ENVIRONMENTAL MONITORING PLAN
FOR
DELAWARE’S INLAND BAYS

REVISED: MAY 2017

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Input was provided by members of the Inland Bays Monitoring Plan Subcommittee and the Center for the Inland Bays Scientific and Technical Advisory Committee (STAC). The STAC also provided review of the final plan. Leslie Jamka of RK&K provided invaluable assistance in collating questionnaire results and assembling early drafts of the plan.

Special thanks go to those who participated in the Water Quality Monitoring Workgroup meeting held in Dover, DE on July 30, 2015: Robin Tyler, David Wolanski, Michael Bott, Debbie Rouse, Hassan Mirsajadi, John Schneider, Larry Trout, Joanna York, Kevin Brinson, Tina Callahan, Ed Whereat, Bill Ullman, Joe Farrell, Judy Denver, and Scott Andres.

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.
EXECUTIVE SUMMARY

The purpose of the Inland Bays Environmental Monitoring Plan (IBEMP) is: (1) to track the status and trends of key environmental indicators of eutrophication and habitat loss/modification that affect the Delaware Inland Bays; and (2) to evaluate the overall effectiveness of the Inland Bays Comprehensive Conservation and Management Plan (CCMP). It serves as a comprehensive inventory of existing, new, and proposed monitoring activities and is intended to guide research, monitoring, and assessment efforts and lead to increased integration of work and consolidation of resources.

The original Monitoring Plan for the Delaware Inland Bays was written in 1995 and last updated in 1996. Since then, collection of additional relevant environmental data has been initiated, responsibilities for collection and programs have changed, and both monitoring technology and the scientific understanding of the Bays have evolved significantly. This updated document provides an opportunity to re-engage partners and stakeholders around its cooperative implementation.

An inventory is provided of existing projects and programs that conduct ongoing, long-term environmental monitoring in Delaware’s Inland Bays. Many of these programs contribute data that are used to develop State of the Delaware Inland Bays reports every five years. Others produce data that may illuminate progress toward achieving goals of the CCMP, provide data for new environmental models, or may be useful for development of new indicators in the future. The programs are organized into five sections that cover monitoring of: (1) surface water; (2) living resources; (3) nutrient loads; (4) groundwater; and (5) wetlands. The expectation is that these programs will continue to be funded and conducted long-term.

Of primary importance in this IBEMP are recommendations made for new monitoring programs, or for enhancement of existing programs. These recommendations are made based upon critical data gaps (including emerging issues), the availability of new methods or technologies, and/or changes needed to make programs sustainable over the long term.

Highest priority recommendations are:

• Development of a new hydrodynamic/watershed model for the Inland Bays;
• Upgrade of the University of Delaware’s Citizen Monitoring Program database to a format that is sustainable long-term and can serve data to the public through STORET and/or the state’s Water Quality Portal;
• Long-term, continuous monitoring of dissolved oxygen and chlorophyll at key stations;
• Monitoring of submerged aquatic vegetation in tidal regions of the Inland Bays; and
• Monitoring of local indicators of sea level rise.

Other recommendations, judged to be important but of slightly lower priority, include:

• Continued monitoring of the tidal prism at the Indian River Inlet;
• Long-term monitoring of oyster recruitment and growth in the Bays, particularly as aquaculture begins, and shellfish restoration and enhancement projects are undertaken;
• Shoreline condition and modification monitoring to evaluate the effectiveness of living shoreline initiatives;
• Continued analyses of tidal marsh acreage and condition using GIS methodology established in a 2104 study conducted by the University of Delaware;
• Monitoring of estuary acidification; and
• Monitoring of recreational Blue Crab and Hard Clam harvests from the Inland Bays.

For each recommended program, partner organizations or agencies are identified to be responsible for, or partner in, its implementation. Where possible, estimated costs and potential funding sources are
Coordination among those organizations involved in data collection, processing and analysis, storage and provision, and presentation is key to the success of monitoring in the Inland Bays.

The IBEMP is a living document intended to evolve to meet future needs for tracking the status and trends of eutrophication and habitat loss/modification within the Inland Bays. In order to ensure that monitoring programs are implemented and coordinated, and that the IBEMP is kept up to date, an Environmental Monitoring Plan subcommittee of the Scientific and Technical Advisory Committee (STAC) will be responsible for biannual review/update, on a schedule corresponding with the state’s development of its 305(b) report to the U.S. EPA.
1. INTRODUCTION

1.1 THE INLAND BAYS AND THEIR WATERSHED

Delaware’s Inland Bays (the Bays) refers to all tidal waters and tidal wetlands encompassing the Indian River Bay, Indian River, Rehoboth Bay, and Little Assawoman Bay (Figure 1). The 292 square mile Inland Bays watershed is located in southeastern Sussex County, and drains to 35 square miles of bays and tidal tributaries. Rehoboth Bay and Indian River Bay are tidally connected to the Atlantic Ocean by the Indian River Inlet. Little Assawoman Bay is connected by the Ocean City Inlet, 10 miles to the south in Maryland. As of 2012, agriculture represented the largest land use in the watershed (31%), followed by developed/developing lands (24%), forested lands (17%), wetlands (16%), and open water (12%) (Figure 2).

Historically, the Bays have been extremely dynamic. Prior to the 1930’s the Indian River system consisted entirely of freshwater with the only connection to the Atlantic occurring during storm surges when the barrier island was breached, at various locations. The Indian River Inlet, as it exists today, was stabilized in the late 1930’s and has deepened over time, passing greater volumes of water and increasing the tidal range of the Bays. This has led to a long-term increase in the salinity of the Bays. The greatest impacts of the salinity shift are evident in the upper reaches of the tributaries where tidal freshwater segments have been virtually eliminated. The dynamic flux of the Inland Bays poses an exceptional challenge to those responsible for monitoring the health of the system and establishing scientifically defensible status and trends data and analyses.

The degradation of the Bays has been a gradual process occurring over many decades, and it is anticipated that the recovery process will proceed over a similar period of time. Nutrient contaminated groundwater in the Inland Bays watershed, for example, moves very slowly, and the contamination reaches depths of hundreds of feet. If all contamination of the aquifer were to stop immediately, it is predicted that it would take 75 to over 100 years for replacement water to purge the system and reach the Bays.

Two areas of priority problems have been identified in the Inland Bays: eutrophication caused by excessive nutrient loading, and habitat loss and modification.

1.2 THE INLAND BAYS ENVIRONMENTAL MONITORING PLAN

1.2.1 Background

A key role of National Estuary Programs is to monitor the effectiveness of actions taken to implement their Comprehensive Conservation and Management Plans (CCMPs). This type of research must include the understanding of the natural variability of the ecosystems and populations that make up the estuary and its watershed.

The Inland Bays Comprehensive Conservation and Management Plan (CCMP), completed in 1995, included 64 goals and objectives that guided the work of the partners and cooperators charged with its implementation. Subsequent to this, Total Maximum Daily Load (TMDL) regulations for nitrogen and phosphorus were established for Indian River, Indian River Bay, and Rehoboth Bay in 1998, and for Little Assawoman Bay and the major tributaries of the Inland Bays in 2005. In 2008 the Inland Bays Pollution Control Strategy (PCS) was promulgated with the intention to implement the TMDLs.

A comprehensive update to the Inland Bays CCMP was published in 2012 as an Addendum to the original plan. The Addendum includes 10 goals and 81 objectives, organized under eight focus areas:

- Nutrient Management
• Stormwater Management
• Water Quality Management
• Managing Living Resources and Their Habitat
• Planning for Climate Change
• Coordinating Land and Water Use Decisions
• Outreach and Education

Actions that would be required to accomplish the goals and objectives were written, as were Performance Measures that could be used to track progress.

During the Center for the Inland Bays (the Center’s) original CCMP development process that culminated in 1995, a Plan for Inland Bays Environmental Monitoring was produced and included as Appendix G of that report. The plan assembled the metadata of relevant environmental parameters collected at the time and put forth hypotheses for their change based on CCMP implementation. An updated Monitoring and Assessment Plan for Delaware’s Inland Bays (1996-2000) was published in December 1996.

Since then, collection of additional relevant parameters has been initiated, responsibilities for collection have changed, and both monitoring technology and the scientific understanding of the Bays have evolved significantly. This requires that the Plan be revised and provides an opportunity to re-engage stakeholders around its cooperative implementation.

The current update to the IBEMP was developed with input from the Center for the Inland Bays Scientific and Technical Advisory Committee (STAC), and the participants of a facilitated Ambient Water Quality Monitoring Plan Workshop held in August 2015.

1.2.2 Objectives

The purpose of the Inland Bays Environmental Monitoring Plan (IBEMP) is to monitor the conditions of the Inland Bays Estuary and Watershed used to evaluate the overall effectiveness of the CCMP. It serves as a comprehensive blueprint for monitoring activities that relate to the mission of the Center.

The IBEMP is a living document intended to evolve to meet future needs for tracking the status and trends of eutrophication and habitat loss/modifycation within the Inland Bays. It is a comprehensive inventory of projects that are ongoing, or are viewed as needed, to monitor progress toward meeting the CCMP goals. The plan is intended to guide research, monitoring, and assessment efforts, and may lead to increased integration of work and consolidation of resources.

The primary objectives of the IBEMP are to:

• Identify monitoring needed to track progress toward the goals for improving water quality and living resources within the Bays;
• Identify projects/programs that are conducting monitoring that meets these goals;
• Identify gaps where data and information are needed (including emerging issues), and suggest alternatives for filling those gaps where possible through integration of work being carried out under active projects;
• Make recommendations for data synthesis, and for coordination among those organizations involved in data collection, processing and analysis, storage and provision, and presentation;
• Identify funding needs and strategies.

1.3 SUMMARY OF PLAN REVISION PROCESS
1.3.1 Ambient Water Quality Monitoring Workshop

As part of the IBEMP update, the Center for the Inland Bays (CIB) hosted a facilitated workshop on July 29, 2015 to discuss ambient water quality monitoring in the Inland Bays. The workshop was facilitated by a contractor, Jim Eisenhardt, of RK&K. Primary goals of the workshop were to:

1. Review current ambient water quality monitoring programs and identify strengths, weaknesses, and areas of improvement;
2. Develop a process to transfer existing and new University of Delaware Citizen Monitoring Program (CMP) data to a public database such as STORET;
3. Include CMP data effectively into the combined Watershed Assessment Report (305(b)) and Determination for the Clean Water Act Section 303(d) List of Waters Needing TMDLs;
4. Evaluate the effectiveness, capacity, and costs of the DNREC water quality portal (developed by DEMAC) to provide DNREC and CMP data to researchers and the public; and
5. Improve the participation of organizations in the review and interpretation of Inland Bays environmental indicator reports.

Prior to the workshop, participants were asked to complete a survey; compiled results are included in Appendix B. Participants represented the following organizations/ agencies: CIB, Delaware Department of Natural Resources and Environmental Control (DNREC), University of Delaware, and the United States Geological Survey (USGS). Representatives from the United States Environmental Protection Agency (EPA) Region III were not in attendance; however, Bill Richardson of the Office of Standards, Assessment and TMDLs provided input prior to the workshop.

Workshop notes are included in Appendix C.

1.3.2 Scientific and Technical Advisory Committee Input and Review

At its meeting on September 18, 2015, the STAC discussed the IBEMP update. The discussion was facilitated by Jim Eisenhardt (RK&K) and the Center’s Science and Restoration Coordinator, Marianne Walch. The focus of the discussion was existing monitoring programs and anticipated monitoring needs.

A questionnaire similar to the one used for the facilitated workshop was sent to key STAC members prior to the meeting. Compiled results of that questionnaire are included in Appendix D. Notes from the discussion held at the STAC meeting are included in Appendix E.

1.3.3 Monitoring Plan Updates

A standing Monitoring Plan Subcommittee is to be appointed by the Chair of the Center’s Scientific and Technical Advisory Committee (STAC). This subcommittee will be responsible for biannual review of, and updates to, the Inland Bays Environmental Monitoring Plan. The biannual period for review was selected to correspond with the State’s Combined 305(b) and 303(d) reports to EPA. At a minimum this subcommittee shall include representatives from the Center for the Inland Bays, DNREC Watershed Assessment Section, DNREC Environmental Laboratory, University of Delaware Citizen Monitoring Program, Delaware Environmental Monitoring and Analysis Center (DEMAC), and the Delaware Geological Survey.

Schedule for Next Reviews/Revisions of the Plan:
- Spring 2019
- Spring 2021

FIGURE 1.1 – Map: The Delaware Inland Bays Watershed
FIGURE 1.2 – Map: Watershed Land Use, 2012

Land Use
- Proposed Development Projects
- Developed/Developing
- Agriculture
- Upland Forest
- Open Water
- Wetland
- Other

Legend:
- Orange: Proposed Development Projects
- Pink: Developed/Developing
- Yellow: Agriculture
- Green: Upland Forest
- Cyan: Open Water
- Olive: Wetland
- Gray: Other
2. ASSESSMENT AND REPORTING

2.1 ENVIRONMENTAL INDICATORS AND STATE OF THE ESTUARY REPORTS

Conditions in the Inland Bays are dynamic and it is essential to monitor temporal and spatial changes in water quality across the watershed and understand how changes relate to the health of the estuary.

Comprehensive assessments of the condition of the Inland Bays were published in 1995, 2004, 2011, and 2016. The State of the Delaware Inland Bays report currently is updated and published every five years. The 2016 report included assessment of 35 individual environmental indicators. The indicators are based on long-term measurements of environmental parameters and management actions. Status and trends are assigned using best professional judgment and reviewed by scientists knowledgeable in these areas. For each indicator, long-term trends are addressed, as well as short-term changes that have occurred since the previous report was published.

The IBEMP is intended, in part, to ensure that long-term collection of data needed to develop these environmental indicators for the Bays is continued.

The table in Appendix A lists the environmental indicators currently used to produce the State of the Delaware Inland Bays reports. The table summarizes the sources of data used to develop each indicator, as well as the relevant CCMP actions addressed by each. These monitoring programs are described in more detail in other sections of the IBEMP.

2.2 HYDRODYNAMIC AND WATER QUALITY MODEL

The first state-of-the-art water quality modeling program implemented in Delaware’s Inland Bays used a calibration database that included data from DNREC, USGS, US Army Corps of Engineers, University of Delaware researchers, citizen monitors and others (Cerco et al. 1994). The model was calibrated using data from 1988-1990 and is largely based on the same model used to manage water quality in Chesapeake Bay (CE-QUAL-W2) (Cerco and Noel 2005). The TMDL was established in 1998. This model included a mechanistic sediment flux model and even included a benthic algal model due to the shallow nature of the bays (Cerco and Seitzinger 1997).

The second TMDL analysis used the aforementioned GEMSS model to establish the approved TMDL in 2004. That model used a calibration dataset that spanned 1998-2000. In March 2004, Entrix, INC. and J.E. Edinger Associates submitted their final report describing the second Total Daily Maximum Load model currently used for Delaware’s Inland Bays (DIB). (Entrix and JEEAI 2004). The model is a fully coupled 1-D watershed and 3-D hydrodynamic-water quality model called the Generalized Environmental Modeling Surface Water System (GEMSS). That model was primarily used to calculate water quality constituents such as nitrogen, phosphorus (particulate/dissolved, inorganic/organic) and dissolved oxygen (DO). The model was calibrated using data collected from 1998-2000.

2.3 TMDL REPORTING AND BENCHMARK GOALS

Section 305(b) of the Federal Clean Water Act requires that states prepare and submit a Watershed Assessment Report to EPA on April 1st of every even numbered year. The 305(b) reports and monitoring data are used to compile a list of impaired waters, commonly referred to as the 303(d) list. When waters are identified as impaired on 303(d) lists, a Total Maximum Daily Load (TMDL) must be developed. All of the 305(b) Reports and 303(d) lists that Delaware has submitted to EPA are available on the DNREC website (http://www.dnrec.delaware.gov/swc/wa/Pages/WatershedAssessment305band303dReports.aspx). Draft Core Documents for the 2016 305(b)/303(d) Integrated Report were posted at the time of completion of
this monitoring plan (March 2017). A copy of the assessment, listing, and reporting methodologies, including benchmark goals and hypotheses, is included here as Appendix F.
3. INLAND BAYS MONITORING PROGRAMS

This section of the Plan reports existing projects and programs that are conducting ongoing, long-term environmental monitoring in Delaware’s Inland Bays. Many of these programs contribute data that are used to develop *State of the Delaware Inland Bays* reports every five years. Others produce data that may illuminate progress toward achieving goals of the CCMP, provide data for new environmental models, or may be useful for development of new indicators in the future.

The programs listed here are organized into five sections:

- 3.1 Monitoring of Surface Water
- 3.2 Monitoring of Living Resources
- 3.3 Monitoring of Nutrient Loads
- 3.4 Monitoring of Groundwater
- 3.5 Monitoring and Assessment of Wetlands

The expectation and recommendation of this Plan is that these programs will continue to be funded and conducted long-term.
3.1 MONITORING OF SURFACE WATER

3.1.1. STATE OF DELAWARE AMBIENT SURFACE WATER QUALITY MONITORING PROGRAM

Description/Objective(s)

The Delaware Department of Natural Resources and Environmental Control (DNREC) maintains a statewide General Assessment Monitoring Network (GAMN) of 134 stations, of which 24 are located in the Inland Bays (Figure 3.1). GAMN stations are considered long-term stations, and data collected support compilation of Watershed Assessment Reports as mandated by the Clean Water Act under section 305(b).

All GAMN stations are monitored for temperature, salinity, dissolved oxygen, pH, alkalinity, hardness, chloride, chlorophyll, biological oxygen demand, total suspended solids, turbidity, organic carbon, nutrients, and Enterococcus bacteria. Tidal waters and lakes/ponds are also monitored where and when possible for water clarity (Secchi depth) and light attenuation. Some nontidal and tidal stations are further monitored for metals, while some nontidal stations are monitored for biology/habitat.

Monitoring frequency at GAMN stations follows a 5-year rotating basin schedule in which every station is monitored monthly for 2 years and monitored every other month for the remaining 3 years. Each station is monitored for conventional parameters such as nutrients, bacteria, dissolved oxygen, pH, alkalinity, and hardness (see Tables 3.1 and 3.2 for a complete list of parameters). Some stations are also monitored for dissolved metals.

Responsible Organization and Contact

The collection of ASWQMP samples and field data is conducted by the DNREC, Division of Water, Environmental Laboratory Section (ELS). The analysis of samples and generation of analytical results is also done by the ELS, with exception of some tests which are outsourced to selected laboratories that have EPA-approved Quality Assurance Management Plans.

Contact: Kathy Knowles, DNREC Environmental Laboratory Manager
kathy.knowles@state.de.us, 302-739-9942

DNREC’s Division of Watershed Stewardship, Watershed Assessment Section, analyzes the data to (1) define the water quality status and trends for each sub-basin and (2) compare the data with water quality standards to assess designated use support as mandated by Section 305(b) of the CWA.

Contact: David Wolanski
david.wolanski@state.de.us, 302-739-9939

Data Collection Cost

The annual cost of water quality monitoring of sites within the Inland Bays Watershed is between $100,000 to $170,000, depending on frequency of monitoring (monthly or every other month). Frequency of monitoring follows a 5-year state-wide rotating basin schedule. Per this schedule, during every 5 years, most monitoring sites in the Inland Bays are monitored monthly for 2 years and are monitored every other month for 3 years.

Annual cost to maintain a continuous monitoring station, such as the one currently deployed at Massey’s Ditch is on the order of $50,000.

Data Use

GAMN data are used to:

- Describe general water quality conditions of the State’s surface waters;
- Identify long term trends in water quality;
• Determine the suitability of Delaware waters for water supply, recreation, fish and aquatic life, and other uses;
• Calculate annual nutrient loads and track progress toward achieving Total Maximum Daily Loads (TMDLs) targets; and
• Evaluate the overall success of Delaware’s water quality management efforts.

The findings are reported biannually to the EPA in the Water Quality Inventory Report as mandated by Section 305(b) of the Clean Water Act (CWA), and are used to identify and prioritize water-quality limited waters as mandated by Section 303(d) of the CWA, as well as waters of high quality. Since the late 1990’s the data have been used to develop and calibrate TMDL models, and in the future will be used to gage the success of TMDL-based Pollution Control Strategies.

Data from this program also are used by the Center to prepare environmental indicator reports, including the pentennial State of the Delaware Inland Bays reports.

Record of Collection

See Table 3.1 for the record of collection at each Inland Bays station.

Collection Method

Water sample collection:
All water sample collections are conducted by the DNREC Field Services Branch according to the Environmental Laboratory’s Operational Procedure, Surface Water Sampling,

Continuous Monitoring:
A portable, automated on-site laboratory was deployed in 2005 at the outlet to Millsboro Pond in order to define inorganic nitrogen and phosphorus loads entering the Inland Bays via the nontidal segment of Indian River. This station, however, has been discontinued.

DNREC has been developing a network of water quality monitoring stations at which data is collected continuously for dissolved oxygen concentration and percent saturation and other parameters (temperature, specific conductivity, pH, and salinity) that exhibit substantial fluctuation over short time scales such as the diel (24-hour) cycle or in response to weather conditions. This monitoring is conducted using YSI 6-series multi-parameter sondes. Measurements are taken at least every 15 minutes when the instruments are deployed. A rotating basin approach in the state is planned by DNREC.

Currently the only continuous monitoring station is deployed in Massey’s Ditch (USGS 01484680), at the Massey’s Landing fishing pier. Water quality data has been collected at this site since November 2011 (https://waterdata.usgs.gov/usa/nwis/uv?01484680). It is funded jointly by USGS and DNREC.

Analysis Methods

See Table 3.2 for a summary of analytical methods used for each parameter.

Data Location
The GAMN data are entered into the STORET database, and are publically available via the Delaware Water Quality Portal (http://demac.udel.edu/waterquality/).

Management Goal
Management goals are defined by the TMDLs approved for each watershed.

Hypothesis and Test Statistics
Methodologies for analyses are defined in the State of Delaware Draft 2016 Assessment, Listing and Reporting Methodologies Pursuant to Sections 303(d) and 305(b) of the Clean Water Act, available from the Division of Watershed Stewardship.
FIGURE 3.1 -- Map showing DNREC GAMN monitoring stations in the Inland Bays.
### TABLE 3.1. -- Summary of DNREC GAMN Stations in the Inland Bays

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Location</th>
<th>Period of Record</th>
<th>Sampling Frequency*</th>
</tr>
</thead>
<tbody>
<tr>
<td>312011</td>
<td>38.557982, -75.089363</td>
<td>1998 to 2016</td>
<td>b</td>
</tr>
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<td>311041</td>
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<td>1998 to 2016</td>
<td>b</td>
</tr>
<tr>
<td>310121</td>
<td>38.521498, -75.133453</td>
<td>1998 to 2016</td>
<td>a</td>
</tr>
<tr>
<td>310071</td>
<td>38.478040, -75.055024</td>
<td>1998 to 2016</td>
<td>b</td>
</tr>
<tr>
<td>310031</td>
<td>38.483943, -75.117882</td>
<td>1998 to 2016</td>
<td>b</td>
</tr>
<tr>
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<td>308371</td>
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<td>1999 to 2016</td>
<td>b</td>
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<td>b</td>
</tr>
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<td>b</td>
</tr>
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<td>b</td>
</tr>
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<td>1998 to 2016</td>
<td>b</td>
</tr>
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<td>b</td>
</tr>
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<td>1998 to 2016</td>
<td>b</td>
</tr>
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<td>306341</td>
<td>38.583450, -75.224515</td>
<td>1998 to 2016</td>
<td>b</td>
</tr>
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<td>306331</td>
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<td>1998 to 2016</td>
<td>b</td>
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<td>306321</td>
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<td>a</td>
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<td>38.606510, -75.111310</td>
<td>1998 to 2016</td>
<td>a</td>
</tr>
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<td>306111</td>
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<td>1998 to 2016</td>
<td>b</td>
</tr>
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<td>38.649121, -75.109355</td>
<td>1998 to 2016</td>
<td>b</td>
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<td>1998 to 2016</td>
<td>b</td>
</tr>
<tr>
<td>305011</td>
<td>38.708891, -75.093022</td>
<td>1998 to 2016</td>
<td>b</td>
</tr>
</tbody>
</table>

* a: Station is monitored monthly every year.
  
b: Station is monitored six times a year for three years, then twelve times a year for two years.
TABLE 3.2 -- Water quality parameters analyzed at DNREC GAMN Stations and analytical methods.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method Reference (EPA)</th>
<th>Reporting Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Column Nutrients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td>EPA365.1 M</td>
<td>0.005 mg/l P</td>
</tr>
<tr>
<td>Soluble Ortho-phosphorus</td>
<td>EPA365.1</td>
<td>0.005 mg/l P</td>
</tr>
<tr>
<td>Ammonia Nitrogen</td>
<td>EPA350.1</td>
<td>0.005 mg/l N</td>
</tr>
<tr>
<td>Nitrite+Nitrate N</td>
<td>EPA353.3</td>
<td>0.005 mg/l N</td>
</tr>
<tr>
<td>Total N*</td>
<td>SM 4500 NC</td>
<td>0.08 mg/l N</td>
</tr>
<tr>
<td><strong>Carbon and Organics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>EPA415.1</td>
<td>1 mg/l</td>
</tr>
<tr>
<td>Dissolved Organic Carbon</td>
<td>EPA415.1</td>
<td>1 mg/l</td>
</tr>
<tr>
<td>Chlorophyll-a (Corr)</td>
<td>EPA 445.0</td>
<td>1 μ/l</td>
</tr>
<tr>
<td><strong>Biochemical Oxygen Demand</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOD$_5$, N-Inhib (CBOD)</td>
<td>SM20*ed-5210B</td>
<td>2.4 mg/l</td>
</tr>
<tr>
<td>BOD$_{20}$, N-Inhib (CBOD)</td>
<td>SM20*ed-5210B</td>
<td>2.4 mg/l</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved oxygen – Winkler</td>
<td>EPA360.2</td>
<td>0.25 mg/l</td>
</tr>
<tr>
<td>Dissolved oxygen – Field</td>
<td>EPA360.1</td>
<td>0.1 mg/l</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>EPA160.2</td>
<td>2 mg/l</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>EPA310.1</td>
<td>1 mg/l</td>
</tr>
<tr>
<td>Hardness</td>
<td>EPA310.2</td>
<td>5 mg/l</td>
</tr>
<tr>
<td>Field pH</td>
<td>EPA150.1</td>
<td>0.2 pH units</td>
</tr>
<tr>
<td>Conductivity - Field</td>
<td>EPA120.1</td>
<td>1 μS/cm</td>
</tr>
<tr>
<td>Salinity</td>
<td>SM20*ed-2520B</td>
<td>1 ppt</td>
</tr>
<tr>
<td>Temperature</td>
<td>EPA170.1</td>
<td>°C</td>
</tr>
<tr>
<td>Secchi Depth</td>
<td>EPA/620/R-01/003</td>
<td>meters</td>
</tr>
<tr>
<td>Light Attenuation</td>
<td>EPA/620/R-01/003</td>
<td>%</td>
</tr>
<tr>
<td>Turbidity</td>
<td>EPA180.1</td>
<td>1 NTU</td>
</tr>
<tr>
<td>Chloride</td>
<td>EPA325.2</td>
<td>1 mg/l</td>
</tr>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enterococcus</td>
<td>SM20*ed-9230C</td>
<td>1 cfu/100 ml</td>
</tr>
</tbody>
</table>
3.1.2 UNIVERSITY OF DELAWARE CITIZEN MONITORING PROGRAM

Description/Objective(s)

University of Delaware Sea Grant Marine Advisory Service’s Citizen Monitoring Program (CMP) was formed in 1991 to support the newly-formed Inland Bays Estuary Program (http://citizen-monitoring.udel.edu/). Through this citizen science program, more than 300 trained volunteers have collected samples at water quality monitoring sites throughout the Inland Bays, and provided important data - including dissolved oxygen, dissolved inorganic nitrogen, dissolved inorganic phosphorus, water clarity, bacteria levels, and other environmental data. Supplemental NEP grants have helped grow shorter-term special interest monitoring programs, including harmful algal species and dissolved oxygen measurements taken from boats.

Combined with the state’s fixed monitoring stations, the additional resolution provided by the more than 15 years of data, from over 30 sampling sites in the Inland Bays, has resulted in a long-term, robust, high-quality data set that provides scientists and resource managers with a clearer picture of the bays’ health and the trend information needed to understand and manage the ecosystem.

Responsible Organization and Contact

The program is managed by the University of Delaware Sea Grant Marine Advisory Service at the College of Earth, Ocean, and Environment in Lewes.

Contact: Edward Whereat
whereat@udel.edu, 302-645-4252

Data Collection Cost

Original support for the CMP came through the National Estuary Program, but since 1994 the Citizen Monitoring Program has received an appropriation from the Delaware General Assembly through a Memorandum of Agreement with DNREC. Additional support currently comes from a variety of sources, including: Sea Grant; DNREC; the Center for the Inland Bays; U.S. EPA; the Delaware Estuary Program; the National Fish and Wildlife Foundation; and local communities.

Reported total cost of the program in federal fiscal year 2016 was $102,737. This included $34,177 federal funding, $45,000 state funding, and $23,560 private in-kind.

In 2015 and 2016, the CIB has covered the cost for nutrient analyses to be conducted by the University of Maryland’s Chesapeake Biological Laboratory. Total annual cost for these analyses is approximately $4,000.

Data Use

CMP data are used by the CIB for status and trend analyses in the CIB’s ‘State of the Inland Bays’ reports, which are published every five years. In addition, CMP data are being used to develop indicator reports for individual tributaries in the CIB’s ‘Your Creek’ project.

Bacteria and harmful algal bloom data collected by the CMP are used by DNREC to support the Delaware Shellfish Monitoring Program and to assess bacteria levels and trends in the state’s coastal watersheds.

Record of Collection

See Table 3.3 for the record of collection at each Inland Bays station.

Collection Method

Data are collected by trained volunteers at sites assigned to them by the CMP Program Manager. Table 3.3 summarizes the CMP monitoring sites that currently are used to assess Inland Bays water quality status and trends. Figures 3.2 to 3.5 provide a maps of CMP sites for individual indicator parameters. Additional sites are monitored in the Bays, but only those that provide long-term data used for Center environmental indicator reports are included here.
Sampling methods are detailed in a guidebook, *Inland Bays Citizen Monitoring Program Volunteer’s Water Quality Monitoring Manual* (revised 2017). They are summarized below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Collection Frequency</th>
<th>Method/Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Weekly</td>
<td>Thermometer</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Weekly</td>
<td>Secchi Disk</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>Weekly</td>
<td>Micro-Winkler Titration</td>
</tr>
<tr>
<td>Salinity</td>
<td>Weekly</td>
<td>Hydrometer</td>
</tr>
<tr>
<td>pH</td>
<td>Weekly</td>
<td>Digital Meter</td>
</tr>
<tr>
<td>Rainfall</td>
<td>Daily</td>
<td>Rain Gauge</td>
</tr>
<tr>
<td>Nitrates</td>
<td>Biweekly</td>
<td>Grab Sample/Lab Analysis</td>
</tr>
<tr>
<td>Orthophosphates</td>
<td>Biweekly</td>
<td>Grab Sample/Lab Analysis</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Biweekly</td>
<td>Grab Sample/Lab Analysis</td>
</tr>
<tr>
<td>Phytoplankton</td>
<td>Biweekly</td>
<td>Grab Sample/Lab Analysis</td>
</tr>
</tbody>
</table>

**Analysis Methods**

Currently, nutrient analyses are subcontracted to the University of Maryland Chesapeake Biological Laboratory in Solomons, MD. Other laboratory analyses are conducted in-house at the University of Delaware, with assistance from trained volunteers.

See Table 3.4 for a summary of analytical methods used for each parameter.

Note that DIP is labeled as Orthophosphate in the state's GAMN dataset. DIN is calculated by summing nitrate+nitrite and dissolved ammonia.

**Data Location**

Data are stored in a database at the University of Delaware College of Earth, Ocean, and Environment in Lewes. Semi-monthly reports are posted online at [http://www.citizen-monitoring.udel.edu/reports/](http://www.citizen-monitoring.udel.edu/reports/). Currently the data cannot be queried or downloaded online. Data are available by request to the CMP Program Manager.

**Management Goal/Hypothesis and Test Statistics**

Data are included as an Appendix to the state’s Combined 305(b) Report and 303(d) List, but are not used directly in listing determinations. The CIB uses CMP data to develop an indicator known as the Water Quality Index (WQI) for eelgrass reestablishment. The WQI is created by relating the values of DIN, DIP, Chlorophyll a, and Secchi depth to the eelgrass restoration criteria developed in the Chesapeake Bay as refined for the Delmarva Coastal Bays (Valdes-Murtha 1997, Batuik et al. 2000). Thresholds are DIN = 0.14 mg/L, DIP = 0.01 mg/L, Chlorophyll a = 15 micrograms per liter, and Secchi depth = 2.2 ft.

All data collected for these parameters that followed the established criteria for inclusion were scaled linearly using the following Excel function:

\[=TREND(calcs!E2:F2, calcs!C4:D4, F2)\]

E2 and F2 represent the top and bottom of the scale desired (0 and 1), and C and D represent the 95th percentile of all data for that parameter and the threshold value for that parameter. F represents the actual parameter value. For Secchi depth, the 5th percentile is used instead of the 95th percentile, because a larger number represents a better Secchi depth, unlike the other parameters where a larger value indicated a worse measurement. After scaling linearly, any values below 0 were changed to 0, and any values exceeding 1 were changed to 1. Then, for each row, the four parameters were added...
together, and the sum was divided by 4 to get a mean WQI for each sampling event at each station. The mean annual WQI values are used for Mann Kendall trend analyses.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Criteria for Indicator Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very poor water quality</td>
</tr>
<tr>
<td>Water Quality Index for Eelgrass Reestablishment (range=0 to 1)</td>
<td>&lt;0.75</td>
</tr>
</tbody>
</table>
### TABLE 3.3 – Summary of Citizen Monitoring Program Stations in the Inland Bays. These are stations currently sampled regularly, as of 2016.

<table>
<thead>
<tr>
<th>Location</th>
<th>Period of Collection</th>
<th>Parameters Collected</th>
<th>Secchi Depth</th>
<th>Total Enterococcus</th>
<th>TSS</th>
<th>Water Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location</td>
<td>Latitude</td>
<td>Longitude</td>
<td>Start Date</td>
<td>End Date</td>
<td>Chl a</td>
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<tr>
<td>IR02</td>
<td>38.59453</td>
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<td>2000</td>
<td>2002</td>
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<td>IR04</td>
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<td>2015</td>
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<td>2015</td>
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<td>2015</td>
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<td>2015</td>
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<td>2015</td>
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<td>IR29</td>
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<td>2015</td>
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<td>2015</td>
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<td>2015</td>
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</tr>
<tr>
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<td>38.66194</td>
<td>-75.13222</td>
<td>2000</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
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</tr>
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<td>2015</td>
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<tr>
<td>RB90</td>
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<td>2015</td>
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</tr>
<tr>
<td>SB01</td>
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<td>2008</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
<td></td>
</tr>
<tr>
<td>SB02</td>
<td>38.51851</td>
<td>-75.06083</td>
<td>2006</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
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</tr>
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<td>SB04</td>
<td>38.51793</td>
<td>-75.05603</td>
<td>2007</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
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</tr>
<tr>
<td>SB05</td>
<td>38.51783</td>
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<td>2009</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
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</tr>
<tr>
<td>SB06</td>
<td>38.51744</td>
<td>-75.05539</td>
<td>2012</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
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</tr>
<tr>
<td>SB07</td>
<td>38.51490</td>
<td>-75.05993</td>
<td>2006</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
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</tr>
<tr>
<td>SB09</td>
<td>38.51033</td>
<td>-75.05663</td>
<td>2008</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
<td></td>
</tr>
<tr>
<td>SB10E</td>
<td>38.52083</td>
<td>-75.06113</td>
<td>2002</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
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</tr>
<tr>
<td>SB10W</td>
<td>38.52057</td>
<td>-75.06350</td>
<td>2002</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
<td></td>
</tr>
<tr>
<td>SB12</td>
<td>38.51356</td>
<td>-75.06233</td>
<td>2002</td>
<td>2015</td>
<td>● ● ● ● ● ● ● ● ● ●</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Stations identified by the CIB as top priority to continue, for use in the State of the Delaware Inland Bays reporting.
2. Station was sampled fewer than five times for any parameter in 2015.
TABLE 3.4 – Summary of Citizen Monitoring Program Analytical Methods

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method Reference (EPA)</th>
<th>Reporting/Quantitation Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Column Nutrients – These analyses are currently performed by the UMCES CBL NASL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble Ortho-phosphorous</td>
<td>EPA365.1</td>
<td>0.0025 mg/l P</td>
</tr>
<tr>
<td>Ammonia Nitrogen</td>
<td>EPA350.2</td>
<td>0.01 mg/l N</td>
</tr>
<tr>
<td>Nitrite + Nitrate N</td>
<td>EPA353.2</td>
<td>0.0035 mg/l N</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved oxygen – Winkler</td>
<td>EPA360.2</td>
<td>0.25 mg/l</td>
</tr>
<tr>
<td>Dissolved oxygen – Field</td>
<td>EPA360.1</td>
<td>0.1 mg/l</td>
</tr>
<tr>
<td>Chlorophyll-a</td>
<td>EPA445.0</td>
<td>1 µg/L</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>EPA160.2</td>
<td>2 mg/l</td>
</tr>
<tr>
<td>Field pH</td>
<td>EPA150.1</td>
<td>0.2 pH units</td>
</tr>
<tr>
<td>Conductivity - Field</td>
<td>EPA120.1</td>
<td>1 µS/cm</td>
</tr>
<tr>
<td>Salinity</td>
<td>SM20⁰ed-2520B and 2520C</td>
<td>1 ppt</td>
</tr>
<tr>
<td>Temperature</td>
<td>EPA170.1</td>
<td>0.5 °C</td>
</tr>
<tr>
<td>Secchi Depth</td>
<td>EPA/620/R-01/003</td>
<td>0.1 meters</td>
</tr>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Enterococcus</td>
<td>SM20⁰ed-9230C</td>
<td>1 cfu/100 ml</td>
</tr>
</tbody>
</table>
FIGURE 3.2 – Map showing locations of Citizen Monitoring Program stations that collect nutrient data.
FIGURE 3.3 – Map showing locations of Citizen Monitoring Program stations that collect dissolved oxygen data.
FIGURE 3.4 – Map showing locations of Citizen Monitoring Program stations that collect Secchi depth data.
FIGURE 3.5 – Map showing locations of Citizen Monitoring Program stations that collect Total Enterococcus data.
3.1.3 STATE FECAL COLIFORM MONITORING PROGRAM

Description/Objective(s)
In order to regulate shellfish harvest areas, the State has monitored levels of total coliform bacteria and, beginning in 2016, fecal coliforms in all three Inland Bays. The goal of this program is to ensure that waters that are approved for shellfish harvest meet water quality standards based on routine water quality assessments. Additionally, this program can be used to justify the opening of previously closed areas for harvest should the data reflect the area is safe, and close previously open areas in the event of high coliform levels.

Responsible Organization and Contact
DNREC Division of Watershed Stewardship
Contact: Michael Bott, Environmental Scientist
Michael.Bott@state.de.us, 302-739-9939

Data Collection Cost
Not available

Data Use
Data are used primarily by DNREC Division of Watershed Stewardship’s Shellfish Program to assess the suitability of the Inland Bays waters for shellfish harvest.

Record of Collection
2008 to present. Fecal coliform collection began in 2016, with plans to succeed total coliforms as the method to assess the suitability of waters.

Collection Method
Ten times per year, 52 sites in Rehoboth and Indian River Bay are sampled and analyzed for fecal coliforms. Little Assawoman Bay is sampled nine times a year at nine sites.

Analysis Methods
Analyses use mTEC agar (M-198) membrane filter medium, for enumerating fecal coliforms in marine and estuarine waters (FDA, 1998).

Data Location
Data are managed and stored by the DNREC Division of Watershed Stewardship Shellfish Program

Management Goal
Standard for total coliforms: no more than 10% or 90th percentile, of past 30 samples exceed 330 mpn/100mL; geometric mean shall not exceed 70mpn/100mL over the past 30 samples.

3.1.4 DGS-USGS STREAM AND TIDE GAGING PROGRAM

Description/Objective(s)
The US Geological Survey (USGS), in cooperation with the Delaware Geological Survey (DGS) through a State-Federal partnership program, operates and maintains stream and tide gages throughout Delaware. The streamgage network is a component of the National Streamflow Information Program (NSIP), a program that provides real-time and long-term current and historical streamflow information that is not only accurate and unbiased, but also meets the needs of many users.

Currently there are nine station locations in the Inland Bays; three of these measure flow (Table 3.5 and Figure 3.6).

Responsible Organization and Contact
The stations located in the Inland Bays are managed by the MD-DE-DC Water Science Center, 1289 McD Drive, Dover, DE 19901. Phone 302-734-2506

Data Collection Cost

Funding for the three drainage stations is provided by DNREC through the DGS. Funding for the operation of the Inland Bays tidal stations are funded by DNREC through the DGS, and the Delaware Department of Transportation. The USGS provides match funding for the streamgage portion of the program.

Data Use

The Delaware Stream and Tide Gage network provides the hydrologic and water quality information necessary to aid in defining, using, and managing surface and groundwater resources. The data are used for a multitude of purposes, including, but not limited to, long-range water resources planning and management, short-term resource management, evaluation of drought-no drought conditions, allocation of water resources for public, industrial, commercial, and irrigation water supplies, flood forecasting and warning, bridge and culvert design, hazard spill response and mitigation, analysis of sea level rise, recreation, and floodplain mapping. The stream and tide data are also utilized in existing real-time early warning systems related to potential flooding, and storm/coastal erosion throughout Delaware. The warning systems are used by the DGS, Delaware Emergency Management Agency, all three county emergency management offices, most municipalities, the National Weather Service, the Office of the State Climatologist, and others.

Record of Collection

See Table 3.5.

Collection Method

Water-stage recorder gages. The peak tidal stage that is recorded by each gage is the elevation of water above the North American Vertical Datum of 1988. Stations have a USGS satellite data-collection platform.

Analysis Methods

Once a complete day of readings are received from a site, daily summary data are generated and made available online. USGS finalizes data at individual sites on a continuous basis as environmental conditions and hydrologic characteristics permit.

Data Location

Stream and tide gage information are available at http://waterdata.usgs.gov/de/nwis/current/?type=flow. Data from USGS stream and tide gage networks in Delaware are also available through the Delaware Environmental Observing System (DEOS) site: http://www.deos.udel.edu/data/.

TABLE 3.5 – Inland Bays Stream and Tide Gage Stations
<table>
<thead>
<tr>
<th>Station No.</th>
<th>Station Name</th>
<th>Latitude</th>
<th>Longitude</th>
<th>HUC-8</th>
<th>Parameters</th>
<th>Period of Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>01484525</td>
<td>Millsboro Pond Outlet</td>
<td>38°35'40.4&quot;</td>
<td>75°17'27.7&quot;</td>
<td>02060010</td>
<td>Discharge, Gage height</td>
<td>May 1986 to September 1988. March 1991 to current year.</td>
</tr>
<tr>
<td>1484695</td>
<td>Beaverdam Ditch near Millville</td>
<td>38°31'17.2&quot;</td>
<td>75°08'00.2&quot;</td>
<td>02040303</td>
<td>Discharge, Gage height</td>
<td>August 1998 to current year.</td>
</tr>
<tr>
<td>01484540</td>
<td>Indian River at Rosedale Beach</td>
<td>38°35'29.5&quot;</td>
<td>75°12'41.7&quot;</td>
<td>02040303</td>
<td>Discharge, Gage height</td>
<td>April 1991 to current year.</td>
</tr>
<tr>
<td>01484549</td>
<td>Vines Creek near Dagsboro</td>
<td>38°33'23.0&quot;</td>
<td>75°12'11.4&quot;</td>
<td>02040303</td>
<td>Tide elevation</td>
<td>Annual maximum, water years 1985-97. May 2015 to current year.</td>
</tr>
<tr>
<td>01484670</td>
<td>Rehoboth Bay at Dewey Beach</td>
<td>38°41'39.2&quot;</td>
<td>75°05'03.2&quot;</td>
<td>02040303</td>
<td>Gage height, tide elevation</td>
<td>April 1985 to September 1997; November 2000 to current year.</td>
</tr>
<tr>
<td>01484683</td>
<td>Indian River Bay Inlet near Bethany Beach</td>
<td>38°36'35.4&quot;</td>
<td>75°04'04.8&quot;</td>
<td>02040303</td>
<td>Gage height, tide elevation</td>
<td>June 1988 to June 1989, April 1991 to December 2010, November 2011 to current year.</td>
</tr>
<tr>
<td>01484690</td>
<td>Unnamed Ditch on Fred Hudson Rd at Bethany Beach</td>
<td>38°33'19.6&quot;</td>
<td>75°03'48.4&quot;</td>
<td>02040303</td>
<td>Tide elevation</td>
<td>May 2015 to current year.</td>
</tr>
<tr>
<td>01484696</td>
<td>Jefferson Creek at South Bethany</td>
<td>38°30'48.8&quot;</td>
<td>75°03'44.4&quot;</td>
<td>02040303</td>
<td>Gage height, tide elevation</td>
<td>July 1999 to current year.</td>
</tr>
<tr>
<td>01484701</td>
<td>Little Assawoman Bay at Fenwick Island</td>
<td>38°27'17.9&quot;</td>
<td>75°03'30.0&quot;</td>
<td>02040303</td>
<td>Gage height, tide elevation</td>
<td>October 1999 to current year.</td>
</tr>
</tbody>
</table>
FIGURE 3.6 – Map showing locations of Tide Gauges in the Inland Bays.
3.1.5 STATE BIOLOGICAL ASSESSMENT OF STREAMS PROGRAM

Description/Objective(s)

This long-term project collects biological and habitat data from nontidal wadable streams in order to relate water quality conditions with biological integrity. Eligible stations must (1) be completely nontidal, (2) have perennial flow, and (3) be uninfluenced by elevated temperature resulting from lentic discharge (i.e. millpond, stormwater pond, etc). The biological data consists of two instream matrices: macroinvertebrate, and periphyton (first initiated in spring - 2005). The habitat data consists of instream and riparian zone matrices.

Beginning in 2006, and every other autumn thereafter, biological (macroinvertebrate), habitat and chemical sampling has occurred under baseflow conditions at 50 stations located along streams that have been placed on the 303(d) list due to impaired biology or habitat. This bi-annual sampling rotates by county, major basin, or both. Conjunctural chemical sampling will be conducted. The data are evaluated to determine whether any form of impairment still exists at each respective station. If impairment is concluded, then effort will be made to identify the cause/s. The procedure for identifying causation is not yet fully outlined but will likely follow the EPA Stressor Identification Guidance Document (Cormier et al, 2000).

In years between 303(d) sampling, up to 50 GAMN stations are be sampled. The biological and habitat methodology is the same as used for the 303(d) sampling.

The immediate objective of this sampling is to determine the overall biological condition of nontidal streams in Delaware. The extended objective is to identify trends in biological condition in these waters.

Responsible Organization and Contact

DNREC Division of Water, Environmental Laboratory
Contact: Kathy Knowles, Laboratory Manager  
Kathy.knowles@state.de.us, 302-739-9942

Data Collection Cost

Not available.

Data Use

All analytical results are provided to the Watershed Assessment Section (WAS). The biological assessment data are used to:

- Define current water quality conditions.
- Identify and define long-term trends in water quality.
- Determine the suitability of Delaware waters for designated uses (e.g. water supply; recreation; fish, aquatic life and wildlife) as specified in the Delaware Surface Water Quality Standards.
- Determine whether the water quality standards are being met.
- Identify and prioritize high quality and degraded waters.
- Support the Total Maximum Daily Load Program.
- Evaluate the overall success of Delaware’s water quality management efforts.

The 305(b) Report is submitted biannually by the WAS to the EPA as mandated by the Clean Water Act (CWA), and the findings are used to identify and prioritize water-quality limited waters as mandated by Section 303(d) of the CWA, as well as waters of high quality. Since the late 1990’s the data have been used to develop and calibrate TMDL models, and in the future will be used to gage the success of TMDL-based Pollution Control Strategies.

Record of Collection

2000 to present
Collection Method

Biology and habitat sampling is done in accordance with methods defined in USEPA (1997). Biology samples are collected at coastal plain sites using a D-framed net.

Periphyton sampling is conducted according to the USGS, National Water Quality Assessment Program (Moulton et al. 2002). Samples will be collected from natural substrates, sticks and/or macrophytes (coastal plain), and rocks (piedmont). Only sticks that have obviously been in the water for an extended period (weeks to months) will be sampled.

Analysis Methods

The field preserved macroinvertebrate samples are outsourced for subsampling and identification to the lowest practical taxon. Level of identification for each phylum is as follows;

- **Arthropoda** genus / some species
- **Annelida** genus / some species
- **Mollusca** genus / some species
- **Bryozoa** family / some genus (statoblasts)
- **Platyhelminthes** genus / some species
- **Cnidaria** genus

For analytical purposes, the species composition and abundance data will be reduced to the genus level. A multi-metric approach will be used to calculate a biological index (BI) for each sample which is expressed as a percentage of the ecoregion reference values (see Gibson 1996). Based on the BI, the site will then be categorized according to condition (i.e. excellent, good, moderately degraded, severely degraded).

The periphyton samples also are outsourced for identification.

Data Location

All completed field-generated and laboratory-generated data are entered into the DNREC ELS Laboratory Information Management System (LIMS).

Management Goal

The data are evaluated to determine whether any form of impairment still exists at each respective station. If impairment is concluded, then effort will be made to identify the cause/s. The procedure for identifying causation is not yet fully outlined but will likely follow the EPA Stressor Identification Guidance Document (USEPA, 2000).

Hypothesis and Test Statistics

From each set of triplicate results (three stations sampled in triplicate for macroinvertebrates and periphyton) a coefficient of variation is developed. The range of these three coefficients of variation is regarded as the within-station spatial variability of the biological community across the entire study area.

3.1.6 NATIONAL AQUATIC RESOURCE SURVEYS

Description/Objective(s)

The National Aquatic Resource Surveys (NARS) are statistical surveys designed to assess the status of and changes in quality of the nation’s coastal waters, lakes and reservoirs, rivers and streams, and wetlands. Using sample sites selected at random, these surveys provide a snapshot of the overall condition of the nation’s water. Because the surveys use standardized field and lab methods, results can be compared from different parts of the country and between years. EPA works with state, tribal and federal partners to design and implement the NARS.

The surveys are designed to answer questions such as:

- What percent of waters support healthy ecosystems and recreation?
• What are the most common water quality problems?
• Is water quality improving or getting worse?
• Are investments in improving water quality focused appropriately?

These surveys are providing nationally-consistent water quality information. Additionally, the national surveys are helping to build stronger water quality monitoring programs across the country by fostering collaboration on new methods, new indicators and new research.

The NARS are made up of four individual surveys that are implemented on a rotating basis. Stations in the Inland Bays watershed during previous field seasons are shown in Figure 3.7. A summary of the indicators used in each survey is provided in Table 3.6.

• National Coastal Condition Assessment (NCCA)

  **Goals:** The goal of the NCCA is to address three key questions about the quality of the Nation's coastal waters: (1) What percent of the Nation’s coastal waters are in good, fair, and poor condition for key indicators of water quality, ecological health, and recreation? (2) How are conditions changing over time? (3) What is the relative importance of key stressors (e.g., nutrients and pathogens) in impacting the biota?

  **Design:** The NCCA sampling is comprised of coastal waters extending from the shoreline to the nearshore boundary of the open water of the oceans and Great Lakes. The assessment is limited to the fringing, shallow band of coastal waters most heavily used by humans and most vulnerable to activities within adjacent coastal watersheds.

• National Lakes Assessment (NLA)

  **Goals:** (1) What is the current biological, chemical, physical and recreational condition of lakes? (2) Is the condition of lakes getting better, worse, or staying the same over time? (3) Which environmental stressors are most associated with degraded biological condition in lakes?

  **Design:** The NLA sampling is comprised of natural lakes, ponds, and reservoirs across the lower 48 states. Starting with the NLA2012, to be included in the survey, a water body had to be a natural or man-made freshwater lake, pond or reservoir, greater than 2.47 acres (1 hectares), at least 3.3 feet (1 meter) deep, and with a minimum quarter acre (0.1 hectare) of open water. Lakes had a minimum retention time of 1 week. The Great Lakes and the Great Salt Lake were not included in the survey, nor were commercial treatment and/or disposal ponds, brackish lakes, or ephemeral lakes. The NLA 2007 assessed only those lakes greater than 10 acres (4 hectares) in size.

• National Rivers and Streams Assessment (NRSA)

  **Goals:** The goals of the NRSA are to determine the extent to which rivers and streams support a healthy biological condition and the extent of major stressors that affect them. The survey supports a longer-term goal: to determine whether our rivers and streams are getting cleaner and how we might best invest in protecting and restoring them. Additionally, the survey compares the condition of streams to those of an earlier study that focused on small streams (the Wadeable Streams Assessment or WSA) conducted by the U.S. Environmental Protection Agency and its partners in 2004.

  **Design:** The NRSA assesses the ecological condition of the full range of flowing waters in the conterminous U.S. (lower 48 states). The target population includes the Great Rivers (such as the Mississippi and the Missouri), small perennial streams, and urban and non-urban rivers. Run-of-the-river ponds and pools are included, along with tidally influenced streams and rivers up to the leading edge of dilute sea water.

• National Wetland Condition Assessment (NWCA)
**Goals:** The NWCA is designed to answer basic questions about the extent to which U.S. wetlands support healthy ecological conditions and the prevalence of key stressors at the national and regional scale. It is intended to complement and build upon the achievements of the U.S. Fish and Wildlife Service Wetland Status and Trends Program, which characterizes changes in wetland acreage across the conterminous United States. Paired together, these two efforts provide government agencies, wetland scientists, and the public with comparable, scientifically-defensible information documenting the current status and, ultimately, trends in both wetland quantity (i.e., area) and quality (i.e., ecological condition).

**Design:** The survey design is developed in partnership with the US FWS Wetlands Status and Trends Program. The NWCA sampling is comprised of all wetlands of the conterminous U.S. The survey encompasses both tidal and nontidal wetlands ranging from the expansive marshes of our coasts to the forested swamps, meadows, and waterfowl-rich prairie potholes of the interior plains.

**Responsible Organization and Contact**

U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds
National Aquatic Resource Surveys
1200 Pennsylvania Avenue, NW (Mailcode 4503T), Washington, DC 20460
https://www.epa.gov/national-aquatic-resource-surveys

Data in Delaware are collected by DNREC Environmental Laboratory Section.
Contact: Kathy Knowles, Kathy.knowles@state.de.us, 302-739-9942

**Data Collection Cost**
Not available.

**Data Use**
The U.S. EPA publishes reports for each survey. In addition, the data are publically available for use in research.

**Record of Collection**

**NCCA:** The first NCCA sampling field season was conducted in 2010. The most recent field season was conducted in 2015.

**NLA:** NLA field season sampling is conducted every five years. Previous field seasons were conducted in 2007 and 2012.

**NRSA:** NRSA sampling field seasons were conducted in 2008-2009 and 2013-2014. The next field season will be conducted in 2018-2019.

**NWCA:** The 2011 National Wetland Condition Assessment (NWCA) was the first sampling season. The second field sampling season was conducted in 2016.

**Collection Method**
Samples for Delaware sites are collected by the DNREC Division of Water, Environmental Laboratory Section.


**Analysis Methods**
Field, laboratory, quality assurance and site evaluation manuals are available on the EPA website: https://www.epa.gov/national-aquatic-resource-surveys/manuals-used-national-aquatic-resource-surveys.
Data Location


Management Goals

Within each survey, the goals are:

- For each indicator of condition, estimate the proportion of the nation's waters in degraded condition within a ± 5% margin of error and with 95% confidence.
- For each indicator of condition, estimate the proportion of waters or resources in a specific ecoregion that fall below the designated threshold for good conditions for selected measures within a ± 15% margin of error and with 95% confidence.
- Estimate the proportion of waters (± 7%) that have changed condition classes for selected measures with 95% confidence.

Hypothesis and Test Statistics


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FIGURE 3.7 - Southern Delaware sites at which NARS data were collected for published reports to date.
TABLE 3.6 - Indicators Evaluated for the National Aquatic Resource Surveys.

<table>
<thead>
<tr>
<th>BIOLOGICAL</th>
<th>CHEMICAL/TOXICITY</th>
<th>PHYSICAL</th>
<th>RECREATIONAL/HUMAN HEALTH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>National Coastal Condition Assessment (NCCA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Benthic macroinvertebrates</td>
<td>• Dissolved oxygen</td>
<td>• Water clarity</td>
<td>• Human health fish tissue contaminants* (Great Lakes only)</td>
</tr>
<tr>
<td>• Chlorophyll a</td>
<td>• Nitrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Ecological fish tissue contaminants</td>
<td>• Phosphorus</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Salinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sediment contaminants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sediment toxicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>National Lakes Assessment (NLA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Benthic macroinvertebrates</td>
<td>• Acidification</td>
<td>• Drawdown</td>
<td>• Algal toxin (microcystin)</td>
</tr>
<tr>
<td>• Chlorophyll a</td>
<td>• Atrazine</td>
<td>• Human disturbance</td>
<td>• Cyanobacteria</td>
</tr>
<tr>
<td>• Zooplankton</td>
<td>• Dissolved oxygen</td>
<td>• Lakeshore habitat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Nitrogen</td>
<td>• Physical habitat complexity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Phosphorus</td>
<td>• Shallow water habitat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sediment mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>National Rivers and Streams Assessment (NRSA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Benthic macroinvertebrates</td>
<td>• Phosphorus</td>
<td>• Streambed sediments</td>
<td>• Enterococci (fecal indicator)</td>
</tr>
<tr>
<td>• Periphyton (algae)</td>
<td>• Nitrogen</td>
<td>• In-stream fish habitat</td>
<td>• Mercury in fish tissue</td>
</tr>
<tr>
<td>• Fish community</td>
<td>• Salinity</td>
<td>• Riparian vegetative cover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Acidity</td>
<td>• Riparian disturbance</td>
<td></td>
</tr>
<tr>
<td><strong>National Wetland Condition Assessment (NWCA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Benthic macroinvertebrates</td>
<td>• Acidification</td>
<td>• Lakeshore habitat/riparian vegetative cover</td>
<td>• Algal toxins (microcystin)</td>
</tr>
<tr>
<td>• Chlorophyll a</td>
<td>• Atrazine</td>
<td>• Human disturbance</td>
<td>• Cyanobacteria</td>
</tr>
<tr>
<td>• Fish assemblage</td>
<td>• Conductivity</td>
<td>• Physical habitat complexity</td>
<td>• Enterococci</td>
</tr>
<tr>
<td>• Fish tissue contaminants</td>
<td>• Dissolved oxygen</td>
<td>• Shallow water habitat/in-stream fish habitat</td>
<td></td>
</tr>
<tr>
<td>• Macrophytes</td>
<td>• Nitrogen</td>
<td>• Streambed sediments</td>
<td></td>
</tr>
<tr>
<td>• Phytoplankton</td>
<td>• Phosphorus</td>
<td>• Water clarity</td>
<td></td>
</tr>
<tr>
<td>• Sediment diatoms</td>
<td>• Salinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Wetland vegetation (introduced species)</td>
<td>• Sediment enzymes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Wetland vegetation (plant community)</td>
<td>• Sediment mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Zooplankton</td>
<td>• Soil chemistry</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.1.7 TOXICS MONITORING
Ambient Water Quality Monitoring, Heavy Metals

Most of the state’s monitoring of toxics has focused on the Delaware Estuary basin. Ongoing monitoring of toxics in the Inland Bays includes sampling and analysis of copper, lead, zinc, and arsenic as part of the state’s Ambient Surface Water Quality Monitoring Program (Table 3.7). This table is current as of FY 2016.

Other more intensive monitoring and assessment of toxics in water, sediment and biota in the Inland Bays has occurred in the past, but these programs have not been continued long-term.

TABLE 3.7 – State monitoring of toxics in surface water the Inland Bays.

<table>
<thead>
<tr>
<th>Station Location</th>
<th>Station ID</th>
<th>Cu, Pb &amp; Zn</th>
<th>As</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burton Pond @ Rt. 24</td>
<td>308031</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Millsboro Pond @ Rt. 24</td>
<td>308071</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Pepper Creek @ Rt. 26 (Main St.)</td>
<td>308091</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Blackwater Creek @ Omar Rd. (Rd. 54)</td>
<td>308361</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Dirickson Creek @ Old Mill Bridge Rd. (Rd. 381)</td>
<td>310031</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Buntings Branch @ Rt. 54 (Polly Branch Rd.)</td>
<td>311041</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Guinea Creek @ Banks Rd. (Rd. 298)</td>
<td>308051</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Whartons Branch @ Rt. 20 (Dagsboro Rd.)</td>
<td>309041</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Lewes &amp; Rehoboth Canal @ Rt. 9</td>
<td>305041</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Little Assawoman Bay @ Rt. 54 (The Ditch)</td>
<td>310011</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>White Creek @ mouth of Assawoman Canal</td>
<td>312011</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Bundicks Branch @ Rt. 23</td>
<td>308371</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Beaver Dam Ditch @ Beaver Dam Rd. (Rd. 368)</td>
<td>310121</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Cow Bridge Branch @ Zoar Rd. (Rd. 48)</td>
<td>308281</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Swan Creek @ Mount Joy Rd. (Rd. 297)</td>
<td>308341</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Lewes &amp; Rehoboth Canal @ Rt. 1</td>
<td>305011</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Indian River Inlet @ Coast Guard Station</td>
<td>306321</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Rehoboth Bay @ Buoy 7</td>
<td>306091</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Masseys Ditch @ Buoy 17</td>
<td>306111</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Indian River Bay @ Buoy 20</td>
<td>306121</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Indian River @ Buoy 49 (Swan Creek)</td>
<td>306181</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Indian River @ Island Creek</td>
<td>306331</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Island Creek upper third</td>
<td>306341</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Little Assawoman Bay Mid-bay (Ocean Park Lane)</td>
<td>310071</td>
<td>● ●</td>
<td></td>
</tr>
</tbody>
</table>
The EPA has some data available on toxics for fish samples and sediment samples from the Inland Bays. Those samples were collected as part of the Environmental Monitoring and Assessment Program (EMAP), which was a research program run by EPA’s Office of Research and Development to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP collected field data from 1990 to 2006. Data are available online (https://archive.epa.gov/emap/archive-emap/web/html/index-37.html). Monitoring of the nation’s aquatic resources is now being routinely conducted by the National Aquatic Resource Surveys, run by EPA’s Office of Water (https://www.epa.gov/national-aquatic-resource-surveys). More information on this program is available in this report (Section 3.1.6).

Monitoring of Burton Island Coal Ash Disposal Area

The Center collected biota and sediment samples from the Inland Bays in 2012 to assess whether material eroding off and/or transported from the Burton Island former coal ash disposal site in upper Indian River is contributing to significant accumulation of toxic trace elements in the local aquatic environment. Mummichogs (*Fundulus heroclitus*), ribbed mussels (*Geukensia demissa*), and surface sediment were collected from five locations along the southern shoreline of Burton Island within Island Creek. Sites were purposely selected to coincide with locations where previous sampling or observations indicated release from Burton Island through either erosion or shallow groundwater transport. Locations within Pepper Creek were sampled for sediment and biota to serve as controls against which the Burton Island results could be compared.

The study concluded that existing conditions and concentration levels of trace elements found in the *Geukensia*, *Fundulus*, and sediment samples currently did not warrant an expansion of sampling to evaluate the potential ecological impacts of bioaccumulation (Riedel and Wilson, 2013). The future conditions of the island could change due to rising water levels and/or changes in the rate of pore water movement, because of this, it is recommended that tissue and sediment samples be periodically sampled and analyzed (in methods consistent with this study) to evaluate any changes in the prevalence and concentration of trace elements and metals through bioaccumulation in the surrounding biota.

A Long-Term Stewardship (LTS) Plan for the ash disposal area was prepared for Indian River Power LLC in 2014 (CB&I Environmental and Infrastructure, Inc., 2014). The LTS Plan includes monitoring requirements for the remedial actions at the site. Field and laboratory data are to be provided electronically to DNREC-SIRS. The monitoring requirements are:

- Annual groundwater monitoring to assess any changing physical conditions from those used to develop the site conceptual model of groundwater flow and to assess any changing chemical conditions used to evaluate the potential for human health and ecological risk.
- Annual monitoring of sediment quality immediately offshore of the site. Shoreline sediment sampling events will consist of a visual shoreline survey near the time of low tide, sample collection and documentation, and laboratory analysis. Shoreline sediment samples will be analyzed for arsenic, barium, and selenium as these metals were identified as sediment constituents of concern (COCs) in the risk assessment (Shaw, 2008).

Requests from the Center for sampling of additional heavy metals in groundwater and sediment, as well as for biological sampling, were not included in the Plan. Nor were numeric criteria based on ecological standards for all constituents of concern, or what might constitute an increase from baseline conditions in these parameters that would require any further remedial action.

Fish Tissue Monitoring

Statewide fish tissue monitoring has been conducted since 1992, and data have resulted in issuance of consumption advisories for striped bass and bluefish caught in the Inland Bays. DNREC currently is conducting a large study of contaminant levels in bluefish and striped bass that may result in an adjustment to the coastal advisory for these species. Data collection will not be complete until sometime later in 2017.

3.2 MONITORING OF LIVING RESOURCES
3.2.1. DELAWARE STATEWIDE VEGETATION COMMUNITY & LAND COVER MAPPING PROJECT

Description/Objective(s)

The Delaware Statewide Vegetation Community Mapping Project seeks to map all of the vegetation communities and land covers present in the state of Delaware. Delineations are drawn to the finest extent possible (no defined minimum mapping unit) using aerial imagery analysis, field observations, and data obtained from others. Approximately 10-20% of the state has been field checked. The project began with a map of the Brandywine Creek and was extended to include the entire state of Delaware.

Responsible Organization and Contact

DNREC Wildlife Species Conservation and Research Program

Contact: Joseph Rogerson
joseph.rogerson@state.de.us, 302-735-3600

Data Collection Cost

Not available.

Data Use

Currently, the maps are used for determining the rarity and status of vegetation communities in Delaware, environmental reviews, and management plans on public lands. These maps can be used as a baseline for sea level rise studies, climate change, and change over time studies from historical imagery.

Record of Collection

Historical analyses and maps of vegetation communities, land covers, and habitats have been published for the following areas in the Inland Bays:

- Thompson Island Nature Preserve (Coxe, 2011)
- Assawoman Wildlife Area (Coxe, 2012a)
- Delaware Seashore State Park (Coxe, 2012b)
- Fenwick Island State Park (Coxe, 2012c)
- Cape Henlopen State Park (Coxe, 2012d)
- James Farm Ecological Preserve (Coxe, 2013)

Collection Method

Field data is obtained primarily from environmental reviews and surveys of public lands in Delaware. Land covers are obtained from the same methods and impervious surfaces are from 2007 impervious surface layer, except for the Brandywine and Red Clay Creek watersheds which were digitized from 2002 aerial imagery. Vegetation communities are determined using the Guide to Delaware Vegetation Communities which is derived and linked to the National Vegetation Classification System (NVCS). The NVCS is a national effort by The Nature Conservancy and Natureserve to standardize the names and classification of vegetation communities in North America. Common names of the vegetation communities in Delaware are the same as those used in the NVCS.

Analysis Methods

All shapefiles for the Delaware Statewide Vegetation Community Map are organized by watershed. Each watershed file has a year after (i.e. 1997, 2002, or 2007) that signifies the imagery that the map is based on. About once a month a complete map will be produced which will be called Delaware Statewide Vegetation Community Map with the date after it.

Data can be used to map a particular vegetation community for a watershed, or to query how much acreage of a vegetation community is present in a watershed.

Data Location
3.2.2 SEAWEED MONITORING

Description/Objective(s)

Small to medium amounts of macroalgae are healthy for estuarine systems. They provide habitat for blue crabs, as well as numerous species of fish, especially in the absence of seagrass beds. However, excess macroalgae can have the opposite effect by smothering benthic organisms and creating hypoxic zones particularly during the early summer mornings before photosynthetic activity resumes. In order to assess levels of macroalgae over time, particularly in response to efforts to reduce nutrient pollution to the Inland Bays, 12 locations in Rehoboth and Indian River Bay are monitored for macroalgae.

The objectives of this study are to see if macroalgae types, distribution, and density appear remarkably different than previously observed levels, and to assess the abundance and distribution of macroalgae over a full growing season in Indian River Bay and Rehoboth Bay. Furthermore, the rapid macroalgae sampling approach employed in this study can be investigated for its feasibility as a means for more regular monitoring of macroalgae abundance and distribution using citizen volunteers.

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring program beginning in the spring of 2017. Previous to this, DNREC Division of Water was in charge of the monitoring program.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Roughly $2,000 for CIB staff time per year
Equipment: $100 in gas and supplies

Data Use

Data is used to track macroalgae abundance over time, and to assess seasonal abundance and distribution.

Record of Collection

Data has been collected irregularly, with sampling occurring in 1999, 2009, 2011, and 2012.

Collection Method

Macroalgal density is determined using a stainless steel grappling hook tossed off the windward side of a boat. Sampling occurs once a month at 12 sites from May through September (Figure 3.8). The hook is 25 cm long, has a width of 24.3 cm with six tines spaced about 9 cm apart and is attached to a 10 m length of 0.95 cm diameter nylon line. The hook is tossed off the windward side of the boat and allowed to settle to the bottom, at which time the line is given five steady tugs and then the hook is hauled into the boat. It was determined that the five tugs result in the hook covering a distance across the bottom of about 3 to 4 m. Three tosses will constitute a single sample that will be placed into a sieve bucket graduated in liters. The bucket will then be shaken from side-to-side a few times to settle and uniformly distribute the algae.

Analysis Methods

The approximate amount of area covered by the grappling hook during the three tosses is 2.5 m. (3.5 meters per toss x width of hook, 0.24m x 3 tosses). The sample of algae collected is reported as liters of algae. Density is categorized as light (0 to 3 liters), moderate (4 to 7 liters) and heavy (> 8 liters).
Dominant groups of macroalgae (e.g. Ulva, Gracilaria, and Agardhiella) are sorted while remaining non-dominant groups are lumped together. Relative percentages of the groups are determined visually.

Data Location
Located at the Delaware Center for the Inland Bays, available upon request.

Management Goal
Document the abundance of macroalgae in the Inland Bays over time, including seasonal patterns of abundance and distribution. Data generated through this program can be used to gauge the potential success of sea grass restoration in areas near sampling locations, and can be used in conjunction with water quality measurements to gauge the success of nutrient pollution reduction efforts.

Hypothesis and Test Statistics
Abundance between sites as well as between years for macroalgae in general, along with each dominant group, can be compared using Kruskal Wallis tests ($\alpha = 0.05$).
FIGURE 3.8 - Map showing location of seaweed monitoring stations in Rehoboth and Indian River Bays.
3.2.3 COASTAL FINFISH ASSESSMENT SURVEY

Description/Objective(s)
The relative abundance and distribution of a number of recreationally important finfish species are assessed using trawl sampling in the Delaware Estuary and Delaware’s Inland Bays (Indian River and Rehoboth Bays). The 16-foot trawl survey used in the Inland Bays is primarily intended to monitor juvenile fish abundance.

Responsible Organization and Contact
DNREC Division of Fish and Wildlife, Fisheries Section
Contact: Michael Greco
Michael.Greco@state.de.us, 302-735-6780

Data Collection Cost
Not available.

Data Use
The indices generated from these surveys are used in the development of interstate fishery management plans and stock assessments. In particular, the surveys are used in the Weakfish (Cynoscion regalis), Striped Bass (Morone saxatilis), Bluefish (Pomatomus saltatrix), Atlantic Menhaden (Brevoortia tyrannus), Black Drum (Pogonias cromis) and Summer Flounder (Paralichthys dentatus) fishery management plans and stock assessments. In addition, data from the surveys are used in establishing time of year restrictions for beach replenishment and dredging. The CIB uses the data to develop fish abundance indicators.

The surveys also serve as platforms for providing specimens to researchers studying life history and biology of fishes. These surveys have provided samples for use in genetics, tissue contaminants, age and growth, food habits, reproduction, and many other studies.

Record of Collection
The Delaware Bay trawl surveys were expanded in 1986 to include monthly sampling (April to October) in the Indian River and Rehoboth Bays.

Collection Method
Sampling with a 16-foot semi-balloon otter trawl is conducted monthly from April through October at 12 fixed stations in the Inland Bays (Figure 3.9).

Sampling at each station consists of a ten-minute trawl tow, typically made against the prevailing tide. Occasionally, tows less than ten minutes are made in cases of unforeseen gear conflicts, draft considerations, etc. In such cases, tows are required to be at least five minutes in duration to be considered valid. Catches from short tows are standardized to ten minutes.

The trawl is hauled over the stern and the catch emptied on a sorting table upon completion of each tow. Finfish were sorted by species and enumerated. A representative subsample of 30 specimens per species is measured for fork length to the nearest half centimeter; the remainder are enumerated. Surface temperature, salinity, and dissolved oxygen, tidal stage, weather conditions, water depth, and engine speed are recorded at the beginning of each tow.

Analysis Methods
Data analysis includes monthly and annual summaries of the catch including a listing of species collected, total number of each species taken, mean catch per tow, and standard deviations. Mean surface salinities and temperatures are calculated similarly by month, station or subarea. Annual young-of-the year index values are calculated, as geometric mean catch per tow, for target species.
Data Location
Data are maintained by the Division of Fish and Wildlife Fisheries Section.

Management Goal/Hypothesis and Test Statistics
Species-specific Stock Assessment Subcommittees test geometric means for individual assessments. First, the relative prevalence for that particular species is determined to see if the survey interacts with it enough to warrant inclusion in the assessment. Next, the survey may be standardized using a generalized linear model. Further, trend analyses are conducted on the survey itself (using ARIMA, Mann-Kendall tests), and combined with age, growth (Von Bertalanffy), maturity F, M (Lorenzen) data for analyses.

FIGURE 3.9 - Map showing DNREC otter trawl survey locations in the Inland Bays.
3.2.4 VOLUNTEER INSHORE FISH AND BLUE CRAB SURVEY

Description/Objective(s)

The shorelines of the Inland Bays provide critical habitat to many juvenile and young-of-the-year fish species along with blue crabs. In an effort to obtain fish population and diversity data from these inshore areas, an Inland Bays volunteer fish monitoring program was implemented to collect data that can be used to create fish indices that complement the data being collected by the DNREC Division of Fish and Wildlife Trawl Survey. The objectives of this program are to conduct seining surveys to determine the abundance, species diversity, and body lengths of the near-shore fish communities in the Delaware Inland Bays and to measure physical and biological parameters to determine which conditions are favorable for nearshore fish and blue crabs in the Inland Bays.

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring program.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Equipment: $700 for nets, buckets, first aid kits, tongs, miscellaneous gear
Staff time: $5,400

Data Use

The data collected from this project will be used primarily by the Delaware Division of Fish and Wildlife and the Center for the Inland Bays. These data will be used to help document trends, seasonality, and annual variability in fish populations over time. Additionally, this data will be used to assess the importance of the shorezone waters for commercially and recreationally important species.

Record of Collection

2011 to present.

Collection Method

16 shoreline sites are monitored once in April and twice a month from May through October using a 30-foot long, 4-foot tall seine net (Figure 3.10). To sample a beach, one volunteer holds one end of the seine net along the beach while another volunteer wades out with the opposite end until the net is fully extended (30 ft). Both volunteers drag the net for 70 feet along the shoreline, with the volunteer in the deeper water walking slightly ahead of the shallow water volunteer. At the 70-foot mark, the inshore volunteer stops and the deep water volunteer swings inshore with the net, at which point both volunteers drag the net ashore having seined 100 feet of shoreline. All fish are identified to species and counted, and the first 25 fish of each species are also measured to the nearest millimeter. The number of blue crabs is also counted. In addition, physical parameters such as dissolved oxygen, water temperature, salinity, wave height, amount of rain in the last 24 hours, and wind speed are also recorded prior to each seine.

Analysis Methods

To assess species abundance over time, geometric mean catch for each species is calculated each year. Differences in catch between the bays are assessed with pairwise Wilcoxon rank sum tests ($\alpha = 0.05$). To assess which variables are important to inshore fish species, correlations to physical variables are assessed for recreationally or commercially important species using Kendall's Tau correlation tests ($\alpha = 0.05$).

Data Location

Data are stored at the Center for the Inland Bays and are made available online at www.inlandbays.org.
**Management Goal**

Data generated through this program can be used to document trends in fish species abundance over time. These data can also be used to inform decision makers on the relative importance of shorelines on various species of fish.

**Hypothesis and Test Statistics**

Differences between bays are assessed using pairwise Wilcoxon rank sum tests ($\alpha = 0.05$). The null hypothesis is that there are no differences in fish abundance between the Inland Bays. Correlations between physical parameters and recreationally or commercially important species’ abundance are assessed with a Kendalls Tau correlation tests ($\alpha = 0.05$). Geometric mean catch per year are calculated for each fish species caught, and these data will be used to assess species trends over time.
FIGURE 3.10 - Map of Inshore Fish and Blue Crab Survey seining sites.
3.2.5 RECREATIONAL FISHING SURVEYS

Description/Objective(s)

The Marine Recreational Information Program (MRIP) survey is used by NOAA Fisheries to quantify and report marine recreational fishing catch and effort. These surveys document pounds of fish caught per trip, number of fishing trips, and pounds of individual fish species caught per year. Data for the Inland Bays are based on surveys conducted by NOAA at the Indian River Inlet.

Responsible Organization and Contact

NOAA Fisheries Service is responsible for this program. DNREC's Division of Fish and Wildlife requests and analyzes local data each year.

Contact: Gordon Colvin, NOAA
301-427-8118, Gordon.colvin@noaa.gov

Data Collection Cost

Not available.

Data Use

Locally, the data are used primarily by DNREC Division of Fish and Wildlife Fisheries Section to assess the impact of recreational fishing on Delaware’s fish species, and adjust management decisions accordingly.

Record of Collection

2004 to present. Recreational fishing survey data exist prior to 2004, but collection used a method differing from MRIP.

Collection Method

Data are collected through field, harvester-intercept interview surveys that record catch rates for species from anglers, and a telephone (or mail survey) that is designed to estimate effort. Average catch rates are applied to the effort estimates to generate landings per year. The MRIP survey also takes into account potential bias due to differences in catch rate at high-activity or low-activity sites, or the amount of fishing occurring at different parts of the day.

Analysis Methods

Each estimate is a combination of catch rates and effort in a particular waterbody. Previously, all fishing locations were treated equally, and in some cases high activity sites were sampled much more than low activity sites in an effort to maximize the amount of data being collected. However, the MRIP survey takes into account site activity and other bias associated with the time the survey was conducted to more accurately arrive at a catch estimate.

Data Location

Data are available from DNREC Division of Fish and Wildlife Fisheries Section upon request.

Management Goal

To incorporate the data into stock assessments, thereby accounting for the impact recreational fishing has upon each species.

Hypothesis and Test Statistics
3.2.6 HARD CLAM SURVEYS

Description/Objective(s)

The hard clam is the most important commercial resource in the Inland Bays, and along with the blue crab, is the most important recreational shellfishery. To enhance the wellbeing of this shellfishery and maintain optimum levels of sustainable harvest an adequate knowledge of the hard clam stock and its variability are necessary. A vacuum suction dredge survey of Rehoboth Bay and Indian River Bay over two years were performed to support these goals and provide information with which to evaluate overall bay health and this important living resource. Objectives of this survey were to determine density and distribution of hard clams and bay scallops within Delaware’s Inland Bays, evaluate clam recruitment and survival since previous surveys were conducted, and evaluate study results and effort in light of management and monitoring objectives.

Responsible Organization and Contact

DNREC Division of Watershed Stewardship

Contact: Michael Bott, Environmental Scientist
Michael.Bott@state.de.us, 302-739-9939

Data Collection Cost

$10,000 per survey.

Data Use

Data is used primarily by DNREC Division of Fish and Wildlife and the Center for the Inland Bays. Data generated by this survey can be used to infer the health of the Inland Bays hard clam shellfishery, and inform the shellfish aquaculture program of potential conflicts in aquaculture sites due to high hard clam densities.

Record of Collection

1967, 1976, 2011. Survey should be repeated by 2019, in order that the data are available for the next State of the Delaware Inland Bays report.

Collection Method

The Venturi Suction Dredge survey method was used for this survey. The dredge was fabricated from aluminum with a mesh net attached capable of capturing clams greater than 8mm. The dredge was powered by a 4”, water pump with a 4” reinforced intake hose and 3” effluent hose attached to the Venturi dredge. The sample quadrat was a 1m² frame constructed from 1” PVC piping with holes drilled into the material to allow the pipe to fill with water and stay weighted on the sediment. The sample stations duplicated the survey points used for the 1667 and 1976 surveys. Sample stations which were located near the Indian River Inlet or in navigational channels were either eliminated or moved to adjacent locations due to safety hazards. In the event a sample location was to near to a shore line to allow operation of the dredge, the quadrat was located as near to the original point as possible and the new coordinates were recorded. Sample stations were located using a hand held GPS to get within 3m of the location, and a weighted buoy was thrown randomly to mark the specific site. Two divers would place the quadrat on the northern side of the buoy weight and remove and record any macro-algae present. One diver would operate the Venturi dredge, excavating all substrate to a minimum depth of 12”. The second diver stabilized the quadrat to prevent movement and verified the station was completely sampled before surfacing. If the substrate could not be excavated to a depth of 12”, the actual depth and limiting factors were recorded. Any clams which were partly located within the inside portion of the quadrat were included in the sample. Clams were included if the diver could run a finger along the inside edge of the PVC pipe and feel the shell within the quadrat. To avoid sampling additional substrate which caved into the sample area, the diver did not re-dredge any portions which were already sampled. Once samples were brought to the surface, all live bi-valve molluscan shellfish were sorted from the material, and measurements of the shell width and length, along with species were recorded. Qualitative sediment
type was also recorded for each site, along with water depth. All calipers used were frequently calibrated on a known standard.

**Analysis Methods**

The data was analyzed using the Kolmogorov-Smirnov test to measure differences in clam distributions between the 1976 survey and the 2011 survey in the Rehoboth Bay, and Indian River Bay. Differences were also assessed between Rehoboth Bay and Indian River Bay for the 2011 survey.

**Data Location**

Upon request to DNREC Division of Fish and Wildlife.

**Management Goal**

This survey can be used to inform decision makers on the current status of hard clams in the Inland Bays in reference to historical levels. Data generated through this survey details the current health of the hard clam population, if restoration efforts are needed, how current management efforts are impacting hard clams, and where the highest densities of hard clams reside in the Inland Bays. This data can also be used to prevent conflicts between aquaculture sites and high density hard clam beds.

**Hypothesis and Test Statistics**

Kolmogorov-Smirnov tests were used to assess differences between the 1976 survey and the 2011 survey, along with differences in hard clam abundance between bays in the 2011 survey.

### 3.2.7 VOLUNTEER HORSESHOE CRAB SURVEY AND TAGGING PROGRAM

**Description/Objective(s)**

Due to their importance to both the medical industry and migratory birds, horseshoe crab spawning activity is monitored through a volunteer spawning survey, at five sandy beaches in the Inland Bays from May through June (Figure 3.11). The objectives of the survey are to assess the importance of the Inland Bays’ horseshoe crab population in regards to the regional population, track the number of spawning crabs over time, and monitor horseshoe crab movement through a long-term tagging program.

**Responsible Organization and Contact**

The Delaware Center for the Inland Bays is responsible for this monitoring.

Contact: Andrew McGowan, Environmental Scientist  
environment@inlandbays.org, 302-226-8105, x112

**Data Collection Cost**

Equipment costs: $150 annually to support five teams  
Staff time: $5,400 annually

**Data Use**

Data from this survey is used primarily by the Center for the Inland Bays and DNREC Division of Fish and Wildlife. The data generated through this survey can help determine the size of the Inland Bays’ horseshoe crab population, relative to the regional population, measure if their numbers are increasing or decreasing over time, and identify important spawning areas that need to be managed and protected.

**Record of Collection**

2015 - present (Surveys began in 2012, but the protocol was switched in 2015 to facilitate comparisons with the Delaware Bay Survey).
**Collection Method**

Sampling occurs on five beaches in the Inland Bays two nights prior to, the night of, and two nights following the new and full moons from May through June. Sampling begins during the nighttime high tide as the tide begins to recede. Teams begin by randomly selecting one end of the beach to start from using a coin flip. Once the end of the beach is determined, the team will walk to that end and extend a pull rope with markings every 1m, at the high tide line towards the opposite end of the beach. The length of the pull rope is dependent on the length of the beach, and is designed to systematically allow the placement of 100 1m² quadrats along the beach. The length of the rope is determined by dividing the overall length of the beach by 50. James Farm, Coastal Kayak, and Tower Road all use a 4 meter pull rope. Bay Colony uses a 6 meter pull rope. Peninsula does not use a pull rope because the length of the beach is only 100m; and therefore all quadrats along the beach are counted. In addition to randomizing the direction of travel, the placement of the quadrats within each rope pull is randomized for a single night. Two quadrats are sampled per rope pull, for a total of 100 quadrats. The same two randomized locations along the pull rope are used for the duration of the night. Once the pull rope has been extended, the 1m² quadrat is placed at the first random quadrat location for that given night. The quadrat is positioned so that one end is even with the line of crabs, and the other end is towards the bay. All crabs which have at least half their body inside the quadrat are sexed and counted. Upon completion of the first quadrat, the team moves the quadrat to the second randomly selected location and repeats the counting process. Once the two quadrats have been counted for the first rope pull, the rope is extended along the next portion of the beach, and the same two random quadrat locations are sampled. This is repeated until 100 quadrats have been sampled. The ‘Horseshoe Crab line’ that is followed is not a straight line, and it may be above or below the water line, however, it is never more than 1m² away from the high tide line.

At each of the sites, salinity samples are also taken for each night. These samples are later tested for salinity. Air and water temperature are also taken with a thermometer.

In addition to counting crabs, 1,000 crabs are also tagged with US Fish and Wildlife Service tags on the left posterior portion of the prosoma. The tagged crabs are sexed and measured for carapace width.

**Analysis Methods**

Average spawning densities per 1m² are calculated for each beach by dividing the total number of crabs per night by 100 (the number of quadrats), and averaging each night to obtain one spawning density per beach. The cumulative spawning density for the Inland Bays represents the average of the five beaches’ averages. Spawning index is calculated in the same manner but includes only females.

Total crab abundance is compared between sites using a pairwise Wilcoxon rank sum test ($\alpha = 0.05$).

**Data Location**

Located at the Delaware Center for the Inland Bays, available upon request.

**Management Goal**

The data generated through this survey can be used to identify important areas for horseshoe crab spawning activity, assess overall trends in horseshoe crab spawning activity over time, and inform decision makers on the movements of horseshoe crabs over the course of a single spawning season or multiple years.

**Hypothesis and Test Statistics**

Correlations between physical parameters and crab abundance are assessed with Kendall’s tau correlation tests ($\alpha = 0.05$). Differences in crab abundance between sites is assessed with pairwise Wilcoxon rank sum tests ($\alpha = 0.05$).
FIGURE 3.11 - Map of Inland Bays horseshoe crab survey and tagging sites. The Ellis Point beach was dropped from the survey in 2015.
3.2.8 DELAWARE BREEDING BIRD ATLAS

Description/Objective(s)

The Delaware Breeding Bird Atlas is primarily a volunteer citizen science project. From 1983 through
1987, over 100 volunteers participated in compiling data for Delaware’s first breeding bird atlas,
Delaware’s largest and most comprehensive ornithological project. This effort, incorporated in The Birds
of Delaware (Hess et al., 2000), summarized the distribution of the breeding birds during those years
along with species accounts and data about all birds that occurred, or thought to have occurred, in the
State. A second Atlas project was conducted between 2008 and 2012.

Responsible Organization and Contact

DNREC Division of Fish and Wildlife, Wildlife Species Conservation & Research Program
Contact: Anthony Gonzon, Project Coordinator
Phone: (302)-653-2880, ext. 123, Email: Anthony.Gonzon@state.de.us

Data Collection Cost

The second Atlas project was funded through the Delaware Division of Fish and Wildlife with funding
from the State Wildlife Grants Program, Division of Federal Assistance, United States Fish & Wildlife
Service.

Data Use

The data are useful for tracking trends in populations and diversity that occur with changes in land use,
habitats, and climate.

Since being published, the first atlas has become an important resource, providing much of the
distribution data about Delaware’s breeding avifauna. It is often used by researchers, scientists,
government officials, and birders. The first Delaware breeding bird atlas established the baseline data
that will be used to compare and examine changes in the distributions of breeding species upon
completion of future atlas projects.

Record of Collection

Surveys for the first Breeding Bird Atlas project were conducted from 1983-1987. The second set of
surveys were conducted from 2008-2012.

Collection Method

Volunteer atlasers are assigned to a geographic “block” to survey. Within that block, the atlaser attempts
to confirm breeding for as many species as possible. A block is approximately 10 sq. miles and is created
using a standardized grid that is overlaid onto a map of Delaware. Delaware has over 265 blocks divided
into six regions in the State. Each of the six regions contains more than 40 blocks.

Each atlaser spends time in their block surveying during the breeding season (for most birds, March -
July), and observing and recording data about the birds they encounter on field cards. Volunteer atlasers
report this data using an online, interactive data entry application or by submitting their field cards for
entry. Once the data are entered the volunteers “save” it to the database for verification. A regional
compiler serves as the primary contact for each region and verifies data. The project coordinator is
responsible for maintaining communications between volunteers, compilers, project supporters,
landowners, and others, and also handles all of the financial and logistical issues of the atlas, including
reports and data analyses.

Analysis Methods

Maps are produced for each breeding species along with other important information such as breeding
safe dates, nesting dates, and arrival and departure estimates.

Data Location
Data are kept by the DNREC Wildlife Species Conservation & Research Program. Data may be accessed online through the Breeding Bird Atlas Explorer, maintained by the USGS Patuxent Wildlife Research Center (http://www.pwrc.usgs.gov/bba).

3.2.9 MID-WINTER WATERFOWL SURVEYS

Description/Objective(s)

For almost 40 years, the Division of Fish and Wildlife has conducted four aerial waterfowl surveys annually to measure long-term trends in duck and goose populations. Flights are usually made in mid-October, mid-November, mid-December and the second week in January, subject to weather and mechanical delays. The January flight is part of a coast-wide effort to survey waterfowl throughout the Atlantic Flyway at approximately the same time. The state surveys cover the primary waterfowl habitat in Delaware, approximately the eastern half of the state, and are divided into 11 zones.

Not all ducks and geese can be seen equally well from a plane. The surveys give fairly accurate information about geese, but duck populations such as wood ducks and sea ducks are almost impossible to count.

The important feature of these counts is that they augur for long-term trends that are useful to measure changes in waterfowl management strategies and the environment. In most cases no single survey count is especially important in itself, but cumulative counts have revealed important changes over the years.

Responsible Organization and Contact

DNREC Wildlife Species Conservation and Research Program

Contact: Joseph Rogerson  
  joseph.rogerson@state.de.us, 302-735-3600

Data Collection Cost

Not available.

Data Use

Data are used by the US Fish and Wildlife Service and the Delaware Division of Fish and Wildlife to adjust hunting regulations in response to population trends.

Data from both the state and Atlantic Flyway counts are used to produce a winter waterfowl indicator for the Delaware Inland Bays reports.

Record of Collection

1974 to present.

Collection Method

These surveys are carried out via a small plane with a pilot and biologist aboard, taking similar routes and using the same techniques each time.

Analysis Methods

Waterfowl counts are summarized within the following zones:

Zone 1 - (Width of the State) Pennsylvania Line to the Delaware Memorial Bridge.
Zone 2 - (Width of the State) Delaware Memorial Bridge to the C&D Canal.
Zone 3 - (Width of the State) C&D Canal to a Line from Liston Point to Kenton.
Zone 4 - (Width of the State) Liston Point to Route 6 (Smyrna).
Zone 5 - (Width of the State) Route 6 to Route 8 Port Mahon.
Zone 6 - (East of 113) Route 8 to Big Stone Beach.
Zone 7 - (East of Route 1) Big Stone Beach to Broadkill River.
Zone 8 - (East of Route 1) Broadkill River to Bend in Lewis Rehoboth Canal South of Gordon’s
Pond.

Zone 9 - South of Gordon’s Pond and All of Rehoboth Bay.
Zone 10 - All Indian River Bay West to Millsboro and South to Salt Pond.
Zone 11 - Salt Pond South to Maryland Line and West to Route 17.

Zones 9, 10, and 11 fall within the Inland Bays watershed.

Data Location
DNREC Division of Fish and Wildlife. Data also are posted to the Delaware Open Data Site (https://data.delaware.gov/Energy-and-Environment/Aerial-Waterfowl-Survey-Data/bxyv-7mgn).

3.2.10 BALD EAGLE & OSPREY NESTING SURVEYS

Description/Objective(s)
The Delaware Division of Fish and Wildlife’s Species Conservation and Research Program (SCRP) monitors bald eagle and osprey populations in the state.

State monitoring efforts are supplemented by data collected through the Citizen Osprey Monitoring Program, managed by the SCRP, in which volunteers monitor osprey platforms and nests. As of 2016, the volunteer monitoring data are submitted to the OspreyWatch program (www.ospreywatch.org), but state data are still analyzed by SCRP. The mission of OspreyWatch is to collect information on a large enough spatial scale to be useful in addressing global climate change, depletion of fish stocks, and environmental contaminants.

The U.S. Geological Survey biologists tested eggs and chicks for contaminants in 2001. Historically, osprey surveys were concentrated in the Inland Bays and Nanticoke River system, but the entire state of Delaware was surveyed in 2003, 2007 and 2014.

Responsible Organization and Contact
DNREC Division of Fish and Wildlife, Wildlife Species Conservation & Research Program

Contacts: Anthony Gonzon (Bald Eagles)
          Anthony.Gonzon@state.de.us, 302-653-2880, ext. 123
          Kate Fleming (Ospreys)
          Kate.Fleming@state.de.us, 302-735-8658

Data Collection Cost
Not available.

Data Use
The data for Delaware are analyzed by SCRP staff to improve understanding of arrival dates, nest success and other aspects of the species’ biology in the state. Information supports conservation decisions and assists the state in identifying any new or emerging issues.

Bald Eagle and Osprey nesting are used as indicators in the State of the Delaware Inland Bays reports.

Record of Collection
Data used for indicator reports: Bald Eagles: 1987 to present.
                             Ospreys: 1991 to present.

The Division has conducted surveys in some form since 1970 to document Osprey nest success. The SCRP decided to end state-wide Osprey surveys on an annual basis in 2007, with the intention of returning to it every five years or so.
Collection Method
Eagle nests are counted by aerial survey. The only state-wide Osprey nest survey conducted since 2007 was in 2014, and it was done entirely from helicopter. Each site was visited only once between June 20th and July 10th. In prior years, nest sites were visited at least twice, so the number of nests documented in 2014 likely is low, as any early season failed nesting attempts would have missed.

Analysis Methods
Starting in 2016, volunteers provide osprey nest observations to the OspreyWatch online reporting application, hosted by the Center for Conservation Biology at http://www.osprey-watch.org/. The data for Delaware are analyzed by SCRP staff to improve understanding of osprey arrival dates, nest success and other aspects of osprey biology in the state.

Data Location
Data are managed by the SCRP, and are available upon request to the Program.
Starting in 2016, volunteers provide osprey nest observations to the OspreyWatch online reporting application. Delaware and Inland Bays data may be viewed on this site.

3.3 MONITORING OF NUTRIENT LOADS

3.3.1. POINT SOURCE WASTEWATER DISCHARGES

Description/Objective(s)
Point source discharges directly to surface water are regulated under the National Pollutant Discharge Elimination Systems (NPDES) Permits Program. Monitoring of these discharges is required by law.

The NPDES Program controls point source discharges to surface waters and land, respectively, by means of a permit which establishes the parameters, limits, schedules, and conditions for each discharge. Also included in this program are the compliance/monitoring reports prepared by the permittee; the surveillance, sampling and inspection of facilities; and an enforcement element. Limits are established based on minimum technology-based standards set pursuant to federal and State laws and regulations. More restrictive controls may be established, if deemed necessary, to meet surface water quality standards.

At this time, there are three point source wastewater facilities discharging to the Inland Bays: City of Rehoboth Beach WWTP (discharging to Rehoboth Bay), the City of Lewes WWTP (discharging to the Lewes-Rehoboth Canal), and the Allen Harim facility near Millsboro (discharging to Wharton Branch). The City of Lewes discharges only 2.5% of its effluent to the Inland Bays.

Responsible Organization and Contact
The DNREC Division of Water, Surface Water Discharges Section
Contact: Program Manager Compliance & Enforcement Branch
glenn.davis@state.de.us, 302-739-9946

Data Collection Cost
The costs of monitoring and reporting of results are borne by the permitted facilities. Funding sources for DNREC operations include Federal Section 106 and 205(g) excess funds, as well as State funding and permit fees. Total cost is not available.

Data Use
Discharge monitoring data are used to ensure that point source discharges into the Bays and tributaries of any pollutant, or combination of pollutants, meet all the applicable requirements under Clean Water Act Sections 301, 302, 306, 307, 308 and 403.

Record of Collection
Varies by permitted facility.

Collection Method
The effluent limitations, frequency of monitoring, parameters tested, and other special conditions vary between the individual facilities according to the requirements specified within their permits. Requirements may also vary between individual outfalls within a given facility. The permits are valid for five years, but may be administratively extended.

All of the discharge facilities monitor flow, and eutrophication indicators such as biological oxygen demand, total suspended solids, total phosphorus, total nitrogen, pH and dissolved oxygen. Some facilities also monitoring fractions of phosphorus and nitrogen. Information concerning collection frequency and the type of samples collected is found in the excerpts from the permits of individual discharge facilities.

Analysis Methods
Each discharge facility and the contractors which they select to provide monitoring and laboratory services must adhere to all the USEPA-approved Methodology and Quality Assurance requirements specified within the permit. Delaware requires NPDES and Land Treatment permit holders to maintain records of all information resulting from any monitoring activities that are required in their permit.

Data Location
Previously data were accessible through the Delaware Environmental Navigator; however, data must now be requested directly through DNREC staff.

Management Goal
The data generated via NPDES monitoring also are used to calibrate and run the point source pollution component of the Hydrodynamic and Water Quality Model. These results determine the progress toward meeting the goals that were set by the TMDL for the Inland Bays of reducing loads of point source nitrogen by 10-15 percent and point source phosphorus by 60 percent.

3.3.2 LAND APPLICATION OF WASTEWATER

Description/Objective(s)
Land application of wastewater (spray irrigation or rapid infiltration basins) is increasingly being used within the Inland Bays watershed in lieu of point source discharges. This treatment approach uses the soil and terrestrial vegetation as a filter and storage system for wastewater constituents such as nutrients and bacteria.

Since land application has the potential to impact surface waters of the State, the Division of Water Resources, Ground Water Discharges Section, is responsible for facilitating and overseeing this activity. Land application facilities, like their NPDES counterparts, operate under a permit which establishes the parameters, limits, schedules, and conditions for each facility.
DNREC also requires compliance/monitoring reports prepared by the permittee; the surveillance, sampling and inspection of facilities; and an enforcement element. The primary objective of this monitoring is to ensure compliance with permit conditions.

**Responsible Organization and Contact**

The DNREC Ground Water Discharges Section, Large Systems Branch, reviews and approves spray irrigation wastewater systems, onsite wastewater treatment and disposal systems with daily flows greater than 2,500 gallons per day, Experimental/Alternative Technologies, Advanced Treatment Units, underground injection wells, and other means associated with land application wastewater treatment.

Contact: Ron Graeber, Program Manager
Ronald.Graeber@state.de.us, 302-739-9948

**Data Collection Cost**

The costs of monitoring and reporting of results are borne by the permitted facilities. Funding sources for DNREC operations include Federal Section 106 and 205(g) excess funds, as well as State funding and permit fees. Total cost is not available.

**Data Use**

Monitoring data are used to verify that the wastewater treatment process for a facility is functioning properly and that the land application activity does not adversely impact surface and groundwater quality in the area, or soils under the site.

The loading route to the Bays of constituents contributed by Land Treatment facilities is considered to be nonpoint source. Presently, nonpoint source loadings to the Bays are estimated using concentration and flow data collected at the tidal/nontidal interface. The land application monitoring data has not been used to estimate the percentage of the total nonpoint source load that is attributable to these facilities.

**Record of Collection**

Varies by permitted facility.

**Collection Method**

Following treatment at a wastewater treatment facility, the reclaimed water is tested for a variety of parameters to ensure that the reclaimed water meets appropriate treatment standards. Then, when weather conditions are suitable for irrigation, the reclaimed water is applied to the field at agronomic rates. Agronomic loading rates are determined by the nutrient levels of the reclaimed water and the nutrient needs of the crops being grown, and should be incorporated into the farm managers Nutrient Management Plan.

The effluent limitations, frequency of monitoring, parameters tested, and other special conditions vary between the individual facilities according to the requirements specified within their permits. This specific information is available for each facility within Attachment 8. Land Treatment permits also require groundwater and soil monitoring, in addition to the limitations an individual permit excerpts (Attachment 8). For one facility (the Town of Georgetown) surface water monitoring is also required in two adjacent streams. The parameters typically monitored in sprayed effluent are similar to NPDES requirements, including eutrophication indicators such as total suspended solids, biological oxygen demand, total phosphorus, total nitrogen (and fractions of nitrogen), pH and dissolved oxygen. Groundwater monitoring includes measurement of water table depth and constituents that are highly soluble and do not readily adhere to soil (under and adjacent to the spray site). Soil monitoring is done to ensure that normal soil functioning is maintained so that expected levels of effluent treatment can occur.

**Analysis Methods**

Each discharge facility and the contractors which they select to provide monitoring and laboratory services must adhere to all the USEPA-approved Methodology and Quality Assurance requirements specified within the permit. Delaware requires NPDES and Land Treatment permit holders to maintain records of all information resulting from any monitoring activities that are required in their permit.
Data Location
Data must be requested from the Groundwater Discharges Section at DNREC.

Management Goal
Limits are established based on minimum technology-based standards set pursuant to federal and State laws and regulations. More restrictive controls may be established, if deemed necessary, to meet Federal or State drinking water quality standards. If background conditions exceed the drinking water standards, then there shall be no concentration increase above the background levels.

3.3.3 NONPOINT SOURCE NUTRIENT LOADS

Description/Objective(s)
The Clean Water Act requires states to identify and list waters within their boundaries that are water quality limited (303(d) List), and develop Total Maximum Daily Loads (TMDLs) for pollutants of concern. As part of developing a TMDL, nonpoint source loads must be estimated. Likewise, in order to assess the progress towards meeting an established TMDL goal, nonpoint source loads must continually be updated and monitored. DNREC Division of Watershed Stewardship annually assesses non-point source loads for all three bays (Indian River, Rehoboth, and Little Assawoman Bay) in the Inland Bays watershed.

Responsible Organization and Contact
The Delaware Department of Natural Resources and Environmental Control Watershed Assessment and management Section of Division of Watershed Stewardship provides non-point source load estimates and evaluation of the load changes over time.

Contact:  John W. Schneider, Section Administrator
John.Schneider@state.de.us,  302-739-9939

Data Collection Cost
The annual cost of water quality monitoring of sites within the Inland Bays Watershed is between $100,000 to $170,000, depending on frequency of monitoring (monthly or every other month). Frequency of monitoring follows a 5-year state-wide rotating basin schedule. Per this schedule, during every 5- years, most monitoring sites in the Inland Bays are monitored monthly for 2 years and are monitored every other month for 3 years.

Data Use
Load estimates are primarily used by DNREC Watershed Assessment and Management Section to assess the health of the Inland Bays water, as well as assess the effectiveness of actions taken in the watershed to reduce nutrient pollution.

Record of Collection
2006 to present. Data exist prior to 2006 but were collected at a frequency insufficient for determining annual loads with high confidence.

Collection Method
Ten water quality monitoring stations throughout the Inland Bays, located in the major tributaries of each bay are used to determine annual loads. These stations are part of the state’s Ambient Surface Water Quality Monitoring Program (see Section 3.1.1). There are two USGS stream gauging stations used to determine stream flow; Millsboro Pond outlet, and Beaverdam Ditch near Millville in Little Assawoman.

Analysis Methods
For each month, average concentrations of N and P at all free flowing sites within a bay’s watershed are calculated. Monthly average flow for the entire bay’s watershed is calculated using stream gage flow
data. Monthly loads of N and P are calculated by multiplying the monthly-average concentration of N or P for that bay by the monthly flow for that bay. Annual loads are calculated by adding monthly loads for entire year.

Data Location
Data is stored at DNREC Watershed Assessment Section of Division of Watershed Stewardship and is available upon request. In addition, the data is available via the following data portal: http://demac.udel.edu/waterquality/.

Management Goal
Data are used to assess if waters in the Inland Bays are meeting established TMDL goals. These data ultimately reflect if the actions taken in the watershed to reduce nutrient pollution are effective.

### 3.3.4 ATMOSPHERIC DEPOSITION OF NUTRIENTS

**Description/Objective(s)**
Nutrients are deposited from the atmosphere directly into the Bays during both wet and dry weather. Deposition of nitrogen is the most significant.

Data from the National Atmospheric Deposition Program/Atmospheric Integrated Research Monitoring Network (NADP/AIRMoN) site at Cape Henlopen can be used to estimate wet deposition rates (fluxes associated with rainfall) of nitrate (NO₃⁻), ammonium (NH₄⁺), and phosphate (PO₄³⁻) to the open waters and the tidal marshes of the Inland Bays on a daily basis. These daily measurements may be summed to determine wet deposition over other time periods.

There are, however, other species in wet deposition, and atmospheric inputs due to another set of chemical and physical processes, collectively described as dry deposition, that deliver N and P to land and water surfaces in the absence of rainfall. These species and processes may also contribute significantly to nutrient delivery to the Bays and their watersheds.

At present, the Cape Henlopen site is the only active site in the Inland Bays watershed where precipitation chemistry is determined (Site ID DE02, Latitude 38.7722, Longitude -75.0992). Therefore, it must serve as the basis for calculating current and future wet deposition rates.

Procedures to calculate the wet and dry deposition rates of N and P species directly to the Inland Bays are described in Ullman et al. (2010).

**Responsible Organization and Contact**
University of Delaware, College of Earth, Ocean, and Environment

Contact: Joseph Scudlark
scudlark@udel.edu, 302-645-4300

**Data Collection Cost**
Not available.

**Data Use**
Data are used to calculate the wet and dry deposition rates of nitrogen and phosphorus species to open waters and contiguous marshes in the Inland Bays, and elsewhere in Delaware for use in mass balance studies.

**Record of Collection**
1993 to present.

**Collection Method**
Samples are collected daily within 24 hours of the start of precipitation, often providing data for all or part of a single storm. The AIRMoN sites are equipped with a wet-only deposition collector and precipitation gage. Each site also has a National Weather Service standard gage for reporting storm total precipitation.

Samples are refrigerated after collection and are sent in chilled insulated shipping containers to the Central Analytical Laboratory (CAL) at the Illinois State Water Survey, where they are kept refrigerated until analysis.

**Analysis Methods**

The CAL measures free acidity (H\(^+\) as pH), conductance, calcium (Ca\(^{2+}\)), magnesium (Mg\(^{2+}\)), sodium (Na\(^+\)), potassium (K\(^+\)), sulfate (SO\(_4^{2-}\)), nitrate (NO\(_3^{-}\)), chloride (Cl\(^-\)), and ammonium (NH\(_4^{+}\)). The CAL also measures orthophosphate, but only for quality assurance as an indicator of sample contamination.

The CAL reviews field and laboratory data for completeness and accuracy, and flags samples that were mishandled, compromised by precipitation collector failures, or grossly contaminated. The CAL delivers all data and information to the NADP Program Office, which applies a final set of checks and resolves remaining discrepancies. Data then are made available on the NADP Web site.

Methods to calculate N and P deposition are described in detail in Ullman et al., 2010.

**Data Location**

Data from the Lewes NADP/AIRMoN site (DE02; located in Cape Henlopen State Park, Lewes) is accessed through the main NADP/AIRMoN website at http://nadp.sws.uiuc.edu/airmon/ or from the AIRMoN Data Retrieval Site at http://nadp.sws.uiuc.edu/AIRMoN/. Additional information about the site and data request forms, can be found there.

**Management Goal**

Despite significant uncertainties in the absolute values of the deposition rates calculated (Ullman et al., 2010), temporal trends may still be revealed. Based on a comparison with samples collected simultaneously on the north shore Indian River Bay, it is understood that extrapolating from Cape Henlopen rain data to the entire Inland Bays represents a conservative (minimum) estimate of wet N deposition rates for this system.

### 3.4 MONITORING OF GROUNDWATER

#### 3.4.1. DELAWARE GROUNDWATER MONITORING NETWORK

**Description/Objective(s)**

Long time-series of water levels in major aquifers serve as critical baseline data for resource management and analyses of aquifer response to pumping, climatic variability, drought hazards, seawater intrusion, and interaction with streams and their ecosystems. The Delaware Geological Survey (DGS) currently monitors groundwater levels in a network of 90 plus wells in Delaware (Figure 3.12). 15 of the wells are located in the Inland Bays watershed. The data are maintained in a relational database and served to stakeholders via a web interface.

DGS is automating data collection, reduction, and archiving to increase efficiency and quality control while sustaining growth of the statewide network over time. This supports evaluation of the long-term availability and sustainability of the groundwater supply, management of the resource, and a myriad of uses by the environmental management, engineering, and science communities.

In anticipation of needs to monitor for saltwater intrusion, DGS installed salinity sensors in 2015 in wells at three locations, Indian River Inlet, Fenwick Island Seashore State Park, and Woodland Beach Wildlife Area.
Groundwater quality data are collected when funded. DGS is seeking resources to expand monitoring to include routine groundwater quality sampling and analyses.

**Responsible Organization and Contact**

Delaware Geological Survey  
Contact: A. Scott Andres, DGS  
*asandres@udel.edu*, 302-831-0599

**Data Collection Cost**

Estimated cost for wells in eastern Sussex County is ~$650,000.

**Data Use**

This monitoring program supports evaluation of the long-term availability and sustainability of the groundwater supply, management of the resource, and other uses by the environmental management, engineering, and science communities.

**Record of Collection**

Records for the oldest wells go back as far as 1957. Details on each well, along with records of collection, are available on the DGS website at [http://www.dgs.udel.edu/datasets/recent-and-historical-groundwater-level-data](http://www.dgs.udel.edu/datasets/recent-and-historical-groundwater-level-data).

**Collection Method**

The DGS database holds over 10.8 million instrument measured and 60 K manual measured groundwater levels. Instrumentation has generated approximately 52.6 K daily temperature and 5700 specific conductance records.

**Analysis Methods**

Data are reviewed by DGS for quality control and then are made available to stakeholders through DGS online sources. Hydrograph data from stream gages in the area have been utilized to compare surface-water baseflow to nearby groundwater levels.

**Data Location**


**Management Goal**

The network supports evaluation of the long-term availability and sustainability of the groundwater supply, management of the resource, models of sea-level rise impacts, and many other uses by the environmental management, engineering, and science communities.
3.4.2 DELAWARE AGRICULTURAL SHALLOW GROUNDWATER MONITORING NETWORK

Description/Objective(s)

Studies in the Delmarva Peninsula have demonstrated that groundwater in shallow unconfined aquifers near agricultural lands is susceptible to contamination from chemicals, including nutrients, applied at the land surface. The agricultural community in Delaware has been working with various State and Federal government agencies to apply a number of conservation practices intended to reduce the amount of nitrate reaching the water table beneath agricultural land in support of Delaware’s nutrient reduction goals. However, changes in nutrient management practices on the land surface may take decades to improve water quality in groundwater discharge to Delmarva streams because of groundwater residence times.

To understand if these changes in agricultural practices are reducing nitrate concentrations in shallow groundwater, and eventually in drinking water and streams, a long-term groundwater monitoring program is being implemented by the USGS, in partnership with the Delaware Department of Agriculture. This network of wells is located in areas with young, oxic, shallow groundwater, overlain by agricultural land, where change will be seen most clearly in a relatively short timeframe.

Much of the documented variability in nitrate concentrations on the Delmarva Peninsula included results from networks with wells in both oxic and anoxic aquifer condition. To maximize the discriminatory power of the statistical tests, the network will have a large sample size (up to 50 wells) and only include wells in oxic aquifer conditions.

Responsible Organization and Contact

USGS and Delaware Department of Agriculture

Contact: Brandon Fleming, USGS Hydrologist

bjflemin@usgs.gov, (443) 498-5561

Data Collection Cost

Not available.

Data Use

Results of nitrate analysis from this study are intended to provide a baseline data set which, if supplemented by sampling results collected under similar hydrologic conditions in future studies, could be used to observe trends in nitrate concentrations.

Record of Collection

October 2014 to present.

Collection Method

A groundwater monitoring network (Figure 3.13), consisting of existing shallow wells from the Delaware Department of Agriculture’s Pesticide network and USGS networks, has been established based on geochemical and land-use characteristics including:

- The presence of oxic aquifer conditions
- Geochemical indicators of agricultural land use based on major ion and nutrient concentrations
- Location of wells with respect to agricultural lands
- Depth of wells, and
- Available age dates for groundwater.

Analysis Methods

Samples have been collected for analysis of nutrients, major ions, and groundwater age and the results will be used to characterize groundwater quality and compared to existing groundwater quality data.
Data Location
U.S. Geological Survey, 5522 Research Park Drive, Baltimore, MD 21228

Management Goal

Hypothesis and Test Statistics

To evaluate changes in nitrate concentrations, statistical matched pair tests are applied to new nitrate analyses from wells sampled during the study and historical analyses (where available).

FIGURE 3.13 - Map of wells included in the Delaware Agricultural Shallow Groundwater Monitoring Network.
3.5 MONITORING AND ASSESSMENT OF WETLANDS

3.5.1. STATE WETLANDS MONITORING AND ASSESSMENT PROGRAM

Description/Objective(s)

The goal of DNREC’s Wetland Monitoring and Assessment Program (WMAP) is to assess the condition, function, and services of wetlands in the state, and to integrate the latest research to understand the connection between the metrics and measures that are evaluated and the actual processes and implications on services that wetlands provide. This information is used to inform the citizens of Delaware and to improve existing education, restoration, protection, and land use planning efforts. The Delaware Wetland Monitoring Strategy (Delaware Department of Natural Resources and Environmental Control, 2011) guides the WMAP’s efforts in the areas of protocol development, wetland monitoring and assessment activities, research, and application of information. The goals and objectives outlined in the monitoring strategy support many of the goals of the Delaware Wetland Conservation Strategy (Delaware Department of Natural Resources and Environmental Control, 2008).

The Program works closely with other states through the Environmental Protection Agency’s Mid-Atlantic Wetlands Program to establish and conduct research methods and share information.

Objectives include:

- Develop scientifically valid wetland assessment methods.
- Assess the current condition of wetlands by watershed and identify major stressors that are impacting wetlands.
- Perform research to improve our understanding of wetland functions, the impact of stressors, and the ecosystem services provided by wetlands to humans and the environment.
- Evaluate the performance of wetland restoration and other compensatory wetland mitigation in replacing wetland acreage and function.
- Educate other state agencies, conservation partners, and the general public to improve efforts to protect and restore wetlands.
- Integrate monitoring and assessment data into watershed restoration plans and other conservation strategies.
- Meet requirements of the Clean Water Act.

The watersheds of the state were prioritized for wetlands monitoring based largely on the TMDL implementation schedule (Figure 3.14). The intent of the state is to monitor these watersheds using a rotating basin approach once an initial assessment of the wetlands within each watershed has been performed. Monitoring of nontidal wetlands in the Inland Bays occurred in 2005-2006; tidal wetlands were monitored in 2008 (Jacobs et al., 2008; Rogerson et al., 2008).

Responsible Organization and Contact

DNREC Wetland Monitoring and Assessment Program

Contact: Alison Rogerson
Alison.Rogerson@state.de.us, (302) 739-9939

Data Collection Cost

Not available.

Data Use

Final reports documenting the condition of tidal and nontidal wetlands in the Inland Bays were completed in 2009 (Jacobs et al., 2009; Rogerson et al., 2009). The data obtained by DNREC from assessing wetlands is being used to design wetland restoration plans for watersheds and to better understand how certain land use decisions affect the health of our wetlands.
Record of Collection

Monitoring of nontidal wetlands in the Inland Bays occurred in 2005-2006; tidal wetlands were monitored in 2008.

Collection and Analysis Methods

Nontidal riverine sites and flats in the Inland Bays are surveyed using a combination of comprehensive and rapid assessment procedures:

- **DECAP - The Delaware Comprehensive Assessment Procedure** is a comprehensive assessment method for collecting data that can be used to determine the condition of a wetland site relative to reference condition (closest to natural and undisturbed). DECAP can be used to assess flat, riverine and depressional nontidal wetland subclasses in the Coastal Plain of Delaware and Maryland. The comprehensive procedure can produce scores for certain wetland functions (services), including habitat, plants, hydrology, buffers, and soil cycling.

- **DERAP - The Delaware Rapid Assessment Procedure** is a rapid field method for determining the general condition of a wetland site. The DERAP can be used in flat, riverine, and depressional wetlands in Delaware and Maryland.

Tidal wetland surveys use a rapid assessment protocol:

- **MidTRAM - The MidAtlantic Tidal Rapid Assessment Method** is a rapid protocol for assessing the condition of estuarine emergent tidal wetlands in Delaware, Maryland, and Virginia. The MidTRAM is validated with intensive biological data based on the bird community and biomass levels.

Data Location

Data are managed and retained by the DNREC Wetland Monitoring and Assessment Program. All data are entered into an Access computer database that has been developed to consistently store wetland assessment data. The Department plans eventually to make wetlands data available through STORET.

Management Goal

DNREC’s goal is to achieve an annual net gain in wetland acreage and condition. The *Delaware Wetland Conservation Strategy* highlights recommends approaches with measurable outcomes for enhancing and improving wetland protection.

Hypothesis and Test Statistics
FIGURE 3.14 - DNREC’s current schedule for statewide wetland assessments.
3.5.2 LONG-TERM SALT MARSH MONITORING

Description/Objective(s)
Three representative salt marshes in the Inland Bays were each instrumented with triplicate Sediment Elevation Tables (SETs) in order to provide high intensity baseline information on sediment elevation changes in salt marshes of the Inland Bays. Locations of the SETs are provided in Figure 3.15. In addition, one marsh (Angola Neck) was outfitted with continuous water level loggers to determine water depth at marsh surface locations. These data can be used to assess whether Inland Bays marshes are keeping pace with sea level rise, and can provide information on potential causal or influential factors of sudden wetland dieback events.

Responsible Organization and Contact
The Delaware Center for the Inland Bays is responsible for this monitoring program in the watershed.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost
Costs for each SET platform are roughly $900 for initial installation, not including labor costs, and $50 annually for maintenance. The SET arm costs $2,000 but can be used at all sites because it is portable. Water loggers cost approximately $2,200 each.

Labor cost is roughly $5,000 a year to monitor the SET tables and water loggers.

Data Use
The information will be used to better understand the variation among processes that result in fringing marsh maintenance or conversion to open water, and will be included in the development of saltmarsh restoration and protection strategies for the watershed.

Record of Collection
Angola Neck: 2008 – present
Piney Point: 2010 – present
Slough’s Gut: 2011 - present

Collection Method
Data are collected twice annually, within 5 days of the full moon in October and April. Each SET table has both a deep SET, which measures overall marsh height change, and a shallow SET, which measures changes in the marsh height as a result of both surface accretion/erosion, and changes in the root zone. Sampling is conducted by attaching the SET arm to a SET table, and placing nine SET pins into the corresponding holes on the SET arm. The pins are gently lowered to the marsh surface, and the height each pin extends above the SET arm is recorded for all nine pins to the nearest half millimeter. The pins are then removed, the SET arm is rotated 90 degrees and the process is repeated until all four directions are sampled. Both the shallow SET and the deep SET are measured in this way. Additionally, each SET table has three feldspar clay accretion plots, which are sampled by cutting away a plug with a knife, and measuring the height of sediment above the top of the clay layer at three different locations on the plug.

Water level data are downloaded from each logger and corrected for barometric pressure using Win-Situ software.

Analysis Methods
Data are analyzed to determine if each SET platform is keeping pace with the current rate of sea level rise by first determining the slope of the change in height for each individual pin at each direction at each SET over time with a linear regression (ex. 9 slopes for direction A at Angola Neck site 1, one for each pin, then 9 slopes for direction B at Angola Neck site 1, one for each pin… etc.). Only the deep SET measurements are used as these reflect all changes in marsh height, as opposed to the shallow SET which only reflects root zone and surface layer changes. The coefficient of each slope is then averaged...
together for all 4 directions at each SET location (ex. 36 slope coefficients averaged at Angola Neck site 1) to determine the average rate of change at a particular SET location. The standard error is also calculated. These values are compared to the mean sea level rise rate of 3.40 mm per year with a lower tailed T-test ($\alpha = 0.05$). If the result of the test is significant, the SET table has significantly less wetland elevation change than local sea level rise. This follows the protocol recommended by the National Park Service.

To assess what specific processes are driving the changes in marsh height, each SET table is analyzed separately using the shallow SET readings, the deep SET readings, and accretion data. As described previously, a slope is calculated for each pin at each position for each SET for the shallow and deep platforms. The slopes are averaged together at each SET to determine the overall slope for a particular SET table. This procedure is performed for both the deep SET readings and the shallow SET readings. The shallow SET readings capture changes occurring only in the root zone and surface layer, or roughly the first 0.6 m of the marsh surface. These changes include root zone growth, compaction, and accretion. By subtracting the shallow SET slope from the corresponding deep SET slope, the changes occurring below the 0.6 m root zone are separated from the overall deep SET measurements. In this way, we are able to determine what is occurring below the root zone.

To determine accretion rate, the nine accretion measurements are averaged together to get the average accretion height. If the height reading is the first reading since laying down a new layer of clay, this height is divided by the number of days since the clay was laid onto the marsh. If the height value is not the first measurement since laying the clay onto the marsh, the height value is subtracted from the previous sampling event’s average height value, and divided by the number of days since the last measurement. This is done to prevent previous accretion events from influencing the current measurements. Each average change in height is averaged together to determine the overall average accretion rate. The average accretion rate for each SET table is then subtracted from the shallow slope values to determine the changes occurring solely in the root zone.

**Data Location**
Located at the Delaware Center for the Inland Bays, available upon request.

**Management Goal**
Inform decision makers on how salt marshes in the Inland Bays are faring with respect to sea level rise, and what processes are responsible for maintenance of marsh elevation or conversion to open water.

**Hypothesis and Test Statistics**
Elevation at each SET table and each marsh as a whole is compared to current sea level rise rates, along with DNREC sea level rise planning scenarios using a lower tailed T-test ($\alpha = 0.05$). The null hypothesis is that the SET platform has equal to or greater wetland elevation change than local sea level rise.
FIGURE 3.15 - Locations of sediment elevation tables in the Inland Bays.
4. DATA MANAGEMENT AND QUALITY CONTROL

The data managers listed for each monitoring program are responsible for the following:

- Collection and analysis of data according to existing or updated monitoring plans. Changes in monitoring frequency or protocols must be communicated to the CIB, and included in any updates to the *Environmental Monitoring Plan for Delaware’s Inland Bays*.

- Providing data to the CIB and/or its partners upon request for use in indicator reports or research projects.

- Quality Assurance Plans must be kept up to date and provided to data users (including the CIB) upon request.

- All monitoring programs funded partially or in whole by the U.S. EPA must have an up to date, approved Quality Assurance Project Plan (QAPP). QAPPs are to be updated every three years. A copy of the approved QAPP must be provided to the CIB for its records.
## 5. DATA COLLECTION TIMELINE

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</thead>
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<tr>
<td>DNREC Ambient Surface WQ Monitoring</td>
<td>monthly or bimonthly</td>
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<tr>
<td>UD Citizen Monitoring Program</td>
<td>weekly or biweekly</td>
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<td>Fecal coliform monitoring</td>
<td>10x per year</td>
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<tr>
<td>Stream/Tide Gauging</td>
<td>Daily</td>
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<td>DNREC Stream Bioassessment</td>
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<td>Natl. Aquatic Resource Surveys – five year cycle</td>
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<td>NRSA</td>
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<td>NWCA</td>
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<tr>
<td>Toxics Monitoring</td>
<td>monthly or bimonthly</td>
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<tr>
<td>Veg./Land Cover Mapping</td>
<td>maps updated monthly</td>
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<tr>
<td>Seaweed Monitoring</td>
<td>monthly</td>
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<tr>
<td>Coastal Finfish</td>
<td>monthly</td>
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<tr>
<td>Inshore Fish &amp; Blue Crabs</td>
<td>2x per month</td>
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<td>Recreational Fishing Surveys</td>
<td>reported annually</td>
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<td>Hard Clam Surveys</td>
<td>TBD</td>
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<td>Horseshoe Crabs</td>
<td>semi-monthly</td>
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<td>Breeding Bird Atlas</td>
<td>Next surveys TBD</td>
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<td>Mid-winter Waterfowl Surveys</td>
<td>annually</td>
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<td>Osprey Nest Counts</td>
<td>annually through volunteers</td>
<td></td>
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<tr>
<td>Bald Eagle Nest Counts</td>
<td>annually</td>
<td></td>
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<tr>
<td>Groundwater level/salinity</td>
<td>daily</td>
<td></td>
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<tr>
<td>Agric. Shallow Groundwater Monitoring</td>
<td>TBD</td>
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<td>DNREC Wetlands Assessment</td>
<td>Current basin rotation ends 2018</td>
<td></td>
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<tr>
<td>Long-term Saltmarsh Monitoring</td>
<td>Semi-annually</td>
<td></td>
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</table>

Note: TBD = To Be Determined.
6. RECOMMENDATIONS AND SUPPORTING PROGRAMS

The previous section of this plan describes ongoing monitoring programs in the Inland Bays that exist currently. Many of these existing programs provide data that are used to develop the long-term indicators for the State of the Delaware Inland Bays reports that are published every five years by the CIB (Appendix A). Thus it is critical that these programs be continued.

This section of the plan provides recommendations for new monitoring programs, or enhancement of existing programs. These recommendations are made based upon critical data gaps, the availability of new methods or technologies, and/or changes needed to make programs sustainable over the long term. Table 5.1 summarizes the recommendations, and each is described more fully below.

TABLE 6.1 - Recommendations for monitoring in the Inland Bays. They are categorized according to priority (** being highest priority).

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Recommended Partners</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Development of a new hydrodynamic/watershed model for the Inland Bays</td>
<td>CIB STAC, University of Delaware, DNREC Division of Watershed Stewardship</td>
<td>***</td>
</tr>
<tr>
<td>2. Upgrade Citizen Monitoring Program database and serve data to public online through STORET and/or the state Water Quality Portal.</td>
<td>Delaware Sea Grant, Delaware Environmental Monitoring and Analysis Center (DEMAC), CIB, EPA Region 3</td>
<td>***</td>
</tr>
<tr>
<td>3. Long-term, continuous monitoring of dissolved oxygen and chlorophyll.</td>
<td>University of Delaware CEOE, DEMAC, with input from STAC</td>
<td>***</td>
</tr>
<tr>
<td>4. Monitoring of submerged aquatic vegetation in the Inland Bays</td>
<td>University of Delaware CEOE, Sea Grant, CIB, DNREC Division of Watershed Stewardship, EPA Region 3</td>
<td>***</td>
</tr>
<tr>
<td>5. Monitoring of local indicators of sea level rise, including a flood monitoring network</td>
<td>Delaware Environmental Observing System (DEOS), DGS</td>
<td>***</td>
</tr>
<tr>
<td>6. Continue monitoring tidal flushing at the Indian River Inlet.</td>
<td>U.S. Army Corps of Engineers, DNREC Division of Watershed Stewardship, DelDOT</td>
<td>**</td>
</tr>
<tr>
<td>7. Monitoring of oyster recruitment and growth in the bays</td>
<td>DNREC Division of Fish and Wildlife, DNREC Division of Watershed Stewardship, Delaware Sea Grant, Delaware State University</td>
<td>**</td>
</tr>
<tr>
<td>8. Shoreline condition and modification monitoring.</td>
<td>CIB, DNREC Wetlands Assessment and Monitoring Program, DNREC Subaqueous Section, VIMS</td>
<td>**</td>
</tr>
</tbody>
</table>
9. Continue analyses of tidal marsh acreage and condition using GIS methodology established in 2104 RARE study.  
University of Delaware Water Resources Agency, CIB

10. Monitoring of Estuary Acidification  
University of Delaware CEOE, Delaware Sea Grant, Delaware Coastal Management Program (DCMP)

11. Monitoring of Recreational Blue Crab and Hard Clam harvests  
DNREC Division of Fish and Wildlife

6.1 HYDRODYNAMIC/WATERSHED MODEL

Since 2000, there has been a significant increase in both understanding and data collection in Delaware’s Inland Bays. In particular, the University of Delaware and Delaware’s Department of Natural Resources and Environmental Control have collected continuous data records for dissolved oxygen (DO) over many years and at many locations. DO is arguably the greatest potential water quality threat to Delaware’s Inland Bays, with multiple fish kills attributable to hypoxia occurring most years. Substantial research efforts have also demonstrated reduced growth rates and behavioral avoidance of hypoxia by juvenile estuary dependent fishes that rely on the Bays for Essential Fish Habitat.

For this reason, the Center requested an independent assessment of the DO calculation in the GEMSS model (Brady, 2014). This report focuses on DO, but improvements in the understanding of nutrient loading and biogeochemical cycling will also be necessary to improve model formulations. The conclusions of this report are that GEMSS is not effective at simulating DO (especially in Indian River and tributaries). The calibration and validation datasets from 1998-2000 include few to no substantive continuous DO records. Assessing model performance in relation to diel-cycling hypoxia is exceedingly difficult, and that was not the original intent of that modeling effort. DO data from 2001-present contains DO fluctuations from 0% to 200% saturation in the headwaters of major creeks/tributaries and the model output contains no such fluctuations. The explanation for this is either: (1) diel-cycling hypoxia only became a significant feature of the water quality in Delaware’s Inland Bays in 2001 or (2) the monitoring program only became robust enough to detect diel-cycling hypoxia in 2001. In either case, the proliferation of data and understanding during the time period strongly argues for re-visiting the modeling framework for the Bays.

Recommendation: There is a critical need for a coupled watershed, hydrodynamic, and water quality model for the Inland Bays that uses current and high-frequency data.

Specific recommendations for future accurate simulations of diel-cycling hypoxia (Brady, 2014) include:

- In the shallow Inland Bays estuary, benthic pelagic coupling between the water column and sediments is potentially a large source of oxygen demand. The current model uses fluxes measured from 1992-1993 and 2001. There is no mechanistic sediment flux model associated with this modeling effort. More recent flux measurements, a sediment flux model, and explicit incorporation of benthic algae will almost certainly be necessary to complete nutrient budgets. There is also potential for the sediment to play a role in time lags between the implementation of the Pollution Control Strategy and response in the estuary that cannot be explored in the current modeling framework.

- Incorporation of primary production and respiration rates into model calibration. Seasonal respiration appears well calibrated, but daily respiration rates are clearly not large enough to generate hypoxia in the early to late morning.
Increased spatial resolution particularly in tidal headwaters where recent fish tagging evidence has highlighted potential fish exposure mechanisms reliant on spatial gradients in DO.

Incorporation of multiple meteorological records that were unavailable or offline during the calibration years (1998-2000) made available by the Delaware Environmental Observing System.

Secondary recommendations:

- Evaluation of sampling protocols for mobile dinoflagellate species that may require vertical profiles to accurately characterize vertically integrated water column primary production and respiration.

- Re-assessment of nutrient loading to include potential groundwater discharge being explored by researchers since 2000.

6.2 UPGRADE OF CITIZEN MONITORING PROGRAM DATABASE

Due to funding and staffing issues, the University of Delaware Citizen Monitoring Program (CMP) has struggled to keep up with nutrient analyses and management of data. The Center recently has provided EPA Section 320 funds to assist the CMP with analysis of backlogged nutrient samples taken at nine stations that are key for producing State of the Delaware Inland Bays and Your Creek indicator reports. But a larger issue is the fact that the current Access database used by the CMP is unsustainable and incapable of exporting data that can be integrated with the state’s water quality databases.

The CIB, the CMP, EPA Region 3, and DNREC have a shared goal converting the current CMP database to a new, supported, sustainable format that allows public, online access and queries of Inland Bays water quality data. Conversion would be made to a database that can export data into the EPA’s STORET data warehouse, and allow sharing of data online via the Delaware Water Quality Portal (http://demac.udel.edu/waterquality/). The new database could include an online site for volunteer monitors to enter their measurements directly, with data validation, including access from mobile platforms.

Recommendation: It is recommended that the Delaware Environmental Monitoring & Analysis Center (DEMAC, University of Delaware), which manages the state’s Water Quality Portal, work with the CMP and the Center for the Inland Bays to develop a CMP data entry template and database processing tools that will allow submission of data to STORET through the EPA’s Water Quality Exchange (WQX).

Specific recommended objectives and actions are:

1. Development of an updated, supportable database structure for the CMP.
   a. Creation of a mechanism and framework whereby CMP data can be submitted.
   b. Development of data ingestion software to input CMP data into a database or repository.
   c. Creation of a QA/QC reviewer access procedure for quality control purposes.

2. Online availability of CMP data to the public.
   a. Creation of a mechanism for automated submission of CMP data into STORET from the newly developed CMP database.
   b. Ingestion of CMP data from STORET into the Delaware Water Quality Portal as an additional “station type” for easy public access to CMP data.

Once this is complete, legacy data should be converted, if possible, for inclusion into STORET.

Successful completion of this project will help ensure long-term sustainability of the Inland Bays Citizen Monitoring Program and fill critical data needs for effective restoration and management of the estuary. A robust, high-quality water quality data set for the bays, combining both volunteer and state-collected data, will be publicly available and searchable through a common online portal. Additionally, this effort
will further a goal of both the Center and EPA to have CMP data incorporated into water quality analyses and models managed by the state.

**Funding:** Estimated cost to complete Objectives 1 and 2 is $50,000. Potential funding sources include EPA grants for NEP monitoring programs.

### 6.3 CONTINUOUS WATER QUALITY MONITORING

Ambient water quality monitoring in the Bays has to date largely followed a traditional paradigm of discrete sampling to collect data from as many locations and as often as funding allows. Typical best-case sampling frequencies are weekly (for the Citizen Monitoring Program) or quarterly (for the State’s GAMN network). While this type of monitoring program may be useful for long-term status and trend analyses, it does not provide sufficient resolution to detect rapidly changing or cycling conditions in the Bays or episodic events. Examples of these in the Inland Bays system include diel-cycling hypoxia (Tyler et al., 2009) and phytoplankton blooms.

Continuous monitoring is increasingly becoming a standard to characterize water quality in shallow coastal systems, where conditions can change frequently over time. Continuous monitoring is the sampling method of choice when water quality variations are to be characterized over time. Multiparameter sondes, for example, are increasingly being used to monitor water quality at fixed monitoring sites, to carry out vertical profiling, or to perform water quality mapping. Flow-through continuous monitoring stations also are developing and have been used at a few sites in the state. DNREC has deployed some continuous sensors at Millsboro Pond in the Bays watershed. New, autonomous platforms are available provide spatial resolution for parameters that cannot be sensed remotely.

Continuous monitoring in coastal environments can be challenging because of rapid biofouling from microscopic and macroscopic organisms, corrosion of electronic components from salt and high humidity, and wide ranges in values of field parameters associated with changing weather and tidal conditions. The sensors that are used to measure water-quality field parameters require careful field observation, cleaning, and calibration procedures, as well as thorough procedures for the computation and publication of final records. However, procedures and technologies for continuous water quality monitoring have evolved greatly in recent years, and continue to evolve. Emerging sensor technology broadens the variety of measurable chemical constituents and reduces the limits of detection. Because it has become possible to make near realtime water-quality monitoring data available on the Internet, continual progress is being made to improve applications and refine quality-control procedures.

**Recommendation:**

Continuous monitoring networks to measure dissolved oxygen and chlorophyll should be developed and deployed in the Inland Bays, with a focus on tributaries. This effort should build upon ongoing work in this area by Dr. Bill Ullman and others, and consider emerging, innovative technologies. The STAC should help guide the selection of sites and station configuration.

**Funding:**

Dependent upon the methods used and number of stations monitored. Annual cost to maintain the continuous monitoring station currently deployed at Massey’s Ditch (USGS 01484680, measuring temperature, specific conductivity, DO, and pH) is on the order of $50,000.

### 6.4 MONITORING OF SUBMERGED AQUATIC VEGETATION

While listed as a major action in CCMP, submerged aquatic vegetation (SAV) restoration efforts in the Inland Bays have stalled. Due to high levels of nutrients, chlorophyll a, and macroalgae, SAV beds in the Inland Bays have all but disappeared. However, recent water quality analyses suggest that water quality has improved in many locations over the long term, and that macroalgae populations are much lower
than previous levels in much of the Inland Bays. This suggests that SAV beds may be able to survive in the Inland Bays once again, and may currently exist in some areas that have seen improvements.

Recent surveys of SAV in the Bays have been limited to the Horned Pondweed meadows discovered a few years ago in Love Creek. No monitoring program currently exists for eelgrass or other baygrasses.

Recommendation:
Monitoring to document what SAV remains in the Inland Bays, and where it’s located are necessary in order to protect any existing SAV beds, as well as focus restoration efforts in areas where SAV beds are known to survive. In addition, the recognition of SAV as an important carbon sink adds impetus to the need for accurate maps at a regional level.
Surveys at five-year intervals are recommended.

Recent technological advances present new options for monitoring and mapping SAV. Aerial surveys are one option. However, the current sparseness of SAV beds in the Inland Bays means that surveyors would be searching for much smaller patches than are typically identifiable by plane. Monitoring may also be conducted either with boats and divers, or with short-range, low elevation drone flights, checking areas for SAV presence and patch size. Divers and drone pilots could maximize their time by focusing efforts in areas where water quality meets SAV requirements as determined through the State of the Bays report and other water quality analyses. A workshop at the November 2017 conference of the Coastal and Estuarine Research Federation (CERF) will be devoted to sharing best practices for SAV monitoring, including new technology options.

Funding:
Funding required is impossible to determine until methodologies are established. EPA’s Region 3 has offered divers and field assistance for projects such as this in the Inland Bays. This could help offset costs of SAV monitoring.

6.5 LOCAL INDICATORS OF SEA LEVEL RISE

There is a critical need in the Inland Bays watershed to conduct monitoring geared specifically to address how sea level rise affects and is perceived by the public. The Inland Bays watershed is particularly vulnerable to sea level rise and its effect on the frequency and intensity of coastal flooding events, emphasizing the need for a modern, dependable coastal flood monitoring and warning system for the Bays’ coastal communities.

The Delaware Coastal Flood Monitoring System (CFMS) was developed, jointly by the Delaware Geological Survey (DGS) and the Delaware Environmental Observing System (DEOS) at the University of Delaware, to provide water level predictions and flood potential for 15 communities on Delaware Bay (http://coastal-flood.udel.edu/). The tool serves three primary functions: to send out warning alerts up to 48 hrs in advance of potential flood conditions, to provide access to current meteorological and hydrologic conditions, and to provide local tidal predictions and map their areas of impact.

The CFMS currently covers only the Delaware Bay coastline. Expansion of the system to the Inland Bays and Atlantic Coast of Delaware is planned by DEOS. However, the NOAA DBOFS operation model used currently does not work well for the Inland Bays system. A different hydrodynamic or statistical model is required.

In 2015, DEOS partnered with DGS and the CIB to conduct a three-year study of water level conditions at various locations in the Inland Bays. Water level sensors were installed in spring of 2015 and likely will be maintained until the summer of 2018. Data collected will help inform development of a flood prediction model specific to these bays.

Recommendation:
Expansion of the CFMS into the Inland Bays will at least partly fill the need for more local indicators of climate change and sea level rise. If a successful model is developed for the Bays, it will provide a
publicly-accessible, real-time tool to create flood inundation potential maps and time series of forecasted tidal predications. The CFMS itself is not meant to be a sea level rise tool, but rather its continued development is contingent upon the availability of tidal water level data from a sensing network like the one currently deployed in the Inland Bays. The data from that same network can lend itself towards sea level rise monitoring and the development/validation of hydrodynamic models if maintained for an extended period of time.

It is recommended that support for developing this tool for the Inland Bays be continued and prioritized. A water level/flood monitoring network should be permanently installed throughout the Bays. These data are needed not only for flood alert tools, but also for development of a new hydrodynamic model for the Inland Bays.

Priority should also be given to long-term local monitoring of other indicators of climate change, such as precipitation, air temperature, and growing season length. The Inland Bays watershed experiences a range of microclimate effects, so data collected at the coast, for example, (or from outside the watershed) cannot easily be extrapolated to inland locations.

Funding:

The annual cost to maintain the current network of CFMS sensors is approximately $15,000, including upkeep of a borrowed (DelDOT-owned) RTK-GPS system. Installation of new sensors would add more cost, so maintaining what is there already is more cost effective, as long as the locations are answering the pertinent science questions.

Currently the CFMS is funded through grants from the DNREC Delaware Coastal Management Program and the Delaware National Estuarine Research Reserve, with funding from NOAA’s Office of Ocean and Coastal Resource Management. Opportunities for additional funding from NOAA, DEMA, and Sussex County should be explored.

6.6 INDIAN RIVER INLET TIDAL FLUSHING

Since it was stabilized in the 1930s, the Indian River Inlet has deepened over time, passing greater volumes of water and increasing the tidal range of the Bays. This has led to long-term increase in salinity of the Bays and contributed to degradation of marshes. Increased tidal flushing through the Inlet also results in greater flushing of nutrients from the system.

Inlet flushing is one of the important indicators included in the State of the Delaware Inland Bays reports. Flushing is estimated through tidal prism calculations. The tidal prism is defined as the volume of water leaving a channel on an ebb tide cycle. The following general equation is used:

\[ P = H A \]

where \( H \) is the average tidal range and \( A \) is the average surface area of the basin. Area is calculated through a series of transects and using bathymetry data for depth.


Tidal prism calculations can be used not only to evaluate the volume of water passing through the inlet, but also the residence time of water within the Inland Bays. Evaluation of the Indian River Inlet flushing indicator during preparation of the 2016 State of the Delaware Inland Bays report revealed a need for dedicated funding to regularly assess the inlet flushing. As the inlet deepens and widens the volume of saltwater will increase and leads to a cascade of ecological impacts. In addition, the change in channel morphology may lead to structural problems with the inlet bridge. 2004 data were provided by the Army Corps of Engineers, Coastal Planning Section.
Recommendation: It is recommended that the state work with the Army Corps to repeat these measurements every five years. Because of its interest in resiliency of coastal roadways and long-term integrity of the inlet and its bridge, DelDOT may be able to contribute to this effort.

Funding: The tidal prism data collected in 2004 was one portion of a larger data collection effort funded under a single contract. The Army Corps estimates the tidal prism portion of the work cost roughly $30,000. The tidal prism data collection effort involved hourly boat-mounted ADCP surveys measured over a 25-hour period along five transects, as shown in Figures 6.1 and 6.2. Today, a similar effort would likely cost closer to $40,000.

FIGURE 6.1 – Hydraulic measurements made at the Indian River Inlet in 2004.
6.7 MONITORING OF OYSTER RECRUITMENT AND GROWTH IN THE BAYS

A major goal of the Center is to restore a sustainable population of native oysters in the Inland Bays. Oyster restoration/enhancement projects (such as living shorelines, oyster reefs, and the CIB’s oyster gardening program) and commencement of oyster aquaculture in the Bays will all contribute to this goal. Currently, however, no regular monitoring of oyster population, distribution, or recruitment in the Bays is occurring. Such monitoring is necessary to evaluate the effectiveness of restoration efforts.

A critical need also exists for studies on post-settlement growth and survival of oysters in the Inland Bays system. Existing literature documenting growth rates for Eastern Oysters is largely from studies of large, protected, or hatchery-spawned animals. Multi-year, population-level estimates of wild growth in local bay waters are necessary in order to understand the dynamics of restored oyster populations, and their ecosystem services, under naturally variable conditions. Such studies have very recently begun in Delaware Bay (Munroe et al., 2017).

Recommendation:
The CIB currently is drafting a Shellfish Enhancement Action Plan that will include recommendations for specific restoration projects such as oyster reefs. All implementation projects should, if feasible, be
monitored for at least three to five years for oyster survival, growth, reef height and size (if applicable),
disease, and recruitment.

In addition, however, it is recommended that regular, long-term surveys of oyster populations and
recruitment be developed for all three Bays. A plan for this monitoring should be a component of the
Shellfish Enhancement Action Plan.

A current research project being conducted under the guidance of Dr. Gulnihal Ozbay at Delaware State
University may provide a template for this monitoring program. The focus is to develop repeatable
methods that can be used later to assess the impact that aquaculture and hatchery raised oysters have on
the local wild oyster population. Components of this effort include: (a) Standardized transect surveys on
riprap–armored shorelines; (b) spat collectors deployed at locations throughout the Bays; and (3) genetic
analyses of spat, to determine the diversity and probable parent populations.

Funding:

While some funding to support monitoring of implementation projects can be written into project grants,
long-term monitoring of these projects likely will require that additional funds be identified.

6.8 SHORELINE MODIFICATION MONITORING

The Center is engaged in an initiative to maximize the use of living shorelines stabilization techniques in
order to protect the water quality and habitat of the estuary. The initiative is a focus of the
Comprehensive Conservation and Management Plan (CCMP) for the Inland Bays and is also a priority for
the State.

A study to assess the shoreline conditions of Rehoboth and Indian River Bays was conducted by the
Virginia Institute of Marine Science (VIMS), Center for Coastal Resources Management, with support from
DNREC’s Wetlands Monitoring and Assessment Program and the Center for the Inland Bays. Data for
Indian River Bay were collected in 2006; data for Rehoboth Bay were collected in 2012. The spatial data
collected in the study were used to build a public web-based mapping and analysis interface
(http://cmap.vims.edu/ShlInv/Delaware/Delaware_shlinv.html). The assessment was not completed for
Little Assawoman Bay at the time, due to funding constraints.

The data developed for the inventory were based on a three-tiered shoreline assessment approach. This
assessment characterized conditions that can be observed from a small boat navigating along the
shoreline. Hand-held GPS units and GPS registered videography were used to collect data on conditions
observed in the field. The three tiered shoreline assessment approach divided the shore zone into three
regions: 1) the immediate riparian zone, evaluated for land use; 2) the bank, evaluated for height, stability,
cover and natural protection; and 3) the shoreline, describing the presence of shoreline structures for
shore protection and recreational use.

A complete and up to date shoreline condition database is an important tool for evaluating success in
meeting the goal of reducing hardened shorelines and increasing the extent of natural/living shorelines in
the Bays. If maintained long-term, the data can be used to develop useful shoreline condition indicators
for the Inland Bays. The online analysis tool can assist land owners, marine contractors, and State
regulators to identify locations where shoreline restoration is needed and what type of shoreline
restoration method would be most appropriate. In particular, the data may be used to help CIB and
others prioritize sites for installation of living shoreline restorations in all three Inland Bays.

Recommendation:

It is recommended that a shoreline inventory be completed for Little Assawoman Bay, and that the
shoreline data collected in 2006 for Indian River Bay be updated within the next one to two years. In
order to use the shoreline data to develop an environmental indicator for the Bays, the data will need to
be updated periodically. Ideally this would happen every five years, to correspond with release of the
State of the Delaware Inland Bays reports.
Funding:
Total cost for the original inventory of Rehoboth and Indian River Bays was ~$125,000. In 2015, VIMS provided a cost estimate of ~$67,000 to complete the inventory for Little Assawoman Bay and update Indian River Bay data.

The Center recommends that this work be completed more cost effectively by using in-house staff and volunteers to collect shoreline photographs and field data from boats. Use of drones may also facilitate data collection. Center staff, or a contractor, would then update the mapping layers and report the results. The Barnegat Bay Partnership recently developed a citizen science program called “Paddle for the Edge,” to monitor shoreline condition. Data are collected from kayaks and canoes using a smartphone app. A similar program could easily be developed for the Inland Bays.

6.9 CONTINUATION OF TIDAL MARSH ACREAGE/CONDITION AS ENVIRONMENTAL INDICATORS

Monitoring the extent and condition of the tidal marshes of the Inland Bays is critical for determining overall health of the estuary and to track trends in its condition. By understanding changes over time it is possible to identify potential areas of concern and prioritize future research and remediation efforts.

The 2016 State of the Delaware Inland Bays report included new salt marsh acreage and condition (fractured pooling) indicators. These indicators were developed using data generated by a Regional Applied Research Effort (RARE) study conducted by the University of Delaware and the Center for the Inland Bays (Jo et al, 2014). The study documented the areal extent of the marshes of the Inland Bays at a number of intervals between 1937 and 2007 using geospatial analyses of aerial photography, State of Delaware wetland maps, and Landsat Thematic Mapper satellite imagery. Historic trends in the extent of vegetated marsh, fractured pooling, ditching, and wetland/upland boundary hardening provide an indication of the general health of the tide marsh system. The RARE study established a methodology for continued analysis of status and trends.

Recommendation:
In order to continue to use tidal marsh acreage and extent of fractured pooling as environmental indicators for the Bays, analyses of updated aerial imagery and land cover data should be repeated at least every five years, using the established GIS methodology. The University of Delaware Water Resources Agency (WRA) is best suited, at this time, to conduct these analyses.

Funding:
To perform the analysis, including data compilation and generation, aerial photointerpretation, GIS processing of files, generation of data for trend analysis, and reporting of status and trend results, the WRA estimates a total cost of $21,100 to $37,700.

6.10 ESTUARY ACIDIFICATION MONITORING

The drivers, patterns, and ecological impacts of acidification in estuaries are not well understood, due to dramatic spatial and temporal variation in the processes that control pH in near-shore environments. Upwelling/overturn, tides, eutrophication, and watershed alteration are expected to interact with increasing atmospheric carbon dioxide and warming waters in complex ways. Proton fluxes may vary seasonally or with weather patterns. Biological impacts may also vary. Yet there is evidence that even a slight increase in acidification disrupts recruitment and growth of shellfish. Responses of other organisms to acidification are less clear.

Currently no long-term acidification monitoring is being conducted in the Inland Bays. Whether or not it is a significant concern is unknown. Monitoring pH in estuaries is not straightforward. Other National Estuary Programs have deployed cutting-edge systems to monitor long-term coastal acidification trends,
including San Francisco Bay, Santa Monica Bay, Tampa Bay, Massachusetts Bay, Casco Bay, Barnegat bay, Long Island Sound, and Corpus Christi Bay. In addition, EPA is measuring acidification in the Mid-Atlantic waters offshore of Chesapeake Bay and Delaware Bay. Dr. Bill Ullman’s group at the University of Delaware currently is studying acidification in the Murderkill Estuary, using a continuous, stable, high frequency pH sensor for estuarine and marine applications.

**Recommendation:**

Collection of data needed to understand proton fluxes and balances in the Inland Bays should be included as a component of a continuous water quality monitoring system (see section 6.3). State of the art sensors suitable for use in brackish or marine waters will be required.

**Funding:**

See Section 6.3.

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### 6.11 RECREATIONAL BLUE CRAB AND CLAM HARVESTS

DNREC’s Division of Fish and Wildlife indicates that obtaining estimates of recreational Blue Crab and Hard Clam harvests is one of the highest priorities for fisheries research in the Inland Bays. Currently no information exists on what quantity of shellfish are being recreationally landed from the Bays. This information would be used to assess the health and status of those shellfish populations and would allow the state to better account for recreational harvest in their management.

**Recommendation:**

The Division of Fish and Wildlife should develop an ongoing recreational Hard Clam and Blue Crab harvest survey in the Inland Bays similar to the MRIP survey currently used by NOAA recreational fish catch. This survey would rely on a field, ‘harvester-intercept’ interview survey that records catch rates for species; and a telephone (or mail survey) that is designed to estimate effort. Average catch rates would be applied to the effort estimates to generate landings per year. These surveys would be conducted annually.

**Funding:**

In 2009, the state contracted with MACRO to conduct this type of survey to generate a recreational landings estimate for Blue Crabs in the state. The cost was $46,000. Cost for the proposed survey is expected to be similar.
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APPENDIX A

ENVIRONMENTAL INDICATORS USED IN PREPARATION OF THE STATE OF THE DELAWARE INLAND BAYS REPORTS
APPENDIX B

COMPILED QUESTIONNAIRE FROM AMBIENT WATER QUALITY MONITORING WORKSHOP, HELD JULY 29, 2015
APPENDIX C

NOTES FROM AMBIENT WATER QUALITY
MONITORING WORKSHOP, HELD JULY 29, 2015
APPENDIX D

COMPILED QUESTIONNAIRE FROM OTHER STAKEHOLDERS
APPENDIX E

NOTES FROM MONITORING PLAN DISCUSSION
HELD AT THE SEPTEMBER 18, 2015 MEETING OF THE
SCIENTIFIC AND TECHNICAL ADVISORY COMMITTEE
APPENDIX F

ASSESSMENT, LISTING, AND REPORTING METHODOLOGIES FOR 305(B) REPORT AND 303(D) LIST DEVELOPMENT, 2016