2.7 CONTAMINANTS

2.7.1 INTRODUCTION

For purposes of evaluating contaminants within the Inland Bays/Atlantic Ocean Basin, two broad categories — *nutrients* and *chemicals* — have been formed to present this section. Specific nutrients discussed include nitrogen and phosphorus. Pathogens, which often occur in unhealthy numbers in the presence of high nutrients in surface waters, will also be included in the discussion of nutrients.

Chemicals are divided into classes, which include petroleum, solvents, and organics, pesticides and herbicides, PCBs, heavy metals, and other inorganics. Contaminants may enter the environment from a variety of sources. These sources include large industries, small businesses, mobile sources, agricultural operations, residential areas, and biological sources, as well as through the air transport of contaminants from outside the Basin.

Some data contained within this section describe *potential* sources of contamination that, if left unmanaged or in the event of an accidental release, could have serious impacts on the environment. Other sources exist that are defined as potential sources because the Department does not currently possess information that definitively links a source to observable contamination. These potential sources may be considered *possible* or *suspected* sources.

Existing contamination may be the result of either past or present human activities. Past practices, such as landfill operations (now closed) and Superfund sites, may still be contaminant sources. Contamination from current activities may occur routinely, as in a permitted discharge of a municipal wastewater treatment plant; or may occur as a result of a spill or leak, as in ground-water contamination from a leaking underground storage tank. Contamination may be transported or exchanged between various media, such as a contaminant that was land applied that is subsequently transported in ground or surface water.

The contaminant assessment that follows describes the various nutrient and chemical contamination sources that the Department has identified as existing within the Inland Bays/Atlantic Ocean Basin. These sources are grouped and presented as *source types*. As an example, landfills are considered a source type. Therefore, all landfills within the Basin are discussed under one heading. Under each source type, additional information is presented for those individual sources where contamination levels are of concern. Trends and/or data gaps within a source type are also identified. In order for users of this section to readily obtain additional information, each source type section includes an appropriate Department contact.

A database, called the *Site Index Database,* has been developed for known and potential contaminant sources

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within the Basin. A copy of this database is included on the accompanying CD-ROM. This database is designed to be an easy-to-update, central registry of contaminant site summary data. This database is not intended to be a replacement for more detailed program-developed databases such as the Site Investigation and Restoration Branch's Site Status Database, but rather to be an index to site data stored by the various programs in the Department. This database includes basic site identification information (name, ID number, XY location, basin), site type (e.g., underground storage tanks, spray irrigation sites, etc.), and a contact for more details about the site. Besides this basic information, the database also includes monitoring activity status and contamination potential ratings by media (soil, sediment, surface water, ground water) and contaminant class (nutrients, bacteria, petroleum, organics, pesticides, PCBs, metals, and inorganics) for each site.

Database contents can be queried and displayed online through the database interface. Through the linking of the database with the GIS program Arc View, any number of sites can be plotted on a map. Using this database, it is possible to answer questions such as "Where are all the known PCB contamination sites in the state?" or, "Are there any contaminated sites near a proposed land acquisition area?" Inland Bays/Atlantic Ocean Basin site data currently loaded in the database include:

- Animal operations;
- Dredge spoils [Confined Disposal Facilities (CDFs)];
- Hazardous waste generators;
- Landfills & dumps;
- Large on-site septic systems;
- National Pollutant Discharge Elimination System (NPDES) outfalls;
- Pesticide loading, mixing and storage facilities;
- Salvage yards;
- State and federal Superfund sites (SIRB);
- Sludge application fields;
- Spray irrigation fields;
- Toxics Release Inventory (TRI) locations; and
- Underground Storage Tank (UST) facilities.

In addition to these, the Department also has data/maps for houses with individual septic systems throughout the Basin and the state.

2.7.2 NUTRIENTS (NITROGEN AND PHOSPHORUS)

2.7.2.1 Category Definition & Characteristics

Nutrient enrichment of surface waters is a natural process, spanning thousands of years, resulting from natural erosion and the breakdown of organic material. However, activities linked to soil erosion, domestic waste disposal, and runoff can greatly increase the rate and amount of nutrients reaching waterways, accelerating the nutrient enrichment process (305[b] Report, 1998). Nitrogen (N) and phosphorus (P) are the major nutrients that cause eutrophication of surface waters. *Eutrophication* is defined as an increase in the nutrient status of natural waters that causes accelerated growth of algae or water plants, depletion of dissolved oxygen, increased turbidity, and a general degradation of water quality. The enrichment of lakes, ponds, bays and estuaries by N and P from surface runoff or ground-water discharge is known to be a contributing factor to eutrophication. According to the *1998 Watershed Assessment Report* (305[b]), nutrients pose a serious threat to water quality, aquatic life, and human health. Most nutrients are transported to estuaries and lakes by rivers and ground water. Agricultural runoff, urban runoff, and municipal and industrial point source discharges are the primary sources of nutrients.

2.7.2.2 Nitrogen

Nitrogen is a complex element and appears in several different forms in the environment. In a gaseous state, it may exist as nitrogen gas (N_2), which is a very stable compound. Nitrogen gas comprises 78 percent of the air we breathe. Gaseous nitrogen also exists as oxides of nitrogen (NO_x) that are formed by combustion — automobile emissions, power plant exhausts, and open burning of leaves, for example.

Ammonia nitrogen (NH_3) is released to the atmosphere by volatilization. For example, 20–30 percent of the total nitrogen found in poultry manure is in the form of ammonia. When poultry manure is applied to the soil as fertilizer, the ammonia in the manure begins to volatilize to the atmosphere. The amount of ammonia that will volatilize depends on how soon the manure is incorporated into the soil. Studies have shown that approximately 20 percent of the ammonia will volatilize within two days if the manure is not incorporated into the soil, and as much as 80 percent of the ammonia will volatilize after seven days if not incorporated.

Nitrogen also exists in complex organic compounds that typically are called *organic nitrogen compounds* (N_{org}). Organic nitrogen is found in humus, manure, and decaying plant and animal matter. Organic nitrogen compounds are relatively stable and remain in the shallow soil profile until converted to inorganic forms of nitrogen by soil bacteria.

Another important form of nitrogen is nitrate/nitrite nitrogen (NO_3^{-1}, NO_2^{-1}). Nitrate nitrogen is highly soluble and can quickly travel through the soil and enter ground water.

When nitrogen is applied to the soil, it undergoes numerous changes. For example, if organic nitrogen is applied to the soil, it first undergoes a process called *mineralization*. Mineralization is a process in which organic forms of nitrogen are converted to ammonium nitrogen (NH_4^{+1}), an inorganic form of nitrogen. This process is controlled by the activity of soil microorganisms and is affected by environmental factors such as temperature, moisture, soil pH, and soil type. Soil bacteria further break down ammonium to nitrate nitrogen in a process called *nitrification*. The process of nitrification requires oxygen and occurs only under aerobic soil conditions. If there is insufficient oxygen in the soils, then nitrification occurs very slowly and anaerobic bacteria utilize the nitrates. Anaerobic bacteria utilize the oxygen molecules in nitrate nitrogen during respiration, ultimately converting the nitrate nitrogen to nitrogen gas (N_2) that flows upward through the soil profile and into the atmosphere. This process is called *denitrification*. Denitrification does not occur in well-drained, aerobic soils.

Finally, some crops — specifically, legumes like alfalfa and soybeans — can "fix" nitrogen gas into the proteins these crops need to live and then release organic nitrogen compounds when they die. This process is called *fixation*. One group of nitrogen-fixing microorganisms is bacteria called Rhizobium. Rhizobium bacteria live within the roots of legumes and provide nitrogen for those crops to grow. Alfalfa, for example, typically fixes approximately 150–250 pounds of nitrogen per acre annually from the atmosphere.

Nitrogen can enter the Inland Bays by a variety of pathways. The pathway taken is greatly influenced by the form of the nitrogen compound.

Direct and indirect atmospheric deposition can discharge a substantial amount of nitrogen and other contaminants to the Inland Bays. Recent studies indicate that as much as 33 percent of the total nitrogen entering the Inland Bays may come from atmospheric deposition (Scudlark and Church, 1999).

When nitrogen compounds are released into the air, they are carried away from their place of origin by wind patterns. Depending on weather conditions and the chemical and physical properties of the pollutants, some nitrogen compounds can be carried significant distances from their source and can undergo physical and chemical changes as they travel. Some of these chemical changes include the formation of new pollutants like ozone, which is formed from nitrogen oxides (NO_x) and hydrocarbons.

Atmospheric deposition occurs when pollutants in the air fall onto the land or water. The term "wet deposition," is used to describe pollutants deposited by snow, fog, or rain. The deposition of pollutants as dry particles (pollen,

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dust) or gases is termed "dry deposition." Nitrogen compounds can be deposited into the Inland Bays either through direct deposition from the air onto the surface of the water, or through "indirect deposition," where nitrogen compounds settle onto the land and are then carried to the bays or their tributaries by runoff or through ground-water recharge.

Determining the contribution of atmospheric nitrogen to the Inland Bays is difficult because of the various pathways atmospheric nitrogen may travel to reach the bays and the episodic nature of precipitation events. Nitrogen loadings from atmospheric sources have been estimated at 8–33 percent by several researchers (*Table 2.7-1*).

Table 2.7-1

ESTIMATES OF ATMOSPHERIC NITROGEN LOADING TO DELAWARE'S INLAND BAYS

REFERENCE	PERCENT NITROGEN FROM ATMOSPHERE
Ritter (1986)	6.2 (Indian River Bay)
	8.8 (Rehoboth Bay)
Cerco et al. (1994)	21–33
Valigura et al. (1996)	21
Horsley & Witten (1998)	23 (Indian River Bay)
	29 (Rehoboth Bay)

In 1999, Scudlark and Church performed a comprehensive examination of atmospheric nitrogen loads to the Rehoboth and Indian River estuaries. Little Assawoman Bay was not included in their examination because it is hydrogeologically disconnected from the Rehoboth/Indian River Bays system.

There are three biologically reactive forms of nitrogen that are of concern when considering atmospheric inputs to surface waters: nitrate nitrogen (NO_3^-), ammonium nitrogen (NH_4^+), and organic nitrogen compounds (N_{org}).

Atmospheric NO_3^- compounds are formed in the atmosphere when nitrogen oxide compounds (NO, NO_2, collectively abbreviated as NO_x), which are formed from a variety of high temperature combustion processes, are oxidized to form nitrates (NO_3^-). Coal-fired power plants and vehicular emissions dominate NOx emissions.

Atmospheric NH_4^+ compounds are predominantly derived from agricultural sources, which include volatilization of animal wastes and fugitive releases from ammonia based fertilizers. Battye et al. (1994) estimated that nearly 90 percent of ammonia emissions in the United States are derived from agricultural sources.

Atmospheric N_{org} is experimentally defined as the difference between the total nitrogen and inorganic nitrogen in a sample. N_{org} is poorly characterized with respect to its source, chemical make-up, and reactivity. N_{org} compounds are derived from a variety of natural and human sources and are found in urea, amino acids, pollen, and decaying vegetation. Until recently, the contribution of N_{org} to atmospheric loading rates has been ignored, or at best, was highly uncertain.

While nitrogen gas (N_2) is a major component of the Earth's atmosphere, it is the more biologically reactive forms of nitrogen, such as nitrates (NO_3^-), ammonium (NH_4^{+1}) and organic nitrogen compounds (N_{org}), that are of concern when considering direct and indirect atmospheric depositions to surface waters.

As discussed previously, direct atmospheric deposition refers to both the wet deposition of nitrogen compounds from precipitation as well as dry deposition from air flow over the bays. Scudlark and Church (1999) collected and analyzed precipitation chemistry data from several atmospheric monitoring stations located within and outside the Inland Bays Basin. Based on their research several trends were observed:

- Precipitation chemistry data indicate that local sources have a relatively small effect ($\leq$ 20%) on NO_3^- precipitation rates.
- Local sources (primarily from manure volatilization and use of ammonia-based fertilizers) are responsible for the majority of the NH_4^+ found in precipitation.

- NH_4^+ concentrations measured at Georgetown and Indian River are consistently higher than at Lewes, by as much as a factor of 2.
- NH_4^+ concentrations at Indian River were consistently higher during summer months when ammonia volatilization from animal manure is greatest.
- Deposition rates for NH_4^+ are increasing within the Basin, indicating a greater impact from local ammonia emissions. *Figure 2.7-1* shows an increasing trend in the NH_4^+ and NO_3^- concentrations at the Lewes station. The trend is statistically significant for NH_4^+ and reflects a 58 percent increase in the mean annual NH_4^+ concentrations over the past 20 years. Coincidentally, broiler production has nearly doubled in Delaware in the two decades between 1975 and 1995 (Martin, and others, 1998). The evidence linking increased NH_4^+ precipitation concentrations with rising broiler production, while circumstantial at present, bears further investigation.
- *Figure 2.7-2* shows long-term volume-weighted monthly average concentrations of NO_3^- and NH_4^+ taken from the Lewes station (Scudlark and Church, 1993). The data clearly show a distinct seasonal variation in atmospheric concentrations of NO_3^- and NH_4^+, peaking during summer months.
- Seasonal trends in precipitation concentrations for NO_3^- and NH_4^+ reflect the use trends in the Basin. NH_4^+ emissions from agricultural sources increase dramatically during summer months, reflecting the volatilization of ammonia from animal manure and the timing of application of liquid ammonia-based fertilizers. Similarly, NO_x emissions from electric utilities increases by approximately 40 percent during summer months, and emissions from vehicular traffic increases by a factor of 2 – 3 from winter to summer as a result of the influx of tourist traffic.

Figure 2.7-1

ANNUAL VOLUME-WEIGHTED CONCENTRATIONS OF NO_3^- AND NH_4^+ IN PRECIPITATION AT LEWES FROM 1978 – 1998

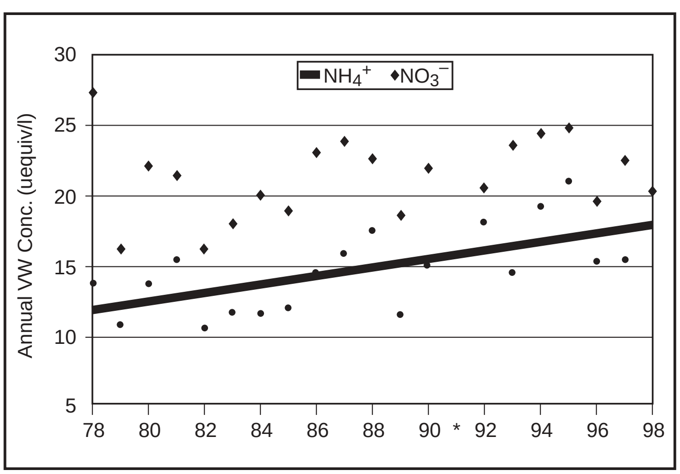
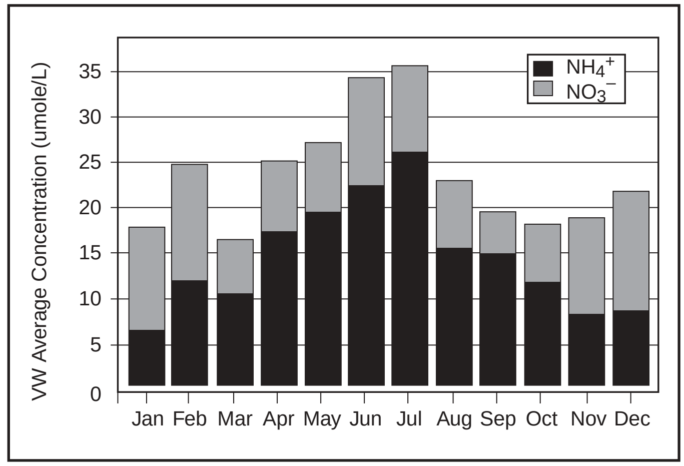


Figure 2.7-2

LONG-TERM (1978 – 1997) VOLUME-WEIGHTED MONTHLY AVERAGE CONCENTRATIONS (µmoles/l) OF NO_3^- AND NH_4^+ AT LEWES ***(Scudlark and Church, 1993)***



Due to its proximity to the Rehoboth and Indian River bays, the length of sampling (>20 years), and the quality of the data recorded, the precipitation data from the Lewes station were used to quantify the wet deposition rates of nitrogen to the Bays from precipitation.

To gauge dry deposition rates, in the absence of actual measurements in the Inland Bays Basin, the wet:dry flux ratios reported at nearby sites with similar land uses were used, taking into account various modeling constraints (Meyers et al., 1999).

Table 2.7-2 presents average direct atmospheric deposition loading rates for the Rehoboth and Indian River bays. Additionally, direct wet and dry deposition rates, along with ranges and uncertainty levels, are presented in *Figures 2.7-3* and *2.7-4,* respectively. *Figure 2.7-5* combines the values from *Figures 2.7-3* and *2.7-4* to reflect the total direct atmospheric loading rates to the Rehoboth and Indian River bays.

From *Table 2.7-2,* the average annual atmospheric loading rate over water can be calculated. The open-water area of the Rehoboth and Indian River bays is 9,137 acres and 9,324 acres, respectively. Thus, the annual-averaged total direct atmospheric nitrogen loading to the Rehoboth and Indian River bays is 75,800 lbs N/acre/year and 77,400 lbs N/acre/year, respectively.

The vertical lines in *Figure 2.7-3 – Figure 2.7-5* represent the degrees of variation and uncertainty in the nitrogen compounds studied. The range of uncertainties reflects the annual variations and spatial variability in wet and dry fluxes over land, along with additional uncertainties in extrapolating land-based dry fluxes over water. The absence of a vertical line associated with the deposition of N_{org} is due to the lack of experimental data to accurately assess reactivity and deposition rates (Scudlark and Church, 1999).

Table 2.7-2

AVERAGE DIRECT ATMOSPHERIC DEPOSITION RATES TO THE REHOBOTH AND INDIAN RIVER BAYS (LBS/ACRE/YEAR)

NITROGEN FORM	WET DEPOSITION	DRY DEPOSITION	COMBINED (WET + DRY)
NO_3^-	2.90	0.97	3.87
NH_4^+	2.48	0.28	2.76
N_{org}	1.25	0.42	1.67
Total	6.63	1.67	8.30

Figure 2.7-3

ANNUAL WET ATMOSPHERIC DEPOSITION RATES (LBS N/ACRE/YEAR), SHOWING THE MEAN AND RELATIVE LEVELS OF VARIATION AND UNCERTAINTY FOR EACH TERM

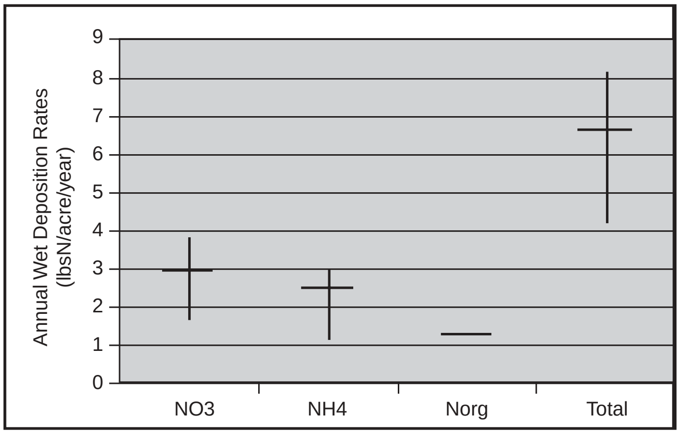


Figure 2.7-4

ANNUAL DRY ATMOSPHERIC DEPOSITION RATES (LBS N/ACRE/YEAR), SHOWING THE MEAN AND RELATIVE LEVELS OF VARIATION AND UNCERTAINTY FOR EACH TERM

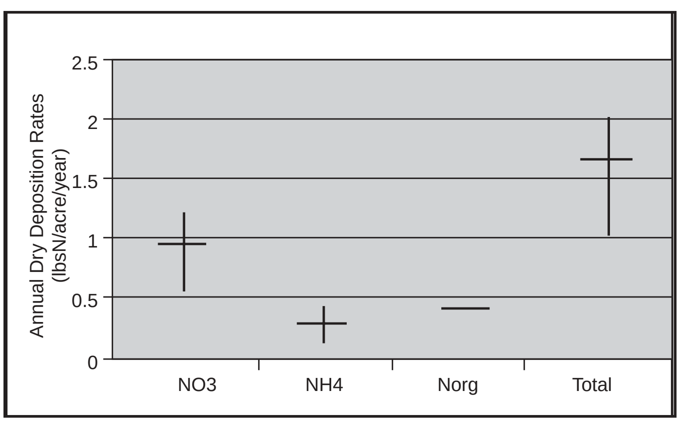
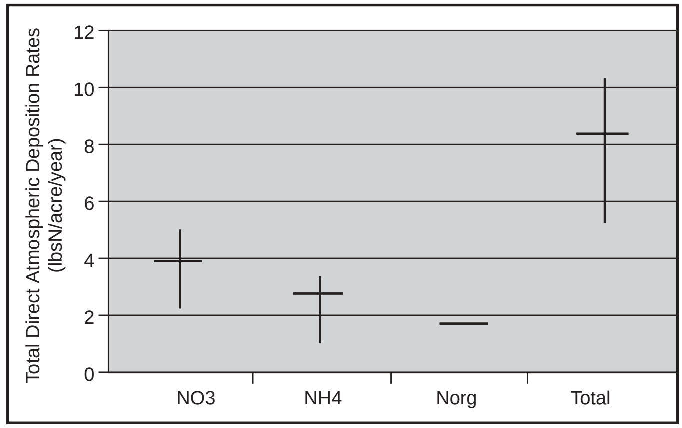


Figure 2.7-5

ANNUAL TOTAL (WET+ DRY) ATMOSPHERIC DEPOSITION RATES (LBS N/ACRE/YEAR) SHOWING THE MEAN AND RELATIVE LEVELS OF VARIATION AND UNCERTAINTY FOR EACH TERM



Indirect atmospheric inputs are those inputs that fall onto land and are then transmitted through the watershed to surface waters via overland flow or through groundwater recharge. Previous assessments of atmospheric nitrogen deposition to the Chesapeake Bay indicates that a majority (about two-thirds) of the atmospheric input actually takes place via this indirect path (Fisher and Oppenheimer, 1988). While the degree of nitrogen transmission through a watershed is generally small, the total loading to the bays is significant because of the large watershed:open water area ratio. For the Inland Bays/ Atlantic Ocean Basin, the ratio is approximately 8:1.

Wet deposition rates onto the land are equivalent to the wet deposition rate onto water. However, dry deposition rates onto the land average three times greater than dry deposition rates onto water, due primarily to the difference in the physical and chemical characteristics of the surfaces (water vs. land) involved.

The amount, intensity, type and frequency of precipitation, along with land use all influence the transmission of atmospherically deposited nitrogen compounds. Of 107 precipitation events studied, the 11 largest accounted for approximately 35 percent of the NO_3^- and 43 percent of the NH_4^+ total annual deposition. These factors vary seasonally and can be highly episodic.

It is not possible to quantify indirect atmospheric loading rates to the bays through direct measuring techniques. In order to gauge the relative contribution of indirect atmospheric loads to the bays, it is necessary to incorporate a computer model to the watershed. The SPARROW model (SPAtially Referenced Regression On Watershed attributes) was chosen because it parameterizes a number of watershed attributes that govern the degree of nitrogen retention and export. Factors considered in the model include land use, vegetation, soil type and permeability, slope, stream density and depth, river discharge rates, denitrification potential, and temperature.

For the Inland Bays/Atlantic Ocean Basin, most of these factors favor low export rates from land to water. These include a relatively flat terrain, high soil permeability, a high percentage of vegetated land use (forest and croplands comprise over two-thirds of the combined Rehoboth and Indian River watersheds), shallow stream depth, high temperatures, and a relatively low freshwater discharge rate. In fact, Andres (1992) estimated that <20 percent of the NO_3^- exported from land to the bays is by means of surface runoff, with the remainder coming from ground-water recharge.

Nitrate that leaches below the crop-rooting zone represents loss of a valuable plant nutrient, and hence an economic cost to agriculture. If the nitrate enters ground water, two major environmental problems can occur. The consumption by humans or animals of drinking water with high nitrate levels is associated with methemoglobinemia (oxygen deficiency in blood) in infants. Ground water with high nitrate levels that discharges into sensitive surface waters can contribute to long-term eutrophication of these water bodies. The most conducive setting for nitrate leaching and ground-water pollution is a sandy, well-drained soil, with shallow water table, in an area that receives high rainfall and frequently applied fertilizer, manure, or other nitrogen source material. However, any situation involving over-application of wastes or fertilizers, or intensive irrigation, has the potential to cause significant nitrate leaching, regardless of soil and climate (Sims, 1995).

Chemical fertilizer, manure, and septic system leachate are major sources of ground-water nitrate contamination in Delaware. Researchers have noted a link between agricultural land activities and elevated ground-water nitrate levels (Ritter, 1984, 1992; Denver, 1989). Poultry production has also been associated with elevated nitrate levels (Andres, 1992). Septic tanks have been identified as a localized source of nitrate, especially when numerous systems are concentrated in an area (Denver, 1989). Provided a source of nitrate exists, a more critical factor is soil type and depth to water table (Ritter, 1984; Andres, 1991; Denver 1989; Bachman, 1984). Even if nitrate sources are extensive, areas with poorly drained soils do not tend to have high nitrate levels in ground water. Low oxygen conditions in poorly drained soils allow for greater denitrification so that nitrogen is lost to the atmosphere rather than leached into ground water.

Land use greatly influences the rate and amount of nitrogen that can migrate from a specific area. In general, forests are efficient at assimilating atmospherically deposited nitrogen compounds, while croplands and pastures are somewhat less efficient. However, agricultural land use encompasses a wide range of farming activities (e.g., cropland, pasture, orchards) and for a given farming activity, the retention of nitrogen can vary significantly (e.g., no-till vs.

Table 2.7-3
PERCENTAGE OF NITROGEN LOADS FROM DIFFERENT SOURCES FOR THE INLAND BAYS

SOURCE	REHOBOTH BAY		LITTLE ASSAWOMAN BAY		INDIAN RIVER BAY	
	Ritter	H&W	Ritter	H&W	Ritter	H&W
Point Sources[1]	27.3	3.1	0	0	12.5	7.6
Urban & Septic Systems[2]	22.9	19.7	11.2	9.2	9.8	23.5
Agriculture	33.6	49.0	54.7	79.9	44.6	57.5
Forest	7.4	<0.1	6.7	<0.1	11.0	<0.1
Rainfall/Atmospheric Deposition	8.8	28	12.8	10.8	6.2	11.9
Wetlands	0	0	0	0	0	0
Boating	<0.1	—-	<0.1	—-	<0.1	—-
Septic Tanks (Ritter only)	11.2		14.6		16	

Source: Ritter (1986); Horsley & Witten, Inc. (1998)

[1] Since the Ritter study, there has been a 30 percent reduction in the number of point sources discharging into the Inland Bays. In addition, nitrogen and phosphorus loadings from remaining point sources have been reduced by 20 and 52 percent, respectively, since the Ritter study because of wastewater treatment facility upgrades to remove nutrients (DNREC, 1997).

[2] Commercial and industrial loadings from the Horsley & Witten report are included under urban sources.

conventional till agriculture, use of Best Management Practices to control nutrient runoff, planting of winter cover crops, etc.). In contrast, urban and residential lands transmit a greater proportion of atmospheric inputs to surface waters, due to a high degree of impervious surfaces in residential settings. This percentage varies greatly depending on the practices used for controlling runoff. Because of their high nutrient assimilative capacity, wetlands tend to use applied nutrients rapidly and efficiently, so nutrient loss from wetlands is relatively low.

Ritter (1986) and Horsley and Witten, Inc. (1998) assessed nitrogen loadings for a variety of land uses (*Table 2.7-3*).

Based on his investigation, Ritter (1986) concluded:

- ◆ Agricultural land use is the largest contributor of nitrogen and phosphorus to the Inland Bays.
- ◆ Over 75 percent of the nitrogen entering Rehoboth Bay, Indian River Bay, and Little Assawoman Bay from non-point sources in a normal year is from ground-water recharge.
- ◆ On-site wastewater systems contribute only 11–16 percent of the nitrogen load to the three bays, but have a considerable impact on ground-water quality in the Basin.

Horsley & Witten, Inc. (1998) concluded:

- ◆ The Inland Bays face a serious threat from nutrients applied to land within the Basin.
- ◆ With the exception of Rehoboth Bay, the loadings of nitrogen to the Inland Bays, under current conditions, are above the projected carrying capacity (*Table 2.7-4*).
- ◆ To protect the bays, a significant reduction in current loadings is needed, and any further loadings must be prevented.
- ◆ To reduce loadings in the Indian River Bay to the level of the bay's carrying capacity, all fertilizer applications would have to be eliminated now — today — to have the needed curative effect. The elimination of all other sources (such as residential and commercial development) would not be enough to prevent further degradation of water quality in Indian River Bay.
- ◆ There is a lag time between when nitrogen from fertilizers or septic systems enters the ground water and when it ultimately discharges into the bays. It may take tens of years for nitrogen application in the upper parts of the Basin to affect bay water quality. This means that the current bay water quality is a reflection of loadings that have taken place over the last 10–30 years.
- ◆ Because loadings have increased over this time, future water quality is likely to worsen.

Table 2.7-4

NITROGEN CARRYING CAPACITY RESULTS — CURRENT CONDITIONS

EMBAYMENT	CAPACITY (LBSN/YEAR)	LOAD[1] (LBSN/YEAR)	DIFFERENCE (+ OR -) (LBSN/YEAR)
Rehoboth Bay	909,000	720,000	-189,000 (below capacity)
Indian River Bay	920,000	2,248,000	+1,328,000 (above capacity)
Little Assawoman Bay[2]	312,000	825,000	+513,000 (above capacity)

Source: Horsley & Witten, Inc. (1998)

[1] Does not include atmospheric deposition loadings.

[2] Does not include the Maryland portion of the watershed.

- ◆ Actions taken today or in the near future to reduce loadings will not have an instant effect on water quality in the bays. It will take time for water quality to improve following any action to reduce or eliminate loadings.
- ◆ Agricultural loadings are the greatest source of nitrogen to the bays, due to the extensive land area used for crop production and poultry operations. It will be necessary to alter agricultural practices to protect water quality in the Inland Bays.
- ◆ The loadings from residential and other developed land uses should be evaluated to reduce loadings from further development.

Horsley & Witten, Inc.'s (1998) results are further depicted in *Figure 2.7-6* through *Figure 2.7-8* (these figures do not include loading from atmospheric deposition).

Taking into account the factors identified earlier, along with the different land uses within the Basin, the average annual indirect atmospheric loading is estimated to be 73,200 pounds of nitrogen for Rehoboth Bay and 153,000 pounds of nitrogen for the Indian River Bay.

The total nitrogen load from atmospheric deposition to the Rehoboth and Indian River bays is the sum of the direct plus indirect atmospheric deposition. For Rehoboth Bay, the total average annual atmospheric nitrogen load is 149,000 lbs N/year; for Indian River Bay, the total average annual atmospheric nitrogen load is 230,400 lbs N/year.

Ground-water recharge provides up to 80 percent of the freshwater input to the Inland Bays and their tributaries (Johnson, 1976). Ground-water sources also provide 100 percent of the drinking water within the Basin. Most forms

Figure 2.7-6

NITROGEN LOAD CONTRIBUTION BY LAND USE: INDIAN RIVER BAY WATERSHED = 2,248,000 LBS NITROGEN PER YEAR

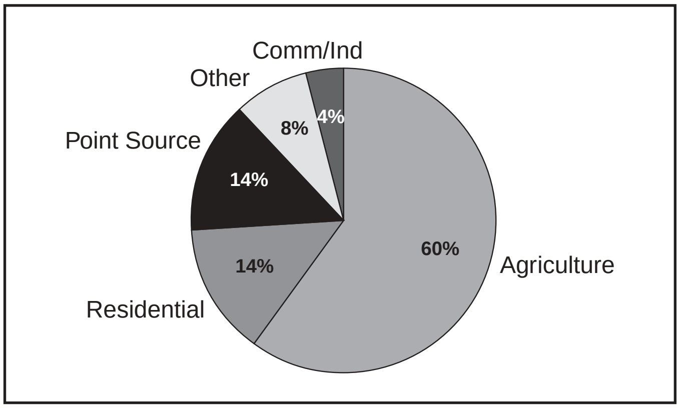


Figure 2.7-7

NITROGEN LOAD CONTRIBUTION BY LAND USE: LITTLE ASSAWOMAN BAY WATERSHED = 825,000 LBS NITROGEN PER YEAR

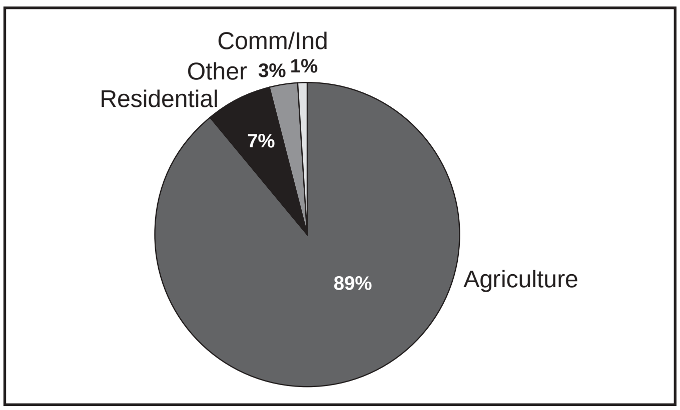
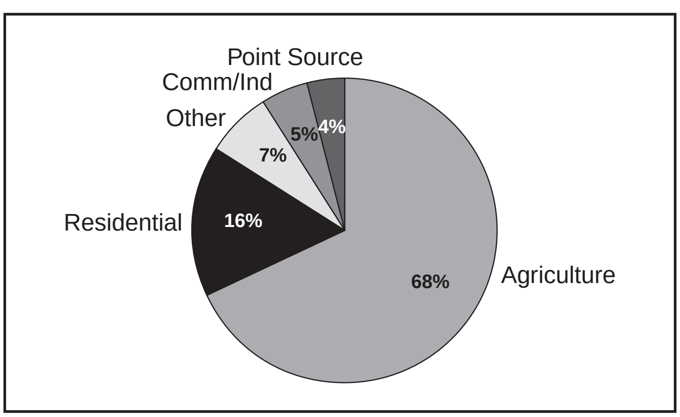


Figure 2.7-8

NITROGEN LOAD CONTRIBUTION BY LAND USE: REHOBOTH BAY WATERSHED = 720,000 LBS NITROGEN PER YEAR



of nitrogen stay in the soil profile and do not readily leach to ground water. The exception to this statement is nitrate nitrogen (NO_3^{-1}). When various forms of nitrogen are applied to the soil, bacteria in the soil convert the nitrogen to nitrate nitrogen, which is the form of nitrogen used by most plants for growth and development. However, any nitrates remaining in the soil after crop uptake are available to enter the ground water. How nitrates move with water in the soil is best illustrated by considering what takes place when soils become wet from rainfall or irrigation. When water is applied to the soil, the soils become wet and the air spaces between soil particles begins to fill with water. If enough water is applied, the air spaces become filled to a point that gravity will cause the water to move downward through the soil column. As water moves downward, nitrates will be carried downward with the water. The downward movement of nitrates in the soil is referred to as *leaching*.

One factor that greatly influences nitrate transport is soils type. The two soil types that predominate in the Inland Bays/Atlantic Ocean Basin are well-drained and poorly drained soils. Well-drained soils are formed mainly of coarse and fine sands. The depth to ground water is typically greater than 5 feet, the soil column is aerobic, and the land is relatively flat. Well-drained soils predominate in the areas north of Indian River Bay. Poorly drained soils are formed mainly of sandy loam or sandy clay loam, the ground-water table is frequently near the surface, soils are often anaerobic, and frequently require artificial drainage before they can be used for farming or development. Poorly drained soils predominate in the areas south of Indian River Bay.

In well-drained soils, once nitrates are leached past the root zone, they are free to enter the ground water. In poorly drained soils, however, water movement through the soil column is slowed and anaerobic conditions can develop. Under anaerobic soil conditions, the nitrates leaching below the root zone are converted to nitrogen gas (N_2) that is released back to the atmosphere.

The occurrence and movement of nitrogen through the environment is summarized in *Figure 2.7-9.*

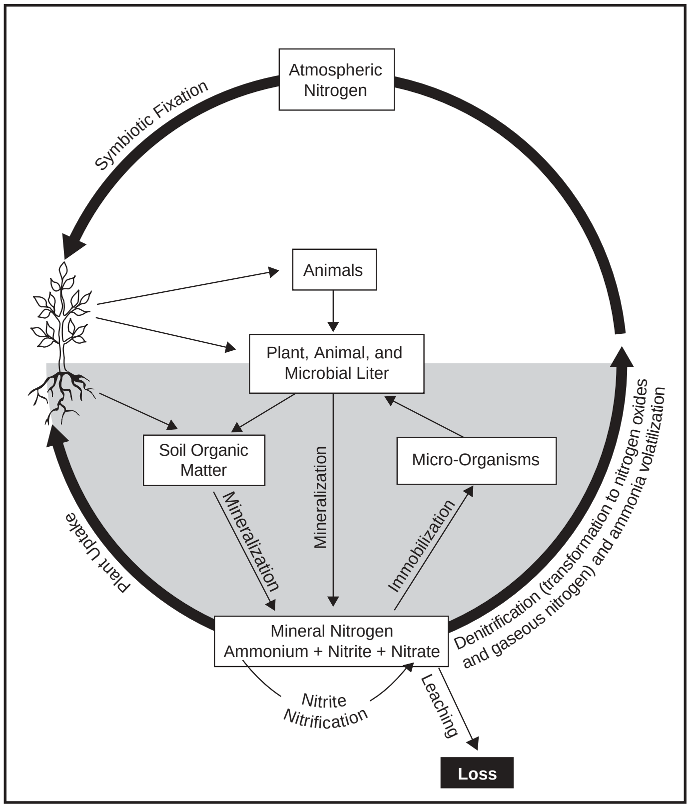
2.7.2.3 Phosphorus

Phosphorus is the eleventh-most abundant mineral in the Earth's crust and does not exist as a gas. Phosphorus is found in nature in three different forms. Natural inorganic phosphorus occurs primarily as complex calcium fluoride phosphate minerals (Ca_5 $(FCO_3)(PO_5)$) that are found in the Earth's crust. Naturally occurring phosphate mineral concentrations in Delaware soils are very low, varying from 4 – 20 milligrams per kilogram (mg/kg).

Phosphorus also exists as organic compounds found in organic matter such as decaying vegetation, manure, and municipal sewage. For example, poultry manure contains

Figure 2.7-9

THE NITROGEN CYCLE



approximately three percent phosphorus by weight as P_2O_5. Phosphorus is also found in complex organic and inorganic compounds associated with the cells of living organisms and is found in teeth, bones, and even in our DNA. Phosphorus bound in these complex compounds breaks down only very slowly over time. Crops cannot use organic phosphorus compounds, but require inorganic phosphates in the form of $H_2PO_4^{-1}$ for growth.

In the phosphorus cycle, phosphorus circulates through the soil, living organisms, and water. When applied to soil, phosphorus compounds quickly bond to soil particles through a process called *adsorption*. As water flows through the soil column, some of the phosphorus is dissolved and made available for plant growth. After the plants die, they release phosphorus back to the soil in the form of organic matter.

Phosphorus is less mobile than nitrogen. The primary means of phosphorus transport into the Inland Bays occurs as a result of non-point source erosion and surface runoff (Cassell et al., 1999). The amount of phosphorus deposited with a runoff event depends on the soil phosphorus concentration, vegetative coverage, topography, and proximity to drainage ways. Many of the agricultural soils in the Basin have high to excessively high levels of phosphorus (Sims et al., 1996). Furthermore, the extensive network of drainage ditches in the Basin carry large quantities of runoff from agricultural fields and urban areas to the Inland Bays. The lack of vegetated buffers near drainage ways in many agricultural fields in the Basin increases the potential loss of phosphorus to surface waters through runoff. Surface runoff losses are greater when soils are disturbed, such as during construction or soon after tilling a field.

Point sources from industrial and municipal wastewater treatment facilities also discharge phosphorus to the bays. In 1997, the 10 point sources within the Basin discharged 11,900 pounds of phosphorus to the Inland Bays (Discharge Monitoring Reports submitted by permittees).

Although phosphorus leaching is usually believed to be of little concern from a ground-water quality perspective, recent studies have shown that subsurface flow of soluble phosphorus to agricultural drainage systems can be a significant pathway for phosphorus transport to the bays (Izuno et al., 1991; Sims et al., 1996).

Soluble levels of phosphorus in ground water have been studied in several agricultural sites within the Basin (Sims and others, 1996). The results show that the release of soluble phosphorus to ground water, and then to drainage ways, is likely due to at least three factors:

- *Initial Soil Phosphorus Concentrations.* When a soil horizon becomes saturated with phosphorus, phosphorus will leach to subsoils where soluble forms of phosphorus may be released to ground water.
- *Depth to Water.* When the water table rises and interacts with subsoils, soluble phosphorus may be released from soil particles and transported short distances with ground-water movement.
- *Proximity to Drainage Ways.* Drainage ditches may be hydrologically connected to the ground water. Consequently, if phosphorus levels in the soils near drainage ditches are high, the potential for soluble phosphorus to be transported by ground water to drainage ditches increases. Current agricultural operations in the Basin leave very little buffer between the cropland and drainage ditches. In many cases, cultivation, fertilization, planting, and harvesting all take place virtually up to the edge of the ditch.

Previous studies indicate that phosphorus enrichment usually occurs only to depths <36 inches (Mozaffari and Sims, 1994). Given this, movement of phosphorus to surface waters via deep ground-water discharge seems unlikely.

Numerous studies have shown that sediments in drainage ditches are enriched with phosphorus (Sallade et al., 1997; Sims et al., 1998). Sediments likely have become enriched with phosphorus due to erosion of soil particles high in phosphorus from adjacent crop lands, shallow ground-water discharge of phosphorus, and direct broadcasting of manure and fertilizers into drainage ways.

Phosphorus loss via drainage ways is an emerging issue of concern in the Inland Bays/Atlantic Ocean Basin because much of the cropland near the bays comprises poorly drained soils and can be farmed only after an extensive network of drainage ditches is installed.

Seventeen ditches from six different farms in the Basin were sampled for phosphorus (Sallade et al., 1997). Those tests showed biologically available phosphorus (BAP) levels ranging from 5 – 1,327 mg/kg in the upper sediment profile (0 – 2 inches) and from 6 – 1218 mg/kg in the lower sediment profile (2 – 6 inches). Average BAP levels were 384 mg/kg and 170 mg/kg, respectively. This strongly suggests that phosphorus is being released from the lower sediment profile under reducing conditions. Further studies have shown that phosphorus concentrations in drainage ways are consistently higher than shallow ground-water concentrations of phosphorus (Sims et al., 1998).

Phosphorus may enter drainage ways when phosphorus-laden soils are inadvertently cast into ditches during construction activities from urban sectors or during agricultural planting and harvesting. Phosphorus may also be discharged directly to drainage ways as a result of application of fertilizers and manure. This pathway is of particular concern within the Basin because many of the agricultural fields in the Basin lack buffers between the fields and drainage ditches. The extent of phosphorus loadings from this pathway has not yet been studied in detail.

Recently, Cassell et al. (1999) submitted a report on the phosphorus budget for the Atlantic Ocean/Inland Bays Basin. Their report culminates an 18-month study of the Basin, its agriculture, and its urban development, including residential activities, tourism, industrial, and commercial activities. Collected data were entered into the Watershed Ecosystem Nutrient Dynamics (WEND-IBW) computer model, which was customized for the Basin. Cassell drew the following conclusions from the model simulation:

- Under current conditions of growth and poultry production in the Basin, it is not possible to reduce the total export of phosphorus to the Inland Bays over the long term (>20 years) solely through the implementation of aggressive urban and agricultural conservation practices.
- Under current conditions of growth in the Basin, computer simulations suggest that when conservation practices are applied to both agricultural and urban lands and phosphorus removal efficiencies of wastewater treatment facilities are increased, there is a reduction in phosphorus export in the short term. But within 10 – 20 years, continuing poultry and population growth overwhelms these reductions.
- When the Basin is considered as a whole system comprised of agriculture, urban, and natural areas, the total future loading of phosphorus is estimated to be approximately 115 – 125 percent of present-day loads in 20 years and 140 – 160 percent of present-day loads in 40 years. These large increases are due primarily to urban growth.
- The rate at which growth occurs in the Basin can have a substantial impact on the amount of phosphorus exported to the Inland Bays over the long term. This applies to all activities in the Basin, including agriculture, residential population, industry, and tourism.
- It appears unlikely that short-term watershed monitoring programs (15 years or less) will be able to detect changes in export of phosphorus outside the Basin unless the change is very large.
- The WEND-IBW model estimates that currently 6 million pounds of phosphorus are imported to the Basin and 2.1 million pounds of phosphorus are exported from the Basin annually *(Figures 2.7-10(a)* and *2.7-10(b))*. Phosphorus levels in the soils of the Basin are increasing at a rate of approximately 3.75 million pounds per year.
- The export of phosphorus from agricultural sites is not the only source of phosphorus entering the bays. Urban activities and natural sources also contribute substantial amounts of phosphorus to the Basin *(Figures 2.7-11(a)* and *2.7-11(b))*.
- The only way to provide long-term protection to the Inland Bays is to implement policies that target both the agricultural and urban activities within the Basin.
- Only when urban growth rates are reduced below the current growth rates and poultry production capacity is reduced (or large amounts of poultry manure is shipped outside the Basin), can the export of phosphorus to the bays be decreased over the long term.

The occurrence and movement of phosphorus through the environment is summarized in *Figure 2.7-12*.

2.7.2.4 Bacteria (Pathogen Indicators)

As the name implies, *indicator bacteria* are indicators of pathogenic (disease-causing) bacteria and viruses. Sources of indicator bacteria (*enterococcus* and coliform) are widespread. Sources of most concern are those of human origin such as raw or inadequately treated sewage. Wildlife and animal operations such as feedlots can also be significant sources of indicator bacteria although they represent less of a risk to human health compared to human wastes [*Watershed Assessment Report (305(b)*], 1998). High levels of bacteria pose an increased risk of illness to shellfish consumers, swimmers, and others who may come in contact with contaminated waters.

Figure 2.7-10 (a)

PHOSPHORUS IMPORT TO THE INLAND BAYS/ ATLANTIC OCEAN BASIN WATERSHED TOTAL ANNUAL IMPORT = 6 MILLION LBS PHOSPHORUS PER YEAR

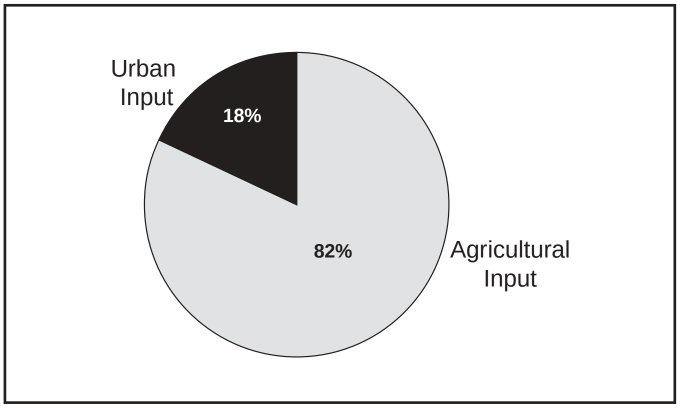


Figure 2.7-10 (b)

FATE OF PHOSPHORUS IMPORTED TO THE INLAND BAYS/ATLANTIC OCEAN BASIN WATERSHED

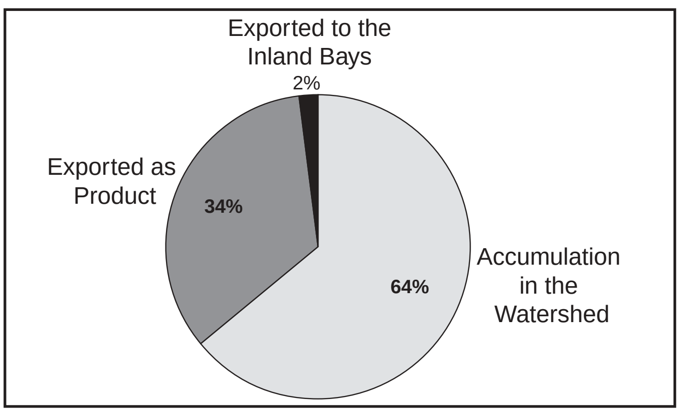


Figure 2.7-11 (a)

ANNUAL EXPORT OF PHOSPHORUS BY SECTOR

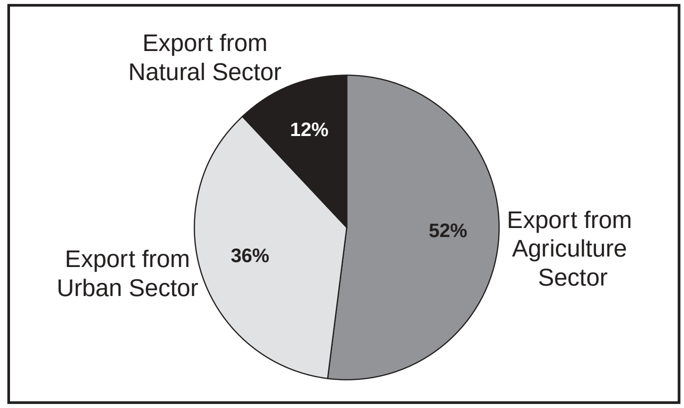
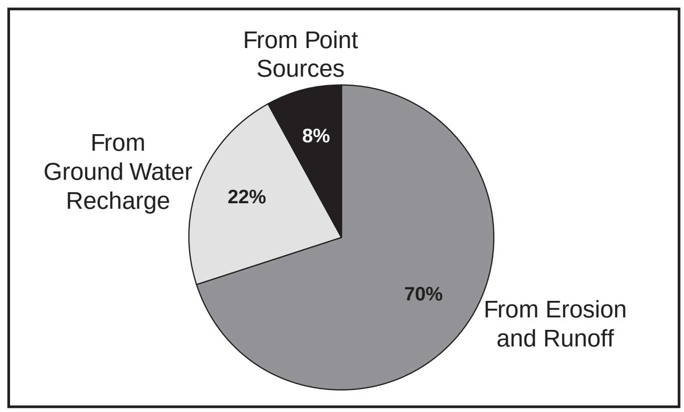


Figure 2.7-11 (b)

ANNUAL EXPORT OF PHOSPHORUS BY TYPE OF DISCHARGE TOTAL ANNUAL EXPORT = 129,000 LBS/YEAR.



A quantitative measure of indicator bacteria in ambient water is performed semi-monthly at numerous sites within the Basin. Delaware uses a standard of 70 total coliform bacteria per 100 ml (running geometric mean), and fewer than 10 percent of samples may exceed 330 total coliform per 100 ml.

Indicator bacteria are reflective of a concern for a variety of human enteric viruses, various other unclassified viruses, shellfish diseases, and bacterial pathogens.

At present, the *Total Maximum Daily Load* (TMDL) concept has been applied in Delaware only to marinas vis-a-vis indicator organisms. The concept is based on theoretical loading of bacteria that could indicate the presence of disease. The potential daily pathogen output from one person's untreated sewage could equal that of treated sewage from hundreds to possibly thousands of people (depending on the level of treatment). The boat/marina-related TMDL concept assumes zero fecal coliform background water and establishes buffers around marinas based on the dilution volume required to reach the 70 total coliform per 100 ml standard. The dilution formula, which includes Delaware-specific loading factors, is as follows:

2 e^9 fc x 3.3 people/boat x .065 discharge rate

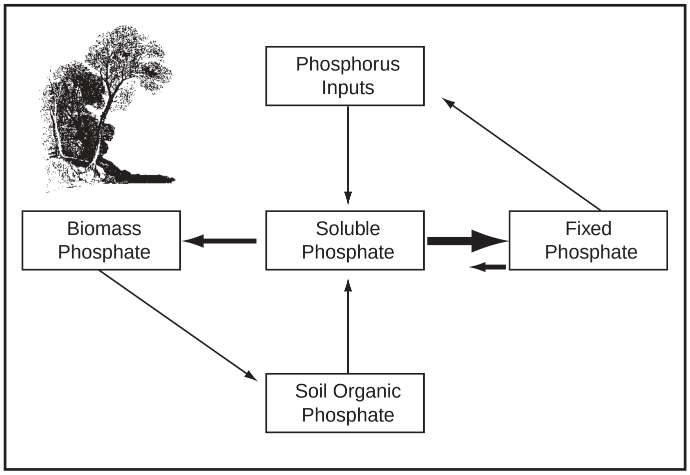
70 total coliforms per 100 ml.

average depth

In addition, the Shellfish and Recreational Water Branch and the Environmental Services Section collaborate in tracking naturally occurring phytoplankton, both toxic and potentially toxic. Over 50 species/genera of phytoplankton have been identified in Delaware's Inland Bays. The presence of potentially toxic species is common at low, "background" levels, and is of no concern. There have been several "events" where potentially toxic species were recorded at bloom-like concentrations, beginning in 1987

Figure 2.7-12

THE PHOSPHORUS CYCLE



with the emergence of *Pfiesteria*, and in 2000 with the emergence of *Chattonella verruculosa,* which was associated with high levels of brevetoxin.

Bacteria data from 40-plus stations in Rehoboth and Indian River bays, along with a qualitative assessment of risk, as measured through the identification of pollution sources, constitute the basis for classifying shellfish-growing waters as to the suitability of the shellfish in those waters for human consumption.

All the above is administered as per specifications set forth in Interstate Shellfish Sanitation Conference (ISSC) literature. ISSC members all adhere to ISSC sanitation and technical specifications. Member states and countries ship shellfish only among themselves to ensure a safe product. Each member state and country's program is assessed annually by the U.S. Food and Drug Administration.

There is a statistical association between human illness and enteric indicator bacteria levels in ambient water. However, these bacteria are not specific to humans and may be associated with numerous warm-blooded animals. In addition, studies indicate that the bacteria are ubiquitous, possibly surviving in the environment, for example, in leaf litter. Additional studies provide supportive evidence that shows little or no association between indicator bacteria levels and human illness in areas not impacted by human sources or concentrations of domestic animals. As such, baseline data need to be established for bacteria (for example in forest or crop field situations). Bacteria levels in excess of background and associated with human or domestic animal sources — either by direct observation or DNA testing — are the basis for establishing TMDLs for bacteria. However, more studies are needed under extremely controlled conditions. In the absence of DNA testing, shoreline surveys such as sanitary assessments of pollution sources are used to identify the above sources. A comprehensive strategy should address all sources.

2.7.2.5 Inventory of Potential Sources

Source Type: Agriculture

Nitrogen and phosphorus originating from agricultural activities have been identified as key factors in non-point source pollution in the Inland Bays/Atlantic Ocean Basin (Sims et al., 1996). There are approximately 72,000 acres of agricultural land in the Basin, representing more than 40 percent of the total land area. The majority of croplands are devoted to growing corn, soybeans, and sorghum, which go to feed the Basin's thriving poultry industry. Agricultural lands are highly susceptible to nutrient loss. Factors such as soil type, depth-to-ground water, topography, ditches and drainage ways, and precipitation all affect nutrient transport in the Basin.

Two soil types predominate in the Basin. Generally, soils are either well drained or poorly drained. The well-drained soils in the Basin typically are made up of sands that may contain some loam or loamy sands. They are highly permeable, which means that water will travel through the soil column quickly to enter the ground-water table. There is no barrier (aquitard) between the upper soil profile and the ground-water table.

Nitrogen loss from well-drained soils usually occurs in the form of nitrate loss to the ground-water table. Nutrients applied to the soils in the forms of fertilizers or manure are quickly converted to nitrates in the soil column. Nitrates not immediately taken up by crops may be flushed past the root zone and into the ground water.

Several activities may exacerbate nitrate loss to ground water on well-drained soils. Application of manure to the soils in the winter and early spring, without a cover crop, may leach considerable amounts of nitrates to ground water. Storage and stockpiling of manure on well-drained soils allow nitrogen to leach through the manure piles and enter ground water. Some older poultry houses placed on sandy soils may leach both ammonia and nitrate nitrogen to the ground-water table. Some of the highest nitrate ground-water concentrations in the Basin — levels in excess of 100 mg/l — are found near older poultry houses situated on sandy soils.

Phosphorus applied to well-drained soils generally will accumulate in the upper soil profile. As soil phosphorus content reaches excessive levels, soluble phosphorus may leach into subsoils and eventually enter the ground water where it may move to nearby drainage ditches that are nearby. Excessive buildup of phosphorus in agricultural soils in the Basin is almost exclusively associated with over-application of poultry manure. Recent soil test summaries in Delaware show that 82 percent of soils receiving some form of animal manure were rated high or excessive in phosphorus and required no additional phosphorus for optimum crop production (Sims, 1996). This is very important because there is an increasing body of evidence that soluble phosphorus loss from soils will increase in proportion to phosphorus soil levels (Sims, 1996).

Poorly drained soils in the Basin are relatively flat, the ground-water table is near the surface during periods of the year, water moves slowly through the soils, and occasional flooding or ponding in areas is common. The soils may contain loamy sands, clays, and silt, and often overlie clay subsoils that may act as a barrier to the ground-water table. Soils may be anaerobic (deficient in oxygen) in areas. Many of these soils require ditching to improve soil drainage for farming. Historically, many of the poorly drained soils that have been ditched to accommodate agricultural activities were non-farmable wetlands prior to ditching.

Nitrogen and phosphorus loss from poorly drained soils is usually associated with lateral (horizontal) flow of surficial waters to ditches and drainage ways, or by direct loss of fertilizers or manure to drainage ditches. Nitrates that slowly percolate through the soil column encounter anaerobic zones that convert the nitrates to nitrogen gas (N_2), which is vented to the atmosphere. Intensive ground-water monitoring within the Basin shows that the deeper ground-water table below poorly drained soils with anaerobic zones are very low in nitrate nitrogen and are often close to natural background levels of less than 0.5 mg/l (Andres, 1991).

Factors that can contribute to surficial lateral loss of nutrients into drainage ways include:

- Applying manure and fertilizers too close to the edges of drainage ways, which allows nutrients to run off into ditches.
- Absences of vegetative buffers near ditches, which accelerate erosion and facilitate movement of nutrients in various forms directly to surface waters.
- Stockpiling manure on the edge of the field, near ditches.

It is estimated that there are 1,800 miles of private ditches and 1,500 miles of publicly maintained tax ditches, draining up to 48 percent of the soils in the Basin. Artificial drainage is extensively used in the southern portions of the Basin where poorly drained soils predominate. Without extensive ditching in the Basin, thousands of acres would be unavailable for agriculture.

Nitrogen and phosphorus may enter drainage ways by several pathways. Nitrates and soluble phosphorus may be transported by shallow lateral ground-water flow to the ditches. Runoff and erosion may carry large amounts of sediment-containing nutrients in various forms directly to ditches, especially during severe thunderstorms. Nutrients from manure may be discharged directly to drainage ways during spreading and application of manure.

Water-quality samples collected from several agricultural drainage waters within the Basin show elevated levels of both nitrogen and phosphorus in the waters, at levels that exceed water-quality standards for streams in the Basin (Sims et al., 1998). Average nitrate concentrations in the waters from two sites averaged 5.8 and 4.6 mg/l. Ammonia nitrogen was also found in the waters ranging from 1.0 to 9.1 mg/l at one site and 0.18 to 6.8 mg/l at another. These values exceed the 0.14 mg/l water quality standard for nitrogen in the Basin. Total phosphorus levels in the waters were also consistently higher than the 0.01 mg/l phosphorus water-quality standard for the Inland Bays. Values of total phosphorus ranged from below detection levels to 0.34 mg/l at one site and 1.7 mg/l at another.

In addition to transporting nutrients directly to the bays, drainage structures may also act as a "sink" for nutrients. Sallade and others (1997) characterized the properties of sediments from 17 drainage ditches in the Basin *(Table 2.7-5)*. Phosphorus levels were very high in the sediment, indicating that considerable loss of nutrients occurred due to soil erosion and runoff. Furthermore, the analysis indicates that phosphorus is being released from the sediment under reducing (anaerobic) conditions, as shown by the lower phosphorus concentrations in the deeper portions of the sediment (greater than 5 centimeters).

Topography and rates of precipitation greatly influence the degree and amount of runoff that may carry nutrients away from an agricultural area. Generally, the topography within the Basin is relatively flat (0–2 percent). However, slope usually increases closer to streams and tributaries, providing a discharge outlet for water accumulating on agricultural areas during severe precipitation events.

Severe storm events, like those associated with hurricanes and northeasters, can dump large quantities of rainwater onto fields in a relatively short period of time. When rainfall rates exceed the soils infiltration rates, water begins ponding on the surface. When enough water has accumulated on the surface, it will begin traveling to a "relief area," usually the lowest point on the farm or a nearby stream. As runoff crosses a field, it will accumulate sediment, dissolved nutrients, and organic matter. This material will ultimately be deposited in the relief area. If the relief area is a low spot in the field, water will pond in the area until it can percolate into the soil. All of the nutrients that were deposited into the relief area may then impact the environment. Nitrogen compounds can be converted into nitrates and enter the ground-water table, while phosphorus compounds may quickly build up in soils. In some cases, drainage structures are constructed in the low-spot relief areas to drain the runoff back to

Table 2.7-5
PHOSPHORUS CHARACTERISTICS OF AGRICULTURAL DRAINAGE DITCH SEDIMENTS IN THE BASIN (SALLADE et. al., 1997)

	MEHLICH 1 P MG/KG	BAP MG/KG	TOTAL P[1] MG/KG	P SORPTION CAPACITY MG/KG*	P SORPTION INDEX L/KG
0–5 cm					
Range	3–62	5–1,327	34–1,285	95–1,671	50–5,819
Mean	22	384	391	688	990
Median	21	248	310	525	706
CV, %	58	85	74	68	107
5–15 cm					
Range	3–47	6–1,218	27–1,111	ND	108–2,374
Mean	16	170	188	ND	477
Median	16	81	105	ND	252
CV, %	56	85	114	ND	97[1]

[1]Determined by summation of fractions.
*Based on 40 top sediments used in sorption isotherm studies.
ND — Not Detected

surface waters. This activity can allow large quantities of nutrients to be discharged directly to surface waters. Similarly, if the lowest area on a farm is the boundary of a stream or other surface water body, most of the runoff from a severe precipitation event will be discharged directly to surface waters, depositing large quantities of nutrients in various forms directly to surface waters.

Nutrient loss to surface waters via runoff can increase significantly in magnitude if the precipitation event occurs soon after fertilizers or manure has been applied. Large quantities of manure may be washed away if severe precipitation events occur between the time the manure is applied and the time it is incorporated into the soil. Additionally, large stockpiles of manure may leach extremely high levels of nutrients during severe precipitation events. Cassell (1999) estimated that 70 percent of the phosphorus that is entering the bays occurs as a result of surface runoff.

Ground-water depths in the Basin vary from at or near the surface to depths of 10–15 feet. Ground-water levels generally fluctuate by as much as 5 feet throughout the year, typically being highest following spring rains. When ground water is near the land surface, the potential for release of soluble phosphorus from soil particles to ground water increases.

In many cases, especially in the southern portion of the Basin, the ground-water table has been artificially lowered through an extensive network of drainage ditches. These ditches were installed beginning in the 1930s to lower the water table that was limiting the agricultural productivity of the land. These ditches can contribute a significant source of nitrogen and phosphorus to the bays.

Poultry

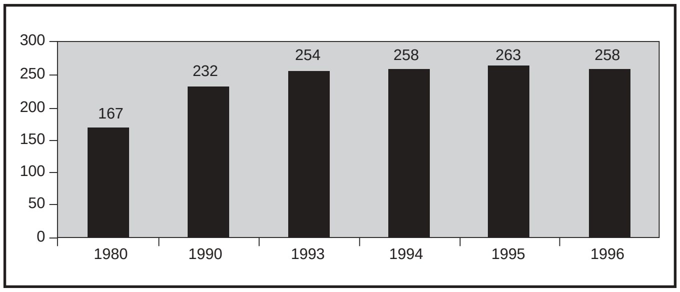
The Delmarva Peninsula has long been noted as the birthplace of the commercial broiler industry. Credit for the beginning of this industry has been given to Mrs. Wilmer Steele of Ocean View, Delaware. For several years, Mrs. Steele operated a small laying flock and raised her own replacements. In 1923, she started a brood of 500 chicks in connection with her laying flock. However, when the birds reached an average of about 2 pounds, she sold the remaining 387 birds for 62 cents per pound to a local buyer. A few years later, the Steeles were raising 25,000 young chickens to sell for meat rather than keeping them for egg production.

Today's poultry industry continues to grow albeit not as quickly as it did for Mrs. Steele. Delaware's poultry industry has nearly tripled since the mid-1950s, and Sussex County is the largest poultry-producing county in the United States. *Figure 2.7-13* shows recent trends in poultry production over recent years.

In 1998, annual broiler production in the Basin exceeded 72 million birds, which represented about 28 percent of Delaware's total 1997 broiler production (*Delaware Agricultural Statistics Summary*, Delaware Dept. of Agriculture, 1998). Local farmers cannot meet the poultry industry's high demand for feed, so large amounts of feed are brought into the Basin from other areas.

In 1997, the poultry industry comprised 241 contract growers and five regionally dominant integrated companies ("integrators") that provided flocks and feed to the contract growers. The integrators also transported, slaughtered, and processed the chickens. The contract growers, however,

Figure 2.7-13
DELAWARE BROILER PRODUCTION (MILLIONS), 1980 – 1996



are completely responsible for managing the manure generated by the 72 million broilers grown annually within the Basin. Approximately 92,000 tons of broiler manure and litter was generated in the Basin in 1997.

On average, one ton of broiler manure contains 69 pounds of nitrogen and 68 pounds of phosphorus as P_2O_5. The total amounts of nitrogen (as N) and phosphorus (as P_2O_5) derived from poultry manure in 1997 were about 5 million pounds of nitrogen and 4.9 million pounds of phosphorus. It is assumed that all of the manure generated in the Basin is used within the Basin. In addition, users of chemical fertilizers imported an additional 6 million pounds of nitrogen and 1.7 million pounds of phosphorus to the Basin in 1997 as reported to the Delaware Department of Agriculture. Thus, in 1997, over 11 million pounds of nitrogen and 6.6 million pounds of phosphorus were applied to agricultural soils in the Basin.

Many studies have shown that the intensification of animal production, as has occurred in Sussex County during the past 30 years, can create serious environmental problems; one of the most important is the effect of animal nutrients from manure on air, soil, and water quality. It is very common to find excess nutrients in areas dominated by animal agriculture because nutrient inputs in feed greatly exceed nutrient outputs in crops and animal products.

Historically, poultry manure in the Basin was often applied to agricultural soils at rates as high as 10 tons per acre and manure was stockpiled outside. Machines for spreading the manure were not routinely calibrated, manure was infrequently analyzed for nutrient content, and manure was often applied in the winter or early spring, before crops could begin using the nutrients in the manure.

During the 1990s, increasing attention was placed on developing comprehensive waste (nutrient) management plans for poultry operators. Components of a waste management plan include the following:

- Determining the amount of manure generated;
- Determining the nutrient requirements of crops in rotation where the manure will be used;
- Routine analysis of the manure to determine its nutrient content;
- Routine soil testing to determine the amount of nutrients like phosphorus, potassium, sulfur and micro-nutrients that are accumulating in the soils;
- Calibration of any equipment used to apply manure to the fields;
- Manure storage, handling, and timing of application; and
- Application of manure to meet the nitrogen requirements of the crops based on realistic yield goals, which are largely determined by soil type and moisture availability from irrigation and rainfall. Routine manure application rates are generally in the range of 3 to 4 tons/acre.

In June 1999, the Delaware General Assembly passed, and Governor Thomas Carper signed, House Substitute Bill 1 for House Bill 250. This bill amended Title 3 of the *Delaware Code* by adding Chapter 22: Nutrient Management. The four purposes of Delaware's Nutrient Management Act (NMA) are:

- To regulate those activities involving the generation and application of nutrients in order to help improve and maintain the quality of Delaware's ground and surface waters and to meet or exceed federally mandated water-quality standards in the interest of the overall public welfare.
- To establish a certification program that encourages the implementation of Best Management Practices in the generation, handling, or land application of nutrients in Delaware.
- To establish a nutrient management planning program.
- To formulate a systematic and economically viable nutrient management program that will both maintain agricultural profitability and improve water quality in Delaware.
- The Nutrient Management Act establishes the following milestones:

  July 1, 2000: All commercial processors shall file a plan with the Delaware Nutrient Management Commission (DNMC) indicating how they will meet the requirements of the act.

  January 1, 2003: The DNMC shall begin official review of nutrient management plans. One-fifth of the plans will be reviewed each year between 2003 and 2007.

  January 1, 2004: Certification of all nutrient handlers must be completed.

  2007: The DNMC shall ensure that the NMA is fully implemented by 2007.

At an application rate of four tons of manure per acre, 272 pounds of nitrogen (as N) and 276 pounds of phosphorus (as P_2O_5) are applied to the soil. If corn is being grown on the field, the University of Delaware recommends one pound of nitrogen per bushel of expected yield. Hence, a realistic yield goal of 150 bushels per acre (bu/ac) should receive a maximum of 150 lbs N/acre. Recommended phosphorus application rates, on the other hand, are dependent on yield goals and soil-test phosphorus levels. For a corn yield of 150 bu/ac, if the soil phosphorus index is 50 (medium phosphorus soil level), the University of Delaware recommends an additional 50 pounds of phosphorus to optimize crop yield.

From the previous example, assuming that the yield target of 150 bu/ac of corn was achieved, an excess of 122 pounds of nitrogen per acre and 226 pounds of phosphorus per acre would be applied. Excess nitrogen in the form of ammonia may volatilize to the atmosphere, or as nitrate may enter the ground-water table. The excess phosphorus, on the other hand, will primarily build up in the soil column.

As one can see from the above exercise, application of poultry manure at rates that are acceptable for crop nitrogen demands continually add much more phosphorus than is removed by the crops because of the unfavorable N:P ratio in poultry manure. This results in a long-term buildup of soil phosphorus to excessive levels. Recent soil test summaries in Delaware show that 82 percent of soils receiving some form of animal manure were rated high or excessive in phosphorus, soil test categories where no further application of phosphorus in any form is recommended (Sims, 1996). Soil test results recorded by the University of Delaware Soil Testing Lab for zip codes within the Basin show that over 70 percent are excessive in phosphorus, and 21 percent are high in phosphorus. Previous research in other Mid-Atlantic states has shown that it can take from 10 to 20 years, with no further application of phosphorus from manure or fertilizers, for normal cropping practices to deplete soil phosphorus from excessive to optimum levels (McCollum, 1991).

Another method of determining nutrient loading rates is via the concept of nutrient mass balance. In principal, the concept of mass balance is simple: nutrient inputs to a farm, urban development, municipality, region, or watershed are all added up to represent "inputs." Nutrients needed to produce optimum crop yields represent "outputs." The difference (input minus output) represents the surplus or deficits of nutrients in the area of interest.

Recently, Sims (1999) developed a mass balance analysis for agricultural operations in Delaware and also for poultry operations in the Inland Bays/Atlantic Ocean Basin. The data are summarized in *Table 2.7-6* and *Table 2.7-7,* respectively.

A mass balance analysis does not assess the fate of the surplus nutrients (i.e., the amount of nutrients that may enter the bays and their tributaries), only the magnitude of

Table 2.7-6
AGRICULTURAL NUTRIENT MASS BALANCE ANALYSES FOR DELAWARE

NUTRIENTS PRODUCED OR SOLD VS. CROP REQUIREMENTS[T]	DELAWARE		NEW CASTLE COUNTY		KENT COUNTY		SUSSEX COUNTY		INLAND BAYS*	
	N	P	N	P	N	P	N	P	N	P
Nutrients Produced or Sold (tons/state/year)										
Commercial Fertilizers	22,800	3,900	3,550	610	7,590	1,300	11,600	2,000	3,039	524
Animal Wastes and Municipal Biosolids	17,943	6,434	737	238	2,552	898	14,652	5,298	3,838	1,388
Total	40,743	10,334	4,287	848	10,142	2,198	26,252	7,298	6,879	1,912
Nutrients Required by Crops	19,815	2,840	2,961	1,015	6,913	963	10,650	757	2,790	198
Nutrient Balance[T]										
Total (tons/year)	+20,928	+7,494	+1,327	-166	+3,230	+1,236	+15,602	+6,541	+4,087	+1,713
Per Acre (lbs/acre/year)	+74	+27	+31	-4	+34	+13	+108	+45	+108	+45

[T]Values in this table are estimates for total nutrients produced or sold. Research has shown that only 50–80 percent of the nutrients produced in animal manures will be available for plant uptake in the year of application (Maryland Department of Agriculture, 1996). Positive values represent nutrient surpluses and negative values represent nutrient deficits. Data on amount and nutrient content of poultry litters from Patterson et al., 1998.

*Extrapolated based on acreage of farmland in Sussex County vs. the acreage of farmland in the Inland Bays/Atlantic Ocean Basin.

the surplus nutrients. A mass balance analysis is still an important tool because it can be used to identify the presence of large-scale nutrient surpluses (e.g., poultry operations), and because large nutrient surpluses (inputs>>outputs) can be expected to exacerbate nutrient losses at all scales, whether they be from individual fields or farms, from watersheds, or even larger regions. Therefore, nutrient mass balance analyses can be an important step in developing long-term nutrient management plans, especially in watersheds where excessive nutrients are associated with water-quality problems.

Source Type: Pesticide and Fertilizer Mixing, Loading, and Storage Areas

These sites serve as areas to store, mix, and load pesticide products and/or liquid and solid fertilizer products. Products are generally stored in large bulk quantities. Products may be stored in individual packages in a warehouse, or in large mixing tanks, drums, or mini-bulk containers.

The potential exists for a product to be released during mixing or loading of the product onto transporter vehicles or application equipment. The potential also exists for storage container failure. While some sites have modern containment systems, including dikes, berms, and product recovery systems, many do not.

Currently, the design of these facilities is not regulated, and no monitoring data exist for these sites. However, the U.S. EPA is developing draft regulations that address this shortcoming. Refer to *Map 2.7-1 Known and Potential Nutrient Sources* for the location of known sites. For more information, contact the Delaware Department of Agriculture, Pesticides Section.

Source Type: On-Site Septic Systems

There are approximately 16,000 homes with on-site septic systems in the Inland Bays/Atlantic Ocean Basin, covering an area of approximately 10,119 acres (Horsley & Witten, 1998). There is no documentation regarding septic systems installed prior to 1968. Many of these older systems are simply cesspools — open-bottomed pits that drain both the solids and liquids directly to underlying soils. Little, if any wastewater renovation occurs in these kinds of on-site systems. The Department's Whole Basin Management program has identified the dwelling units within the Basin that utilize on-site septic systems (*Map 2.7-2 Septic System Locations*).

Non-conforming systems such as cesspools are located throughout the Basin. These systems are grandfathered for continued use until they either fail, the homeowner adds an additional bedroom, or the homeowner wants to replace the structure served by the system. These pre-regulation systems pose a significant threat to water quality when they provide the principal method of waste disposal in more densely populated areas such as Oak Orchard, Riverdale, and Cedar Neck Road, to just name a few. These areas, and others like them in the Basin, face significant problems when it comes to upgrading their septic systems. Existing dwellings, outbuildings, driveways, well locations, watercourses, and isolation distances must be taken into consideration before locating an area for a new system. These problems are often compounded by having to fit the septic system on a quarter-acre lot. Homeowners contemplating replacement of a "working" non-conforming system in order to upgrade their home will usually resort to remodeling their home to avoid replacing their septic system.

On-site wastewater regulations first went into effect in 1968 and were rewritten in 1985. The 1968 regulations developed siting criteria and square footage requirements based on soil only. As a result, thousands of septic systems within the Inland Bays/Atlantic Ocean Basin were improperly installed on soils that would be unsuitable under today's siting criteria, primarily due to seasonal high

Table 2.7-7

ESTIMATED NITROGEN AND PHOSPHORUS BALANCE FOR POULTRY OPERATIONS IN THE INLAND BAYS/ATLANTIC OCEAN BASIN

TOTAL INPUTS TO WATERSHED

Nutrient	Feed	Animals	Fertilizers	Legumes	Total
		(Mg/yr)			
Nitrogen	10,725	95	3,355	1,161	15,336
Phosphorus	2,175	12	970	0	3,157

TOTAL OUTPUTS FROM WATERSHED

	Animals	Crops	Total
	(Mg/yr)*		
Nitrogen	4,804	4,093	8,898
Phosphorus	601	552	1,152

WATERSHED NUTRIENT SURPLUS OR DEFICIT[T]

	Total (Mg/yr)	Total (kg/ha/yr)	% of Inputs
Nitrogen	+6,438	+229	42
Phosphorus	+2,005	+71	64

[T]Positive numbers indicate surplus, negative numbers indicate deficit.

* Mg/yr = million grams/year (one million grams = 1.101 tons)

water tables at depths shallower than 48 inches. In addition, the systems lacked the necessary maintenance for proper operation and were located on lots smaller than one-half acre, which is the minimum lot size required by current regulations.

Systems installed in poorly drained soils with high water tables tend to sit in the water table during the wet season and then dry out during the summer months. Compounding the problem is the fact that these early systems were sized on percolation rates that if assigned today by soil texture would be twice the size. In addition, sizing criteria for single-wide mobile homes were used, further reducing the square footage of the drain field. Replacement systems in poorly drained soils, under today's current regulations, would require the installation of elevated sand mound systems. Once again, homeowners contemplating replacement hold off as long as possible before replacing their in-ground gravity system that may be improperly sited, but is "working" to the homeowners' standards.

Regulations adopted in 1985 to replace the first statewide regulations of 1968 are still in effect today. These regulations provide a soil-based approach to siting on-site wastewater disposal systems. Soil criteria are used to select the best system permitted by the site-specific soil conditions. System type and sizing is determined by using site-specific soil evaluations and percolation tests. Obtaining a septic permit for new construction today is far more difficult than in the past. Density requirements and isolation distances to watercourses, property lines, and on-site and adjacent wells must be met. Furthermore, a property can be denied an on-site septic system if the soils are found unsuitable for waste disposal or if isolation distances cannot be met (refer to *Map 2.7-3 Septic System Suitability*).

If a property is denied, and if the parcel was created by plat or deed prior to April 8, 1984, a permanent holding tank may be approved provided certain conditions are met. Permanent holding tanks were included in the regulations to provide an alternative for homeowners denied on-site systems on previously recorded lots; however, the use of these tanks on a permanent basis is a problem. There are approximately 200 holding tanks in use within the Basin. Many of the owners pump the wastewater onto the ground to avoid the pumping fee and some have installed drain fields or made holes in the tanks to allow drainage. Others have illegally installed gray water lines for the sinks, showers, and tubs. They are a source of untreated wastewater illegally discharged into and onto the ground.

In 1994, the Department compared three years' worth of the pumping records of 38 holding tanks located in a development adjacent to White's Creek to the property owners' water meter records provided by the water utility company. This comparison revealed that total water consumption was approximately 2,787,000 gallons. Pump-out records show a total of 648,275 gallons were pumped and transported to a treatment plant. This equates to less than 24 percent of the "gallons used" actually being transported to a wastewater facility for treatment. It seems unlikely that the remaining 76 percent was lost by evaporation or other outdoor water uses. Holding tanks that are permitted specifically for no discharge are actually a major contaminant source due to improper management and illegal retrofitting by the property owner.

Total nutrients discharged from septic tanks to the soils in the Basin were calculated based on a study of the characteristics of septic systems in the Red Mill Pond area (Jones, 1995). Based on this study, it is estimated that as much as 500,000 pounds of nitrogen and 130,000 pounds of phosphorus are discharged to the soils annually from septic systems in the Basin.

Assessing the loading rates from septic systems to the bays and their tributaries is a complicated task. However, a few conclusions can be reached. It is expected that over 90 percent of the phosphorus discharged from septic tanks will remain in the soil profile below the disposal field. Phosphorus discharges to the bays from septic systems usually occur only when the disposal field fails and raw sewage begins to accumulate on the surface. Precipitation runoff then carries the sewage to the bays or their tributaries. Nitrogen compounds discharged to the disposal fields, on the other hand, are converted to nitrates that are pushed downward to the ground-water table. In poorly drained soils, most of the nitrates are converted to nitrogen gas (N_2) and vent directly to the atmosphere. It is estimated that over 30 percent of the septic systems within the Basin are located on poorly drained soils. In well-drained soils, all of the nitrates discharged to the disposal field enter the ground water.

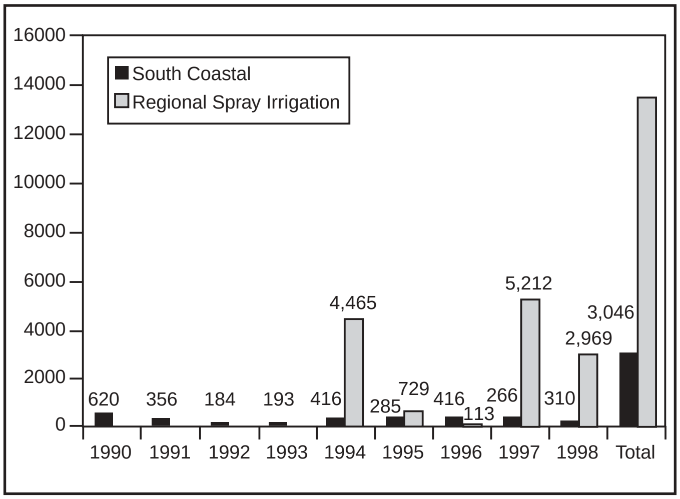
Since 1993, three new regional sewer districts have been created within the Basin. These districts use lagoon treatment followed by irrigation of the reclaimed water onto agricultural land as a fertilizer substitute. These sewer districts have eliminated over 13,000 septic systems within the Basin (*Figure 2.7-14*).

Source Type: Large On-Site Community Disposal Systems

Large community septic systems are on-site wastewater disposal systems that serve more than one lot or parcel or more than one dwelling unit of a planned development or industrial use. The projected daily wastewater flow in these types of systems is greater than 2,500 gallons. A large community system is a more complex waste disposal system, usually comprised of holding tanks for solids and a pressure-dosed distribution system. Similar to domestic wastewater from smaller on-site septic systems, community systems contain a wide range of substances: dissolved

Figure 2.7-14

NUMBER OF SEPTIC SYSTEMS ELIMINATED OR NOT CONSTRUCTED IN THE INLAND BAYS DUE TO CONNECTION TO A LAND TREATMENT FACILITY OR OCEAN OUTFALL



organic matter, heavy metals, pathogenic microorganisms, and nutrients such as nitrogen and phosphorus.

In the Inland Bays/Atlantic Ocean Basin, there are 38 active large on-site wastewater treatment and disposal systems. Since 1994, an additional 20 large on-site systems within the Basin have been abandoned because the facilities connected to large regional spray irrigation wastewater facilities. All projects with estimated flows exceeding 2,500 gpd must be accompanied by a preliminary ground-water assessment, which is then reviewed by the Department's Ground Water Protection Branch. Eighty-five percent of the large on-site community systems fall under the state's criteria for requiring a site to have a licensed operator to maintain the system to ensure proper maintenance and operation. Seventy-seven percent of the large community system owners are required to monitor ground water on the project site for the following parameters: depth to water table, temperature, pH, specific conductance, total nitrogen, ammonia as nitrogen, nitrate (NO_3) as nitrogen, coliform bacteria (total & fecal), and total dissolved solids. These monitoring parameters enable the Department to detect contaminants entering the ground water from on-site disposal systems. Such monitoring also helps the Department to discover/prevent ground-water contamination from crossing the property boundary of the site.

Source Type: Land Application of Wastes

Land application of wastewater, biosolids, and other residual wastes in a soil system is a viable alternative for the treatment, disposal, and beneficial reuse of municipal and some industrial wastes. Land treatment of wastewater and other wastes provides one of the most environmentally sound methods of managing wastewater and other residuals. The constituents (nutrients) in the wastewater are taken up by selected plants (farming), fixed in soluble forms (metal, phosphorus) in the soil, evolve as gases (ammonia), or leach into the ground water (nitrate and nitrite) where they are diluted. Land application of wastewater and other wastes provides ground-water recharge and enables governmental agencies the power to create incentives to maintain farmland or green spaces. The basic criteria for land treatment are:

- Quality standards for ground water and surface waters are not exceeded;
- Land application of wastes does not present a significant health problem; and
- The soil is not degraded so as to prevent future use for agriculture, forestry, or other planned development.

Current land treatment facilities are designed for a 25- to 50-year site life based on wastewater flow, nutrient loading, and metal loading. During the operation of systems, nutrient and metal content of the wastewater is monitored yearly to track the actual site life of these facilities over the long term. Generally, long-term effects of land treatment have shown decreased nutrient loading (compared with conventional farming fertilization practices); nutrient (nitrate) reduction in ground-water recharges; stream discharge decreases due to required conservation planning; and agricultural lands preservation.

In the Inland Bays/Atlantic Ocean Basin, there are 10 permitted spray- irrigation land-treatment facilities (refer to *Map 2.7-1*), ranging from poultry processors and community systems to large regional spray-irrigation facilities. These systems have a projected daily flow of wastewater ranging from 15,000 to 4,000,000 gpd. All permitted land treatment systems undergo a comprehensive design review process. The review covers soil and hydrologic investigative work, and treatment and wasteloading calculations. After the permit review process is completed, land treatment systems are constructed based on plans and specifications submitted to the Department, and done so under the supervision of licensed operators. These licensed operators, in turn, properly operate and maintain the systems.

Currently, the Division of Water Resources is working with point source dischargers in the Basin to identify alternatives to stream discharge. Spray irrigation is a preferred alternative to stream discharge provided that suitable land is available. All spray irrigation facilities in the Basin monitor the ground water for the following parameters: depth to water table, temperature, pH, specific conductance, total nitrogen, ammonia as nitrogen, nitrate as nitrogen, phosphorus, sodium, chloride, total dissolved solids, and coliform bacteria (domestic waste facilities only). These monitoring requirements enable the Department to detect contaminants entering the ground water from the land treatment systems. They also the help Department prevent ground-water contamination from crossing adjacent property boundaries of the site. For further information, contact the Ground-Water Discharges Section.

A list of all active spray-irrigation facilities in the Basin is shown in *Table 2.7-8*.

Source Type: National Pollutant Discharge Elimination (NPDES) Reporting Facilities

Municipal and industrial sites that discharge wastewater to surface waters are subject to limitations, monitoring requirements, and other terms and conditions identified in the individual NPDES permit issued to each site. Individual permittees must report monitoring results monthly, using the Discharge Monitoring Report (DMR) form developed specifically for each facility. The DMR lists parameters in the discharge that have a reasonable potential to cause or contribute to water-quality problems in receiving waters. Example parameters are temperature, dissolved oxygen, pH, copper, oil & grease, benzene, and PCBs. Although the DMRs are submitted monthly, actual monitoring frequency ranges from "continuously" to "once per year," depending on the discharge's characteristics and its volume relative to the receiving waters. *Table 2.7-9* shows the list of currently active sites.

Industrial sites that discharge only storm water may be permitted under an NPDES General Permit, which is a single permit that applies to a group of similar dischargers (e.g., trucking operations). Monitoring for storm-water discharges is typically less frequent, for example, three times in five years.

In addition to eight sanitary wastewater treatment plants in the Inland Bays/Atlantic Ocean Basin, there are three industrial point source discharges of treated wastewater, all in Millsboro:

- ◆ Conectiv's Indian River electric generating station;
- ◆ Vlasic, Inc., a pickle processing facility; and
- ◆ Townsend's, Inc., a chicken processing facility.

Point sources discharge treated wastewater that contains nutrients directly to the bays or their tributaries. In 1975, there were 26 permitted facilities discharging to the bays or their tributaries, but today there are only 9 (2 additional facilities discharge to the Atlantic Ocean) (refer to *Table 2.7-9*). Permitted discharge rates for 1975 – 2000 declined from 12.2 million gallons per day (MGD) to 7.7 MGD. All point sources discharging wastewater must treat the wastewater prior to discharging it to surface waters.

Table 2.7-8
1999 – 2000 NUTRIENT LOADING DATA FOR LAND TREATMENT FACILITIES IN THE INLAND BAYS/ATLANTIC OCEAN BASIN

FACILITY NAME	AVAILABLE ACREAGE	CROPS GROWN	ANNUAL FLOW (MGY)#	TOTAL NITROGEN APPLIED (LBS/ACRE/YEAR)	TOTAL PHOSPHORUS APPLIED (LBS/ACRE/YEAR)
Angola Estates	8.4	Orchard Grass	17.2	164	50
Georgetown	169.7	Grass, Row Crops	87.4	235	23
Long Neck	208	Row Crops	172.5	211	84
Piney Neck	55	Row Crops, Forest	27.7	51.1	39
Plantations	10.1	Orchard Grass	6.3	91.5	36
Townsend's, Inc.	880	Row Crops	675.9	144	77
Baywood *	13.8	Grass	0	NA	NA
Vlasic**	35	Row Crops	0.47	157	3
Allens Hatchery***	2.5	Grass	0	NA	NA
Wolf Neck	319	Row Crops	272.8	98	87
Total Average	1,950.2		1,260.3	143.9	53.9

MGY Million Gallons per year

* Construction completed, irrigation activities expected to begin in the summer of 2001.

** Non-contact cooling water only.

*** Has not irrigated since 1993; permit remains active.

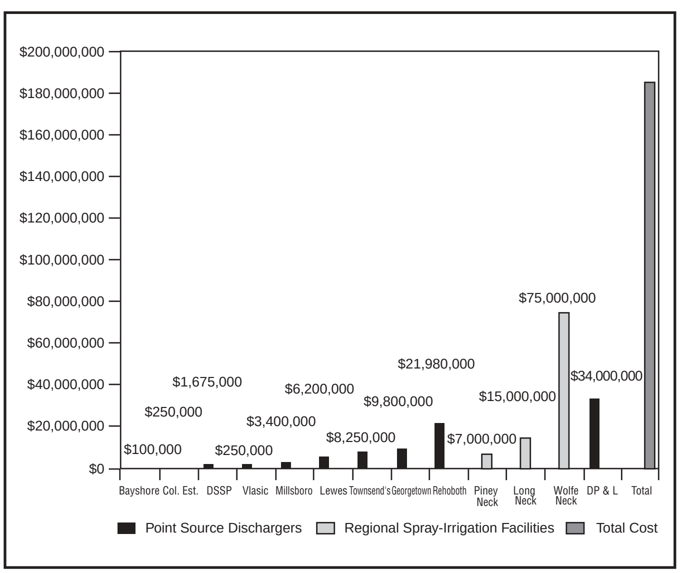
Over the past 10 years, most point source dischargers in the Inland Bays have upgraded their wastewater treatment facilities to reduce nutrient levels in the wastewater. From 1988 to 1997, nitrogen and phosphorus loads from point sources have decreased by 20 percent and 52 percent, respectively, even though total flows have increased. Over $185 million has been spent on constructing and upgrading wastewater treatment facilities in the Inland Bays/Atlantic Ocean Basin (*Figure 2.7-15*).

Table 2.7-9
POINT SOURCE DISCHARGES FOR THE INLAND BAYS/ATLANTIC OCEAN BASIN

PERMIT NO.	FACILITY NAME	MAJOR/ MINOR	INDUSTRIAL/ MUNICIPAL
DE 0020257	Georgetown WWTF	Minor	Municipal
DE 0021512	Lewes WWTF	Major	Municipal
DE 0020028	Rehoboth WWTF	Major	Municipal
DE 0050164	Millsboro WWTF	Minor	Municipal
DE 0020061	Colonial Estates WWTF	Minor	Municipal
DE 0050750	Bayshore MHP**	Minor	Municipal
DE 0000736	Vlasic, Inc.	Major	Industrial
DE 0000086	Townsend's, Inc.	Major	Industrial
DE 0050580	Conectiv of DE	Major	Industrial
DE 0050008	South Coastal Regional#	Major	Municipal
DE 0020010	Selbyville#	Major	Municipal

** Backwash from water softener only
# Discharges to the Atlantic Ocean

Figure 2.7-15
WASTEWATER TREATMENT FACILITY CONSTRUCTION COSTS



Currently, DNREC is working with several point source dischargers in the Basin to identify alternatives to stream discharge. Delaware Seashore State Park eliminated their discharge in March 2000. Townsend's discharge will be eliminated in 2001.

There are currently eight sanitary wastewater treatment plants (STP) that discharge to the Basin.

Bayshore Mobile Home Park

This facility is a mobile home park that is occupied primarily during the summer season and is located on County Road 358, 1.4 miles north of Ocean View. The discharge consists of backwash from a drinking-water supply filtration system.

Effluent limitations have been established for flow (0.0069 million gallons per day, MGD), total suspended solids (TSS), iron, and pH. Requirements for additional monitoring in the permit include biochemical oxygen demand (BOD_5), and nutrients (total and orthophosphorus, nitrate, nitrite and ammonia nitrogen, and total Kjeldahl nitrogen, TKN).

Colonial Estates Mobile Home Park

This mobile home park discharges treated sanitary wastewater to an unnamed tributary of Indian River. The facility is located on County Road 331 near Millsboro.

Effluent limitations have been established for flow (0.016 MGD), TSS, BOD_5, fecal coliform, total coliform, total residual chlorine (TRC), and pH. Permit requirements for additional monitoring include dissolved oxygen (DO) and nutrients (nitrate, ammonia nitrogen, and total phosphorus).

Figure 2.7-16
1997 NITROGEN LOADS FROM POINT SOURCES IN THE INLAND BAYS BASIN (LBS)

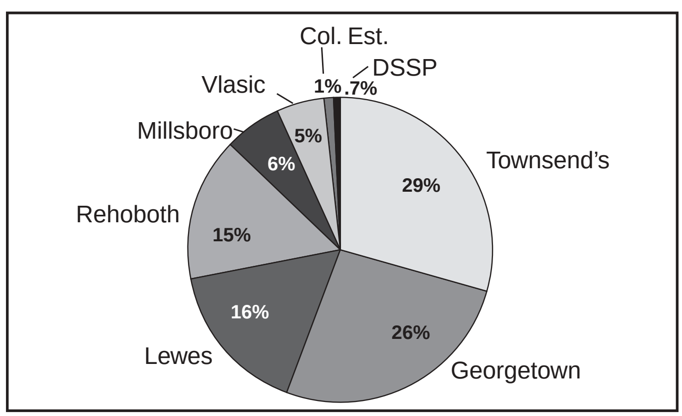
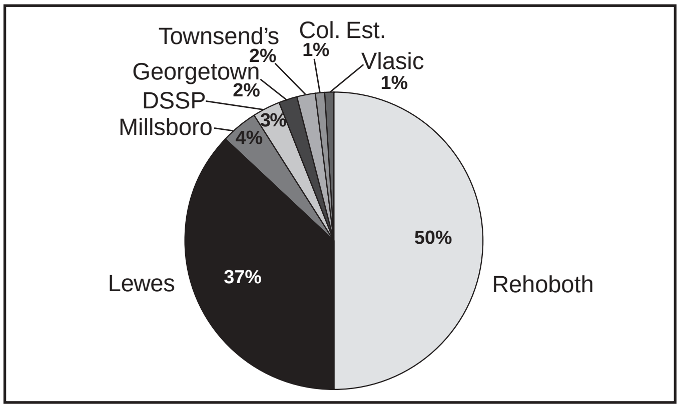


Figure 2.7-17

1997 PHOSPHORUS LEADS FROM POINT SOURCES IN THE INLAND BAYS BASIN (LBS)



Georgetown STP

The Georgetown wastewater treatment facility is a POTW that receives sanitary and industrial wastewater from Georgetown and surrounding areas. The facility is located on Stevenson Lane in Georgetown. The facility has one outfall that discharges into the Eli Walls Tax Ditch that eventually flows into the Inland Bays through Indian River.

Effluent limitations have been established for flow (0.5 MGD), TSS, BOD_5, fecal coliform, TRC, total phosphorus, DO, and pH. Permit requirements for additional monitoring include biomonitoring, *Enterococcus* bacteria, and total nitrogen.

Lewes STP

The City of Lewes operates a municipal wastewater treatment facility that receives wastewater from the city collection system. The facility is located on American Legion Road in Lewes. The facility has one outfall that discharges to the Lewes segment of the Lewes-Rehoboth (LR) Canal.

Effluent limitations have been established for flow (0.75 MGD), TSS, BOD_5, fecal coliform, TRC, and pH. Requirements for additional monitoring in the permit include total nitrogen, total phosphorus, DO, biomonitoring, and *Enterococcus* bacteria.

Millsboro STP

The Town of Millsboro operates and maintains wastewater treatment facilities for domestic sewerage from the Town of Millsboro and Stockley Hospital. The wastewater treatment facilities are located at State Street in Millsboro. Treated effluent is discharged to Tiger Branch, a small tributary of the Indian River.

Effluent limitations have been established for flow (0.566 MGD), BOD_5, TSS, nutrients, total phosphorus, fecal coliform, and pH. Permit requirements for additional monitoring include total nitrogen and *Enterococcus* bacteria.

Rehoboth Beach STP

The City of Rehoboth Beach operates and maintains wastewater treatment facilities for primarily domestic sewerage from Rehoboth Beach and neighboring areas: North Shores, Henlopen Acres, and the Dewey Beach Sanitary District. The wastewater treatment facilities are located on State Road Extended. Treated effluent is discharged into the Lewes and Rehoboth Canal, which is considered a tributary to Rehoboth Bay.

Effluent limitations have been established for flow (3.4 MGD), BOD_5, DO, total nitrogen, total phosphorus, TSS, fecal coliform, and pH. Permit requirements for additional monitoring include biomonitoring and *Enterococcus* bacteria.

South Coastal Regional

Sussex County operates a regional municipal wastewater treatment plant, the South Coastal Regional Wastewater Treatment Facility (WWTF), that serves the southeastern tip of Delaware, below the Inland Bays. The facility is located on County Road 368, south of Ocean View, Delaware. The South Coastal WWTF discharges to a diffuser in the Atlantic Ocean. A treatment plant at Delaware Seashore State Park was abandoned in March 2000, and wastewater from the park now discharges to South Coastal WWTF.

Effluent limitations have been established for flow (6.0 mgd), BOD_5, TSS, fecal coliform, TRC, and pH. Permit requirements for additional monitoring include hardness (as $CaCO_3$), dissolved copper, total copper, *Enterococcus* bacteria.

Selbyville

The Town of Selbyville operates a municipal wastewater treatment plant that serves the town. The facility is located on County Road 386, Polly Branch Road. The wastewater discharge pipes from Selbyville and the South Coastal WWTF combine and discharge through a shared diffuser in the Atlantic Ocean.

Effluent limitations have been established for flow (1.25 mgd), BOD_5, TSS, fecal coliform, TRC, and pH. Permit requirements for additional monitoring include hardness (as $CaCO_3$), dissolved copper, total copper, and *Enterococcus* bacteria.

Source Type: Landfills

Decomposition of organic waste such as household garbage or food processing by-products disposed of in landfills and dumps can be a source of unwanted nutrients to ground water and surface water. The decomposition process in landfills produces soluble nitrogen-rich decay products such as ammonia, nitrate, and complex organic compounds. Rainwater seeping through the waste transports these soluble nitrogen-rich compounds into ground water that ultimately discharges into streams.

To produce significant quantities of nutrients, a landfill must contain large quantities of organic waste.

To be considered a potential nutrient source for the purposes of this assessment, a landfill or dump has to be at least 5 acres in size and contain household garbage or food processing by-products. Four landfills in the Inland Bays/Atlantic Ocean Basin meet these criteria. These sites are closed landfills under the jurisdiction of the Site Investigation and Restoration Branch of the Department. Refer to *Section 2.7.3.2, Source Type: Superfund Sites,* for information about these landfills.

Source Type: Toxics Release Inventory (TRI) Facilities

Manufacturing facilities report annually under the Toxics Release Inventory (TRI) on any reportable toxic chemical that is manufactured, processed, or otherwise used above certain thresholds. The reportable list includes 575 individual chemicals and 28 chemical categories. Reports contain data on releases of the specific chemical to air, water, and land, as well as information on chemicals in waste transported off-site or managed on-site.

There are eight facilities within the Basin that have reported under TRI since reporting began for calendar year 1987 (refer to *Table 2.7-10* in Section 2.7.3, and *Map 2.7-4 Known and Potential Chemical Sources*). For the most recent reporting year (1999), seven facilities submitted 22 reports for 17 different chemicals. The Delmarva Power Indian River plant has ranked as the top facility statewide for on-site releases to the air, water, and land for the past two years as a result of their reporting large amounts of acid gases formed as coal combustion by-products. Oil and coal-fired power plants were added to TRI starting with the 1998 reports.

For more information about the TRI database, contact the Emergency Planning and Community Right-to-Know (EPCRA) Reporting Program.

2.7.3 CHEMICALS

2.7.3.1 Category Definition and Characteristics

Contaminant sources located within the Inland Bays/Atlantic Ocean Basin consist of a variety of chemical contaminants, including heavy metals, solvents and organics, polychlorinated biphenyls (PCBs), pesticides and herbicides, and petroleum. Chemical contamination may adversely impact human health or the environment through various toxic effects that different chemicals pose.

Chemical contaminants have been grouped into the following classes:

- *Heavy Metals* — Includes iron, arsenic, cadmium, chromium, manganese, nickel, lead, barium, and zinc. Some metals are carcinogenic or poisonous to humans and/or other organisms. In high concentrations, metals such as iron or manganese can render water unsuitable for drinking due to taste and staining, even though they might not cause specific health problems.
- *Solvents and Other Organic Compounds* — Includes organic chemicals such as chlorinated solvents, degreasers, paint thinners, alcohols, and certain chemical feedstocks. Many of these chemicals are carcinogenic or poisonous to humans and/or other organisms.
- *PCBs* — A class of organic compounds formerly used in electrical transformers and switches. These compounds are generally insoluble in water and break down very slowly under normal environmental conditions. They can accumulate in stream sediments where they can be directly or indirectly ingested by fish. Most forms of PCBs are considered carcinogenic.
- *Pesticides and Herbicides* — Are carcinogenic and/or poisonous to humans and other organisms. Many pesticides or herbicides have the potential of being biologically concentrated in the highest part of the food chain.
- *Petroleum* — Includes but is not limited to gasoline, heating oil, diesel fuel, kerosene, and waste oil. Certain compounds contained within each product, such as benzene, are carcinogenic or poisonous to humans and/or other organisms.
- *Other Inorganic Compounds* — Includes chemicals such as chlorides, sulfates, and Total Dissolved Solids (TDS).

Contaminant sources located within the Inland Bays/Atlantic Ocean Basin containing the above chemical groups are discussed in more detail under the different source types discussed below. Source locations are provided on *Map 2.7-4*.

2.7.3.2 Inventory of Potential Sources

Source Type: Agriculture

In addition to the nonpoint source nutrients discussed above, many agricultural practices also apply non-nutrient chemicals, such as lime or pesticides, to large areas of land in the Basin. If care is not taken, this can be a significant source of chemical contamination.

Source Type: Pesticide and Fertilizer Mixing, Loading, and Storage Areas

These sites store, mix, and load pesticide products, and liquid and solid fertilizers. The products are usually purchased in large, bulk quantities, and stored in individual packages in a warehouse or in large mixing tanks, drums, or mini-bulk containers.

Product may potentially be released during mixing or loading into transporter or application equipment. The product storage containers may also fail. While some sites have modern containment systems, including dikes, berms, and product recovery systems, others do not.

Currently, the design of such facilities is not regulated. Consequently, no data are available on pesticide/fertilizer releases from mixing, loading, or storage areas.

Source Type: Landfills

Waste disposed of in landfills and dumps can be a source of a wide variety of contaminants. Rain water seeping through a landfill dissolves or leaches out contaminants present in the waste. The resulting leachate, if not properly managed and contained, may contaminate nearby ground water and surface water. The composition and concentration of the leachate depends on the type and volume of waste in the landfill. Landfills and dumps in the Inland Bays/Atlantic Ocean Basin primarily contain:

- *Municipal Waste* — Trash from households, offices, and stores with significant amounts of putrescible food waste;
- *Miscellaneous Non-Putrescible Waste* — Waste from road cleanup activities, construction and demolition activities, old appliances, etc.; and/or
- *Coal Ash* — from combustion of coal to generate electric power and steam.

Leachate from municipal waste landfills is typically high in complex organic degradation compounds, ammonia, chlorides, alkalinity, chemical and biological oxygen demand (COD and BOD), iron, and sulfate. It may also have smaller amounts of volatile organic compounds and heavy metals. Besides leachate, municipal waste landfills also generate large amounts of methane gas.

Leachate from miscellaneous non-putrescible waste landfills is typically high in alkalinity, iron, and sulfate, but lacks the organic decay products and ammonia typical of municipal waste leachates. It may also contain smaller amounts of volatile organic compounds and heavy metals. Miscellaneous non-putrescible waste landfills can generate methane gas if they contain wood waste and hydrogen sulfide gas if they contain gypsum wallboard.

Leachate from coal-ash landfills is typically high in sulfate and iron and often contains a variety of heavy metals, including arsenic. These landfills do not generate gases.

Excluding the landfills covered under the Site Investigation and Restoration Branch (SIRB), the Indian River Power Plant coal-ash facility is the only landfill currently operating in the Inland Bays/Atlantic Ocean Basin (*Map 2.7-4*). The Indian River power plant has been operating since 1956. Currently, there are four coal-burning electrical generating units in use at the site. The plant burns approximately 1.2 million tons of coal annually and produces approximately 275,000 cubic yards of fly ash and 48,000 cubic yards of bottom ash. The ash is disposed of in an unlined, active landfill on the site. There is also an inactive unlined ash landfill on the eastern end of Burton Island. In addition, coal is stored on Burton Island just east of the plant in an unlined storage area.

Metals are present in the coal and the ash, but they are not very soluble or mobile in ground water. But degradation of the sulfur in coal can lead to acid production and increased mobilization of the metals present. Studies performed in the 1970s to support the landfill application indicated that arsenic and selenium were likely to be the most soluble of the metals leached from the ash.

Surface-water monitoring shows generally increasing levels of total arsenic in Island Creek. Although levels of selenium in Island Creek are elevated, they have generally remained level, with no single grab sample exceeding the marine chronic surface water standard of 0.71 milligrams per liter since sampling began in 1981. Besides the two surface-water-monitoring locations in Island Creek, the solid waste permit requires that runoff from the active landfill be monitored at the outfall of its sedimentation Basin. For more information about this landfill, contact the Solid Waste Management Branch.

In addition to the Indian River Power Plant coal-ash landfill, there are several closed landfills that were formerly used by county or municipal governments for the disposal of municipal solid waste. Refer to the Source Type: Superfund Sites category for information on these landfills.

Source Type: Hazardous Waste Facilities

The Hazardous Waste Management Branch regulates facilities that generate, accumulate, transport, treat, store, or dispose of hazardous waste. Many manufacturing processes commonly generate hazardous waste. If released, hazardous waste can cause notable harm to human health and the environment. Hazardous waste can be of two types:

- *Listed Hazardous Waste*. Listed hazardous wastes are specifically identified in the *Delaware Regulations Governing Hazardous Waste*. Currently, there are more than 400 such wastes listed. The wastes are listed as hazardous because they are known to be harmful to human health and the environment.
- *Characteristic Hazardous Waste*. Even if a waste is not listed, it may still be regulated as hazardous if a *characteristic* of hazardous waste is exhibited. Characteristics of a hazardous waste include ignitabilty, corrosivity, reactivity, and toxicity.

Within the Inland Bays/Atlantic Ocean Basin, 44 facilities are identified as hazardous waste generators. Of these, none have been identified as large-quantity generators (LGQ), generating greater than 2,200 pounds of hazardous waste per month. Twenty-eight facilities have been identified as small-quantity generators (SQG), generating between 220 pounds and 2,200 pounds of hazardous waste per month. Fourteen facilities have been identified as conditionally exempt small-quantity generators (CESQG), generating less than 220 pounds per month. The Site Index Database contains a list of these sites, along with the types of hazardous waste generated at each site (*Map 2.7-4*).

Although all facilities regulated by the Hazardous Waste Management Branch have the potential to release contaminants to the environment, most facilities manage their wastes in a responsible manner and, thereby, minimize the possibility of a release occurring. Furthermore, the proactive regulatory stance adopted by the Hazardous Waste Management Branch has increased companies' awareness and usage of proper hazardous waste management practices. For further information about hazardous waste generators in the Inland Bays/Atlantic Ocean Basin, please contact the Hazardous Waste Management Branch.

Source Type: Hazardous Chemical Inventory Reporting Facilities

Facilities report under the Hazardous Chemical Inventory for each hazardous chemical (as defined by OSHA) or extremely hazardous substance (EHS) present above threshold quantities. The basic threshold is 55 gallons or 500 pounds, whichever is lower, based on the maximum amount present on site at any time during the calendar year. Certain EHSs have a lower threshold. For each chemical or mixture, facilities report the identity of the substance, the amount present, and storage location information. This information has three primary purposes. Local Emergency Planning Committees (LEPCs) use it to develop plans to prepare for and respond to chemical emergencies in their districts. The 911 Fire Dispatch centers access the chemical information during emergencies at facilities and provide this information to local fire fighters and other emergency personnel responding to the site. The information is also available to the public to promote public participation in managing chemical risks in the community.

Approximately 1,200 facilities statewide report chemicals each year to the Hazardous Chemical Inventory, with an estimated 250 of these facilities located in the Inland Bays/Atlantic Ocean Basin. The data are made available to users through the Computer-Aided Management of Emergency Operations, or CAMEO, data system. The CAMEO system contains basic facility information such as facility name and street address, as well as the chemical-specific inventory information. CAMEO also contains a variety of other data modules used for emergency planning and response.

CAMEO runs in conjunction with a basic GIS mapping system named *MARPLOT*. While New Castle County is presently the only county to use MARPLOT, efforts are under way in Sussex County to map reporting facilities. Mapping will be performed by the Sussex County LEPC. MARPLOT layers should be easily transferred to the Department's GIS system for inclusion in watershed assessments. While these facilities report only the presence of chemicals and not releases to the environment, a geospatial representation of these facilities would contribute greatly to the Department's overall knowledge of potential sources of chemical contamination.

Therefore, the Inland Bays/Atlantic Ocean Basin Team recommends that the Department encourage and support the efforts of the LEPCs to map the facilities in their districts and to periodically update information. If efforts by the LEPCs do not meet the needs of the Department, the team recommends that funding be sought to have this mapping performed either by the LEPCs or the Department.

The Hazardous Chemical Inventory reporting and CAMEO data system are managed by the Emergency Planning and Community Right-to-Know (EPCRA) Reporting Program and can be contacted.

Source Type: Toxics Release Inventory (TRI) Reporting Facilities

Manufacturing facilities report annually under the Toxics Release Inventory (TRI) on any reportable toxic chemical that is manufactured, processed, or otherwise used above certain thresholds. The reportable list includes 575 individual chemicals and 28 chemical categories. Reports contain data on releases of the specific chemical to air, water, and land, as well as information on chemicals in waste transported off-site or managed on-site.

There are eight facilities within the Basin that have reported under TRI since reporting began for calendar year 1987 (refer to *Table 2.7-10* and *Map 2.7-4*). For the most recent reporting year (1999), seven facilities submitted 22 reports for 17 different chemicals. The Delmarva Power Indian River plant has ranked as the top facility statewide for on-site releases to the air, water, and land for the past two years as a result of their reporting large amounts of acid gases formed as coal combustion by-products. Oil and coal-fired power plants were added to TRI starting with the 1998 reports.

For more information about the TRI database, contact the Emergency Planning and Community Right-to-Know (EPCRA) Reporting Program.

The investigation and remediation of this country's most serious hazardous waste sites are performed through the Federal Superfund Program, which established a National Priority List (NPL). In 1990, Delaware enacted the Hazardous Substance Cleanup Act (HSCA), administered

Table 2.7-10
TRI FACILITIES REPORTING IN THE INLAND BAYS/ ATLANTIC OCEAN BASIN (1988 – 1999)

FACILITY NAME	YEARS	CHEMICALS REPORTED
Barcroft	1987–1999	Chlorine, Hydrochloric Acid, Nitric Acid, Sodium Hydroxide, Sulfuric Acid
D&B Industrial Group	1997–1999	Methyl Ethyl Ketone
Delmarva Power Indian River	1998–1999	Arsenic Compounds, Barium Compounds, Copper Compounds, Chromium Compounds, Hydrochloric Acid, Hydrogen Fluoride, Lead Compounds, Manganese Compounds, Nickel Compounds, Sulfuric Acid, Zinc Compounds
MFG Justin Tanks	1987–1999	Acetone, Styrene
Mountaire Farms-Selbyville	1987–1998	Ammonia, Chlorine, Sulfuric Acid
Mountaire Farms Feedmill	1996–1999	Copper Compounds, Manganese Compounds, Zinc Compounds
Townsend's	1987–1999	Ammonia, Atrazine, Chlorine, Copper Compounds, Dimethoate, Ethylene Glycol, N-Hexane, Manganese Compounds, Phosphoric Acid, Phosphorus, Propylene, Selenium Compounds, Sodium Hydroxide, Sulfuric Acid, Zinc Compounds
Vlasic Foods	1987–1992, 1995–1997, 1999	Acetone, Ammonia, Chlorine, Methanol, Polycyclic Aromatic Compounds, Sodium Hydroxide, Sulfuric Acid

by the Site Investigation and Restoration Branch (SIRB), to deal with other potentially harmful sites not addressed through the federal program. In 1993, the SIRB Branch initiated the Voluntary Cleanup Program (VCP), which is administered under the Hazardous Substance Cleanup Act. The VCP is primarily designed to address properties that are being evaluated for transaction or redevelopment and properties where no immediate threat to human health or the environment exists.

Source Type: Superfund Sites

A total of 26 sites, either under state or federal jurisdiction, are located in the Inland Bays/Atlantic Ocean Basin. Descriptions are provided for many of the active sites.

Selbyville Dump is a small, 5-acre municipal landfill that was operated by the Town of Selbyville during the 1960s. It is located on the outskirts of town, adjacent to Polly Branch near the town's wastewater treatment facility. An evaluation in 1997 identified low levels of semi-volatile organic compounds (SVOCs), DDT, and PCBs in surface soils and high concentrations of heavy and transitional metals in shallow ground water, which discharges directly into Polly Branch and later flows into Bunting's Branch and Little Assawoman Bay. Observed levels of aluminum, iron, lead, manganese, and zinc exceeded Delaware Surface Water Quality Standards. Elevated metals concentrations were also identified in Polly Branch sediments. However, a subsequent Rapid Bioassessment concluded that due to poor habitat and eutrophication of Polly Branch, the landfill has no discernible impacts.

Sussex County Landfill #2, Stockley, is a municipal landfill that was operated by Sussex County during the 1960s–1980s. It is located 3.25 miles northwest of Millsboro. Beryllium has been found in the soil at concentrations ranging from 7–16 milligrams per kilogram. Limited ground-water contamination of the shallow aquifer by low concentrations of volatile organic chemicals (VOCs, 160 micrograms per liter chlorobenzene) and heavy metals (6 milligrams per liter barium) has been documented. Iron exceeds Ambient Water Quality Criteria. Leachate from the landfill has contaminated shallow ground water that discharges to adjacent Sheep Pen Ditch, which eventually flows into Indian River. Groundwater use restrictions are in place in the area, pending further investigation regarding the extent and magnitude of ground-water contamination.

Sussex County Landfill #3 is located approximately one mile northwest of Angola. It is a municipal landfill that was operated by Sussex County during the 1960s–1980. Shallow ground water that is contaminated with low concentrations of organic constituents and various metals (150 micrograms per liter xylenes, 30 micrograms per liter 4-chloro-3-methylphenol, iron and manganese) discharges into nearby Chapel Branch and eventually flows into Herring Creek and Rehoboth Bay. Downstream surface water exhibits elevated concentrations of 14 metals. Barium, iron and manganese exceed Ambient Water Quality Criteria.

Sussex County Landfill #6, Omar, is a municipal landfill that was operated by Sussex County from 1971–1980. It is located 3.5 miles east of Frankford. Leachate from the landfill has contaminated shallow ground water (72 micrograms per liter chlorobenzene, 17 micrograms per liter pentachlorophenol, iron, and manganese) but few contaminants have been observed in adjacent Blackwater

Creek, which flows eventually into Indian River. The only contaminant confirmed as increasing in downstream surface-water samples is cyanide at 14 micrograms per liter.

Fort Miles, closed in 1958, operated two incinerators, a burn pit, a vehicle disposal area, a paint storage shed, and a suspected landfill. Investigations of these areas revealed a wide range of metals in ground water and surface soils.

The NCR site, where cash registers and electronic equipment were manufactured, is located on a 140-acre property one-half mile southeast of Millsboro and operated from 1964–1980. It is now on the National Priority List (NPL). Enameling, chrome plating, assembly, and degreasing operations were conducted at the NCR plant. Wastes from the plating operations were discharged to concrete and unlined lagoons on-site. Environmental investigations identified high concentrations of chromium in the pits, which were excavated and disposed off-site in 1981. Shallow ground water at the site is contaminated with trichloroethylene (TCE, up to 290,000 micrograms per liter) and other volatile organic chemicals (VOCs, for example, methylene chloride, 1,2-dichloroethylene, and chloroform), as well as chromium (up to 533 micrograms per liter). Surface-water samples from Iron Branch, which flows into Indian River, yielded much lower (up to 70 micrograms per liter) concentrations of TCE and other VOCs and chromium (up to 57 mg/L of hexavalent chromium). Trace concentrations of VOCs and chromium levels approximately equal to background values were identified in sediments. Remedial actions consist of air-stripping the contaminated ground water and treating the chromium in ground water via coagulation and filtration, with discharge of treated ground water to on-site ground-water infiltration galleries. Ground-water use restrictions are in place pending completion of the ground-water remedy.

The Bay Colony and Mallard Creek residential subdivisions were constructed in the mid- to late 1980s on County Road 348 along the south-central bank of Indian River Bay. Previous agricultural land use included the use of the pesticide 1,2-dichloropropane (1,2-DCP) as a soil fumigant on a portion of the property. Residual DCP has migrated into shallow ground water and has been identified in the nearby public supply well (contaminated area known as the Indian River DCP site). A 1997 investigation concluded that the plume of 1,2-DCP, with concentrations up to 20 micrograms per liter, is moving northward approximately 250 ft/yr. The plume is expected to reach Indian River Bay within five years. While an air-stripper has been installed on the impacted well, the comparatively low concentrations observed on-site preclude treatment of the plume itself. It will be allowed to naturally attenuate. Limited fate and transport data suggest that upon release into surface water, 1,2-DCP will volatilize and be diluted. Impacts to aquatic fauna are expected to be negligible.

The Sussex Lumber Company site is an inactive wood treatment facility located west of Rehoboth Beach, which operated from 1958–1973. Operations consisted of a pressure wood treatment process and a chromium-copper-arsenate salt formula wood preservative, which is a waterborne preservative that makes these chemicals mobile in the aqueous environment. High concentrations of arsenic (30,600 milligrams per kilogram), chromium (trivalent chromium 24,100 mg/kg; hexavalent chromium 45 mg/kg) and antimony (670 mg/kg) have been confirmed in on-site soils. No ground-water contamination has been identified. In order to prevent exposure to these metals and to minimize their potential future migration to ground water, a soil stabilization remedy was selected which binds the metals/metalloids to a phosphate/cement mixture. The remedy was completed in January 1998.

Additional information regarding the sites mentioned in this section and other sites may be obtained from the accompanying Site Index Database, the SIRB Web Site *(http://www.sirb.awm.dnrec.state.de.us),* or from the Site Investigation and Restoration Branch directly.

Source Type: Underground Storage Tank Sites

Leaking underground storage tank (UST) sites have been the source of over 2,000 reported releases of chemical contaminants into Delaware's environment for the past 20 years. Contaminant releases often result from:

- Corrosion, breaks, ruptures or other types of structural damage in the tank or associated piping, dispensers, or other tank system components;
- Loose fittings in the tank system piping, associated dispensers, or other tank system components; or
- Spills and overfills that routinely occur during tank filling and dispensing operations.

Except for spills and overfills, contaminants are released below ground, and no release may be suspected by the tank owner or operator as many tank leak rates are often very low compared to the amount of fuel dispensed. Unless the tank is equipped with properly functioning leak detection equipment, and unless the operator is trained to use such equipment properly, leaks can continue unnoticed for many years. Such leaks continue undetected until a sensitive receptor, such as a water well (i.e., drinking water), utility line, or a building basement (explosive situation) has been impacted. By that time, the area that was impacted may have been severely environmentally damaged and the resulting site remediation costs escalated to several million dollars.

Released contaminants (including petroleum products) migrate downward through backfill, soils, and sediments surrounding the tank to the water table. Most products stored in USTs have a specific gravity that is less than one. As a result, any free-phase product that makes it to the water table not only floats on ground water but will migrate in the direction of ground-water flow. Because the water table in the Delaware portion of the Inland Bays/Atlantic Ocean Basin is often within 10 feet of the ground surface, a very small release from a UST may be sufficient to contaminate ground water. Once ground water becomes contaminated, the potential to impact domestic or public drinking-water wells increases, especially if these wells are screened in the water-table aquifer. Surface-water bodies such as rivers, ponds, or lakes can also be impacted by a release from a UST facility.

UST site releases have become a growing concern in Delaware, including the Inland Bays/Atlantic Ocean Basin, over the past 20 years, especially because water wells and other sensitive receptors have been impacted.

Most UST systems in Delaware store petroleum products which include, but are by no means limited to, gasoline, kerosene, jet fuels, diesel fuel, heating oil, and used oils. USTs may also contain a variety of hazardous substances, such as chlorinated solvents.

Petroleum products can contain more than 100 different hydrocarbon compounds, many of which have been shown to be toxic to humans and wildlife. For example, benzene, a common constituent of gasoline, has been shown from epidemiological studies to be a human carcinogen. Benzo(a)anthracene and benzo(a)pyrene, which are common constituents of heating fuels, are probable human carcinogens.

Chemical compounds are commonly added to petroleum products to make these products burn more efficiently, and to reduce emission of toxic chemical compounds into the air. For example, the requirements of the Federal Clean Air Act Amendments of 1990 require that gasoline dispensed in Delaware contain up to 15 percent methyl tertiary butyl ether (MTBE). Unlike benzene and other hydrocarbon compounds present in petroleum, MTBE does not significantly biodegrade in the natural environment and dissolves into ground water much more easily, thus making remediation more difficult. Dissolved MTBE molecules migrate through ground water much more rapidly than other hydrocarbon compounds. As a result, MTBE is usually one of the first chemicals from a release to impact drinking-water supplies. The EPA is currently conducting studies to determine if MTBE is a carcinogen. MTBE contamination is of great concern to the UST Branch because it has been documented in an increasingly greater number of new and existing leaking UST sites over the past few years.

There are currently 330 registered UST facilities and 228 identified leaking UST sites located in the Inland Bays/Atlantic Ocean. Essentially, closed or inactive leaking UST sites are those sites where site investigation and remedial actions have been completed, and apparent threats to human health, safety, or the environment have been eliminated. Thus, the UST Branch requires no further action at closed or inactivated sites.

Although no data exist on the number of active sites in the Basin prior to 1997, it is likely that trends for the Delaware portion of the Inland Bays/Atlantic Ocean Basin are similar to those of the entire state. That is, available data shows that the number of active sites statewide increased rapidly from 1983 through 1990 and then leveled off at about 550 sites. It is likely that the number of active sites will slowly decrease over the next several years.

Any UST site in the Basin, even one where no known release has occurred, is a potential source of contamination. Concern for releases is genuine, as even a small release can impact and degrade ground water due to occurrence of the water table so close to the ground surface. As a result, all registered UST sites in the Inland Bays/Atlantic Ocean Basin are included in the accompanying Site Index Database. Each registered UST site is also shown on *Map 2.7-4.*

It is important to note that not every UST in the Inland Bays/Atlantic Ocean Basin is registered with the Department. This includes UST facilities that are "exempt" under current regulations from registering with the Department. Most of the "exempt" USTs are heating oil tanks with capacities of 1,100 gallons or less for which no leaks or releases have occurred. Once a release has occurred, an "exempt" UST *becomes regulated* and the release must be cleaned up to levels that are not a threat to human health, safety, or the environment (as required at any leaking UST site). The Department has documented many cases of releases that have occurred in previously "exempt" tanks and where stringent site remediation was required. Therefore, any currently "exempt" tank also has release potential.

Releases from "exempt" tanks are more difficult to detect and track because the Department does not regulate them. Detection occurs only during property transfer proceedings or after a sensitive receptor, such as a water well, has been impacted. Thus, it is likely many releases have occurred from "exempt" tanks that the Department is not aware of, whereas those from regulated tanks under similar circumstances would likely be known. The relative lack of release data for "exempt tanks" represents a major data gap at UST sites.

Current UST regulations require that any UST installed after 1985 must comply with "new" tank standards, including protection against corrosion, and be equipped with spill and overfill protection and leak detection equipment. New tank systems cannot be put into operation until they pass a precision tank test (which is used to determine if a tank is leaking). Those tanks installed before the regulations went into effect in 1986 must have been either upgraded to comply with new tank standards before 1991 (except for corrosion protection) or be removed from the ground. Tanks not equipped with adequate corrosion protection were required to be upgraded to comply with new tank corrosion protection requirements. Inventory control, recordkeeping, precision tank testing, as well as monitoring of leak detection equipment (including vapor and observation wells) and corrosion protection equipment, are required by owners and operators of all regulated USTs.

Major goals of the Underground Storage Tank Branch are to:

- Ensure that tank owners and operators bring their tanks into compliance with the regulations;
- Report any releases; and
- Effectively remediate contamination released at UST sites.

UST facility and leaking UST site records are available to the public through the Freedom of Information Act (FOIA) process. Anyone who wishes to review information regarding a specific UST site or has any questions regarding current UST regulations or UST Branch policies and guidelines should contact the UST Branch.

Source Type: Large On-Site Community Disposal Systems

Large community septic systems are a potential source of chemical contamination. The typical contamination is consumable salts, especially chloride (Cl). However these systems can also act as rapid pathways for various household chemicals (degreasers, cleansers, etc.) to the subsurface.

Source Type: Land Application of Wastes

In a Land Treatment System (LTS), wastewater is treated in a series of aerobic and facultative lagoons, then disinfected. Detention time — the length of time a unit of wastewater remains in a lagoon — is typically greater than 30 days. The treated, reclaimed water typically meets stream discharge standards for all parameters except nutrients.

However, instead of discharging the reclaimed water to streams, it is applied to agricultural land through center-pivot or solid-set irrigation systems to provide nutrients and water necessary for crop productivity. The reclaimed water is analyzed for nitrogen and phosphorus content, and the amount of reclaimed water that can be applied is limited based on the nutrient needs of the crops being grown. By sampling the percolate traveling through the soil column under LTSs, it has been shown that over 90 percent of the total nitrogen applied and 99 percent of the total phosphorus applied is either taken up by crops or stored in the soil.

Furthermore, vegetated buffer strips surround the irrigation areas, significantly reducing runoff from the fields. Storage lagoons are also provided, so wastewater is not applied during precipitation events or when the soil is frozen.

Currently, there are 10 LTSs located in the Inland Bays/Atlantic Ocean Basin (refer to *Table 2.7-8*). In 1997, the LTSs treated a total of 1.2 billion gallons of wastewater and discharged a total of 338,900 pounds of nitrogen and 63,600 pounds of phosphorus onto vegetated lands. Taking a mass balance approach, the net surplus of nitrogen and phosphorus from the LTSs was 17 pounds per acre and 0.32 pounds per acre, respectively.

Land Treatment Systems are the preferred method of managing wastewater in the Inland Bays/Atlantic Ocean Basin, provided that sufficient agricultural land is available for irrigation.

Source Type: Dredge Spoil Areas

The Department's Shoreline and Waterway Management Section initiates channel dredging projects in the Inland Bays in response to legislative and constituent demand. One of the primary needs relative to the successful implementation of any given project is a confined disposal facility (CDF) to retain the dredged material. Currently, the Section recognizes 10 upland CDFs in the Inland Bays/Atlantic Ocean Basin ranging in size from three to seven acres (refer to *Map 2.7-4*). Six of these areas are considered to be active sites. In carrying out projects, the Section has developed the following list of best management practices with particular emphasis placed on CDFs:

- Plan and implement projects with the idea of dredging only what is necessary to accommodate the existing boating traffic in any given area. (Generally speaking, dredge channels 60 feet wide and to a depth of (-4.0) feet mean low water. In federally authorized channels, follow the dimensions established by the U.S. Army Corps of Engineers.)
- Locate all upland, confined disposal facilities as far as possible from wetlands to avoid impacts to such. (If wetlands exist in close proximity, leave at least a 25- to 30-foot buffer when constructing).
- Locate all upland, confined disposal facilities as far as possible from private and public wells or water supplies to preclude the possibility of saltwater intrusion from occurring.
- Design and construct all upland, confined disposal facilities with the idea of reducing potentially detrimental environmental impacts. A rectangular-shaped facility, where the influent and effluent are located at opposite ends of the area, is by far and away the most effective design.
- Design and construct all facilities with a 2 to 1 consideration of volume change from the material *in situ* to each site to increase ponding depth and improve suspended solids retention efficiency.
- When possible, design and construct spur dikes within each facility to increase the retention time of suspended solids and circumvent short-circuiting.

- Implement erosion and sediment control measures before and after the construction of disposal facilities in accordance with the State Sediment and Stormwater Regulations (e.g., install silt fence around perimeter of areas; seed, mulch, and fertilize dike walls), to prevent degradation of surrounding areas.
- While projects are in progress, continually monitor the effluent from the facilities to ensure that the federal standard of 8 parts per thousand is maintained.
- When filling an underwater area, utilize containment curtains, if possible, to control/reduce the extent of the discharge-generated plume (turbidity).
- Adhere to any special conditions contained in federal and state permit approvals for projects (e.g., dredging windows).

Source Type: Salvage Yards

Automobile salvage yard and scrap metal recycling facilities provide a valuable service by recovering and recycling usable materials from discarded vehicles and equipment. While salvage operations are beneficial, the associated products and generated wastes have the potential to harm human health and the environment. Products and wastes from salvage operations include used oil, antifreeze, spent solvents, refrigerants, petroleum fuels, lead-containing wastes (e.g., batteries), tires, automobile fluff, and other solid wastes. Mismanagement of these products and wastes contributes to soil, water, and air pollution. Additionally, data exist linking the mismanagement of salvage materials containing polychlorinated biphenyls (PCBs) to the degradation and contamination of water systems. PCB contamination is responsible for the continued fish advisory precautions placed on numerous water bodies throughout Delaware. A total of two salvage yards are located in the Inland Bays/Atlantic Ocean Basin. The Site Index Database contains information about the automobile salvage yards identified in the Basin. For more information regarding automobile salvage yards, contact the Hazardous Waste Management Branch.

Source Type: National Pollutant Discharge Elimination (NPDES) Reporting Facilities

Municipal and industrial sites that discharge wastewater to surface waters are subject to limitations, monitoring requirements, and other terms and conditions identified in the individual NPDES permit issued to each site. Individual permittees must report monitoring results monthly, using the Discharge Monitoring Report (DMR) form developed specifically for each facility. The DMR lists parameters in the discharge that have a reasonable potential to cause or contribute to water-quality problems in receiving waters. Example parameters are temperature, dissolved oxygen, pH, copper, oil & grease, benzene, and PCBs. Although the DMRs are submitted monthly, actual monitoring frequency ranges from "continuously" to "once per year", depending on the discharge's characteristics and its volume relative to the receiving waters. *Table 2.7-9* shows the list of currently active sites.

Industrial sites that discharge only storm water may be permitted under an NPDES General Permit, which is a single permit that applies to a group of similar dischargers, e.g., trucking operations. Monitoring for storm-water discharges is typically less frequent, for example, three times in five years.

Source Type: On-Site Septic Systems

Septic systems are the main method for treatment of domestic wastewater used in the rural or unsewered areas of the Inland Bays/Atlantic Ocean Basin. In portions of unsewered sections, especially rural homesteads and older subdivisions, cesspools are still being used. Most are undocumented. A cesspool is usually a large, open-bottomed tank, which drains both liquid and solid wastes directly underground. A septic system is a more engineered waste disposal system compared to a cesspool and is usually comprised of a septic tank for solids and distribution box and drainage field for liquids. The drainage field may be either gravity-fed or pressure-dosed (refer to *Map 2.7-2*).

Although domestic wastewater can contain a wide range of substances, its chemical composition is relatively simple compared to municipal wastewater, which obtains liquid wastes from a variety of sources including housing, commercial, and industrial activities. Potential contaminants in domestic wastewater include dissolved organic matter, heavy metals, biological oxygen demand (BOD), pathogenic microorganisms, and soil nutrients such as nitrogen and phosphorus.

2.7.3.3 Atmospheric Contaminants

In 1970, Congress amended the Clean Air Act (CAA) of 1963 and authorized the Environmental Protection Agency to establish National Ambient Air Quality Standards (NAAQS) for pollutants shown to threaten human health and welfare. Primary standards were set according to criteria designed to protect public health, including an adequate margin of safety to protect sensitive populations (children, asthmatics, and the elderly). Secondary standards were set according to criteria designed to protect public welfare (decreased visibility, damage to crops, vegetation, buildings, etc.).

The pollutants that currently have NAAQS are ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$), and lead (Pb). These are commonly referred to as the "criteria pollutants." When air quality does not meet the NAAQS, the area is said to be in non-attainment with the NAAQS. Currently, in the State of

Delaware, there are no standards for acid rain, nitrogen deposition, or air toxics.

Given Delaware's generally flat topography, outdoor or ambient air moves fairly smoothly through and is generally well mixed across the entire state. Predominant airflow is from west to east. In summer, southwesterly winds prevail, while in the winter northwesterly winds are dominant.

Although the 1990 Clean Air Act is a federal law covering the entire country, the states do much of the work required to carry out the specific provisions of the Act. These provisions include the development of State Implementation Plans (SIPs) that show what steps each state will take to comply with the NAAQS and its progress toward attainment.

Under this law, EPA sets limits on how much of a pollutant can be in the air anywhere in the United States. This ensures that all Americans have the same basic health and environmental protections. The law allows individual states to have stronger pollution controls, but states are not allowed to have weaker pollution controls than those set for the rest of the country.

Ozone

Ozone is a highly reactive gas that is the main component of smog. While ozone in the upper atmosphere (stratosphere) is beneficial because it absorbs ultraviolet light, in the lower atmosphere (troposphere) it is considered a pollutant. It is a strong respiratory irritant that affects healthy individuals as well as people with impaired respiratory systems. It can cause respiratory inflammation and reduced lung function. It also adversely affects trees, crops (soybeans are a particularly sensitive species), and other vegetation. Ozone is also implicated in white pine damage and reduced growth rates for red spruce at high elevation sites. Milkweed is another native plant species that is sensitive to ozone, has been used as an indicator of elevated ozone levels, and is a good example of how ozone can impact an ecosystem. It is the only food source for the larva of the monarch butterfly; thus ozone damage to milkweed can indirectly affect the monarch butterfly population.

Ozone is not emitted directly by a pollution source but is formed in the atmosphere by the reaction of nitrogen oxides and volatile organic compounds in the presence of sunlight and warm temperatures. Ozone is therefore a problem only in the summer months; in Delaware, the season for ozone monitoring runs from April through October.

Ozone trends are difficult to measure because of the influence of meteorology. In general, ozone concentrations in recent years (1990s) have been significantly lower and there have been fewer exceedances of the one-hour standard than during similar weather patterns in the 1980s. Improvements are due to measures such as improved pollution controls on large industrial sources, vapor recovery on gasoline pumps, and lower volatility of gasoline and various solvents.

In response to new research on the effects of ozone on human health, EPA revised both the form and the level of the ozone standard in July 1997. The new standard is an eight-hour average of 0.08 ppm. An area will attain this standard when the three-year average of the annual fourth highest daily maximum eight-hour concentration is less than or equal to 0.08 ppm. Areas previously in nonattainment of the one-hour standard must be redesignated to attainment before the one-hour standard is revoked. The Inland Bays/Atlantic Ocean Basin — indeed, all of Sussex County — has been redesignated to attainment of the one-hour standard. Areas will not be officially designated as meeting or failing to meet the eight-hour standard until July 2001. Current monitoring data indicate that the entire state of Delaware, including the Inland Bays/ Atlantic Ocean Basin, will not meet this new standard.

Fine Particulates

In 1996, the U.S. EPA completed its review of the PM_{10} NAAQS. The result is a change in form of the PM_{10} standards and the addition of new annual and 24-hour $PM_{2.5}$ standards. These new standards are based on recent studies showing human health impacts of $PM_{2.5}$, at levels lower than the existing PM_{10} standards. The new standards are designed to emphasize monitoring and evaluation of community-wide levels of fine particulates. There are limited data on ambient levels of $PM_{2.5}$. As of January 3, 1999, monitoring for fine particulates began at four sites in Delaware. Existing PM_{10} data indicate that Delaware will not meet the new fine particulate standard and that concentrations will probably be higher in the more urbanized areas of the state.

PM_{10} is the portion of total suspended particulates that is less than 10 microns in diameter and thus small enough to be inhaled into the lungs. PM_{10} can include solid or liquid droplets that remain suspended in the air for various lengths of time. Particles small enough to be inhaled can carry other pollutants and toxic chemicals into the lungs. Fine particulates, $PM_{2.5}$, is the portion of total suspended particulates that is less than 2.5 microns in diameter. $PM_{2.5}$ is generated mainly by combustion processes. Sources include large point sources, such as fossil-fuel-burning power plants as well as mobile sources, both on and off road. Area sources also contribute to fine particulate emissions. Fine particles can be emitted directly from a source (primary pollution) or form in the atmosphere from combinations of compounds (secondary pollution). They can travel long distances due to their extremely small size and behave almost like a gas. This means that long-distance transport is more important for fine particles than coarse particles and regional or national control strategies will be needed to address air-quality problems.

Major effects of PM_{10} and $PM_{2.5}$ can include aggravation of existing respiratory and cardiovascular disease, alterations in immune responses in the lung, damage to lung tissue, and premature mortality. The most sensitive populations are those with chronic obstructive pulmonary or cardiovascular disease, asthmatics, the elderly, and children. Particulates are also a major cause of reduced visibility and can be involved in corrosion of metals (acidic dry deposition).

Other Atmospheric Pollutants

Air quality in Sussex County meets all remaining NAAQS as determined by the monitoring station located in Seaford, just outside of the Inland Bays/Atlantic Ocean Basin. There are other pollutants with NAAQS that are not monitored in the Basin, but are monitored elsewhere in Delaware. These pollutants include sulfur dioxide, particulate matter, nitrogen dioxide, carbon monoxide, and lead.

Sulfur Dioxide (SO_2)

Sulfur dioxide is a pungent, poisonous, colorless gas. It is an irritant that can interfere with normal breathing functions, even at low levels. It aggravates respiratory diseases such as asthma, emphysema, and bronchitis. High particulate levels can magnify these effects. Sulfur dioxide can also cause plant chlorosis and stunted growth. Sulfur dioxide can bind to dust particles and aerosols in the atmosphere, traveling long distances on the prevailing winds. It can be oxidized to a sulfate ion and combine with water vapor to form sulfuric acid and fall as acid rain. Airborne sulfur compounds also contribute to degradation of visibility.

Sulfur dioxide levels declined rapidly in the 1970s and appear to have remained fairly steady over the last 10 years. The improvement is largely due to the change to low or lower sulfur fuels in power plants as well as to improved emission control technologies.

Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a reddish-brown toxic gas. It irritates the lungs and upper respiratory system and lowers resistance to respiratory infections. It is also known to damage vegetation by stunting growth and reducing seed production. Also, nitrogen dioxide contributes to acid rain, ozone formation, and nitrogen deposition from the atmosphere to bodies of water. Nitrogen compounds deposited as either acid rain or dry deposition contribute to the total nutrient loading in a watershed. Studies conducted in the Inland Bays/Atlantic Ocean Basin, as part of the National Estuary Program, indicate that direct atmospheric deposition alone contributes 27 percent of the total nitrogen load (Cerco et al., 1994).

Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, poisonous gas produced by incomplete combustion of fossil fuels. It contributes to the formation of ozone. Carbon monoxide reduces the blood's ability to carry oxygen. Exposure to moderate concentrations can cause fatigue, headache, and impaired judgment and reflexes; at high levels, unconsciousness and death can result. People with heart disease, angina, emphysema, and other lung or cardiovascular diseases are most susceptible. Carbon monoxide concentrations are highest along heavily traveled highways and decrease quickly with increasing distance from traffic.

Lead

Lead is a highly toxic metal that affects several physiological processes including the renal (kidney), nervous, and blood-forming systems. It accumulates in both bone and soft tissues. Lead is no longer monitored in Delaware; monitors ran from 1978 to 1989 in New Castle County. Concentrations of lead in ambient air decreased 94 percent between 1978 and 1988. This dramatic improvement is attributed to the change from leaded to unleaded gasoline for automobiles. In 1989, the majority of samples collected were below the analytical detection limit, at which time the state ended its ambient air monitoring for lead.

2.7.3.4 Bay-Bottom Sediments

Concerns about contaminated bay-bottom sediments and the safety of shellfisheries have received increasing attention in recent years in the Delaware and other Mid-Atlantic estuaries, but limited attention has been paid to Delaware's Inland Bays. Bay-bottom sediments are contaminated with inorganic and organic compounds (metals, nutrients, petroleum, solvents, PCBs) from both point and nonpoint sources. The latter are poorly understood and often little characterized. A 1996 cooperative study between EPA and the states of Maryland and Delaware identified contaminated sediments, particularly in poor-circulation areas such as dead-end canals, as contributing factors to the continued degradation of the Inland Bays (U.S. EPA, 1996).

Basin-specific analyses were not performed, but some trends are discernible. For example, a general trend of increasing contamination from south to north. Chincoteague Bay, Virginia, was the least contaminated and Indian River Bay had the most sites with multiple-contaminant exceedances. One ER-M exceedence was noted in Indian River Bay near Lingo Creek and Pot Nets. Two other ER-M exceedances were noted in dead-end canals on Johnson's Branch and Chapel Branch off Rehoboth Bay (U.S. EPA, 1996).

In the open areas of the bays, the most ubiquitous contaminants exceeding ER-L thresholds in greater than 25 percent of the samples were DDT and its metabolites, DDD and DDE, arsenic, and nickel. ER-M exceedances were noted for the pesticides chlordane and dieldrin, and for DDE and benzo(a)anthracene (U.S. EPA, 1996).

Pollutant concentrations in dead-end canals were significantly higher for copper, silver, and 11 organic compounds (including pesticides and PCBs) than in the open-water areas of the bays, particularly with regard to PAH compounds. A more extensive suite of contaminants was also identified in the canal samples. Subsequently, biological sampling indicated that benthic fauna diversity was also significantly lower in the canals compared to the bays as a whole (Maxted et al., 1997; U.S. EPA, 1996). Although contaminants tend to accumulate in dead-end canals, the low dissolved oxygen concentrations they produce by their high chemical and biological oxygen demands do migrate out into open waters where they pose a threat to surrounding areas. Nor are contaminants completely contained in dead-end canals and other poor circulation areas. Periodic high-energy events, such as natural storms and man-made dredging, serve to remobilize contaminated sediments and move them into the bays. In the meantime, these areas represent biologically dead zones in which fish and shellfish that enter the canals are exposed to a combination of hypoxia and chemical contaminants (Maxted et al., 1997).

2.7.3.5 Organic Compounds

Polycyclic aromatic hydrocarbons (PAHs) have been identified as contaminants of concern in the Basin. They have been found at hazardous waste sites, in surface soils, stream sediments, and sediments within the Inland Bays themselves, particularly in dead-end canals. In some instances, the observed concentrations exceed ecological thresholds, posing potential risks to ecological receptors.

PAHs represent a group of organic chemicals formed from the incomplete burning of petroleum, garbage, or other organic substances. They are mostly man-made and to a lesser extent are naturally occurring and are found throughout the environment in all media. Low to moderate amounts of PAHs are ubiquitous at hazardous waste sites and LUST facilities. More than 100 PAHs have been identified, but only 15 of the more common ones are considered in human and ecological risk assessments. Most PAHs do not occur alone, but as mixtures of two or more species. Of these, several are considered probable human carcinogens (Group B2): benzo(a)anthracene, benzo(a)-pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene and indeno(1,2,3-cd) pyrene. Animal studies show that exposure to high concentrations of PAH compounds result in enzymatic, immunological, hematological, developmental, and reproductive impacts, in addition to tumor formation. Bioconcentration factors vary, with the heavier PAHs listed above having significant bioconcentration potential. Biomagnification, however, has not been observed (ATSDR, 1997).

Lighter-molecular-weight PAHs volatilize more readily than the heavier-molecular-weight carcinogenic species. Because of their high organic partitioning coefficients and low solubilities, PAHs do not readily leach from soils or sediments, so they are not very mobile in the environment.

Solubility of PAHs generally decreases with increasing molecular weight. Most PAHs adsorb onto soil, sediment, or suspended organic floc and are thereby removed from the aqueous environment. Physical degradation and microbial biodegradation occur at measurable rates under aerobic conditions, but proceed very slowly in oxygen-poor environments. Thus, PAHs may persist for a long time in anaerobic areas such as stagnant dead-end canals.

2.7.3.6 Pesticides/PCBs

DDT (1,1,1-trichlor-2,2-bis(p-chlorophenyl)ethane) is a man-made insecticide that was widely used to control mosquito populations in the United States until its use was banned in 1972. As a result of the compound's persistence in the environment, however, DDT and its degradation daughter products DDD and DDE are still found in generally low concentrations throughout the United States in soils and in stream sediments.

These pesticides have been identified throughout the Basin in surface soils, stream sediments and bay-bottom sediments in some instances at concentrations deemed harmful to ecological receptors. These pesticides target the central nervous system, but animal studies show that exposure to even low concentrations of DDT, DDD, or DDE results in liver damage and harmful reproductive effects. These harmful impacts have been documented in both humans and animals. In addition, DDT and its metabolites are considered probable human carcinogens (Group B2). They are lipophillic (stored in fatty tissue). DDT and DDE bioconcentrate in organisms and biomagnify in the food chain. One of the earliest concerns regarding the toxicity of these pesticides came to light with the observed thinning of eggshells of birds, especially raptors, and the decreased viability of bird embryos (ATSDR, 1997).

DDT, DDD, and DDE bind strongly to soil and sediment particles, are only slightly soluble, and are not often found in the aqueous environment. When identified in surface water, DDT most likely indicates the presence of organic floc or fine sedimentary particles in the sample. DDT, DDD, and DDE persist for a long time in the environment. Volatilization and photodegradation has been known to occur in surface soils and surface water. While microbial biodegradation of DDT, DDD, and DDE may occur in both aerobic and anaerobic environments, this phenomenon is erratic and not well understood. It may depend on available microbial populations and variations in redox chemistry.

2.7.4 DATA GAPS AND RECOMMENDATIONS

1. Develop Best Management Practices and an accompanying manual that promotes riparian buffers to help trap nutrients and improve water quality in both channelized and natural streams.
2. Systematic eliminate all point sources discharging nitrogen and phosphorus to the water bodies within the Basin.
3. Implement the Conservation Reserve Enhancement Program (CREP) in the Basin on 2,000 to 3,000 acres by the year 2002. The following BMPs will be implemented: filter strips, riparian buffers, wildlife habitat, wetland restoration, and hardwood tree planting.
4. Implement "follow-up" in FY 2002 to track implementation of BMPs on state and federal lands. Plans were written in FY 99.
5. Provide technical/financial assistance in support of Delaware's Nutrient Management legislation for implementation of structural and non-structural BMPs such as manure storage, cover crop, etc.
6. Provide recommendations/support for development and implementation of economically viable alternative uses of manure, including composting and pellitizing.
7. Provide technical/financial support for developing and implementing "pilot projects" such as manure transport, phytase enzyme in feed mills, etc.
8. Provide technical support for Animal Feeding Operations/Confined Animal Feeding Operations and nutrient management regulations.
9. Implement a conservation design. If developers could not use this approach, they would need to justify why they could not meet it prior to getting approval for a lesser approach. Zoning impediments to this would need to be identified. (*Work with county planning officials.)*
10. Implement conservation/nutrient management planning/implementation in accordance with Delaware's Nutrient Management legislation in the Inland Bays. Tracking of activities can be submitted to the Nutrient Management Commission upon request. *Lead Agency: Nutrient Management Commission*
11. Finalize and adopt Phosphorus Index and accomplish training for nutrient management planners by FY 2000. *Lead Agency: University of Delaware*
12. Develop and implement nutrient management plans on golf courses in accordance with nutrient management legislation. *Lead Agencies: Nutrient Management Commission & DNREC*
13. Currently, the storm-water regulations include a goal of 80 percent reduction in total suspended solids (TSS). A similar goal should be set for nutrient reduction that is consistent with TMDLs.
14. Septic regulations should be amended to establish a deadline for the owners of grandfathered lots of less than one-half acre to develop their land or lose their grandfather status.
15. Septic regulations should require top-seamed septic tanks (they are now two-piece tanks, top & bottom) and every tank should be installed with a riser above grade. The riser provides access to the tank and identifies its location. In addition, manufactured seals and sealants now used in the field should be tested for watertightness. Each tank manufacturer should be inspected semi-annually and tanks randomly tested for watertightness.
16. Begin a program to sample water quality in ditches and on-site wells in areas with small lots and nonconforming systems. It is suspected that in some of the poorly drained subdivisions, the ditching is providing the outlet for the wastewater. This would help prioritize problem areas.
17. Start a program beginning with the Inland Bays area to replace all non-conforming septic systems. Give homeowners plenty of notice that within so many years, (say 2–4 years) all non-conforming systems have to be upgraded. Older subdivisions served by cesspools will have to address their wastewater needs as a whole.
18. Start a program to inspect gravity systems every three years and engineered systems annually. Thousands of permits are issued annually, but once the systems are installed there is no follow up. This is a problem especially in Sussex County due to systems installed years before homes are built. Timers, electrical connections, and pressure settings are not correct, which can cause premature failures. Require septic tanks and dosing chambers to be pumped every two years. Licensed waste haulers could provide this service.
19. Require all homeowners with holding tanks to record on their deed a notice that the property is served by a holding tank. All renewal fees must be paid prior to the transfer of the property.
20. Before a holding tank can be issued, the entire parcel should be denied a system. If an alternative system can be approved, no holding tank would be approved.
21. Place a moratorium on permanent holding tanks in subdivisions that are being served by an increasing number of tanks.

22 Set criteria for ratio of holding tanks to total lots in a subdivision.

23. Systems washed away during storm events along the beach, should not be replaced. These shoreline communities should have central sewer.
24. Create a law that requires septic certification prior to the sale of any improved property. All non-conforming

systems would have to be replaced before any property transfer. *Lead Agency: General Assembly*

25. Establish a large fee for permanent and temporary holding tanks**.** *Lead Agency: General Assembly*
26. Deny the placement of new (non-replacement) alternative septic systems outside of investment areas and restrict their placement in investment areas to reduce impacts to wetlands and important habitats.
27. Assess septic system failure rate for the Basin through remote sensing and verification by grounding survey.
28. State Revolving Fund money and support should go to projects with extreme environmental need or economic hardship. *Lead Agency: Wastewater Advisory Council*
29. Advocate cover crop program.
30. Support implementation of phytase feed lines by all integrators on the shore by year 2003.

31 Identify the areas where a significant amount of ground water is being consumed and the Department has little or no water-quality data.

32. Finalize and implement pollution control strategies to meet established TMDLs for Indian River, Indian River Bay, and Rehoboth Bay.
33. Develop and implement storm-water monitoring plan.
34. Cosely monitor Maryland's *Pfiesteria* Action Plan as it contains proposed land-based solutions to the overall nutrient-loading problem.
35. Focus nutrient management plans for intensive animal-based agriculture on farm-scale nutrient balance rather than exclusively on field-scale crop response to nutrients applied in animal wastes.
36. Targeted ground-water monitoring should be incorporated more frequently into BMP implementation proj-ects. If possible, monitoring plans should be developed to discern short-term effects and predict long term trends to provide a better indication of implementation impact.
37. Determine ground-water system lag time in various sites throughout the state. This could be very helpful in establishing timetables to see results of Pollution Control Strategies.
38. Obtain grants to repair or replace malfunctioning septic systems in environmentally sensitive areas. Incorporate innovative technologies where appropriate.
39. As the state moves to implement TMDLs and Pollution Control Strategies, it is very important that the lands the government owns or control be managed properly. Therefore, all agricultural lands owned by state and federal governments must be assessed and have comprehensive conservation plans developed for them. These plans should then be incorporated into the land lease agreements and daily management practices.
40. With the widespread nutrient inputs throughout the Basin, it is important to locate all of the various sources accurately so that local action can be taken. In particular, as population increases in rural areas, septic system are installed to dispose of the waste. The regional density of these systems and their proximity to sensitive resource are important pieces of the nutrient management puzzle. Therefore, all septic systems in Basins (state) should be mapped using aerial photography. This information, when placed in a GIS format, should be used to answer more specific questions about system placement and density.
41. Atmospheric deposition is proving to be a major contributor to acidification, nitrogen loading, and toxification of waterways. There is currently little or no specific information on the impact of atmospheric deposition to the Inland Bays/Atlantic Ocean and other Delaware basins. It is recommended that options be explored for acquiring the necessary resources to conduct computer modeling and other research to quantify the impact of atmospheric deposition on the Inland Bays/Atlantic Ocean and other basins.
42. Incorporate septic mapping data in the development of Pollution Control Strategies.
43. Develop a series of Best Management Plans (BMPs) for all sources of erosion in order to keep sediment and nutrients out of wetlands, waterways, and the bays in general. Develop management plans to designate and develop riparian buffers and establish habitat criteria for maintaining said buffers. *Lead Agency: Nutrient Management Commission*
44. Do not allow overboard disposal of dredge spoils.
45. Educate the public regarding the proper disposal of motor oil and household chemicals. Continue to support the efforts of the Delaware Solid Waste Authority in its household hazardous waste collection program.
46. Adequate information currently exists to evaluate status and trends for the criteria pollutants: volatile organic compounds, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. Data collection and evaluation should continue unchanged.
47. Due to the proximity of Conectiv's fly-ash landfill to the Inland Bays, the Department should evaluate the effect of surface- and ground-water discharge from the landfill to Island Creek and Indian River Bay.
48. Evaluate the effect of maintenance dredging dead-end canals and the resulting redeposition of potentially contaminated sediments.
49. Phase out CCA-treated lumber for shoreline stabilization in aquatic environments.
50. National studies have shown that high ozone levels cause crop damage and reduce yield, thus adversely

impacting our food supply and causing millions of dollars in losses to the agricultural community. Little or no information is available on the level of crop damage and associated impacts on the Inland Bays/Atlantic Ocean and other Delaware basins. It is recommended that options be explored for acquiring the necessary resources to study and quantify the level of crop damage and associated impacts in the Inland Bays/Atlantic Ocean Basin.

51. Aboveground storage tanks are currently unregulated; develop regulations for operation, spill/overfill protection, leak detection, tank testing requirements, and corrosion protection.
52. Develop education process for owners of exempt Underground Storage Tanks about proper maintenance and leak detection to avoid becoming a regulated LUST.
53. Implement a storm-drain stenciling program to raise the awareness of the public concerning the relationship between stormwater runoff and river quality.
54. Due to the nature and scope of the ozone problem, it is essential that we continue to participate with other states, regional, and federal agencies on data sharing efforts. Delaware currently works with, and should continue to work with, other states, regional agencies, and EPA to communicate ozone data.
55. Explore options for acquiring the needed support to produce comprehensive periodic inventories of SO_2, PM_{10}, TSP, lead, and toxics.
56. Explore options for acquiring the needed support to produce comprehensive periodic inventories of greenhouse gases.
57. Develop a method to allocate area, mobile, and biogenic emissions to geographic basins and graphically portray those emissions.

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