MARYLAND DEPARTMENT OF NATURAL RESOURCES

Martin O'Malley, Governor
John R. Griffin, Secretary

Maryland Tributary Strategy Patuxent River Basin Summary Report for 1985-2005 Data

August 2007

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Executive Summary

Situated between two large metropolitan areas—Baltimore and Washington—the Patuxent River Basin is the largest watershed entirely within the State of Maryland. Land cover in the basin is mostly forested (43 percent), however, significant portions of the basin is urban (31 percent) and agricultural (24 percent). Below is a summary of the results presented in the body of the report:

LOADINGS

Modeled nitrogen, phosphorus, and sediment loadings have decreased from 1985-2005. Some improvements made in the Patuxent before 1985 are not reflected in this dataset.

- Total nitrogen loadings are down by 1.31 million pounds per year, representing 71 percent attainment of the Tributary Strategy goal. Urban runoff contributes most of the nitrogen (34 percent). Contributions of wastewater sources of nitrogen (including municipal wastewater treatment plants and industrial outputs as point sources and septic sources) have decreased since 1985, but still contribute 28 percent of the nitrogen load. Agriculture now plays a smaller role, contributing 22 percent of the nitrogen load due to implementation of agricultural best management practices and land conversion.
- Total phosphorus loadings are down 0.23 million pounds per year, representing 84 percent attainment of the Tributary Strategy phosphorus goal. Urban non-point runoff is the principal contributor to this load (38 percent). Point sources (wastewater discharges) used to contribute half of the basin's phosphorus load, but now only contribute one quarter. Agriculture contributes about 23 percent of the phosphorus load.
- Sediment loadings are down approximately 70,000 tons per year, attaining 62 percent of the Tributary Strategy goal. Agricultural lands contribute less sediment now than they did in 1985 (down to 54 percent from 75 percent), but urban non-point sources now contribute a larger percentage (28 percent - up from 14 percent in 1985).

WATER QUALITY and NUTRIENT LIMITATION

- Total nitrogen and total phosphorus in the upper Patuxent have some significant increasing non-linear trends (for the period 1985-2005). Overall, concentrations are down since 1985, but recent trends are increasing. Special attention is needed to halt this increase nutrients and reverse improvements made to date. Upper Patuxent algal abundance is generally relatively good and improving. Water clarity, however, is degrading at almost all stations and is relatively poor. Summer bottom dissolved oxygen concentrations are also degrading in the upper Patuxent.
- Mid-river water and habitat quality is degrading with regards to total nitrogen, water clarity and algal abundance, but total phosphorus still maintains an improving trend at one station. Non-linear trend results for nitrogen concentrations indicate that although concentrations were once decreasing, these trends have leveled off or may even be increasing in more recent years (since the late 1990s to early 2000s). There are no significant trends for total suspended solids and summer bottom dissolved oxygen. Current conditions are relatively poor for total nitrogen (one station), total phosphorus, total suspended solids, water clarity and algal abundance, while summer bottom dissolved oxygen concentrations are fair.
- The lower Patuxent River has somewhat better water and habitat quality than the rest of the river. Total nitrogen and total phosphorus both maintain an improving long-term trend at the

first of the lower stations, and relative status is fair to good. However, the station closest to the mouth of the river has a significant non-linear trend for total phosphorus indicating that concentrations are increasing (since the mid 1990s), though concentrations are still relatively good. Water clarity is mostly fair but degrading; total suspended solids are improving at all stations and are mostly relatively good. Summer bottom dissolved oxygen concentrations show no trends but are good at three of the four stations.

- During 2003-2005, seven Continuous Monitoring stations were maintained in the Patuxent River. All but two stations (Mataponi and Benedict) met the instantaneous dissolved oxygen criteria (<3.2 mg/L) more than 97 percent of the time in all three years. All stations failed the 30-day mean dissolved oxygen criteria (5mg/L) at least some portion of all three years, although the percent failure varied between stations.
- In the winter, the upper and middle river are completely nutrient saturated/light limited; the lower river is also predominantly nutrient saturated/light limited. In the spring, the upper river remains nutrient saturated/light limited, while nitrogen limitation is slightly more important in the middle river and phosphorus limitation is most important in the lower river. By summer, nitrogen limitation has increasing importance from upstream to downstream and growth in the lower river is predominantly nitrogen limited in the summer. Nutrient saturation/light limitation is almost complete in the upper river in the fall, while the lower river has some return to phosphorus limitation.

BIOLOGICAL RESOURCES

- Bay grass beds are meeting and exceeding goals in the tidal fresh and oligohaline reaches. Only very small grass beds exist in the lower estuary (mesohaline), at less than ten percent of the goal.
- Phytoplankton is fair-bad to bad in the Patuxent River. Phytoplankton communities have been improving in the upper river, but degrading in the lower river over the 1985-2005 period.
- Harmful Algal Blooms in the lower Patuxent River and its tributaries have been primarily by blooms of the dinoflagellates *Prorocentrum minimum* and *Karlodinium veneficum* (formerly *Karlodinium micrum).* Such blooms may have impacts to shellfish and reduce light levels which may affect the success of submerged aquatic vegetation growth. Of special note, a “Black Tide” caused by *K. veneficum* was located on St. Leonard Creek in June 2003; the bloom density was so concentrated that the water appeared black on the surface. Evidence of the bloom continued through July, expanding well into the main channel region of the river between Jack Bay and St. Leonard Creek.
- Benthic communities in the Patuxent are generally Marginal or Meet Goals, except in areas in the mid to lower areas of the river where summer bottom dissolved oxygen levels are poor (less than 2 mg/L) and at the mouth of the river and benthic communities are Degraded or Severely Degraded. In 2005, the amount of bottom area failing the Benthic Restoration Goals was 92 km^2 of a total of 128 km^2 (72 percent). Multiple stressors include chemical contamination, eutrophication and low dissolved oxygen stress.

Introduction

The Chesapeake Bay is the largest estuary in North America. The Bay is famous for providing delicious seafood as well as a myriad of recreational and livelihood opportunities, such as boating, fishing, crabbing, swimming, and bird-watching. By the 1970s, however, the Bay was in serious decline. In 1975, the United States Congress directed the Environmental Protection Agency (EPA) to conduct a comprehensive study of the most important problems affecting the Chesapeake Bay. The findings of this study formed the crux of the first Chesapeake Bay Agreement, signed in 1983 by Maryland, Virginia, Pennsylvania, Washington DC, the Chesapeake Bay Commission and the EPA. Additional scientific information gained from monitoring data and modeling efforts was used to amend that Agreement, resulting in the 2000 Chesapeake Bay Agreement (http://www.chesapeakebay.net/agreement.htm).

Scientific studies showed that three of the biggest problems facing the health of the Chesapeake Bay and its tributaries (the rivers and streams that flow into the Bay) are excess nitrogen, phosphorus, and sediments. The nutrients nitrogen and phosphorus fuel excessive algae growth. These algae, as well as suspended sediments, cloud the water and prevent bay grasses from getting enough light. When healthy, bay grasses provide essential habitat for crabs and fish as well as food for waterfowl. When algae die, they decompose using up essential oxygen. This lack of oxygen kills bottom-dwellers such as clams and sometimes fish. In addition, excess nutrients sometimes favor the growth of harmful algae. Harmful algae can be toxic to aquatic animals and even humans. For more details on the Bay's ecosystem and the problems facing it, see http://www.dnr.state.md.us/Bay/monitoring/mon_mngmt_actions/monitoring_mgmt_actions.html.

To help achieve Maryland's share of the reductions in nitrogen, phosphorus, and sediment to the Bay and its tributaries, a Tributary Strategy Team has been appointed for each of the ten Chesapeake Bay subwatersheds in Maryland:

- Upper Western Shore Basin
- Patapsco/Back Rivers Basin
- Lower Western Shore Basin
- Patuxent River Basin
- Upper Potomac River Basin
- Middle Potomac River Basin
- Lower Potomac River Basin
- Upper Eastern Shore Basin
- Choptank River Basin
- Lower Eastern Shore Basin

Each team is comprised of business leaders, farmers, citizens, and state and local government representatives who work together to identify the best ways to reduce nutrient and sediment inputs to the Bay.

This report provides:

- Patuxent River Basin characteristics
- Nutrient and sediment loadings to the Patuxent River Basin based on model results (the model is developed using monitoring data)
- Overview of monitoring results
    - links to indepth non-tidal water quality information
    - non-tidal and tidal water quality status and trends (based on monitoring data, i.e., measured concentrations from 1985 to 2005)
    - shallow-water monitoring results to date
    - nutrient limitation information
    - Bay grasses acreage over time
    - information on phytoplankton community health
    - information on Harmful Algal Bloom occurrences
    - information on benthic (bottom-dwelling) community health
- Individual wastewater treatment plant outputs

This report documents current status of the habitat and water quality (how good or bad it is) and long-term trends (how has water quality and habitat improved or worsened since 1985) within the context of information about the basin.

Patuxent River Basin Characteristics

The Patuxent River is the largest river completely in Maryland. Its basin drains 932 square miles of land within Maryland's Western Shore (Figure PXT1). This area includes portions of St. Mary's, Calvert, Charles, Anne Arundel, Prince George's, Howard, and Montgomery Counties. Three main streams drain into the upper Patuxent River: the Little Patuxent, which drains much of the urbanizing area of Columbia; the Middle Patuxent, which drains agricultural lands in the northern part of its drainage and the outer suburban areas of Columbia in the southern part of its basin; and the (upper) Patuxent River, which has remained primarily agricultural. The Patuxent River Basin lies both in the Piedmont and Coastal Plain physiographic provinces.

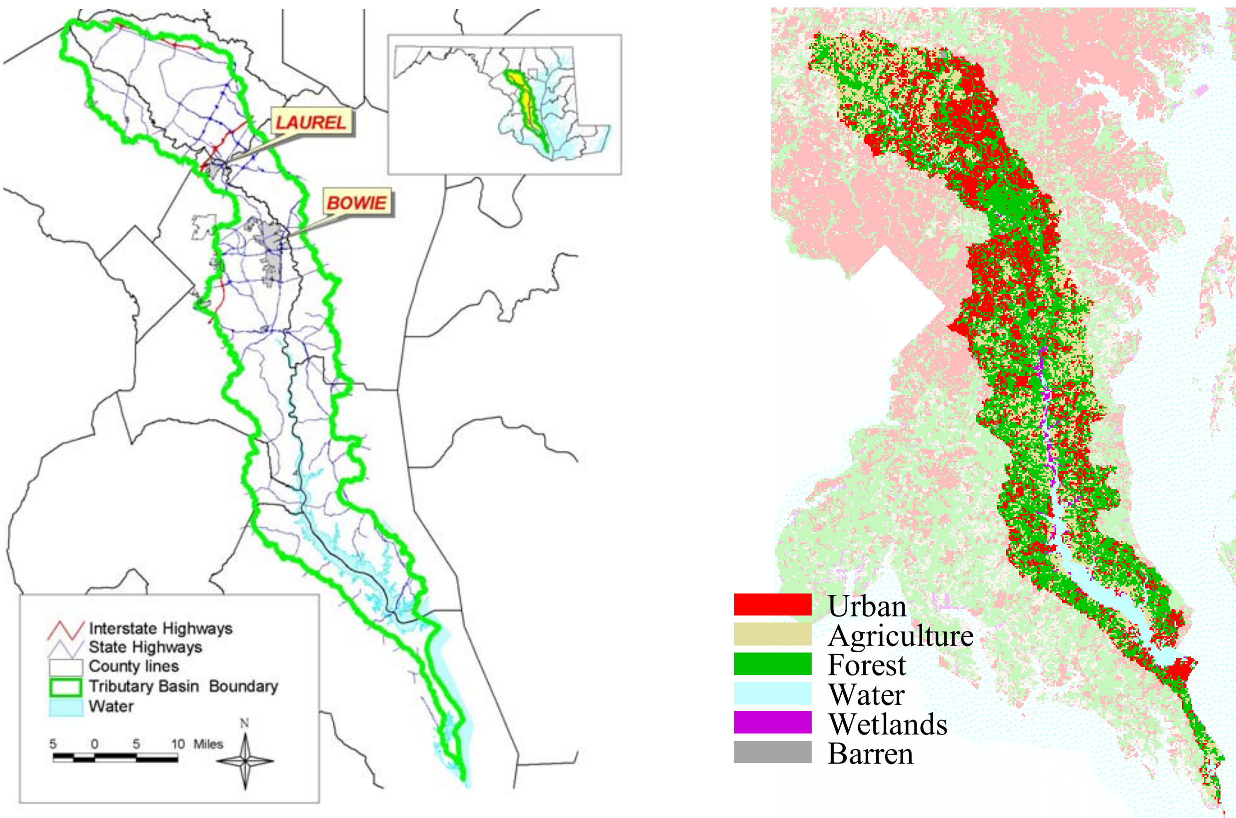
The Patuxent River Basin lies between two large nearby metropolitan areas–Baltimore, Maryland and Washington, D.C. Consequently, the watershed has gone through significant suburban development in the past few decades. The 2000 census population for the basin was 618,000 people. The thriving suburban communities of Columbia and Laurel have developed along the Interstate 95 corridor, which bisects the upper half of the basin. The city of Bowie has also undergone much recent development.

The Maryland Department of Planning land use categories are defined as follows:

- urban – includes residential, industrial, institutional (such as schools and churches), mining, and open urban lands (such as golf courses and cemeteries)
- agriculture – includes field, forage, and row and garden croplands; pasturelands; orchards and vineyards; feeding operations; and agricultural building/breeding and training facilities, storage facilities, and built-up farmstead areas

- forest – includes deciduous forest, evergreen forest, mixed forest, and brush
- water – includes rivers, waterways, reservoirs, ponds, and the Bay
- wetlands – includes marshes, swamps, bogs, tidal flats, and wet areas
- barren – includes beaches, bare exposed rock and bare ground

Figure PXT1- Map of the Patuxent River Basin and 2002 Maryland Department of Planning Land Use data.
Data from the Maryland State Highway Administration and the Maryland Department of Planning.



As of 2002, most (43 percent) of the Patuxent River Basin was forested. About a third (31 percent) of the basin was urban land; the land above the fall line is more urbanized than that below the fall line.

About a quarter (24 percent) of the Patuxent River Basin was agricultural land. Tributary strategy goals for BMPs have also been established to reduce non point source loads from agricultural lands. As of 2004, Tributary Strategy goals have been met for implementation of agricultural BMPs for nutrient management plans and conservation tillage, and good progress (more than 50 percent of goal) with respect to soil conservation and water quality plans, runoff control, stream protection (with and without fencing) and tree planting. For more information, please see (http://dnrweb.dnr.state.md.us/watersheds/surf/bmp/bmp.asp?trib=pax).

The Chesapeake Bay Program model categorizes nutrient and sediment loads from both point sources (end of pipe inputs from wastewater treatment plants and industrial outfalls) and non-point sources. The non-point loads are estimated from a variety of sources including land cover, agriculture records, etc. Generally, the categories in Figure PXT2 include:

- point sources – out of pipe from waste water treatment plants and industrial releases
- non-point sources
    - urban – from industrial, residential, institutional, mining and open urban lands
    - septic – onsite wastewater treatment/disposal
    - agriculture –from row crop, hay, pasture, manure acres
    - forest –from forested lands
    - mixed open –from non-agricultural grasslands including right-of-ways and some golf courses
    - atmospheric deposition to water – deposited from the atmosphere directly to water

For more detailed information, see the document *Chesapeake Bay Watershed Model Land Use Model Linkages to the Airshed and Watershed Models* at **http://www.chesapeakebay.net/pubs/1127.pdf**.

As of 2005, the most significant contributor of nitrogen in the Patuxent River Basin was urban sources (34 percent) (Figure PXT2), followed by agriculture (22 percent), point sources (16 percent) and septic (12 percent). For phosphorus, the largest contributor was urban sources (38 percent), followed by point sources (25 percent) and agriculture (23 percent). Agriculture was the dominant source of sediment load (54 percent) followed by urban sources (28 percent).

Compared to 1985 loadings, 2005 nitrogen loadings are down by 1.31 million pounds per year (currently 71 percent of goal), but need an additional reduction of 0.55 million pounds per year to meet the Tributary Strategy goals (Figure PXT3). For phosphorus, 2005 loadings are down 0.23 million pounds per year (currently 84 percent of goal), but need an additional reduction of 0.05 million pounds per year to meet Tributary Strategy goals. Sediments are down approximately 70,000 tons per year (62 percent of goal), but need an additional reduction of approximately 43,000 tons per year.

Figure PXT2 – 2005 Nitrogen, Phosphorus and Sediment Contribution to the Patuxent River Basin by Source.
Data from 2005 'Progress' Watershed Model 4.3 Delivered Loads, Chesapeake Bay Program 11-30-06 http://www.chesapeakebay.net/data/index.htm.

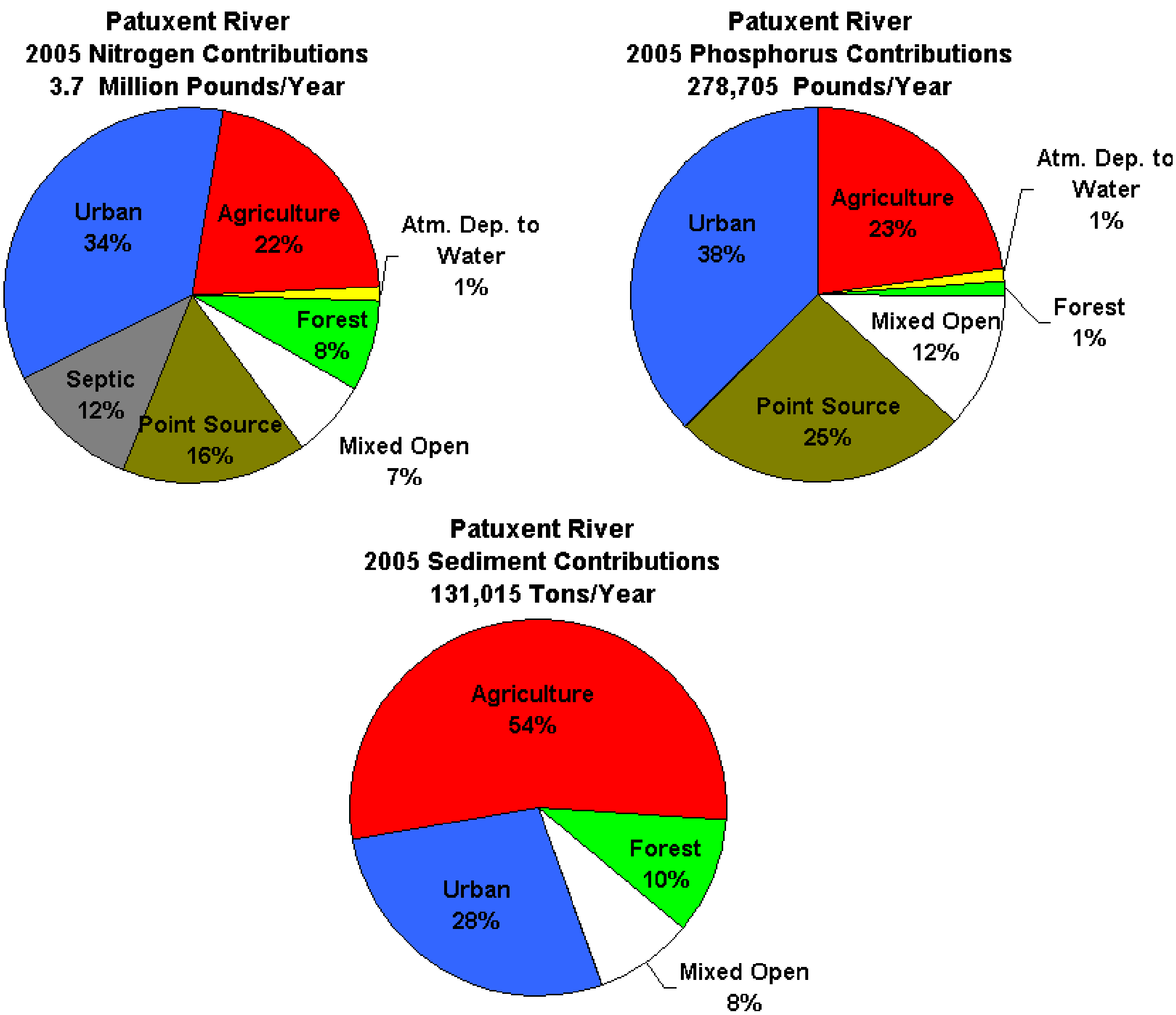
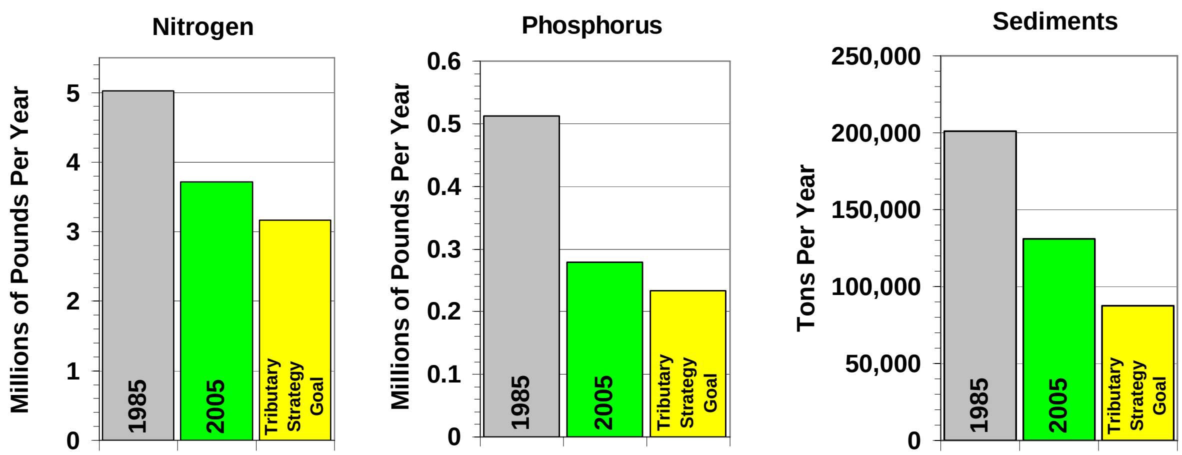


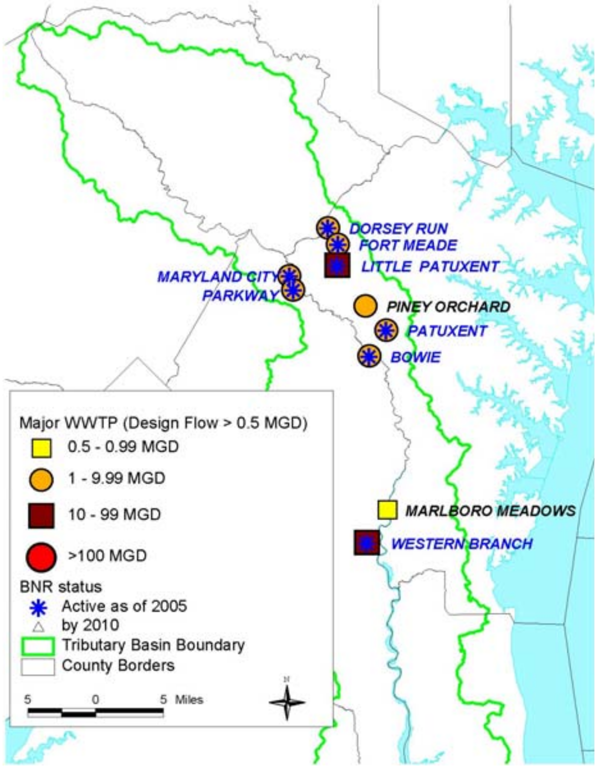
Figure PXT3 –1985 and 2005 Total Loadings for Total Nitrogen, Total Phosphorus and Sediment to the Patuxent River Basin.
Units are included in the labels on the y-axis.
Data from **http://www.chesapeakebay.net/data/index.htm**.



Tributary Strategy goal from MD Tributary Strategy 06 FINAL 04/21/2004, Chesapeake Bay Program.
Load Estimates provide a rough approximation of the nutrient reduction expected from the implementation of BMPs. They do not reflect current water quality conditions.

There are ten major wastewater treatment plants (greater than 0.5 million gallons per day, MGD, design flow). As of 2005, eight facilities have activated Biological Nutrient Removal (BNR) technology (Figure PXT4). Appendix A contains graphs of average monthly nutrient loads and effluent volumes from the basin's major wastewater treatment facilities and dates for BNR implementation. BNR technology removes additional nitrogen than traditional methods, bringing nitrogen concentrations in effluent to below 8 mg/L. More recent improvements in wastewater treatment technology, called Enhanced Nutrient Removal (ENR), further remove nitrogen, reducing nitrogen concentrations to below 3 mg/L in effluent. ENR also removes additional phosphorus, reducing phosphorus concentrations to below 0.3 mg/L in effluent. ENR technology is scheduled to be implemented at seven facilities by 2010. For more information, please see **http://www.dnr.state.md.us/bay/tribstrat/implementation_plan.html**.

Figure PXT4 – Major Wastewater Treatment Plants in the Patuxent River Basin.
Data are available at **http://www.chesapeakebay.net/data/index.htm**.



Anne Arundel County has developed a watershed management tool, which reveals the nutrient loading implications of prospective planning decisions in the watershed. Information is available on the Internet at: **http://www.aacounty.org/LandUse/OECR/WatershedManage.cfm.**

Overview of Monitoring Results

Water and Habitat Quality

Long-term Non-tidal Water Quality Monitoring

Important water quality parameters are measured at three long-term non-tidal monitoring stations in the Patuxent River Basin. One station is located upstream of two large water supply reservoirs (Triadelphia and T. Howard Duckett Reservoirs); the remaining stations are located downstream of these impoundments. Parameters measured include nutrients and total suspended solids. A number of constituents, including nutrients and suspended solids, can settle and may be detained in the reservoirs such that sites downstream of the dams often have better water quality than sites upstream of impounded waters.

For the analyses in this report, nitrogen, phosphorus and total suspended solids concentrations are determined from surface measurements. Current status is determined based on the most recent three-year period (2003-2005) compared to a Statewide baseline data set. Relative status of good, fair, or poor conditions are determined in comparison to the baseline data. For a detailed description of the methods used to determine status, see http://www.dnr.state.md.us/Bay/tribstrat/status_trends_methods.html.

Linear trends are determined for the period 1995-2005; non-linear trends are determined over the longer period 1986-2005 (Figures PXT5-PXT7). Both are determined to be significant if $p \leq 0.01$. For a detailed description of the methods used to determine linear trends, see http://www.dnr.state.md.us/Bay/tribstrat/status_trends_methods.html. For a detailed description of the methods used to determine non-linear trends, see Wazniak *et al.* (2007).

Nitrogen concentrations at the non-tidal stations were relatively poor at one station (above the reservoirs) and relatively good at the other two sites (Figure PXT5). There were no significant trends over the shorter time period (1995-2005), but over the long time period there was a significant non-linear trend at the station at Rt. 50 (TF1.0T). This non-linear trend indicates that the decreasing concentrations observed earlier in the time period (prior to 2001) have leveled off or begun to increase, though increases in concentrations have not yet been large enough to detect as an increasing trend in the 1995-2005 timeframe.

Phosphorus concentrations are fair to good and decreasing over the short time period at the Rt. 50 station (Figure PXT6). The station farthest upstream also has a decreasing trend over the entire time period, however, the Rt. 50 station has a significant non-linear trend. The graph in Appendix B shows that concentrations are still lower overall since 1985, but the non-linear trend result indicates that the decreasing concentrations have either leveled off or begun to increase in the recent period (since 2002).

Figure PXT5a – Total Nitrogen Concentrations at non-tidal stations in the Patuxent River Basin.
Relative Status from 2003-2005; Linear trends from 1995-2005, significant at $p \leq 0.01$.

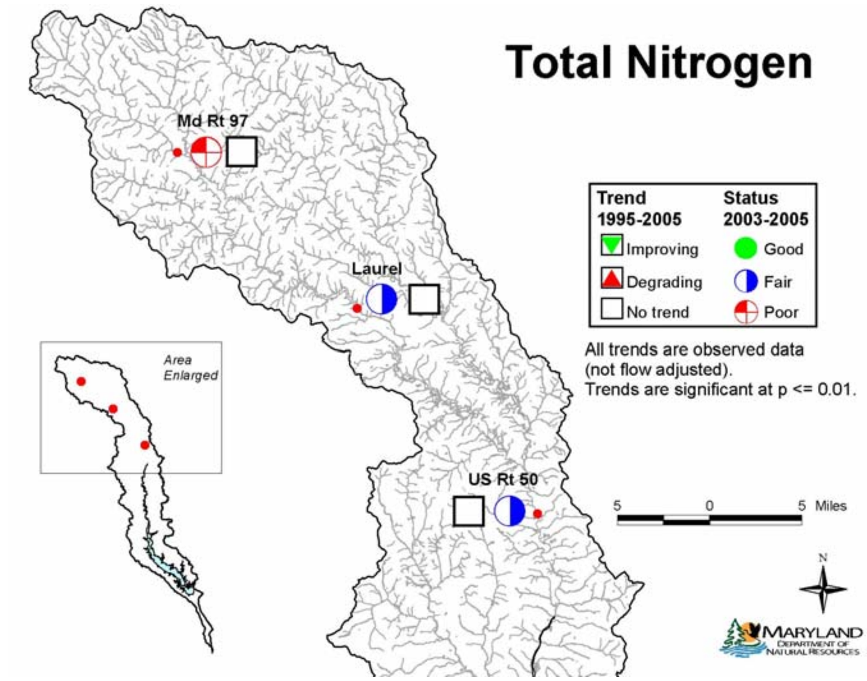


Figure PXT5b – Total Nitrogen Concentrations at non-tidal stations in the Patuxent River Basin.
Non-linear trends from 1986-2005; when non-linear trend is not significant ($p > 0.01$), significant linear trends for 1986-2005 are reported.

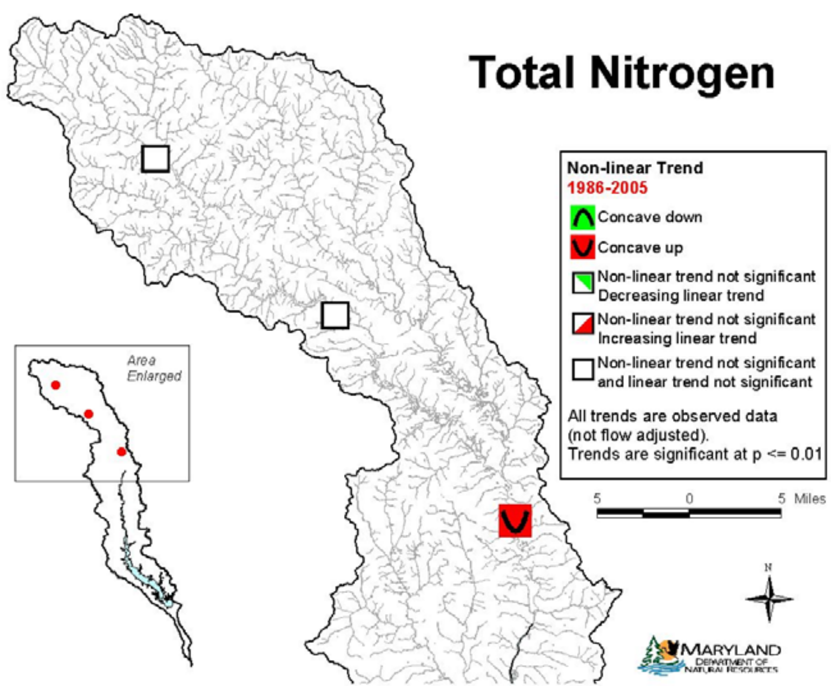


Figure PXT6a – Total Phosphorus Concentrations at non-tidal stations in the Patuxent River Basin.

Relative Status from 2003-2005; Linear trends from 1995-2005, significant at p = 0.01.

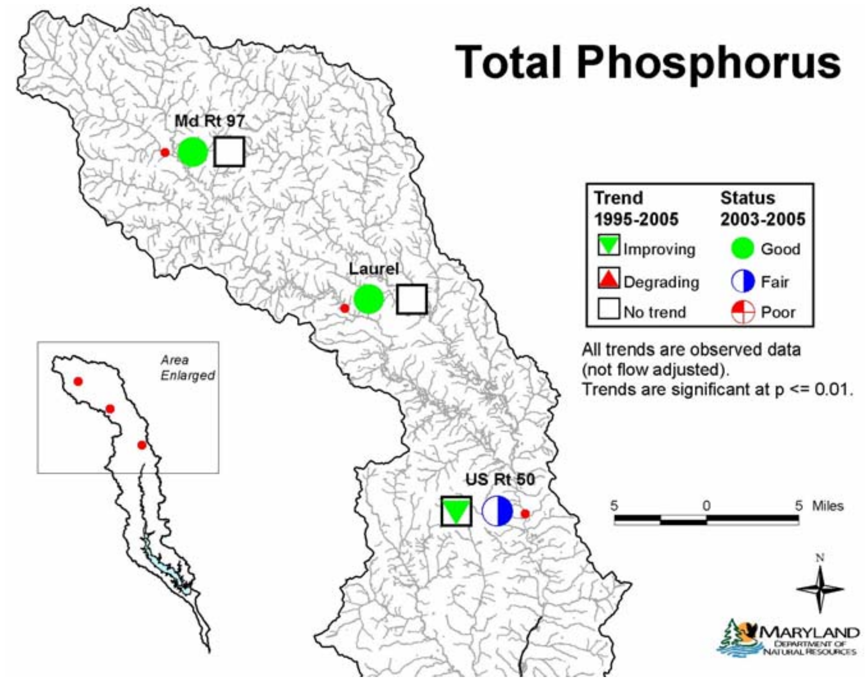


Figure PXT6b – Total Phosphorus Concentrations at non-tidal stations in the Patuxent River Basin.

Non-linear trends from 1986-2005; when non-linear trend is not significant (p > 0.01), significant linear trends for 1986-2005 are reported.

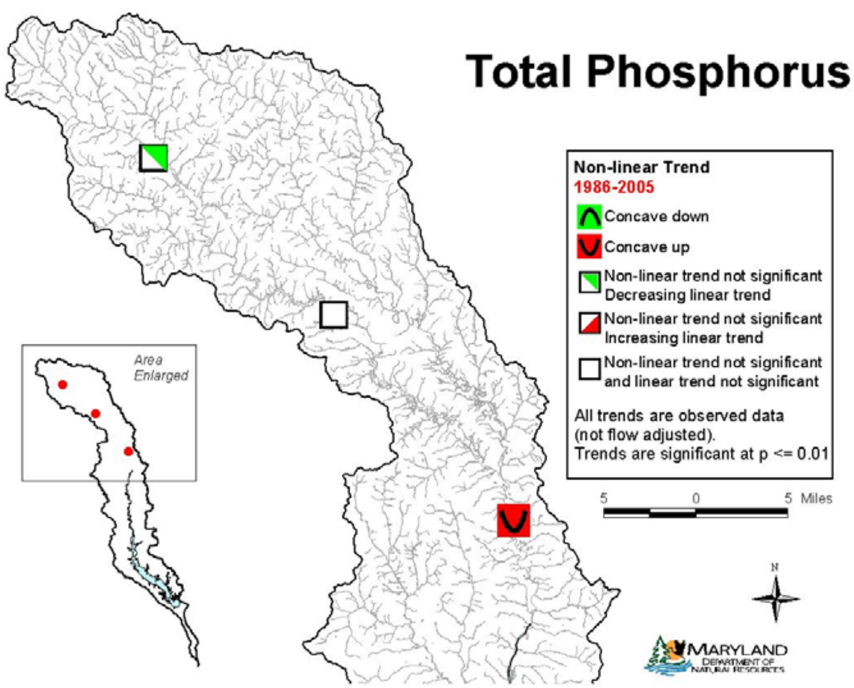


Figure PXT7a – Total Suspended Solids Concentrations at non-tidal stations in the Patuxent River Basin.
Relative Status from 2003-2005; Linear trends from 1995-2005, significant at $p \leq 0.01$.

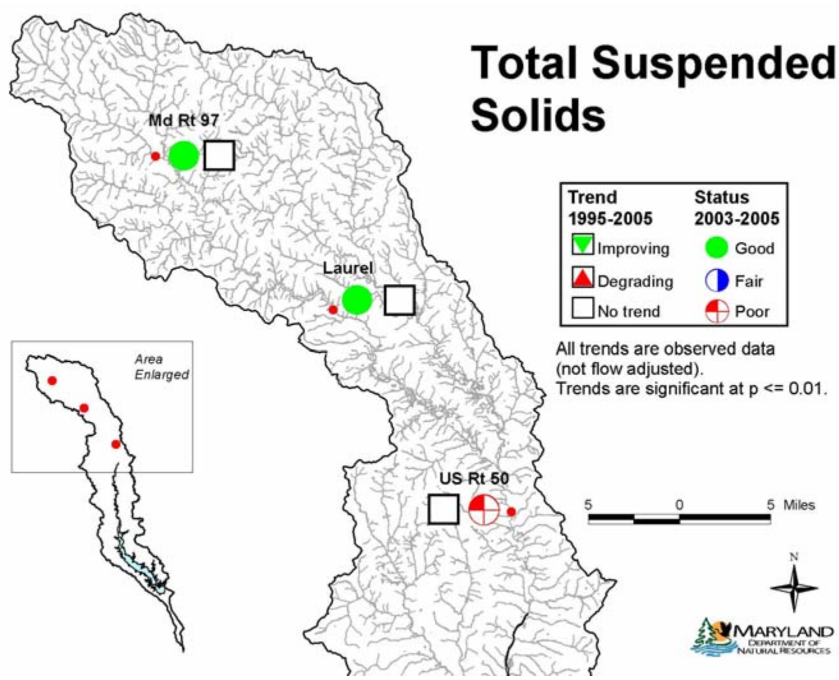
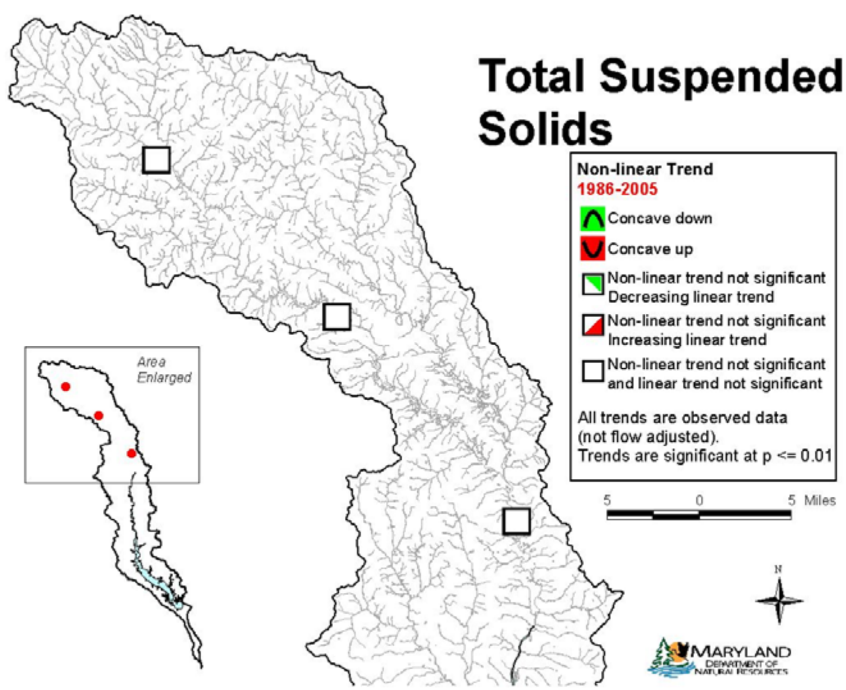


Figure PXT7b – Total Suspended Solids Concentrations at non-tidal stations in the Patuxent River Basin.
Non-linear trends from 1986-2005; when non-linear trend is not significant ($p > 0.01$), significant linear trends for 1986-2005 are reported.



Suspended sediment concentrations are good at the two upstream stations, but the Rt. 50 station has relatively poor (high) suspended sediment concentrations (Figure PXT7). No trends were detected in sediment concentrations.

The long-term water quality data are shown in Appendix B. High rainfall and flow increase nutrient and suspended solids concentrations. Thus, if all else were held equal, nutrient and suspended solids concentrations would be worse in a wet year (e.g., 1989, 1994, 1996, and 2003) than in a dry year (e.g., 1985, 1988, 1992, and 2002).

Additional Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at: **http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html**
MBSS also reports stream quality information summarized by county at: **http://www.dnr.state.md.us/streams/mbss/county_pubs.html** In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: **http://www.dnr.state.md.us/streams/mbss.**

Montgomery County's Department of Environmental Protection posts information on their Countywide Stream Protection Strategy at:
http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/CSPS/index.asp

Water quality information collected by Maryland's volunteer Stream Waders is available at:
http://www.dnr.state.md.us/streams/mbss/mbss_volun.html

Long-term Tidal Water Quality Monitoring

Good water quality is essential to support the animals and plants that live in the Patuxent River. Important water quality parameters are measured at eleven long-term tidal monitoring stations in the Patuxent River. Parameters measured include nutrients, water clarity (Secchi depth), dissolved oxygen, total suspended solids, and algal abundance.

State thresholds have been established for some parameters (dissolved oxygen, water clarity), but not for nitrogen, phosphorus, suspended solids or chlorophyll; for more information, please see the *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity, and Chlorophyll a for Chesapeake Bay and its Tributaries* (EPA 2003) at http://www.chesapeakebay.net/baycriteria.htm. For those parameters with established thresholds, assessment methods are still under development and are not yet being applied to the long-term tidal water quality data. Once these new methods are finalized, water quality criteria assessments will be included in the basin summary report. Current status is determined based on the most recent three-year period (2003-2005), compared to a baseline data set, and assigned a status *relative* to the baseline data. For summer bottom dissolved oxygen, the current concentrations are compared to ecologically meaningful thresholds to assign a status of good (concentrations > 5 mg/L), fair (concentrations 2-5 mg/L), or poor (concentrations < 2 mg/L).

Please see the detailed methods description at
http://www.dnr.state.md.us/Bay/tribstrat/status_trends_methods.html

Linear trends are determined for the period 1995-2005; non-linear trends are determined for the period 1985-2005 (Figures PB9-PB14). Both are determined to be significant if $p \leq 0.01$. For a detailed description of the methods used to determine linear trends, see http://www.dnr.state.md.us/Bay/tribstrat/status_trends_methods.html. For a detailed description of the methods used to determine non-linear trends, see Wazniak *et al.* (2007). **The total suspended solids trend results may be affected by a change in laboratory in 1990 and should be used with caution (please see Appendix C for more information).**

For the analyses in this report, nitrogen, phosphorus, algal abundance and total suspended solids concentrations are determined from surface above pycnocline measurements. Summer bottom dissolved oxygen concentrations are determined from bottom layer measurements collected between June and September.

Total nitrogen in the upper tidal Patuxent (upper most five stations) is currently relatively fair or good; one station (TF1.3) has a significantly improving trend in the shorter time period (1995-2005, Figure PXT8). However, this same station and all but one of the other upper Patuxent stations have significant increasing non-linear trends. The non-linear trend results indicate that although concentrations were once decreasing, these previous improvements in nitrogen concentrations have leveled off or may even be increasing in more recent years (since the early 2000s). Overall, concentrations are still down since 1985 (Appendix B), but need special attention to prevent concentrations from continuing to increase and reverse improvements made to date.

The upper Patuxent phosphorus concentrations show the same pattern as nitrogen, with improving linear trends over the shorter time frame of 1995-2005, but significantly increasing non-linear trends for the 1985-2005 period (Figure PXT9). Generally, concentrations are still down since 1985 (Appendix B), but need special attention to prevent phosphorus levels from continuing to increase and reverse improvements made to date.

Upper Patuxent algal abundance is relatively good except at one station (TF1.5, currently relatively bad status), and has improving trends at three of the five stations (Figure PXT10). Two stations have significant non-linear trends further indicating decreasing algal abundance. Water clarity, however, is degrading at almost all stations and is relatively poor (Figures PXT11 and PXT12), and summer bottom dissolved oxygen concentrations are also degrading in the upper Patuxent (Figure PXT13).

Mid-river water and habitat quality (at the next two stations downstream) is comparatively degraded in terms of total nitrogen, water clarity and algal abundance, but total phosphorus still maintains the long-term improving trend at one station (Figures PXT8-PXT13). The non-linear trend results for nitrogen concentrations indicate that although concentrations were once decreasing, these previous improvements in nitrogen concentrations have leveled off or may even be increasing in more recent years (since the late 1990s). Overall, concentrations are still down since 1985 (Appendix B) at the first station (TF1.7), but at the second station (RET1.1)

concentrations are again at levels similar to the beginning of the monitoring period. Total suspended solids and summer bottom dissolved oxygen have no significant trends.
The lower Patuxent River (lowest four stations) has somewhat better water and habitat quality than the rest of the river (Figures PXT8-PXT13). Total nitrogen and total phosphorus both maintain an improving long-term trend at the first of the lower stations, and relative status is fair to good. However, the station closest to the mouth of the river has a significant non-linear trend for total phosphorus indicating concentrations are again increasing (since the mid 1990s), though concentrations are still relatively good. Water clarity is mostly fair but degrading both in for the 1995-2005 and 1985-2005 time periods; however, total suspended solids are mostly relatively good. Summer bottom dissolved oxygen concentrations show no trends but are good at three of the four stations.

The long-term water quality data are shown in Appendix B. High rainfall and flow increase nutrient and suspended solids concentrations. Thus, if all else were held equal, nutrient and suspended solids concentrations would be worse in a wet year (e.g., 1989, 1994, 1996, and 2003) than in a dry year (e.g., 1985, 1988, 1992, and 2002).

Figure PXT8 – Total Nitrogen Concentrations in the Patuxent River Basin.
First Panel: Relative Status from 2003-2005. Linear trends from 1995-2005, significant at $p \leq 0.01$.
Second Panel: Non-linear trends from 1985-2005. When non-linear trend is not significant ($p > 0.01$), significant linear trends for 1985-2005 are reported.

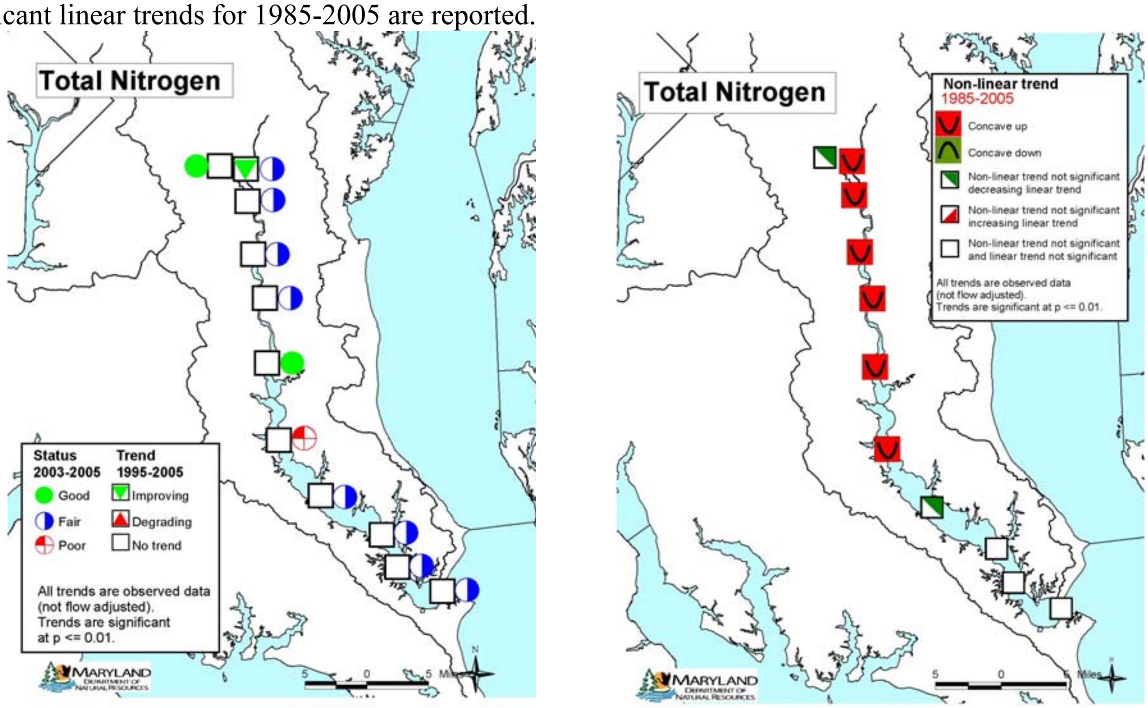


Figure PXT9 – Total Phosphorus Concentrations in the Patuxent River Basin.
First Panel: Relative Status from 2003-2005. Linear trends from 1995-2005, significant at $p \leq 0.01$.
Second Panel: Non-linear trends from 1985-2005. When non-linear trend is not significant ($p > 0.01$), significant linear trends for 1985-2005 are reported.

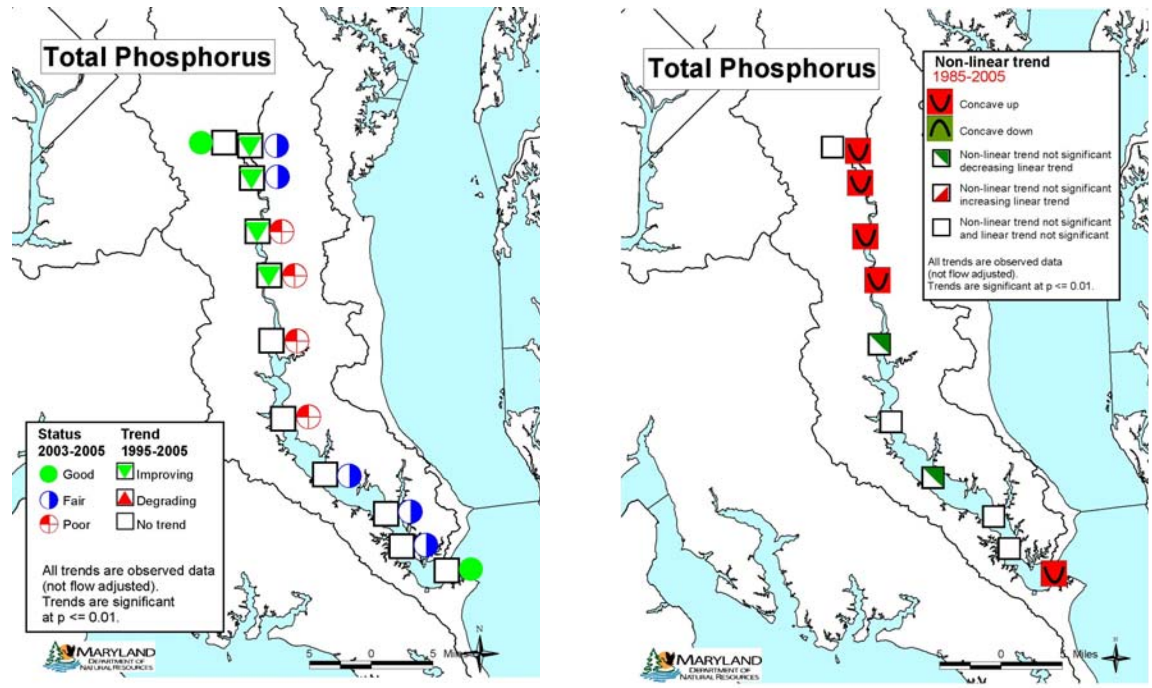


Figure PXT10 – Abundance of Algae in the Patuxent River Basin.
First Panel: Relative Status from 2003-2005. Linear trends from 1995-2005, significant at $p \leq 0.01$.
Second Panel: Non-linear trends from 1985-2005. When non-linear trend is not significant ($p > 0.01$), significant linear trends for 1985-2005 are reported.

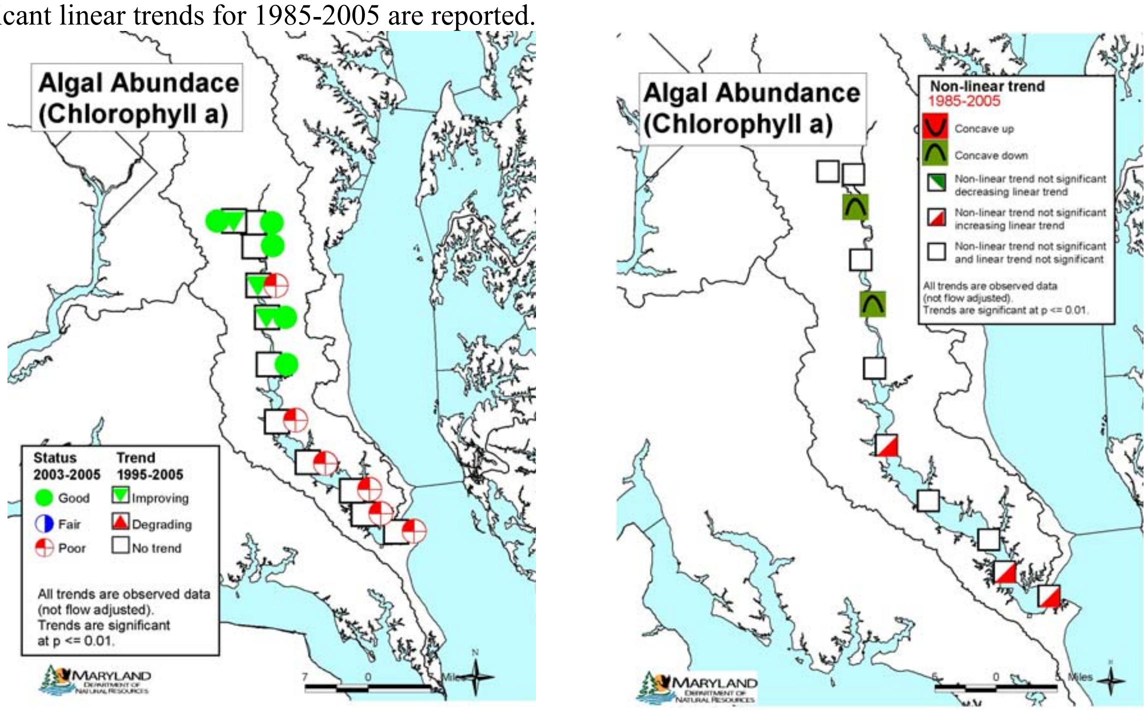


Figure PXT11 – Total Suspended Solids Concentrations in the Patuxent River Basin.
First Panel: Relative Status from 2003-2005. Linear trends from 1995-2005, significant at $p \leq 0.01$.
Second Panel: Non-linear trends from 1985-2005. When non-linear trend is not significant ($p > 0.01$), significant linear trends for 1985-2005 are reported. **The longer-term (1985-2005, second panel) total suspended solids trend results may be affected by a change in laboratory in 1990 and should be used with caution (please see Appendix C for more information).**

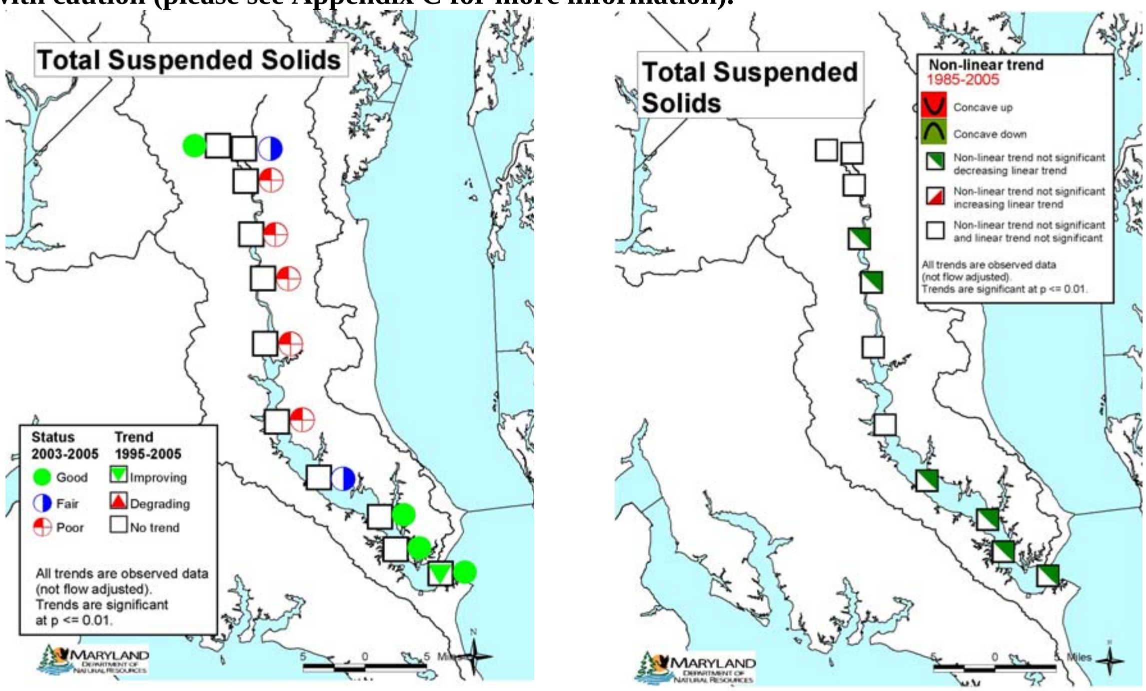


Figure PXT12 – Water Clarity (Secchi Depth) in the Patuxent River Basin.
First Panel: Relative Status from 2003-2005. Linear trends from 1995-2005, significant at $p \leq 0.01$).
Second Panel: Non-linear trends from 1985-2005. When non-linear trend is not significant ($p > 0.01$), significant linear trends for 1985-2005 are reported.

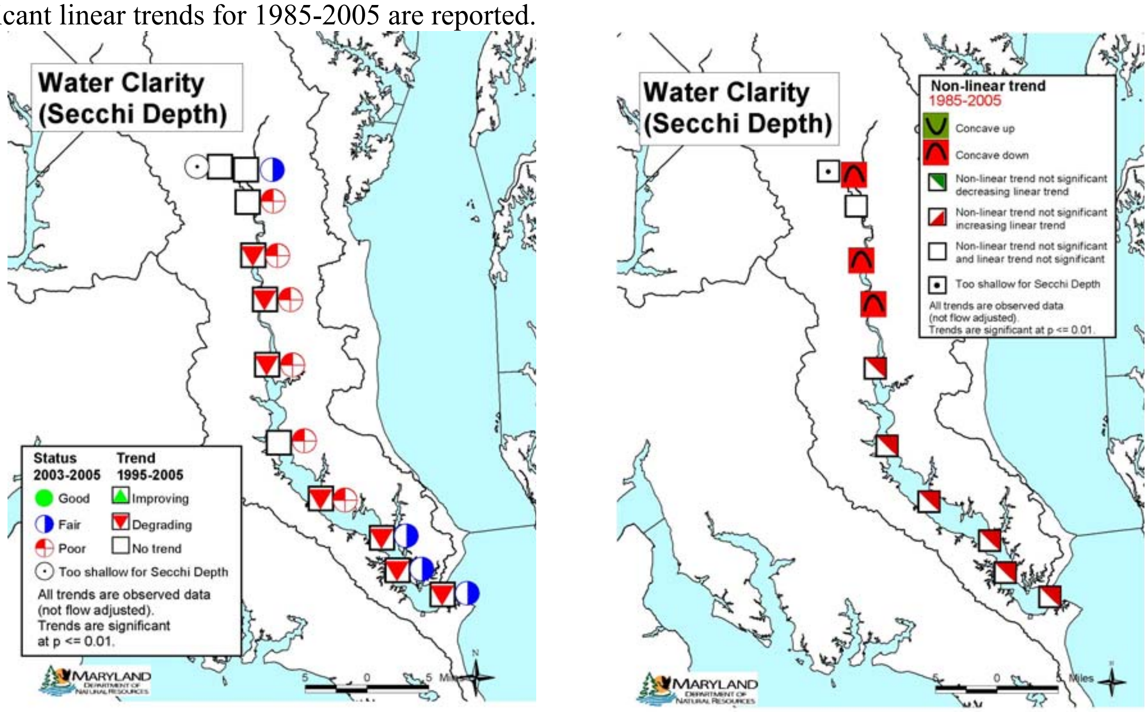
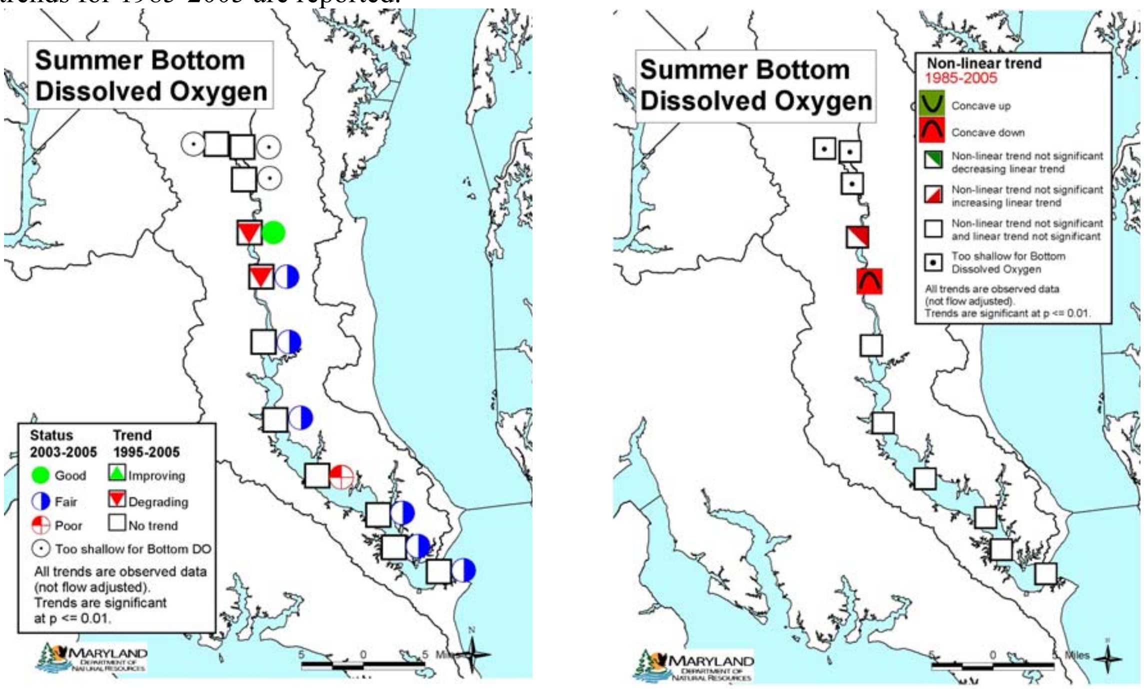


Figure PXT13 –Dissolved Oxygen in the Patuxent River Basin.
First Panel: Status from 2003-2005. Linear trends from 1995-2005, significant at $p \leq 0.01$. Second Panel: Non-linear trends from 1985-2005. When non-linear trend is not significant ($p > 0.01$), significant linear trends for 1985-2005 are reported.



Shallow water Tidal Water Quality Monitoring Data

The Shallow water monitoring program consists of two complementary components- the Continuous Monitoring component and the Water Quality Mapping component:

> Continuous Monitoring Methods**:** The Continuous Monitoring component is designed to collect a temporal record of water quality data from fixed shallow water locations throughout the Chesapeake Bay. These data are collected through the use of YSI™ 6600 EDS multiparameter datasondes, which record the following water quality parameters at fifteen-minute intervals during March-November (to correspond with the submerged aquatic vegetation growing season): dissolved oxygen, turbidity (water clarity), fluorescence (to estimate chlorophyll concentration), water temperature, specific conductance/salinity, and pH. Instrumentation is calibrated prior to deployment and exchanged at each site bi-weekly. During the instrument swap, the newly calibrated instrument is placed alongside the previously deployed instrument and allowed to record two simultaneous readings fifteen minutes apart. This creates two comparison records, which may be used to ensure both instruments are reading accurately. Additionally, each instrument undergoes a thorough post-calibration to verify that it continues to read each parameter accurately following its two-week deployment.

During the instrument swap, Secchi depth and photosynthetically active radiation (PAR) are recorded and later used to calculate light attenuation (K_d) used to determine water clarity. A discrete, whole water sample also is collected and processed for chlorophyll *a*, total suspended solids, and nutrients. Current and archived raw water quality sonde data are available on the "Eyes on the Bay – Continuous Monitoring" website:
http://mddnr.chesapeakebay.net/newmontech/contmon/index.cfm

Water Quality Mapping Methods: The Water Quality Mapping component collects spatially intensive measurements with a shipboard system of water quality probes that measure dissolved oxygen, turbidity (water clarity), fluorescence (an indicator of phytoplankton concentration), water temperature, salinity, and pH from a flow-through stream of water collected approximately 0.5 meters below the water's surface. Each water quality measurement is associated with spatial and temporal data (date, time, water depth, and geographic (GPS) coordinate information).

Water quality mapping allows data to be collected rapidly (approximately every four seconds) over large areas, while the boat is traveling at speeds up to 25 knots. The instrument system is compact and can be housed on a small boat, which facilitates sampling in shallow water and creates the ability to measure water quality conditions in an entire small tributary or a complete section of a larger tributary in one day.

During each cruise, calibration samples are collected at multiple stations for nutrients, photosynthetically active radiation (PAR), and total suspended solids, as well as, depth profiles of standard water quality parameters. Current and archived monthly cruise maps are available on the "Eyes on the Bay – Water Quality Mapping" website: http://mddnr.chesapeakebay.net/sim/index.cfm

Continuous Monitoring and Water Quality Mapping calibration stations are shown for the Patuxent River Basin (Figure PXT14, Table PXT 1); long-term water quality stations are also indicated on the map. In 2005, DNR maintained seven Continuous Monitoring stations in the tidal fresh, oligohaline (middle tidal), and mesohaline (lower tidal) reaches of the river.

Figure PXT14 - Water Quality Monitoring Stations and Water Quality Mapping Cruise Track

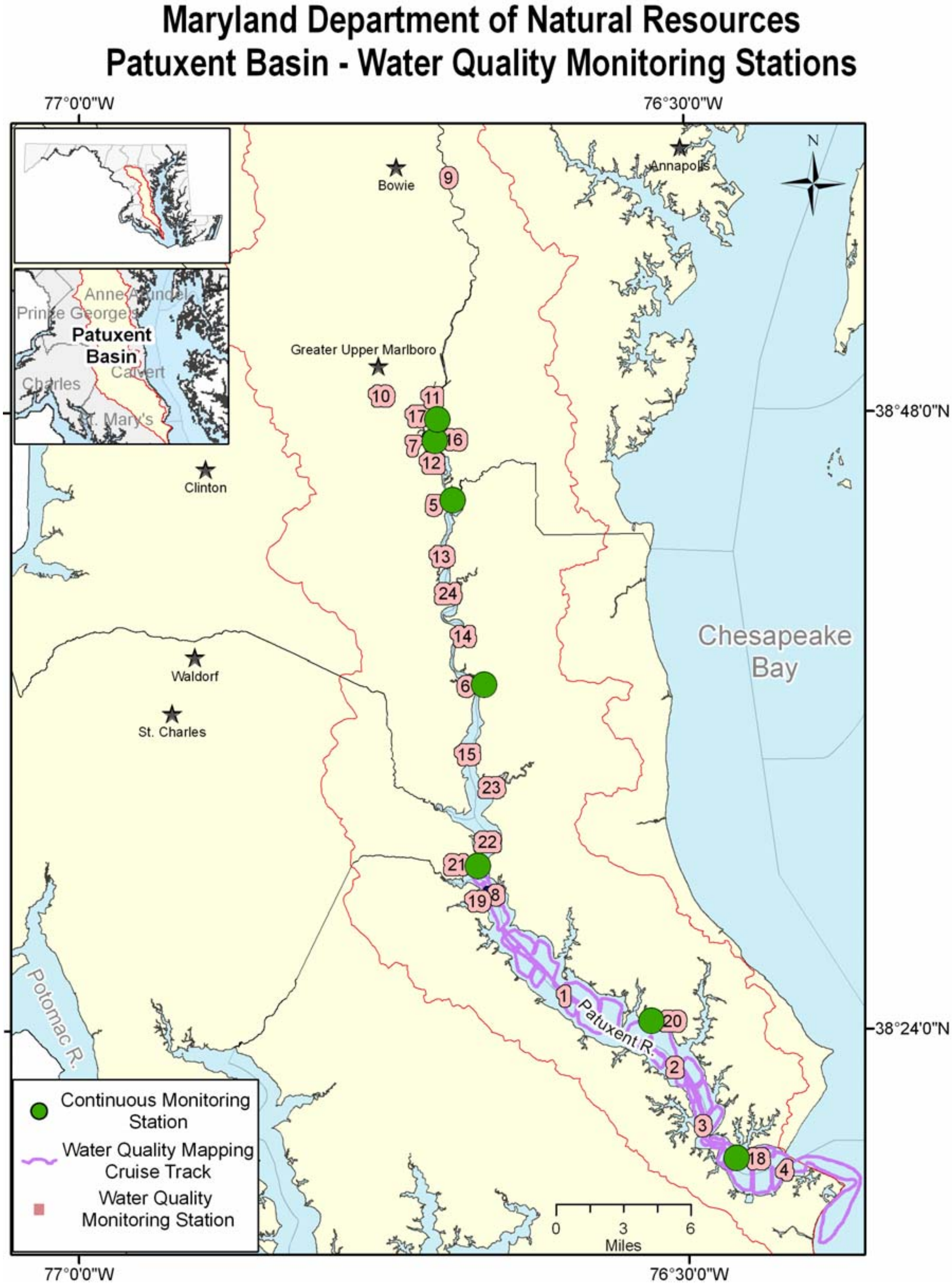


Table PXT1 – Continuous Monitoring (CM), Long Term Fixed (LTF), and Water Quality Mapping (WQM) Stations in the Patuxent River Basin (2003-2005)

ID	Tributary	Station	2003	2004	2005
1	Patuxent	LE1.1	LTF, WQM	LTF, WQM	LTF, WQM
2	Patuxent	LE1.2	LTF	LTF	LTF
3	Patuxent	LE1.3	LTF, WQM	LTF, WQM	LTF, WQM
4	Patuxent	LE1.4	LTF, WQM	LTF, WQM	LTF, WQM
5	Patuxent	MTI0015	CM	CM	CM
6	Patuxent	PXT0311	CM, WQM	CM, WQM	CM, WQM
7	Patuxent	PXT0455	CM, WQM	CM, WQM	CM, WQM
8	Patuxent	RET1.1	LTF	LTF	LTF
9	Patuxent	TF1.0	LTF	LTF	LTF
10	Patuxent	TF1.2	LTF	LTF	LTF
11	Patuxent	TF1.3	LTF	LTF	LTF
12	Patuxent	TF1.4	LTF	LTF	LTF
13	Patuxent	TF1.5	LTF	LTF	LTF
14	Patuxent	TF1.6	LTF	LTF	LTF
15	Patuxent	TF1.7	LTF, WQM	LTF, WQM	LTF, WQM
16	Patuxent	WXT0001	LTF	LTF	LTF
17	Patuxent	WXT0013	CM	CM	CM
18	Patuxent	XCF9029	CM, WQM	CM, WQM	CM, WQM
19	Patuxent	XDD9298	WQM		
20	Patuxent	XDE4587	CM, WQM	CM, WQM	CM, WQM
21	Patuxent	XED0694	CM, WQM	CM, WQM	CM, WQM
22	Patuxent	XEE1502	WQM	WQM	WQM
23	Patuxent	XEE3604	WQM	WQM	WQM
24	Patuxent	XFD1283	WQM	WQM	WQM

The Patuxent watershed has a large drainage area (~ 608,000 acres) and its population has increased dramatically in the past 50 years. As a result, there has been a related increase in impervious surface area and rain events have a significant impact on water quality conditions in the river. Severe rainstorms often produce quick-moving, sediment-laden run-off, which cause turbidity spikes, such as those recorded at Jug Bay (PXT0445, ID-7) (Figure PXT15). As water moves down river, the sediment from the run-off gradually settles out and results in lower turbidity levels at downstream stations such as King's Landing (PXT0311, ID-6) and Pin Oak (XDE4587, ID-20) (Figure PXT15).

Three Continuous Monitoring stations were maintained in the tidal fresh region of the Patuxent River in 2005: Iron Pot Landing (WXT0013, ID-17), Jug Bay (PXT0455, ID-7), and Mataponi Creek (MTI0015, ID-5) (Figure PXT14, Table PXT1). Jug Bay is surrounded by tidal wetlands, which help alleviate the impact of storm-water run-off by absorbing and retaining much of the water and sediment. However, when large rain storms occur, the wetlands occasionally overflow. When this happens, pH levels drop due to increased levels of acidic tannins (naturally found in marshes and bogs) entering the river. One such decrease in pH resulted from a precipitation event that dropped approximately six inches of rain from Oct 7th through 8th (Figure PXT17). Mataponi Creek (MTI0015) showed the most significant drop in pH as it is located immediately downstream of the bog area (Figure PXT16).

Figure PXT15 – The Effect of Rain Storms on Turbidity Levels along an Upstream-Downstream Gradient in the Patuxent River (2005)

(Upstream ——————————————————► Downstream)

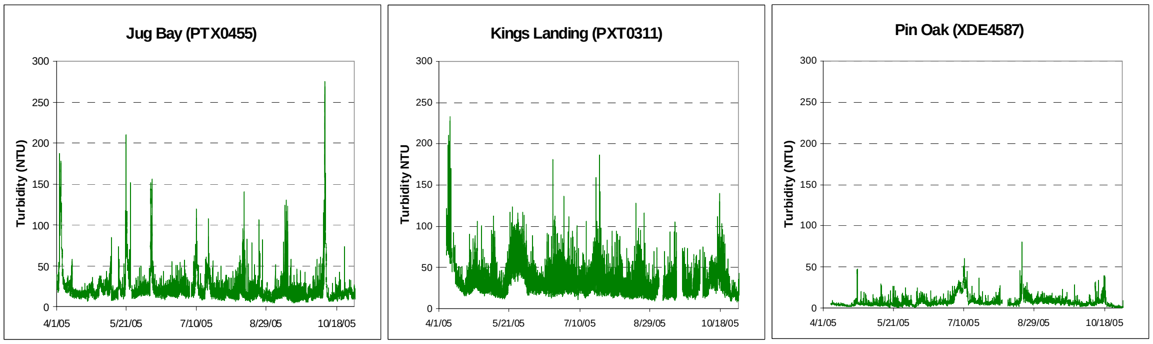
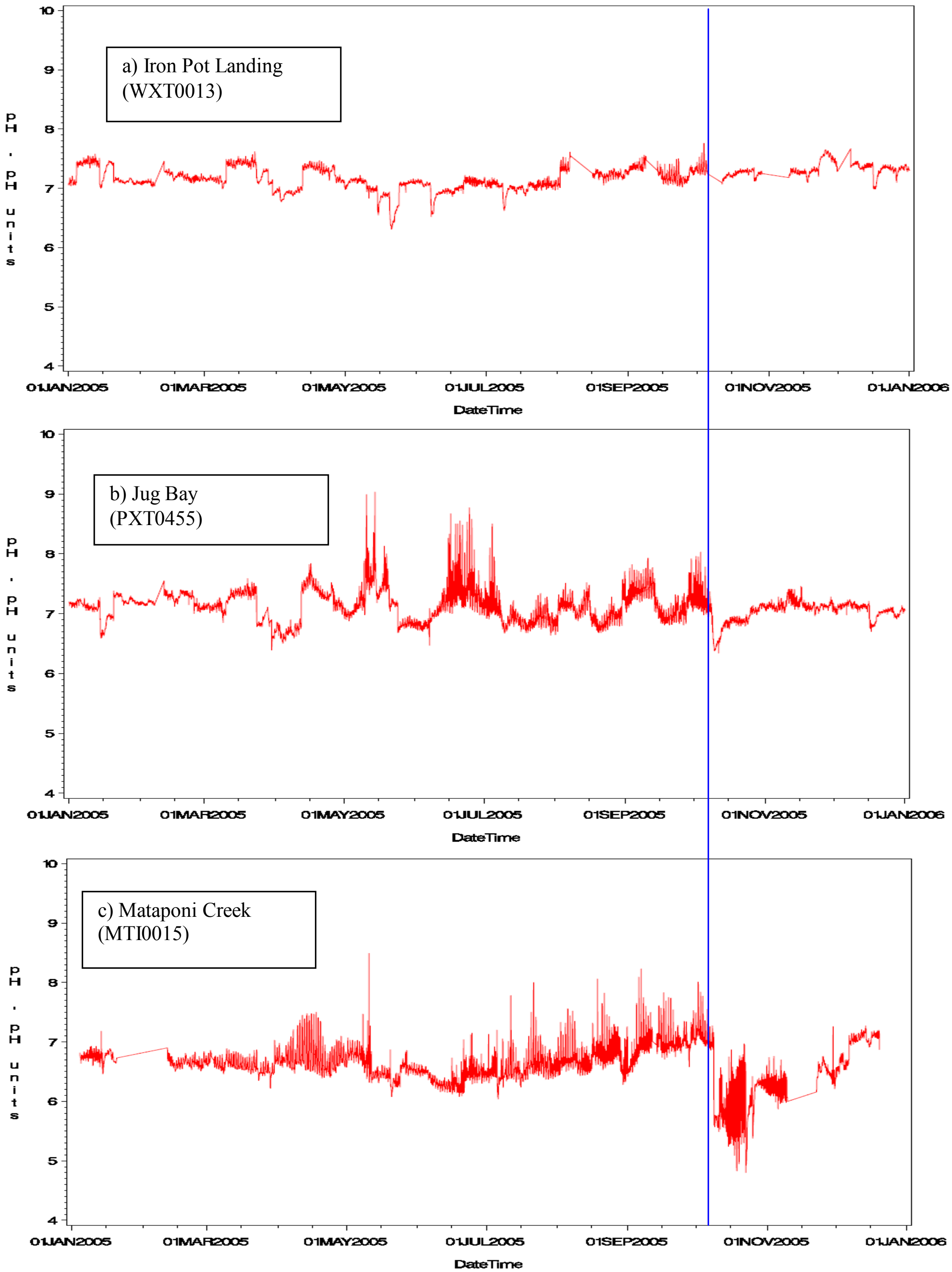


Figure PXT16 - Overhead View of the Wetland Upstream of Mataponi Creek (MTI0015) Continuous Monitoring Station (image from Google Earth.)

Figure PXT17 – Time Series of Continuous Monitoring pH data (Jan-Dec 2005).
The blue line indicates the large rain event of Oct 7 – 8.



1. Critical Habitat Criteria Assessment

The percentage of dissolved oxygen (DO) measurements that fell below the instantaneous (3.2 mg/L) and 30-day mean (5 mg/L) dissolved oxygen criteria for open-water fish and shellfish use in the Chesapeake Bay was calculated for the Continuous Monitoring stations using June to September data from 2003 through 2005 (Table PXT2). Only two stations on the Patuxent River, Mataponi (MTI0015, ID-5) and Benedict (XED0694, ID-21), failed to support the instantaneous dissolved oxygen criteria (<3.2 mg/L) more than three percent of the time in all three years (Table PXT2) However, measurements at Mataponi failed to meet the instantaneous dissolved oxygen criteria (32-44 percent) more often than measures from Benedict (3-15 percent). All stations in all three years failed the 30-day mean dissolved oxygen criteria (5 mg/L) (Table PXT2), although, the percent failure varied between stations.

Table PXT2 – Patuxent River Basin – Continuous Monitor Percent Failure

Year	Tributary	Station	ID	Dissolved Oxygen Thresholds		Fluorescence Thresholds		Turbidity Threshold
				<3.2 mg/L	<5 mg/L	>15 ug/L	>50 ug/L	>6.6 NTU
2003	Patuxent	MTI0015	5	44.44	66.44	0.02	0.00	85.54
	Patuxent	PXT0311	6	0.00	19.99	0.29	0.00	100.00
	Patuxent	PXT0455	7	0.00	5.24	2.29	0.00	99.96
	Patuxent	WXT0013	17	0.00	1.06	2.14	0.18	91.74
	Patuxent	XCF9029	18	1.22	11.49	31.58	5.22	1.77
	Patuxent	XDE4587	20	2.32	15.97	45.65	5.78	31.94
	Patuxent	XED0694	21	8.91	45.15	26.03	5.61	97.30
2004	Patuxent	MTI0015	5	42.86	63.12	0.20	0.00	88.02
	Patuxent	PXT0311	6	0.55	31.88	3.89	0.22	100.00
	Patuxent	PXT0455	7	0.18	18.33	12.12	0.50	99.85
	Patuxent	WXT0013	17	0.00	1.26	0.11	0.00	85.58
	Patuxent	XCF9029	18	0.96	4.71	23.31	0.94	7.87
	Patuxent	XDE4587	20	0.65	4.63	20.48	1.67	54.79
	Patuxent	XED0694	21	3.51	30.41	14.52	0.33	98.33
2005	Patuxent	MTI0015	5	32.35	59.16	1.34	0.01	73.56
	Patuxent	PXT0311	6	0.20	52.24	3.53	0.05	100.00
	Patuxent	PXT0455	7	1.19	17.91	10.00	0.75	100.00
	Patuxent	WXT0013	17	0.00	4.95	0.37	0.00	97.87
	Patuxent	XCF9029	18	1.49	12.08	19.11	0.43	18.87
	Patuxent	XDE4587	20	2.82	12.19	34.27	1.91	65.00
	Patuxent	XED0694	21	14.64	49.55	28.52	2.24	99.41

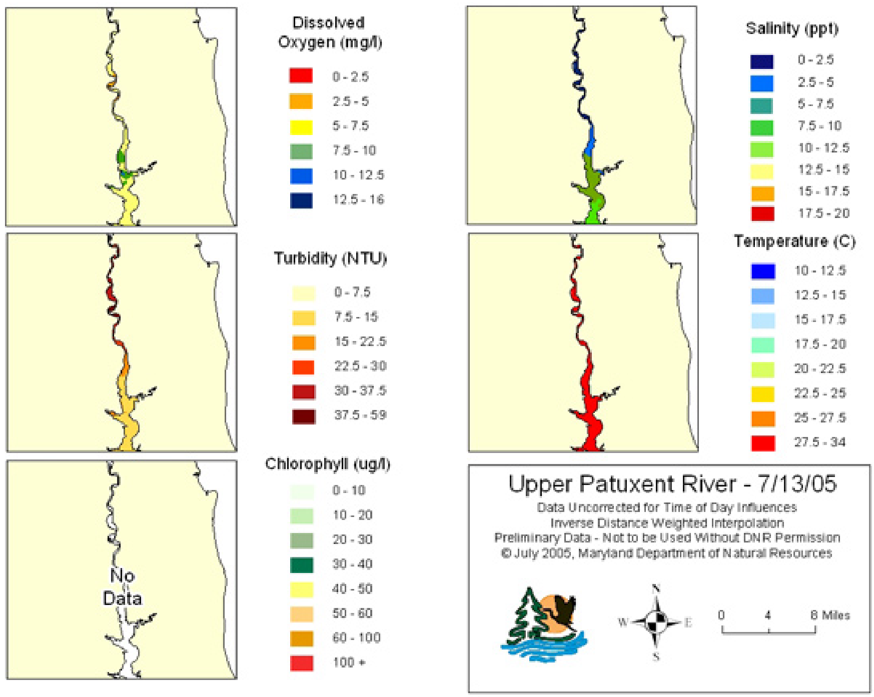
Fluorescence, a measure of total chlorophyll (Chl) concentration as an estimate of algal abundance, was recorded at all seven Continuous Monitoring sites throughout the SAV growing season (March-October). From 2003 through 2005, Chl measurements at all seven sites exceeded the acceptable 15 :g/L threshold at some point during the growing season (Table PXT2). Only three of these sites, however, exceeded this threshold more than five percent of the time: Chesapeake Biological Lab (CBL) (XCF9029, ID-18), Pin Oak (XDE4587, ID-20), and Benedict (XED0694, ID-21). The majority of sites also failed the critical 50 :g/L nuisance threshold at some time during the SAV growing season but at all seven sites fewer measures failed the 50:g/L threshold than the 15 :g/L threshold (Table PXT2).

Turbidity, a measure of the amount of suspended particles in the water column, often is used as a surrogate for water clarity. A turbidity threshold of 6.6 NTU denotes the boundary between acceptable and marginal water clarity for submerged aquatic vegetation (SAV) growth in the Patuxent River Basin. All sites failed to meet the turbidity threshold at some point during the SAV growing season; although, the percent failure varied between stations (Table PXT2). The continuous monitoring site at CBL (XCF9029, ID-18) exceeded the turbidity threshold less often than other sites (<19 percent of measurements) during all three years. This may be due to its location near the mouth of the Patuxent River, where water quality is impacted by both the river and the influx of Chesapeake Bay water. Pin Oak (XDE9029, ID-20), which is located immediately upstream of CBL, also showed a smaller failure rate (32-65 percent) than the five stations located further upstream.

2. 2005 Water Quality Mapping Highlights

In the Patuxent River Basin, the Upper Patuxent River was mapped from April through October 2005, while the Lower Patuxent River was mapped from March through November 2005. An example of a Lower Patuxent dataflow cruise is shown in Figure PXT15. In the Upper Patuxent River, water quality mapping recorded a decrease in dissolved oxygen, which coincided with the presence of an algal bloom between July and August (Figure PXT18). Water quality mapping recorded a similar trend in the Lower Patuxent River one month later, between August and September (Figure PXT19). This event was characterized by a rapid increase in phytoplankton (chlorophyll) concentrations followed by a bloom die-off related to anoxic (low dissolved oxygen) conditions (Figure PXT19). All maps from 2003, 2004 and 2005 are available on the Water Quality Mapping website: http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm

Figure PXT18 - Upper Patuxent River 2005 Water Quality Mapping Highlights
(http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm#patuxent)



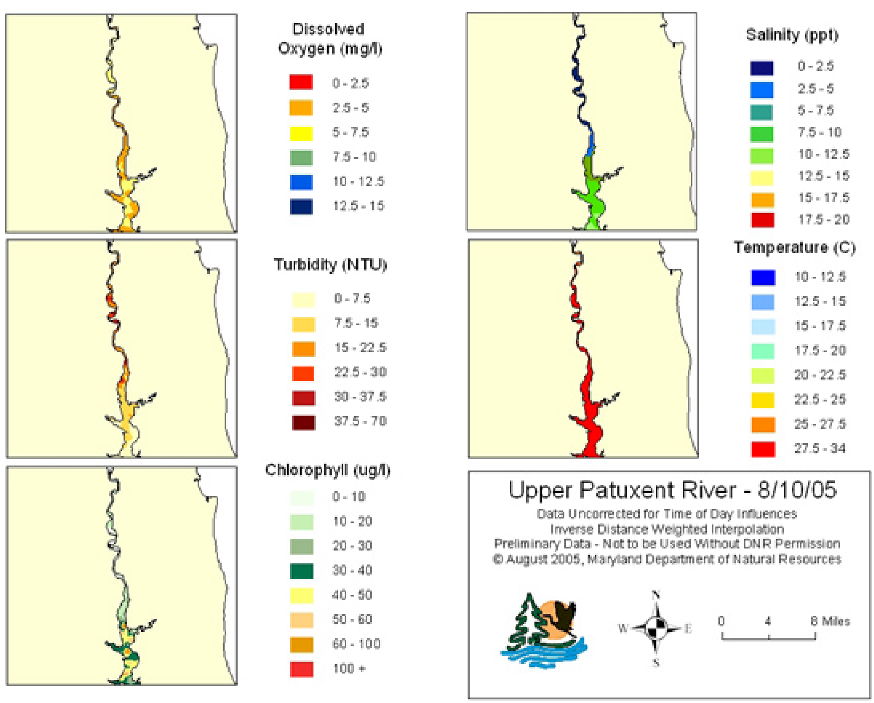
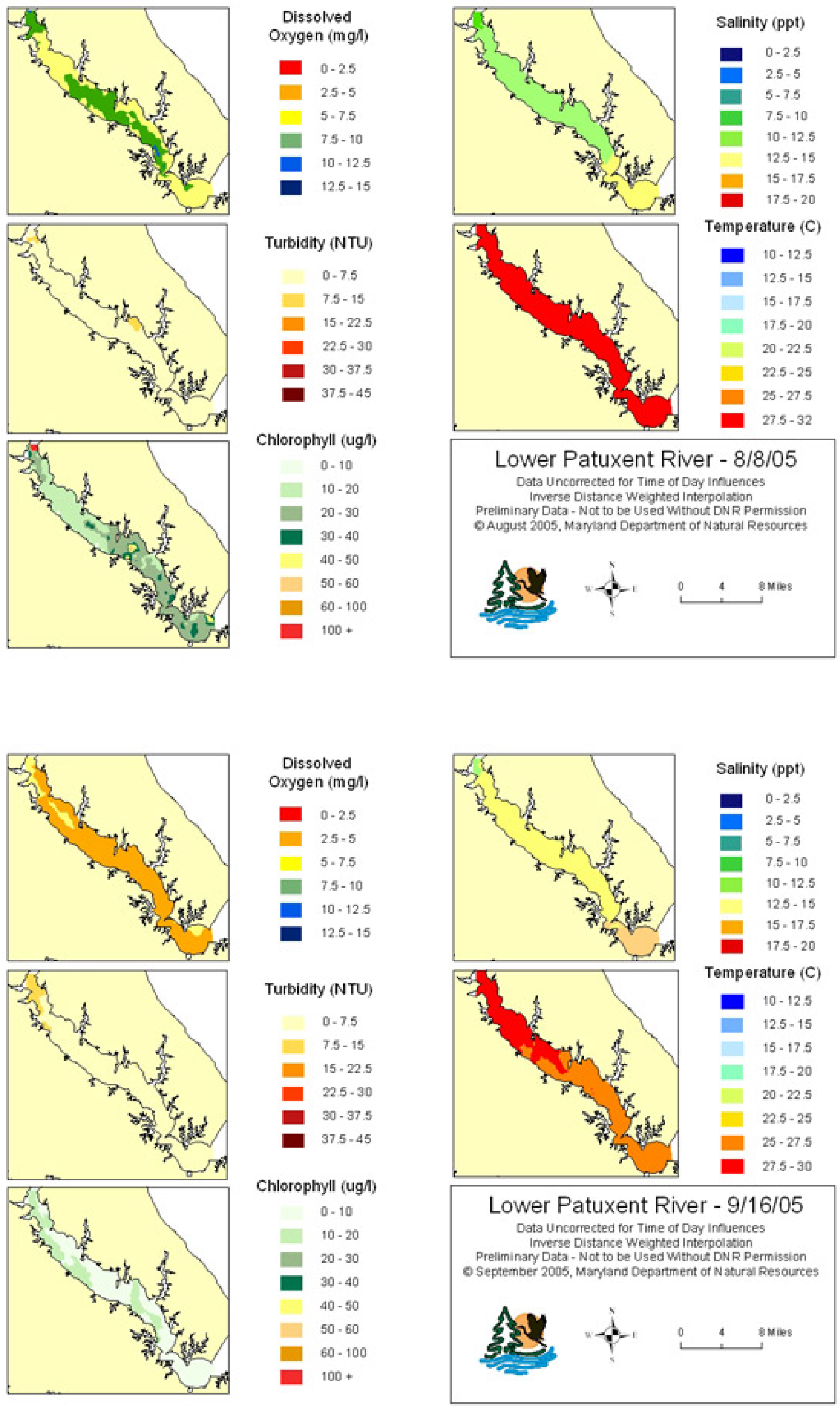


Figure PXT19 - Lower Patuxent River 2005 Water Quality Mapping Highlights.
(http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm#patuxent)



Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as nutrients are available. If nutrients are limited, then the available ratio of nitrogen to phosphorus affects phytoplankton growth. Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus. If one of the nutrients is not available in the adequate quantity, phytoplankton growth is limited by that nutrient. If both nutrients are available in excess, then the system is nutrient saturated.

Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall, when normal precipitation is low and stream and stormwater input is reduced (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

Phosphorus limitation occurs when there is insufficient phosphorus, i.e., there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are available to the estuary from stormwater flow.

If both nitrogen and phosphorus are available in excess (nutrient saturation), then phytoplankton growth may be limited by unsuitable light or temperatures. In this case, if phytoplankton are exposed to appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nutrients must be added to increase algal growth. Light limitation occurs more frequently in upstream tidal fresh areas and turbidity maximum zones (light-limited because of higher turbidity) or in winter (inadequate light and temperature for some phytoplankton).

Nutrient limitation models were used to predict nutrient limitation for the stations in the Patuxent River. Results are summarized graphically for the most recent three-year period (2003-2005) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November) (Figure PXT20). In the winter, the upper and middle river are completely nutrient saturated/light limited; the lower river is also predominantly nutrient saturated/light limited. In the spring, the upper river remains nutrient saturated/light limited, while nitrogen limitation is slightly more important in the middle river and phosphorus limitation is most important in the lower river. By summer, nitrogen limitation has increasing importance from upstream to downstream and is growth in the lower river is predominantly nitrogen limited in the summer. Nutrient saturated/light limitation is almost complete in the upper river in the fall, while the lower river has some return to phosphorus limitation.

Nutrient limitation model results were also combined into an annual average based on weighting factors used in Fisher and Gustafson (2005). Due to a laboratory change in 1998, this analysis is done for 1999-2005 data only (Figure PXT22). The upper river stations have had predominantly nutrient saturated/light limited conditions for the entire period; nitrogen limitation is also somewhat important in the more downstream stations, in particular during the drought year of 2002, but phosphorus limitation is not evident at any of the stations. Nitrogen limitation becomes dominant at the second middle river station (RET1.1), but note that in the 2003-2005 period used for the current conditions analysis above, light limitation was slightly more important on an annual basis in 2003 and 2004. In the lower river nitrogen limitation is dominant on an annual basis through 2002, but light limitation was also important in 2003, 2004 and 2005. At the lowest two stations, phosphorus limitation becomes important and even dominant at the station closest to the mouth of the river (LE1.4) in 2003, 2004 and 2005.

Managers can use these predictions based on monitoring information to assess what management approach will be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton grown. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream into an area that is nitrogen limited, fueling phytoplankton growth there. When used along with other information available from the water quality and watershed management programs, nutrient limitation predictions are a valuable tool allowing managers to make more cost-effective management decisions.

Figure PXT20- Seasonal nutrient limitation 2003-2005, shown as the proportion of samples in each limitation category.

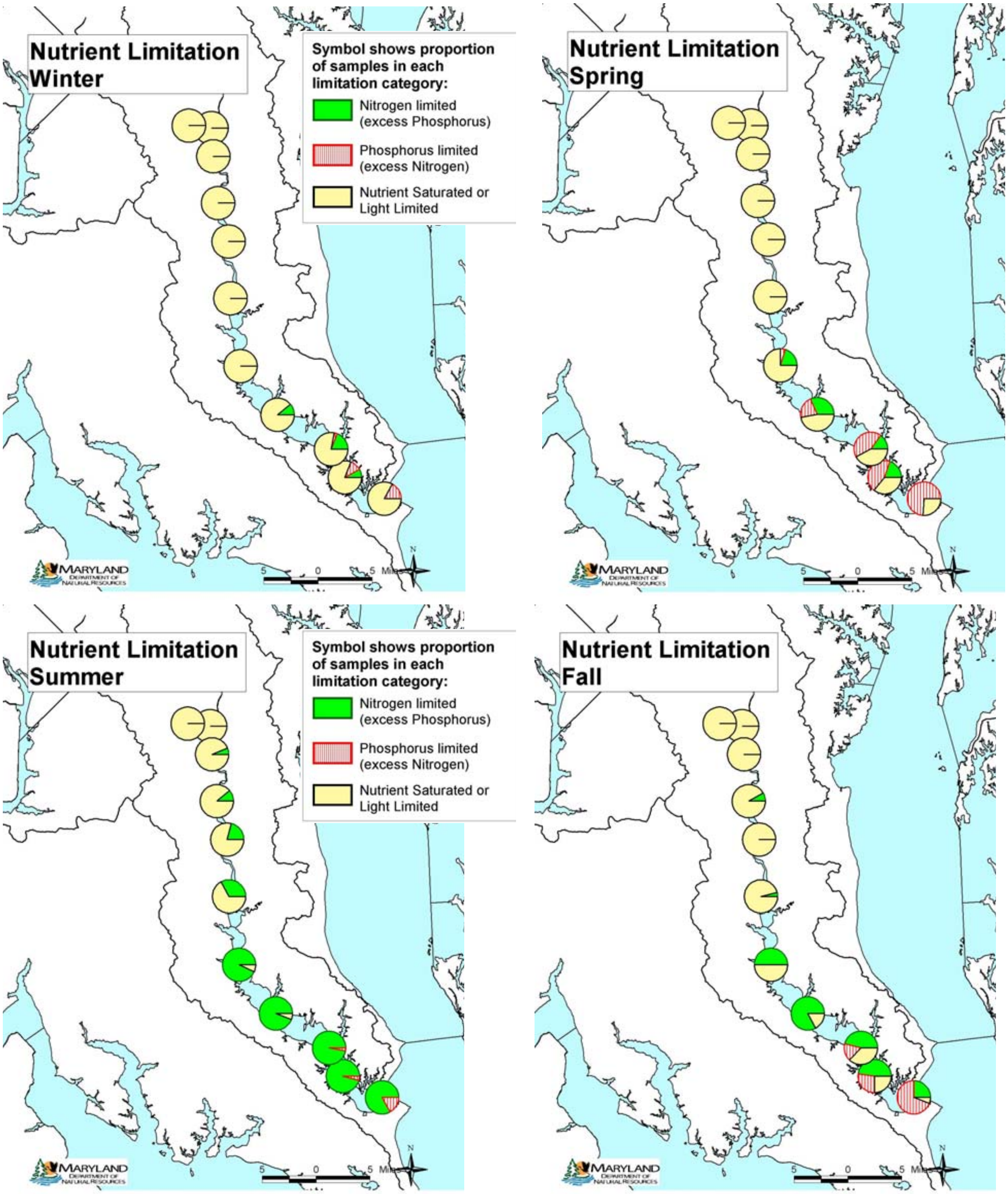


Figure PXT21a- Annual nutrient limitation from 1999-2005- upper river (tidal fresh stations). Number of months included in the annual average is indicated next to the year. Nutrient limitation cannot be determined if even one of the required parameters is unavailable due to missing data.

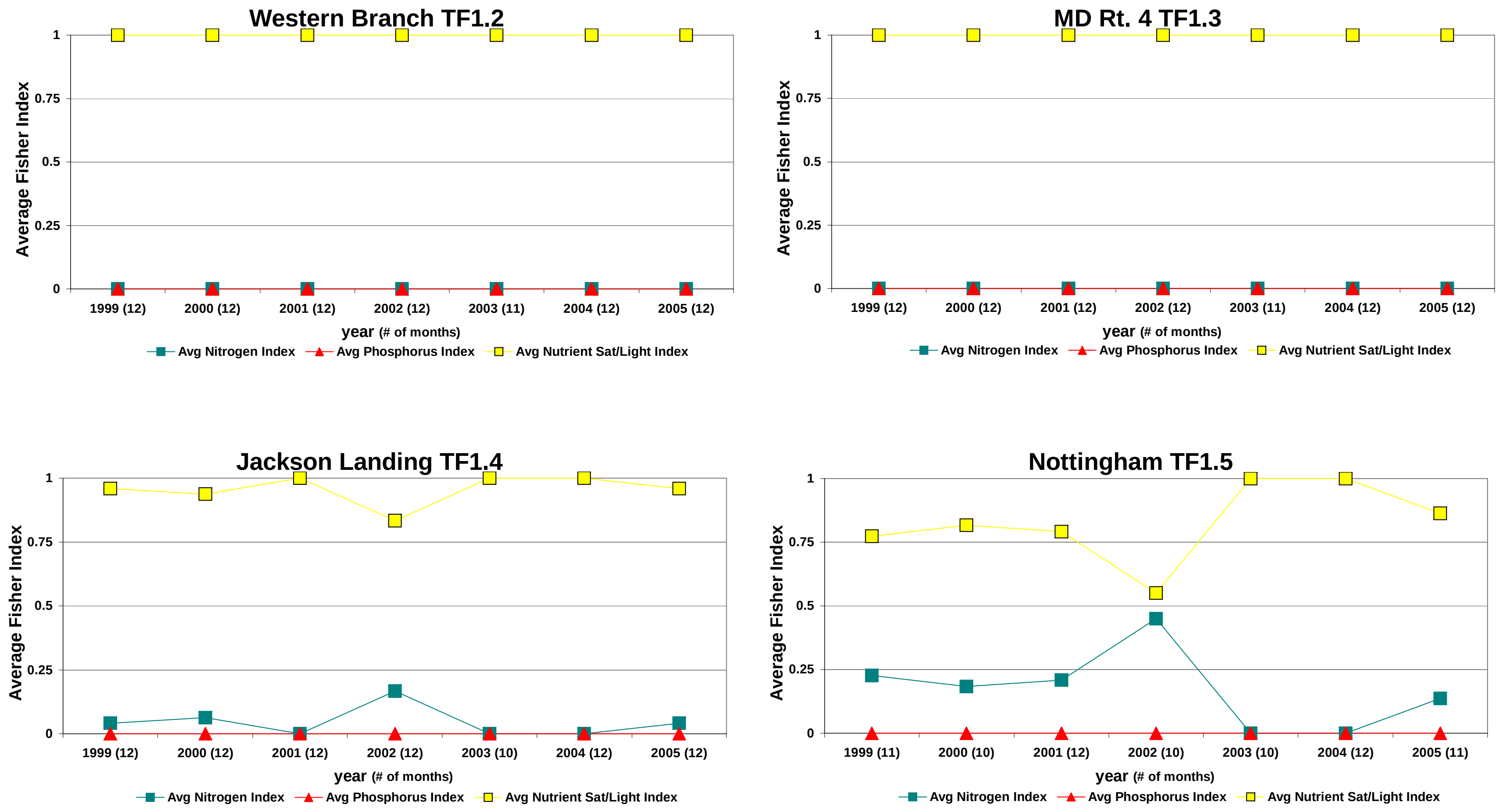
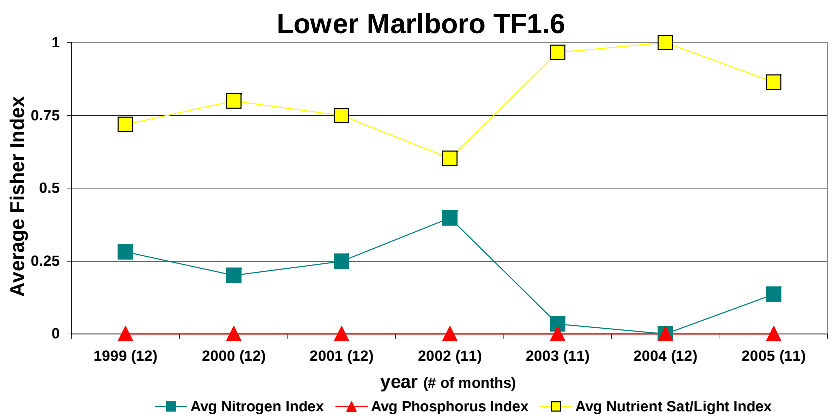
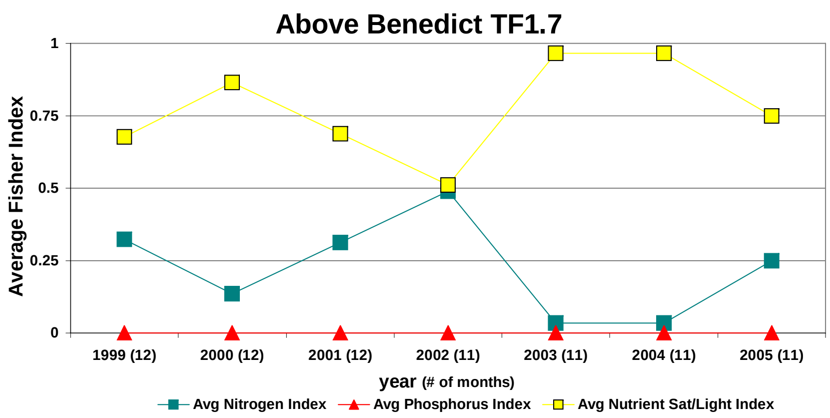


Figure PXT21b- Annual nutrient limitation from 1999-2005-middle river.
Number of months included in the annual average is indicated next to the year. Nutrient limitation cannot be determined if even one of the required parameters is unavailable due to missing data.





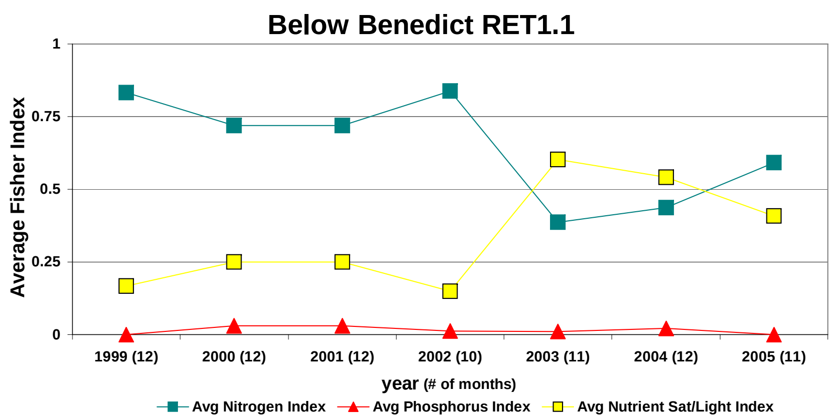
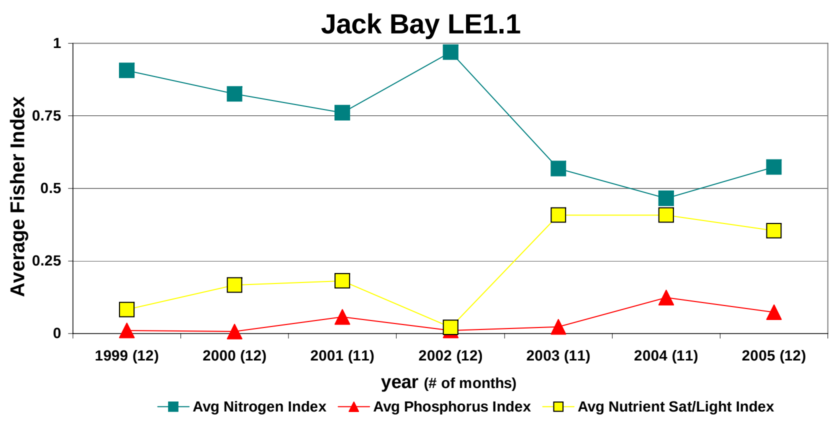
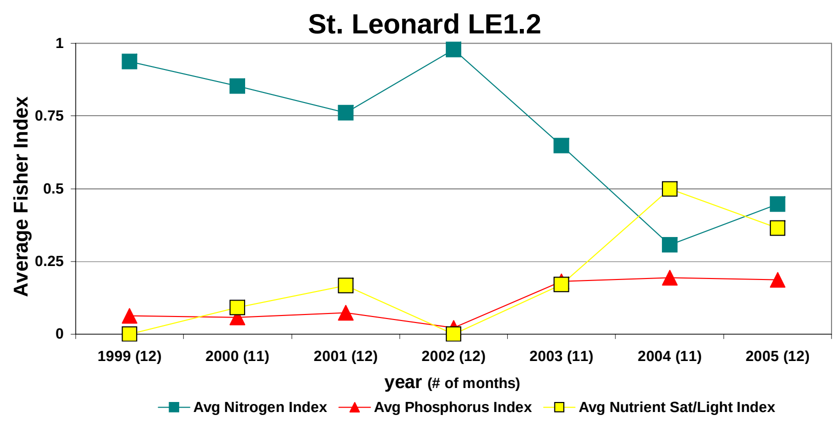
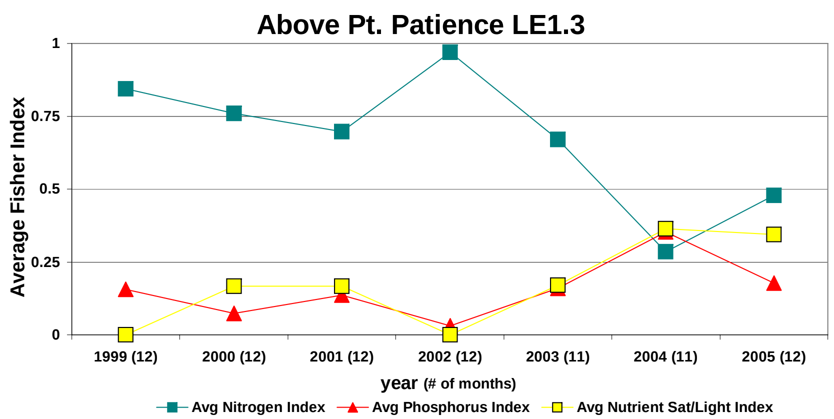
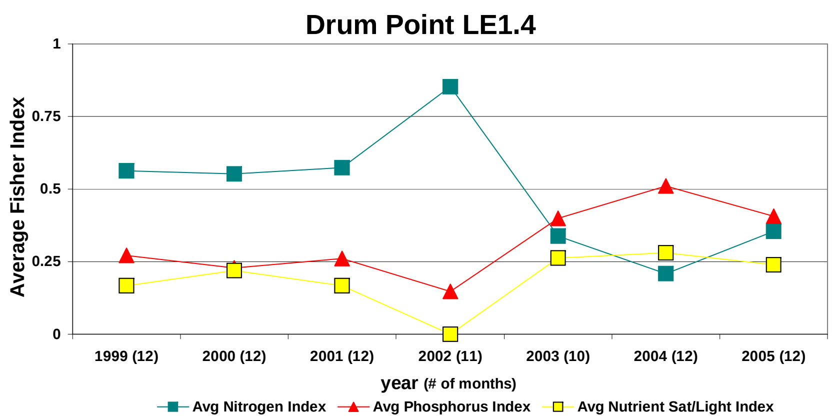


Figure PXT21c- Annual nutrient limitation from 1999-2005-lower river (mesohaline).
Number of months included in the annual average is indicated next to the year. Nutrient limitation cannot be determined if even one of the required parameters is unavailable due to missing data.









Bay Grasses (Submerged Aquatic Vegetation—SAV)

The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems (Dennison *et al.* 1993). SAV is important not only as an indicator of water quality, but also as a critical nursery habitat for many estuarine species. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region (Perry and Deller, 1995).

SAV distribution is determined through the compilation of aerial photography directed by the Virginia Institute of Marine Science. Reports detailing methodology and annual SAV coverage are available at www.vims.edu/bio/sav. Details on species of SAV discussed in this report can be found at www.dnr.maryland.gov/bay/sav/key.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The "Percent Light at Leaf" habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves (Kemp *et al.,* 2004). The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older "Habitat Requirements" of five water quality parameters are still used for diagnostic purposes (Dennison *et al.*, 1993).

Upper Patuxent: The tidal fresh Patuxent River has seen a remarkable growth of SAV since 1993. The 2005 aerial survey identified 324 acres of SAV there - the most ever recorded and more than 150 percent of the revised goal (Figure PXT22). SAV can be found from Waysons Corner downstream to Nottingham, including Jug Bay, with dense patches fringing the shoreline. Ground-truthing efforts by MD-DNR, staff from Patuxent River Park and Jug Bay Wetlands Sanctuary and citizens have found 16 species of SAV in this region with the most commonly identified ones being hydrilla, common waterweed, and coontail. There are five water quality monitoring stations in this area (near the Route 4 bridge, the confluence of Western Branch, near the Western Branch Waste Water Treatment Plant, near the ruins of the old railroad bridge at Jug Bay Wetlands Sanctuary and near the confluence of Kings Creek). Data from these sources indicate that most SAV habitat requirements fail for this region (percent light at leaf, light attenuation, concentration of suspended solids and phosphorus), with only algae levels passing (nitrogen levels are not applicable to the tidal fresh regions) (Figure PXT23). Even though there are poor water quality conditions here, plants may be growing on very shallow mudflats, which provide them with enough light to grow.

Middle Patuxent: The middle Patuxent area has also seen remarkable re-vegetation in recent years as mapped by the Virginia Institute of Marine Science annual aerial survey. Beginning in 1994, when SAV first reappeared in this region with 53 acres, SAV coverage increased to 125 acres in 2005, exceeding the revised goal of 115 acres (Figure PXT22). Ground-truthing efforts by MD-DNR, Patuxent River Park staff, and citizens have found 12 species of SAV in this region with the most commonly identified ones being coontail, common waterweed, and curly pondweed. There are two monitoring stations in this area, one near Short Point and the other just north of Cedarhaven. The water quality data from these sites indicates that this region fails most

SAV habitat requirements (percent light at leaf, light attenuation, suspended solids, nitrogen, and phosphorus concentrations), with only algae levels passing (Figure PXT23).

Lower Patuxent: The lower Patuxent River has not shown a similar recovery in terms of SAV coverage. The VIMS annual aerial survey has found only very small SAV beds (less than 25 acres) here since 1987 (Figure PXT22); in 2002 140 acres were found. This is well below the revised SAV goal of 1,634 acres. In 2004, there were 42 acres of SAV and none identified in 2005. The few beds that have been found recently were in the Parker Wharf and Broomes Island areas. Ground-truthing efforts by NOAA, EPA, Chesapeake Biological Laboratory and Patuxent River Park staff and citizens have found horned pondweed and widgeon grass. There are 5 water quality monitoring stations in this reach of the Patuxent River, located near Long Point, Jack Bay, mouth of St. Leonards Creek, mouth of Cuckold Creek, and one station between Drum and Fishing Points. Data from these stations indicate that suspended solids and nitrogen pass the SAV habitat requirements, while light attenuation and percent light at leaf fail (Figure PXT23). Phosphorus and algae concentrations are borderline relative to the habitat requirements.

Several large-scale eelgrass restoration projects occurred in the lower Patuxent in 2004 and 2005. Eelgrass seed was distributed over approximately 5.25 acres near the Chesapeake Biological Laboratory pier, 3 acres at Myrtle Point, 2.25 acres at the mouth of Hungerford Creek and approximately 6.25 acres at Parran's Hollow, just north of Jefferson Patterson Park, where 9 acres were seeded. Additionally, small adult shoot test plots were installed at each of these locations. Intensive monitoring of recruitment and survival has occurred throughout 2005 and 2006. A large eelgrass defoliation and die-off occurred throughout the lower Chesapeake Bay in late summer of 2005, possibly due to a combination of hot summer water temperatures, low winds and lower light levels (a similar defoliation event was observed in 1975). Eelgrass seedlings, grown from seeds dispersed prior to the die-off, were observed growing in the defoliated areas in late fall of 2005, and eelgrass plants were also found growing throughout the restoration project areas in 2006.

Figure PXT22 –Bay Grasses (Submerged Aquatic Vegetation) Distribution in the Patuxent River Basin.

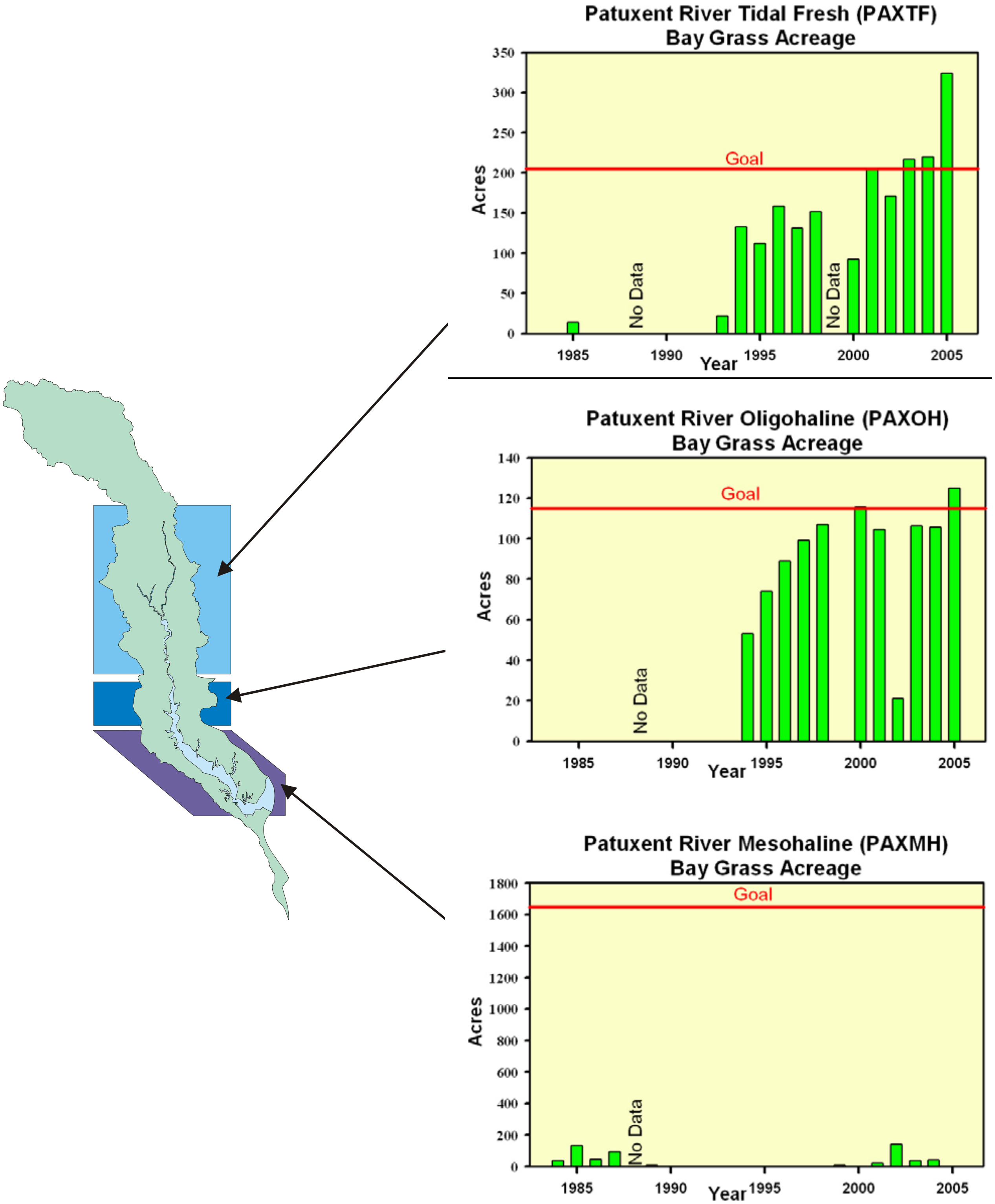
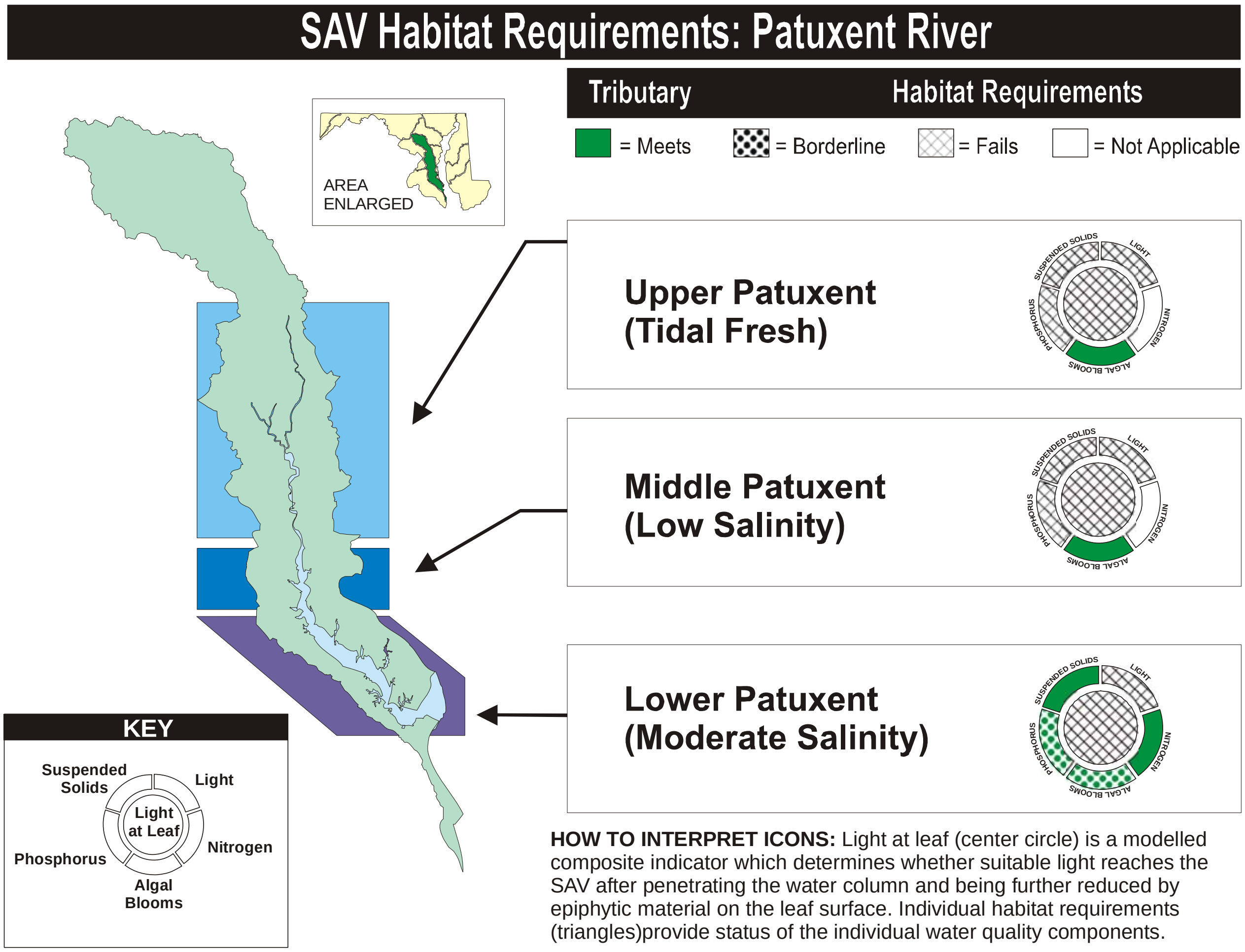


Figure PXT23 –Bay Grasses (Submerged Aquatic Vegetation) Distribution in the Patuxent Basin.



Phytoplankton Community

Phytoplankton (generally algae) are the primary producers in the Bay, and many species travel up the food chain to fish, either directly or through zooplankton. However, too much phytoplankton or the wrong kinds degrade the Bay. Too much phytoplankton can shade out bay grasses, and can cause low dissolved oxygen levels at night and when the cells die off. The "wrong kinds" of phytoplankton include cyanobacteria (bluegreens) and some pigmented dinoflagellates. Cyanobacteria are generally smaller cells and not as nutritious and palatable to zooplankton as are the cryptomonads, diatoms, and dinoflagellates. Although many types of dinoflagellates provide a good food source, some of the pigmented dinoflagellates can release toxins and cause red or mahogany tides and fish kills; large blooms of potentially toxic algae are sometimes referred to as Harmful Algal blooms (HABs).

The phytoplankton monitoring program samples 13 stations in the Maryland portion of the Bay including three stations in the Patuxent River at long-term water quality monitoring stations in each tidal zone (tidal fresh, oligohaline and mesohaline). The phytoplankton index of biotic integrity (PIBI) at the two upper stations indicated a fair-bad phytoplankton community in spring 2005 (scores of 2.0 at the upper and 2.1 at the middle station, with greater than 3 being considered meeting the goal for phytoplankton community health criteria), and bad phytoplankton community at the lower station (PIBI score of 1.5). In summer 2005, all three stations were in the fair-bad category (scores of 2.3, 2.0 and 2.3 from upper to lower stations). The PIBI has also been decreasing at the lower river station in the spring and summer, but increasing at the upper river station in the summer over the 1985-2005 period (Lacouture et al 2006).

Harmful Algae

In the Patuxent River Basin, samples are routinely collected at four of the long-term tidal water quality stations by Maryland Department of Natural Resources for phytoplankton community analysis via light microscopy; harmful algal bloom species (see Marshall 1996, 2003, Marshall *et al.* 2005) are noted and if concentrations of concern are observed for these organisms further investigations including toxin testing may ensue to track the bloom conditions. At two of the long-term tidal water quality stations, samples are also collected and assessed for a specific suite of HAB species using polymerase chain reaction (PCR) techniques to assess for their presence/absence (Bowers *et al.* 2000, 2001, 2004) and some species (e.g. *Karlodinium micrum*) are subjected to categorical quantification (low, medium and high densities). In addition, event-based sampling (in response to a reports of human health effects, fish kills, discolored water, etc.) helps detect and track harmful algal species.

The lower Patuxent River and its tributaries have been affected primarily by dinoflagellate blooms of *Prorocentrum minimum* and *Karlodinium veneficum* (formerly *Karlodinium micrum*) between 2003-2005. Some of the highest densities recorded between 1982-2003 for *P. minimum* in Maryland tidal waters were found in the lower Patuxent River including St. Thomas Creek (2003, ranked 8th) and Patuxent River proper (2003, ranked 4th and 1989, ranked 2nd) (Tango *et al.* 2005). Such blooms may have impacts to shellfish and further affect light resources and the success of submerged aquatic vegetation (Tango *et al.* 2005).

Noticeably visible bloom conditions have occurred from *P. minimum* and *K. veneficum*, most notably in May-July 2003. Monitoring indicated that *P. minimum* was present in the lower Patuxent and its tributaries from late-May through early-June with maximum concentrations reaching 243,800 cells/ml. Dense blooms such as these have resulted in areas of hypoxia, or low oxygen, a condition which is stressful to Bay life. Further tracking information can be found in MD DNR Habnews for June 5, 2003, A "Black Tide" caused by *K. veneficum* (MD DNR HABnews June 24, 2003) was located on St. Leonard Creek in June. The bloom density of 1.5 million cells/ml on Wednesday June 18th was so concentrated that the water appeared black on the surface; by comparison, bloom densities that have been associated with toxic algal events of *K. veneficum* linked to fish kills have occurred at 10,000 to 30,000 cells/ml based on research by Dr. Alan Place and Jon Deeds (Center of Marine Biotechnology, Baltimore, MD). Water samples were collected by Richard Lacouture (Morgan State Estuarine Research Center - MSUERC) and showed the bloom was concentrated in the upper 0.3 meter (1 foot) of the water column. At 1 meter below the surface down to the bottom of the creek the water was essentially clear of the algal bloom. On Friday June 20th, a fish kill of silversides was identified in association with the St. Leonard's Creek mouth related to ponded water that was cutoff from the main channel of the creek during low tide. The fish kill prompted additional investigation of St. Leonard Creek, however, there was no evidence of a broader scale fish health event. Algal samples were again collected and the cell concentrations declined but remained significant at 50,000 cells/ml in the surface water. Evidence of the bloom continued through July expanding well into the main channel region of the river between Jack Bay and St. Leonard Creek; Battle Creek was one specific location investigated (for more information please see http://mddnr.chesapeakebay.net/hab/news_7_3_03_b.cfm).

Regionally, there was a link to a fish kill with *K. veneficum* in 2003. Approximately 8000 dead fish of 15 species were found on the Chesapeake Bay side of the Patuxent River Naval Air Station on July 2nd; the investigation suggested the kill occurred one day earlier. Maryland Department of the Environment reported that witnesses had observed dark colored water and crabs at the water surface or on the beach. Water quality at the location on July 2nd however was normal (8.9 mg O_2/L). Moderate densities of the possibly toxic dinoflagellate *K. veneficum* were reported from a water sample collected at the site. Nearby Gooses Creek was discovered to have freshly dead and dying Atlantic silversides. Water quality indicated strong algal bloom conditions with dissolved oxygen at 154 percent of saturation levels and pH of 8.63. A water sample revealed bloom levels of *K. micrum* at 56,915 cells/ml. Additional water samples and weak but live silversides were collected for further lab analysis. Water samples were positive for karlotoxin, an ichthyotoxin (i.e., a fish-killing toxin) according to Dr. Allen Place.

In 2004 MD DNR had no bloom investigations to report for the river but 2005 resembled 2003. The lower Patuxent River was a hotbed of Mahogany Tide between May 23 and June 1 (MD DNR HABnews June 8, 2005). Bloom concentrations for six samples ranged from 9010-63,000 cells/ml. The potentially ichthyotoxic (i.e., fish killing) dinoflagellate, *K. veneficum*, replaced the late spring Mahogany Tide of *Prorocentrum minimum* in the lower Patuxent River. Samples collected by Maryland Department of Natural Resources (MD DNR) on June 21st from Jack Bay contained 4,293 *K. veneficum* cells/ml. A sample collected from Mackall Cove on St. Leonard Creek by Morgan State Estuarine Research Center on June 27th contained 105,000 *Karlodinium* cells/ml. No fish kills were identified associated with the bloom on the Patuxent River, however, a similar type of bloom on the Corsica River (Chester River watershed) in September 2005 led to a fish kill of 30,000-50,000 fish (for more information please see http://mddnr.chesapeakebay.net/hab/news_100505.cfm).

See more information on harmful algae blooms in Maryland at http://www.dnr.state.md.us/Bay/hab/index.html.

Benthic Community

Benthic animals (bottom-dwellers) form an integral part of the ecosystem in the Bay. For example, small worms and crustaceans are key food items for crabs and demersal (bottom foraging) fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column and locally improving water clarity. Thus the health of a benthic macroinvertebrate community is a reliable and sensitive indicator of estuarine habitat quality.

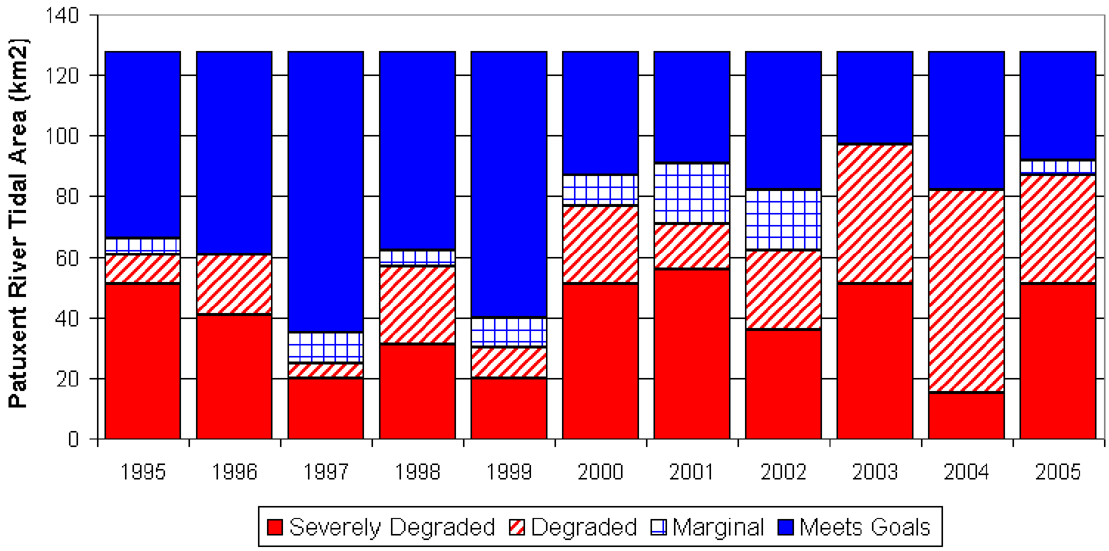
Benthic community condition is measured at both long-term stations and at randomly selected stations that change annually. A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc., see Weisberg *et al.* 1997). The B-IBI serves as a single-number indicator of benthic community health. For more details on the benthic monitoring program, see http://esm.versar.com/Vcb/Benthos/backgrou.htm

Long-term trends and a three-year average Benthic Index can be calculated at the long-term locations (four in the Patuxent River). At the upper two stations, Benthic Index condition is Marginal over the 2003-2005 period, and the lower station condition is degrading (Figure PXT25). At the station mid river station, Benthic Index condition Meets Goals, but the lowest station is Degraded (low dissolved oxygen area) (Figure PXT25).

Benthic condition varies with location within the basin. The Patuxent River is sampled as a single stratum, so statistical testing is possible using the random site data to estimate the tidal area (km^2) failing to meet Chesapeake Bay Benthic community restoration goals. In 2005, the amount of area failing the goals was 92 km^2 of a total of 128 km^2 (72 percent, Figure PXT24).

Llansó et al (2005) state that degradation in the Patuxent River is probably the result of multiple stressors including contamination, eutrophication and low dissolved oxygen stress. In particular, Llansó et al (2005) determined that the lower river sites are impaired by contaminants effects, as well as summer hypoxia. Hypoxia was severe in 2003 but moderate in 2004. Examination of the site-specific results gives additional detail to the spatial variability in benthic community condition in this basin (Figure PXT26). Clusters of Severely Degraded samples occur in the mid to lower areas of the river where summer bottom dissolved oxygen levels are poor (less than 2 mg/L) and at the mouth of the river, while shallow areas of the river often have benthic populations that Meet Goals or are Marginal.

Figure PXT24- Patuxent tidal area meeting or failing Benthic Restoration Goals.



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Due to the link to increased hypoxia/anoxia and inputs of nutrients to the waterbodies, higher flows, such as in years 2003 and 2005, lead to increases in extent and intensity of degradation of benthic communities throughout the Chesapeake Bay and tributaries, especially in lower portions of the major rivers including the Potomac (Llansó et al 2004, Llansó et al 2005). In particular, 2003 had the highest percent of degraded area for the monitoring period (1995-2005) for the Patuxent (Figure PXT24). Although annual flow was above normal for 2004, much of it was associated with storms in September, after the summer period that most influences benthic community condition (Llansó et al 2004).

For information on benthic community health throughout the Bay, see the Comprehensive Report 1984-2004 (Llansó et al 2005) and the Comprehensive Report 1984-2005 (Llansó et al 2006) at http://www.esm.versar.com/Vcb/Benthos/referenc.htm.

Figure PXT25- B-IBI results for long-term fixed station locations.
First panel: mean of 2003-2005 values. Symbol indicates the B-IBI category: Meets Goal (score of 3-5), Marginal (2.6-3), Degraded (2-2.6) and Severely Degraded (1-2). Second Panel: Trends in benthic community condition for Patuxent River fixed stations, 1985-2005. Trend period is 1985-2005.

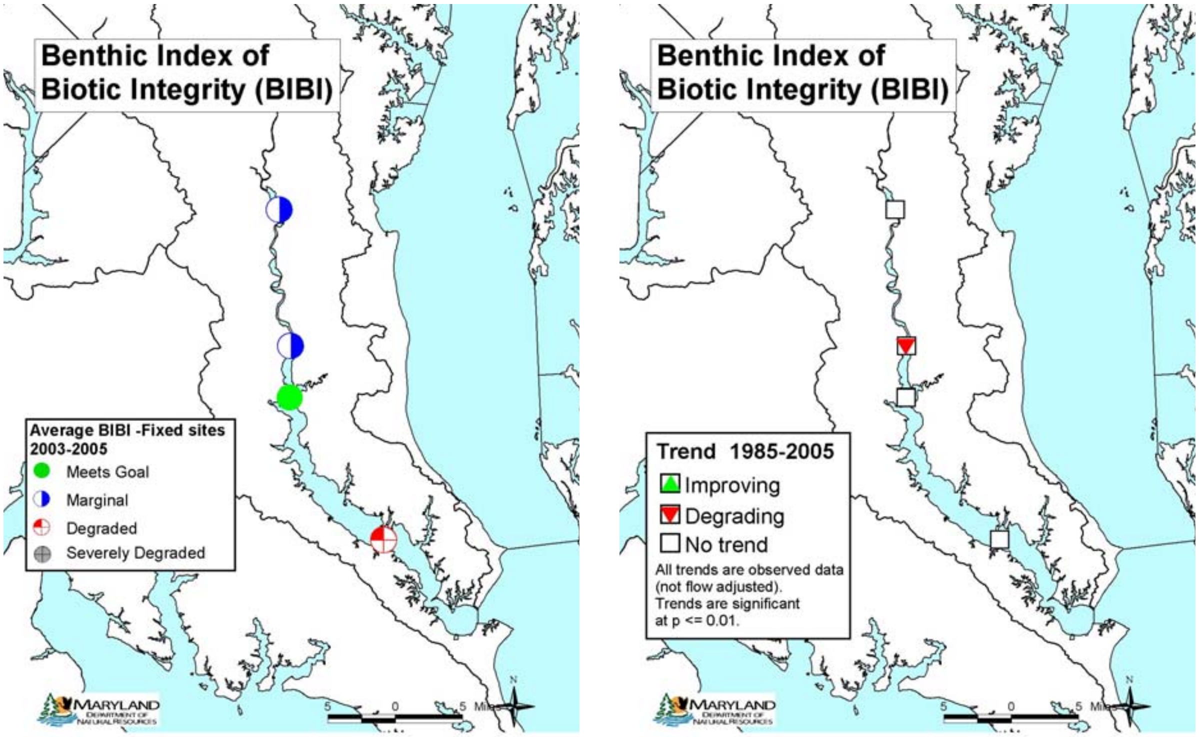
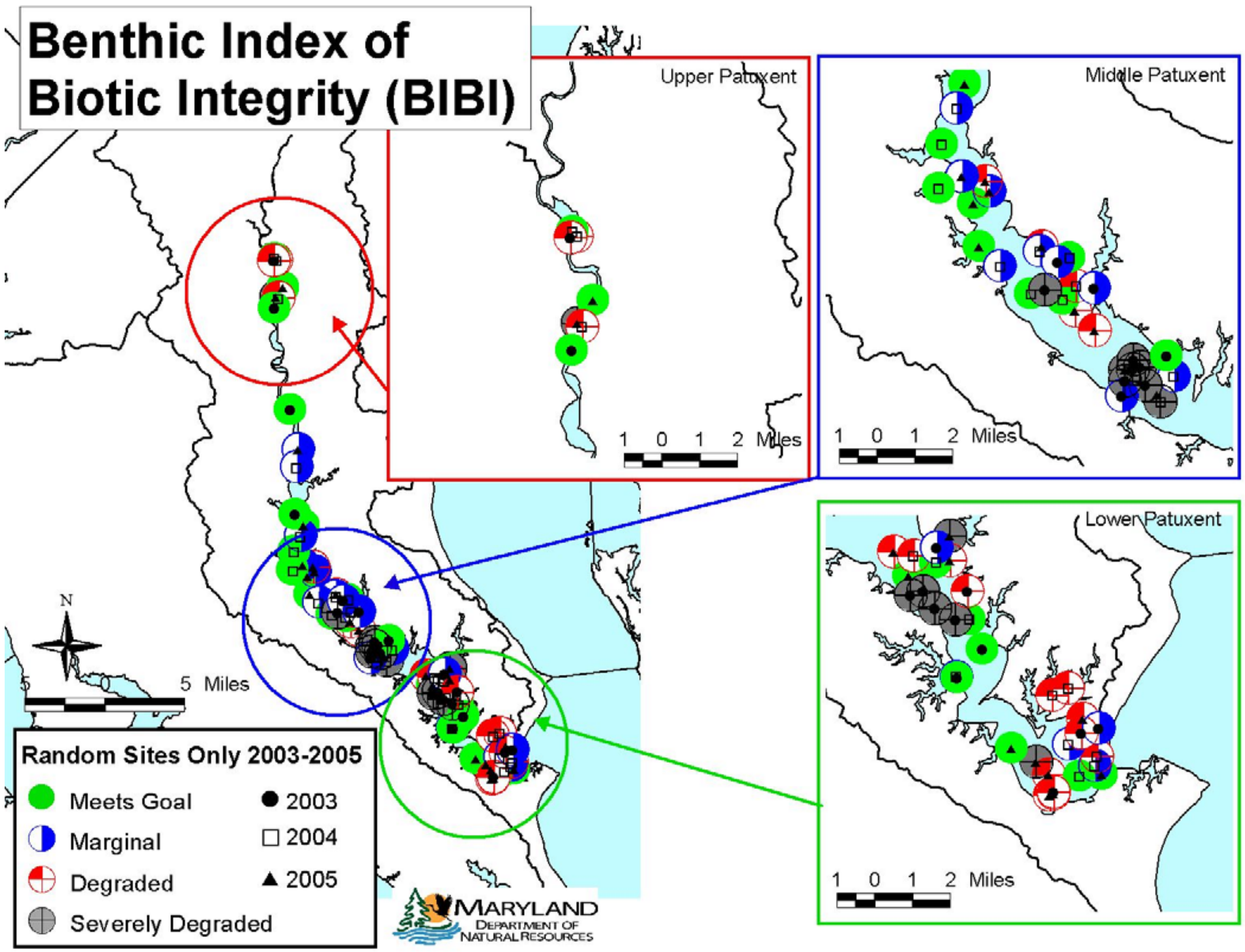


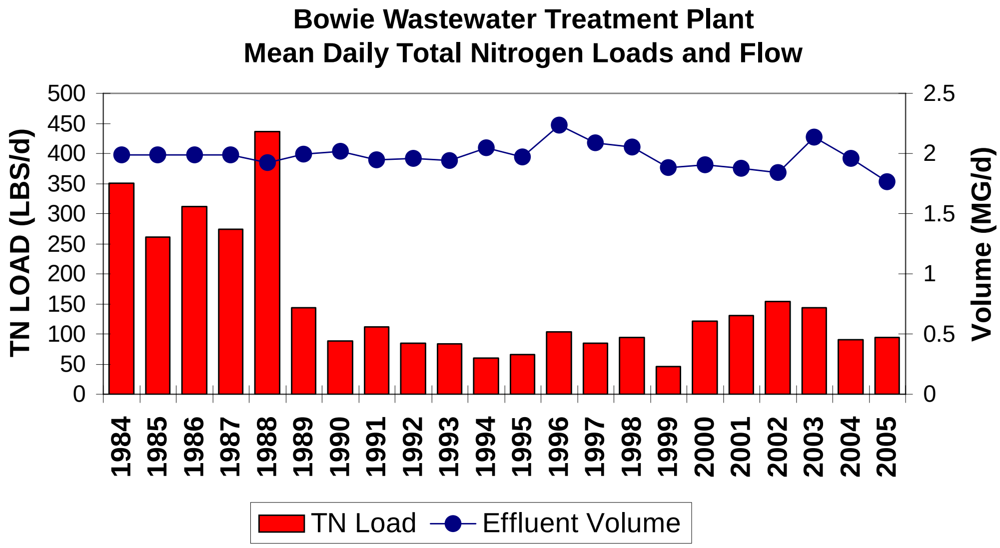
Figure PXT26- B-IBI results for random sites collected in 2003, 2004, and 2005.
Center symbols indicate the year the sample was collected; larger symbol indicates the B-IBI category: Meets Goal (score of 3-5), Marginal (2.6-3), Degraded (2-2.6) and Severely Degraded (1-2).

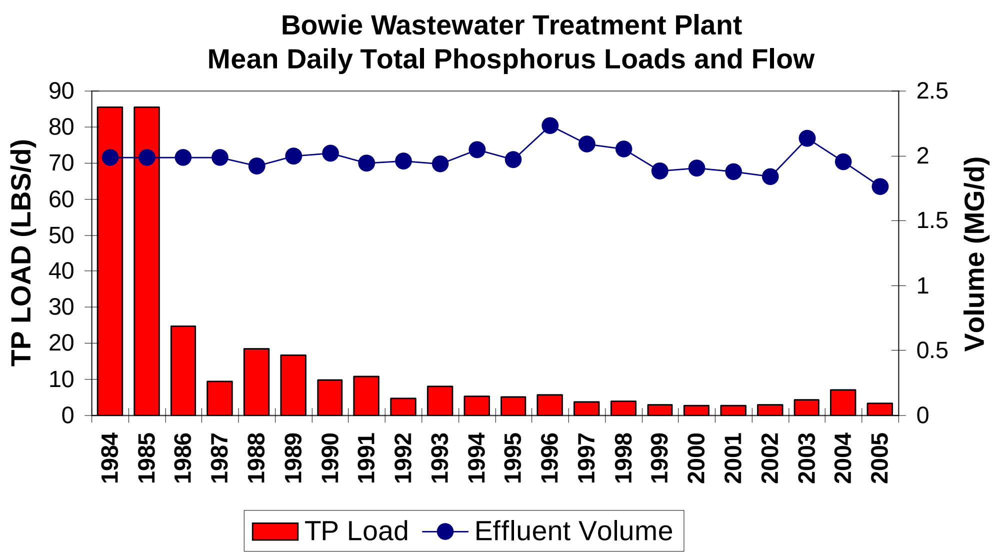


Appendix A – Nutrient Loadings from Major Wastewater Treatment Facilities in the Patuxent River Basin

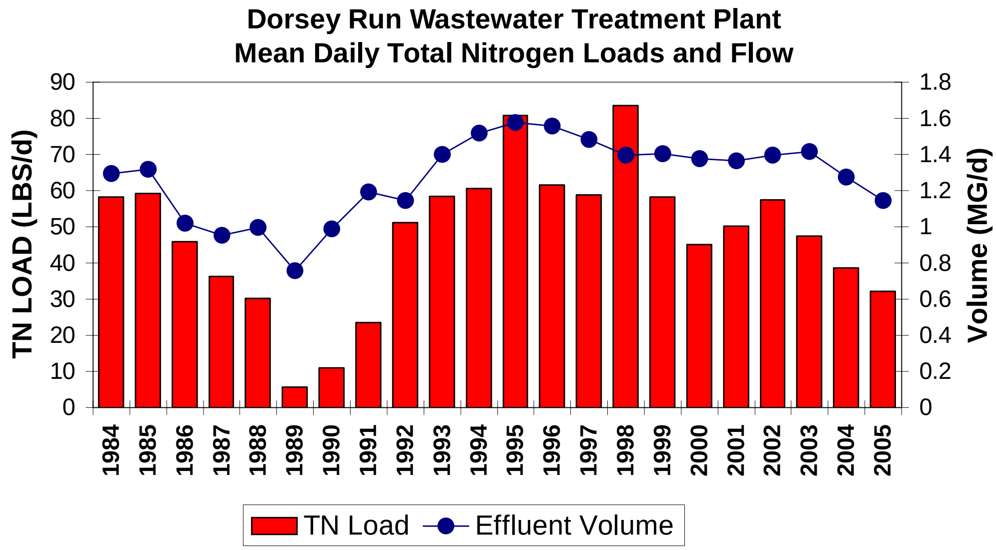
Annual means of daily wastewater treatment plant loads (red bars) are shown with daily wastewater treatment plant flows (blue line) based on Maryland Department of Environment data for 1985 to 2005. Data are from The Chesapeake Bay Program CBP Nutrient Point Source Database (http://www.chesapeakebay.net/data/index.htm). Note that the scale varies for each graph. Figure PXT2 shows the location of these wastewater treatment facilities.

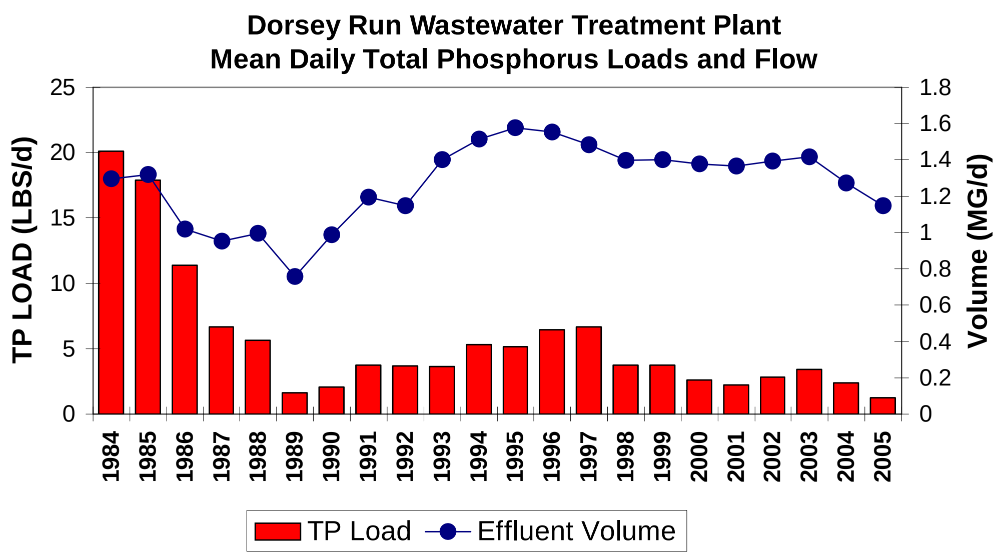
Dates for implementation of Biological Nutrient Removal (BNR) and Enhanced Nutrient Removal (ENR) are included for State facilities; information is not available for Federal and private facilities. Please see http://www.dnr.state.md.us/bay/tribstrat/implementation_plan.html (Department of Natural Resources website) and http://www.mde.state.md.us/Water/CBWRF/pop_up/enr_status_map.asp (Maryland Department of the Environment website) for more information.



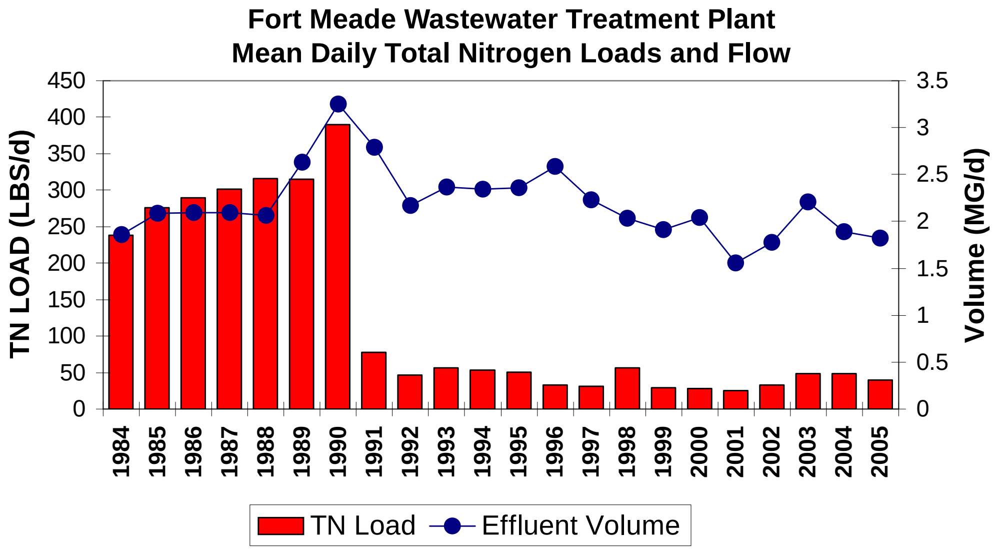


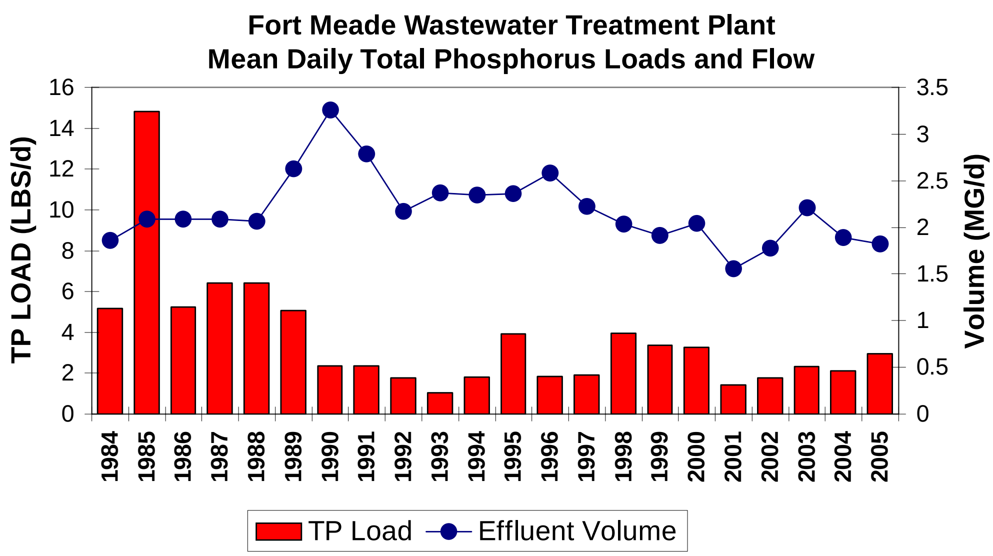
BNR technology was implemented at this facility in 1991.
ENR technology is scheduled to be implemented by 2010.



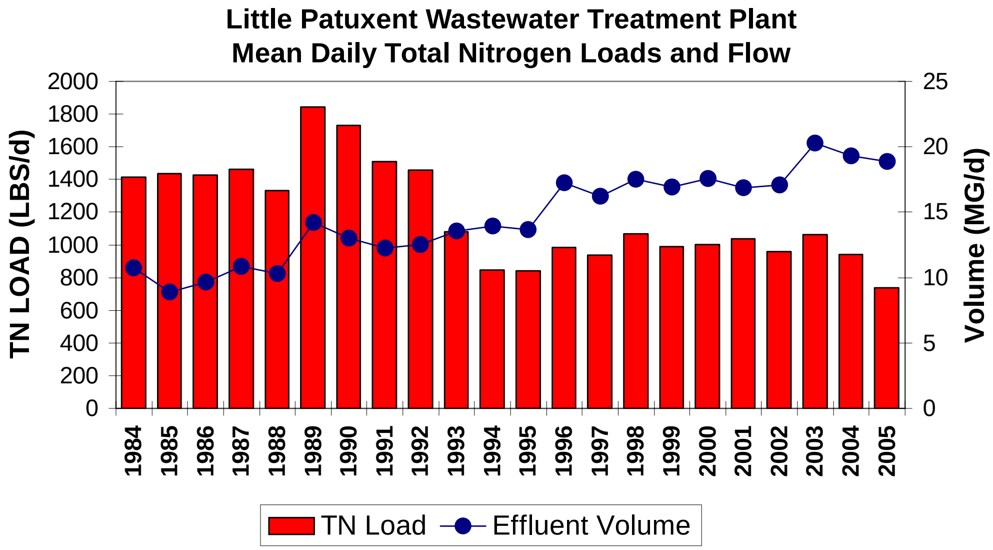


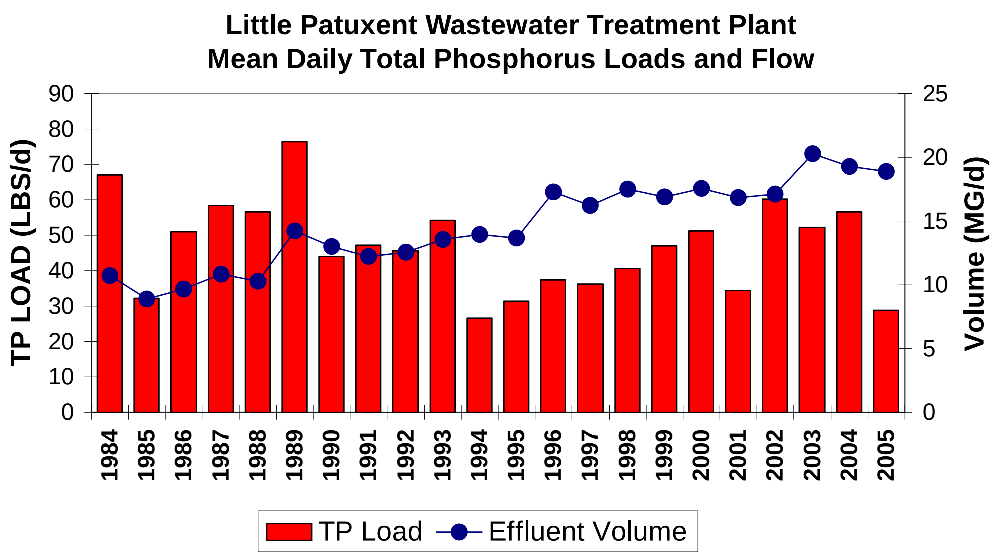
BNR technology was implemented at this facility in 1992.
ENR technology is scheduled to be implemented by 2010.



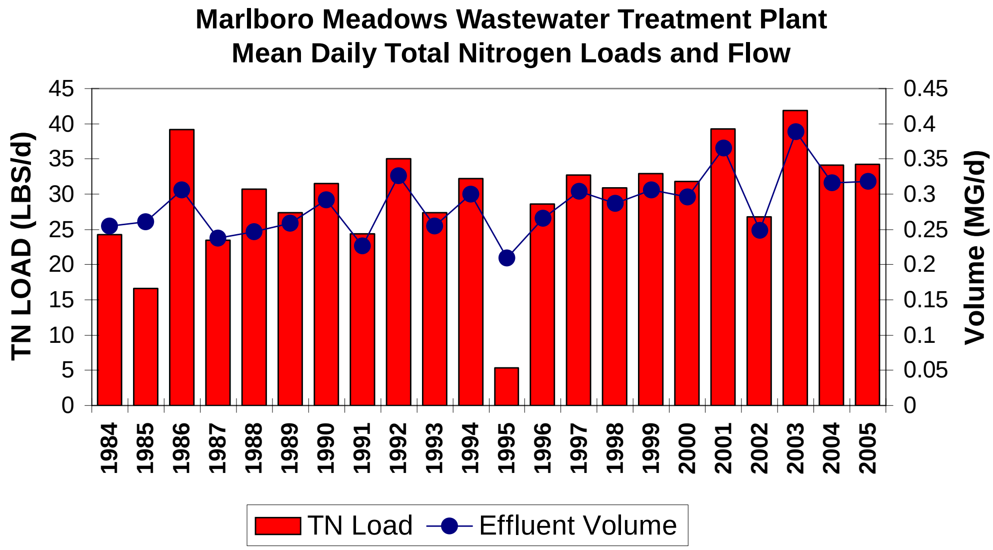


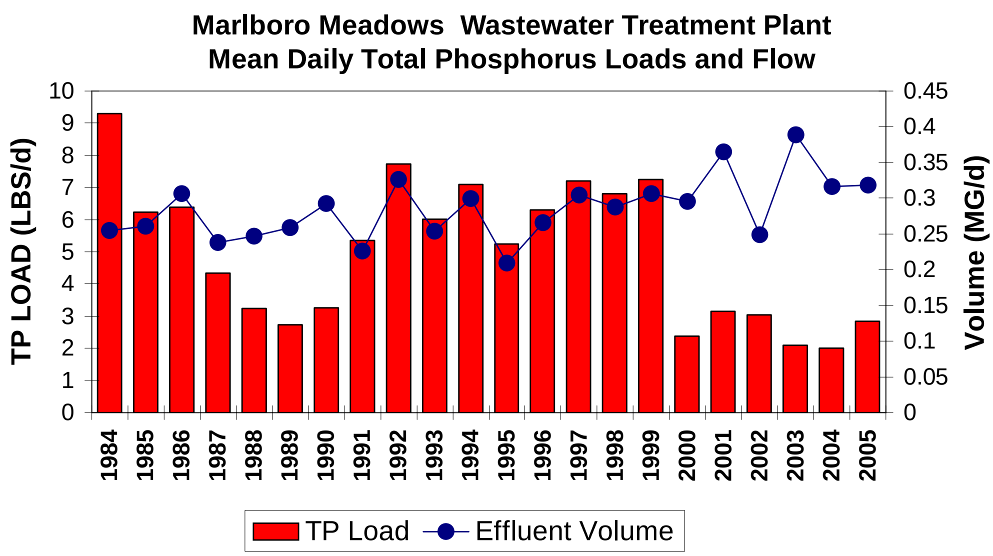
BNR technology was implemented at this facility in 1990.
Federal facility: ENR information not available.



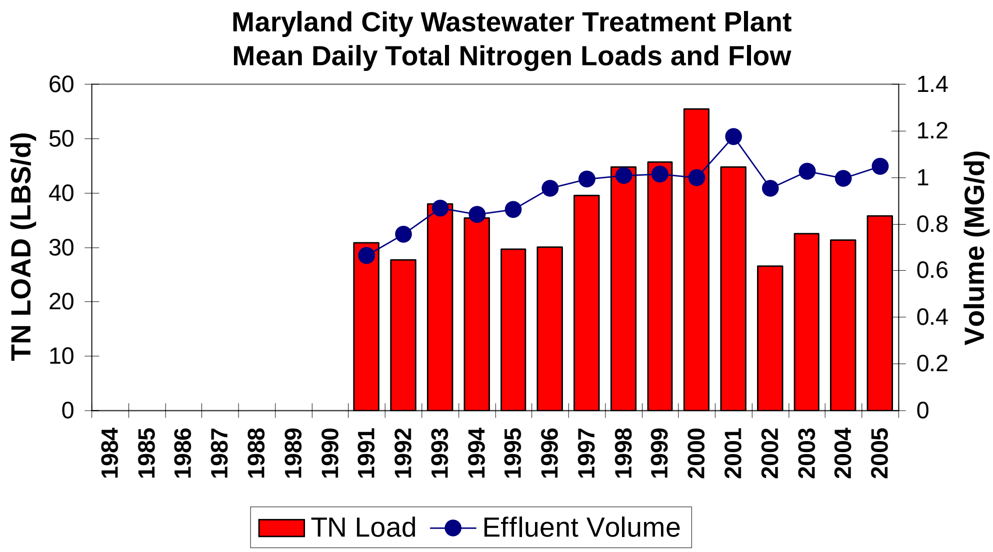


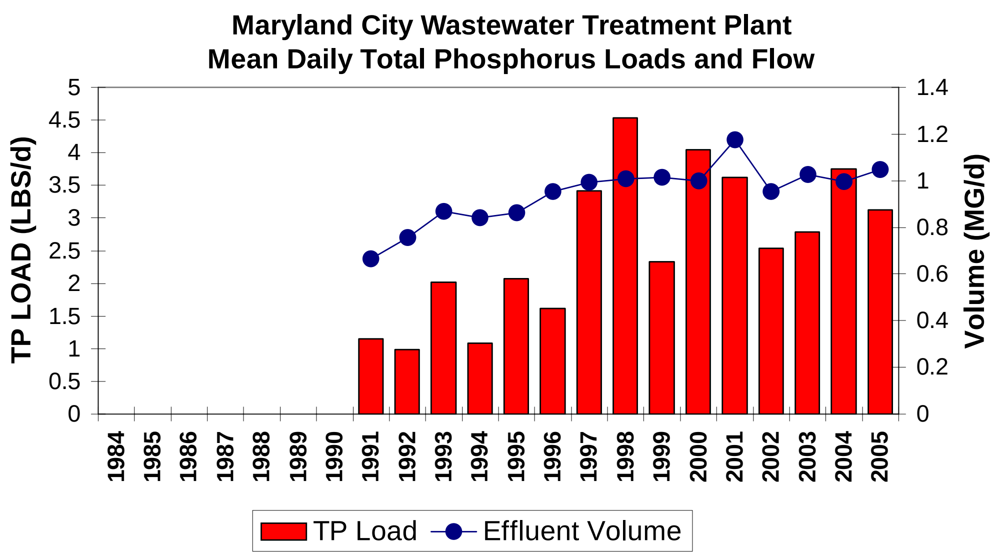
BNR technology was implemented at this facility in 1999.
ENR technology is scheduled to be implemented by 2010.



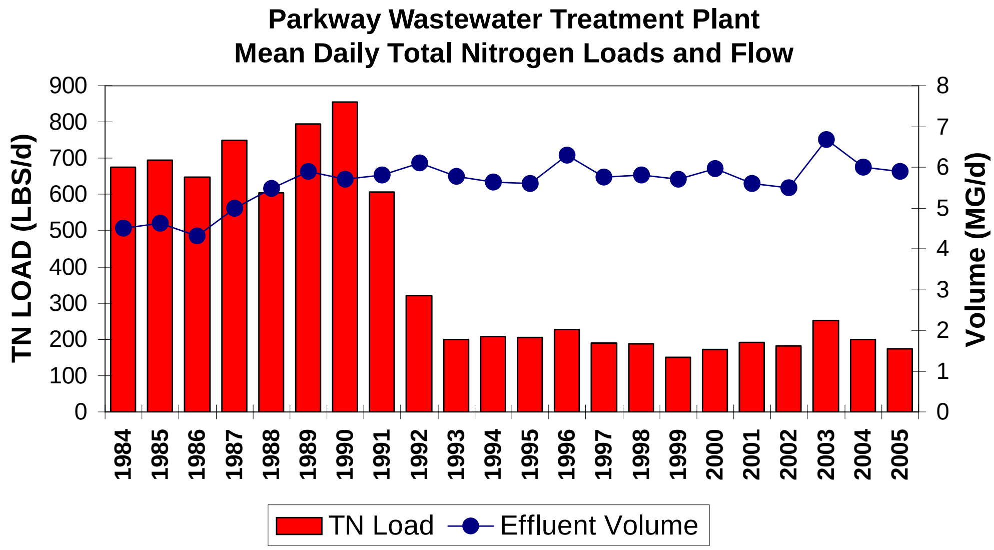


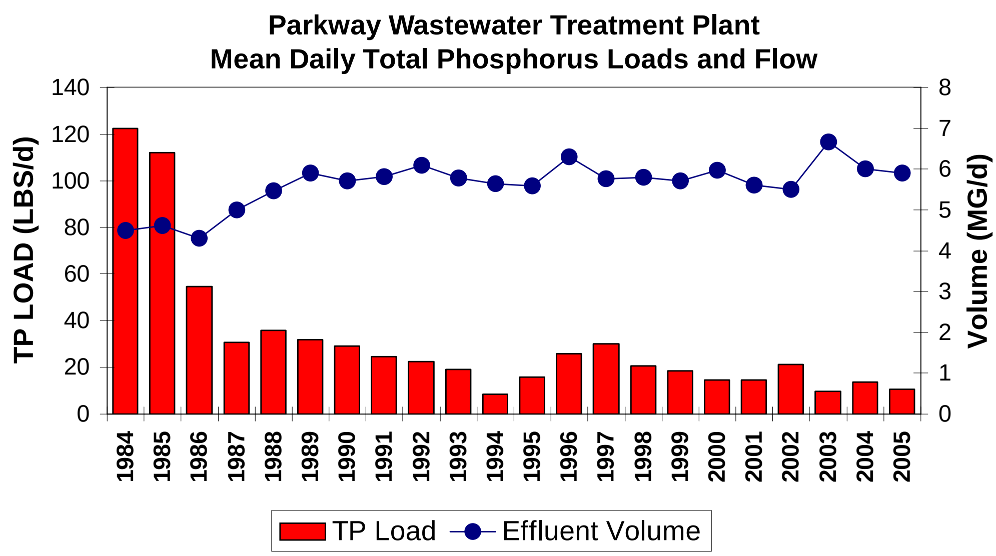
Private facility: BNR and ENR information not available.



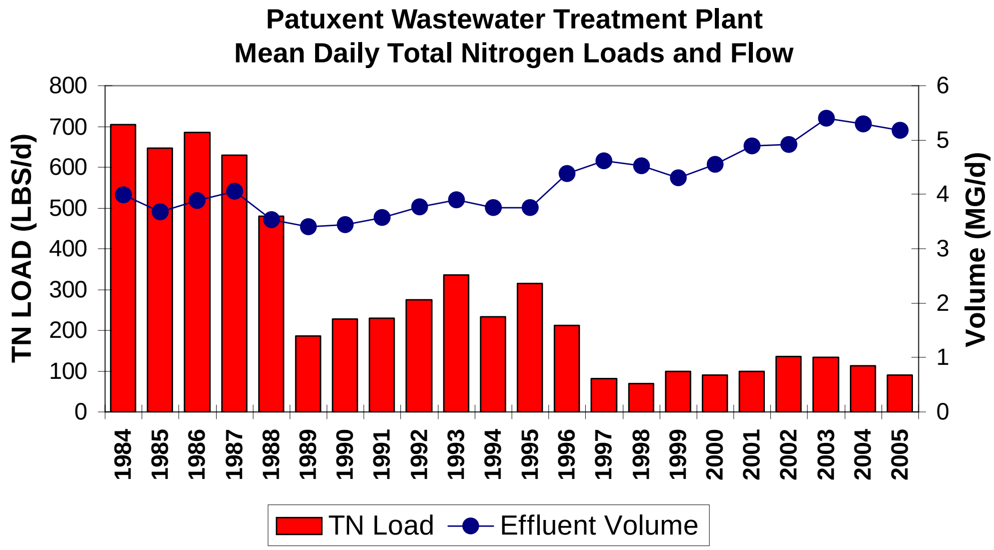


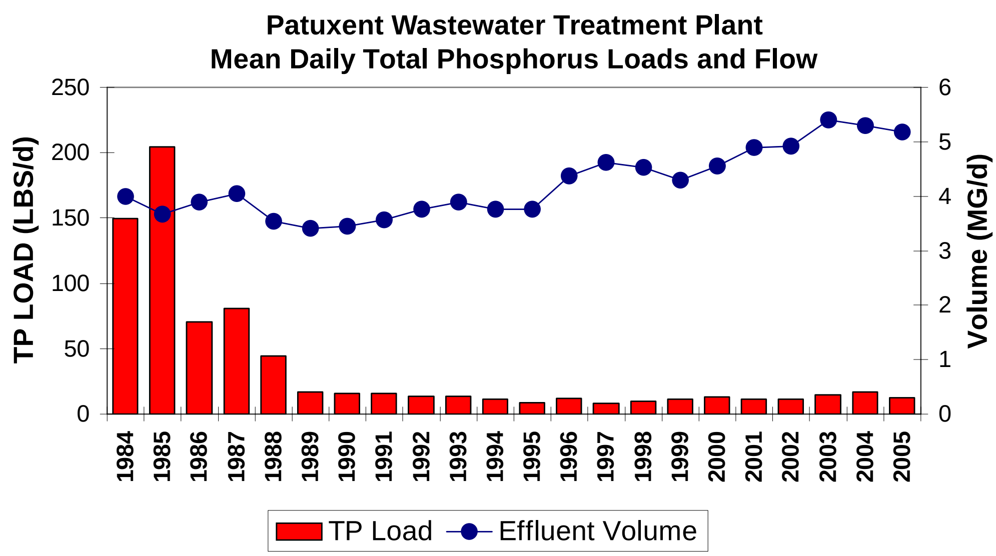
BNR technology was implemented at this facility in 1990.
ENR technology is scheduled to be implemented by 2010.



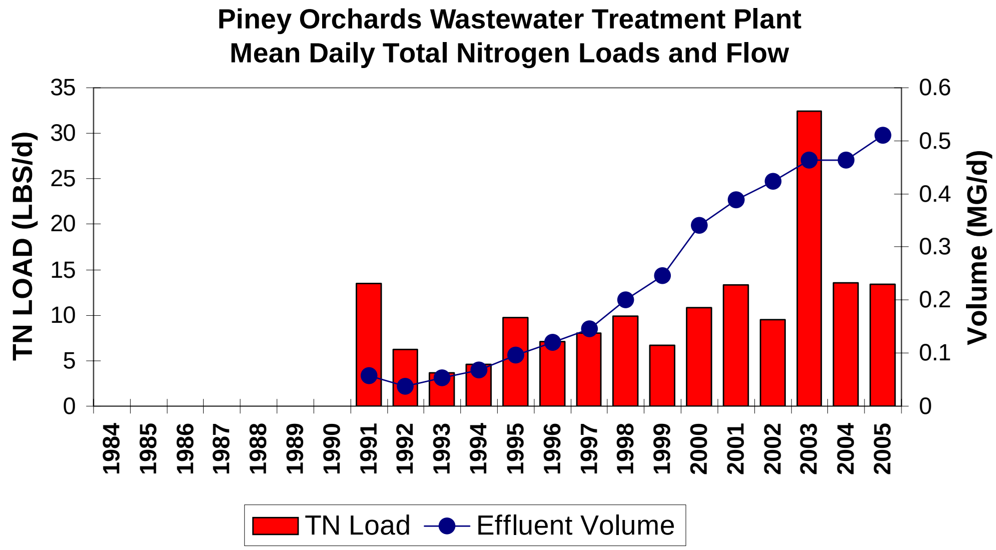


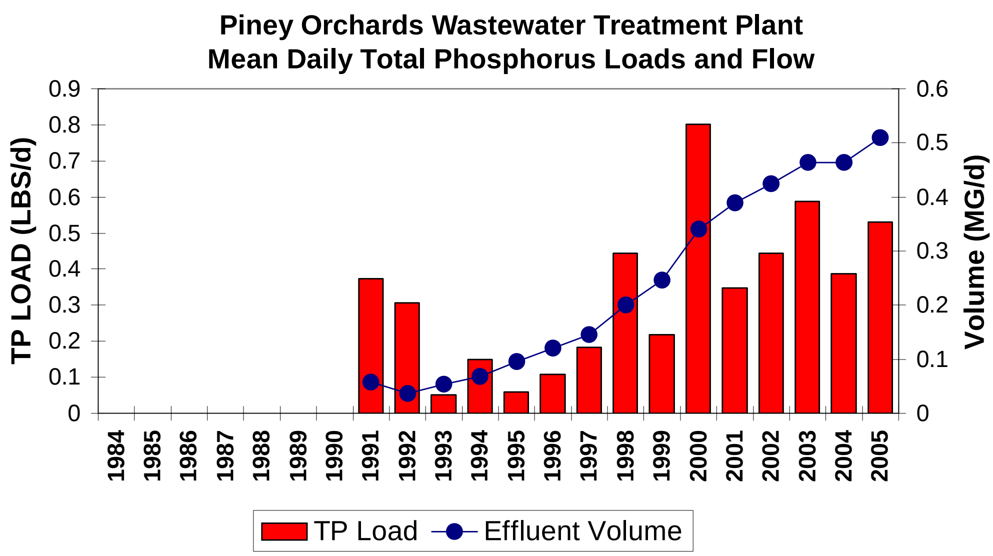
BNR technology was implemented at this facility in 1992.
ENR technology is scheduled to be implemented by 2010.



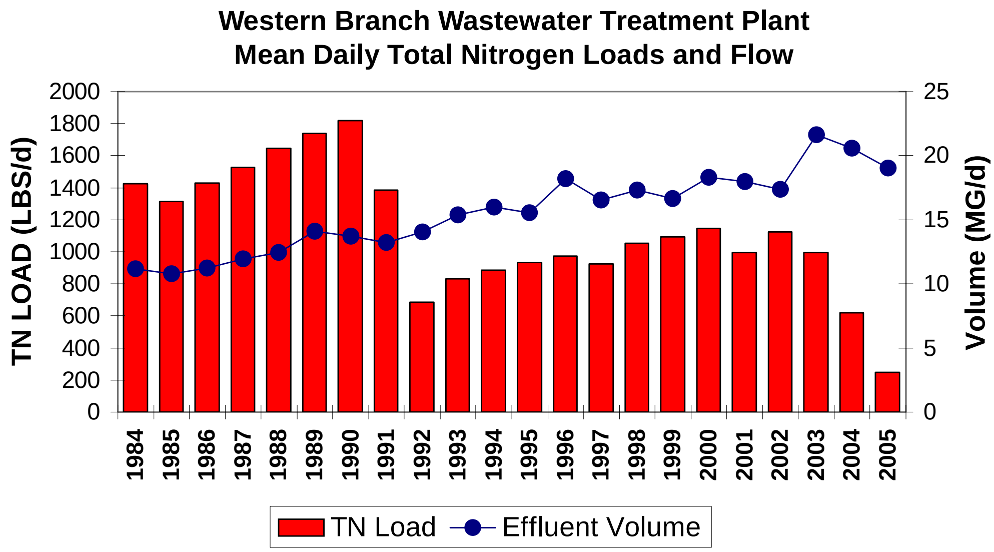


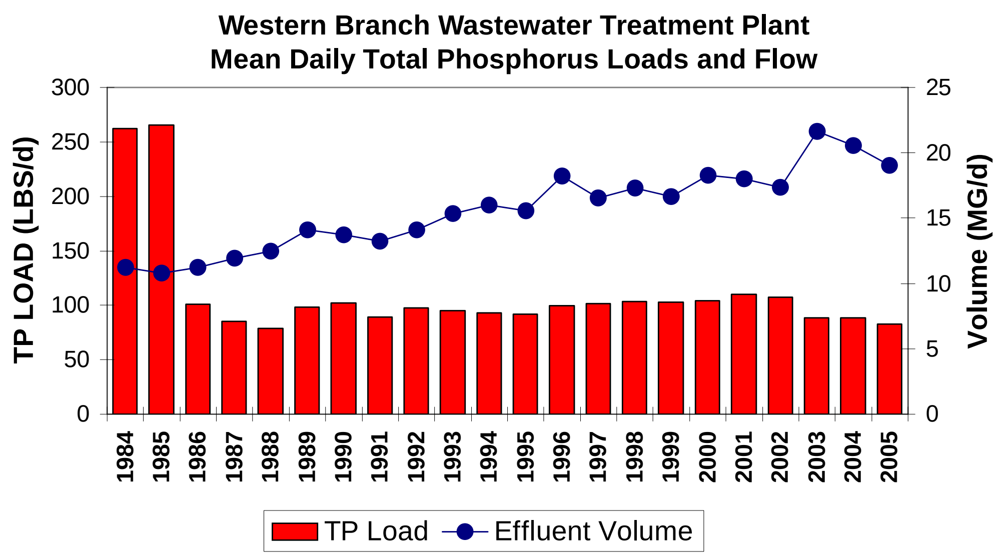
BNR technology was implemented at this facility in 1990.
ENR technology is scheduled to be implemented by 2010.





Private facility: BNR and ENR information not available.





BNR technology was implemented at this facility in 1995.
ENR technology is scheduled to be implemented by 2010.

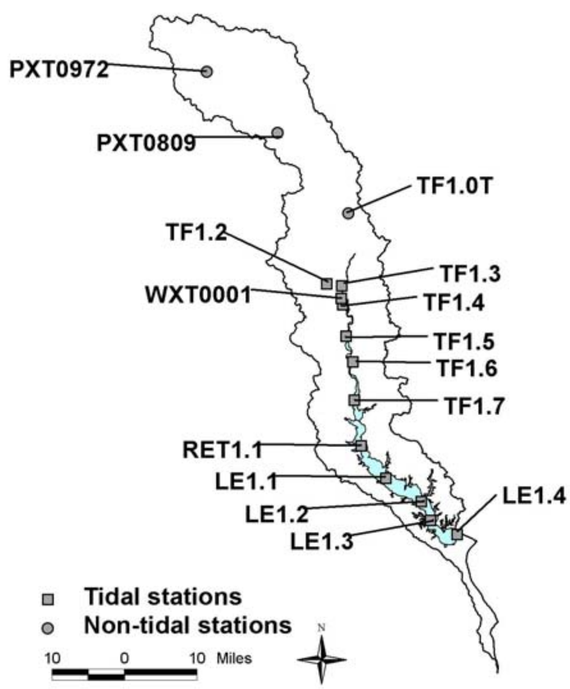
Appendix B – Long-term Tidal Water Quality Data

Water quality concentrations based on measured concentration data taken at long-term stations are graphed as follows:

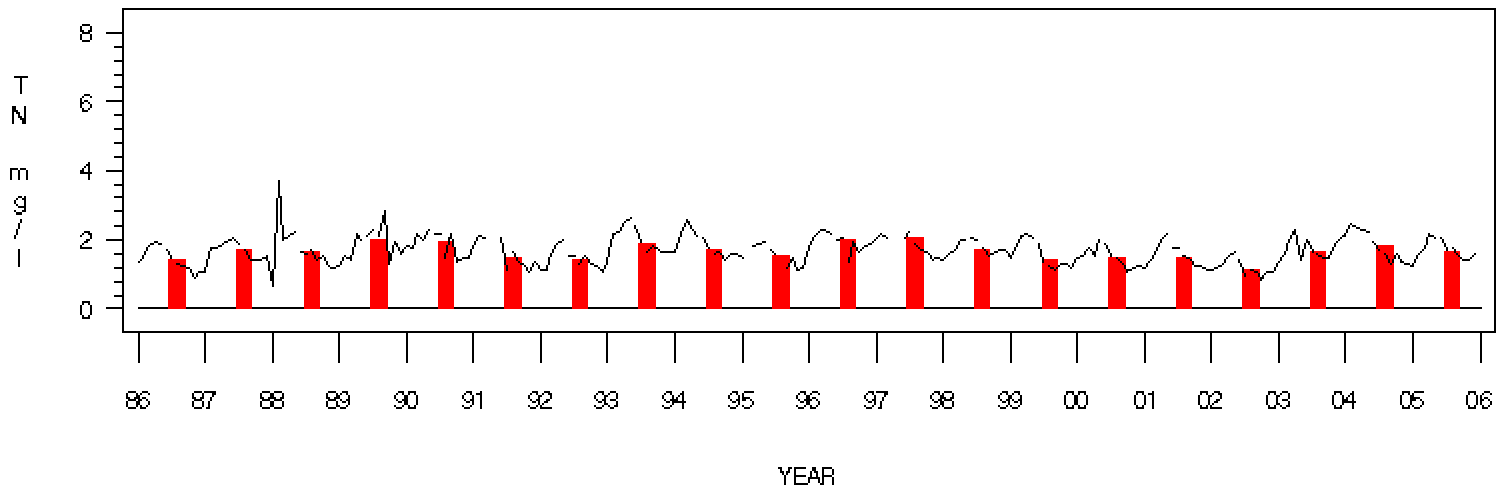
- For non-tidal stations, concentrations for total nitrogen, total phosphorus and total suspended solids for surface layer sample are shown for each sampling date as small black dots; annual medians of those values are shown as red bars.

- For tidal stations, concentrations for total nitrogen, total phosphorus, total suspended solids and chlorophyll *a* are means of the surface and above pycnocline data, shown for each sampling date as small black dots; annual medians of those values are shown as red bars. Dissolved oxygen data is for the bottom layer and summer (June-September) only; red bar is the summer median for each year. Secchi depth is presented as the measurements (black dots) and the annual median value (red bar). **The longer-term (1985-2005) total suspended solids trend results may be affected by a change in laboratory in 1990 and should be used with caution (please see Appendix C for more information).**

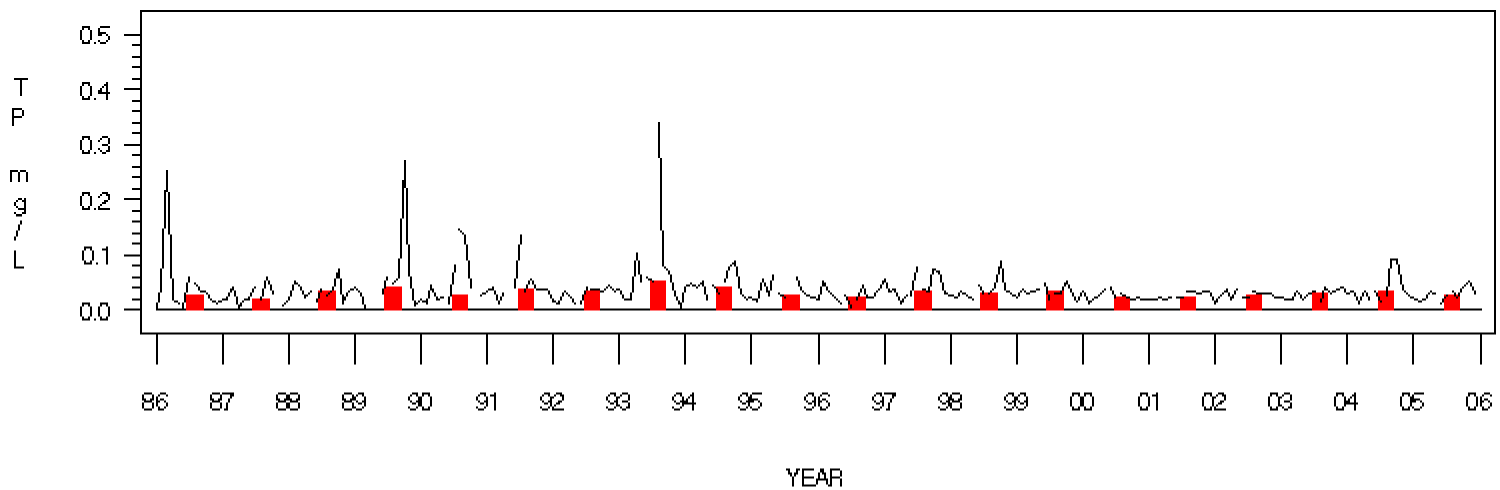
Note that parameter values tend to fluctuate highly from year to year, and much of this fluctuation can be attributed to flow conditions. For example, in high flow years (wet years), nutrient levels are higher than in dry years. Also, the timing of the spring freshet and other weather conditions can determine the strength and duration of the pycnocline, strongly affecting dissolved oxygen levels. Topography, hydrogeology, stream hydrology, how a basin is developed and management actions all affect the influence of weather conditions.



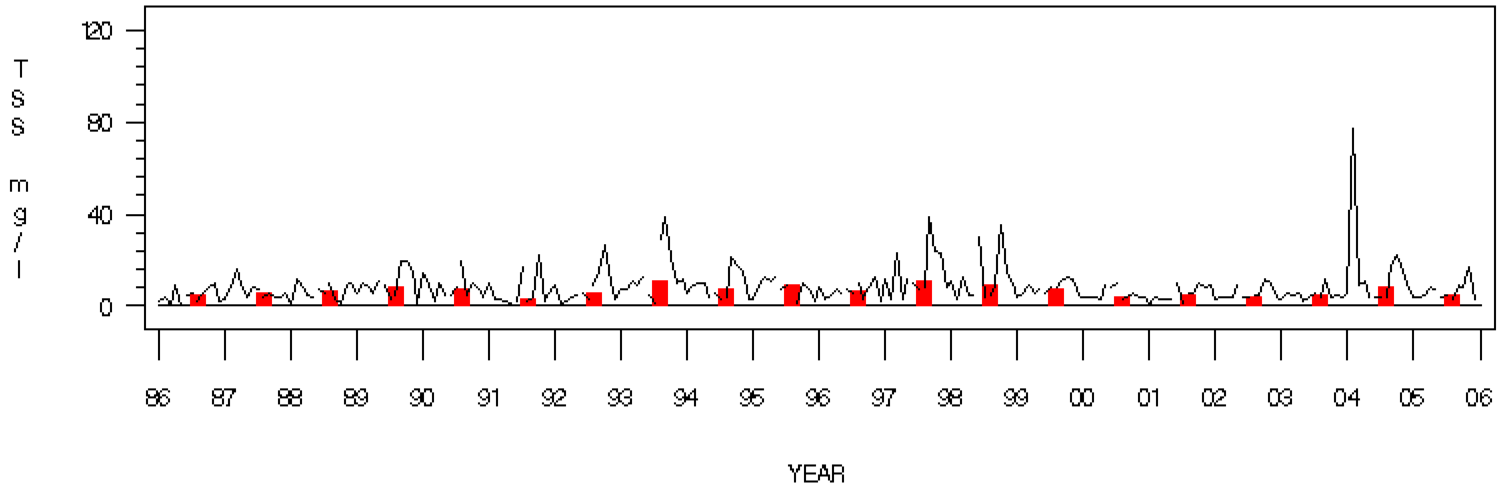
Total Nitrogen at PXT0809 (Patuxent River below Rocky Gorge Dam), 1986–2005, layer= S



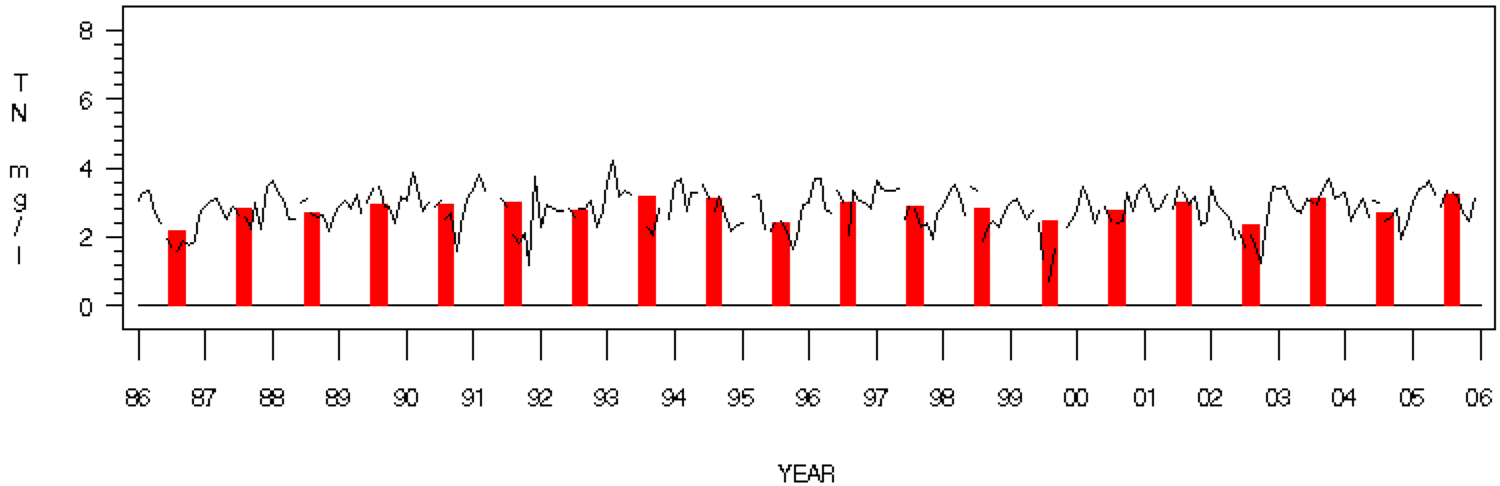
Total Phosphorus at PXT0809 (Patuxent River below Rocky Gorge Dam), 1986–2005, layer= S



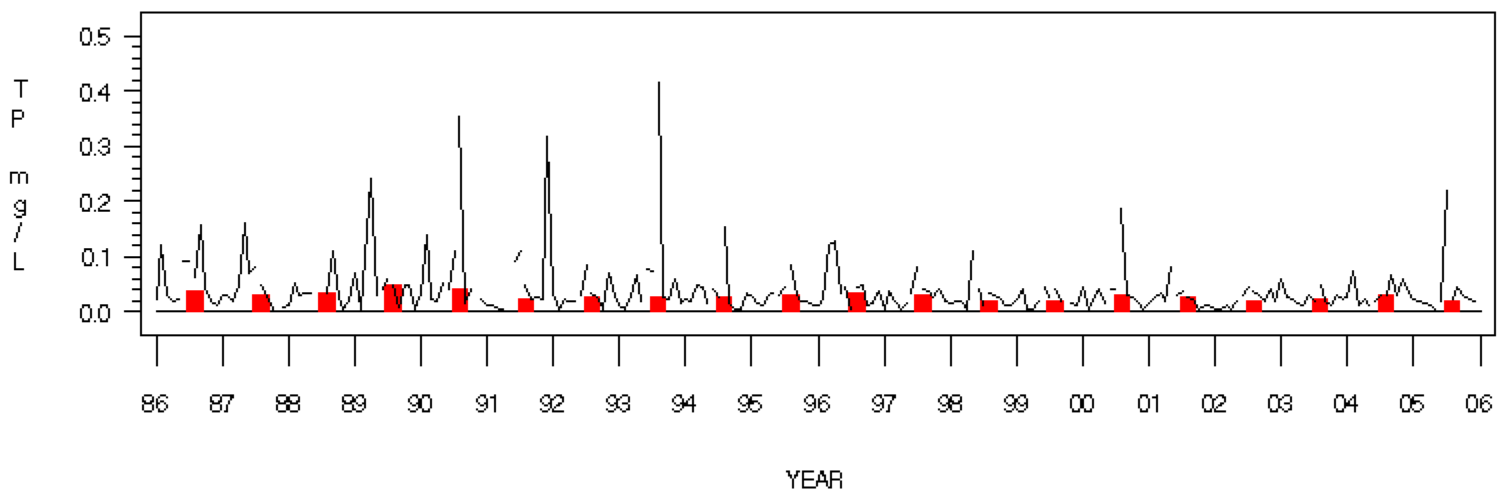
Total Suspended Solids at PXT0809 (Patuxent River below Rocky Gorge Dam), 1986—2005, layer= S



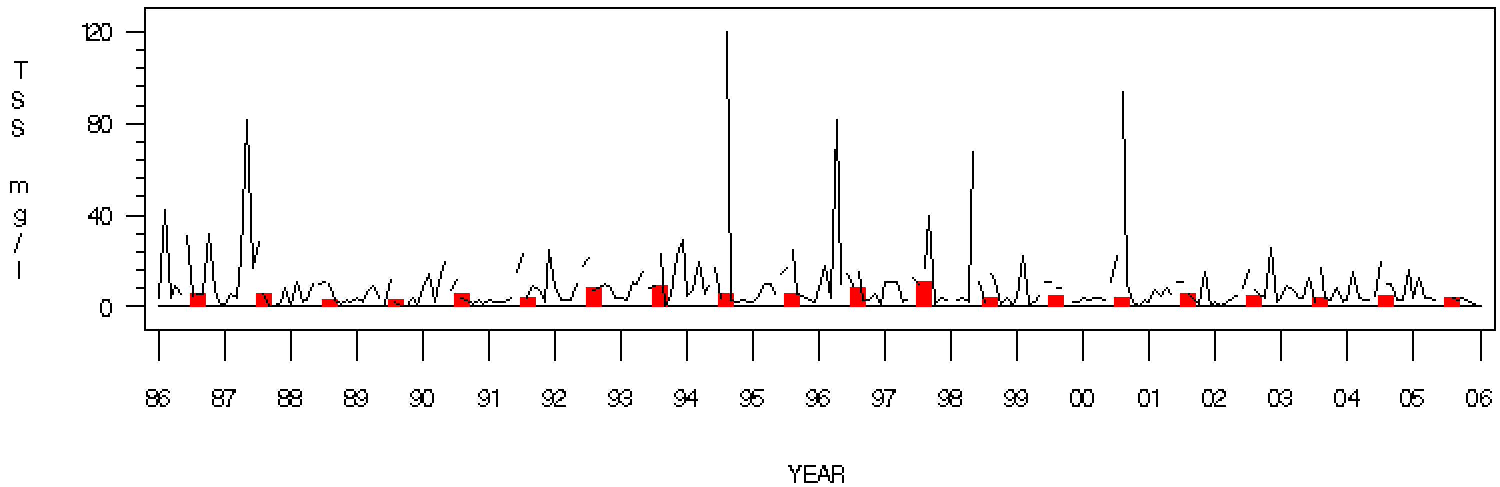
Total Nitrogen at PXT0972 (Patuxent River at Bridge on Rte 97 near Unity), 1986–2005, layer= S



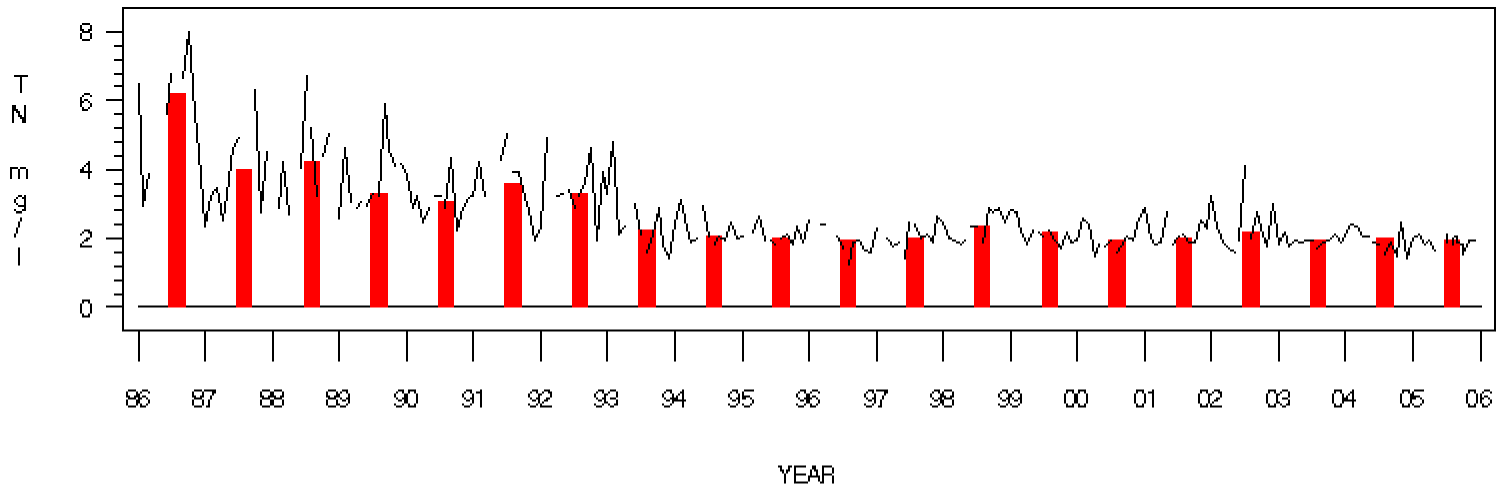
Total Phosphorus at PXT0972 (Patuxent River at Bridge on Rte 97 near Unity), 1986–2005, layer= S



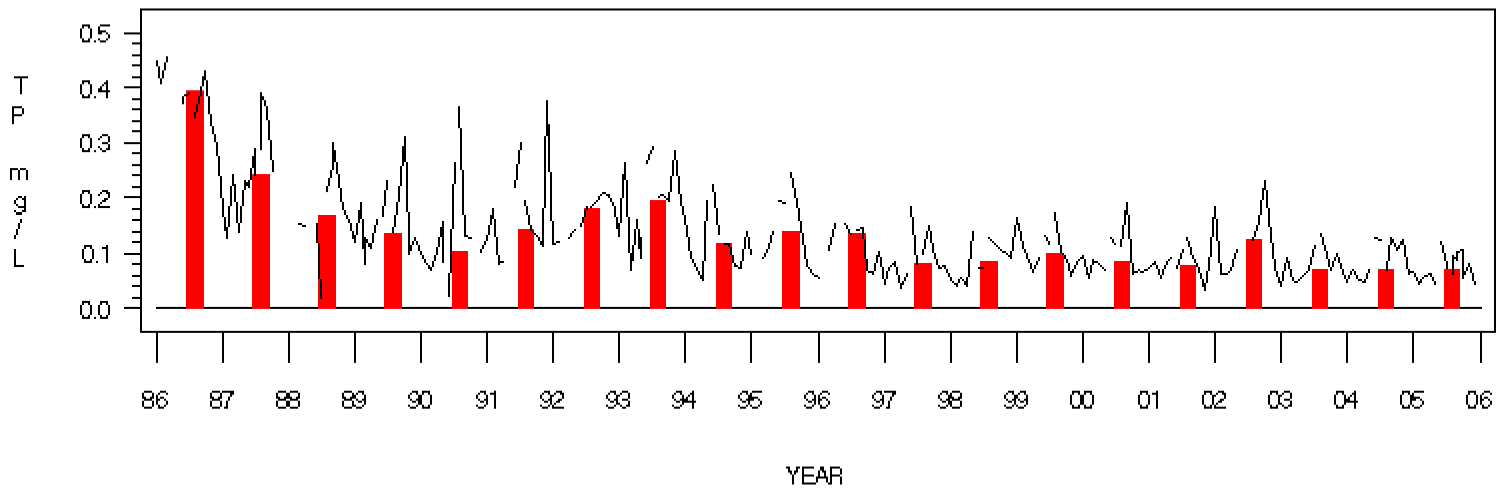
Total Suspended Solids at PXT0972 (Patuxent River at Bridge on Rte 97 near Unity), 1986—2005, layer=S



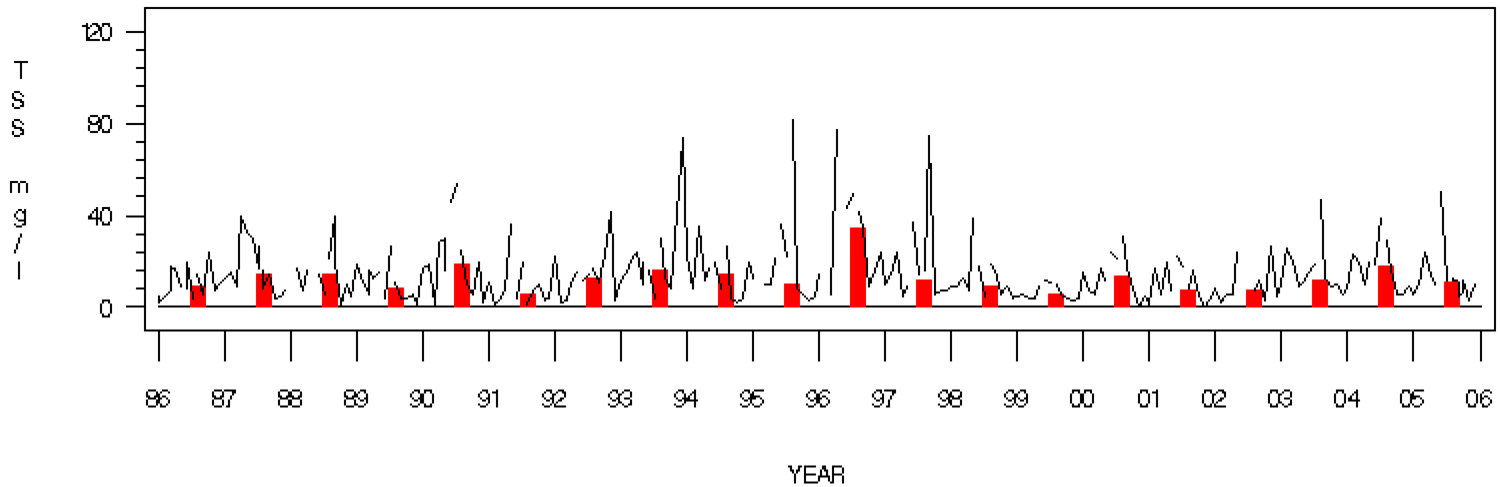
Total Nitrogen at TF1.0T (Patuxent River MD Rte 50 bridge), 1986–2005, layer= S

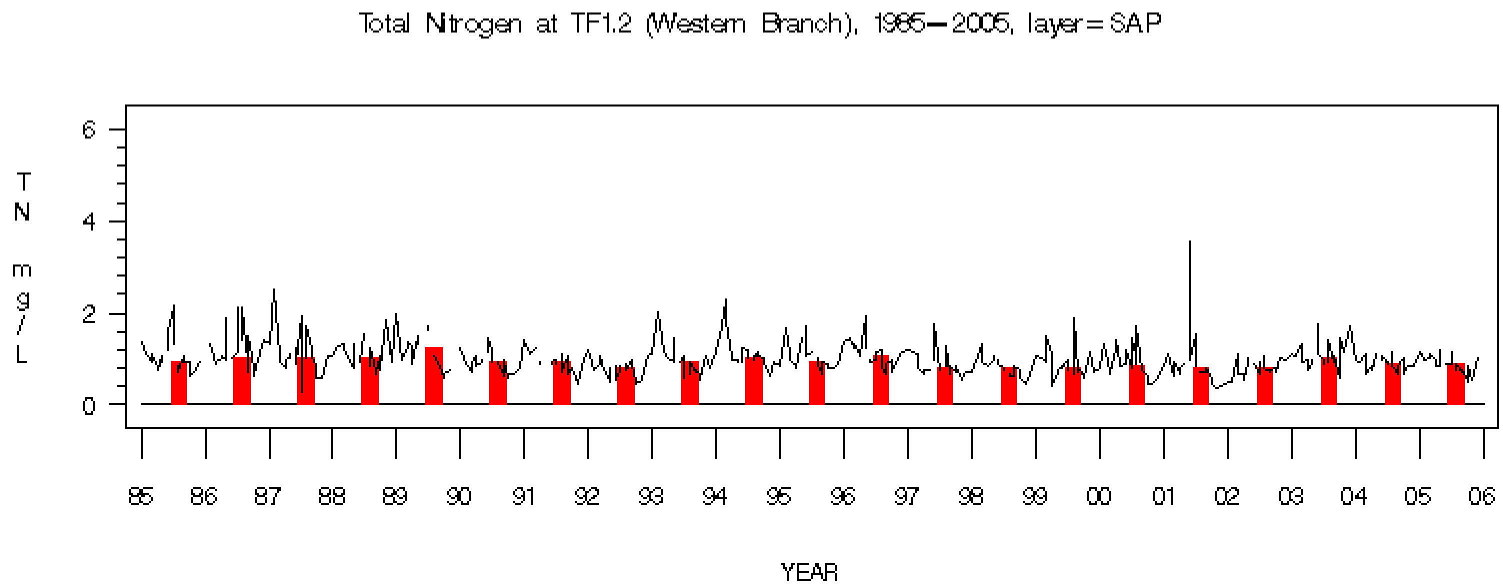


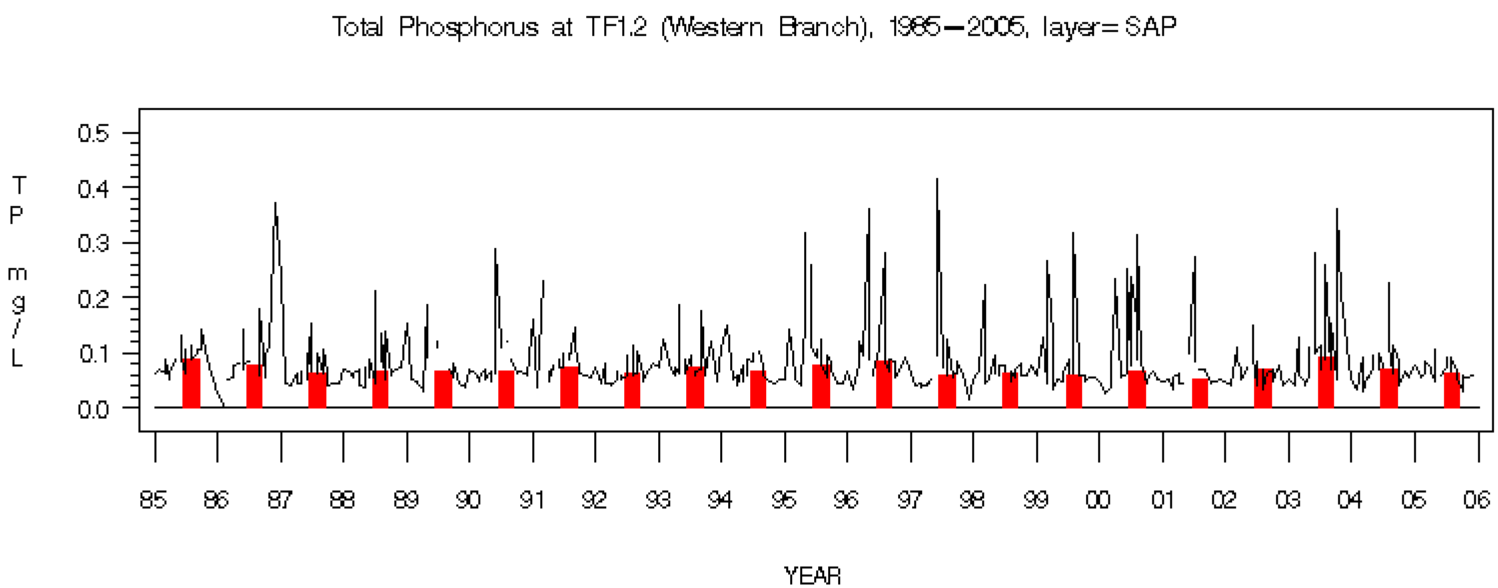
Total Phosphorus at TF1.0T (Patuxent River MD Rte 50 bridge), 1986–2005, layer= S

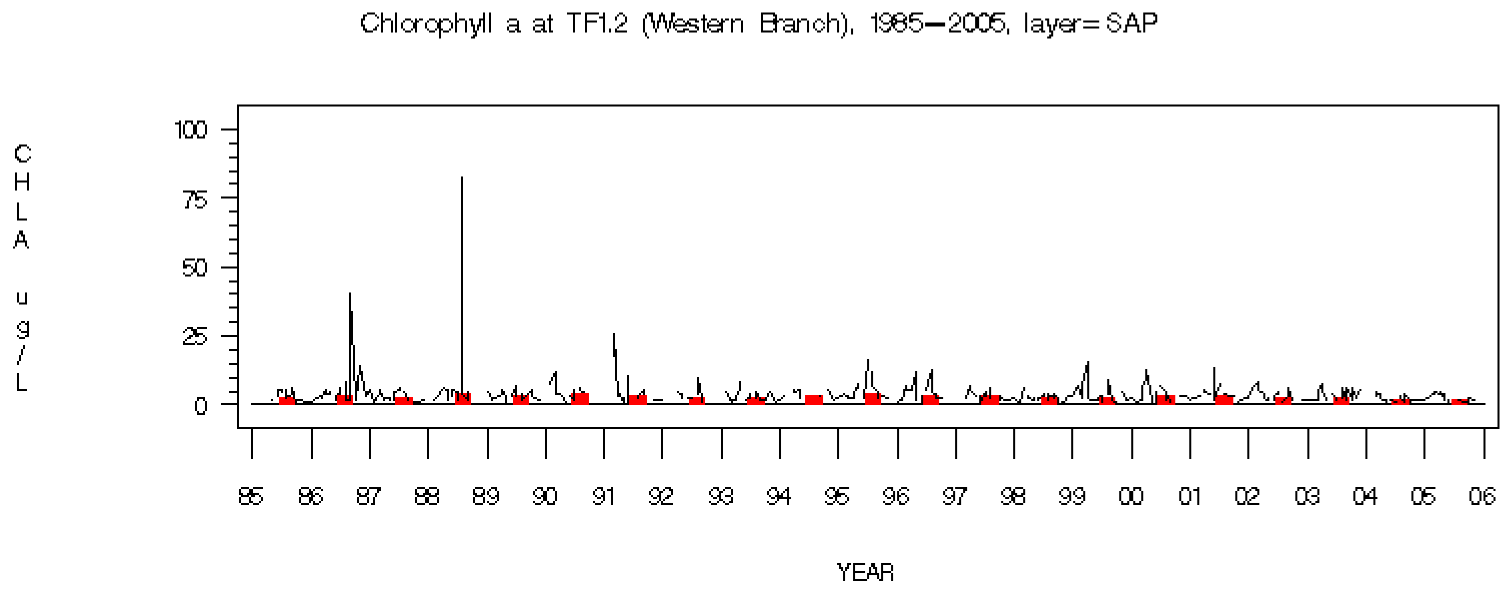


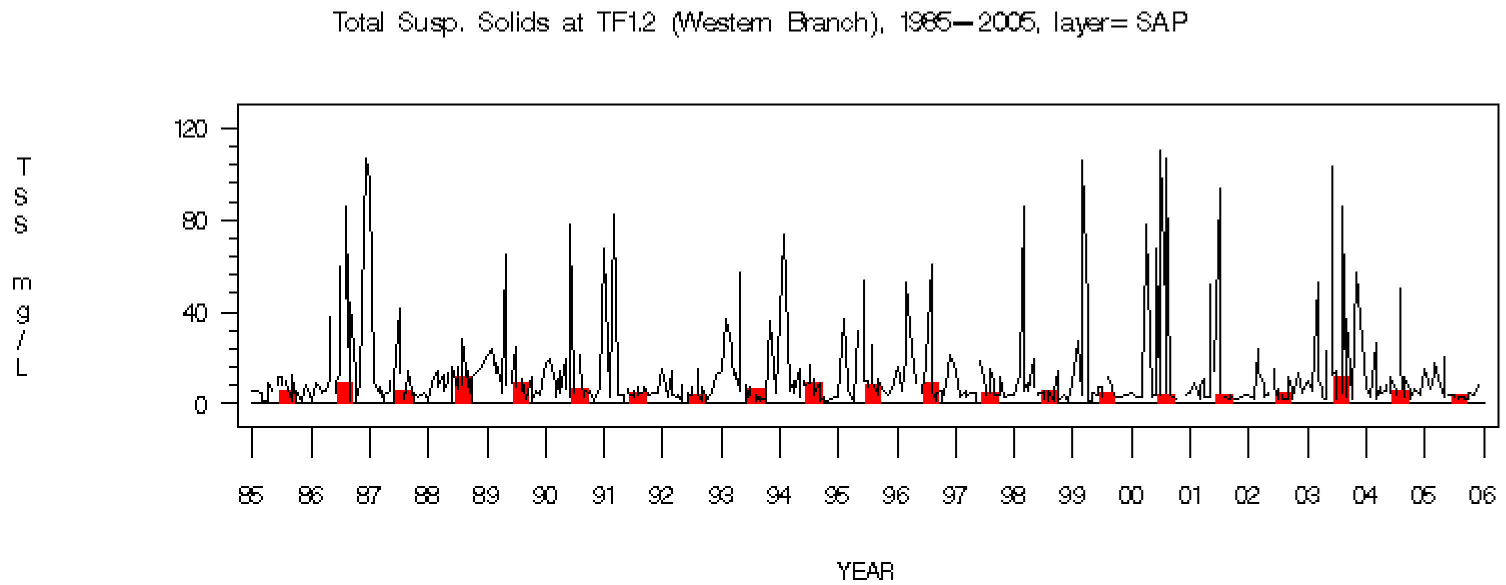
Total Suspended Solids at TF1.0T (Patuxent River MD Rte 50 bridge), 1986—2005, layer=S



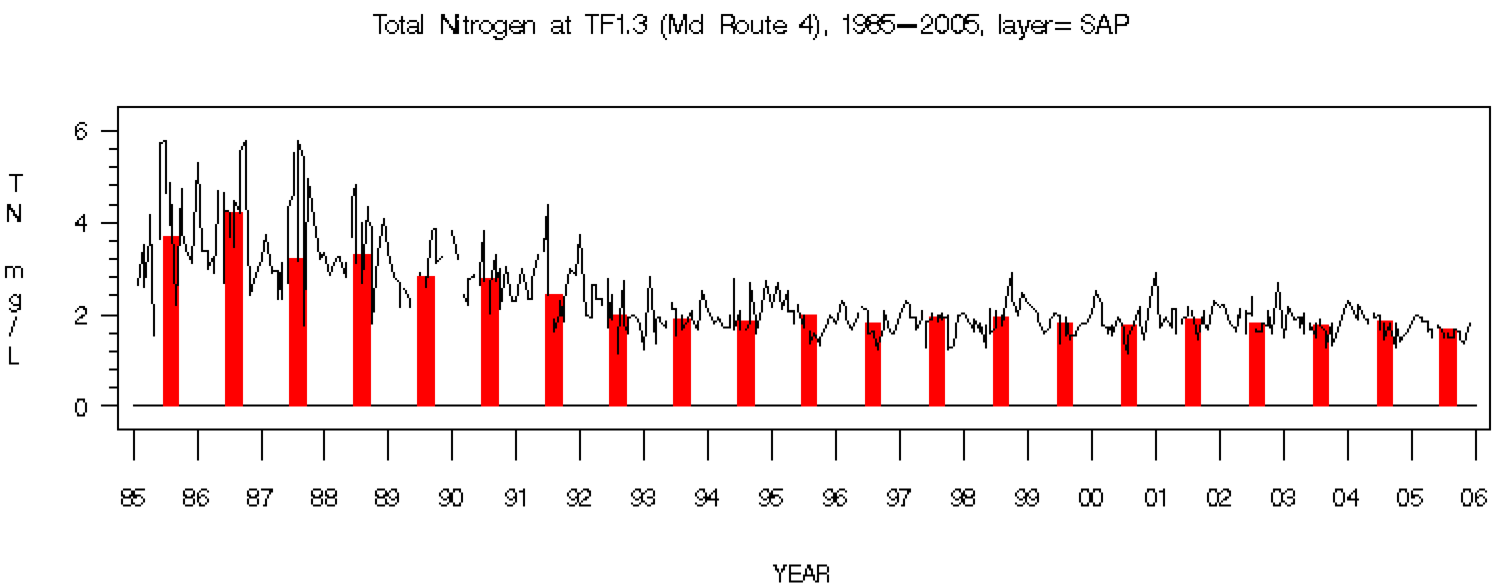

Total Nitrogen at TF1.2 (Western Branch), 1985–2005, layer=SAP
TN mg/L
0
2
4
6
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

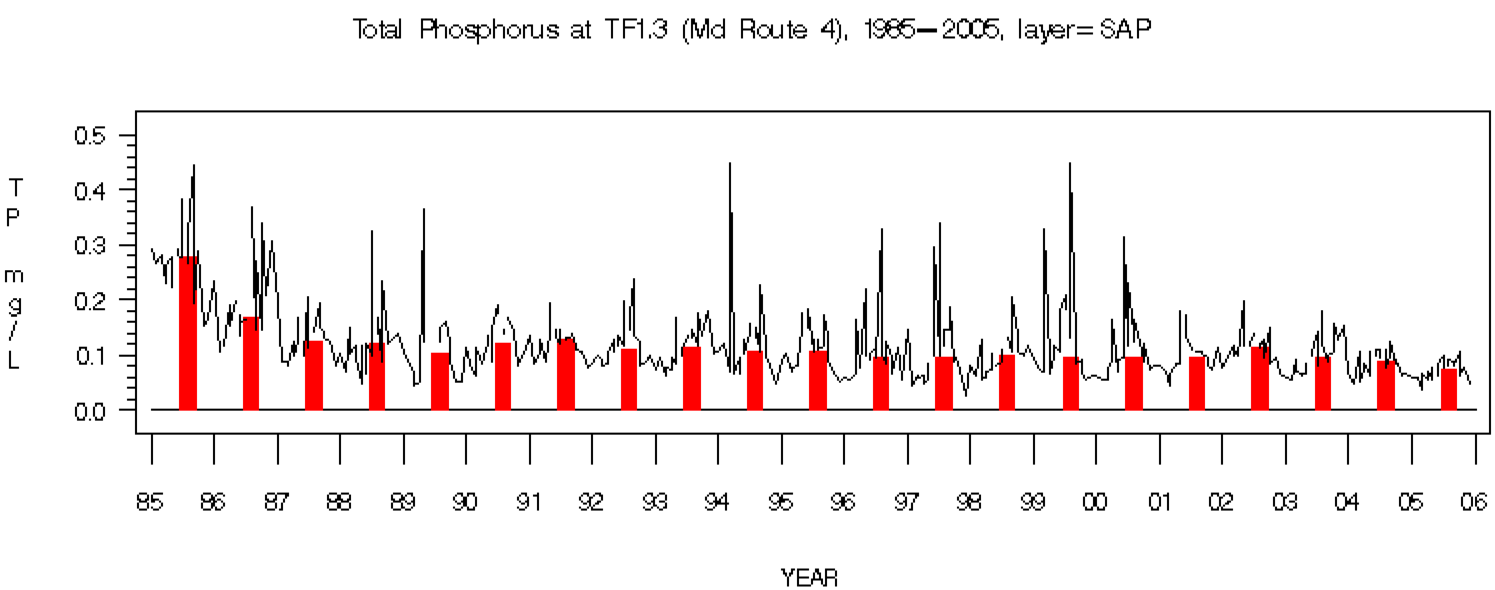

Total Phosphorus at TF1.2 (Western Branch), 1985–2005, layer=SAP
TP mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

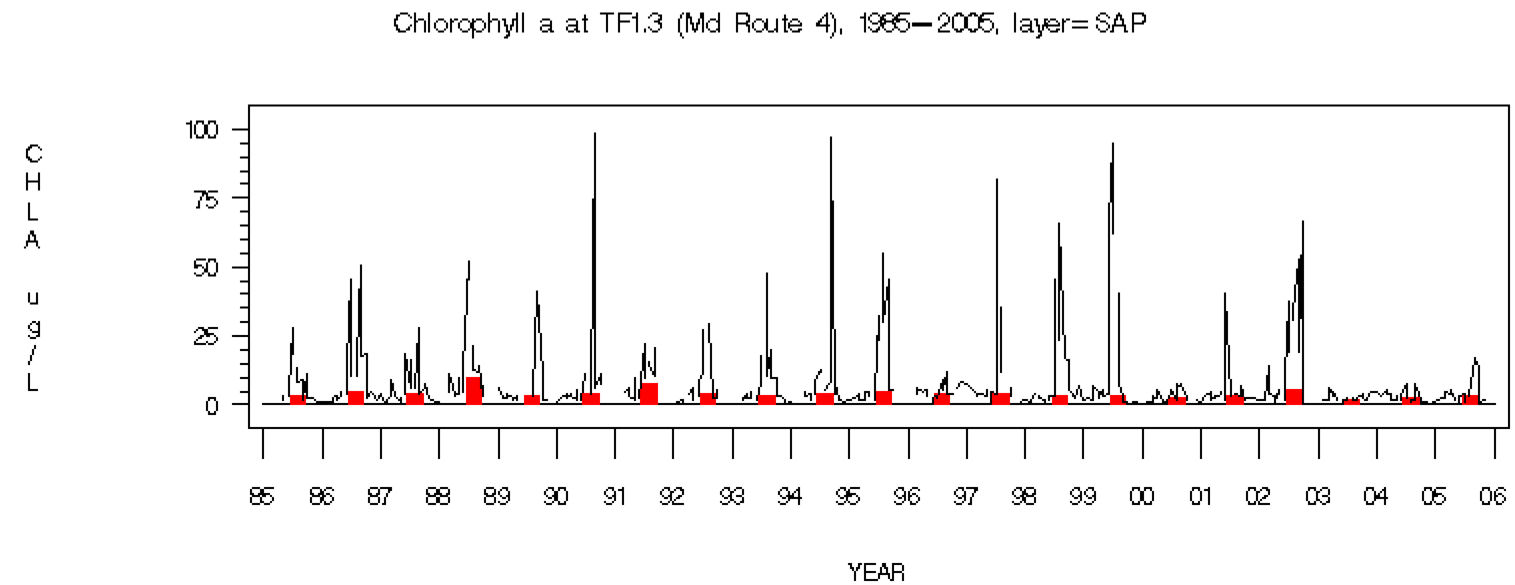


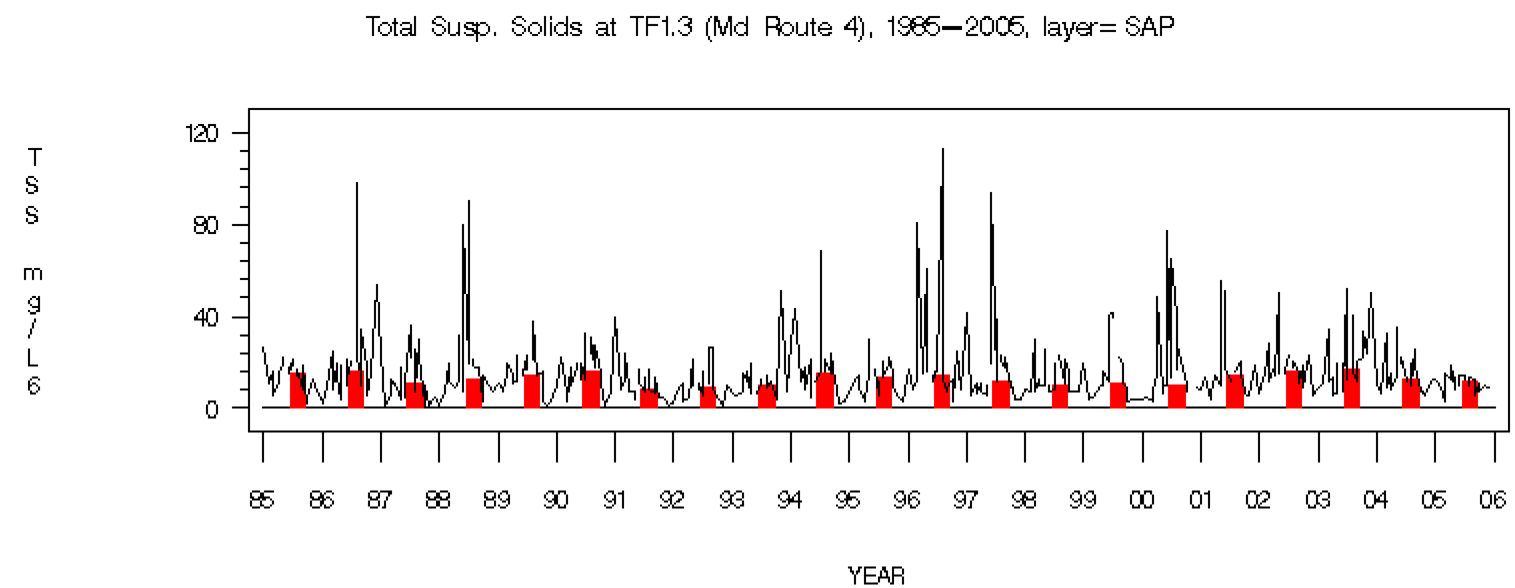


Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations. NOTE: Station is to shallow for Secchi depth or bottom dissolved oxygen measurements.

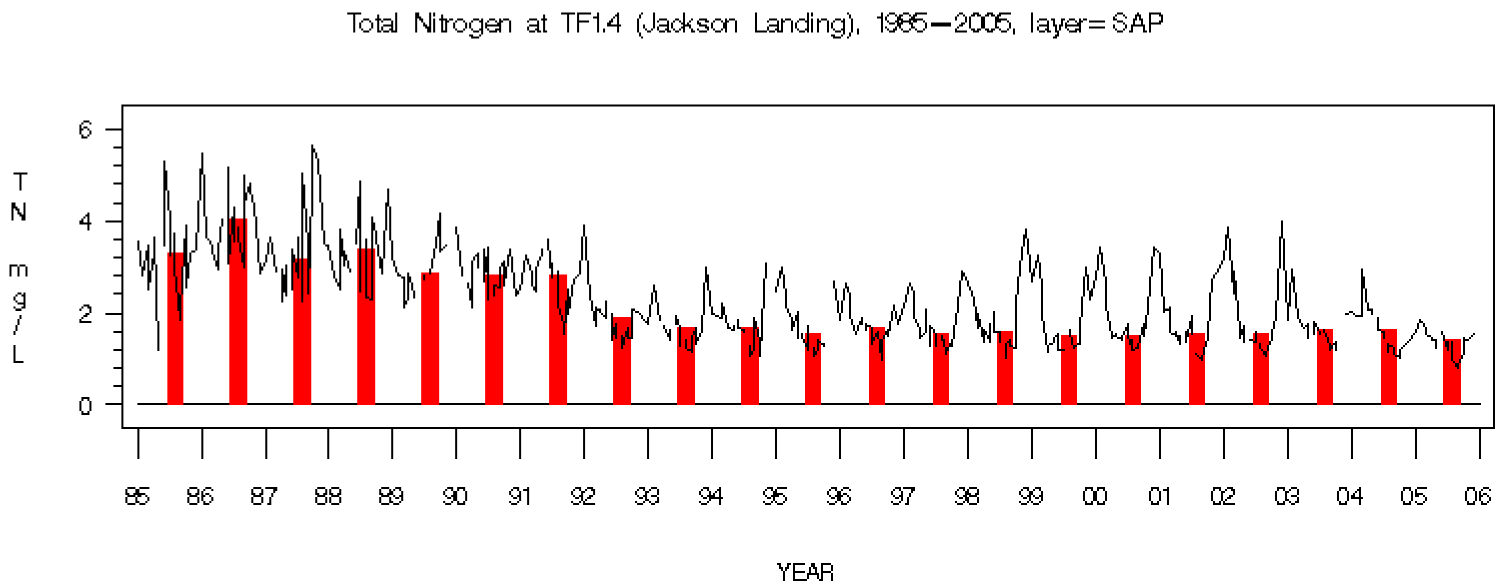

Total Nitrogen at TF1.3 (Md Route 4), 1985—2005, layer= SAP
T
N
mg/L
0
2
4
6
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
YEAR

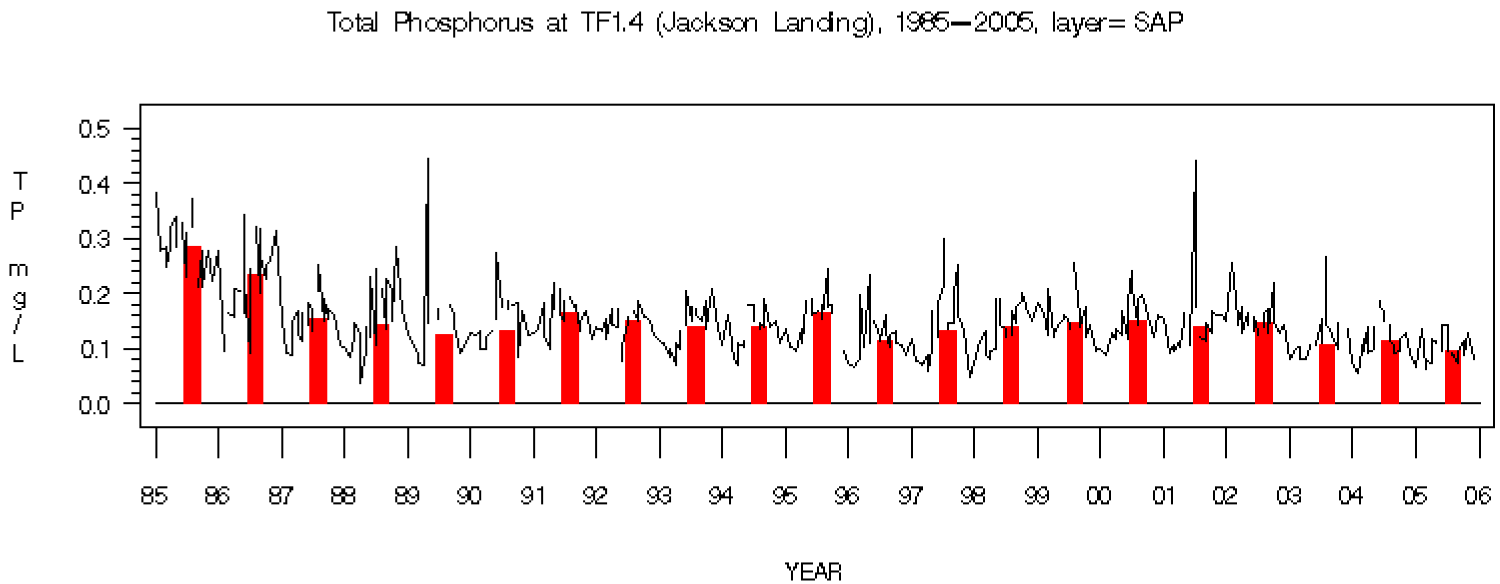

Total Phosphorus at TF1.3 (Md Route 4), 1985—2005, layer= SAP
T
P
mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
YEAR

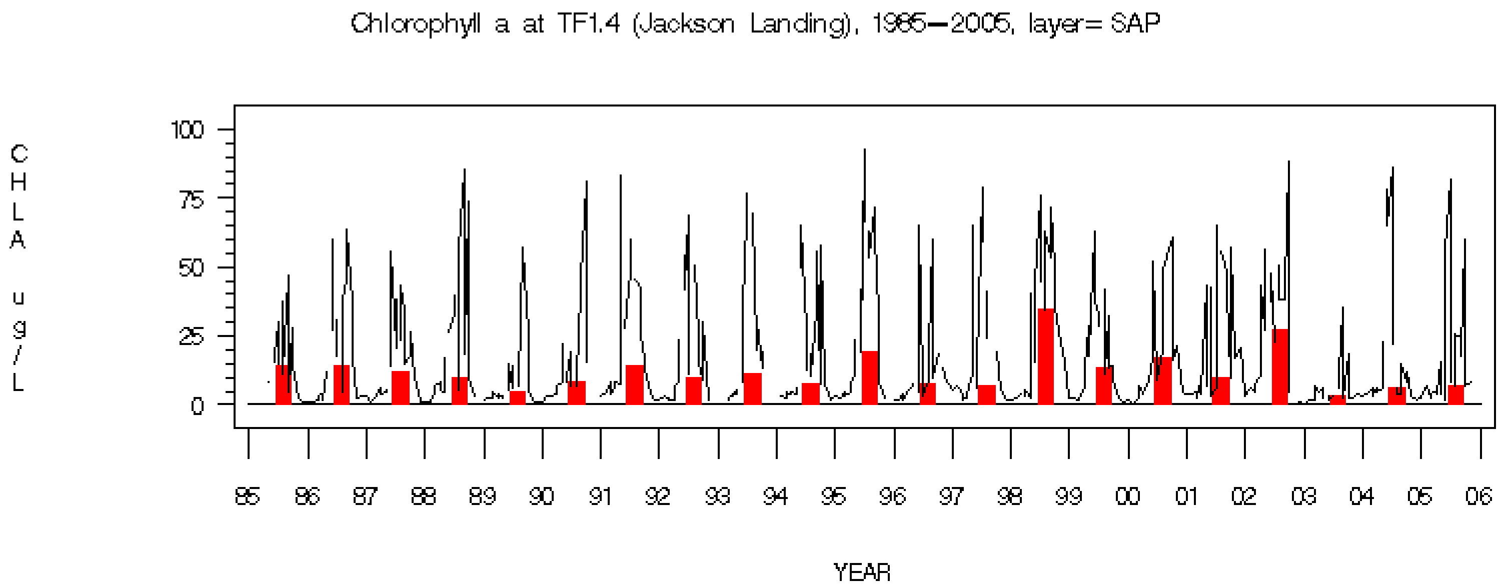


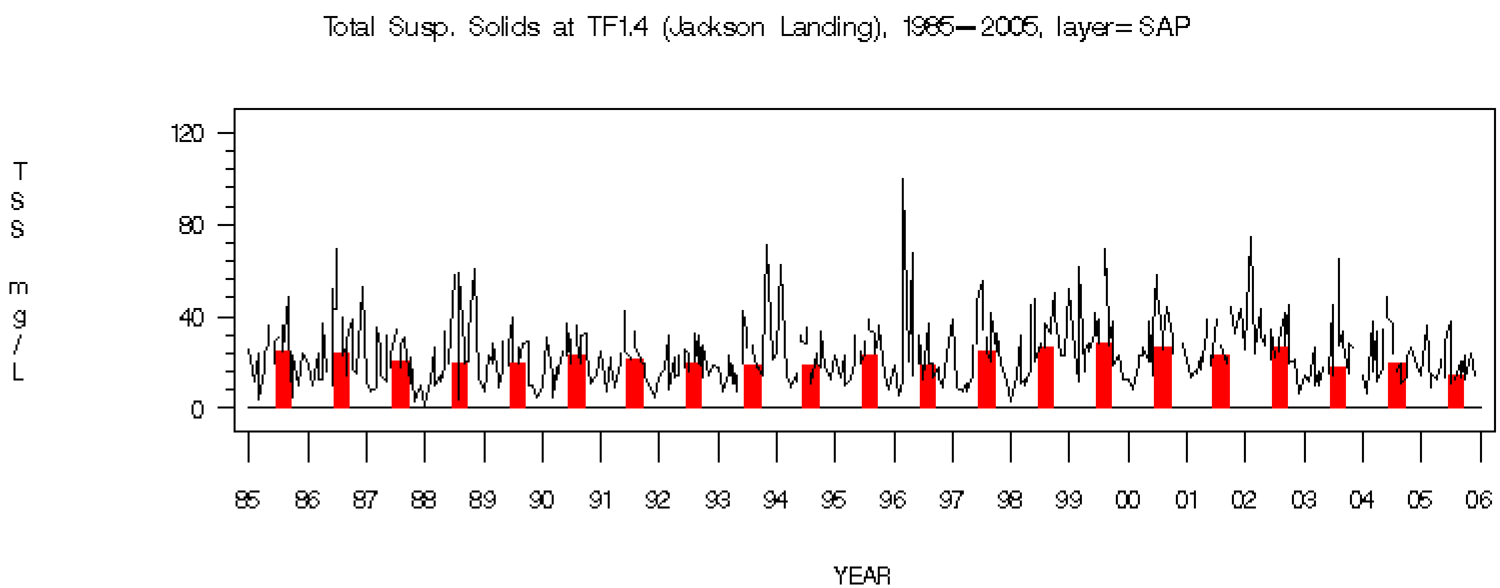


Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations. NOTE: Station is to shallow for Secchi depth or bottom dissolved oxygen measurements.

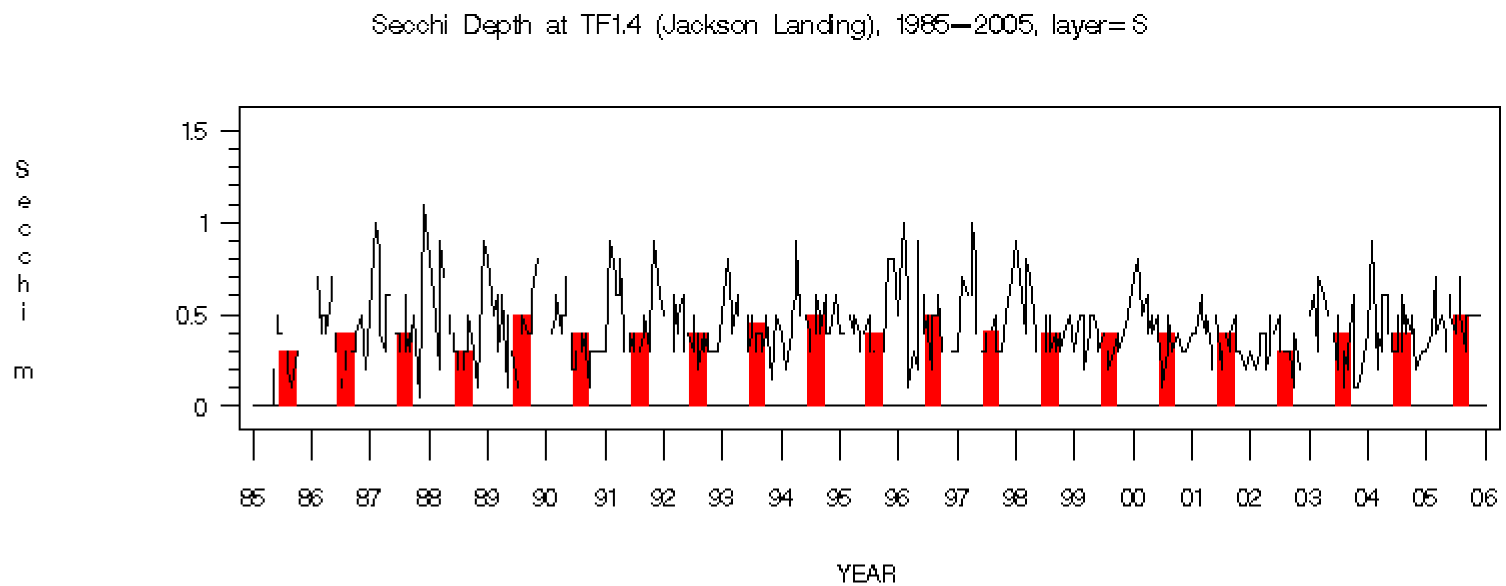

Total Nitrogen at TF1.4 (Jackson Landing), 1985—2005, layer= SAP
TN mg/L
0
2
4
6
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR


Total Phosphorus at TF1.4 (Jackson Landing), 1985—2005, layer= SAP
TP mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR



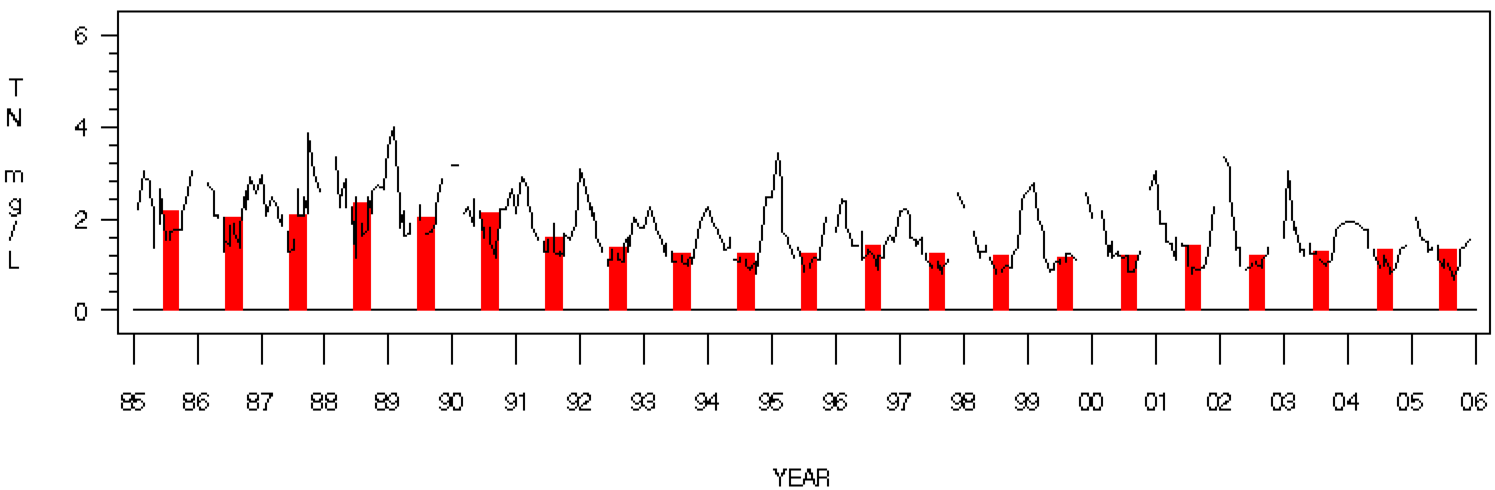


Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.

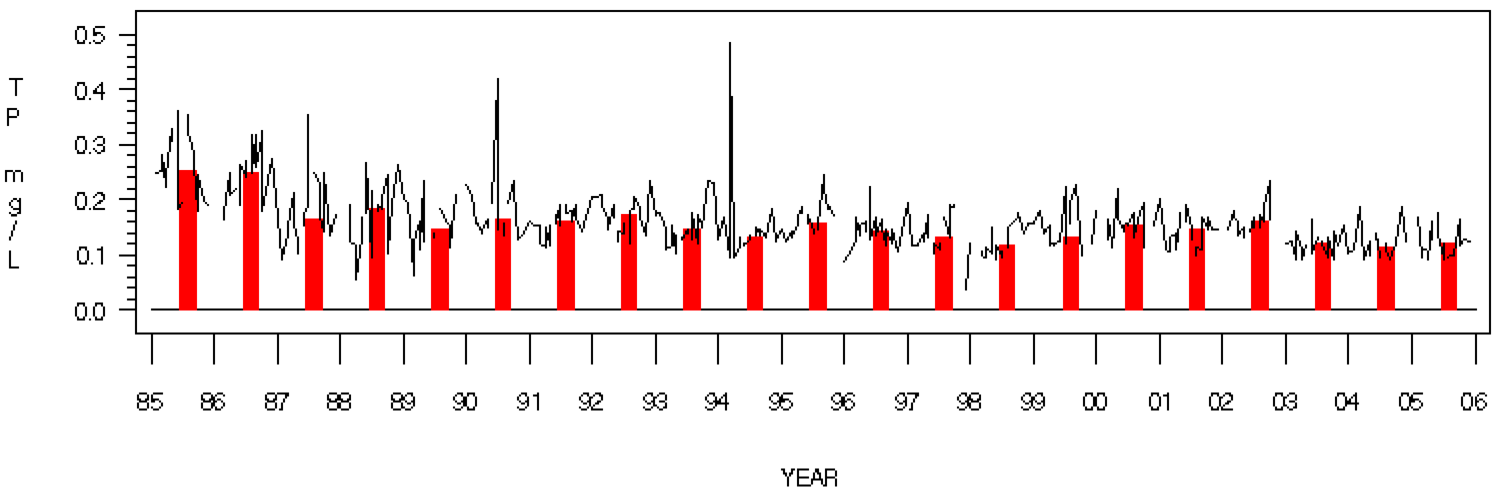


NOTE: Station is to shallow for bottom dissolved oxygen measurements.

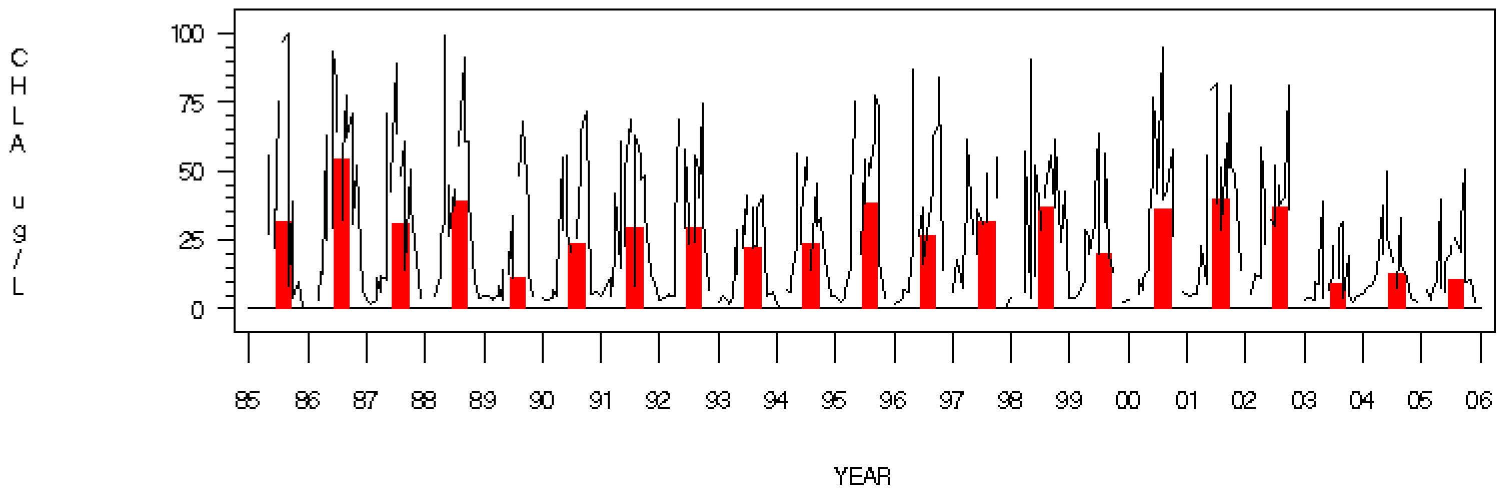
Total Nitrogen at TF1.5 (Nottingham), 1985–2005, layer=SAP



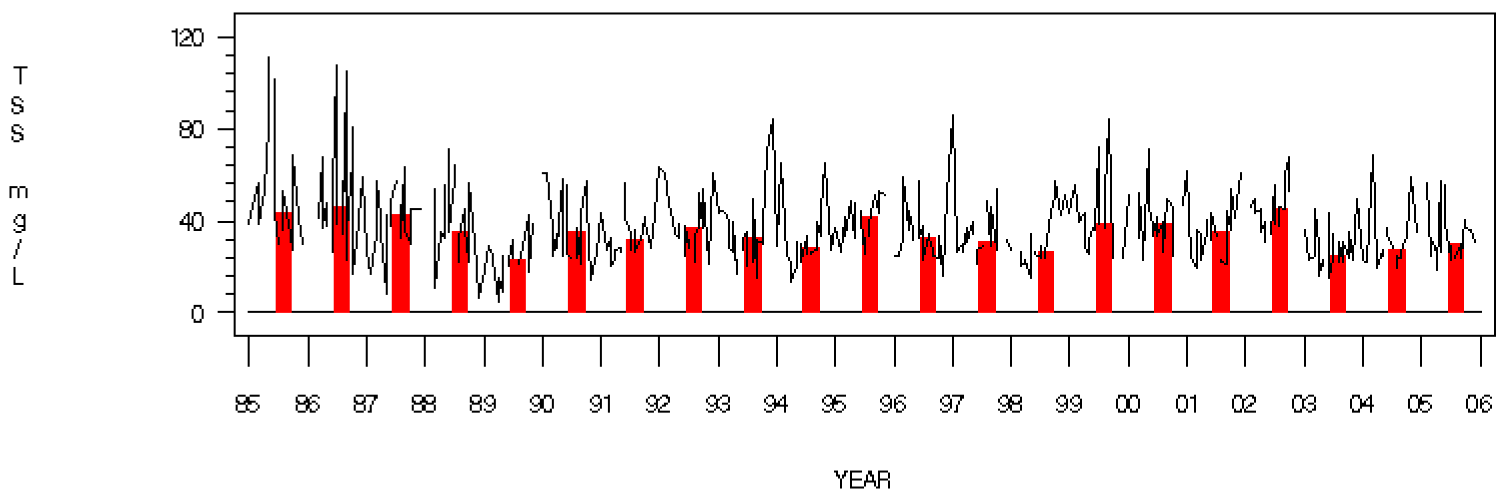
Total Phosphorus at TF1.5 (Nottingham), 1985–2005, layer=SAP



Chlorophyll a at TF1.5 (Nottingham), 1985–2005, layer=SAP

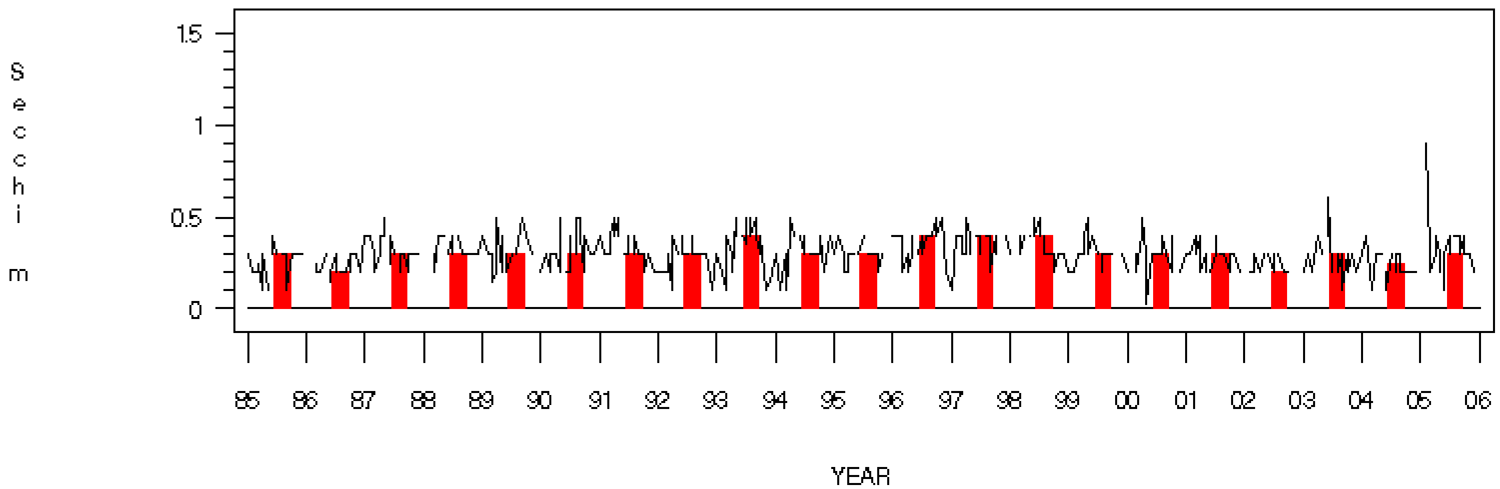


Total Susp. Solids at TF1.5 (Nottingham), 1985–2005, layer=SAP

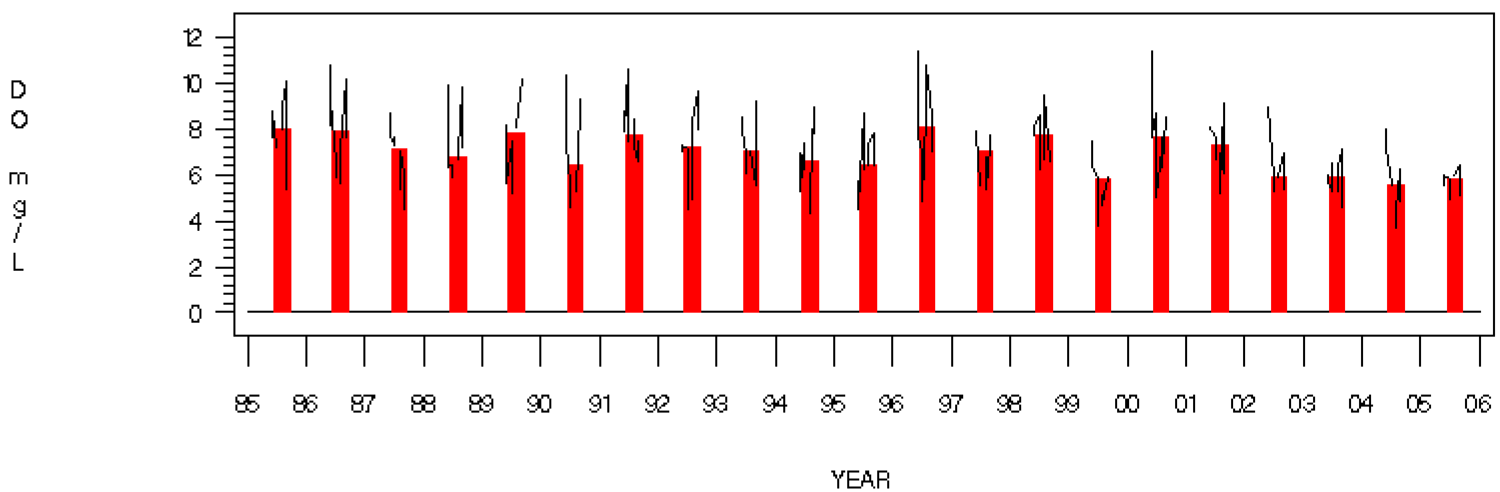


Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.

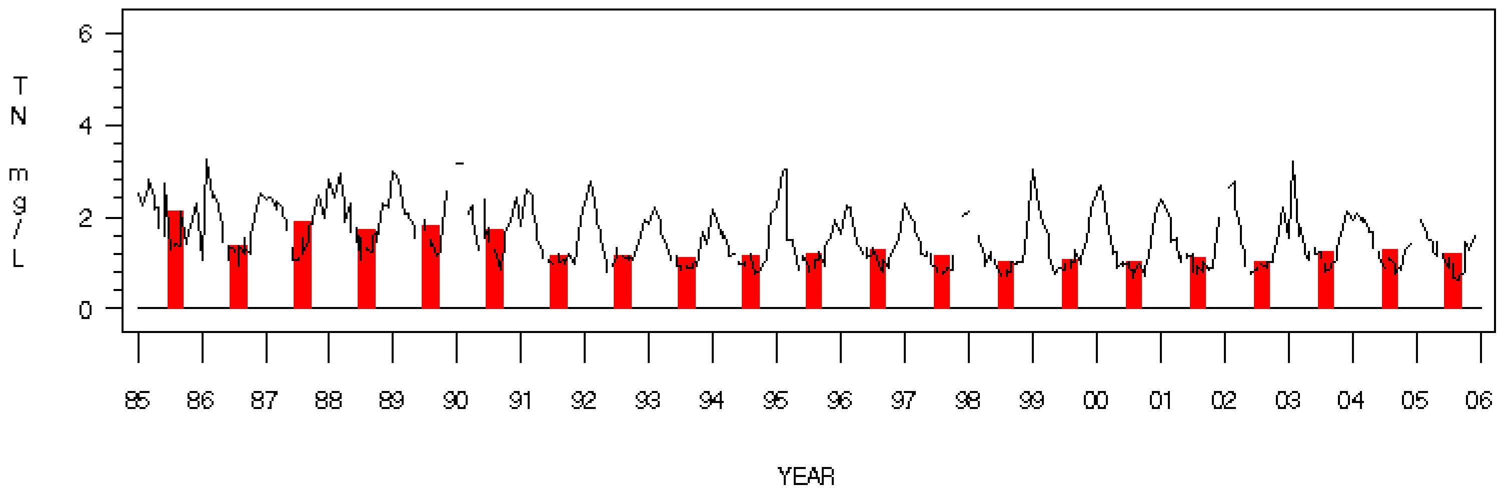
Secchi Depth at TF1.5 (Nottingham), 1985–2005, layer= S



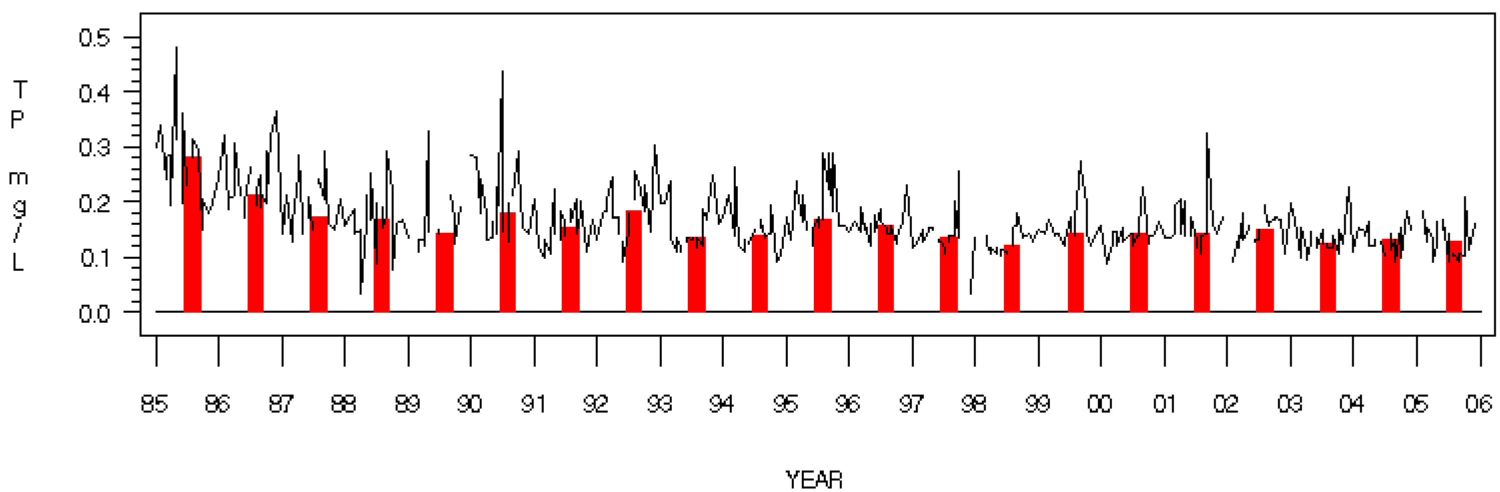
Dissolved Oxygen at TF1.5 (Nottingham), 1985–2005, layer= BDO

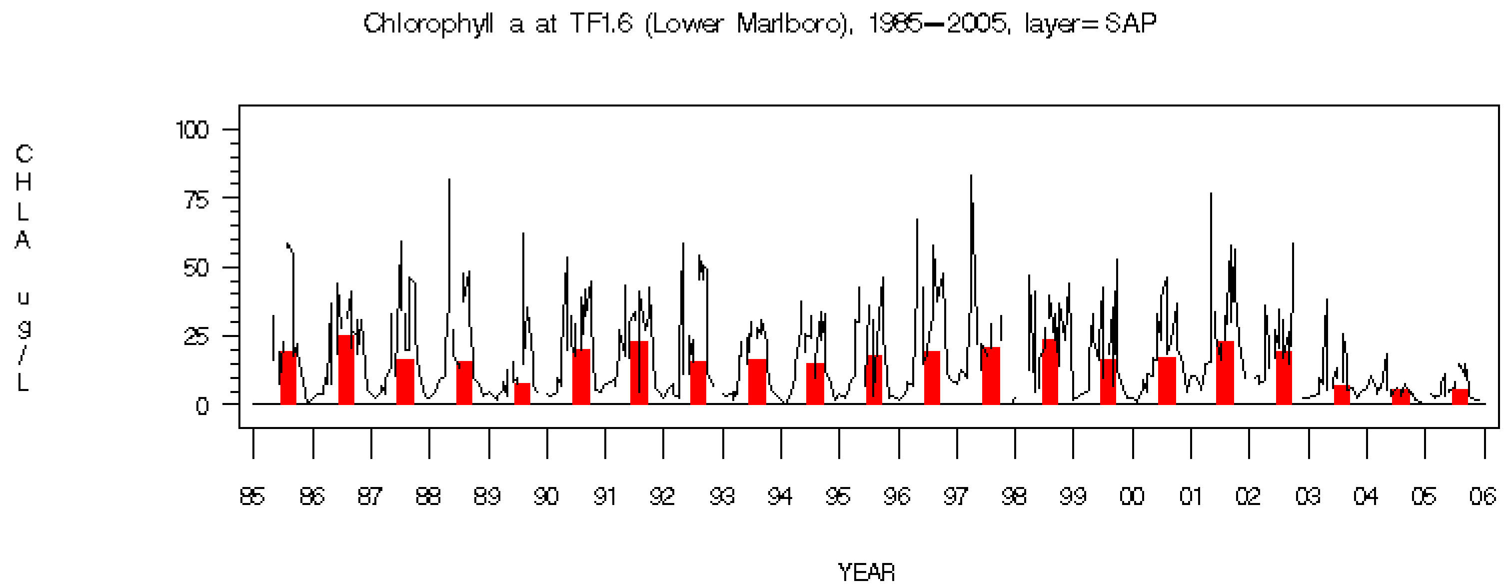


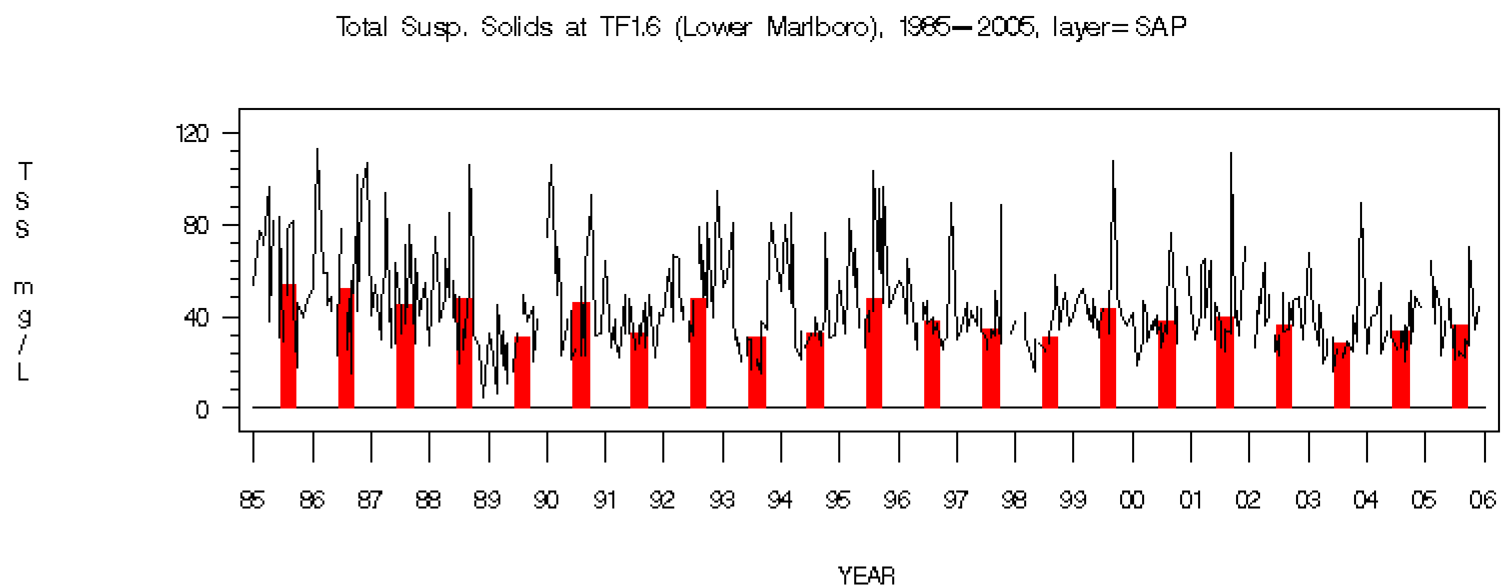
Total Nitrogen at TF1.6 (Lower Marlboro), 1985—2005, layer=SAP



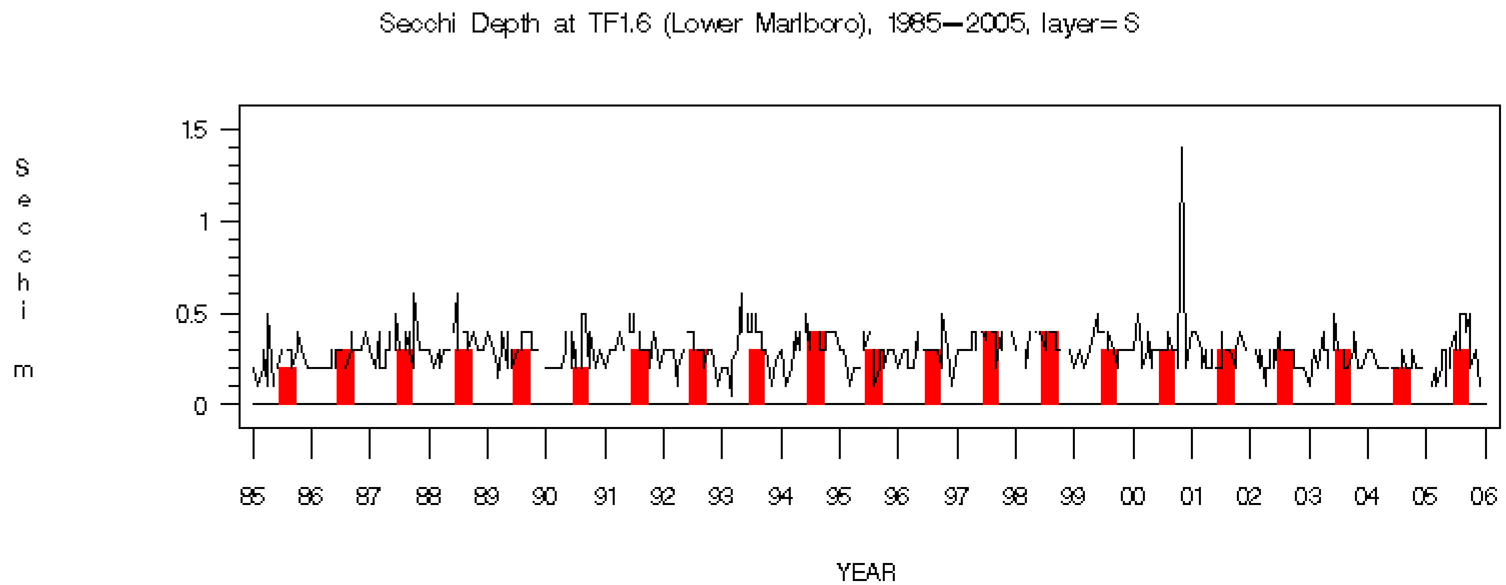
Total Phosphorus at TF1.6 (Lower Marlboro), 1985—2005, layer=SAP

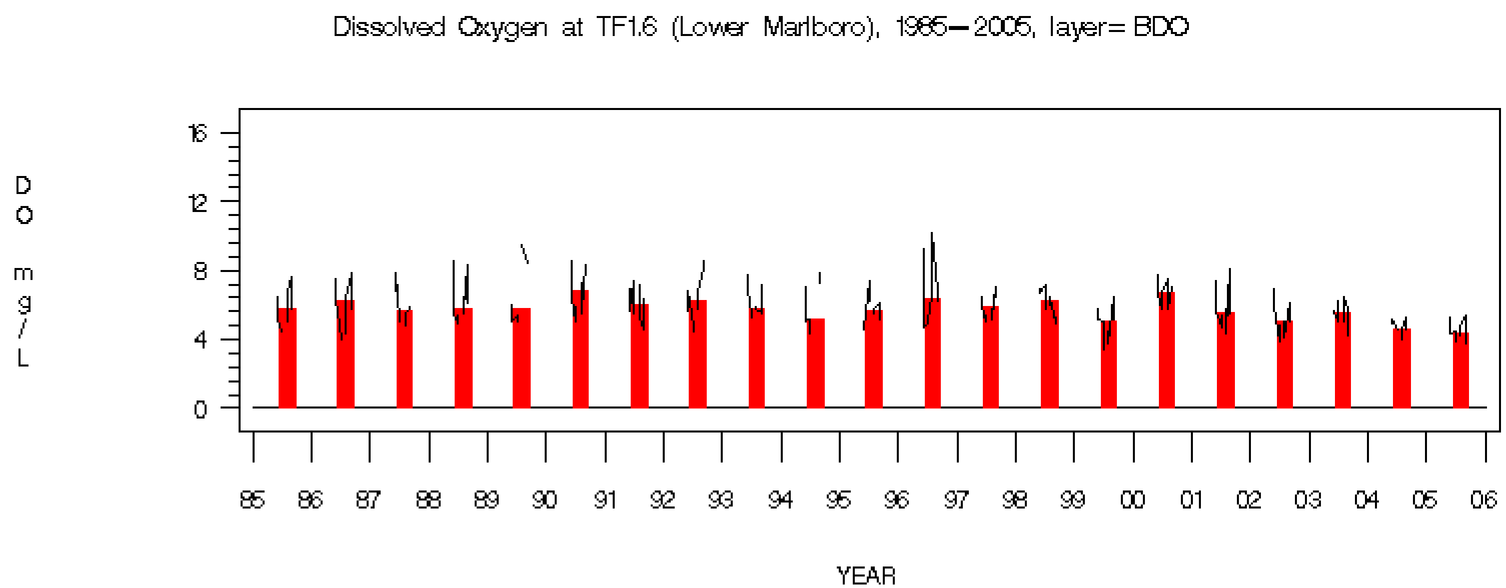


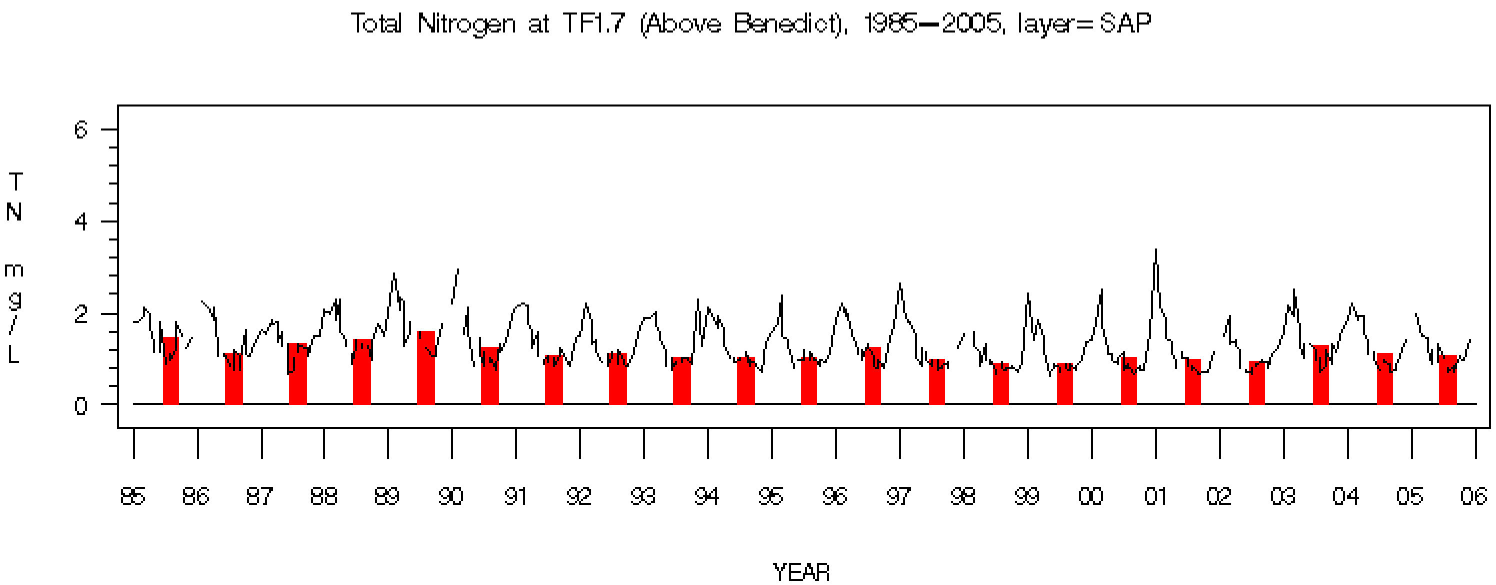


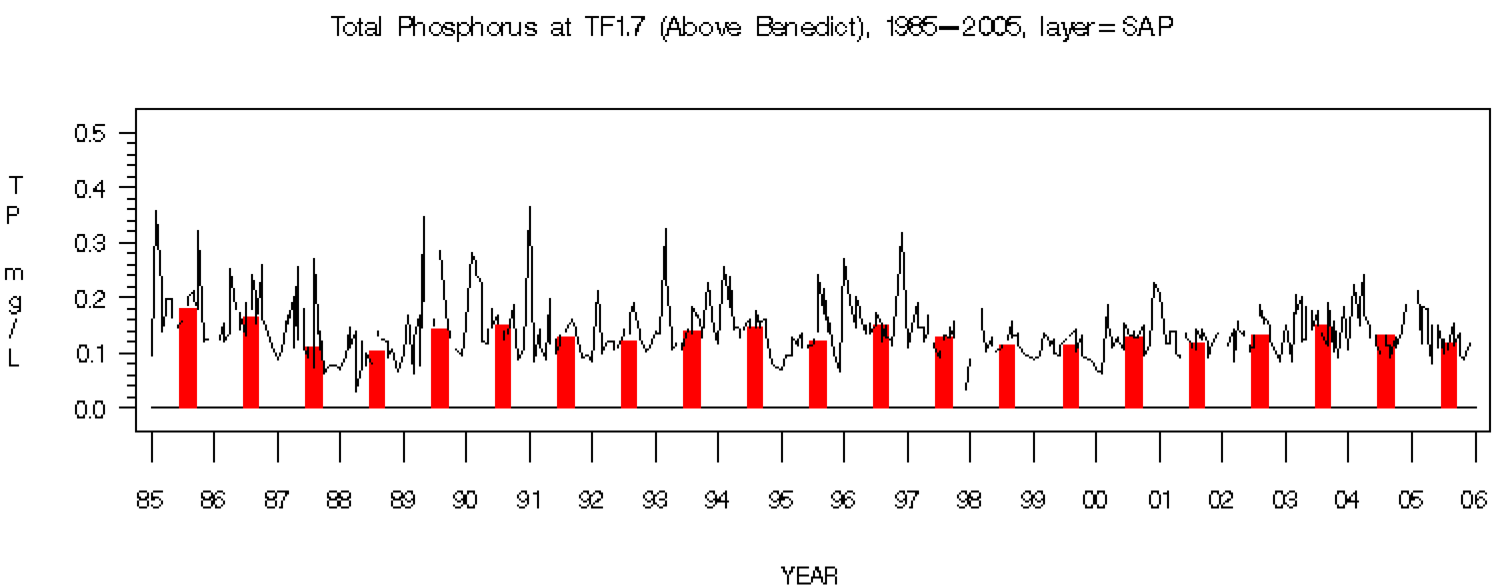


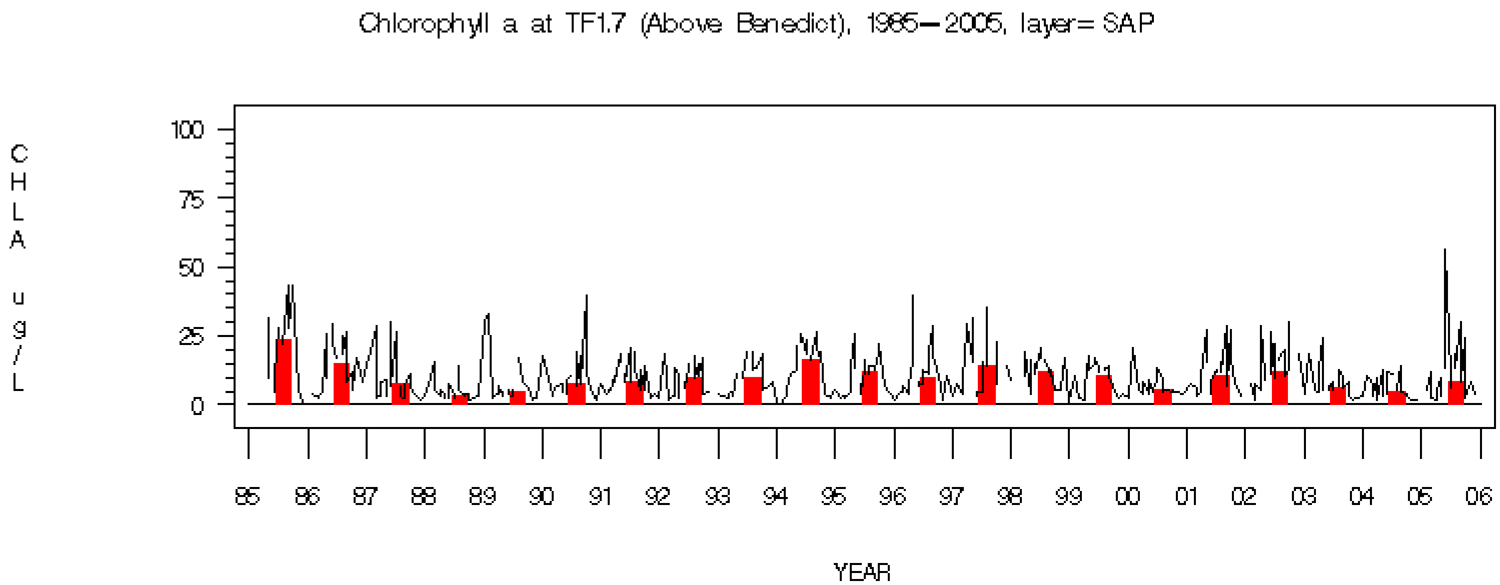
Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.

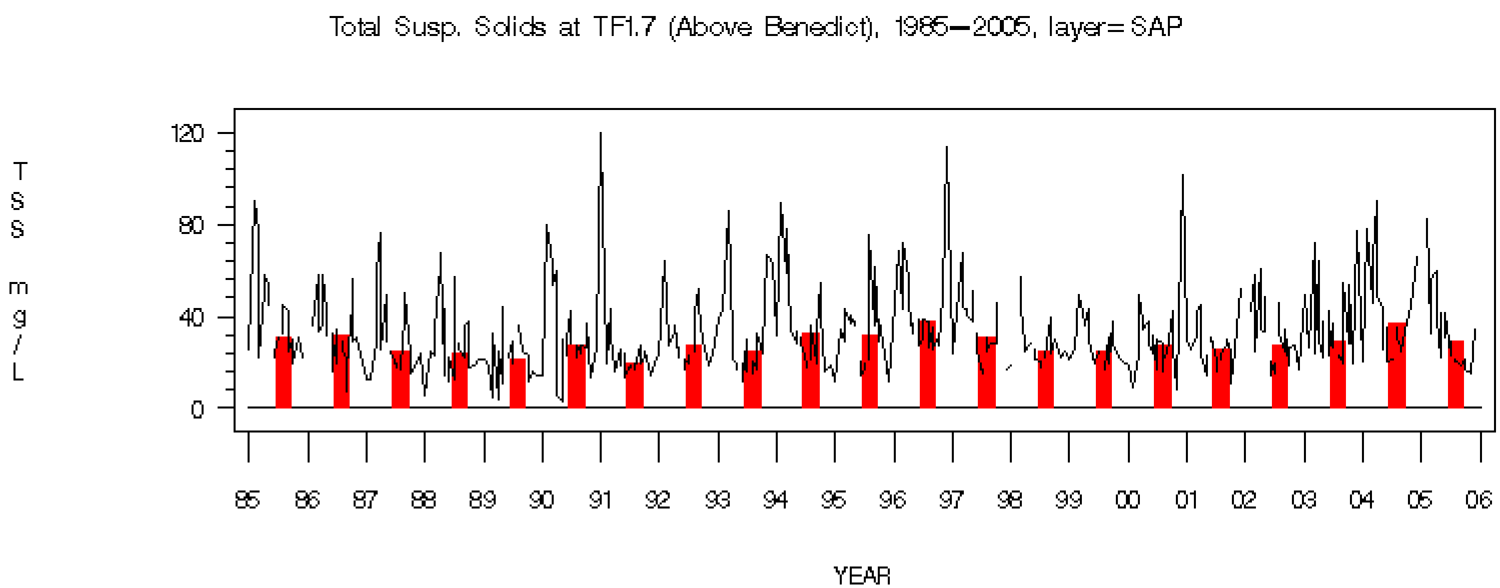

Secchi Depth at TF1.6 (Lower Marlboro), 1985–2005, layer= S
Secchi m
0
0.5
1
1.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR


Dissolved Oxygen at TF1.6 (Lower Marlboro), 1985–2005, layer= BDO
DO mg/L
0
4
8
12
16
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

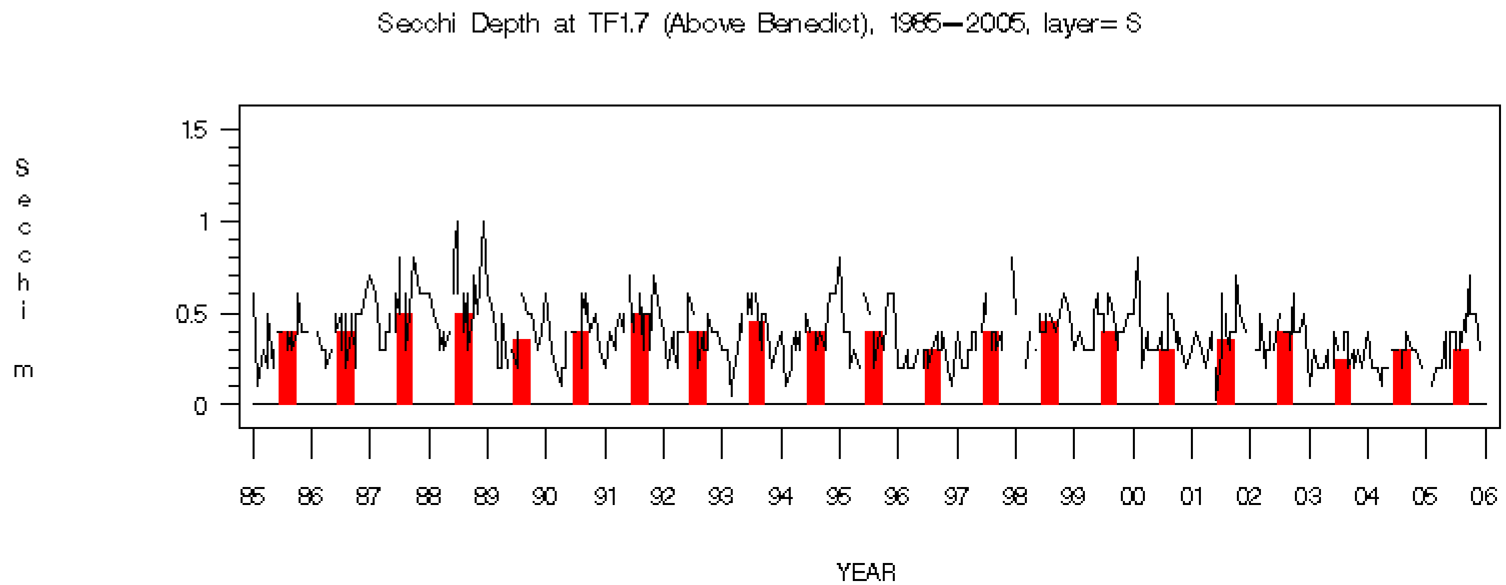

Total Nitrogen at TF1.7 (Above Benedict), 1985—2005, layer=SAP
T N mg/L
0
2
4
6
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

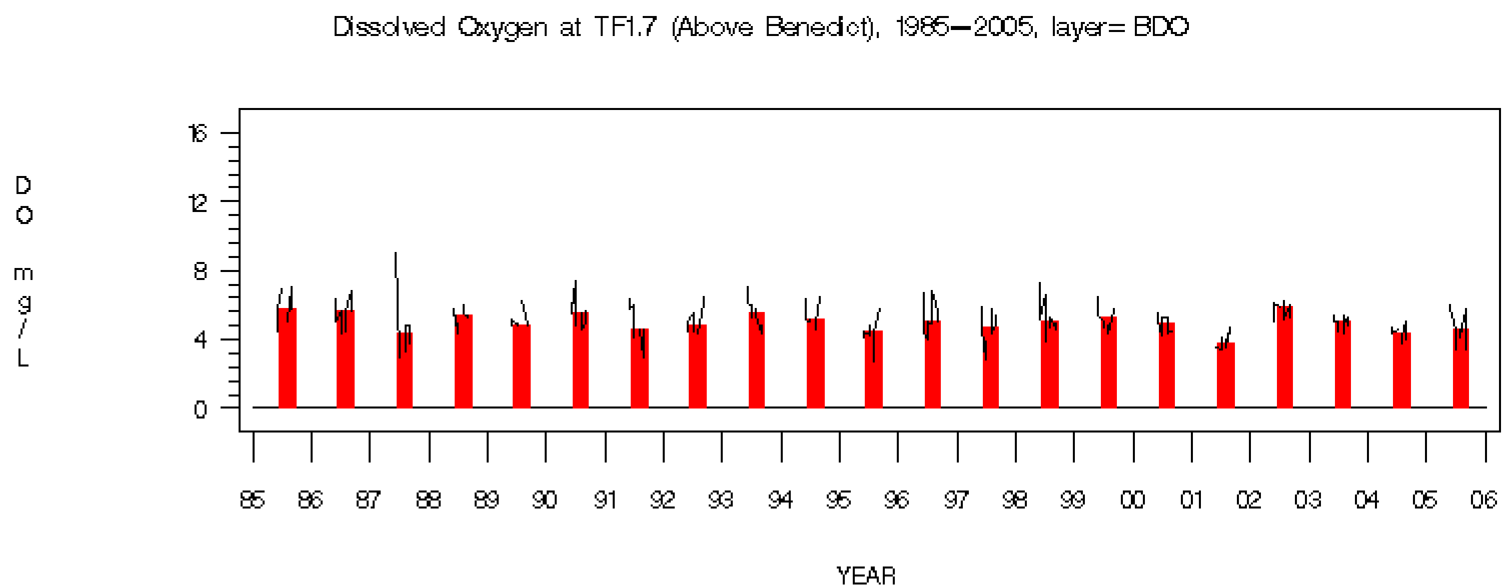

Total Phosphorus at TF1.7 (Above Benedict), 1985—2005, layer=SAP
T P mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR



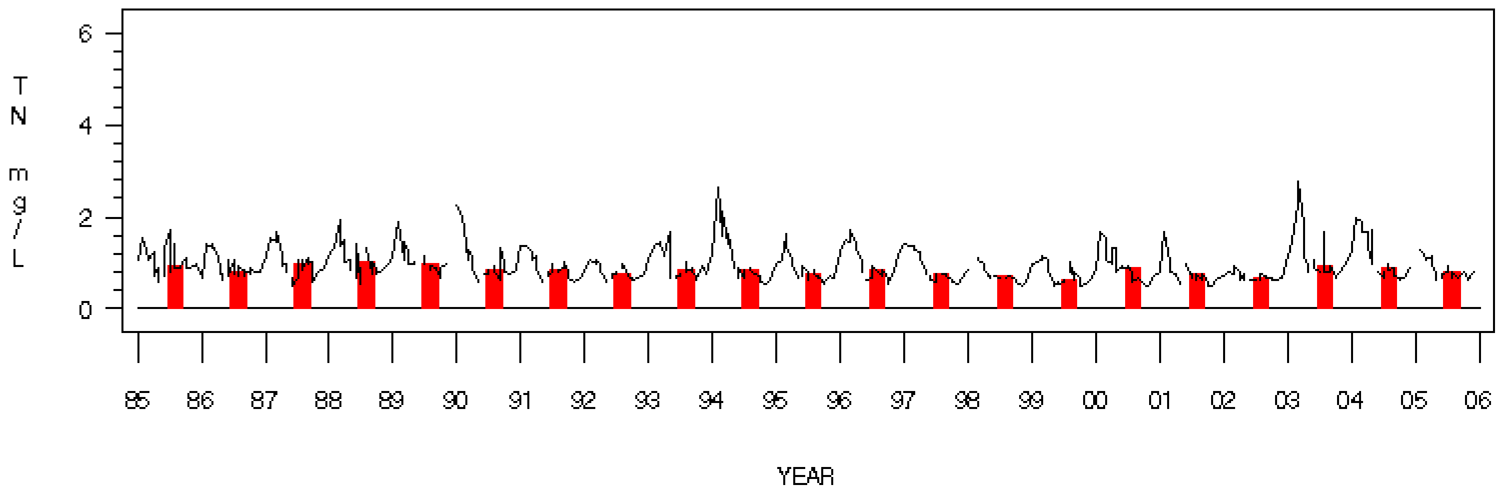


Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations

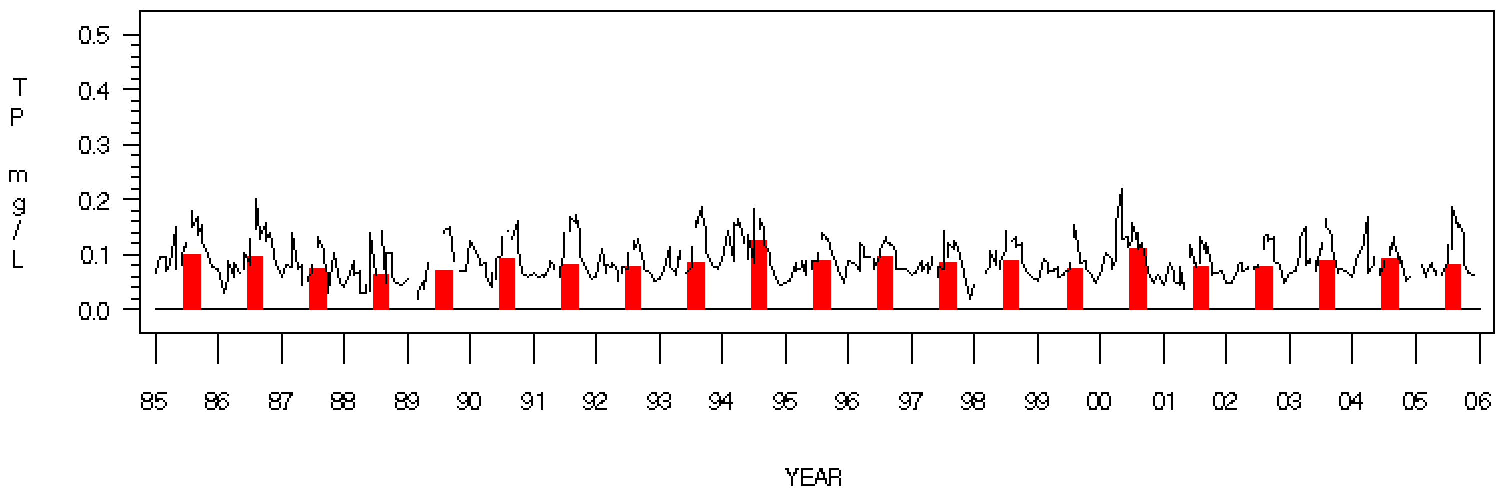

Secchi Depth at TF1.7 (Above Benedict), 1985—2005, layer= S
S e c c h i m
1.5
1
0.5
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

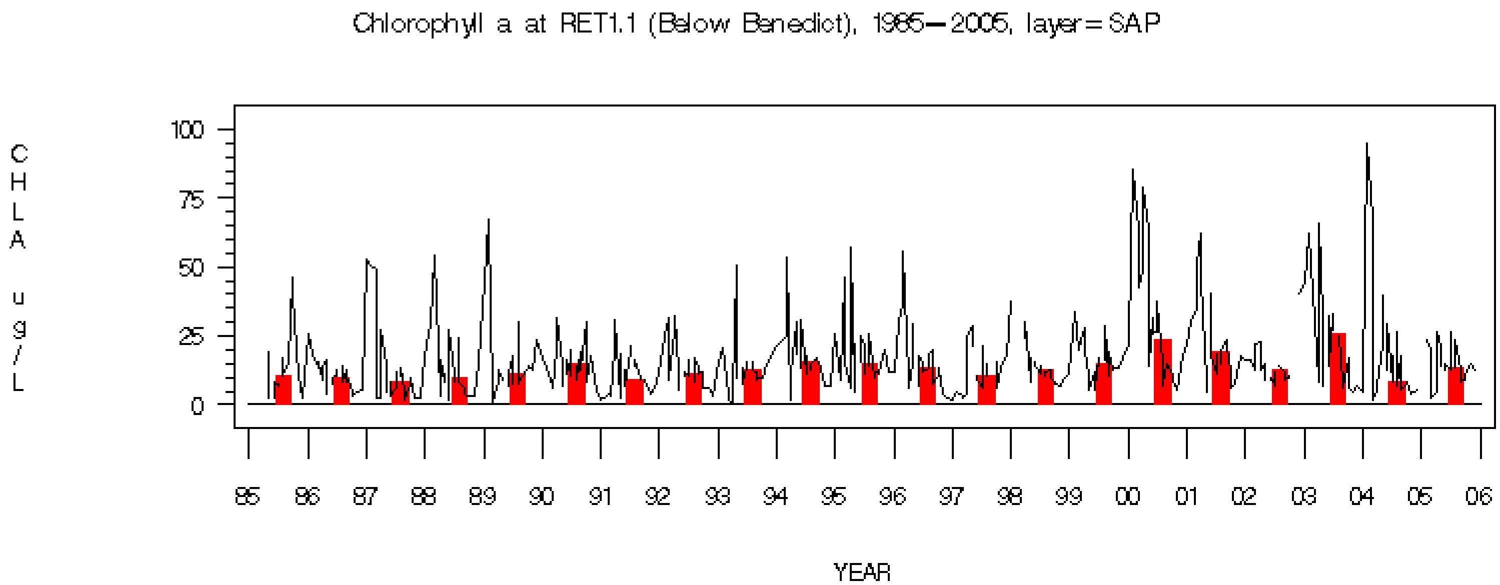

Dissolved Oxygen at TF1.7 (Above Benedict), 1985—2005, layer= BDO
DO mg/L
16
12
8
4
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

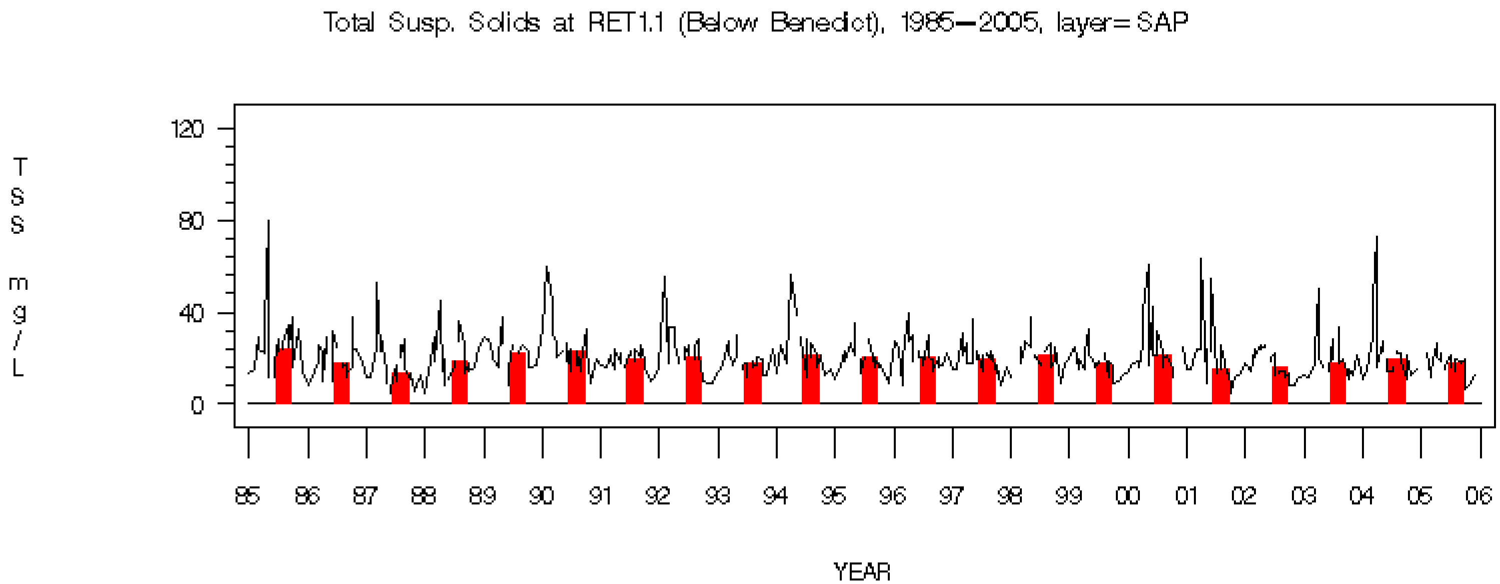
Total Nitrogen at RET1.1 (Below Benedict), 1985–2005, layer=SAP



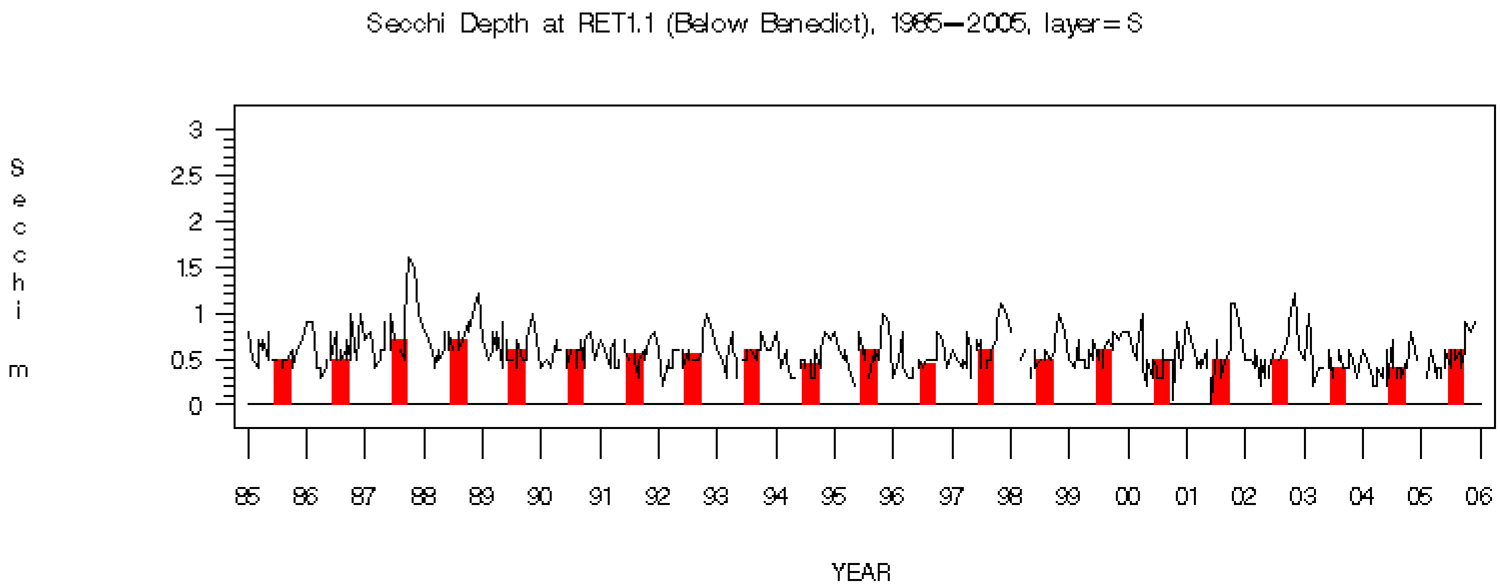
Total Phosphorus at RET1.1 (Below Benedict), 1985–2005, layer=SAP

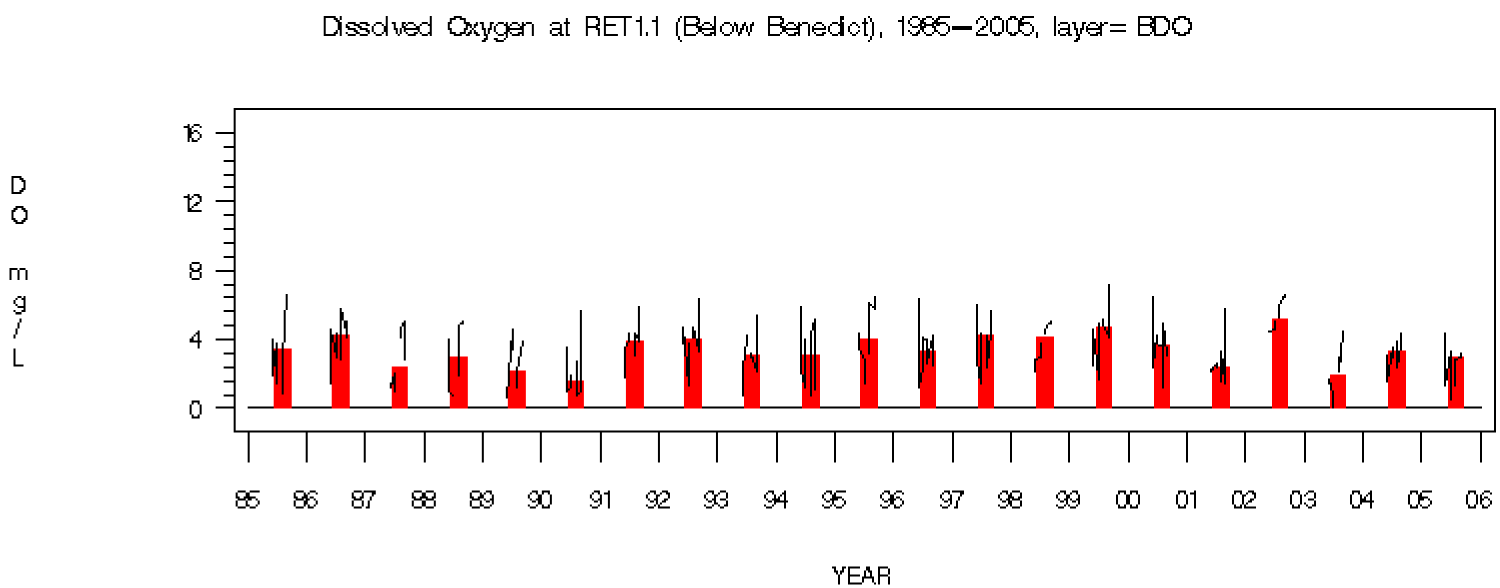


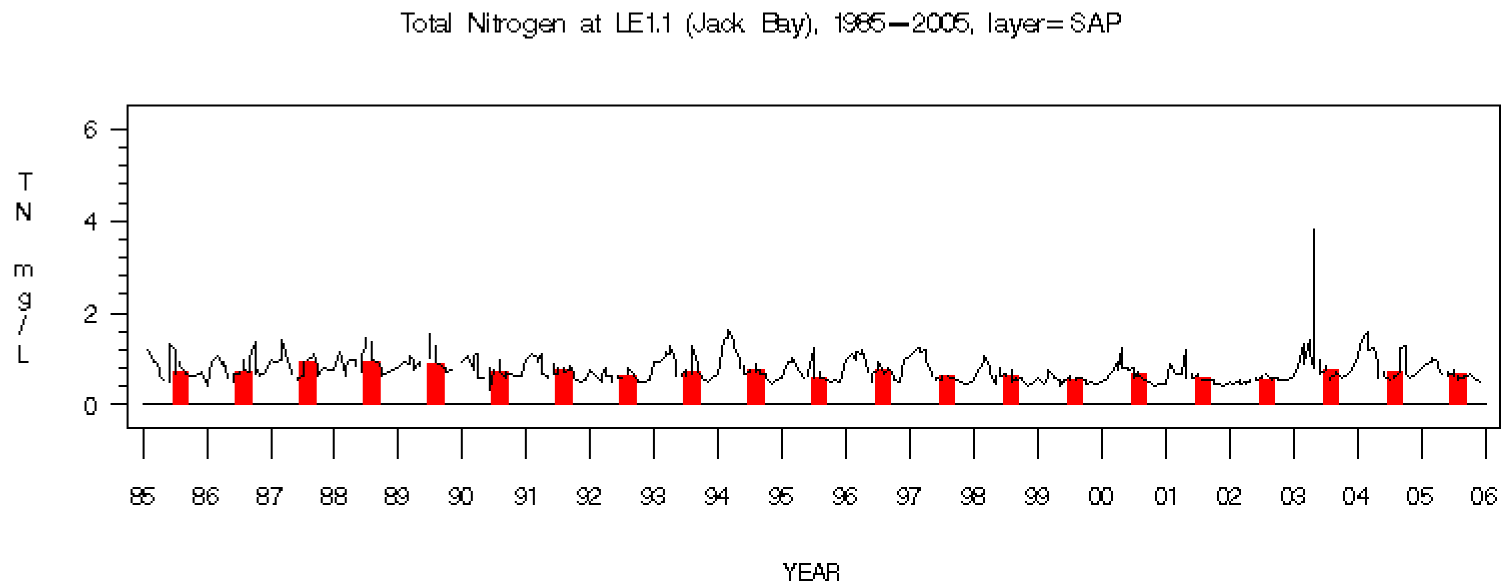


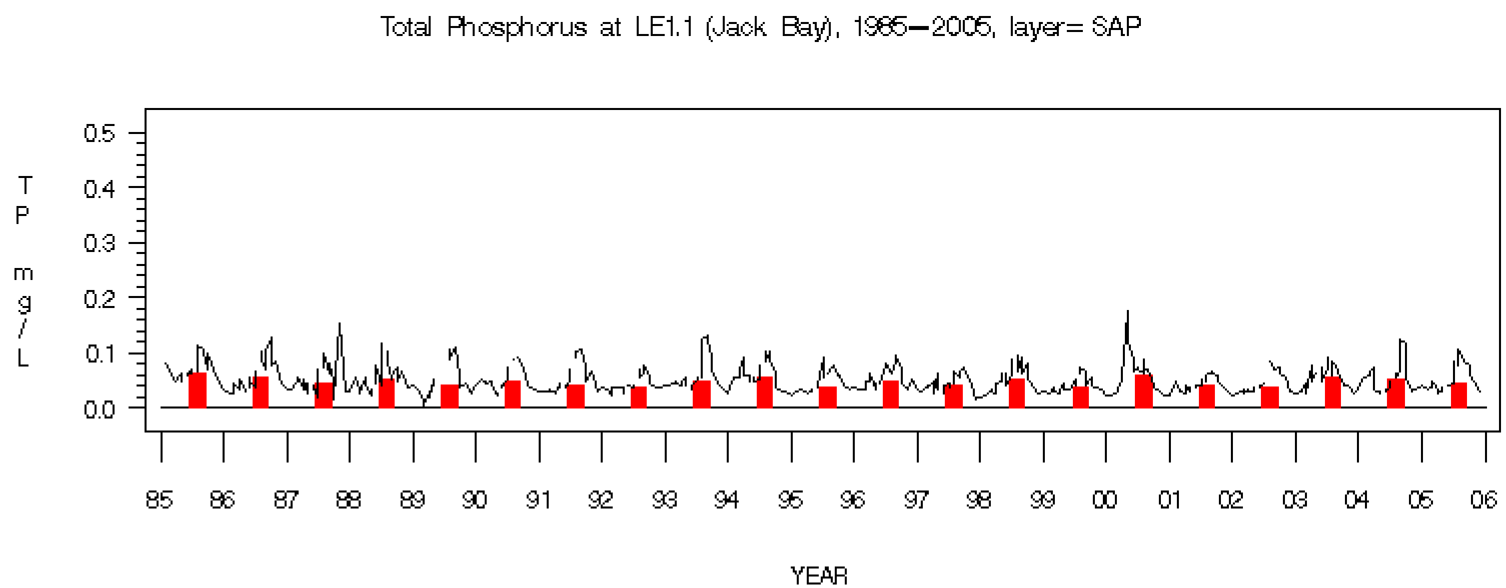


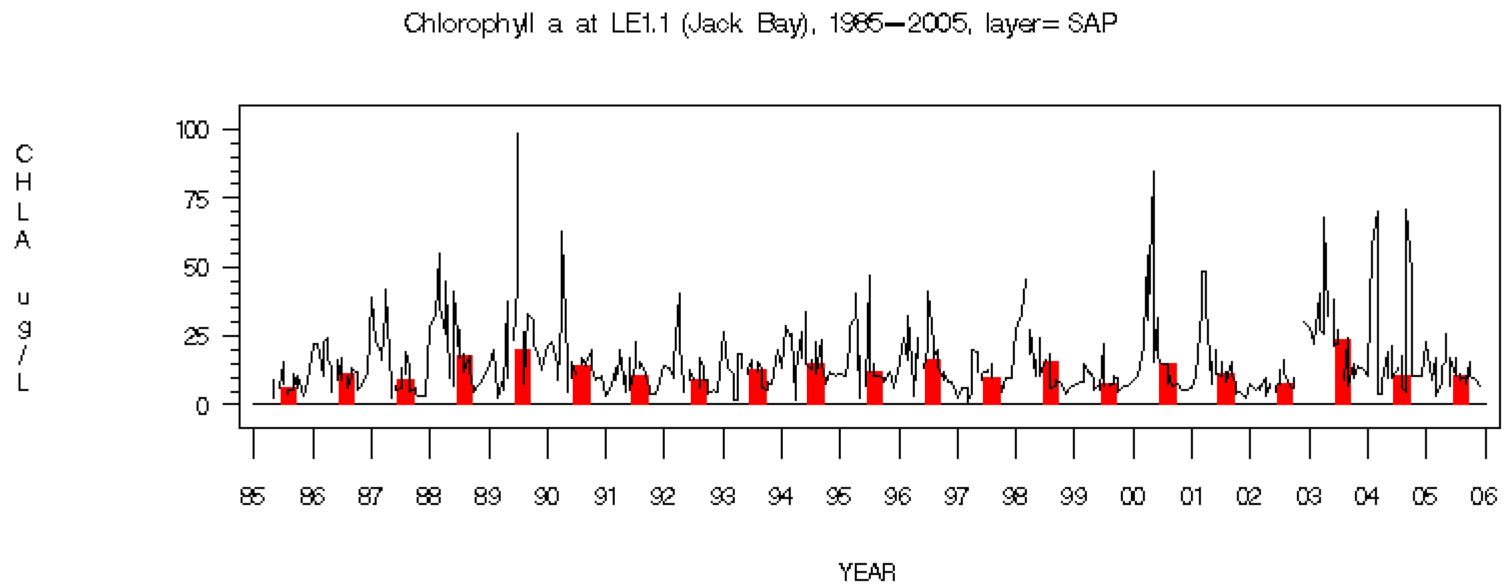
Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.

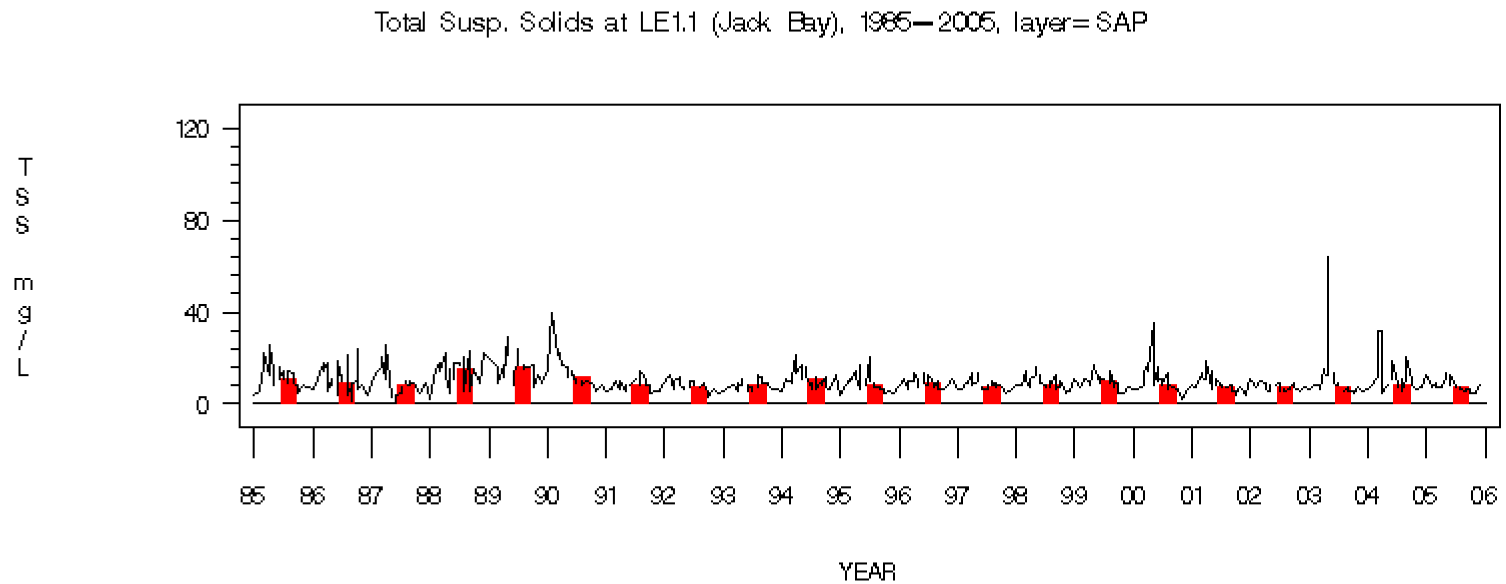

Secchi Depth at RET1.1 (Below Benedict), 1985–2005, layer=S
Secchi m
3
2.5
2
1.5
1
0.5
0
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
YEAR


Dissolved Oxygen at RET1.1 (Below Benedict), 1985–2005, layer= BDO
DO mg/L
16
12
8
4
0
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
YEAR


Total Nitrogen at LE1.1 (Jack Bay), 1985—2005, layer= SAP
T N mg/L
0
2
4
6
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

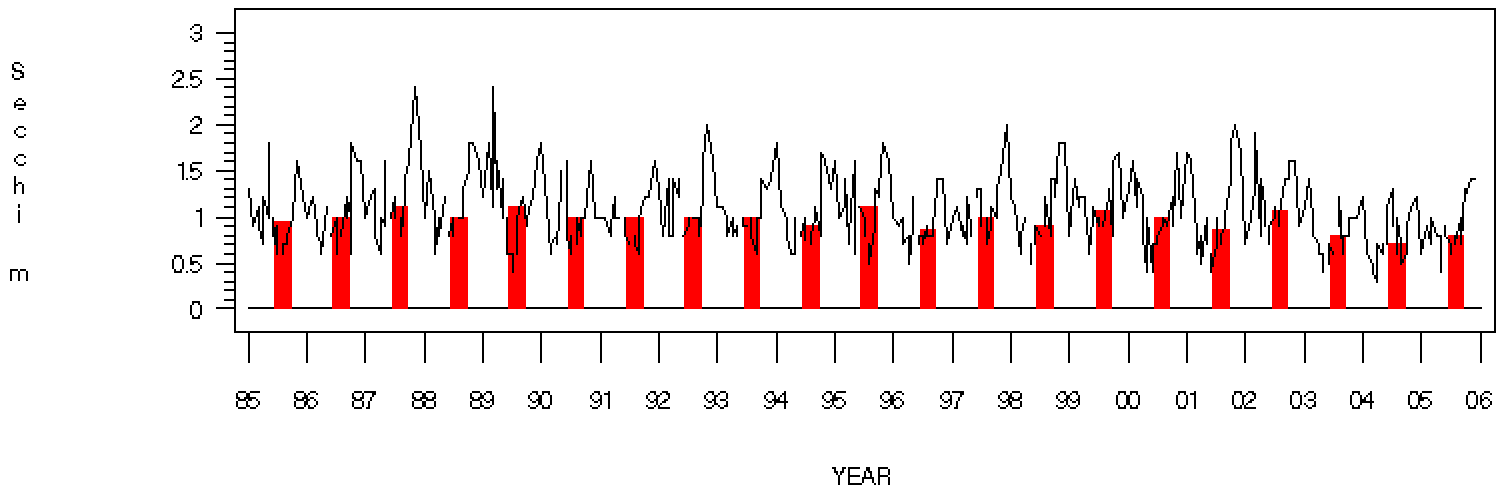

Total Phosphorus at LE1.1 (Jack Bay), 1985—2005, layer= SAP
T P mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR



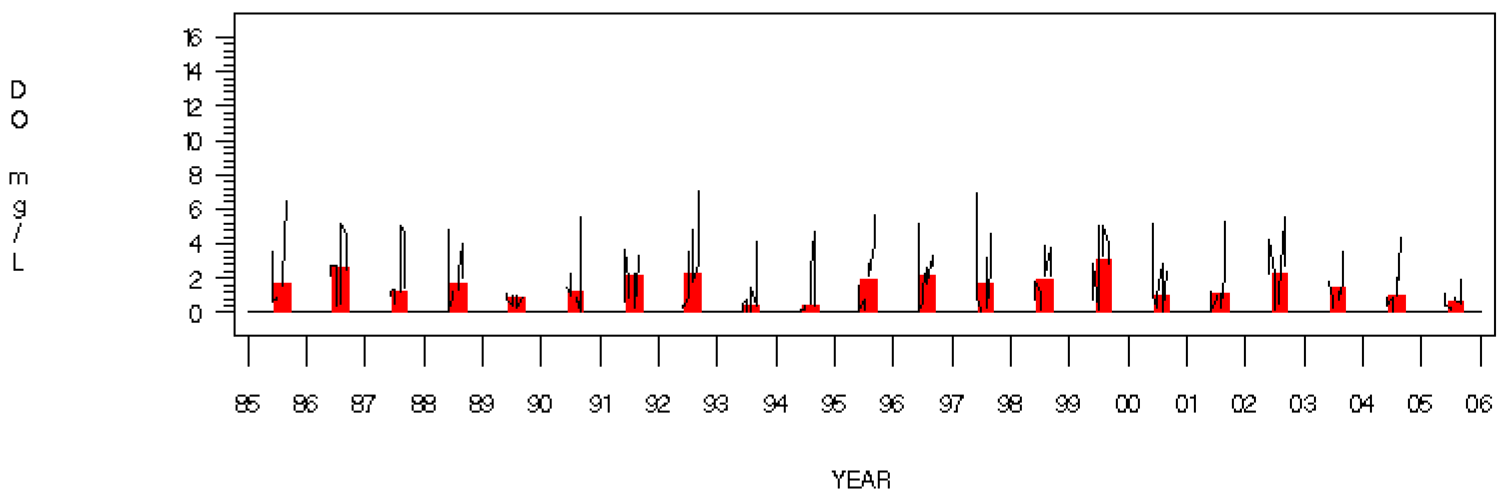


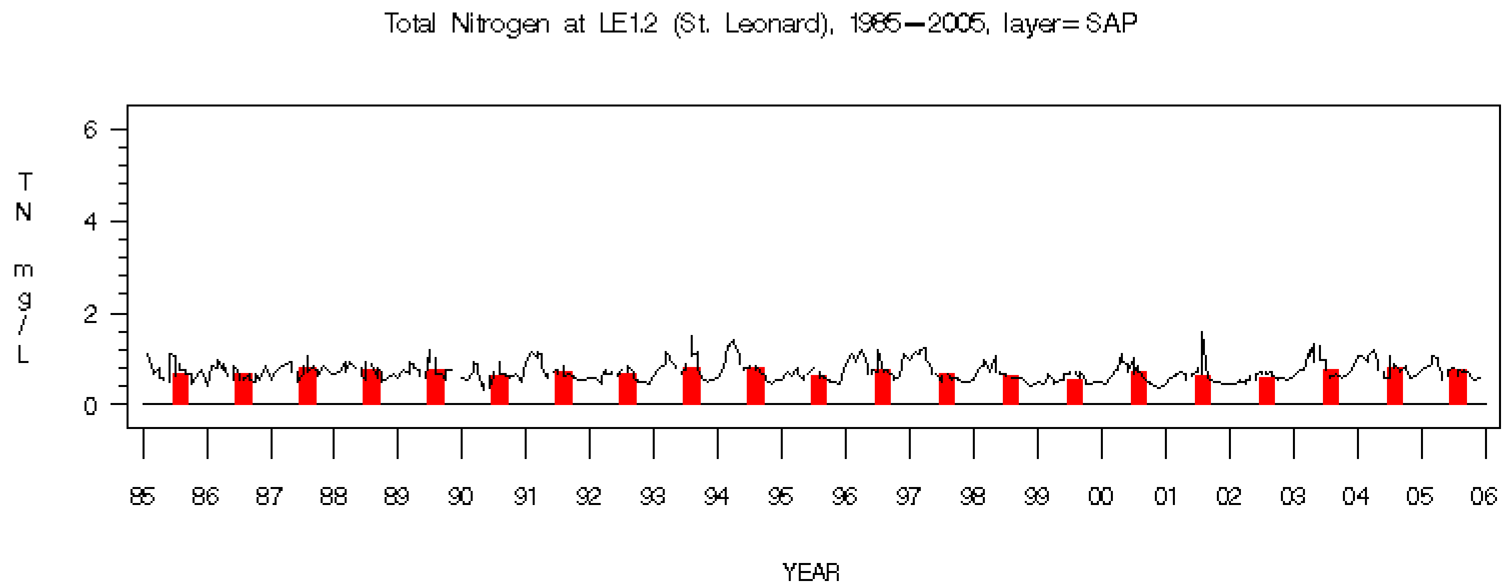
Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.

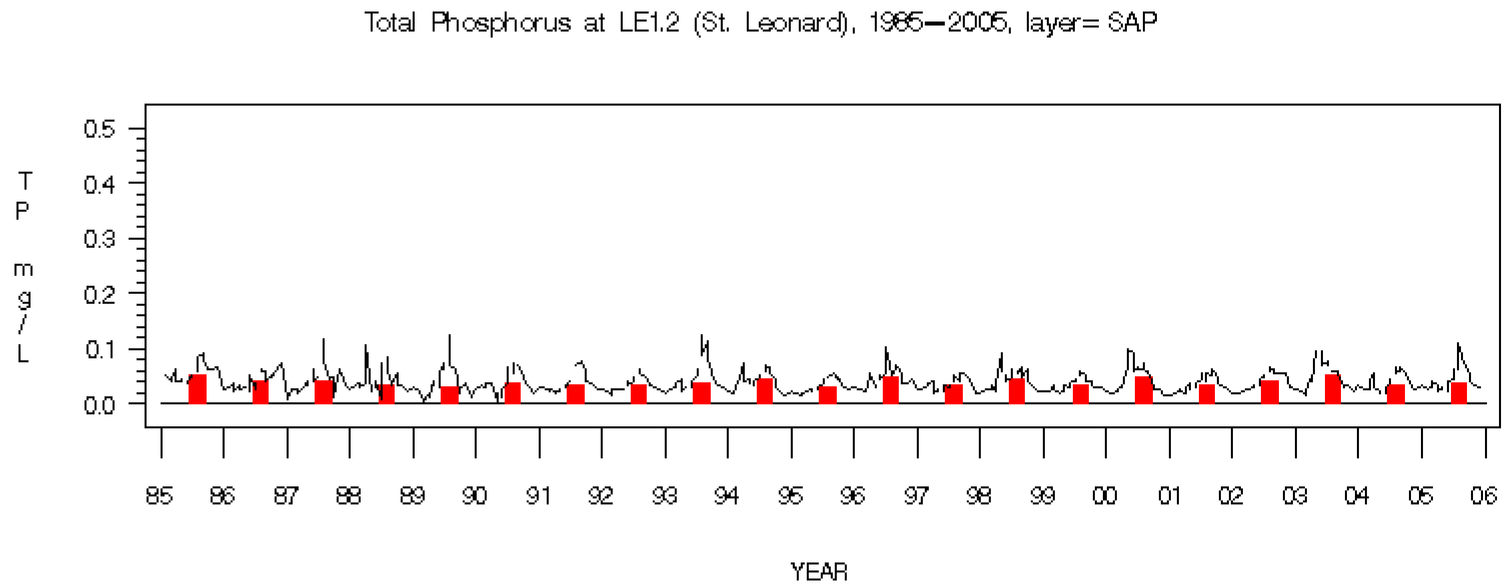
Secchi Depth at LE1.1 (Jack Bay), 1985–2005, layer= S

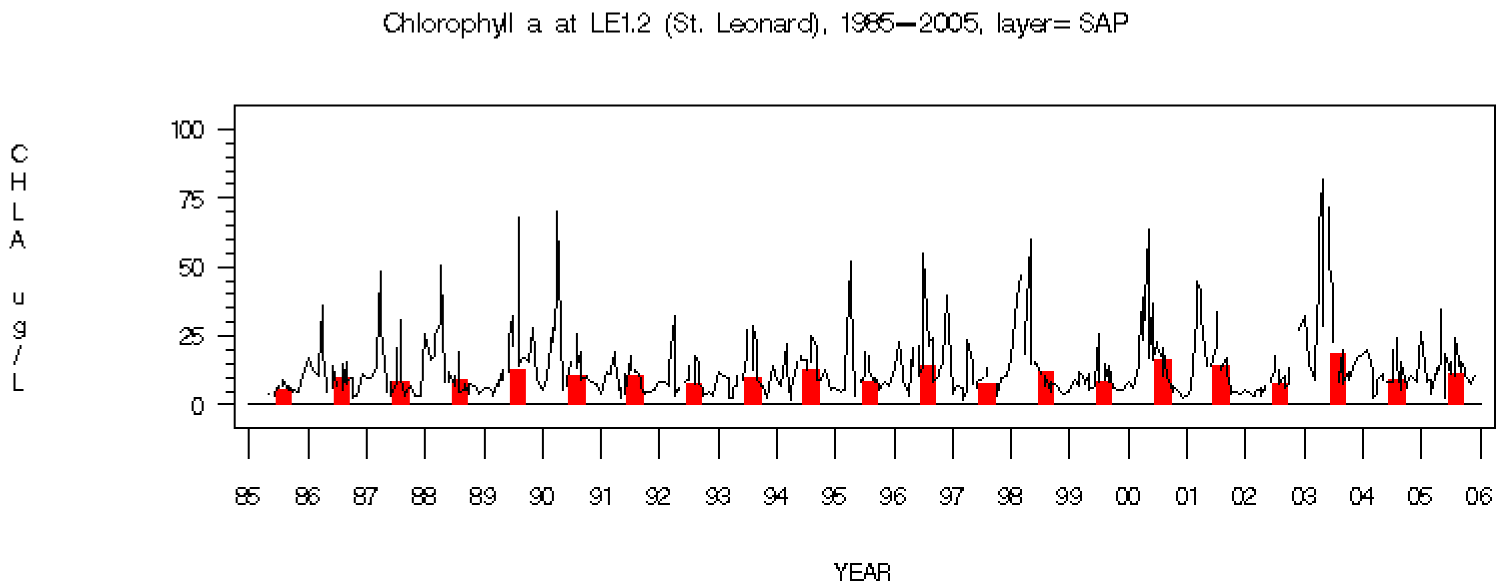


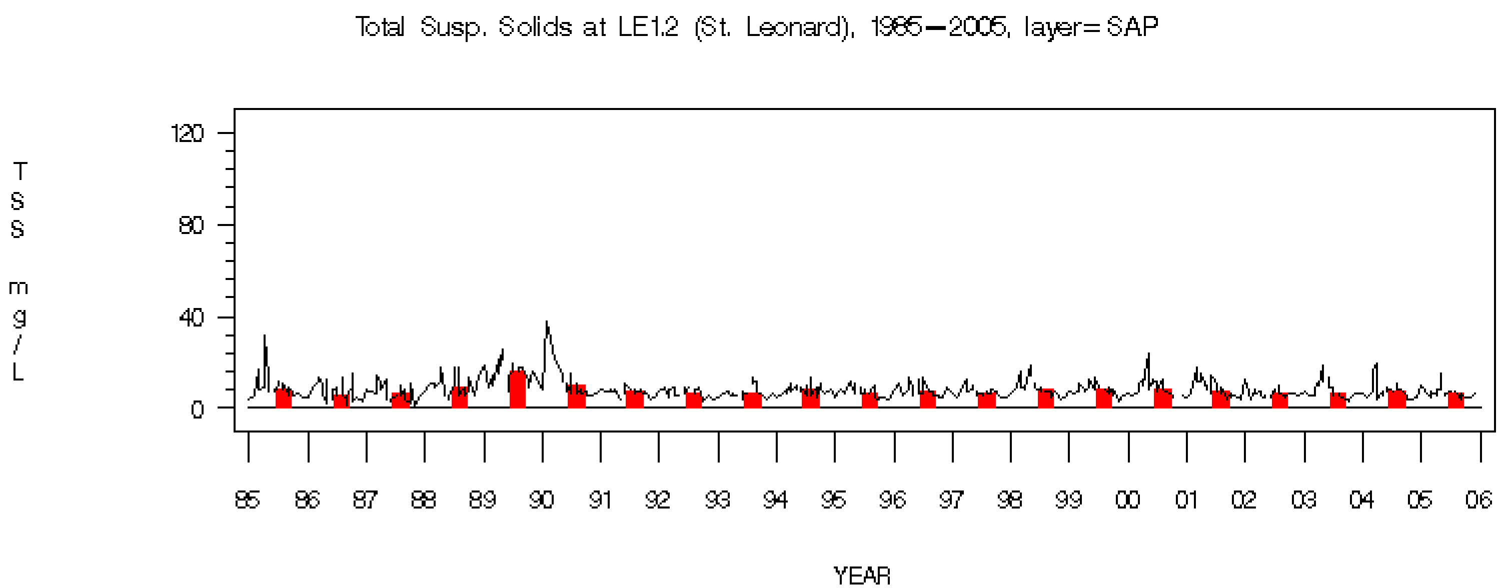
Dissolved Oxygen at LE1.1 (Jack Bay), 1985–2005, layer= BDO



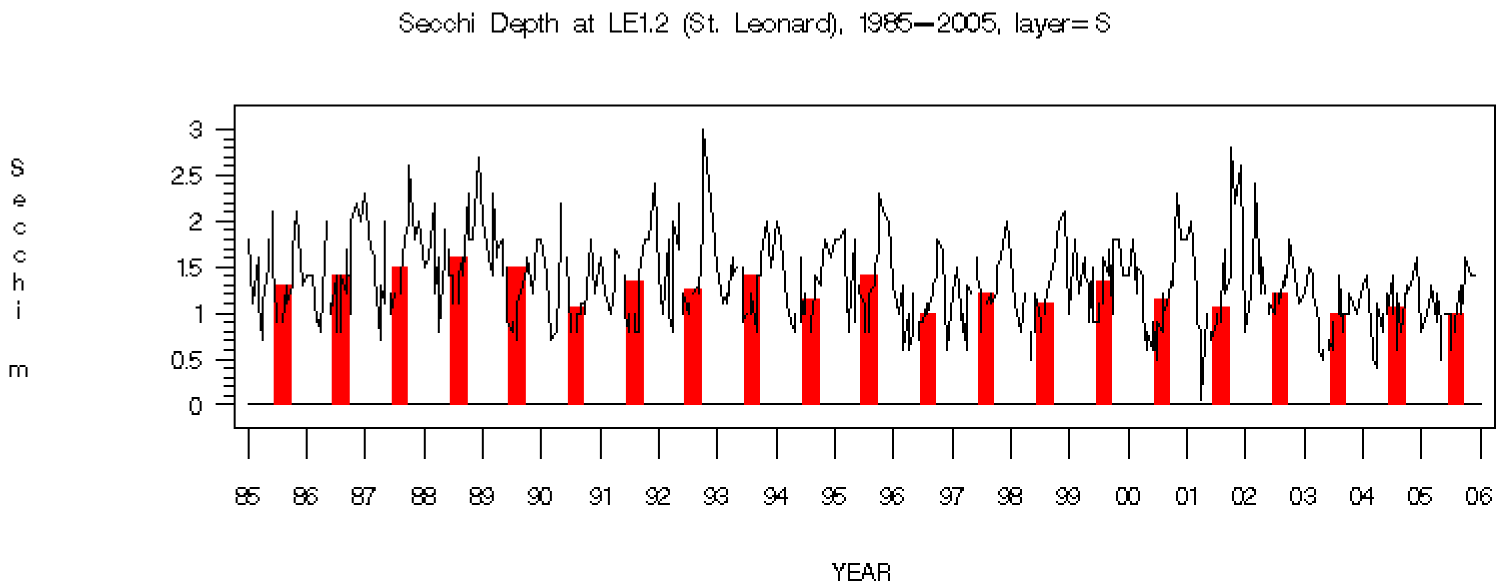

Total Nitrogen at LE1.2 (St. Leonard), 1985–2005, layer= SAP
TN mg/L
0
2
4
6
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
YEAR

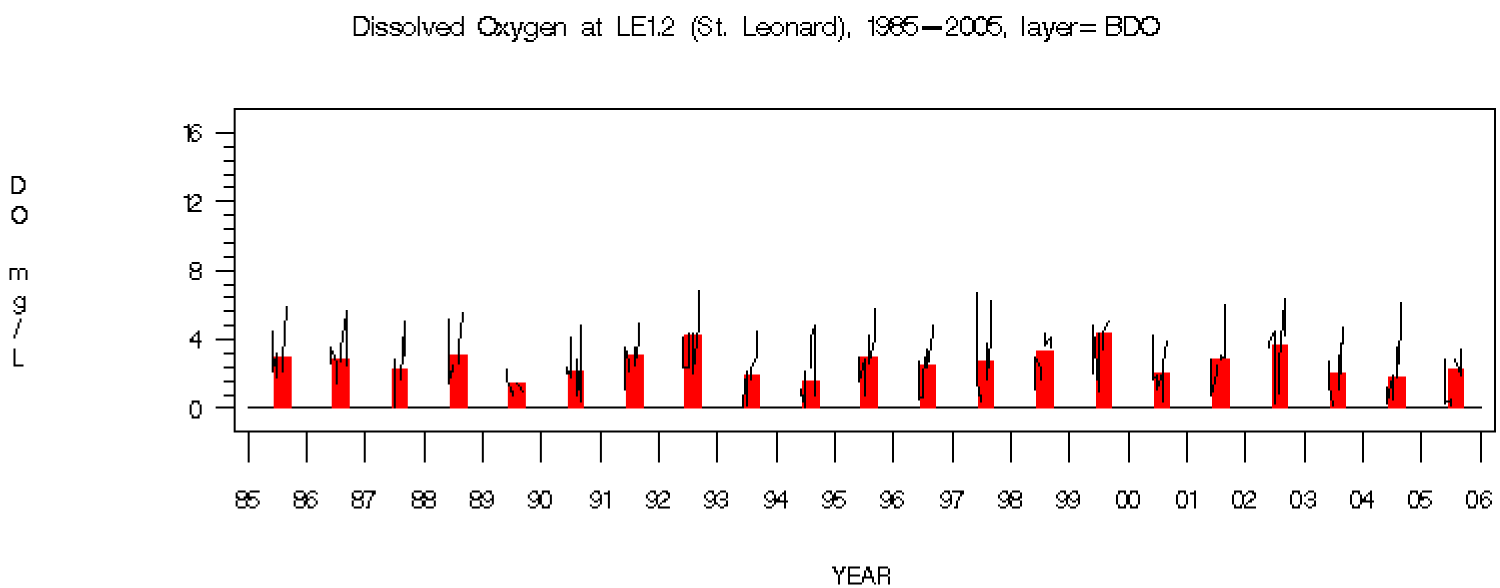

Total Phosphorus at LE1.2 (St. Leonard), 1985–2005, layer= SAP
TP mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
YEAR



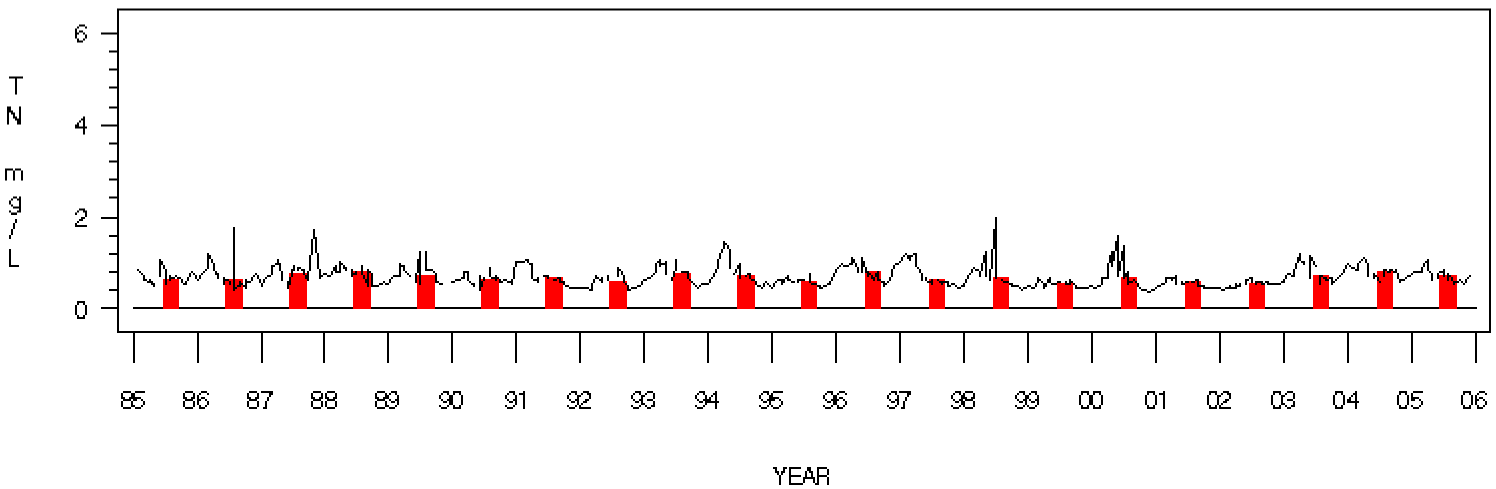


Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.

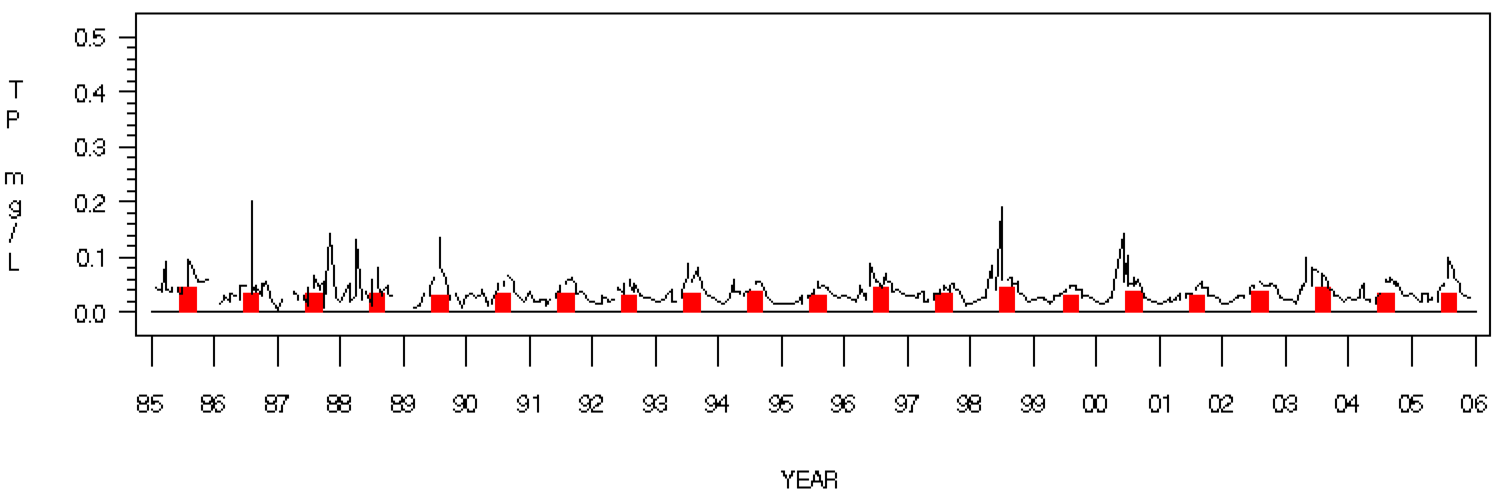

Secchi Depth at LE1.2 (St. Leonard), 1985—2005, layer= S
Secchi m
0
0.5
1
1.5
2
2.5
3
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR


Dissolved Oxygen at LE1.2 (St. Leonard), 1985—2005, layer= BDO
DO mg/L
0
4
8
12
16
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

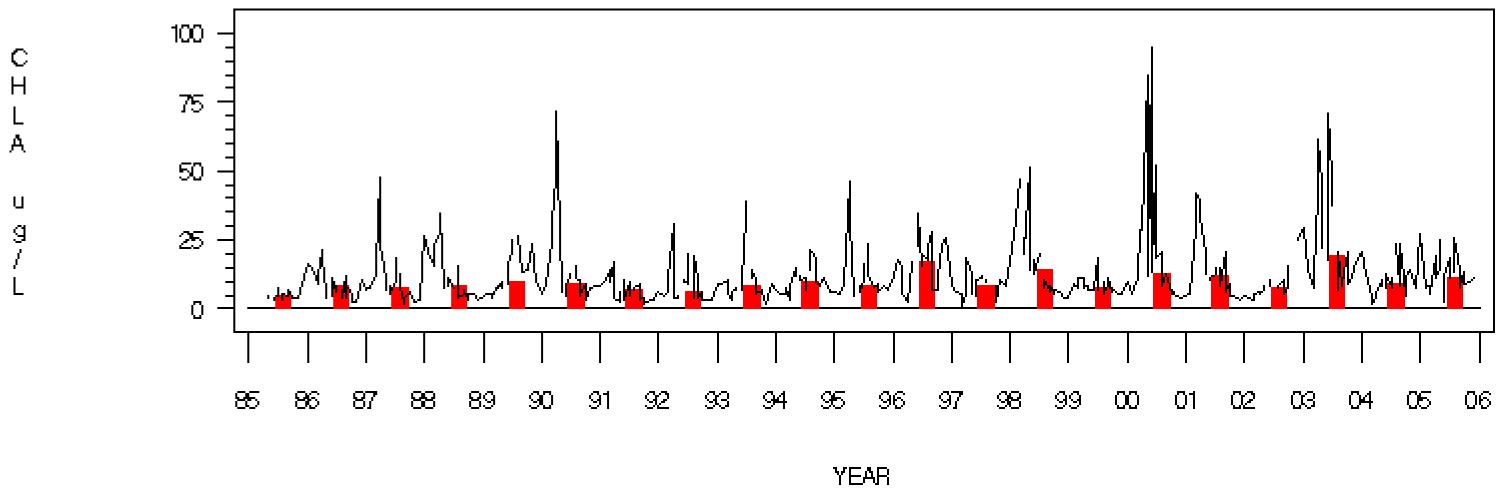
Total Nitrogen at LE1.3 (Above Pt. Patience), 1985–2005, layer= SAP



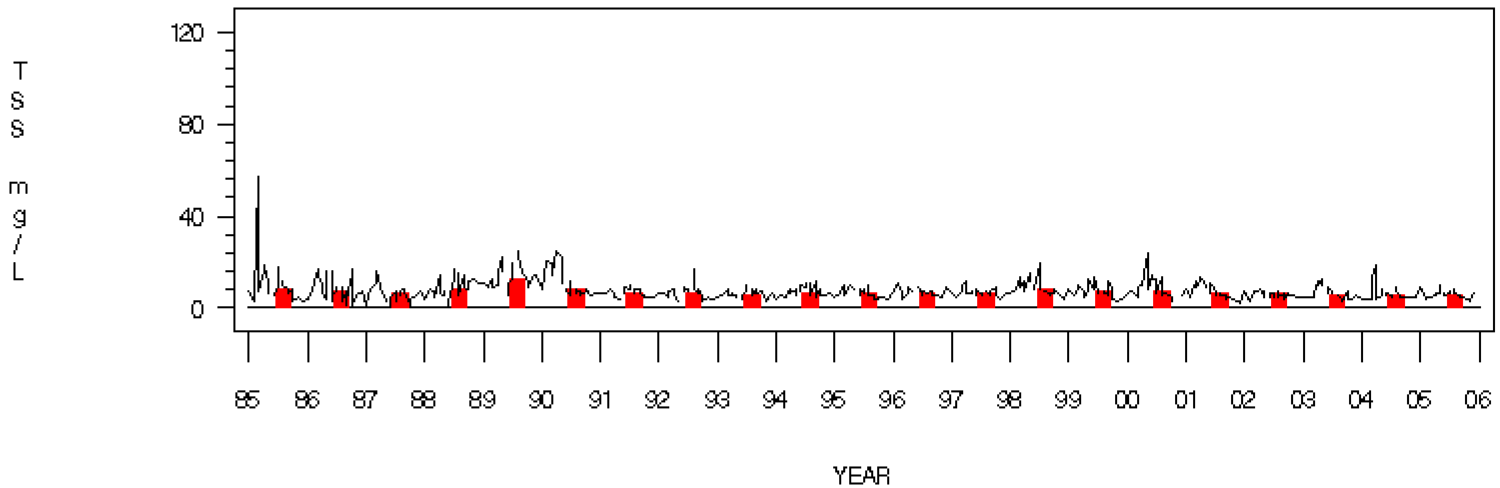
Total Phosphorus at LE1.3 (Above Pt. Patience), 1985–2005, layer= SAP



Chlorophyll a at LE1.3 (Above Pt. Patience), 1985—2005, layer= SAP

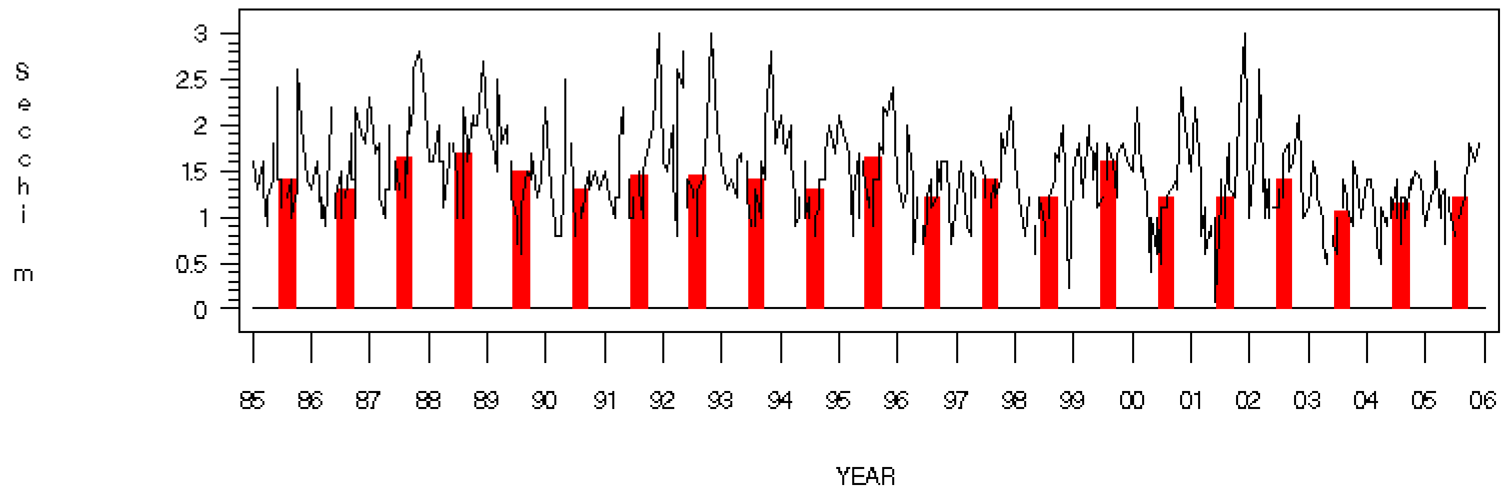


Total Susp. Solids at LE1.3 (Above Pt. Patience), 1985—2005, layer= SAP

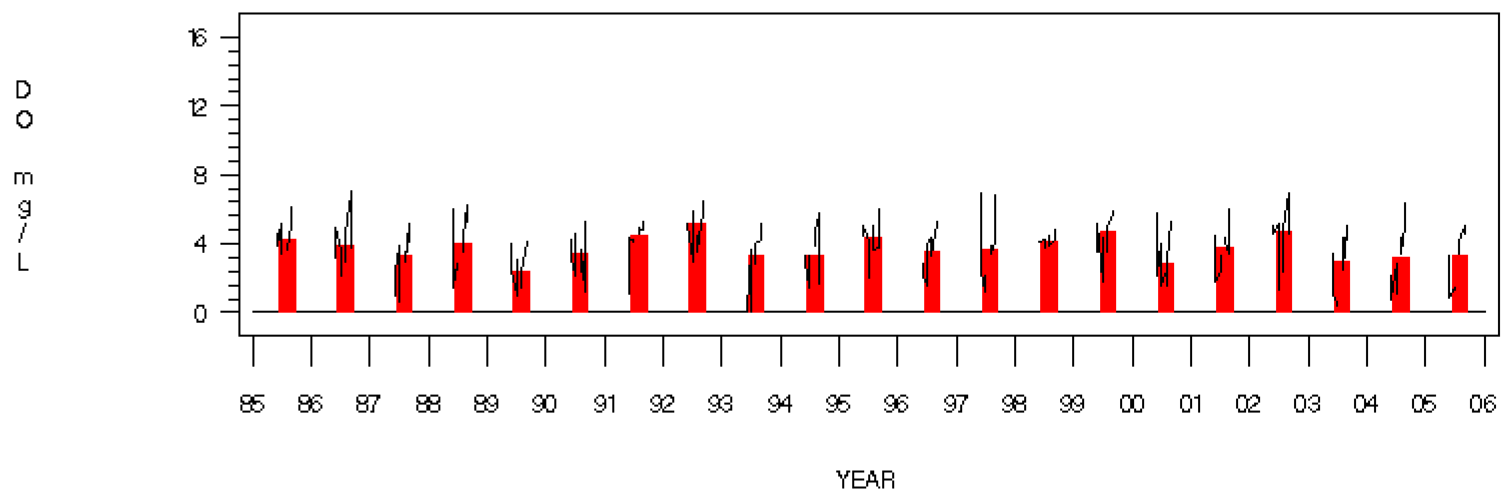


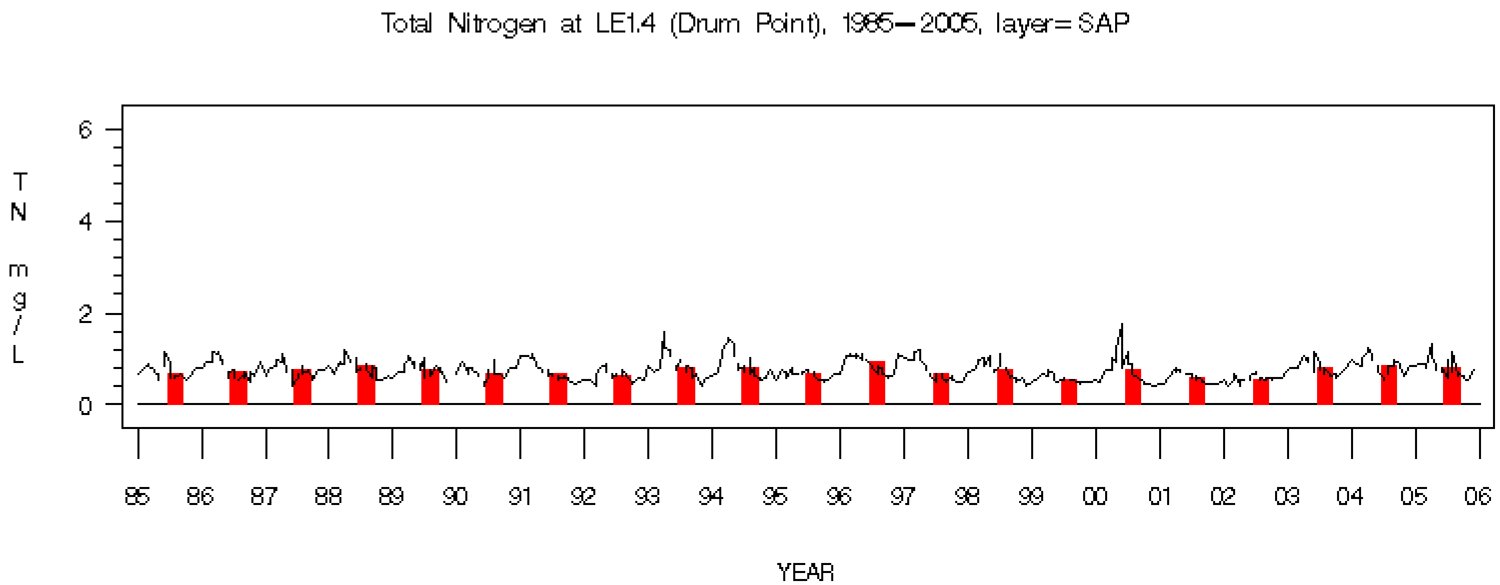
Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.

Secchi Depth at LE1.3 (Above Pt. Patience), 1985—2005, layer=S

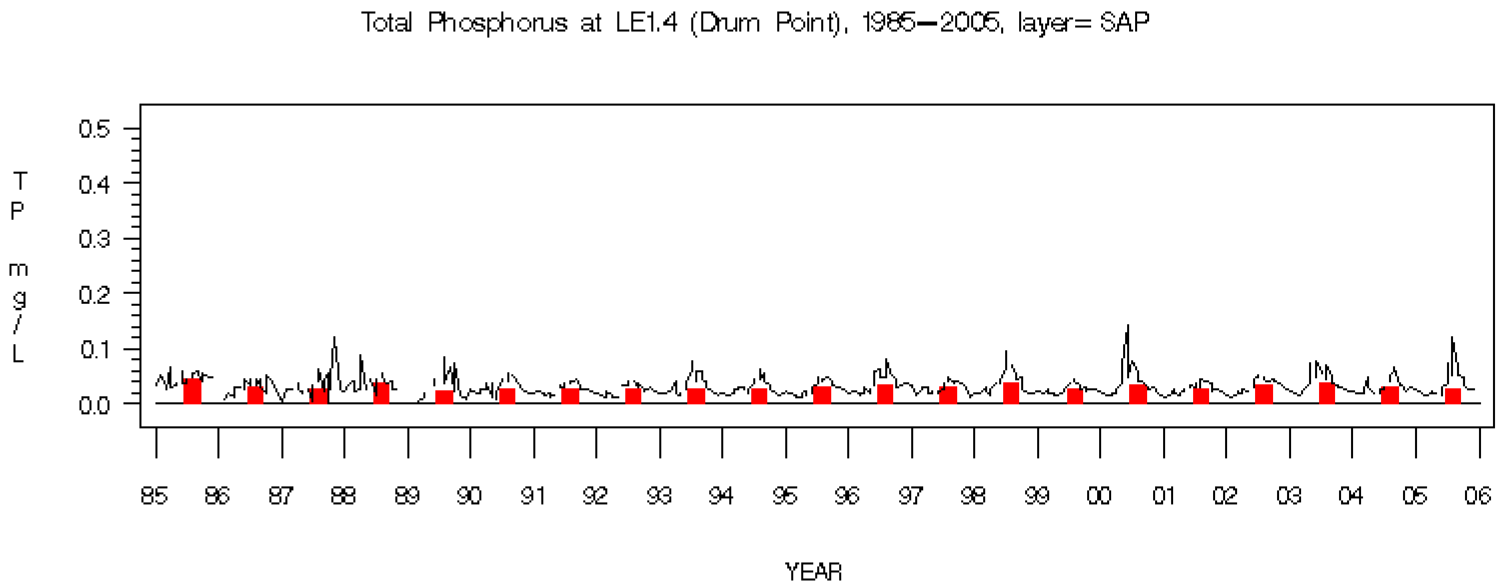


Dissolved Oxygen at LE1.3 (Above Pt. Patience), 1985—2005, layer= BDO

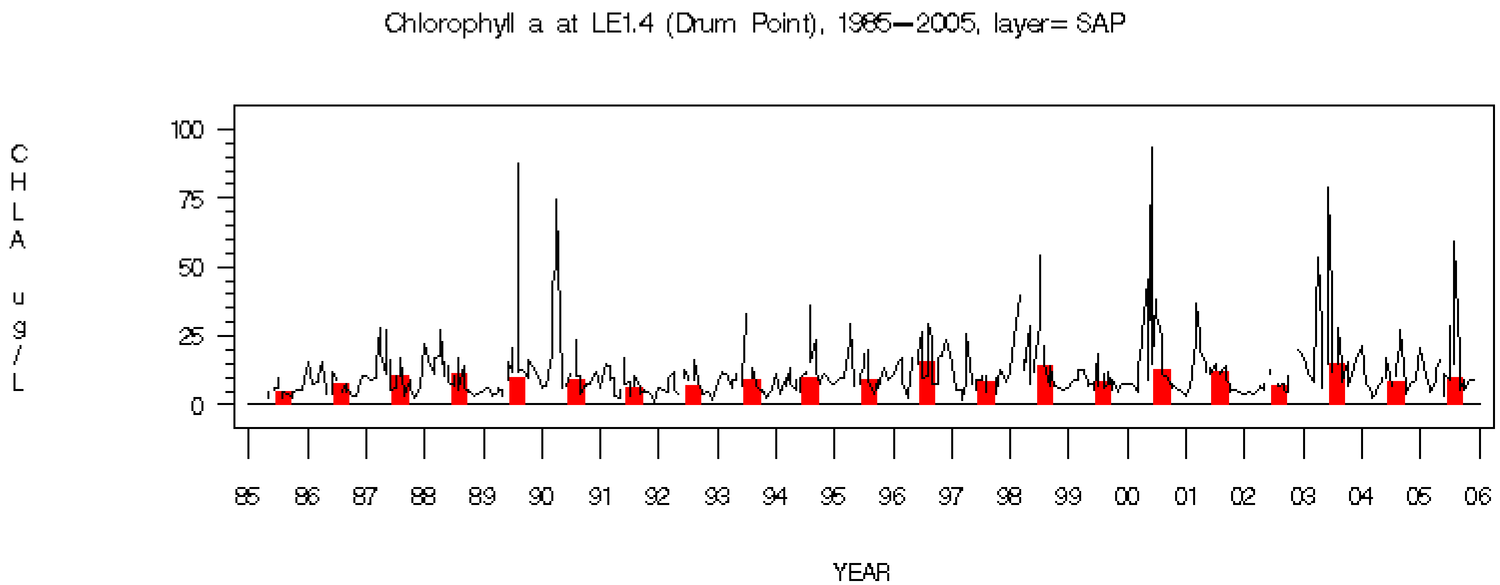


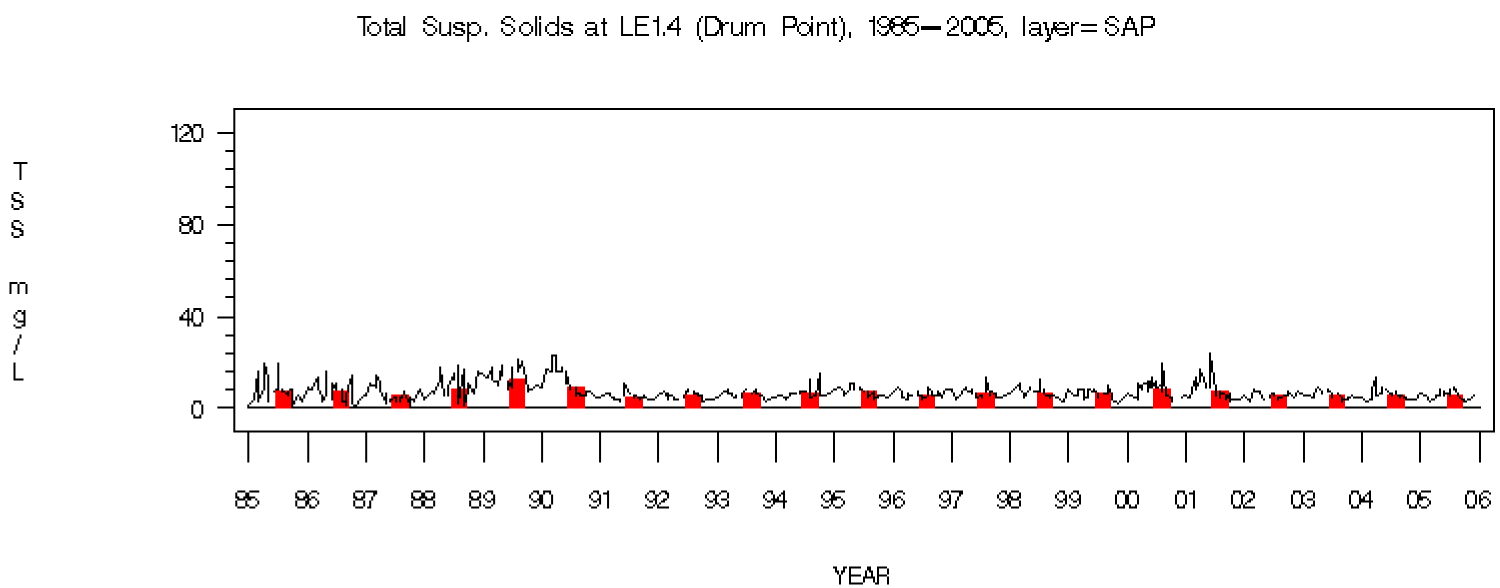


Total Nitrogen at LE1.4 (Drum Point), 1985—2005, layer=SAP
TN mg/L
0
2
4
6
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

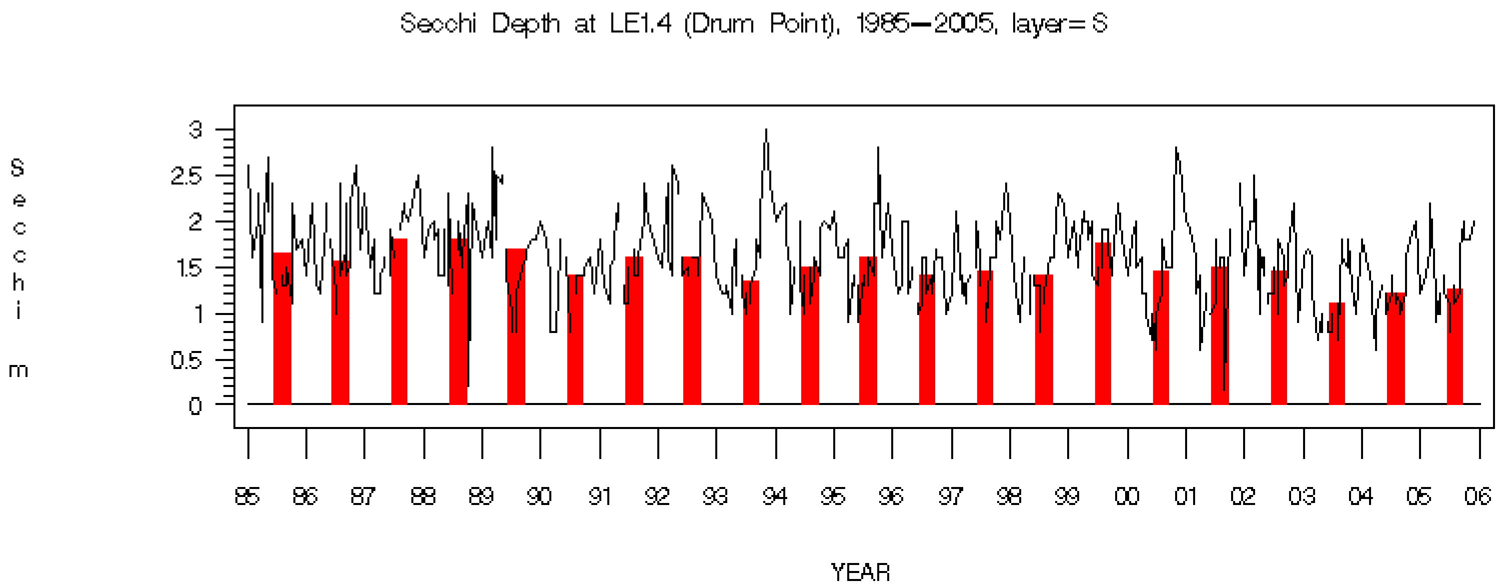


Total Phosphorus at LE1.4 (Drum Point), 1985—2005, layer= SAP
TP mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

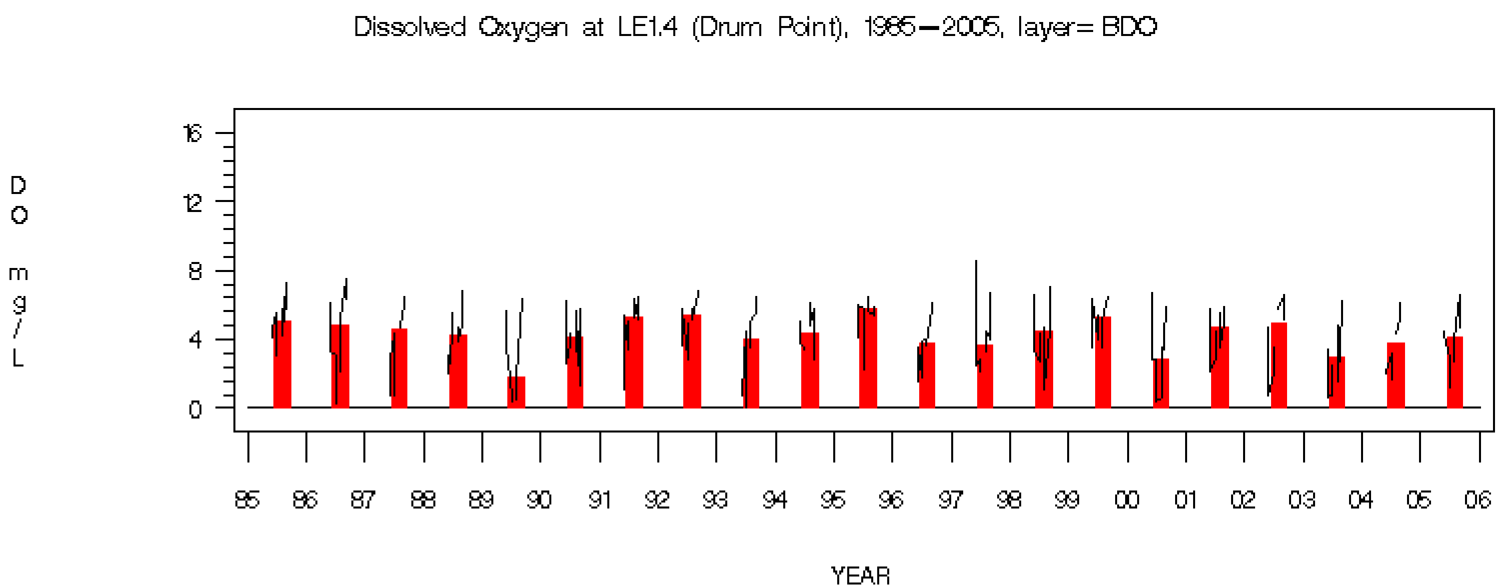




Please see Appendix C for information on the potential problems with the long-term total suspended solids concentration data at the tidal stations.



Secchi Depth at LE1.4 (Drum Point), 1985—2005, layer= S
Secchi m
0
0.5
1
1.5
2
2.5
3
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR



Dissolved Oxygen at LE1.4 (Drum Point), 1985—2005, layer= BDO
DO mg/L
0
4
8
12
16
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
YEAR

Appendix C – Potential Problems With the Long-term Total Suspended Solids Concentration Data.

The Department of Natural Resources changed laboratories for the analysis of nutrients and total suspended solids in July 1990 for tidal water quality analysis for Patuxent River tidal stations. Chlorophyll *a* analyses were not affected because chlorophyll continues to be analyzed by the same laboratory. While this change has not had a detectable effect on total nitrogen or total phosphorus measured by the two laboratories for the different time periods, there has been a discernable shift in total suspended solids concentrations. As a result, trends in total suspended solids should be interpreted with caution; especially those at stations in the higher salinity tidal tributaries.

The method used to analyze concentrations of total suspended solids was the same for both laboratories; however, a slight difference in how the methods were implemented may have affected the results. Water quality samples collected between 1985 through June 1990 were analyzed using un-washed filter pads where as those collected since July 1990 were analyzed using pre-washed filter pads. As a result, total suspended solids concentrations from some stations have a "step" in the data. That is, samples collected since July 1990 tend to have slightly lower total suspended solids concentrations solely due to the change in laboratories, and not as a result of management actions to reduce total suspended solids concentrations.

The decreasing step trend is more evident in samples from higher salinity tidal areas, possibly because these areas generally have lower concentrations of total suspended solids and/or higher concentrations of salts (which would be washed away by rinsing). The step-trends are less noticeable in tidal fresh areas, where total suspended solids are much higher, and the change due to different filter processing methods represents a very small percentage of the total concentration. For example, if the total suspended solids concentration at a tidal fresh station averages 100 mg/L, a decrease of 1 mg/L due to a change in laboratories will not be noticeable, whereas this same change will have a larger impact on a sample from a higher salinity tidal station where the average total suspended solids concentration is only 10 mg/L.

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