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Wetland Trends in Delaware: 1981/82 to 1992

A National Wetlands Inventory Report

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Wetland Trends in Delaware: 1981/2 to 1992

by

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Introduction

The U.S. Fish and Wildlife Service has been inventorying wetlands across the country as part of its National Wetlands Inventory Program since the mid-1970s. During this time, the Service completed an inventory of Delaware's wetlands, published a report on the findings (Tiner 1985), and completed a statistically based wetland trends analysis for the state (Tiner and Finn 1986). In the mid-1990s, the State of Delaware produced an updated and more detailed inventory using 1992 aerial photography.

The Delaware Department of Natural Resources and Environmental Control (DNREC) has primary responsibility for managing the state's natural resources and is very concerned about the changing status of wetlands, especially the inland wetlands. These wetlands are not presently regulated by the state, although federal regulations are in effect. When the updated inventory was completed, the DNREC approached the Service about the possibility of conducting a wetland trends analysis study covering the previous decade (1980s-1990s). The DNREC through its Watershed Assessment Section provided funds to the Service to do this work. The subject report presents the findings of this study.

Methods

Wetland trends analysis is performed by comparing aerial photographs or other remotely sensed data captured at two or more time periods. For this study, color infrared aerial photographs from April 1981/March 1982 and March 1992 were analyzed. The photo scales were different: 1:58,000 for the former and 1:40,000 for the latter. The effective study interval was approximated at 10 years.

Identification of wetland losses, gains, and changes in type was done by comparing the 1981/82 aerial photographs to the 1992 photos. Both the original NWI interpretations and the updated DNREC wetland maps[1] were used as general guides. The trends analysis emphasized photointerpretation (i.e., photo-signatures) over what was mapped by the NWI, since the 1:40K photos provided much better resolution of wetland types and boundaries than the 1981/82 imagery used to produce NWI maps. Using a Bausch and Lomb SI-95 system, photo to photo analysis was performed for all study quarter-quads to detect wetland trends. A wetland change overlay was prepared for each photo. This overlay was later transferred to a 1:12,000 map overlay (matching the DNREC wetland map) using a Bausch and Lomb zoom transfer scope. The wetland trend overlays were subsequently digitized for analysis.

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[1]These maps were prepared by Photo Science, Inc. (now Earthdata International), Gaithersburg, Maryland. Wetlands are shown on 1:12,000 digital orthophoto quarter-quadrangles. They are classified according to the official U.S. Fish and Wildlife Service's wetland classification system (Cowardin et al. 1979) with added DNREC modifiers to identify riparian wetlands, coastal plain ponds, certain types of farmed wetlands, etc. (see "Statewide Wetlands Mapping Project" by L. T. Pomatto, Jr.; undated DNREC draft report).

Wetland losses and gains were identified as going to (loss) or coming from (gain) a specific land use or land cover. The Anderson et al. (1975) classification was used for typing the land cover or use for nonwetlands. Some of the major categories used are: 1) industrial development, 2) commercial development, 3) residential development, 4) highways and roads, 5) ponds (classified by Cowardin et al. 1979), 6) transitional land (land undergoing some type of development - unknown use), 7) rangeland (open fields and shrub thickets), 8) cropland, 9) pasture, and 10) upland forest. Wetlands including changes from one wetland type to another were classified according to the Cowardin et al. system (1979). Wetland changes as small as 0.1 acre were identified. Changes in wetland type focused on human-induced changes, especially timber harvest. Vegetation changes due to "natural succession" were not identified as the study focus was on more direct, human-caused changes.

The DNREC wanted wetland trends data for the state reported on a watershed or drainage area basis. They have divided Delaware into four major drainage basins: 1) Northern Piedmont, 2) Delaware Bay, 3) Chesapeake Bay, and 4) Inland Bays (Figure 1). The original study design called for a minimum of 100 quarter-quads to be sampled. A list of more than 100 quads was compiled through random selection. The DNREC requested complete analysis for the Northern Piedmont and Inland Bays drainage basins, so all quarter-quads in those basins were analyzed. For the other two drainages, more than half of each basin was examined for wetland trends. About 75 percent of the Delaware Bay drainage area was evaluated and 60 percent of the Chesapeake Bay drainage. The final tally of quarter-quads analyzed was 128 (see Figure 2).

Wetland trends statistics were generated for the Northern Piedmont and Inland Bays drainage basins from a 100 percent sample. For the other basins, wetland trends were estimated using a nearest neighbor technique. Since a complete assessment of wetland trends was not done for the quarter-quads in these areas, the trends for unsampled quads had to be estimated. This was done by extrapolating the results from a neighboring quad of similar wetland characteristics (that had been analyzed for wetland trends). The rationale for this correlation was that what happens in one quad should be similar to that occurring in a neighboring quad with similar qualities. The projected changes were therefore derived from a given quad's nearest neighbor. The data were normalized relative to the actual extent of wetlands present in the quad based on the wetland acreage totals derived from the DNREC wetland maps.

After preparing wetland trends overlays for the quarter-quads, field work was performed to check interpretations. Approximately 25 percent of the quads were checked during a September 8-9 field trip. The major issues requiring field checking were: 1) large tracts of forested wetlands converted to residential, commercial, and industrial development, 2) possible missed wetlands not shown on the 1992 maps, 3) inconsistent mapping of ditched wetlands on the 1992 maps, 4) large tracts of possible forested wetlands that had been harvested but mapped inconsistently as either a palustrine emergent and/or shrub wetland or upland, and 5) spoil deposition in wetlands in the Wilmington area. Although some inconsistencies were found in the 1992 (e.g., missed wetlands including cutover forested wetlands), no attempt was made to correct the maps as this was beyond the scope of the study. The trend results, however, identified changes to any photointerpretable wetland (whether or not it appeared on the DNREC maps) to insure the accuracy and completeness of the wetland trends analysis.

Upon making final edits to the trend overlays, they were digitized for geographic information system (GIS) application and data analysis. Results were generated using ARC/INFO software. Summaries of wetland trends were prepared for the state and for each major drainage basin.

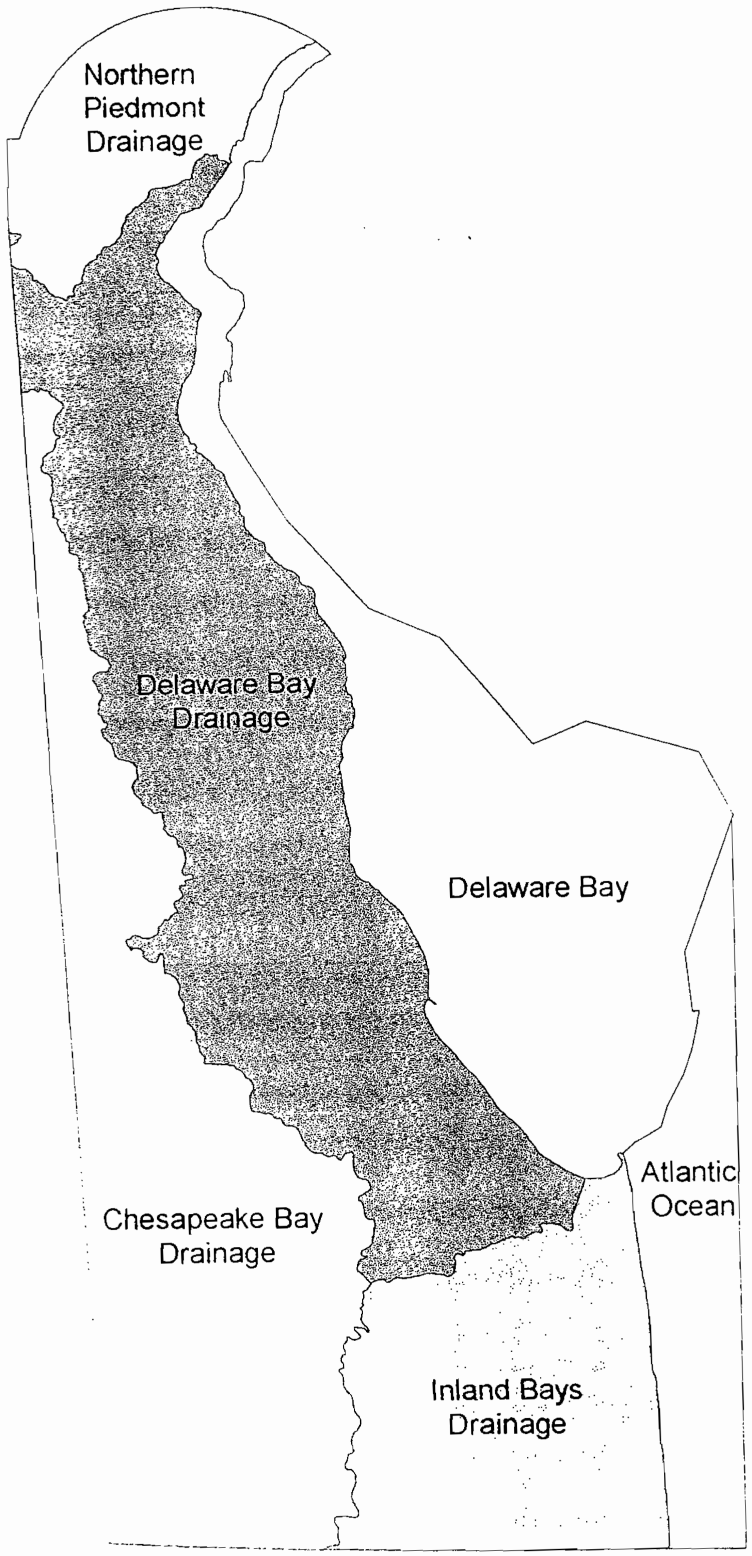

Figure 1. Delaware's four major drainage basins.

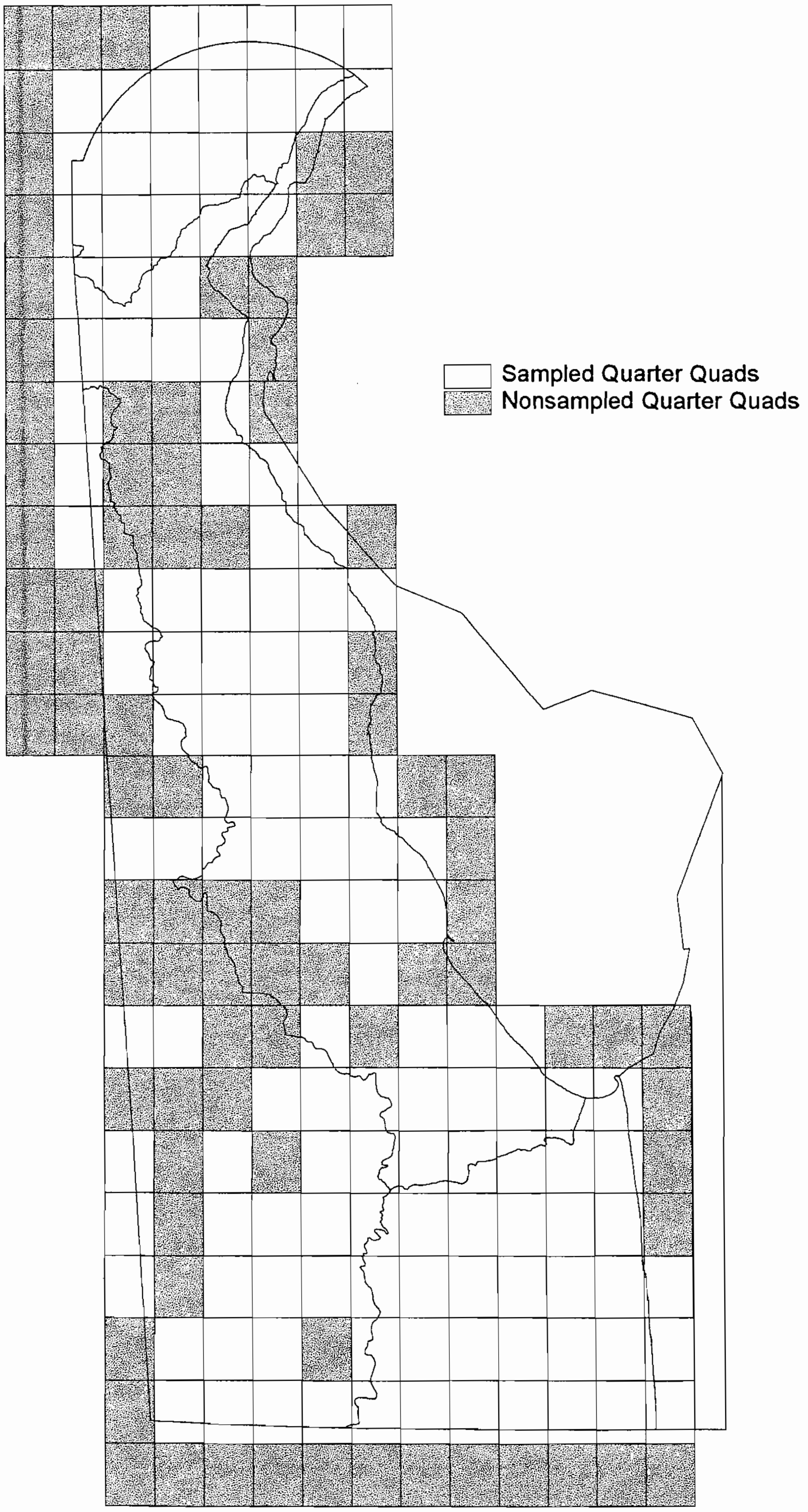

Figure 2. Distributuion of quarter quad sampling plots for the wetland trends study.

Results

The results are presented in both narrative and tabular form. Statewide results are given first, followed by wetland trends for individual drainage basins.

Statewide Trends

Estimated Conversion of Vegetated Wetlands

Nearly 2000 acres of vegetated wetlands were destroyed from 1981/2 to 1992. Most of this loss involved palustrine vegetated wetlands (Table 1). Roughly 1890 acres of these wetlands disappeared, while about 106 acres of estuarine vegetated wetlands were eliminated.

The main cause of wetland loss for the palustrine vegetated wetlands was agricultural activities which accounted for half of their losses alone (954 acres). Residential development also exacted a large toll on these wetlands - 436 acres or nearly 25 percent of their losses. Pond construction and highway/road projects affected nearly equal amounts of palustrine vegetated wetlands, with each being responsible for about 7 percent of the losses.

Palustrine forested wetlands experienced the greatest losses. A total of 1505 acres were converted to nonwetlands, ponds, and farmed wetlands. Eighty percent of the converted palustrine vegetated wetlands were this type. Forested wetlands alone accounted for 76 percent of the total loss of vegetated wetlands (both estuarine and palustrine types). An additional 2045 acres of these wetlands were harvested for timber. Statewide losses of other palustrine vegetated wetlands were: 255 acres of palustrine scrub-shrub wetlands and 129 acres of palustrine emergent wetlands. In all, palustrine vegetated wetlands comprised 95 percent of the losses of Delaware's vegetated wetlands between 1981/2 and 1992.

About 106 acres of estuarine vegetated wetlands were converted to other uses. Over half of the losses were due to impoundments (52.2 acres), mostly saltwater impoundments. Nearly a third of the losses were due to filled wetland for unknown purposes (32.7 acres including transitional land and rangeland). Filling for highway/road projects and for residential development accounted for about 11 acres of coastal marsh loss (about 5 acres each).

Estimated Changes in Vegetated Wetland Type

Changes from one vegetated wetland type to another were significant during the study period. In general, these changes should not be viewed as wetland loss because nearly all of them were the result of timber harvest (i.e., cutover PFO) and the succession of vegetation types following harvest (e.g., PEM to PEM/SS to PSS/EM to PSS to PFO).[2] An estimated total of

[2]PFO = palustrine forested wetland; PEM = palustrine emergent wetland; PSS = palustrine scrub-shrub wetland; PEM/SS and PSS/EM are mixtures of the prior two types.

3474 acres changed from 1981/2 to 1992. An estimated 2045 acres of palustrine forested wetlands were cutover and became emergent and/or scrub-shrub wetlands (1350 and 695 acres, respectively). These wetlands should eventually revert to forested wetlands. From the 1980s to the 1990s, 754 acres of palustrine emergent wetlands became shrub wetlands, while 305 acres became forested wetlands. Nearly 370 acres of shrub wetlands became forested wetlands following the succession pathway induced by timber harvest practices.

If the vegetation type changes induced by timber harvest are included in the analysis, there were net gains in palustrine emergent wetlands and scrub-shrub wetlands (293 acres and 1081 acres, respectively). These gains came at the expense of forested wetlands (timber harvest). Seventy-seven percent of these changes came from the Chesapeake Bay drainage area where logging activities in wetlands were significant. These changes, however, can largely be viewed as temporal changes as it appears that these wetlands are actually previously harvested forested wetlands that will most likely regain their forested condition within 20+ years.

Besides the effects of forestry practices, only 2.2 acres of other changes were recorded. A 1.1-acre gain in palustrine emergent wetland from impoundment of an estuarine emergent wetland and a 1.1-acre loss of palustrine forested wetland to estuarine emergent wetland. The net effect on estuarine emergent wetlands was no change during the study interval.

Estimated Changes in Nonvegetated Wetlands

These wetlands consist mostly of freshwater ponds and tidal flats along the coast. Of these types, changes in pond acreage was the most dynamic (Table 2). Statewide pond acreage increased by an estimated 609.4 acres. Although 889.7 acres were established, pond conversion to other lands eliminated 280.3 acres of pre-existing ponds. Conversion to land with unknown future use (i.e., transitional land) accounted for 64 percent of these pond losses. About half of the gain in pond acreage came from agricultural land, while 21 percent of the new ponds was built in former upland plant communities and 16 percent was constructed in wetlands. Forested wetlands were most affected by pond construction with 94.8 acres of ponds created in this wetland type. This amounts to 67 percent of the vegetated wetlands converted to ponds. Other vegetated wetlands converted to ponds were: 24.5 acres of palustrine emergent wetlands, 15.8 acres of palustrine scrub-shrub wetlands, and 7.3 acres of estuarine emergent wetlands.

Nearly 200 acres of tidal flats (estuarine unconsolidated shores) were converted to a dredged material disposal site at the mouth of the Christina River. This single action was responsible for virtually all of the estuarine nonvegetated wetland loss.

Table 1. Statewide changes in vegetated wetlands in Delaware: 1981/2-1992.

Wetland Change	Cause	Acreage Affected
EVeg Gain from	Palustrine Forested Wetland	1.1
	(Subtotal)	(+1.1)
EVeg Loss to	Estuarine Deepwater (Impoundmt)	44.9
	Transitional Land	18.2
	Rangeland	14.5
	Pond (Impoundment)	7.3
	Tidal Flat	5.7
	Highway/Road	5.5
	Residential Development	5.3
	Commercial Development	2.1
	Palustrine Emergent Wetland	1.1
	Industrial Development	0.9
	(Subtotal)	(-105.5)
Net EVeg Change	=	*-104.4 (loss)*
PVeg Gain from	Pond Colonization	34.8
	Cropland	20.3
	Rangeland	10.6
	Pasture	9.5
	Upland Forest	4.6
	Farmed Wetland	3.4
	Lacustrine Deepwater	2.9
	Sand/Gravel Pits	1.3
	Estuarine Wetland	1.1
	Idle Fields	0.9
	Transitional Land	0.2
	(Subtotal)	(+89.6)
PVeg Loss to	Agriculture-related*	954.2
	Residential Development	435.7
	Pond Construction	135.1
	Highway/Road	128.5
	Rangeland	88.1
	Industrial Development	49.8
	Transitional Land	32.7
	Airport	27.5
	Riverine Deepwater Habitat	14.9
	Commercial Development	11.0

	Estuarine Deepwater (impoundmt)	5.9
	Upland Forest (drained)	4.9
	Estuarine Emergent Wetland	1.1
	Transportation/Communication	0.7
	(Subtotal)	(-1890.1)
PVeg Type Change	Timber Harvest	2035.4
	Succession**	1426.6
	Palustrine Forested Wetland to Palustrine Emergent Wetland (excavated)	10.1
	(Subtotal)	(3472.1)
*Net PVeg Change****	=	*-1800.5 (loss)*
TOTAL Net Change in Vegetated Wetland	=	-1904.9 (loss)

*Does not include pond construction on farms.
**Following pre-1981/2 timber harvest.
***Excludes PVeg acreage changing from one PVeg type to another.

Table 2. Changes in nonvegetated wetlands in Delaware: 1981/2-1992.

Wetland Change	Cause	Acreage Affected
ENonveg Loss to	Estuarine Deepwater	3.2
	Dredged Material Disposal Site	199.1
	Subtotal	-202.3
Net ENonVeg Change	=	*-202.3 (loss)*
PNonveg Gain from	Agricultural Land	437.0
	Upland Vegetated Areas	190.5
	Wetlands	142.4
	Transitional Land	95.3
	Other Land	17.0
	Developed Land	7.5
	Subtotal	+889.7
PNonveg Loss to	Transitional Land	180.5
	Wetlands	34.8
	Developed Land	23.5
	Other Land	20.0
	Upland Vegetated Areas	18.0
	Agricultural Land	3.5
	Subtotal	-280.3
Net PNonVeg Change	=	*+609.4 (gain)*

Drainage Basin Trends

<u>Northern Piedmont Drainage</u>

The Northern Piedmont Drainage encompasses 182 square miles. This drainage represents approximately 9 percent of the state's land mass. Wetlands are not particularly widespread in this area of rolling hills and much urban development. The watershed is quite developed especially along the I-95 corridor. Wilmington is the largest municipality in the watershed.

Conversion of Vegetated Wetlands

From the 1980s to the 1990s, Piedmont vegetated wetlands experienced net losses of nearly 140 acres. Palustrine vegetated wetlands received the greatest impact, declining by a net amount of 137.8 acres. In total, 147 acres of these palustrine wetlands were converted to other uses, 14 acres of forested wetlands were cut over and 1.7 acres of PFO were converted to PEM1Fx. Only 9.2 acres of palustrine vegetated wetlands became established during the decade. This small gain was usually the result of vegetative colonization of ponds. Tables 3 and 4 summarize the trends data for Piedmont vegetated wetlands collectively and by individual types.

Seventy percent of the palustrine vegetated wetland losses during the study decade was attributed to residential development (Table 3). The second-leading cause of the loss of this wetland type was industrial development which was responsible for 18 percent of the losses.

Palustrine forested wetlands received the heaviest losses, with about 110 acres converted the upland of some type (Table 4). These wetland losses accounted for 75 percent of the total losses of palustrine vegetated wetlands. An additional 1.7 acres were excavated and became a palustrine emergent wetland. Forested wetlands also were impacted by silviculture as 14 acres were harvested and changed to palustrine emergent and shrub types. Nearly 26 acres of palustrine scrub-shrub wetlands were lost, mostly to residential development. About 10 acres of palustrine emergent wetlands were converted to upland (7.9 acres) or open water (ponds; 2.4 acres). In addition to the palustrine vegetated wetland losses, 2.0 acres of palustrine farmed wetland were converted to residential development.

Only 9.2 acres of new palustrine vegetated wetlands became established in former uplands or ponds from 1981/2 to 1992. All but 0.9 acres of this gain came from the establishment of palustrine emergent wetlands in shallow ponds (mostly new ponds built during the study period). In addition, a 1.7-acre palustrine emergent wetland was created by excavation in a palustrine forested wetland.

Estuarine wetlands were not significantly impacted by development during the study decade. Only 0.7 acres of estuarine emergent wetland were converted to industrial development and 0.5 acres of estuarine nonvegetated wetland became impounded estuarine deepwater habitat.

Wetland Type Changes Induced by Timber Harvest

Only 14.0 acres of palustrine forested wetlands were harvested for timber. This resulted in a 1.4-acre gain in palustrine emergent wetland and a 12.6-acre gain in palustrine scrub-shrub wetland. These types however are successional stages of forested wetlands in various states of recovery after timber harvest and are best separated from the more persistent or relatively stable types of emergent and shrub wetlands.

Changes in Nonvegetated Wetlands (Ponds)

Pond acreage also declined in the Northern Piedmont drainage area. This was the only drainage area in the state to experience a net loss in ponds: a net loss of about 116 acres of ponds was recorded (Table 5). Despite the construction of nearly 66 acres of new ponds, nearly 182 acres of pre-existing ponds were destroyed, producing a net loss of acreage during the 1980s. Most (93%) of the gains came from upland sites. Most of the losses were due to filled land that was in a transitional state (its intended use could not be determined), although it is likely to be residential or industrial development.

Deepwater Habitat Changes

The only change in deepwater habitat detected in the Northern Piedmont Drainage during the study period was a 0.5-acre increase in estuarine deepwater habitat. This gain came from impoundment of a tidal flat.

Table 3. Changes in palustrine vegetated wetlands (PVeg) in the Northern Piedmont Drainage: 1981/2-1992.

Wetland Change	Cause	Acreage Affected
Gain in PVeg	Cropland	3.8
	Rangeland	2.0
	Pond Colonization	2.0
	Pasture	1.0
	Idle Fields	0.3
	Upland Forest	0.1
	(Subtotal)	(+9.2)
Loss of PVeg	Residential Development	103.3
	Industrial Development	26.4
	Pond Construction	4.6
	Highway/Road Construction	4.5
	Herbaceous Rangeland	3.9
	Commercial Development	1.6
	Idle Fields	0.8
	Transp/Communications	0.7
	Upland Forest (drained PFO)	0.5
	Shrubby Rangeland	0.4
	Transitional Land (in development)	0.3
	(Subtotal)	(-147.0)
PVeg Type Change	Timber Harvest	14.0
	PFO to PEM1Fx (excavated)	1.7
	(Subtotal)	(15.7)
*Net PVeg Change**	=	*-137.8 (loss)*

*Excluding PVeg wetland acreage changing from one PVeg type to another.

Table 4. Gains and losses of estuarine and palustrine vegetated wetlands by type for the Northern Piedmont Drainage: 1981/2-1992. Note: Changes in wetland type as a result of timber harvest are not included as these wetlands represent forested wetlands in succession. (E2EM = estuarine emergent; PEM = palustrine emergent; PFO1 = palustrine forested; PSS = palustrine scrub-shrub).

Wetland Type	Wetland Change	Cause	Acres
E2EM	Loss	Industrial Dev.	0.7
	Net Change	=	-0.7 (loss)
PEM	Gain	Cropland	3.8
		Pond Colonization	2.0
		Forested Wetland (excavated)	1.7
		Rangeland	1.1
		Pasture	1.0
		Idle Fields	0.3
		Upland Forest	0.1
		(Subtotal)	(+10.0)
	Loss	Herb. Rangeland	3.9
		Pond	2.4
		Residential Dev.	2.3
		Highway/Road	0.7
		Industrial Dev.	0.7
		Commercial Dev.	0.3
		(Subtotal)	(-10.3)
	Net Change	=	-0.3 (loss)
PFO-Deciduous	Loss	Residential Dev.	86.3
		Industrial Dev.	20.6
		Emergent Wetland	1.7
		Commercial Dev.	1.3
		Highway/Road	1.1
		Upland Forest	0.5
		Shrub Rangeland	0.4
		Transitional Land	0.3
		(Subtotal)	(-112.2)
	Net Change	=	-112.2 (loss)

PSS-Deciduous	Gain	Rangeland	0.9
		(Subtotal)	(+0.9)
	Loss	Residential Dev.	14.7
		Industrial Dev.	5.1
		Highway/Road	2.7
		Pond Construction	2.2
		Idle Fields	0.8
		Transp./Commun.	0.7
		(Subtotal)	(-26.2)
	Net Change	=	-25.3 (loss)

Table 5. Changes in ponds in the Northern Piedmont Drainage: 1981/2-1992. Note: These figures do not include acreage of ponds that are vegetated with persistent vegetation; such ponds are considered a type of palustrine vegetated wetland (e.g., emergent wetland).

Nature of Change	Cause	Acreage
Pond Gain from	Rangeland	21.8
	Upland Forest	11.0
	Transitional Land	6.7
	Idle Fields	5.7
	Industrial Land	4.6
	Cropland	4.1
	Recreational Land	3.7
	PEM Wetland	2.4
	PSS1 Wetland	2.2
	Pasture	1.9
	Sand/Gravel Pit	0.7
	Commercial Land	0.5
	Residential Land	0.3
	(Subtotal)	(+65.6)
Pond Loss to	Transitional Land	150.0
	Sand/Gravel Pits	12.9
	Highway/Road	5.4
	Industrial Development	4.4
	Residential Development	3.3
	PEM Wetland	2.0
	Rangeland	1.6
	Commercial Development	1.2
	Upland Forest	0.9
	(Subtotal)	(-181.7)
Net Change	=	*-116.1 (loss)*

Delaware Bay Drainage

The Delaware Bay Drainage is the largest of the four major drainages in Delaware. It occupies 41 percent of the state and totals approximately 814 square miles. It includes a considerable mixture of urban/suburban areas, forests, and agricultural land. The drainage is practically bisected by Highways 13 and 113, along which major population centers have established. Among the larger cities and towns are Dover, New Castle, Odessa, Smyrna, and Milford.

Estimated Conversion of Vegetated Wetlands

From 1981/2 to 1992, there was an estimated net loss of both estuarine and palustrine vegetated wetlands (78.4 acres and 679.2 acres, respectively). The latter experienced the greatest losses, with about 743 acres converted mostly to nonwetlands. Projected estuarine losses totaled almost 80 acres.

Residential development took the biggest toll on palustrine vegetated wetlands, accounting for about 35 percent of the losses (Table 6). Agriculture-related activities were the next leading cause of wetland loss, responsible for 28 percent. Highway and road construction followed, comprising 10 percent of these losses. Palustrine forested wetlands received the heaviest impacts, losing about 439 acres which represented 59 percent of the palustrine vegetated wetland loss (Table 7). Palustrine scrub-shrub wetlands were next, accounting for 27 percent of the losses or nearly 202 acres. About 14 percent of the losses affected palustrine emergent wetlands. For this type, conversion to cropland was the leading cause of loss.

Some new palustrine vegetated wetlands became established during the study decade. A 60-acre gain in palustrine emergent wetlands was detected (Table 7). These marshes either developed in existing ponds (32.8 acres) or were constructed on farmland (e.g., cropland, pasture, or farmed wetland; 22.2 acres). The latter increase may have been associated with new pond or impoundment construction or, possibly, wetland restoration on formerly drained hydric soils and farmed wetlands, or simply, the recolonization of previously cultivated hydric soils. The only other new palustrine vegetated wetland was a 2.9-acre palustrine scrub-shrub/emergent wetland that developed along the shore of a lacustrine waterbody.

Estuarine vegetated wetlands also experienced net losses (78.4 acres). An estimated total of 79.5 acres of these marshes was eliminated, while only 1.1 acres were established. The causes of this loss were the following: 1) 36.8 acres converted to estuarine open water (impoundment and dredged channels), 2) 37.4 acres filled for various purposes, 3) 4.2 acres converted to freshwater ponds, and 4) 1.1 acres converted to palustrine emergent wetland. The proposed use of most of the filled marsh could not be determined and was designated as transitional land where the land was disturbed and as rangeland where open fields and shrub thickets occupied the fill. An estimated 5.5 acres were filled for highways and roads.

Wetland Type Changes Induced by Timber Harvest

Palustrine vegetated wetlands also experienced changes in type, affecting almost 250 acres (Table 6). Nearly all of this change was due to silvicultural activities as only 3.5 acres of palustrine forested wetlands changed to palustrine emergent wetland due to excavation. An estimated total of 123 acres of forested wetlands were harvested, thereby changing to successional stages (i.e., emergent and/or scrub-shrub types). Nearly 120 acres of these successional types (from a pre-1980 harvest) changed to either shrub or forested wetlands as these former forested wetlands began to move on the successional pathway to return to forest cover. An estimated 92.7 acres of these successional-stage emergent wetlands changed to woody wetlands (87.1 acres to shrub wetlands and 5.6 acres to forested wetlands), while 27.2 acres of successional-stage shrub wetlands became forested wetlands from 1981/2 to 1992.

Estimated Changes in Farmed Wetlands

Palustrine farmed wetlands experienced a net loss of 25.5 acres. An estimated total of 27.7 acres were converted to uplands, ponds, or emergent wetlands. Only 2.2 acres of new farmed wetlands were gained, all from former pasture. Fifty-three percent of the losses was due to pond construction. An estimated 7.8 acres were filled for farm buildings, accounting for 28 percent of the losses. Other losses of farmed wetlands were: 1) 2.6 acres to palustrine emergent wetland, 2) 2.3 acres to residential development, and 3) 0.3 acres to transitional land (unknown use).

Estimated Changes in Nonvegetated Wetlands

In the Delaware Bay Drainage, two major types of nonvegetated wetlands occur: palustrine types (essentially ponds) and estuarine types (mostly intertidal flats or unconsolidated shore). The former experienced a net increase of almost 215 acres, while the latter wetlands had a net loss of over 200 acres.

An estimated total of 303 acres of ponds were built, yet 88 acres of pre-existing ponds were converted to upland or vegetated wetlands (Table 8). Of the pond acreage created, 36 percent came from cropland, while about 26 percent came from wetlands, mostly palustrine vegetated types. Of the lost pond acreage, about half was filled for various types of upland development. Nearly 37 percent of the lost pond acreage became palustrine emergent wetlands due to sedimentation and subsequent colonization by nonwoody plants.

Estuarine nonvegetated wetlands suffered substantial losses. Over 200 acres of tidal flats were lost. Construction of a dredged material disposal site at the mouth of the Christina River eliminated 199.1 acres from 1981/2 to 1992 (10.5 acres represent the dikes and 188.6 acres contain the dredged material). Another 2.7 acres of tidal flats became estuarine deepwater habitat at the mouth of the Mispillion River apparently due to natural erosional forces.

Estimated Deepwater Habitat Changes

Deepwater habitat changes were mostly gains in estuarine and lacustrine waters (estimated 55.4 and 80.8 acres, respectively). Riverine deepwater habitat experienced only a small loss of 0.7 acres which were impounded to create a pond.

The projected increase in estuarine waters was attributed to the following: 1) 36.8 acres from estuarine vegetated wetlands (due mostly to impoundments), 2) 5.9 acres from palustrine tidal forested wetland, 3) 7.0 acres from agricultural land, 4) 2.6 acres from transitional land, and 5) 0.4 acres from rangeland.

The estimated gain in lacustrine deepwater habitat acreage came mostly from rangeland (71% or 57.1 acres). Conversion of cropland to deepwater habitat was the second-leading cause of lacustrine water gain, accounting for 23 percent (18.7 acres). The rest came from ponds (3.8 acres) and transitional land (1.2 acres).

Table 6. Estimated changes in palustrine vegetated wetlands (PVeg) in the Delaware Bay Drainage: 1981/2-1992.

Wetland Change	Cause	Acreage Affected
PVeg Gain from	Pond Colonization	32.8
	Cropland	13.8
	Pasture	5.8
	Rangeland	3.5
	Lacustrine Deepwater	2.9
	Farmed Wetland	2.6
	Upland Forest	1.5
	Estuarine Wetland	1.1
	Transitional Land	0.2
	(Subtotal)	(+64.2)
PVeg Loss to	Residential Development	256.9
	Agriculture-related*	211.4
	Highway/Road	122.0
	Pond Construction	59.6
	Rangeland	35.1
	Airport	27.5
	Transitional Land	10.2
	Industrial Development	8.9
	Estuarine Deepwater (impoundmt)	5.9
	Upland Forest (drained)	4.4
	Estuarine Wetland[3]	1.1
	Commercial Development	0.4
	(Subtotal)	(-743.4)
PVeg Type Change	Timber Harvest	122.9
	Succession following Harvest	119.9
	PFO to PEM (excavated)	3.5
	(Subtotal)	(246.3)
*Net PVeg Change***	=	*-679.2 (loss)*

*Does not include pond construction on farms.
**Excludes PVeg acreage changing from one PVeg type to another.

[3]Excavation work around a palustrine forested wetland peninsula (surrounded by large E2EM wetland complex) and subsequent timber harvest apparently led to establishment of a 1.1-acre E2EM wetland based on interpretation of the 1992 photos. Site inaccessible.

Table 7. Estimated gains and losses in estuarine and palustrine vegetated wetlands by type for the Delaware Bay Drainage: 1981/2-1992. Note: Changes in wetland type as a result of timber harvest are not included as these wetlands represent forested wetlands in succession. (EVeg = mostly estuarine emergent; PEM = palustrine emergent; PFO = palustrine forested wetland; PSS = palustrine scrub-shrub).

Wetland Type	Wetland Change	Cause	Acres
EVeg	Gain	PFO Wetland	1.1
		(Subtotal)	(+1.1)
	Loss	Estuarine Deepwater (excav./impounded)	36.8
		Transitional Land	17.4
		Rangeland	14.5
		Highway/Road	5.5
		Pond Construction	4.2
		PEM Wetland	1.1
		(Subtotal)	(-79.5)
	Net Change	=	-78.4 (loss)
PEM	Gain	Pond Colonization	32.8
		Cropland	13.8
		Pasture	5.8
		Rangeland	3.5
		PFO Wetland (excavated)	3.5
		Farmed Wetland	2.6
		Upland Forest	1.5
		Estuarine Wetland	1.1
		Transitional Land	0.2
		(Subtotal)	(+64.8)
	Loss	Cropland	42.5
		Rangeland	23.5
		Pond Construction	16.0
		Transitional Land	9.5
		Residential Dev.	5.8
		Industrial Dev.	3.8
		Agriculture-Other	0.2
		(Subtotal)	(-101.3)
	Net Change	=	-36.5 (loss)

PFO-Deciduous	Loss	Residential Dev.	128.7
		Highway/Road	115.0
		Farmed Wetland	57.4
		Pond Construction	37.8
		Farm Buildings	13.7
		Rangeland	11.6
		Estuarine Water	5.9
		Cropland	5.1
		Agriculture-Other	4.4
		PEM Wetland	3.5
		Industrial Dev.	3.2
		Airport	2.6
		Estuarine Wetland	1.1
		Transitional Land	0.7
		Commercial Dev.	0.4
		(Subtotal)	(-391.1)
	Net Change	=	-391.1 (loss)
PFO-Evergreen	Loss	Cropland	48.8
		Farmed Wetland	2.5
		Highway/Road	1.4
		(Subtotal)	(-52.7)
	Net Change	=	-52.7 (loss)
PSS-Deciduous	Gain	Lacustrine Water	2.9
		(Subtotal)	(+2.9)
	Loss	Residential Dev.	122.4
		Farmed Wetland	30.7
		Airport	24.9
		Agriculture-Other	6.1
		Highway/Road	5.6
		Pond Construction	5.4
		Upland Forest	4.4
		Industrial Dev.	1.9
		(Subtotal)	(-201.4)
	Net Change	=	-198.5 (loss)
PSS-Evergreen	Loss	Pond Construction	0.4
	Net Change	=	-0.4 (loss)

Table 8. Estimated changes in ponds in the Delaware Bay Drainage: 1981/2-1992. Note: These figures do not include acreage of ponds that are vegetated with persistent vegetation; such ponds are considered a type of palustrine vegetated wetland (e.g., emergent wetland).

Nature of Change	Cause	Acreage
Pond Gain from	Cropland	107.6
	PFO Wetland	37.8
	Pasture	29.3
	Transitional Land	28.9
	Upland Forest	22.8
	PEM Wetland	16.0
	Rangeland	15.2
	Farmed Wetland	14.7
	Idle Fields	11.1
	Agriculture-Other	6.3
	PSS Wetland	5.8
	Estuarine Wetland	4.2
	Industrial Development	1.2
	Sand/Gravel Pits	1.1
	Riverine Deepwater	0.7
	Residential Development.	0.1
	(Subtotal)	(+302.8)
Pond Loss to	PEM Wetland	32.8
	Transitional Land	25.5
	Rangeland	12.0
	Airport	6.8
	Lacustrine Deepwater	3.8
	Sand/Gravel Pits	3.3
	Farmed Wetland	3.2
	Residential Development	0.5
	(Subtotal)	(-87.9)
Net Change	=	*+214.9 (gain)*

Chesapeake Bay Drainage

The Chesapeake Bay Drainage is located in the western part of Delaware and includes the Nanticoke River watershed draining southwesterly into the Bay. It encompasses about 648 square miles, representing 32 percent of Delaware's land surface area. The area occupies a portion of the Coastal Plain where wetlands are quite abundant. In addition to floodplain wetlands along various rivers and tributary streams, this region contains a high number of very small depressional wetlands commonly called "Delmarva bays" or simply "potholes." These wetlands are especially abundant in the northern section of the watershed near the Maryland state line. The basin is essentially rural with Seaford, Laurel, and Greenwood being among the larger communities.

Estimated Conversion of Vegetated Wetlands

From 1981/2 to 1992, there was a projected net loss of over 700 acres of palustrine vegetated wetlands (Table 9). About 722 acres were converted to nonwetlands or open water. Roughly 84 percent (or 608.7 acres) of these losses were due to agriculture. Only 10 acres of new palustrine vegetated wetlands became established between 1981/2-1992.

Most of the palustrine vegetated wetland losses involved forested wetlands (Table 10). An estimated 701 acres were destroyed during the study decade. Seventy-seven percent (or 540.8 acres) of these losses affected deciduous forested wetlands. Nearly 400 acres of these deciduous wetlands were converted to farmed wetland, while other agricultural activities accounted for an additional 49.2 acres of palustrine forested wetland losses. In total, agricultural operations were responsible for 82 percent of the losses of this wetland type. Palustrine evergreen forested wetlands were similarly affected by agriculture. Ninety percent (or 144.7 acres) of their losses was attributed to conversion to farmed wetland alone, with agriculture operations being responsible for nearly all of the losses of this type of forested wetland.

The Chesapeake Bay Drainage also had small net losses of other vegetated wetlands. A 1.0-acre loss was projected for emergent wetlands and 10.8-acre loss for deciduous scrub-shrub wetlands (Table 10).

Wetland Type Changes Induced by Timber Harvest

Forestry practices had a significant impact on wetlands in the Chesapeake Bay Drainage, affecting an estimated total of 2721 acres. Nearly 60 percent of this acreage (or 1573.2 acres) represented forested wetlands harvested between 1981/2 and 1992. Upon cutting, these wetlands became successional-stage wetlands: 1088.8 acres of palustrine emergent wetlands and 484.4 acres of scrub-shrub wetlands. The former types likely resulted from timber harvest in the late 1980s and early 1990s, while the latter types probably signify earlier harvests in the 1980s. Other former forested wetlands logged prior to the 1980s were also moving along the successional pathway with 520 acres returning to forested wetlands by

1992. In total, an estimated 1150 acres of successional-stage wetlands (pre-1980 forested wetlands) changed vegetation type during the study decade: 1) 627.8 acres of emergent wetlands became shrub wetlands, 2) 271.6 acres of emergent wetlands became forested wetlands, and 3) 248.4 acres of shrub wetlands became forested wetlands.

Estimated Changes in Farmed Wetlands

Palustrine farmed wetlands also experienced the following changes during the study decade: 1) 6.6 acres were converted to ponds, 2) 13.1 acres were converted to upland (8.3 acres impacted by agriculture and 4.8 acres by industrial development), 3) 0.6 acres were recolonized by emergent wetland vegetation , and 4) 28.8 acres were established in cropland and pasture. This amounted to an estimated net gain of 8.5 acres in palustrine farmed wetlands.

Estimated Changes in Nonvegetated Wetlands

During the study decade, there was an projected net gain of 212.4 acres in palustrine nonvegetated wetlands (ponds) (Table 11). About 63 percent (or 134.3 acres) of this gain came from agricultural lands (e.g., cropland, pasture, farmed wetland, and idle fields). Another 27 percent came from excavations in transitional land and upland forest. About 8 percent (or 17.0 acres) of the new ponds came from palustrine vegetated wetlands. An estimated 0.5 acres of pre-existing ponds were lost during the 1980s.

Estimated Deepwater Habitat Changes

In the Chesapeake Bay Drainage, both lacustrine and riverine deepwater habitats experienced gains. The former increased by 59.6 acres (projected), resulting from excavation in idle fields, whereas the latter increased by 14.9 acres (projected) through excavation (channelization) of palustrine forested wetlands.

Table 9. Estimated changes in palustrine vegetated wetlands (PVeg) in the Chesapeake Bay Drainage: 1981/2-1992.

Wetland Change	Cause	Acreage Affected
Gain in PVeg	Pasture	2.7
	Cropland	2.6
	Rangeland	1.6
	Sand/Gravel Pits	1.3
	Upland Forest	0.7
	Idle Fields	0.6
	Farmed Wetland	0.6
	(Subtotal)	(+10.1)
Loss in PVeg	Agriculture-related*	608.7
	Herbaceous Rangeland	32.5
	Transitional Land	20.5
	Pond Construction	16.4
	Riverine Deepwater Habitat	14.9
	Industrial Development	12.4
	Residential Development	9.3
	Commercial Development	5.6
	Highway/Road	2.0
	(Subtotal)	(-722.3)
PVeg Type Change	Timber Harvest	1573.2
	Succession following Harvest	1147.8
	PFO to PEM (excavated)	1.4
	(Subtotal)	(2722.4)
*Net PVeg Change*** =		*-712.2 (loss)*

*Does not include pond construction on farms.
**Excludes PVeg acreage changing from one PVeg type to another.

Table 10. Estimated gains and losses in palustrine vegetated wetlands by type for the Chesapeake Bay Drainage: 1981/2-1992. Note: Changes in wetland type as a result of timber harvest are not included as these wetlands represent forested wetlands in succession. (PEM = palustrine emergent; PFO = forested; PSS = scrub-shrub).

Wetland Type	Wetland Change	Cause	Acres
PEM	Gain	Cropland	2.0
		Rangeland	1.6
		Sand/Gravel Pits	1.3
		Upland Forest	0.7
		Forested Wetland (excavated)	0.6
		Farmed Wetland	0.6
		Idle Fields	0.6
		Pasture	0.4
		(Subtotal)	(+7.8)
	Loss	Pond Construction	5.0
		Agriculture-Other	2.6
		Farmed Wetland	0.7
		Residential Dev.	0.5
		(Subtotal)	(-8.8)
	Net Change	=	-1.0 (loss)
PFO-Deciduous	Gain	Cropland	0.6
		(Subtotal)	(+0.6)
	Loss	Farmed Wetland	395.5
		Rangeland	23.5
		Transitional Land	18.2
		Feedlot	15.7
		Cropland	15.0
		Riverine Deepwater	14.9
		Industrial Dev.	12.4
		Farm Buildings	12.4
		Pond Construction	10.1
		Residential Dev.	8.8
		Commercial Dev.	5.6
		Agriculture-Other	5.2

PFO-Deciduous (continued)		Highway/Road	2.0
		Idle Fields	0.9
		Emergent Wetland	0.6
		(Subtotal)	(-540.8)
	Net Change	=	-540.8 (loss)
PFO-Evergreen	Loss	Farmed Wetland	144.7
		Cropland	10.7
		Feedlot	4.1
		Pond Construction	0.7
		(Subtotal)	(-160.2)
	Net Change	=	-160.2 (loss)
PSS-Deciduous	Gain	Pasture	2.3
		(Subtotal)	(+2.3)
	Loss	Rangeland	9.0
		Transitional Land	2.3
		Farmed Wetland	1.2
		Pond Construction	0.6
		(Subtotal)	(-13.1)
	Net Change	=	-10.8 (loss)

Table 11. Estimated changes in ponds in the Chesapeake Bay Drainage: 1981/2-1992. Note: These figures do not include acreage of ponds that are vegetated with persistent vegetation; such ponds are considered a type of palustrine vegetated wetland (e.g., emergent wetland).

Nature of Change	Cause	Acreage
Pond Gain from	Cropland	84.8
	Transitional Land	30.9
	Upland Forest	25.6
	Pasture	19.0
	Farmed Wetland	15.7
	PFO Wetland	10.8
	Agriculture-Other	8.1
	Idle Fields	6.7
	PEM Wetland	5.0
	Rangeland	4.1
	PSS Wetland	0.6
	Sand/Gravel Pit	0.6
	Commercial Land	0.3
	Residential Land	0.2
	(Subtotal)	(+212.4)
Pond Loss to	Farmed Wetland	0.3
	Industrial Development	0.2
	(Subtotal)	(-0.5)
Net Change	=	*+211.9 (gain)*

Inland Bays Drainage

The Inland Bays Drainage encompasses approximately 361 square miles in the southeastern part of the state. It represents about 18 percent of Delaware's land surface area. The drainage basin contains both palustrine and estuarine wetland types. The predominant influence of the estuarine system is witnessed by the name of the drainage basin. Three coastal bays dominate the eastern portion of the basin: Indian River Bay, Rehoboth Bay, and Little Assawoman Bay. The region has a mixture of urban/suburban/resort development along the coast, with forests and agricultural lands inland.

Conversion of Vegetated Wetlands

During the 1980s and early 1990s, the Inland Bays Drainage endured net losses of both palustrine and estuarine vegetated wetlands. Most of the losses involved palustrine types, especially forested wetlands.

Overall, there was a net loss of 271.3 acres of palustrine vegetated wetlands (277.4 acres lost versus 6.1 acres gained) (Table 12). Forty-eight percent of the losses were attributed to agricultural operations. Residential development was responsible for about 24 percent of the losses. Pond construction was the third-ranked cause of palustrine vegetated wetland loss, accounting for 20 percent of these lost wetlands.

Forested wetlands were most adversely affected (Table 13). A total of 254.3 acres of forested wetlands were lost during the 1980s. This figure represents over 90 percent of the palustrine vegetated wetland losses. Deciduous forested wetlands received the bulk of the negative impacts, with 178.4 acres converted to mostly to nonwetlands. Agricultural operations alone was the leading cause of deciduous forested wetland loss (68.2 acres), being responsible for 38 percent of the total losses. Residential development was a close second, accounting for 33 percent of the deciduous forested wetland losses. Pond construction was also a significant factor, causing 26 percent of the losses. Farming activities also were the major cause of loss of evergreen forested wetlands, with 56.7 acres converted to farmed wetland. This conversion alone accounted for 75 percent of the losses of this wetland type.

Small net losses of scrub-shrub wetlands were detected. About 14 acres of these wetlands were converted to nonwetlands or ponds.

Palustrine emergent wetlands experienced a net gain of 0.8 acres (Table 13). This was the only vegetated wetland type to increase.[4] A total of 9.6 acres of these emergent wetlands

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[4]Excluding effects of timber harvest that caused temporary changes in plant composition. Recall that cutting of forested wetlands causes an increase in both palustrine emergent and scrub-shrub wetlands -- successional stages of forested wetlands rather than typical emergent or shrub wetlands.

were created, whereas 8.8 acres were converted.

Wetland losses were also detected in two estuarine wetland types: emergent wetlands (salt and brackish marshes) and forested wetlands. The latter type represents former freshwater wetlands that are now periodically inundated by tidal salt water. About 20 acres of estuarine emergent wetlands were destroyed (Table 13). Fifty-seven percent of the acreage was either excavated (8.1 acres) or impounded (3.1 acres). Residential development was responsible for 27 percent of these losses. During the 1980s, a total of 5.7 acres of estuarine forested wetlands became intertidal flats, presumably due to a combination of sea level rise and coastal plain subsidence.

Wetland Type Changes Induced by Timber Harvest

During the study decade, 484.2 acres of wetlands were impacted by forestry operations. Recently harvested forested wetlands totaled 325.3 acres. After timber cutting, this acreage became other wetland types (successional stages of forested wetlands). A total of 152.8 acres became successional emergent wetlands and 172.5 acres became successional scrub-shrub wetlands by 1992. These wetlands will likely return to forested wetlands in the next two decades.

Nearly 160 other wetland acres (158.9 acres) were affected by pre-1980 timber harvests. These wetlands represent former forested wetlands on the post-harvest successional trajectory to become forested wetlands. A total of 120 acres reverted to forested wetlands during the 1980s: 92.3 acres from successional-stage shrub wetlands and 27.7 acres from successional-stage emergent wetlands. Nearly 40 acres (38.9 acres) of successional palustrine emergent wetlands became scrub-shrub wetlands by 1992.

Changes in Farmed Wetlands

In the Inland Bays Drainage, palustrine farmed wetlands experienced a net gain of 37.2 acres. This was the result of an increase of 62 acres coming from palustrine wetlands combined with a loss of 24.8 acres. Most of this gain was at the expense of forested wetlands (18.0 acres from PFO1 and 43.8 acres from PFO4) as only 0.2 acres came from palustrine emergent wetlands . The losses were due to residential development (11.2 acres), pond construction (7.4 acres), feedlot construction (4.0 acres), farm buildings (2.0 acres), and palustrine emergent wetland (0.2 acres).

Changes in Nonvegetated Wetlands

During the study decade, there was an estimated net gain of nearly 300 acres in palustrine nonvegetated wetlands (ponds) (Table 14). Nearly 40 percent of the gain was from agricultural lands, with 23 percent alone coming from cropland (excluding farmed wetland). Nineteen percent of the gains came from palustrine vegetated wetlands. Only 10 acres of pre-existing ponds were filled.

Deepwater Habitat Changes

During the study decade, estuarine deepwater habitats experienced a net gain of 7.6 acres. This resulted from excavation of a mixed upland forest to create 7.6 acres of open water for a marina in Black Water Beach at the mouth of the Indian River.

Table 12. Changes in palustrine vegetated wetlands (PVeg) in the Inland Bays Drainage: 1981/2-1992. Note: The only increase in Pveg wetlands was in the PEM category, while all types experienced losses.

Wetland Change	Cause	Acreage Affected
PVeg Gain from	Rangeland	3.5
	Upland Forest	2.3
	Farmed Wetland	0.2
	Cropland	0.1
	(Subtotal)	(+6.1)
PVeg Loss to	Agriculture-related*	133.3
	Residential Development	66.2
	Pond Construction	54.5
	Rangeland	16.2
	Commercial Development	3.4
	Industrial Development	2.1
	Transitional Land	1.7
	(Subtotal)	(-277.4)
PVeg Type Change	Timber Harvest	325.3
	Succession following Harvest	158.9
	PFO to PEM (excavated)	3.5
	(Subtotal)	(487.7)
*Net PVeg Change***	=	*-271.3 (loss)*

**Does not include pond construction on farms.

**Excludes PVeg acreage changing from one PVeg type to another.

Table 13. Gains and losses in estuarine and palustrine vegetated wetlands by type for the Inland Bays Drainage: 1981/2 - 1992. Note: Changes in wetland type as a result of timber harvest are not included as these wetlands represent forested wetlands in succession. (E2EM = estuarine emergent; E2FO = estuarine forested; PEM = palustrine emergent; PFO = palustrine forested wetland; PSS = palustrine scrub-shrub).

Wetland Type	Wetland Change	Cause	Acres
E2EM	Loss	Estuarine Deepwater (excavated)	8.1
		Residential Dev.	5.3
		Pond (impoundment)	3.1
		Commercial Dev.	2.1
		Transitional Land	0.8
		Industrial Dev.	0.2
		(Subtotal)	(-19.6)
	Net Change	=	-19.6 (loss)
E2FO	Loss	Tidal Flat	5.7
	Net Change	=	-5.7 (loss)
PEM	Gain	Rangeland	3.5
		Forested Wetland (excavated)	3.5
		Upland Forest	2.3
		Farmed Wetland	0.2
		Cropland	0.1
		(Subtotal)	(+9.6)
	Loss	Farmed Wetland	6.1
		Pond Construction	1.1
		Cropland	0.9
		Residential Dev.	0.4
		Transitional Land	0.3
		(Subtotal)	(-8.8)
	Net Change	=	+0.8 (gain)

PFO-Deciduous	Loss	Residential Dev.	59.2
		Pond Construction	45.5
		Cropland	25.3
		Farmed Wetland	18.0
		Agriculture-Other	14.3
		Feedlot	5.9
		Farm Buildings	4.0
		PEM Wetland (excavated)	3.5
		Industrial Dev.	2.1
		Rangeland	2.0
		Commercial Dev.	0.9
		Pasture	0.7
		Transitional Land	0.5
		(Subtotal)	(-181.9)
	Net Change	=	-181.9 (loss)
PFO-Evergreen	Loss	Farmed Wetland	56.7
		Rangeland	14.2
		Residential Dev.	4.3
		Pond Construction	0.7
		(Subtotal)	(-75.9)
	Net Change	=	-75.9 (loss)
PSS-Deciduous	Loss	Pond Construction	6.6
		Commercial Dev.	2.5
		Residential Dev.	1.6
		Feedlot	1.4
		(Subtotal)	(-12.1)
	Net Change	=	-12.1 (loss)
PSS-Evergreen	Loss	Transitional Land	0.9
		Residential Dev.	0.7
		Pond Construction	0.6
		(Subtotal)	(-2.2)
	Net Change	=	-2.2 (loss)

Table 14. Changes in ponds in the Inland Bays Drainage: 1981/2-1992. <u>Note</u>: These figures do not include acreage of ponds that are vegetated with persistent vegetation; such ponds are considered a type of palustrine vegetated wetland (e.g., emergent wetland).

Nature of Change	Cause	Acreage
Pond Gain from	Cropland	71.9
	Upland Forest	70.2
	PFO Wetland	46.2
	Pasture	29.3
	Transitional Land	28.8
	Rangeland	19.8
	Idle Fields	10.4
	Sand/Gravel Pits	10.2
	Farmed Wetland	7.4
	PSS Wetland	7.2
	Estuarine Wetland	3.1
	Agriculture-Other	3.0
	PEM Wetland	1.1
	Residential Dev.	0.3
	(Subtotal)	(+308.9)
Pond Loss to	Transitional Land	5.0
	Rangeland	3.5
	Industrial Dev.	1.3
	Residential Dev.	0.4
	(Subtotal)	(-10.2)
Net Change	=	*+298.7 (gain)*

Discussion

Comparison Between Drainage Basins

Changes in Palustrine Wetlands

All drainage basins experienced net losses of vegetated wetlands and net gains in nonvegetated wetlands (ponds) with the exception of the Northern Piedmont drainage area (Table 15). This region had a net loss of ponds as well as losses of various vegetated wetland types.

Forested wetlands were most affected by wetland conversion as well as by forestry. Forty-six percent of the net losses of forested wetlands (i.e., conversion to nonwetlands, open water, and estuarine wetlands) occurred in the Chesapeake Bay Drainage. Timber harvest of these wetlands was also heaviest in this drainage basin -- 77 percent of the harvested wetlands were located in this region.

Agricultural operations were responsible for about half of the conversions of palustrine vegetated wetlands (excluding timber harvest). These activities had the biggest adverse impact in the Chesapeake Bay and Delaware Bay Drainages (estimated totals of 608.7 acres and 211.4 acres of lost wetlands, respectively). Residential development accounted for 23 percent of the statewide losses of palustrine vegetated wetlands. These losses were heaviest in the Delaware Bay and Northern Piedmont Drainages (256.9 acres and 103.3 acres, respectively). Conversion of palustrine vegetated wetlands to ponds was most common in the Delaware Bay and Inland Bays drainage basins (59.6 acres and 54.5 acres, respectively). Highway and road construction produced the greatest losses in the Delaware Bay Drainage where 122 acres were eliminated.

Some vegetated wetland gains were detected, although the magnitude of wetland losses resulted in overall net losses of these types. The largest gains in palustrine vegetated wetlands occurred in the Delaware Bay Drainage. About 72 percent of the newly established palustrine vegetated wetlands (or 64.2 acres) were found in this drainage basin. Ninety-nine percent of the new wetlands were palustrine emergent wetlands. About 40 percent of these newly established vegetated wetlands was attributed to colonization of shallow ponds by emergent wetland vegetation.

All drainage basins except the Northern Piedmont Drainage had net gains in palustrine nonvegetated wetlands - ponds (Table 15). The latter region had a net loss of 116.1 acres. The largest increase in ponds was in the Inland Bays Drainage with an estimated net gain of 298.7 acres. It had over 80 acres of new ponds than the next ranked region. Pond creation was nearly equal in both the Delaware Bay and Chesapeake Bay Drainages. Each of this areas experienced a net increase of between 210-215 acres of ponds.

Changes in Estuarine Wetlands

The Delaware Bay Drainage had about 91 percent of the losses of this wetland type (Table 15). The Inland Bays Drainage had nearly all of the remaining losses. Most of the losses were to impoundments and dredging operations. The largest estuarine wetland loss involved an intertidal flat that was filled for holding dredged material at the mouth of the Christina River. See individual drainage area summaries for specifics.

Table 15. Comparison of wetland trends between Delaware's four major drainage basins.

	Net Acreage Change in Vegetated Wetlands				Net Acreage Change in Nonvegetated Wetlands	
Drainage Basin	EVeg	PEM	PSS	PFO	ENonVeg	PNonVeg
Northern Piedmont	-0.7	-0.3	-25.3	-112.2	-0.5	-116.1
Delaware Bay	-78.4	-36.5	-198.9	-443.8	-201.8	+214.9
Chesapeake Bay	NA	-1.0	-10.8	-700.4	NA	+211.9
Inland Bays	-25.3	+0.8	-14.3	-257.8	0	+298.7
State Totals	-104.4	-37.0	-249.3	-1514.2	-202.3	+609.4

Comparison with Past Studies

In 1986, the U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency jointly published a report on wetland trends in the Mid-Atlantic states (Tiner and Finn 1986). The study was an intensification of the national wetland trends analysis study for five states: Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. The study utilized statistical sampling of randomly selected 4-square mile plots to generate statistics on the wetland status and trends from the mid-1950s to the late-1970s/early-1980s. The results for Delaware will be compared with those from the current study to learn how wetland trends have changed over the last 40 years. Copies of the Tiner and Finn report can be obtained by contacting the U.S. Fish and Wildlife Service's Northeast Regional Office (see title page for address). The following discussion will use the mean estimates presented in the Tiner and Finn report and will not designate standard errors.

The wetland results for Delaware from Tiner and Finn are summarized for each major wetland type in Table 16. Over the 26-year study period, net losses of almost 38,000 acres of palustrine vegetated wetlands and nearly 3900 acres of estuarine vegetated wetlands were recorded. Actually losses of existing palustrine vegetated wetlands totaled about 41,000 acres. Similar losses of estuarine vegetated wetlands amounted to slightly more than 4700 acres. Some gains in each wetland type lowered the net loss rate.

Compared with the results of the current study (1981/2-1992), a significant decline in wetland losses is revealed. The estimated yearly loss rate of palustrine vegetated wetlands in the Tiner and Finn study was 1459 acres. The current study found that this rate had greatly declined to 180 acres per year. For estuarine vegetated wetlands, the annual loss rate from 1955-1981 was estimated at 149 acres. During the recent decade, this rate dropped by more than an order of magnitude to about 10 acres. These figures demonstrate a significant improvement in wetland conservation as wetland destruction has declined most significantly.

From the 1950s to the 1980s, forested wetlands suffered the heaviest losses (Table 16). This trend continued in the recent decade. This, however, was not unexpected since this type is the most abundant wetland type in the state (representing nearly 90 percent of Delaware's nontidal wetlands according to Tiner 1985). These losses represented about 78 percent of the vegetated wetland losses from 1955-1981 and in the past decade, accounted for 76 percent of the losses of these wetlands. During the 26-year period, an estimated total of 4306 acres of forested wetlands were harvested, for an annual cut rate of 166 acres. More recently, timber harvest appears to have increased slightly. From 1981/2 to 1992, an estimated 2045 acres were cut, for an yearly average of 205 acres.

Pond acreage continued to grow. From 1955-1981, an estimated net gain of 2089 acres was reported (Tiner and Finn 1986). This amounts to an annual increase of 80 acres. During the current study decade, pond acreage proceeded to rise by an estimated 609 acres (61 acres/year). In the earlier period, 46 percent of the new ponds came from vegetated wetlands, while more recently, only 16 percent of the new ponds were constructed in wetlands. During the 1980s, about half of the acreage of new ponds came from agricultural land. From 1955-1981, only 13 percent of the expanded pond acreage was due to excavation on farmland.

Table 16. Summary of estimated wetland gains and losses for Delaware: 1955-1981 as reported in Tiner and Finn (1986). Data reported are mean values (see the 1986 report for accompanying standard errors of these estimates).

Wetland Type	Wetland Change	Cause	Acres
EVeg	Gain from	Palustrine Wetland	368
		Est. NonVeg. Wetld	281
		Estuarine Water	150
		Other Land	16
		Urban Land	11
		(Subtotal)	(+826)
	Loss to	Urban Development	2998
		Estuarine Water	921
		Lakes/Impoundments	243
		Other Land	172
		Est. NonVeg. Wetld	147
		Palustrine Wetland	137
		Agricultural Land	46
		Pond	40
		(Subtotal)	(-4704)
	Net Change	=	-3878 (loss)
PVeg	Gain from	Other Land	1728
		Agricultural Land	510
		Urban Land	241
		Estuarine Wetland	144
		Pond	76
		(Subtotal)	(+2699)
	Loss to	Other Land	22022
		Agricultural Land	11373
		Urban Development	4742
		Lakes/Impoundments	1087
		Pond Construction	997
		Estuarine Wetland	368
		Estuarine Water	32
		(Subtotal)	(-40621)
	Net Change	=	-37922 (loss)

PEM	Gain from	Other Land	423
		PSS Wetland	243
		Urban Land	226
		Agricultural Land	148
		Pond Colonization	74
		(Subtotal)	(+1114)
	Loss to	Agricultural Land	2012
		Urban Development	662
		Lakes/Impoundments	415
		Other Land	372
		Pond Construction	183
		(Subtotal)	(-3644)
	Type Change	Forestry-related*	2296
		Prior-cut Succession*	2369
		(Subtotal)	(4665)
	Net Change*	=	-2530 (loss)
PFO	Gain from	Other Land	856
		Agricultural Land	363
		E2Veg	91
		Urban Land	3
		Pond	3
		(Subtotal)	(+1316)
	Loss to	Other Land	20434
		Agricultural Land	8570
		Urban Development	3468
		Pond Construction	718
		Lakes/Impoundments	596
		Estuarine Wetland	280
		Estuarine Water	5
		(Subtotal)	(-34071)
	Type Change	Timber Harvest*	4306
		Prior-cut Succession*	8789
		(Subtotal)	(13095)
	Net Change*	=	-32755 (loss)

*Timber harvest changes - not included in net change as they are temporal changes.

PSS	Gain from	Other Land	450
		Estuarine Wetland	54
		Urban Land	13
		(Subtotal)	(517)
	Loss to	Other Land	1216
		Agricultural Land	791
		Urban Development	612
		PEM Wetland	243
		Pond Construction	96
		Estuarine Wetland	88
		Lakes/Impoundments	76
		Estuarine Water	26
		(Subtotal)	(-3148)
	Type Change	Recent Timber Cut*	2500
		Prior-cut Succession*	6910
		(Subtotal)	(9410)
	Net Change*	=	-2631 (loss)

*Timber harvest changes - not included in net change as they are temporal changes.

Study Conclusions

Significant gains in wetland conservation have been made since the early 1980s. The study found an enormous drop in the estimated annual loss rate of vegetated wetlands when compared to an earlier study: from about 1600 acres (1955-1981) to about 190 acres (1981/2-1992). Estuarine vegetated wetlands experienced the greatest percentage reduction in losses. They are now lost at a rate of about 10 acres per annum versus 149 acres for the earlier 26-year interval. Losses of palustrine vegetated wetlands remain much higher - at nearly 10 times that of estuarine vegetated wetlands. These palustrine wetlands are being lost at an estimated rate of 180 acres per year. This, however, still represents a significant decline from their preceding loss rate (1459 acres from 1955-1981). Pond acreage continues to increase as before, although at a slightly lower annual rate (61 acres versus 80 acres for 1955-1981).

Despite tremendous improvements in wetland conservation through passage of a state wetland law to protect tidal wetlands and strengthened Federal wetland regulations, net losses of all major wetland types, except ponds (palustrine nonvegetated wetlands), were detected for the 1981/2-1992 period. Wetland restoration projects have been initiated in the 1990s, so further improvements are expected as we enter the next century.

Although the status of wetlands has greatly improved during the last decade, readers should note that channelization and drainage still pose serious problems for palustrine vegetated wetlands in Delaware. Although it was beyond the scope of the current study to analyze the effects of ditching and channelization beyond their direct effect (excavations and fills large enough to be delineated), a significant amount of ditching was detected during the 1981/2-1992 period. In most cases, it was not possible to determine the magnitude of the effect of such ditching (i.e., if a recently ditched palustrine forested wetland was effectively drained). Onsite investigations are usually required to make a thorough assessment of the scope and effectiveness of drainage.

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References

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Washington, DC. FWS/OBS-79/31.

Pomatto, L.T., Jr. Undated. Statewide Wetlands Mapping Project - the SWMP. State of Delaware Department of Natural Resources and Environmental Control, Division of Water Resources, Dover, DE. Draft report.

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service, National Wetlands Inventory, Newton Corner, MA and Delaware Department of Natural Resources and Environmental Control, Wetlands Section, Dover, DE

Tiner, R.W., Jr. and J.T. Finn. 1986. Status and Recent Trends of Wetlands in Five Mid-Atlantic States: Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. U.S. Fish and Wildlife Service, Newton Corner, MA.