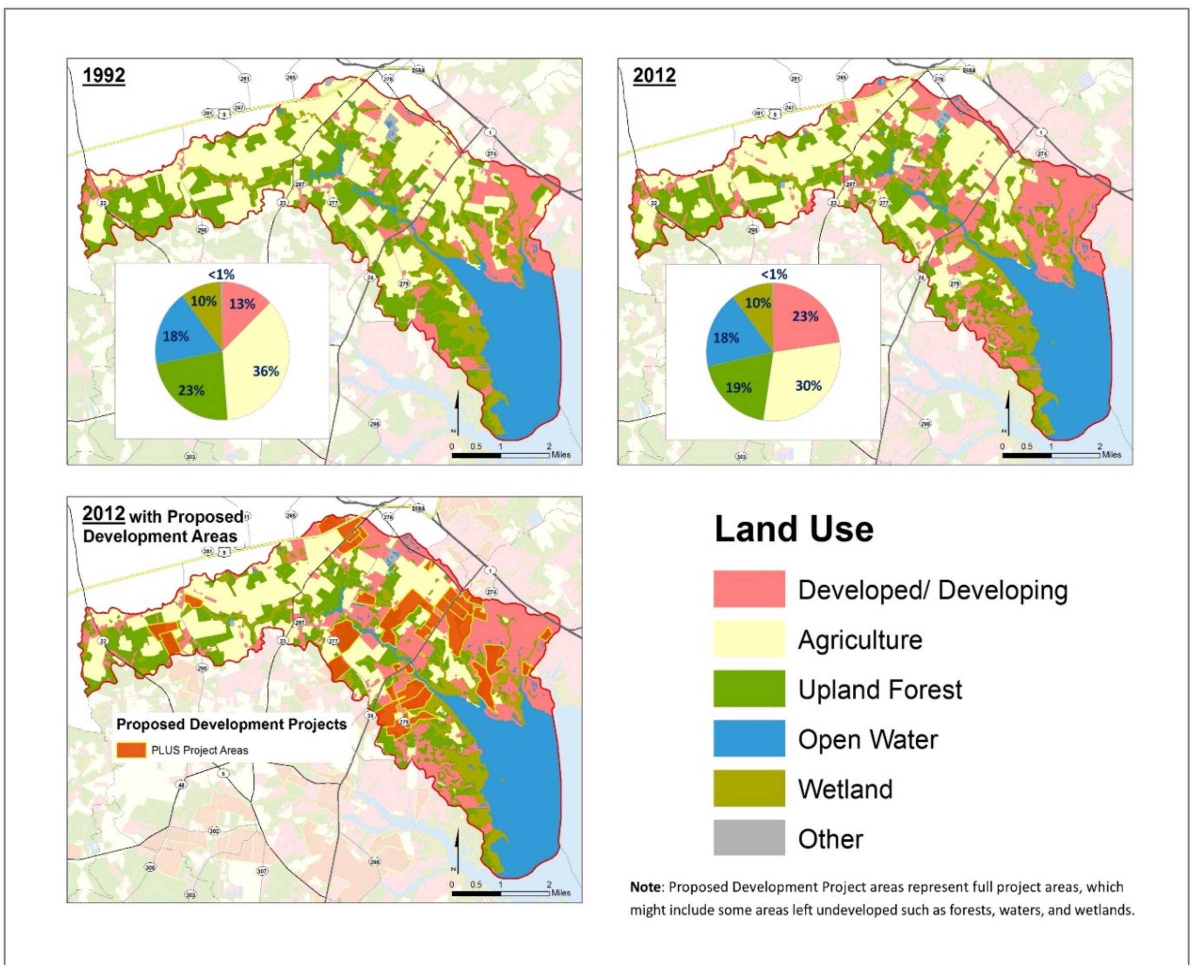


Figure 5. Maps of land use over time in the Love Creek watershed, including proposed development areas.

Looking Ahead – Land Use

- The conversion of croplands to development may reduce nutrient loads to the Creek over time.
- Increased impervious surfaces which come with development will tend to speed the delivery of pollutants to the Creek.
- The loss of forestland to development is also likely to result in more nutrient inputs to the Creek.
- The location of new developments near marshes and creeks may degrade the natural function of wetlands and shorelines.
- Potential future development, as proposed to the State of Delaware Preliminary Land Use Service (PLUS), indicates that rapid development along waterways is likely to continue.

Indicator: Septic System Permits

Septic systems can be a significant source of nutrients to tidal creeks. Even properly maintained septic systems can leach on average, 10.6 pounds of nitrogen and 0.7 pounds of phosphorus into groundwater each year.

Improperly maintained septic systems can also contribute loads of bacteria to creeks if untreated waste reaches the creek through groundwater. There are roughly 18,000 septic systems within the watersheds of the Inland Bays; the densities and number of systems are shown on these maps.

The Love Creek watershed has a high number (1,340) and density of active septic permits (55.5 permits per sq. mi.), relative to other creek watersheds draining to the Inland Bays(Figure 6).

The density map of septic systems in the Love Creek watershed (Figure 7) shows that they are concentrated in the eastern part of the watershed around the lower creek and Rehoboth Bay. While active septic permits still exist in areas in communities where sewer service has been provided, these systems likely are, or soon will be, abandoned.

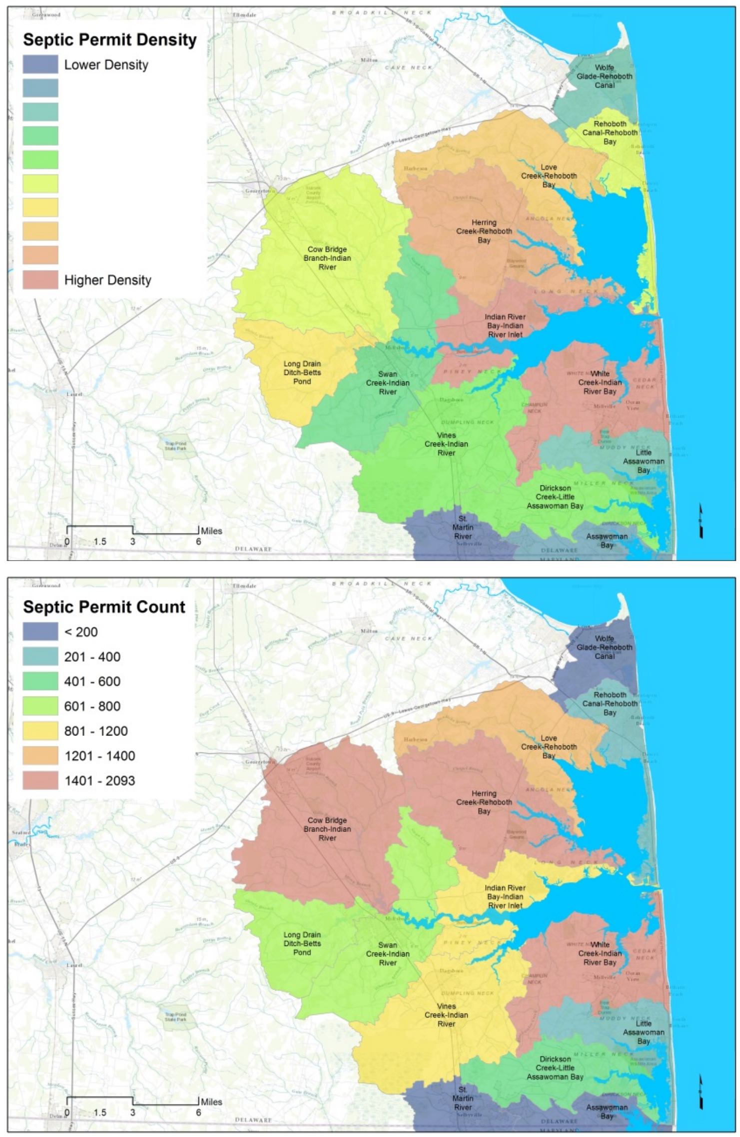


Figure 6. Relative density and numbers of septic system permits in subwatersheds of the Inland Bays.

Looking Ahead – Septics

- Sussex County and private wastewater utilities are expanding sewer service to more communities in the Love Creek watershed (Figure 8). Even properly maintained septic systems leach nutrients into groundwater. Converting septic systems to central sewer provides a much higher level of sewage treatment and eliminates the potential for increased pollution that can occur when septic systems are not regularly maintained.
- 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 pollution to the bays.

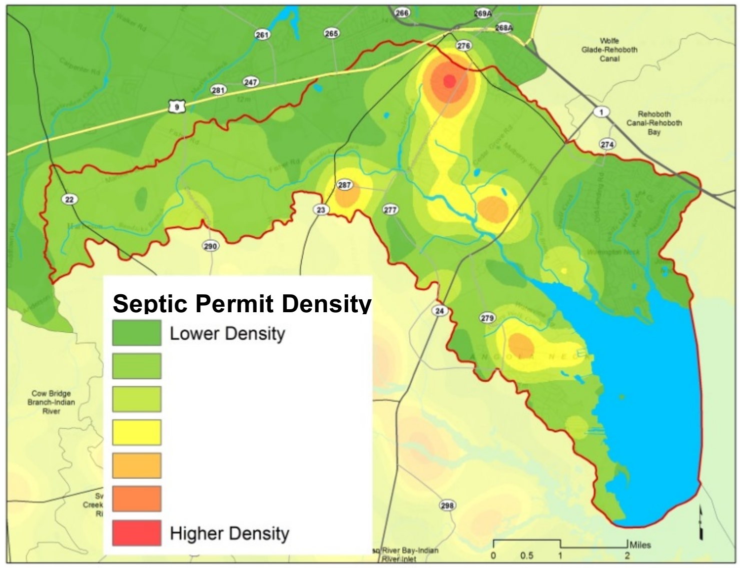


Figure 7. Density map of active septic systems in the Love Creek watershed.

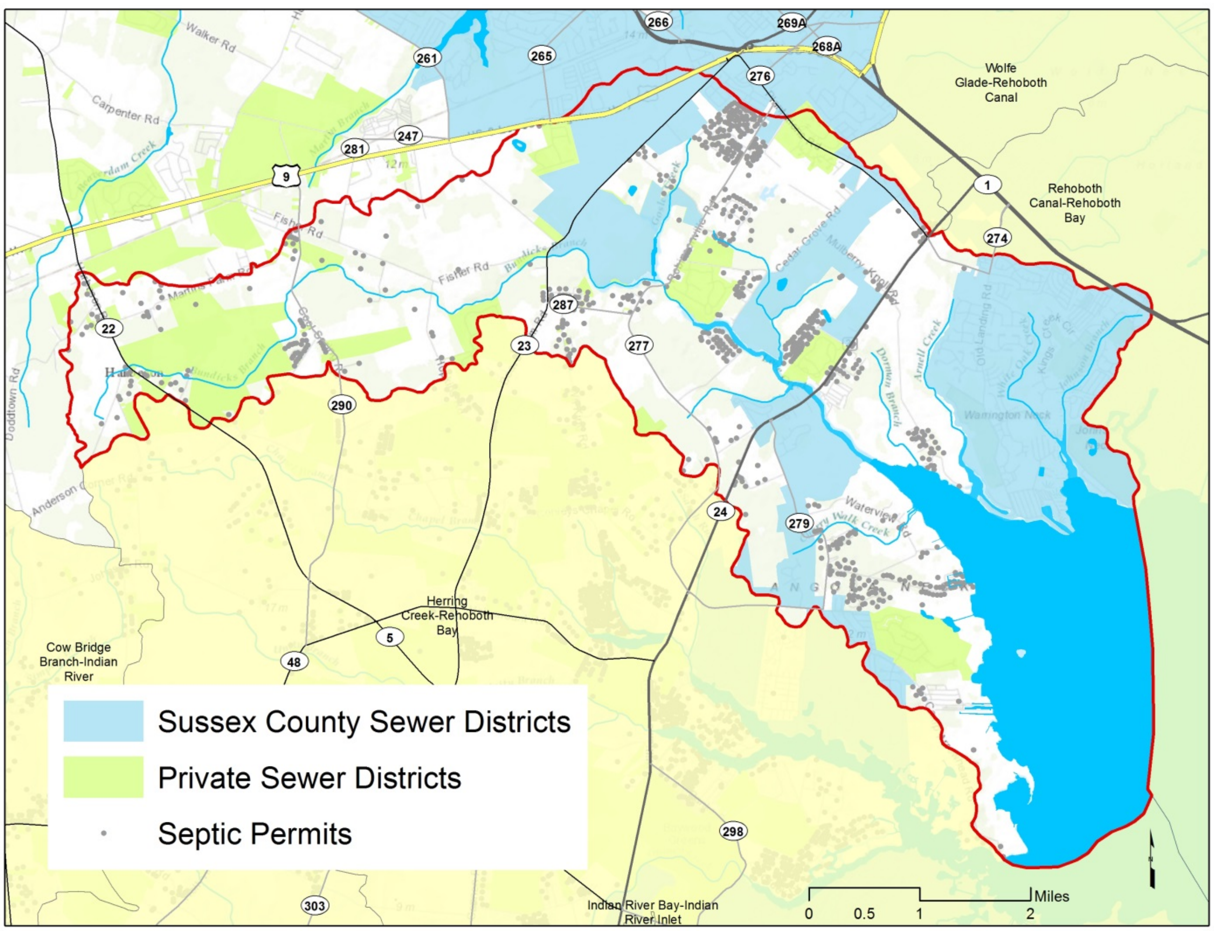


Figure 8. Sewer districts and active septic permits in the Love Creek watershed.

- The Inland Bays PCS also requires that new and replacement septic systems must provide advanced waste treatment (known as 'Performance Standard Nitrogen 3' or PSN3). 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.

Indicator: Nutrient Loads

Nutrients enter the Inland Bays through surface runoff, groundwater, shoreline erosion, and atmospheric deposition. Nitrogen and phosphorus loads vary by land use; farms, developments, even forests contribute nutrients to the creeks. Nutrients in Love Creek are primarily from fertilizers, manure, stormwater runoff, wastewater, and septic systems.

"Nutrient load" refers to the total amount of nitrogen or phosphorus entering the water during a given time, such as "pounds of nitrogen per year." Nonpoint source nutrient loads are calculated from measurements of nitrogen and phosphorus taken over time in the stream - basically *concentration* times *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 highly related to stream flow, which is related to the amount of precipitation in a year. When stream flow is higher, nitrogen and phosphorus loads are generally higher. This is because higher levels of precipitation lead to more polluted surface runoff and groundwater flow into the creek.

Nitrogen Loads

- Nitrogen loads to Love Creek have failed to meet water quality standards every year since 2006. In 2013, nitrogen loads were over twice the TMDL goal (Figure 9).
- There appears to have been no consistent increase or decrease in these loads over time, indicating no significant increase or decrease in sources of nitrogen entering Love Creek.

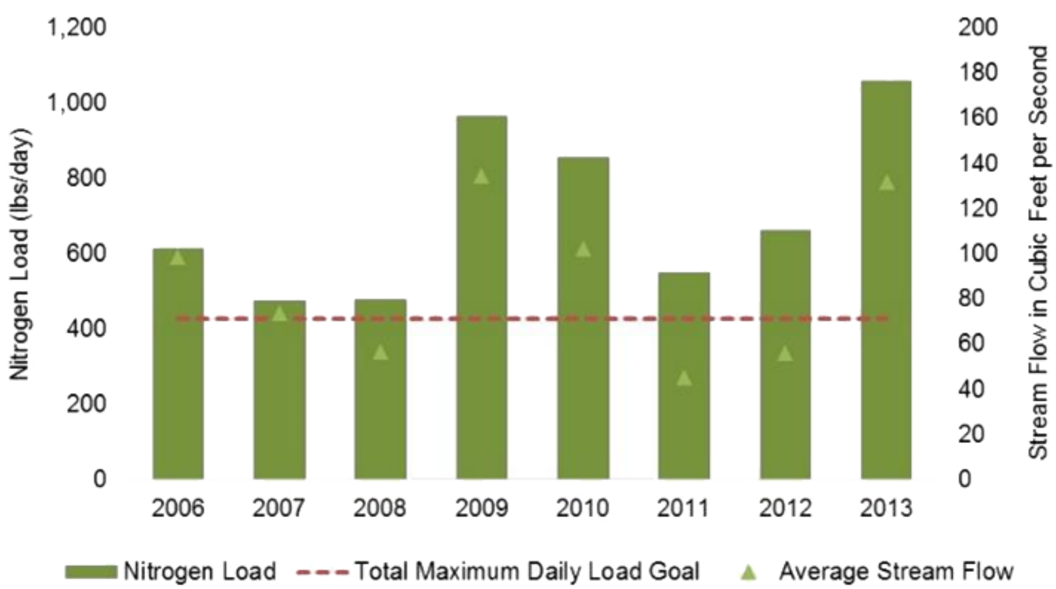


Figure 9. Annual loads of nitrogen to Love Creek, with streamflow.

Phosphorus Loads

- *Phosphorus loads to Love Creek have been well below the Total Maximum Daily Load allowable every year since 2006 (Figure 10).*
- As with nitrogen, phosphorus loads vary from year to year with stream flow (which is tied to precipitation).
- There appeared to be no overall trend of increase or decrease in phosphorus loads, again indicating no significant increase or decrease in sources.

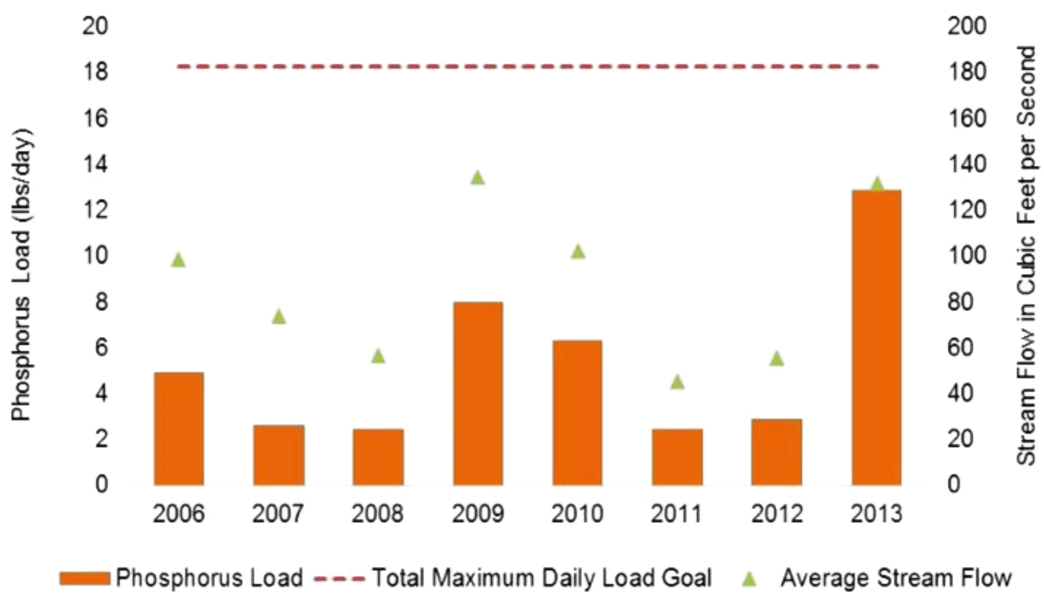


Figure 10. Annual loads of phosphorus to Love Creek, with streamflow.

Water Quality

Indicator: Dissolved Nitrogen and Phosphorous Concentrations

Nutrients are necessary for the growth of beneficial grasses and algae in tidal creeks. However, an excess of nutrients can cause an overabundance of algae, unhealthy dissolved oxygen levels, and cloudy waters.

Water quality can be measured in two ways - by pollutant load, or by pollutant concentration. "Load" is the amount (mass) of a pollutant that is discharged into a water body during a period of time (i.e. pounds per year). The loads of nitrogen and phosphorus are a measure of what is entering the creek and should reflect management and land use changes. "Concentration," on the other hand, is the amount of a pollutant found in a certain volume of water (for example, milligrams of dissolved nitrogen per liter). The concentrations of nutrients in the creek reflect the loads, but they also are affected by the creek biology. Legacy nutrients and unmeasured loads may also impact concentrations in the water. Both concentration and load provide information of environmental significance.

Nutrient concentration is a useful indicator of water quality because it has biological significance to aquatic organisms. The concentration of nutrients in the water will predict the response of plants and animals in the water, and the overall character of the water bodies, regardless of the source of those nutrients. Knowing the sources of the nutrients (land application, groundwater, or atmospheric deposition) is important so that reductions in identified sources can be planned and implemented.

The relationship between nutrient concentration and nutrient load can vary and depends on the flow, the volume of water in the river, and watershed characteristics. Both nitrogen and phosphorus take different forms once they enter the water column, leading to varying dissolved concentrations. Phosphorus tends to become bound onto sediments and may at times be re-released into the water. Both nitrogen and phosphorus are transformed through microbial action and become incorporated into algae and detritus. Mathematical models of nutrient loading from various sources may be used to predict nutrient concentrations in the creek.

Median concentrations of dissolved inorganic nitrogen (DIN) and phosphorus (DIP) on Love Creek were determined from samples taken at two monitoring stations. With a goal to promote healthy dissolved oxygen concentrations at a level needed to allow bay grasses to reestablish in our Bays, the state has established water quality standards for nitrogen and phosphorus (0.14 mg/L and 0.01 mg/L, respectively), which are compared against the median values.

Nitrogen Concentrations

At the upstream DNREC monitoring station near Goslee Mill dam, nitrogen concentrations did not meet the water quality standard and showed an increasing trend from 1998 to 2008. DNREC discontinued monitoring this station in 2008 due to budget constraints. Therefore data after that date reflect only concentrations at the downstream station.

At the downstream station at the Route 24 bridge, monitored continuously by the UD Citizen Monitoring Program (CMP) since 1998, nitrogen concentrations were lower overall but still did not meet the water quality standard (Figure 11). While there was no overall trend here, there was an encouraging sign of a decrease in recent years. More years of data are required to determine if the decrease will continue.

Phosphorus Concentrations

Phosphorus concentrations usually met the water quality standard and have gradually decreased at the downstream station at the Route 24 bridge (Figure12). The decrease is good news for the creek's health.

The decrease in dissolved phosphorus may be related to conversion of agricultural lands to other land uses, improved nutrient management practices on farms and developments, and a conversion of septic systems to central sewer. The decrease may also be due in part to improvements, in the early 2000s, in treatment processes at the Rehoboth Beach Wastewater Treatment Plant that discharges to Rehoboth Bay.

Figure 11. Dissolved inorganic nitrogen (DIN) in Love Creek, measured at the Route 24 bridge.

Figure 12. Dissolved inorganic phosphorus (DIP) in Love Creek, measured at the Route 24 bridge.

Looking Ahead – Nutrients

- Nitrogen remains a major problem in Love Creek.
- Loads of both nitrogen and phosphorus to Love Creek will certainly be affected by the projected changes in land use in the watershed. The net effect of conversion of crop lands to housing is not completely clear and should be closely monitored.
- Conversion of communities from septic systems to central sewer will continue to have a positive impact on nutrient loads from groundwater. But increased stormwater runoff from development and roads may have a negative impact.

Indicator: **Bay Grasses**

Bay grasses are a critical part of coastal bay ecosystems. They provide wildlife with food and habitat, add oxygen to the water, remove nutrient pollution, trap sediment and reduce erosion.

The presence of bay grasses is a good indicator of water quality, since they require relatively clear water to grow and survive, and many species need water with low nutrient levels. Inputs of sediment and excess nutrients into creeks and bays can cloud the water and block sunlight from reaching bay grasses.

Extreme temperatures can also cause some bay grasses, such as eelgrass, to die. In this way, bay grasses are a "canary in the coal mine" when it comes to indicating estuary health. Improving water clarity is the most important step in bay grass restoration, because bay grasses need sunlight to grow.

In 2010, a significant amount of the bay grass Horned Pondweed (*Zannichellia palustris*), was discovered in the shallow waters of upper Love Creek (Figures 13 and 14). Horned Pondweed grows in in fresh and medium-salinity tidal waters. Migratory waterfowl feed on the plant and its seeds. It also provides excellent habitat for fish and crabs. Although it can survive in waters that are

Figure 13. Submerged Horned Pondweed growing in the upper reaches of Love Creek.

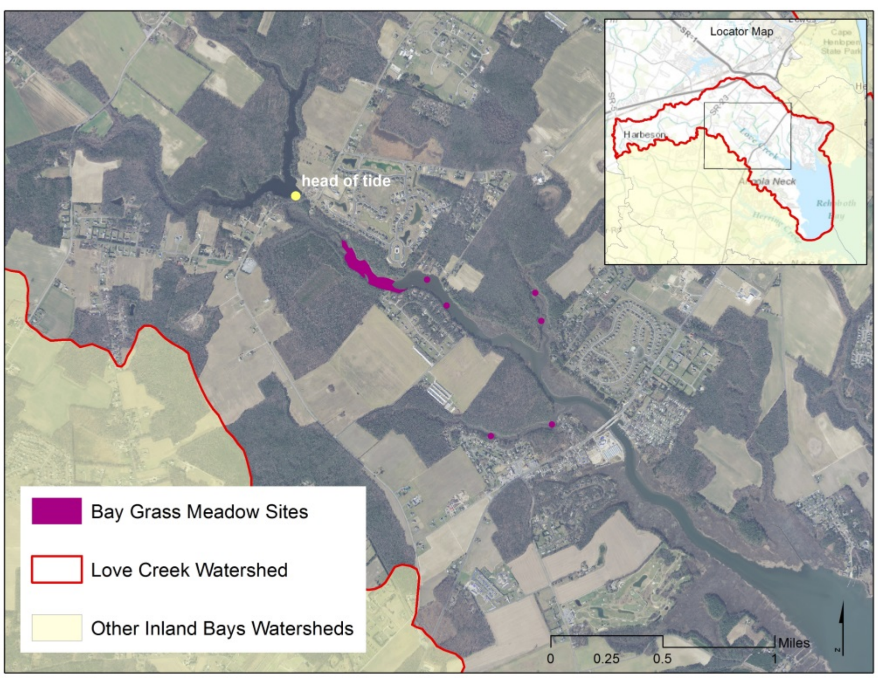


Figure 14. Locations of submerged bay grasses in Love Creek.

enriched with nutrients, Horned Pondweed still requires clear water and sunlight to grow.

By holding back sediment and nutrients, the Goslee Mill Pond dam and the extensive forested buffers on the upper parts of the creek may contribute positively to water clarity, allowing for growth of these bay grasses. In 2014, more Horned Pondweed meadows were discovered in smaller tributaries of Love Creek including the Hetty Fisher Glade and Stillman Glade. These meadows form part of a diverse mix of terrestrial and aquatic plants in the forested buffers and fringing marshes near the head-of-tide. They are the only large meadows of bay grass left in the Inland Bays. Special care should be taken to preserve the forested buffers in the Love Creek watershed to protect this important habitat.

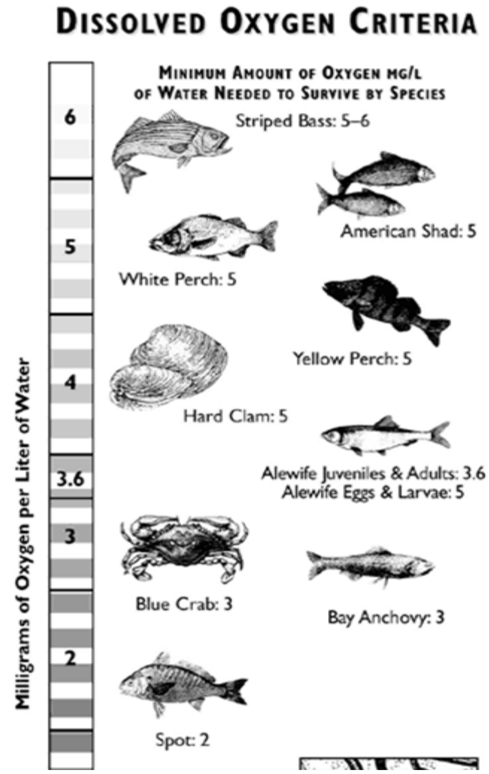


Figure 15. Various organisms require different levels of dissolved oxygen (DO) to survive. In general, higher DO levels are preferable and indicate higher water quality.

Looking Ahead – Bay Grasses

- Projected development in the upper portions of the Love Creek watershed threatens the health of the remaining bay grass meadows and other unique plant communities.
- Protection of forested buffers in these areas is critical.

Indicator: **Dissolved Oxygen Concentrations**

Levels of dissolved oxygen that meet minimum standards and are relatively stable are important to support healthy and balanced populations of aquatic life (Figure 15). Young fish and shellfish rely on healthy dissolved oxygen levels in their tidal creek nursery grounds. Excess nutrients fuel algal growth and eventual decomposition, causing oxygen to drop below healthy levels, especially on summer mornings.

Delaware has a minimum standard of 4 milligrams of dissolved oxygen per liter of water (mg/L) for a tidal creek to be considered healthy. If the minimum daily levels fall below this level too often, water quality is considered impaired.

Dissolved oxygen was monitored from 1998 to 2014 by the University of Delaware Citizen Monitoring Program at the Route 24 bridge. Over that period, 80% percent of observations met the water quality standard of 4 mg/L (Figure 16). There was no trend in this indicator.

Monitoring of upstream portions of the creek have identified instances of low and wildly fluctuating dissolved oxygen levels that were not healthy for aquatic life. Continuous, or real-time, monitoring of the creek for dissolved oxygen (rather than collection of less frequent discrete samples as is done now) would more accurately portray creek health.

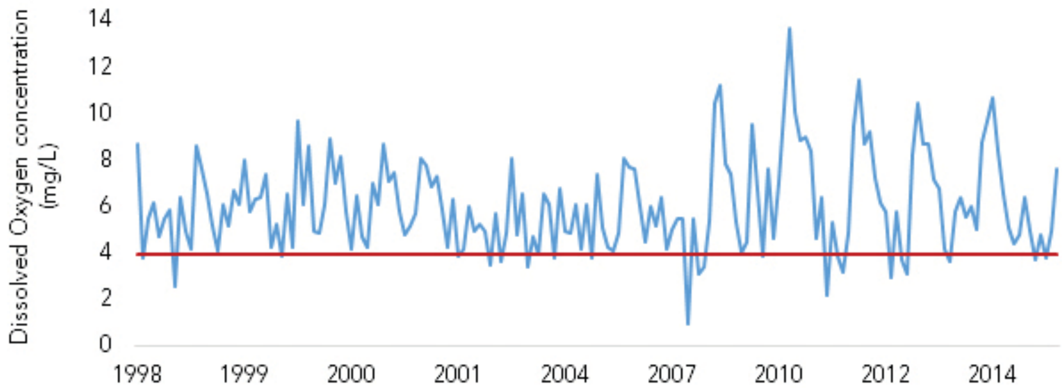


Figure 16. Dissolved oxygen concentrations in Love Creek, measured on summer mornings.

Looking Ahead – Dissolved Oxygen

- Low dissolved oxygen is directly tied to excess nutrients, so control of nitrogen and phosphorus loads to Love Creek will continue to be critical for the survival and health of aquatic life there.

Indicator: Bacteria Concentrations

The freedom to swim in natural waters is one of the great joys of living on the coast. However, there is reason for caution in some waters. Potentially harmful waterborne bacteria and pathogens can enter our water from many sources, including waste from wildlife, pets, septic systems, manure, marine sanitation devices, and even bottom sediments. Increases in impervious surfaces such as roofs, roads, and parking lots in developed areas can also cause bacteria to be washed into waters.

In Love Creek, monitoring of recreational water quality is conducted by the University of Delaware Citizen Monitoring Program. They measure levels of *Enterococcus*, a type of bacteria that can indicate the presence of other harmful bacteria and pathogens. A long-term safe swimming standard of 35 colony forming units (CFUs) of *Enterococcus* per 100 milliliters of water is used to advise water users. Varying advisory levels are provided for various degrees of human contact with the water.

- *From 2003 to 2014, average Enterococcus levels from June to September consistently exceeded the safe swimming standard in Love Creek (Figure 17).*
- *The average levels have increased significantly over time and in many samples, the concentration of Enterococcus was very high.*
- These levels can vary by location within a tributary, typically increasing upstream.
- *In 2013, DNREC ordered a portion of Love Creek closed to all commercial and recreational shellfish harvesting due to increased bacteria levels.* The source of the bacteria and the reason for the increase is unclear. It is likely coming from a number of different sources including wastes from wildlife, pets, marine recreation sources, and septic systems.

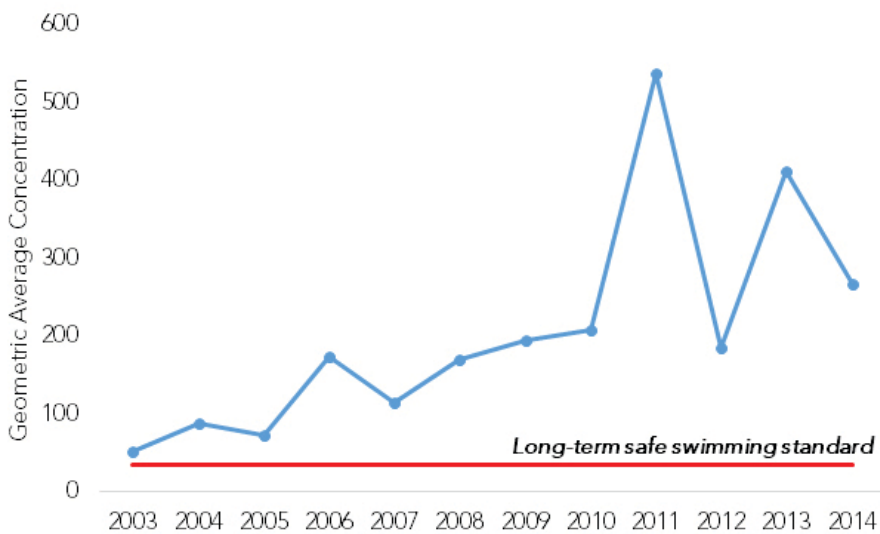
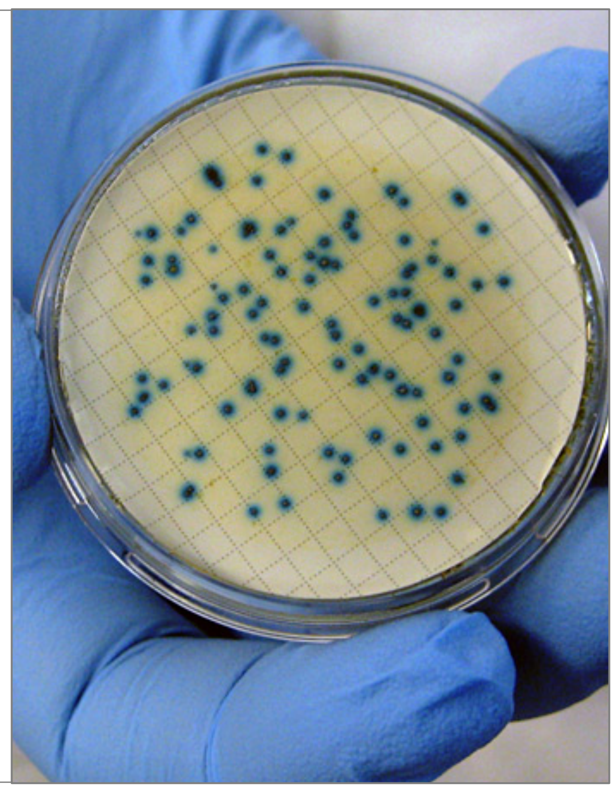


Figure 17. Concentration of *Enterococcus* indicator bacteria in Love Creek.

Indicator Bacteria

Members of two bacteria groups, coliforms and fecal streptococci (the genus *Enterococcus*), are used as indicators of sewage contamination because they are commonly found in human and animal feces. Although generally not harmful themselves, the presence of these "indicator" bacteria in water suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. Since it is difficult and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for indicator bacteria instead.

The U.S. EPA recommends *Enterococcus* as the best indicator of health risk in salt water used for recreation and as a useful indicator in fresh water as well.



In December 2013, DNREC conducted a small microbial source tracking study in Love Creek, in response to elevated levels of total coliform bacteria measured in shellfish waters in the upper tidal portions of the creek. Microbial source tracking is a set of genetic "fingerprinting" techniques used to determine whether fecal bacteria are being introduced into waterbodies through human, wildlife, or domestic animal sources. A copy of the report summarizing methods and results can be found in Appendix B. This study was only a one-time snapshot of the sources of fecal bacteria in Love Creek. But it showed that gulls, humans and dogs can, at times, all be important contributors to fecal pollution in the tidal and non-tidal portions of Love Creek. More studies such as this one are needed to fully understand the main sources of indicator bacteria in the watershed.

Looking Ahead – Bacteria

- Love Creek has many sources of fecal bacteria, including humans, wildlife, farmed animals and pets. Projected development in the Love Creek watershed may increase the proportion of human sources.
- Controlling levels of fecal bacteria in the creek will require a better understanding of the specific sources.

Conclusions

The condition and trends within the Love Creek watershed mirror those of the Inland Bays as a whole. These include 1) land use changes that are urbanizing the landscape and increasing stormwater pollution; 2) the flow of excess nutrients into the waterways that cause algae growth and decreases in oxygen levels; 3) and the loss of forests, wetlands and buffers that filter water, provide habitat for native plants and animals, and help prevent flooding .

The watershed of Love Creek is changing quickly.

Still intensively used by agriculture, it is also experiencing development and population pressures that have brought commercial development, increased traffic and the need for additional infrastructure. These changes put Love Creek at continuing risk for water quality degradation and declining overall watershed health.

The recession and housing downturn that began in 2008 slowed development across the watershed. But, many projects that were on hold are now underway, many of them in the western part of the watershed in the sensitive headwaters area of Love Creek. Development can potentially add to the pollution load in the creek, though it might also lead to a lowering of nutrient levels from agriculture as crop lands are converted to houses. More research is needed to determine the net effect of the conversion of farmland to housing. *Loss of forests - particularly forested buffers along the shorelines as new development occurs, is a significant threat to the health of the creek..*

Nutrient loads of nitrogen and phosphorus from the watershed do not appear to have a strong trend, but will certainly be affected by the projected changes in land use. Nitrogen levels remain very high. It will be important to assess not only loads of nutrients based on monitoring data, but to specifically identify where the nutrients are coming from and what actions need to be taken to eliminate them.

On a positive trend, the nutrient impacts to Love Creek from the widespread use of septic systems will lessen as more communities are converted to central sewer.

Concentrations of dissolved phosphorus in Love Creek have remained relatively low and are improving slightly. Nitrogen continues to be a major pollutant in the tributary, with levels remaining above the water quality standard. The conversion of agricultural land to development may lower nitrogen levels in the creek, but identifying sources and implementing Best Management Practices (BMP's) to reduce them will be essential, not just for agricultural sources but nitrogen coming from our increasingly urbanized landscape. BMP's, including cover crops on farmland, rain gardens, ponds and swales to capture stormwater in developed areas, and protective vegetated buffers along shorelines will all be important to manage nutrients.

Despite impairments, there are healthy plant communities in the marsh areas of upper Love Creek, intact forested buffers along much of the shoreline and thriving salt marshes in lower Love Creek. Preservation of these important habitats should be a high priority. In summer and early autumn, the marsh on upper Love Creek is ablaze with flowers, including some rare in Delaware. While many of our Inland Bays creek banks are choked with Phragmites, on Love Creek there are still forested banks buffering the shoreline in many locations, and a diversity of trees, shrubs and wildflowers in the marshy areas.

There is good news under the water as well. The presence of bay grasses, specifically Horned Pondweed, is a positive indicator of health in Love Creek. While once plentiful, bay grasses have seen drastic declines in recent decades throughout the Inland Bays. The emergence of thriving bay grass beds around the bays would be a significant indicator that water quality and watershed health is improving.

Dissolved oxygen levels in the creek remain a concern, both for recreational use and for the health of plant and animal life. Healthy bay grasses and thriving plant communities on Love Creek should help dissolved oxygen levels remain above the critical level for many animals (4 mg/L). Reducing the amount of nutrients entering the creek will decrease algae growth, keep the water clearer for bay grasses and allow for healthy levels of dissolved oxygen.

Bacteria levels, as measured by *Enterococcus* concentrations, bear directly on human health and determine whether the creek is safe for 'water contact' recreation. Based on bacteria levels measured during the swimming season, the waters of Love Creek exceed the safe standard roughly 20% of the time. *The overall trend based on sampled data indicates that water quality is worsening in terms of bacteria pollution. Identifying and removing the sources of bacteria in the creek should be a priority in the Love Creek watershed.*

Recommendations

- Forested buffers along Love Creek and its tributaries should be retained as new development occurs, and expanded on other lands, in order to protect the unique habitats that currently exist in the upper portions of the creek.
- Natural shorelines and tidal marshes must also be protected. Wherever feasible, living shoreline stabilization techniques should be used in place of riprap or bulkheads when shoreline management is necessary.
- Additional water quality monitoring stations, and continuous monitoring of dissolved oxygen, would provide a clearer picture of trends in nutrient concentrations and DO.
- Additional microbial source tracking studies should be conducted in Love Creek and its tributaries to better understand the main sources of fecal indicator bacteria in the watershed.
- Bay grasses and plant communities should be monitored, as they provide a good indicator of habitat quality and are uniquely healthy at this time in Love Creek.
- Communities in the Love Creek watershed should be encouraged to adopt best practices for stormwater management, lawn care and pet waste, in order to reduce inputs of nutrients to the waterway.
- Owners of agricultural properties within the watershed should be encouraged to continue to follow best practices for nutrient management and to adopt more effective practices whenever feasible.

APPENDIX A

Data and Methods Used in This Report

Land use

To determine land use changes in the Love Creek watershed, data were acquired 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. An effort was made to enable comparison across years, during which imaging sensors, ground resolution, and photointerpretation techniques changed. From a large number of potential categories from each year, a smaller set of land use/land cover types were identified to enable such comparison across years. The final report presents changes across the period 1992 to 2012, the analysis included tracking cover changes for each five year period.

The simplified land use classification scheme consisted of six broad categories:

- Developed/Developing
- Agriculture
- Upland Forest
- Open Water
- Wetlands
- Other

The following table documents the correspondence, based on the Anderson Land Use Coding system, to this simplified classification:

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

LULC Code	Land Use/ Land Cover	Simplified Landuse
111	Single Family Dwellings	Developed/Developing
112	Multi Family Dwellings	Developed/Developing
114	Mobile home Parks/Courts	Developed/Developing
120	Commercial	Developed/Developing
121	Retail Sales/Wholesale/Professional Services	Developed/Developing
122	Vehicle Related Activities	Developed/Developing
123	Junk/Salvage Yards	Developed/Developing
125	Warehouses and Temporary Storage	Developed/Developing
129	Other Commercial	Developed/Developing
130	Industrial	Developed/Developing
140	Transportation/Communication	Developed/Developing
141	Highways/Roads/Access roads/Freeways/Interstates	Developed/Developing
142	Parking Lots	Developed/Developing
143	Railroads	Developed/Developing
144	Airports	Developed/Developing
145	Communication - antennas	Developed/Developing
146	Marinas/Port Facilities/Docks	Developed/Developing
149	Other Transportation/Communication	Developed/Developing
150	Utilities	Developed/Developing
160	Mixed Urban or Built-up Land	Developed/Developing
170	Other Urban or Built-up Land	Developed/Developing
180	Institutional/Governmental	Developed/Developing

190	Recreational	Developed/Developing
211	Cropland	Agriculture
212	Pasture	Agriculture
213	Idle Fields	Agriculture
215	Truck Crops	Agriculture
220	Orchards/Nurseries/Horticulture	Agriculture
230	Confined Feeding Operations/Feedlots/Holding	Agriculture
240	Farmsteads and Farm Related Buildings	Agriculture
290	Other Agriculture	Agriculture
310	Herbaceous Rangeland	Agriculture
320	Shrub/Brush Rangeland	Agriculture
330	Mixed Rangeland	Agriculture
410	Deciduous Forest	Upland Forest
420	Evergreen Forest	Upland Forest
430	Mixed Forest	Upland Forest
440	Clear-cut	Upland Forest
510	Waterways/Streams/Canals	Water
520	Natural Lakes and Ponds	Water
530	Man-made Reservoirs and Impoundments	Water
540	Bays and Coves	Water
550	Tidal Open Water	Water
560	Non-tidal Open Water	Water
610	Non-tidal Forested Wetland	Wetland
622	Non-tidal Scrub/Shrub Wetland	Wetland
623	Non-tidal Emergent Wetland	Wetland
660	Tidal Forested Wetland	Wetland
672	Tidal Scrub/Shrub Wetland	Wetland
673	Tidal Emergent Wetland	Wetland
720	Beaches and River Banks	Other
730	Inland Natural Sandy Areas	Other
750	Extraction	Other
760	Transitional (incl. cleared, filled, and graded)	Developed/Developing
770	Tidal Shoreline	Other
780	Non-tidal Shoreline	Other

The following chart (Figure 1) summarizes the changes across the six categories, within the Love Creek watershed, for each of the five year periods.

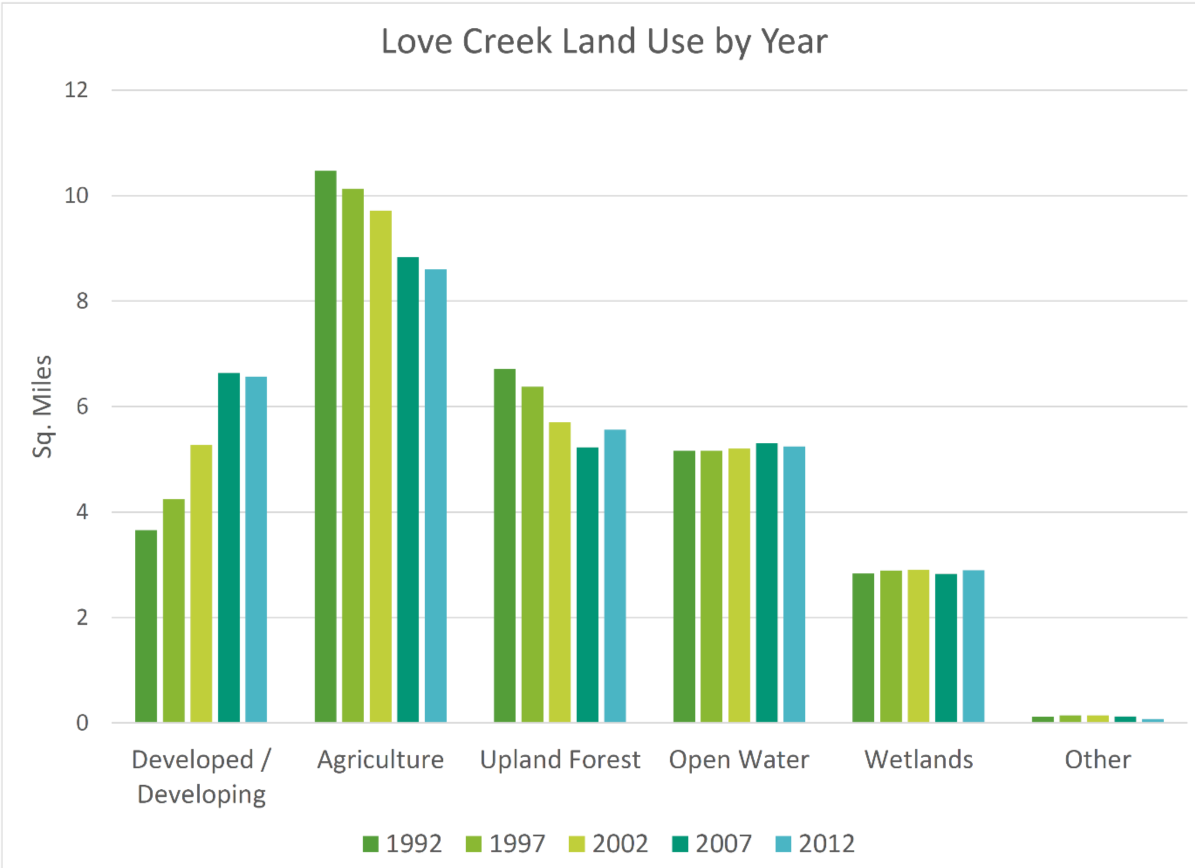


Figure 1 -- Land use change in the Love Creek watershed, 1992 - 2012.

The raw land use data in 2012 (which will remain provisional until sometime in 2015) indicates a relatively large increase in wetlands within the watershed; however, this was not likely due to real changes on the ground, but rather to an increase in the amount of forested wetlands identified. Information from the State's 2009 National Wetlands Inventory project identified a significant number of forested wetland areas that had previously been classified as upland forest, based on ground verification and the use of hydric soils data. In the derivation of the 2012 dataset information from the 2009 wetlands project was used to alter the later land use data, leading to an increase in land area identified as wooded wetlands. To account for this, we reclassified forested wetland areas in the 2012 data that had been classified upland forest in the 2007 dataset back to upland forest. Even though this processing step might potentially lead to under-representation of actual freshwater wooded wetlands in the bays, it was necessary to enable comparisons across years.

Another apparent anomaly in the data is an increase in the amount of forest identified between 2007 and 2012. These changes do not represent a significant increase in intact, high-value forest land in the watershed, but rather transition to early-growth forest in areas previously classified as "scrub-shrub" and in developing lands which remained vacant (potentially due to the economic slowdown). Other potential discrepancies in the classification among years include variation in the quality, spectral characteristics, or spatial resolution of the base imagery, differences in photo interpretation methodology, and varying priorities within the agencies funding the interpretation.

Nutrient loads from non-point sources

DNREC's Watershed Assessment and Management Section, within the Division of Watershed Stewardship, has provided loading and flow data for the Delaware Inland Bays between 2006 and 2013. The loads are provided in pounds per year for total nitrogen (TN) and total phosphorous (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).

For watersheds, such as Love Creek, that have monitoring stations, loads were calculated from measured concentration data for each constituent, while in watersheds without a stream monitoring station, the loads were estimated by pro-rating the load calculated for the whole region to the area of those watersheds without available measurements.

The following table summarizes the loads and loading rates, for each year (2006 - 2013) for TN and TP in Love Creek, based on actual monitoring data. The first row shows the 2004 TMDL baseline.

Table 2 -- Loads and loading rates for TN and TP in Love Creek, 2006 – 2013.

YEAR	Creek	Drainage area (sq. mi.)	Load, TN (lb/yr)	Load, TP (lb/yr)	Loading Rate, TN (lb/yr/ac)	Loading Rate, TP (lb/yr/ac)	Monitored
2004 TMDL Baseline	Love Cr	21.94	260,897	11,193	19	0.8	
2006	Love Cr	21.94	223,539	1,797	16	0.1	√
2007	Love Cr	21.94	173,775	946	12	0.1	√
2008	Love Cr	21.94	174,215	903	12	0.1	√
2009	Love Cr	21.94	352,234	2,910	25	0.2	√
2010	Love Cr	21.94	312,390	2,308	22	0.2	√
2011	Love Cr	21.94	201,043	890	14	0.1	√
2012	Love Cr	21.94	241,959	1,044	17	0.1	√
2013	Love Cr	21.94	386,608	4,709	28	0.3	√

Septic systems

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. DNREC tracks all active septic permits within the Ground Water Discharge Section of the Division of Water, while the County maintains an inventory of all tax parcels that receive a sewer bill from them. In some cases active sewer permits may fall within properties receiving a sewer bill from the County. This could indicate that there is a lag between when a septic system is abandoned and when the State's database is updated to reflect that, or that a property owner chooses to maintain a septic field, even though receiving sewer service.

The Delaware Public Service Commission manages private company sewer service areas for the Inland Bays, which indicate where sewer service is being provided, or will be provided when development occurs in the future. Much of the rapidly developing areas in the eastern portion of the Love Creek watershed are or will be served by private sewer service. Sussex County also provides septic service in the region, and is expanding that service across the Love Creek watershed (in the eastern portion).

The map of sewer districts (which includes county and private providers, see map in Discussion section) indicates that many of the more established, developed areas in the eastern portion of the watershed have service connections through the county, while the newer developments to the west are or will be primarily being served by private sewer companies.

As previously noted, many active septic permits still exist in areas where sewer service is being provided and connections are active. Lots with public sewer provision through the county should have their septic systems abandoned within a short time-frame. The density of active septic permits, therefore, should drop significantly once these systems are abandoned.

The following table summarizes the number of active septic permits by Inland Bay watershed in Delaware, along with the density, in number of septic permits per square mile. Net septic permits are 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 3 -- Septic permit summary for watersheds in the Inland Bays.

Watershed	Land Area, Sq. Mi.	Septic Permits	Permit Density (per sq. mi.)	Permits w/ County Sewer	Net Septic Permits
Assawoman Bay	6.8	172	25.4	84	88
Cow Bridge Branch-Indian River	44.8	1470	32.8	21	1449
Dirickson Creek-Little Assawoman Bay	18.9	581	30.8	179	402
Herring Creek-Rehoboth Bay	33.8	2093	61.9	509	1584
Indian River Bay-Indian River Inlet	17.6	1124	63.7	453	671
Little Assawoman Bay	13.1	254	19.4	124	130
Long Drain Ditch-Betts Pond	17.6	753	42.8	3	750
Love Creek-Rehoboth Bay	24.2	1340	55.5	486	854
Rehoboth Canal-Rehoboth Bay	11.4	382	33.5	382	0
St. Martin River	7.8	61	7.8	3	58
Swan Creek-Indian River	29.4	797	27.1	25	772
Vines Creek-Indian River	35.7	1117	31.3	62	1055
White Creek-Indian River Bay	26.9	1749	65.1	904	845
Wolfe Glade-Rehoboth Canal	10.0	155	15.5	149	6
TOTAL	**298.0**	**12048**	**40.4**	**3384**	**8664**

Dissolved Nitrogen and Phosphorous Concentrations

To assess the status and trends of water quality in the Love Creek tributary, 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 these dissolved nutrients can cause a condition of over-enrichment, or "eutrophication," in bodies of water. Eutrophication can lead to fish and shellfish kills, toxic algal blooms and the loss of seagrass beds which are important feeding and nursery areas for marine life.

The head-of-tide occurs just below Goslee Mill Pond, near the point where Robinsonville Road (Rd. 277) crosses Love Creek. Only stations within the creek and downstream of that point were considered, and only monitoring sites with enough data of sufficient quality were used.

Two stations were selected to represent the water quality in the Love Creek: DNREC station #308291 and CMP station RB34. 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. Data were available for station #308291 from 1998 through 2008. 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. Data from site RB34 were available from 1998 through 2012. 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).

Bay Grasses/Submerged Aquatic Vegetation

Personnel from the University of Delaware Citizen Monitoring Program (CMP), with support from the Center have identified several locations in tidal Love Creek hosting Submerged Aquatic Vegetation (SAV), specifically the regionally widespread but locally rare horned pondweed (*Zannichellia palustris*). Several sites were located south of Goslee Pond (near the head-of-tide) and on two nearby, downstream tributaries. Farther up the creek toward Goslee Pond there is a more mixed association of emergent vegetation and SAVs. Horned pondweed is fairly tolerant of high nutrient levels, but its presence still points to relatively good water quality in these creeks. The presence of forest buffers in this otherwise fairly developed area might help foster this species in Love Creek. Maps were created from both areal and point data provided by the Center and the CMP.

Dissolved Oxygen Concentration

Dissolved Oxygen (DO) levels in the Love Creek were obtained for the period from the datasets as described above (see the section "Dissolved Nitrogen and Phosphorous Concentrations").

Since it was important to obtain data only during summer months (June through September) and before 9:30 AM (at which time photosynthetic activity would tend to raise oxygen levels), data for both sampling locations were filtered to meet those criteria. Since the DNREC monitoring site #308291 did not have a sufficient number of data point that met the criteria, only the CMP sampling site, RB34 was used in the analysis.

It was found that of the samples at RB34 that met the seasonal and time-of-day criteria (i.e., summer mornings), 22 out of 108 (20.4%) samples did not meet the water quality standard for DO of 4 parts per million (mg/L). Figure 2 shows summer (June through September) morning DO levels at station RB34 over the period.

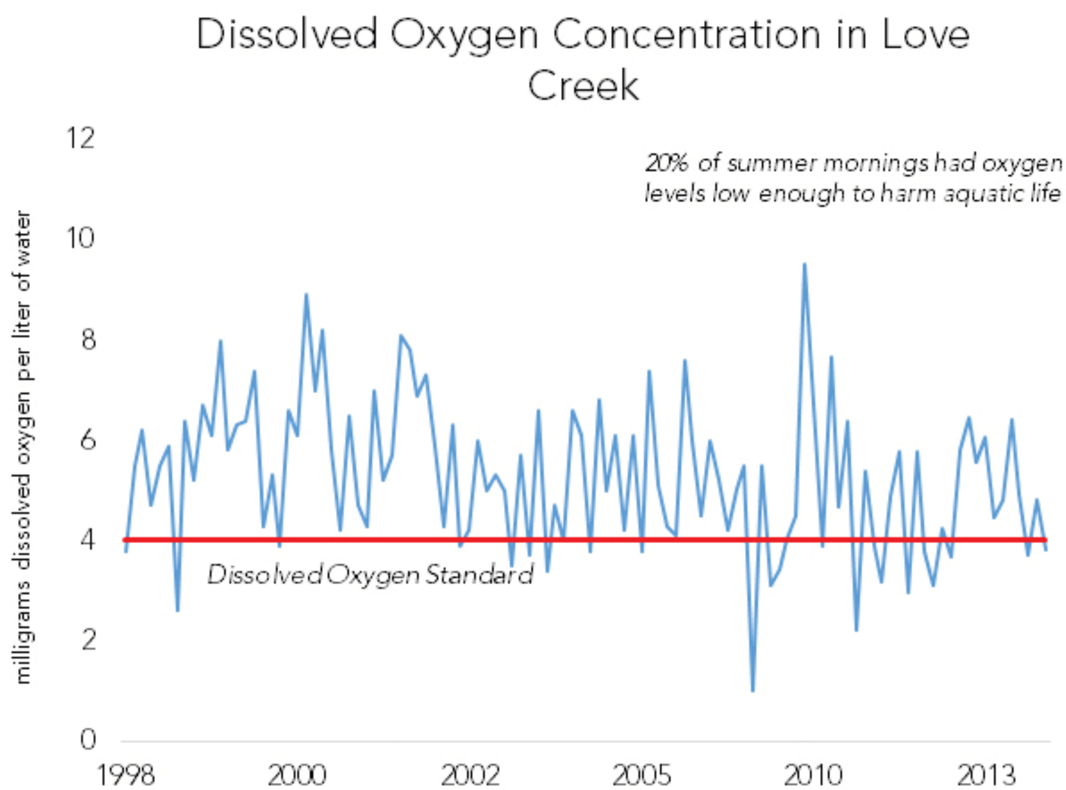


Figure 2 -- Dissolved oxygen levels for summer morning samples across the period 1998 – 2014, CMP site RB34. Red line indicates water quality standard of 4 mg/L.

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; it has the strongest correlation with the risk of people acquiring gastroenteritis from inadvertent ingestion of water. Bacteria data for CMP sampling site RB34 were available from 2003 to 2014, of which only samples from the summer swimming months (June through September) were considered.

The geometric means for summertime bacteria levels were found to exceed the long-term safe swimming standard of 35 CFU per 100mL, and this trend seems to be worsening (Figure 3).

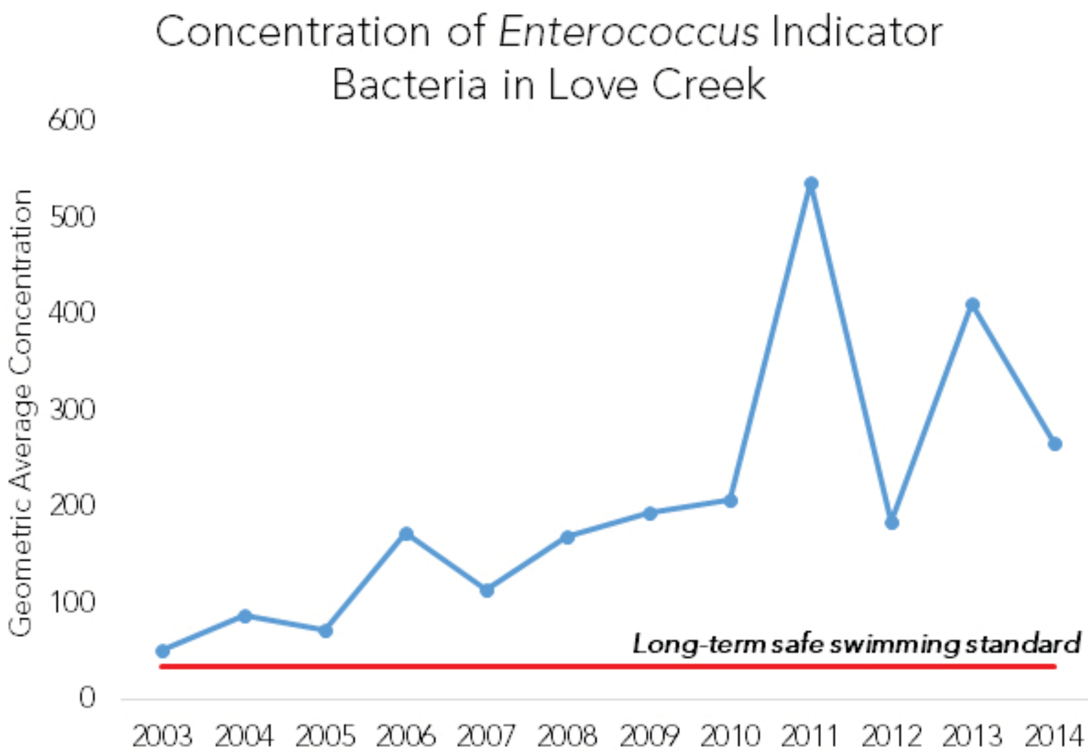


Figure 3 -- Concentration of Enterococcus Bacteria in Love Creek, summertime geometric mean at CMP site RB34.

The instantaneous safe swimming standard of 104 CFU per 100 mL of water is also regularly exceeded throughout the summer swimming season in Love Creek (see Figure 4).

Statistical analysis using the non-parametric Kendall-Mann test for trend indicates a significant increasing trend in the concentration of Enterococcus in the Love Creek at the sampling site (Figure 5). This test indicates that there is a monotonic increase in Enterococcus concentration over the period with a probability (P-value) of 2.21×10^{-7}.

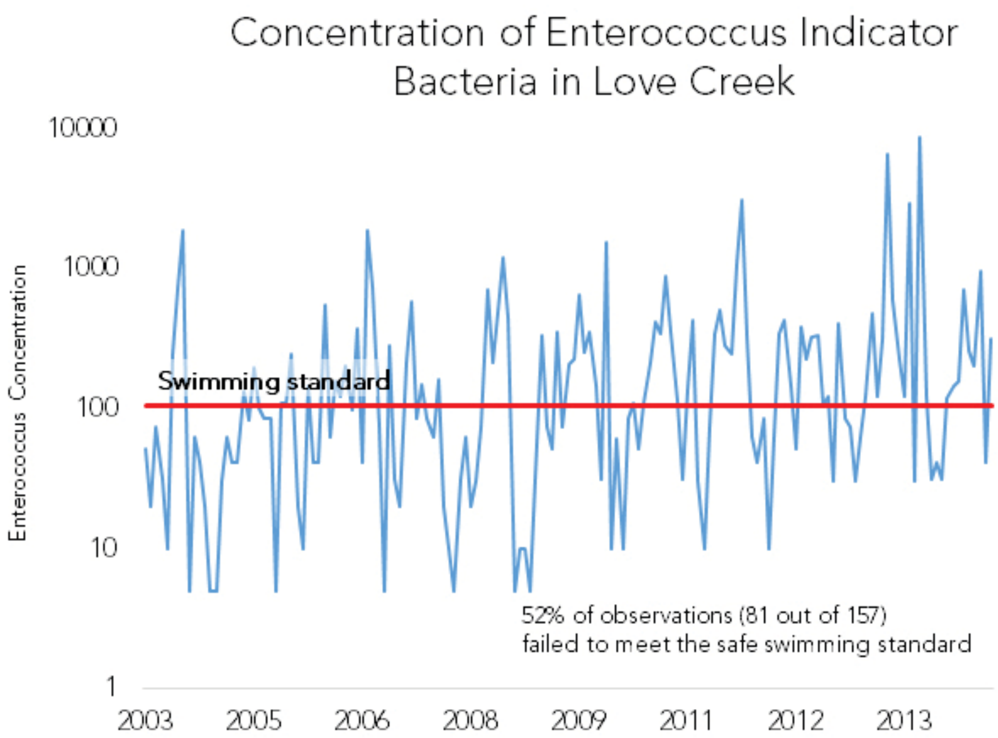


Figure 4 -- Enterococcus concentrations in Love Creek during the summer swimming season, 2003 – 2013, at CMP monitoring site RB34.

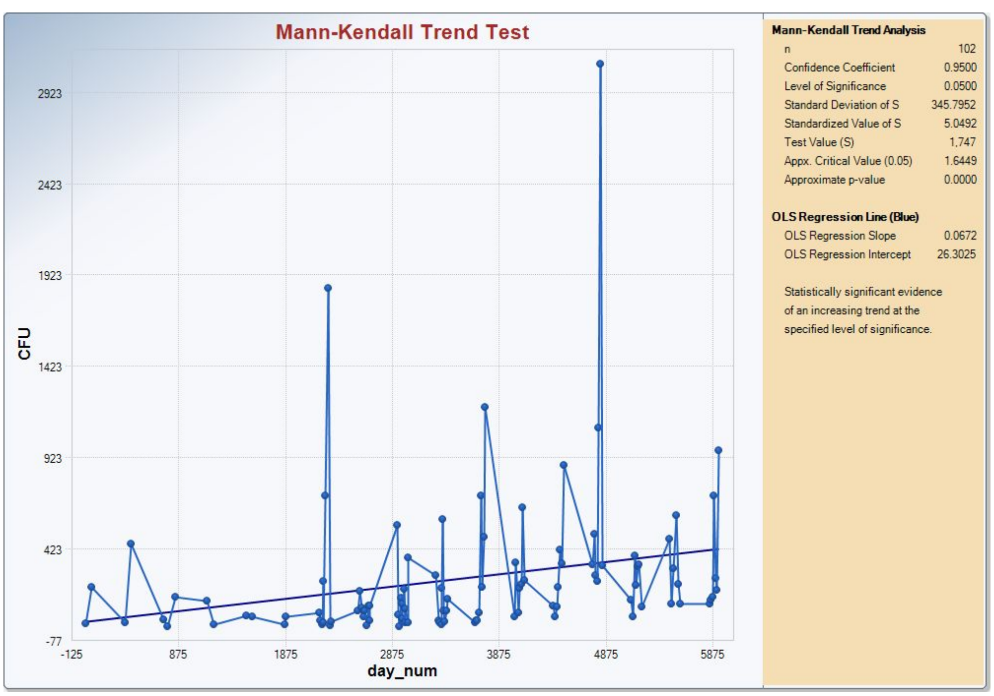


Figure 5 -- Summary of Enterococcus summertime trends at CMP monitoring site RB34, using the Mann-Kendall Trend test.

APPENDIX B

Love Creek Microbial Source Tracking Summary Report

2013 Love Creek Molecular Source Tracking Sample Results

DNREC Watershed Assessment and Management Sections

Background

Love Creek is a tributary located in the northwestern portion of Rehoboth Bay. The watershed drains 18,528 acres of mixed land uses including agricultural, forest and residential. Over the last several decades, land use trends have seen an overall increase in residential areas and respective decreases in agricultural and forested lands.

Beginning in the fall of 2012, the Shellfish and Recreational Water Programs began to detect increases in total coliform bacteria through monthly testing of shellfish waters in the upper tidal portions of Love Creek. The increases in the frequency of samples with elevated bacteria levels did not exceed the National Shellfish Sanitation Program (NSSP) water quality standards for approved shellfish harvesting, but indicated that shoreline surveys were required to identify any actual or potential pollution sources. In early 2013, shoreline surveys of the Love Creek Watershed indicated the presence of potential pollution sources originating from onsite wastewater treatment systems which resulted in prohibiting shellfish harvesting in portions of tidal Love Creek, in accordance with the NSSP.

In December 2013, the Watershed Assessment and Management Sections collected water samples at four locations in Love Creek, tidal and non-tidal, to be analyzed for the presence of species specific biomarkers of fecal contamination. Samples were analyzed by Source Molecular Corporation for the presence of seagull, human, dog, chicken and cattle fecal contributions to the watershed.

Sample Sites

The sample stations selected represent different regions of the Love Creek Watershed, from headwater tributaries to marine portions near the Rehoboth Bay.

Figure 1. Location and distribution of four sample stations within the Love Creek Watershed

The sample station BB is located on Bundick's Branch, a freshwater tributary of Love Creek. Station LCS is located on the downstream portion of Love Creek at the spillway of Gosleemill Pond. Station LCTP is located on the tidal portion of Love Creek near the intersection of Rt. 24. Station MKL is located in lower Love Creek near the confluence with the Rehoboth Bay.

Sample Collection

Samples were collected on December 11, 2013 following the protocol provided by Source Molecular Corporation. The samples were shipped overnight and received by the lab within the acceptable time and temperature range. Samples were analyzed using quantitative polymerase chain reaction (qPCR) *Bacteroidetes* gene markers for the presence and quantification of species specific sources. Following analyses, results for both the detection and quantification of fecal sources were delivered to DNREC.

Results

Results from quantification analyses (Appendices 1-5) were categorized into five classifications; Absent, Trace, Minor Contributor, Important Contributor and Major Contributor. In samples determined as absent, the levels of *Bacteroidetes* were below the detection limit for the real time qPCR assay used for analyses. Results that indicated trace, were above the detection limits for qPCR, but were below the limits for quantification. Human and dogs were all identified as important contributors at the time of sampling at all stations. Gulls were important contributors at three of the four stations. At the time of sampling, cows were minimal contributors to fecal pollution at three of the four stations, while chicken fecal indicators were absent at all stations (Table 1).

Table 1. Quantification interpretations for *Bacteroidetes* species specific fecal contributors at four samples stations in the Love Creek Watershed

Sample Site	**Chicken**	**Cow**	**Dog**	**Human**	**Gull**
BB	**Absent**	**Absent**	**Important Contributor**	**Important Contributor**	**Important Contributor**
LCS	**Absent**	**Trace**	**Important Contributor**	**Important Contributor**	**Trace**
LCTP	**Absent**	**Trace**	**Important Contributor**	**Important Contributor**	**Important Contributor**
MKL	**Absent**	**Trace**	**Important Contributor**	**Important Contributor**	**Important Contributor**

Conclusion

The sampling conducted in the Love Creek Watershed was a snapshot of the fecal bacteria contributors to the watershed at the time of sampling. To fully understand the fecal pollution sources associated with the watershed, long term sampling over different seasons and weather conditions would be needed to draw any finite conclusions. What can be determined from the analyses conducted is that

during at least some environmental conditions, gulls, humans and dogs can all be important contributors to fecal pollution in the tidal and non-tidal portions of Love Creek. This also coincides with the recent increase in residential land use which increased the presence of human and dog fecal sources in the watershed. Shoreline surveys indicated that there were potential anthropogenic sources of pollution in the watershed and accumulations of dog feces or failing septic systems could easily contribute to elevated bacterial levels during storm runoff or tidal flooding events. To fully understand the complex dynamics of fecal pollution in this watershed, further long term sampling would be required.

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