ESTIMATES OF TOTAL NITROGEN, TOTAL PHOSPHORUS, TOTAL SUSPENDED SOLIDS, AND BIOCHEMICAL OXYGEN DEMAND LOADINGS TO TAMPA BAY, FLORIDA: 1995-1998

Prepared for:

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1. INTRODUCTION

The Tampa Bay Estuary Program (TBEP) has previously developed loading estimates for the 1985-1991 and 1992-1994 periods (Zarbock et al., 1994; 1996). These estimates were developed for total nitrogen, total phosphorus, and total suspended solids loadings to the bay. This report is the third in the series of loading estimates, for the period 1995-1998.

The 1985-1994 loading estimates were used in the development of empirical relationships between total nitrogen loadings and observed chlorophyll concentrations in three mainstem segments of the bay: Old Tampa Bay, Hillsborough Bay, and Middle Tampa Bay (Janicki and Wade, 1996). These relationships were part of the empirical model relating total nitrogen loadings to chlorophyll concentrations, chlorophyll concentrations to light availability, and light availability to seagrass restoration acreage.

1.1 Objectives

The TBEP is currently performing an update of the relationships developed for the empirical model. This update requires revisiting the relationships using the water quality data collected since 1994. The 1995-1998 loading estimates will be used primarily for inclusion in the empirical model, and secondarily to estimate contributions from different loading sources. ***The objective of this report is to provide annual average loading estimates for total nitrogen, total phosphorus, total suspended solids, and total biochemical oxygen demand for the 1995-1998 period.*** These annual average estimates are derived from monthly loading estimates, using methods similar to those used previously (Zarbock et al., 1994; 1996).

The estimated 1992-1994 mean annual total nitrogen loadings represent those identified by the TBEP expected to result in light availability sufficient to meet the TBEP's seagrass restoration goals. The empirical model relating total nitrogen loadings to seagrass restoration goals (Janicki and Wade, 1996), and observed increases in seagrass coverage through 1992, suggested that light availability necessary for obtaining seagrass restoration goals could be met by establishing a "hold the line" strategy for nitrogen loadings. This strategy would hold nitrogen loadings to each segment of the bay to the average levels of 1992-1994. The TBEP adopted this strategy in 1996, and local government partners agreed to preclude increases in future nitrogen loadings to the bay to aid in this effort.

Comparison of mean annual TN loadings for the 1995-1998 period to the loadings from the 1992-1994 period allows examination of the sources responsible for changes in loadings during the 1995-1998 period. It also allows comparison of 1995-1998 nitrogen loadings to the "hold the line" loadings of 1992-1994.

Estimated pollutant loadings are reported for each bay segment (Figure 1-1). These loadings were developed by estimating loadings from each previously identified source in the watershed of the bay (Figure 1-2). The following sections present the methods and results of the 1995-1998 loading estimates. These sections include:

- **Descriptions** of the methods used and data summaries for the estimated loadings from each loading source for the 1995-1998 period;

- **Descriptions** of the estimated hydrologic loadings for the 1995-1998 period, with comparison of 1995-1998 estimated annual hydrologic loadings to the mean annual 1992-1994 hydrologic loadings;

- **Summary** of the estimated total bay pollutant loadings, the estimated pollutant loadings to each bay segment, and a discussion of the differences in estimated total pollutant loadings of the 1995-1998 period from those of 1992-1994, and their causes; and

- **Conclusions** concerning the results of this update.

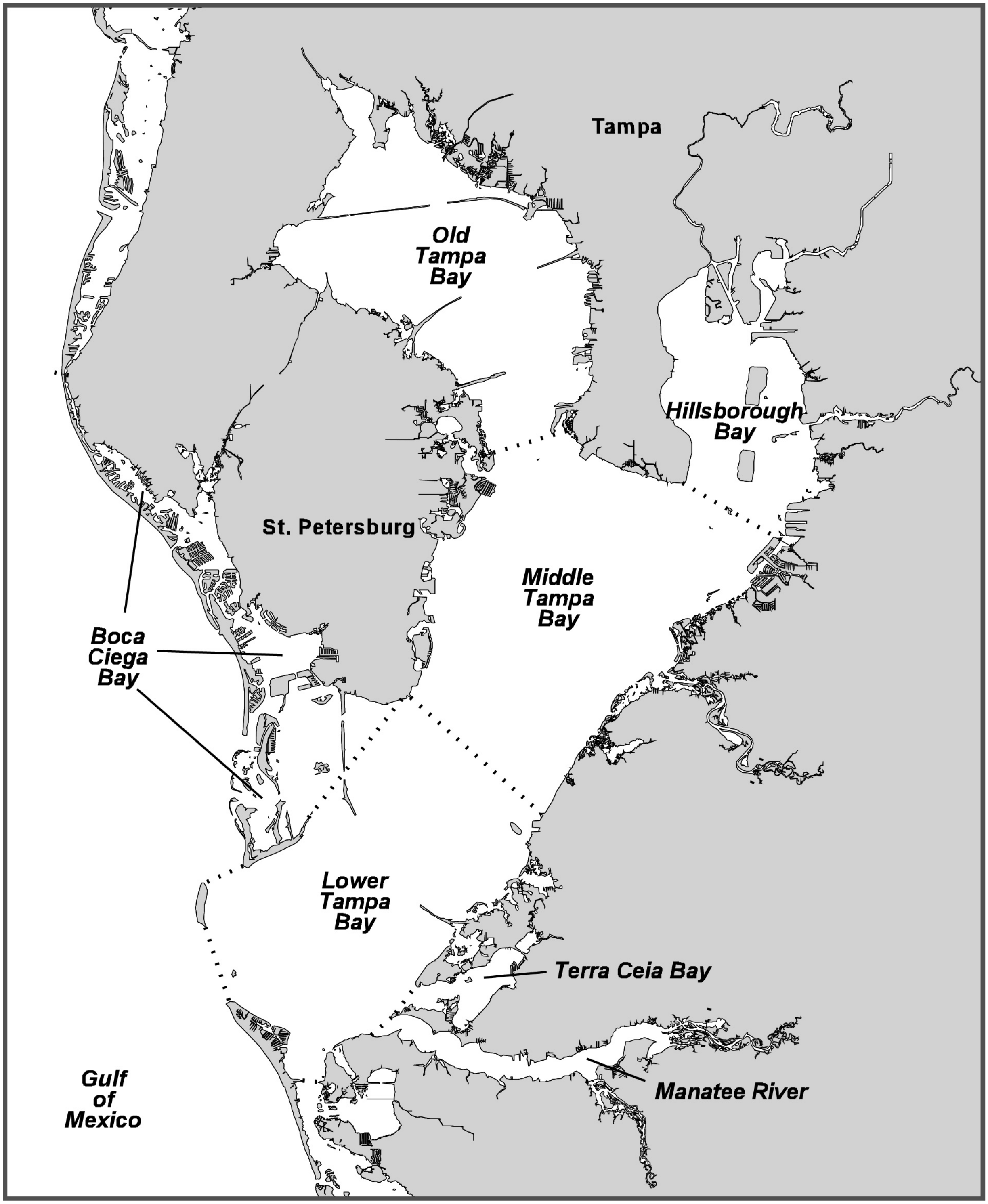

Figure 1-1. Bay segments of Tampa Bay.

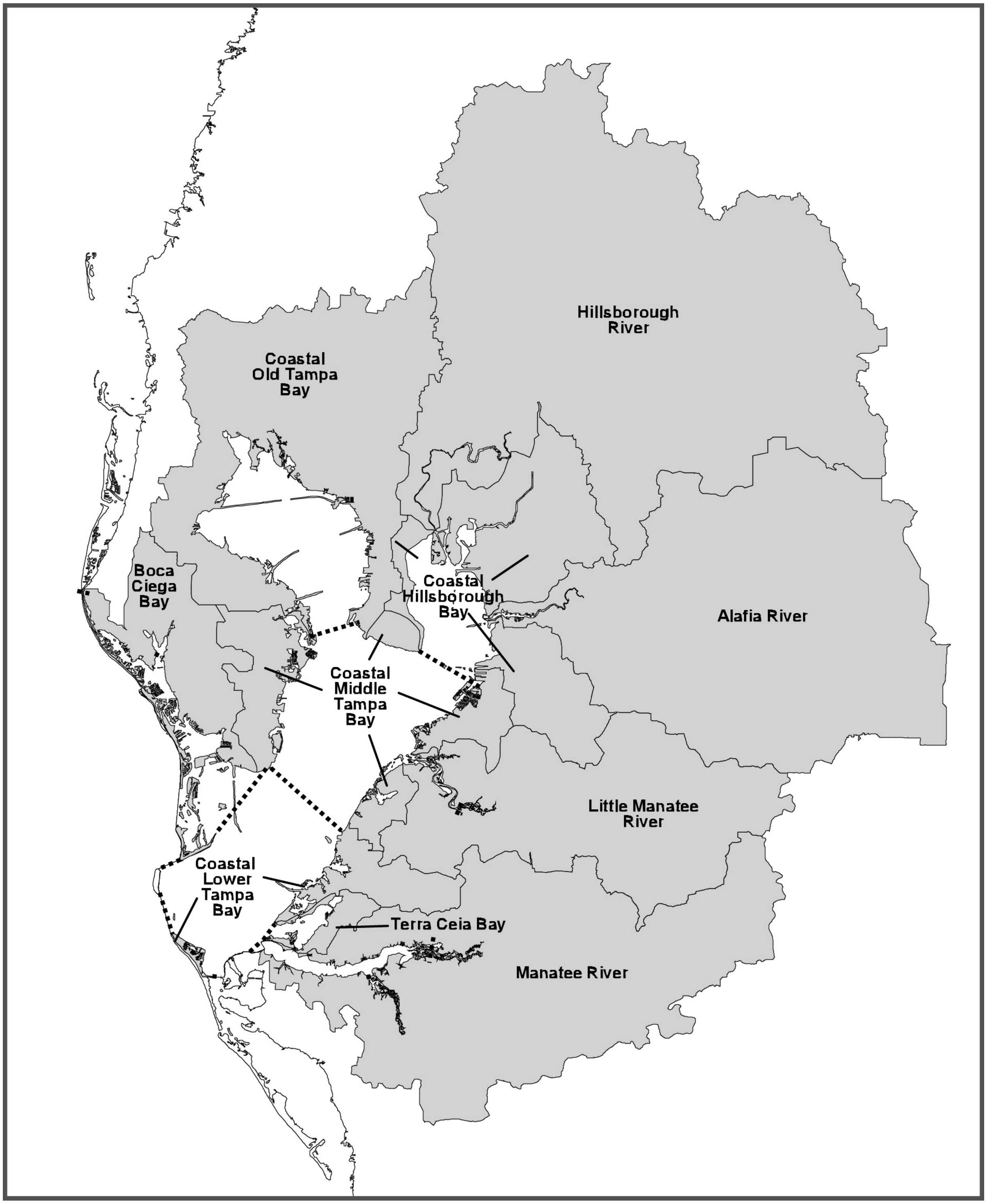

Figure 1-2. Major basins of the Tampa Bay watershed.

2. LOADING SOURCES

As in previous loading estimates (Zarbock et al., 1994; 1996), seven sources were examined for their contributions to loadings of total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) to the bay. Loading estimates of biochemical oxygen demand (BOD) were also developed for the 1995-1998 period. The loading sources examined were:

- atmospheric deposition,
- domestic point sources,
- industrial point sources,
- springs,
- groundwater,
- material losses from fertilizer handling facilities, and
- nonpoint sources.

The methods used to develop the loading estimates and summaries of the results for each loading source are given in the following subsections. Modifications to the methods used for developing estimates from each source are described in each of the subsections.

2.1 Atmospheric Deposition

Total atmospheric deposition is defined as the sum of wet deposition (rainfall) and dry deposition (gaseous constituent interaction and dust fallout) directly to the surface of the bay. Deposition of pollutants to the watershed of the bay is incorporated into nonpoint source loading estimates.

There are three data types needed to estimate total atmospheric deposition. First, an estimate of the hydrologic load to the bay via precipitation is needed. Secondly, an estimate of the pollutant concentration in that precipitation is also needed. Lastly, an estimate of dry deposition is needed, either from empirical data or model-based estimates.

2.1.1 Methods

The hydrologic load to the bay via precipitation was estimated in the same manner as in the previous loading estimates (Zarbock et al., 1994; 1996). An inverse distance-squared method was applied to data from 22 National Weather Service (NWS) rainfall monitoring sites in or near the Tampa Bay watershed to provide bay segment-specific monthly hydrologic loads from rainfall inputs.

For the previous loading estimates, TN concentration data in precipitation were obtained from the National Atmospheric Deposition Program (NADP) Verna

Wellfield site (Zarbock et al., 1994; 1996). This site is near the southern boundary of the Tampa Bay watershed in Sarasota County, and represented the nearest site measuring precipitation concentration data. Concentrations of TP in precipitation were estimated based on data collected by the Tampa National Urban Runoff Study (NURP) (Metcalf & Eddy, 1983), and the mean TP concentration of 0.195 mg/L from the study was used for all rainfall events (Zarbock et al., 1994). The TN loadings from precipitation were estimated by multiplying the monthly precipitation-weighted mean TN concentrations from the Verna site and the monthly segment-specific hydrologic loads to estimate monthly wet TN loads to each bay segment. Similarly, the constant TP concentration derived from the NURP study was multiplied by the monthly segment-specific hydrologic loads to estimate monthly wet TP loads to each bay segment.

The previous loading estimates derived dry deposition of TN and TP using a ratio of dryfall to wetfall from the Florida Acid Deposition Study (FADS). Results of the study suggested that the dry:wet deposition ratio in Hillsborough County was 2.04:1 (ES&E, 1987). Thus, the monthly wet deposition was multiplied by 3.04 to estimate the total monthly TN and TP loading attributable to atmospheric deposition directly to the surface of the bay (Zarbock et al., 1994; 1996).

For the 1995-1998 period, more site-specific data were available for the atmospheric deposition loading estimate. In August 1996, the TBEP initiated monitoring as part of the Tampa Bay Atmospheric Deposition Study (TBADS). This program includes sampling elements for both wet and dry deposition at an intensive monitoring site located on the Gandy Bridge Causeway. The data available from TBADS that can be used to estimate atmospheric deposition to Tampa Bay include precipitation pollutant (nitrogen and phosphorous) concentration data, wet and dry deposition rates, and an estimate of the ratio of dry:wet deposition.

Four methods of estimating atmospheric deposition of TN were evaluated to arrive at the most defensible approach for providing these estimates. The data used were for the time period August 1996 through July 1998. The methods evaluated are described below.

Method 1. This method was the same as that employed in previous loading estimates for Tampa Bay (Zarbock et al., 1994; 1996). Estimates of wet deposition of TN were calculated by multiplying precipitation-weighted mean monthly TN concentrations in rainfall by the total monthly hydrologic loading via rainfall to each bay segment. The TN (nitrate and ammonia nitrogen) concentration data were from the monitoring done at the NADP Verna Wellfield site. The hydrologic loads were estimated using rainfall data obtained from the NWS. The dry:wet deposition ratio was 2.04:1, as used for the previous estimates.

The equation for wet deposition of nitrogen was as follows:

$$Nwet_{m,s} = [N]_m * H_{m,s},$$

where:

$Nwet_{m,s}$	=	wet deposition of nitrogen (kg/month) for each month *m* and bay segment *s*,
$[N]_m$	=	monthly mean precipitation-weighted nitrogen concentration (kg/m^3) in the rainfall measured at the NADP Verna site for each month *m*, and
$H_{m,s}$	=	estimated hydrologic load (m^3/month) from rainfall for each month *m* and bay segment *s*.

The dry:wet deposition ratio of 2.04:1 was used to estimate dry deposition to each segment of the bay, as follows:

$$Ndry_{m,s} = 2.04 * Nwet_{m,s},$$

where:

$Ndry_{m,s}$	=	dry deposition of nitrogen (kg/month) for each month *m* and bay segment *s*, and
$Nwet_{m,s}$	=	wet deposition of nitrogen (kg/month) for each month *m* and bay segment *s*.

The total atmospheric deposition to a bay segment was given as the sum of the wet and dry deposition, as follows:

$$Ntot_{m,s} = Nwet_{m,s} + Ndry_{m,s},$$

where:

$Ntot_{m,s}$ = total atmospheric deposition of nitrogen (kg/month) for each month *m* and bay segment *s*.

Method 2. This method utilized the same equations for estimating atmospheric deposition as used in Method 1. However, the dry:wet deposition ratio used was derived from data gathered at the TBADS Gandy sampling site. The estimated ratio of dry:wet deposition from the TBADS was 1.003:1. It was assumed that this ratio was constant across all bay segments and time.

Method 3. This method utilized the mean monthly wet and dry deposition rates obtained from TBADS. It was assumed that these rates were constant across all bay segments.

The equation for the wet deposition of nitrogen was:

$$Nwet_{m,s} = NWETRATE_m * A_s,$$

where:

$Nwet_{m,s}$	=	wet deposition of nitrogen (kg/month) for each month *m* and bay segment *s*,
$NWETRATE_m$	=	mean wet deposition rate (kg/m^2/month) for each month *m*, and
A_s	=	surface area (m^2) of each segment *s*.

The dry deposition rate for nitrogen was estimated using the following equation:

$$Ndry_{m,s} = NDRYRATE_m * A_s,$$

where:

$Ndry_{m,s}$	=	dry deposition of nitrogen (kg/month) for each month *m* and bay segment *s*,
$NDRYRATE_m$	=	mean dry deposition rate (kg/m^2/month) for each month *m*, and
A_s	=	surface area (m^2) of each segment *s*.

The total atmospheric deposition was estimated as the sum of the dry and wet deposition, as in Methods 1 and 2.

Method 4. This method utilized a combination of several methods described above. Method 4 utilized the most site-specific data for both concentrations and hydrologic loads to the bay segments, as opposed to Method 2, for example, in which the wet deposition rate was held constant over all bay segments. Method 4 allowed for segment-specific differences in monthly wet deposition rates as a function of the segment-specific hydrologic loads. The wet nitrogen concentration data from the TBADS site, as in Method 3, and the segment-specific hydrologic loads, as in Method 1, were used to estimate wet nitrogen deposition. Dry deposition was estimated using the TBADS-derived seasonal dry:wet deposition ratio, which was 1.05 for the dry season (months 1-6, 11, and 12) and 0.66 for the wet season (months 7-10).

Estimates of dry deposition of nitrogen from monitoring performed at the TBADS site were used only to derive the seasonal dry:wet deposition ratio. Estimates of dry deposition of nitrogen at the TBADS site were not summed with estimated wet deposition of nitrogen at the site to arrive at a total deposition estimate applicable to the entire bay. Rather, spatial variations in segment-specific wet deposition, driven by differences in estimated rainfall to the various segments, were expected to result in spatial variations in segment-specific dry deposition as well. Thus, the seasonal dry:wet deposition ratios, as estimated from the TBADS data, were applied to estimate total deposition on a segment-specific basis.

The equation for estimation of wet deposition of nitrogen was as follows:

$$Nwet_{m,s} = [N]_m * H_{m,s},$$

where:

$Nwet_{m,s}$ = wet deposition of nitrogen (g/month) for each month *m* and bay segment *s*,

$[N]_m$ = mean precipitation-weighted nitrogen concentration (g/m^3) in the rainfall measured at the Verna Wellfield for January 1995 through July 1996, and at the TBADS site for August 1996 through December 1998, for each month *m*, and

$H_{m,s}$ = estimated hydrologic load (m^3/month) from rainfall for each month *m* and bay segment *s*.

The dry deposition of nitrogen to each bay segment was estimated as follows:

Dry season: $Ndry_{m,s} = 1.05 * Nwet_{m,s}$, for months 1-6, 11, and 12, and
Wet season: $Ndry_{m,s} = 0.66 * Nwet_{m,s}$, for months 7-10,

where

$Ndry_{m,s}$ = dry deposition of nitrogen (g/month) for each month *m* and bay segment *s*, and

$Nwet_{m,s}$ = wet deposition of nitrogen (g/month), for each month *m* and bay segment *s*.

The total atmospheric deposition to each segment for each month was the sum of the segment- and monthly-specific wet and dry deposition, as follows:

$$Ntot_{m,s} = Nwet_{m,s} + Ndry_{m,s},$$

where:

$Ntot_{m,s}$ = total atmospheric deposition of nitrogen (kg/month) for each month *m* and bay segment *s*.

Evaluation of Methods. A comparison of the average monthly atmospheric deposition resulting from each of the methods evaluated for the August 1996 – July 1998 period is shown in Table 2-1. Total nitrogen deposition resulting from Methods 2 and 3 was less than that from Method 1. This follows from the utilization in Methods 2 and 3 of a lower dry:wet ratio (1.003:1) than in Method 1 (2.04:1), yielding lower dry and total deposition. Method 3 resulted in higher wet deposition than did Methods 1 and 2, primarily because of the higher wet nitrogen concentrations at the Gandy site than at the Verna site (Pribble and Janicki, 1999). Relative to Method 1, Methods 2 and 3 significantly underestimated total deposition. Method 4 resulted in the highest total deposition, and most closely estimated the loadings from the original method (Method 1). The dry deposition resulting from Method 4 was lower than that from Method 1, but Method 4 wet deposition was higher.

Table 2-1. Average monthly total atmospheric deposition of nitrogen to Tampa Bay derived by the four methods, August 1996 – July 1998.

METHOD	Wet Deposition (tons/month)	Dry Deposition (tons/month)	Total Deposition (tons/month)
Method 1	31	63	94
Method 2	31	31	62
Method 3	36	36	72
Method 4	55	55	110

Based on the results of this evaluation and consultation with the Tampa Bay Atmospheric Deposition Group, the TBEP selected Method 4 as the most appropriate for estimation of atmospheric deposition for the 1995-1998 period. This method utilizes the most site-specific data for both concentrations and hydrologic loads to the bay segments. This method includes segment-specific differences in monthly wet deposition rates as a function of the segment-specific hydrologic loads. The data used for estimation of the 1995-1998 loadings are described in the following.

The precipitation nitrogen (nitrate and ammonia) concentration data for January 1995-July 1996 used for estimating wet deposition were from the monitoring done at the NADP Verna Wellfield site. Concentration data for the same two nitrogen species for August 1996-December 1998 were taken from wet deposition monitoring at the TBADS site (Pribble and Janicki, 1999; Poor, 2000). As for previous loading estimates, segment-specific hydrologic loads derived from 22 NWS rainfall monitoring sites were used to estimate wet nitrogen deposition. For the 1995-1998 estimates, dry deposition of nitrogen was estimated using the seasonal dry:wet deposition ratio derived from the TBADS data, also constant across all bay segments but varying in time.

The estimation of phosphorus deposition utilized the same equations, with wet phosphorus concentrations for January 1995-July 1996 set to a constant value of 0.195 mg/L, as in previous loading estimates (Zarbock et al., 1994), and wet concentrations for August 1996-December 1998 obtained from monitoring at the TBADS site. No atmospheric concentration data for phosphorus were measured at the TBADS site, so that estimates of dry deposition of phosphorus were obtained using the same seasonal dry:wet ratios as utilized for estimation of nitrogen deposition.

A database containing the data used for estimation of the wet and dry deposition of TN and TP for 1995-1998 can be found on the accompanying CD. This database contains monthly data for TN and TP concentrations in rainfall at the Verna Wellfield and TBADS sites, estimates of monthly dry deposition of TN at the TBADS site, and estimates of monthly rainfall volumes to each bay segment.

2.1.2 Data Summary

Annual average pollutant loads from atmospheric deposition directly to the surface of Tampa Bay for the 1995-1998 period were estimated at approximately

- TN - 1,094 tons/year, and
- TP - 259 tons/year.

Annual average bay segment loads for TN ranged from 310 tons/year to Middle Tampa Bay to 18 tons/year to Terra Ceia Bay. The largest bay segments received the greatest TN loads from atmospheric deposition, with Lower Tampa Bay receiving 267 tons/year and Old Tampa Bay receiving 245 tons/year. Annual average bay segment loads for TP ranged from approximately 73 tons/year to Middle Tampa Bay to 4 tons/year to Terra Ceia Bay. Atmospheric deposition of TP amounted to approximately 64 tons/year to Lower Tampa Bay and 57 tons/year to Old Tampa Bay.

The 1995-1998 average annual TN loads due to atmospheric deposition to Tampa Bay (1,094 tons/year) were approximately the same as those of the 1992-1994 period (1,101 tons/year). Average annual TP loads to the bay for the 1995-1998 period (259 tons/year) were much less than those of the 1992-1994 period (807 tons/year). The large reduction in TP loading for the 1995-1998 period in relation to the 1992-1994 period was largely a function of the precipitation phosphorus concentrations used. For TP loading estimates for 1992-1994, the total phosphorus concentration used was a constant 0.195 mg/L (Zarbock et al., 1996). This constant concentration was only used for 19 months of the 1995-1998 period, with the total phosphorus concentration data obtained from the TBADS site used for the remaining 29 months. The mean precipitation-weighted monthly total phosphorus concentration obtained from the TBADS site was 0.008 mg/L, much less than the constant 0.195 mg/L used previously.

The change in the dry deposition factor used for the 1995-1998 estimate particularly reduced the estimated TN load from atmospheric deposition, given similar rainfall amounts, compared to the previous estimation method. Despite this change in methodology, the estimated TN loading from atmospheric deposition during 1995 through 1998 was very similar to that estimated for the 1992-1994 period. This was a result of the higher rainfall observed during the 1995-1998 period.

2.2 Domestic Point Sources

Point sources of flow and pollutant loadings are defined as discharges that originate at a discrete location, such as from a pipe or a small, definable land area (such as for land application of treated wastewater effluent). Domestic sources include publicly and privately owned wastewater treatment plants.

Previous loading estimates only accounted for those point sources with annual average daily flows (ADF) of at least 0.1 million gallons per day (MGD) (Zarbock et al., 1994; 1996). Prior to developing loading estimates to the bay from domestic point sources for the 1995-1998 period, an evaluation of the TN loading contributions of all domestic point sources, including those with less than 0.1 MGD ADF, was performed at the request of the Nitrogen Management Consortium. The Consortium requested this evaluation to quantify the importance of small point sources to TN loading to Tampa Bay.

For this evaluation, loading estimates were based on discharge and nitrogen concentration data obtained from reviews of Monthly Operating Reports (MORs) and Discharge Monitoring Reports (DMRs) held by the Environmental Protection Commission of Hillsborough County (EPCHC). Only facilities in Hillsborough County were examined, and the evaluation was limited to 1995 data. A total of 135 domestic point sources were identified in Hillsborough County. Loading estimates were made for large (0.1 MGD ADF or greater) and small (less than 0.1 MGD ADF) facilities.

Based on the loading estimates derived for the facilities, it was found that the 16 facilities in Hillsborough County with greater than 0.1 MGD ADF during 1995 accounted for more than 99% of the estimated domestic point source TN loads from the county. It was therefore decided to continue to use the criterion of at least 0.1 MGD ADF to limit the domestic point sources included in the estimation of loadings for the 1995-1998 period.

2.2.1 Methods

The estimated pollutant loadings from domestic point sources were derived using the same methods as used in previous loading estimates (Zarbock et al., 1994; 1998). Domestic point sources identified for use in estimation of 1995-1998 loadings are shown in Table 2-2, and include all direct surface discharges and all land application discharges with an ADF of 0.1 MGD or greater.

Domestic point sources were identified by reviewing FDEP point source discharge locations in relation to the Tampa Bay watershed. The locations of all point sources in Florida were obtained from the PCS database provided by FDEP. These locations were used to create a GIS coverage, and then mapped for FDEP Tampa office staff review. The domestic point sources in the Tampa Bay watershed with ADF of 0.1 MGD or greater were identified with the assistance of FDEP Tampa office staff.

Data sources used to estimate domestic point source discharges and concentrations data to Tampa Bay for 1995-1998 are as follows:

- MORs and DMRs obtained from the EPCHC and the Tampa office of the FDEP; and

- MOR and DMR data obtained directly from the domestic wastewater treatment facilities for those data not obtained from the EPCHC and FDEP.

A database of domestic point source discharge information was developed, listing monthly discharge rates and TN, TP, TSS, and BOD concentration data. Both surface water dischargers and facilities with land application of effluent were included. Monthly data from a total of 39 major domestic point source dischargers (Table 2-2) were included. Included in the major domestic point sources are eight facilities that were not included in the 1992-1994 estimates, and nine facilities that were included in the 1992-1994 estimates are not included in the 1995-1998 list. The database containing the 1995-1998 data is provided on the CD accompanying this report.

The database was subjected to quality control measures to ensure that the most accurate flows and concentrations obtainable were used in the loading estimates. The entries were scanned for incongruous data points. Obvious outliers (such as flows of two or three orders of magnitude higher than the design capacity of the facility) were removed from the record. Complete records existed for most domestic wastewater treatment plants, with facilities reporting flow rate and concentrations for TN, TP, TSS, and BOD on a monthly basis. Attempts were made to locate sources of valid data to replace missing or invalid values, often by contacting facility personnel directly.

For those data gaps that could not be filled with actual recorded data, two methods were used to complete the record, depending upon the amount of data missing, as follows.

- If 1-3 months' of data were missing consecutively, discharge and/or pollutant concentrations were set to those of the last month for which values existed.

- If more than 3 months' of data were missing consecutively, discharge and/or pollutant concentrations were set to the monthly averages of the 1995-1998 record.

In some cases, a form of nutrient other than total nitrogen was reported. For example, if both total nitrogen and nitrate nitrogen were recorded for some months at a facility, but only nitrate nitrogen was recorded for most months, the average ratio of nitrate to total nitrogen was calculated for those months with both values. The resulting ratio was applied to the other months, resulting in an estimate of total nitrogen for those months. If only nitrate nitrogen data existed, then total nitrogen concentration was set to the reported concentration of nitrate nitrogen.

If no data for a certain parameter were available for a facility and it was known or suspected that loadings of that chemical did occur, then other similar facilities were examined. Typical or averaged data from these facilities were used to fill data gaps if no other source of information was available. This method was chosen as an alternative to showing missing data for loads from major point sources.

The proportions of data records for which data were estimated based on previous months' records, average monthly values, or pollutant concentrations from other similar facilities are as follows, based on TN concentration data needs:

- approximately 2% of the records were filled using previous months' data;

- approximately 11% of the records were filled using facility mean values; and

- approximately 3% of the records were filled using pollutant concentration values from similar facilities.

Surface Discharge

Many of the inventoried domestic facilities utilize direct surface discharge for effluent disposal. Surface water inputs from domestic point sources were estimated for both the gaged and ungaged basins of the watershed, expressed as a volume per unit time, such as MGD. The flows from each point source were assigned to the subbasin that receives the discharge, allowing the aggregation of point source flows for each major drainage basin and each bay segment. All of the effluent released via surface discharge was assumed to reach the Tampa Bay system. Domestic point source loadings were subtracted from the total gaged nonpoint source loads, discussed later, to avoid double counting of point source loadings originating upstream of gages.

Estimates of point source pollutant loading for surface water discharges were obtained by multiplying the reported concentration of the pollutant of concern and the discharge volume. With appropriate conversion factors, this calculation yields a mass per unit time, such as tons per year of pollutant (TN, TP, TSS, BOD).

Land Application

Treated effluent from domestic facilities is frequently discharged onto the land, most commonly for reuse by spray irrigation or into percolation ponds. The applied effluent either evaporates, is taken up by vegetation, becomes surface runoff (generally a very small component of the total volume), or infiltrates to the water table. Therefore, pollutant loadings from this source that reach the bay generally do so via groundwater. In this loading analysis, land application effluent loads are calculated separately from groundwater loads.

Land application loadings were estimated using recorded effluent quality data from specific facilities, with "typical" reduction rates applied to the nitrogen and phosphorus once in the environment. These reduction rates are the same as those used previously for loading estimations for the 1985-1994 period (Zarbock et al., 1994; 1996), and account for attenuation of pollutants in the environment prior to the effluent flow reaching the receiving water of Tampa Bay. Pollutant loading reductions applied to loads discharged to land were as follows:

Table 2-2. Domestic point sources in the Tampa Bay watershed (1995-1998).	
Facility Name	**Bay Segment**
City of Bradenton	Manatee River
City of Clearwater East	Old Tampa Bay
City of Clearwater Northeast	Old Tampa Bay
Hillsborough County Dale Mabry	Old Tampa Bay
Hillsborough County Eagles	Old Tampa Bay
Hillsborough County Falkenburg	Hillsborough Bay
City of Tampa H.F. Curren	Hillsborough Bay
City of Lakeland	Hillsborough Bay
City of Largo	Old Tampa Bay
Manatee County North County Regional	Lower Tampa Bay
Manatee County Southeast Subregional	Manatee River
MacDill A.F.B.	Middle Tampa Bay
Meadowlands	Hillsborough Bay
City of Mulberry	Hillsborough Bay
Hillsborough County Northwest Regional	Old Tampa Bay
City of Oldsmar	Old Tampa Bay
On Top of the World	Old Tampa Bay
City of Palmetto	Terra Ceia Bay
Pasco Center Subregional	Hillsborough Bay
Pasco County Southeast Subregional	Hillsborough Bay
Pebble Creek	Hillsborough Bay
City of Plant City	Hillsborough Bay
Polk County Southwest Regional	Hillsborough Bay
Hillsborough County River Oaks	Old Tampa Bay
Hillsborough County South County Regional	Middle Tampa Bay
City of St. Petersburg Albert Whitted	Old Tampa Bay, Middle Tampa Bay, and Boca Ciega Bay
City of St. Petersburg Northeast	
City of St. Petersburg Northwest	
City of St. Petersburg Southwest	
Hillsborough County Summerfield Subregional	Hillsborough Bay
Tarpon Lake Village	Old Tampa Bay
Tarpon Woods	Old Tampa Bay
Trout Creek	Hillsborough Bay
Hillsborough County Valrico	Hillsborough Bay
Hillsborough County Van Dyke	Old Tampa Bay
Wesley Chapel	Hillsborough Bay
City of Zephyrhills	Hillsborough Bay
Pinellas County South Cross Bayou	Boca Ciega Bay
Pinellas County Northwest	Old Tampa Bay

TN (spray irrigation)	: 95% reduction for City of St. Petersburg facilities,
	: 90% reduction for all other facilities,
TN (percolation pond)	: 70% reduction,
TP (all)	: 95% reduction,
TSS (all)	: 95% reduction, and
BOD (all)	: 95% reduction.

These rates were the same as those used previously for TN, TP, and TSS (Zarbock et al., 1994; 1996), with the attenuation of BOD loads set to the same rate as that for TP and TSS.

2.2.2 Data Summary

Annual average pollutant loads from domestic point sources to Tampa Bay for the 1995-1998 period were estimated at approximately

- TN - 426 tons/year,
- TP - 356 tons/year,
- TSS - 255 tons/year, and
- BOD - 287 tons/year.

Annual average bay segment loads for TN ranged from 270 tons/year to Hillsborough Bay to 1 ton/year to Lower Tampa Bay. Annual average bay segment loads for TP ranged from 277 tons/year to Hillsborough Bay to <1 ton/year to Lower Tampa Bay. Annual average bay segment loads for TSS ranged from 153 tons/year to Hillsborough Bay to <1 ton/year to Lower Tampa Bay. Annual average bay segment loads for BOD ranged from 168 tons/year to Hillsborough Bay to <1 ton/year to Lower Tampa Bay.

The 1995-1998 average annual TN loads to Tampa Bay (426 tons/year) are higher than those of the 1992-1994 period (362 tons/year). Average annual TP loads to the bay for the 1995-1998 period (356 tons/year) are lower than those during the 1992-1994 period (385 tons/year). Average annual TSS loads to the bay for the period 1995-1998 (255 tons/year) are nearly the same as the 1992-1994 annual average (253 tons/year).

Most of the increase in estimated domestic point source total nitrogen loadings occurred to Hillsborough Bay. These increases were due in part to increases in effluent volume from a small number of facilities, and in part to higher average total nitrogen concentrations from some facilities, compared to levels during the 1992-1994 period.

2.3 Industrial Point Sources

Industrial point sources include dischargers of process water and other effluent not categorized as domestic sewage. As done for domestic point sources, an evaluation of the TN loading contributions of all industrial point sources, including those with less than 0.1 MGD ADF, was performed at the request of the Nitrogen Management Consortium. Industrial point source loading estimates were based on discharge and nitrogen concentration data obtained from reviews of Monthly Operating Reports (MORs) and Discharge Monitoring Reports (DMRs) held by the FDEP Tampa office. Only facilities in Hillsborough County were examined, and the evaluation was limited to 1998 data. A total of 46 industrial point sources were identified in Hillsborough County. Loading estimates were made for large (0.1 MGD ADF or greater) and small (less than 0.1 MGD ADF) facilities.

Based on the loading estimates derived for the facilities, it was found that the 23 facilities in Hillsborough County with greater than 0.1 MGD ADF accounted for almost 98% of the estimated industrial point source TN loads from the county. It was therefore decided to continue to use the criterion of at least 0.1 MGD ADF to limit the industrial point sources included in the estimation of loadings for the 1995-1998 period.

2.3.1 Methods

The estimated pollutant loadings from industrial point sources were derived using the same methods as used in previous loading estimates (Zarbock et al., 1994; 1998). Industrial point sources identified for use in estimation of 1995-1998 loadings are shown in Table 2-3, and include all direct surface discharges and all land application discharges with a permitted ADF of 0.1 MGD or greater.

Industrial point source identification was initiated using those sources identified for the 1992-1994 loading estimates (Zarbock et al., 1996). These sources were first checked to identify which sources were operational during the 1995-1998 period, with those that were no longer discharging removed from the list. Additional industrial point sources in the Tampa Bay watershed not included in the 1992-1994 list and meeting the 0.1 MGD discharge criterion were then identified with the assistance of FDEP staff. The locations of all point sources in Florida were obtained in a database from FDEP. These locations were used to create a GIS coverage, and then mapped for FDEP Tampa office staff review.

Data sources used to estimate industrial point source discharges and loadings to Tampa Bay for 1995-1998 are as follows:

- Monthly Operating Reports (MORs) and Discharge Monitoring Reports (DMRs) obtained from the Environmental Protection

Commission of Hillsborough County (EPCHC) and the Tampa office of the FDEP; and

- MOR and DMR data obtained directly from the industrial wastewater treatment facilities for those data not obtained from the EPCHC and FDEP.

A database of industrial point source discharge information was developed, listing monthly discharge rates and TN, TP, TSS, and BOD concentration data. Both surface water dischargers and facilities with land application of effluent were included. Monthly data from a total of 28 major industrial point source dischargers (Table 2-3) were included. Included in the major industrial point sources are six facilities that were not included in the 1992-1994 estimates, and three facilities that were included in the 1992-1994 estimates are not included in the 1995-1998 list. The database containing the 1995-1998 data is provided on the accompanying CD.

The database was subjected to quality control measures to ensure that the most accurate flows and concentrations obtainable were used in the loading estimates. The entries were scanned for incongruous data points. Obvious outliers (such as flows of two or three orders of magnitude higher than the design capacity of the facility) were removed from the record. Attempts were made to locate sources of valid data to replace missing or invalid values, often by contacting facility personnel directly.

For those data gaps that could not be filled with actual recorded data, two methods were used to complete the record, depending upon the amount of data missing, as follows.

- If 1-3 months' of data were missing consecutively, discharge and/or pollutant concentrations were set to those of the last month's for which values existed.

- If more than 3 months' of data were missing consecutively, discharge and/or pollutant concentrations were set to the monthly averages of the 1995-1998 record.

In some cases, a form of nutrient other than total nitrogen was reported. For example, if both total nitrogen and nitrate nitrogen were recorded for some months at a facility, but only nitrate nitrogen was recorded for most months, the average ratio of nitrate to total nitrogen was calculated for those months with both values. The resulting ratio was applied to the other months, resulting in an estimate of total nitrogen for those months. If only nitrate nitrogen data existed, then total nitrogen concentration was set to the reported concentration of nitrate nitrogen.

If no data for a certain parameter were available for a facility and it was known or suspected that loadings of that chemical did occur, then other similar facilities were examined. Typical or averaged data from these facilities were used to fill data gaps if no other source of information was available. This method was chosen as an alternative to showing missing data for loads from major point sources.

The proportions of data records for which data were estimated based on previous months' records, average monthly values, or pollutant concentrations from other similar facilities are as follows, based on TN concentration data needs:

- approximately 1% of the records were filled using previous months' data;
- approximately 29% of the records were filled using facility mean values; and
- approximately 17% of the records were filled using pollutant concentration values from similar facilities.

Surface Discharge

Most of the inventoried industrial facilities utilize direct surface discharge for effluent disposal. Surface water inputs from industrial point sources were estimated for both the gaged and ungaged basins of the watershed, expressed as a volume per unit time, such as MGD. The flows from each point source were assigned to the subbasin that receives the discharge, allowing the aggregation of point source flows for each major drainage basin and each bay segment. All of the effluent released via surface discharge was assumed to reach the Tampa Bay system. As for domestic point source loadings, industrial point source loadings were subtracted from the total gaged nonpoint source loads, discussed later, to avoid double counting of point source loadings originating upstream of gages.

Estimates of industrial point source pollutant loading for surface water discharges were calculated by multiplying the reported concentration of the pollutant of 2concern and the discharge volume. With appropriate conversion factors, this calculation yields a mass per unit time, such as tons per year of pollutant (TN, TP, TSS, BOD).

Land Application

Treated effluent from industrial facilities is sometimes discharged onto the land, most commonly into percolation ponds. The applied effluent either evaporates, is taken up by vegetation, becomes surface runoff (generally a very small component of the total volume), or infiltrates to the water table. Therefore, pollutant loadings from this source that reach the bay generally do so via groundwater. In this loading analysis, land application effluent loads are calculated separately from groundwater loads.

Land application loadings were estimated using recorded effluent quality data from specific facilities, with "typical" reduction rates applied to the nitrogen and phosphorus once in the environment. These reduction rates are the same as those used previously for loading estimations for the 1985-1994 period (Zarbock et al., 1994; 1996), and account for attenuation of pollutants in the environment prior to the effluent flow reaching the receiving water of Tampa Bay. The reduction rates are listed above in the description of the domestic point source loading estimate methods.

Table 2-3. Industrial point sources in the Tampa Bay watershed (1995-1998).

Facility Name	Bay Segment
Agrifos Nichols Mine (fka Mobil)	Hillsborough Bay
Agrifos Nichols Prep Plant (fka Mobil)	Hillsborough Bay
Alpha/Owens-Corning	Hillsborough Bay
Bridgeway Acres Landfill	Old Tampa Bay
Cargill East Tampa	Hillsborough Bay
CF Industries Plant City	Hillsborough Bay
Coronet Industries	Hillsborough Bay
CSX Transportation Winston Yard	Hillsborough Bay
Crystals International	Hillsborough Bay
Florida Power and Light Manatee Steam	Middle Tampa Bay
FDEP Stock Enhancement Program	Middle Tampa Bay
Estech Inc. Silver City Mine	Hillsborough Bay
Farmland Hydro Green Bay Plant	Hillsborough Bay
Farmland Hydro Port Sutton	Hillsborough Bay
Florida Juice	Hillsborough Bay
IMC Agrico Four Corners Mine	Middle Tampa Bay
IMC Agrico Haynesworth Mine	Hillsborough Bay
IMC Agrico Kingsford	Hillsborough Bay
IMC Agrico Lonesome Mine	Hillsborough Bay
IMC Agrico Port Sutton	Hillsborough Bay
Mulberry Phosphates	Hillsborough Bay
Nitram Chemical	Hillsborough Bay
Pakhoed Dry Bulk Terminals	Hillsborough Bay
Piney Point Phosphates	Lower Tampa Bay
TECO Big Bend Station	Middle Tampa Bay
TECO Gannon Station	Hillsborough Bay
Trademark Nitrogen	Hillsborough Bay
Tropicana North America	Manatee River

2.3.2 Data Summary

Annual average pollutant loads from industrial point sources to Tampa Bay for the 1995-1998 period were estimated at approximately

- TN - 208 tons/year,
- TP - 177 tons/year,
- TSS - 798 tons/year, and
- BOD - 1088 tons/year.

Annual average bay segment loads for TN ranged from 120 tons/year to Hillsborough Bay to 4 tons/year to Old Tampa Bay, with no industrial point source TN loadings to Boca Ciega Bay or Terra Ceia Bay. Annual average bay segment loads for TP ranged from 132 tons/year to Hillsborough Bay to 1 ton/year to Old Tampa Bay, with no industrial point source TP loadings to Boca Ciega Bay, Terra Ceia Bay, or the Manatee River. Annual average bay segment loads for TSS ranged from 474 tons/year to Hillsborough Bay to 1 ton/year to Lower Tampa Bay, with no industrial point source TSS loadings to Old Tampa Bay, Boca Ciega Bay, or Terra Ceia Bay. Annual average bay segment loads for BOD ranged from 779 tons/year to Hillsborough Bay to 2 tons/year to Lower Tampa Bay, with no industrial point source BOD loadings to Boca Ciega Bay or Terra Ceia Bay.

The 1995-1998 average annual TN loads to Tampa Bay (208 tons/year) are higher than those of the 1992-1994 period (149 tons/year). Average annual TP loads to the bay for the 1995-1998 period (177 tons/year) are greater than those of the 1992-1994 period (108 tons/year) as well. Average annual TSS loads to the bay for the period 1995-1998 (798 tons/year) are less than those for the 1992-1994 period (909 tons/year).

The increases in estimated mean nutrient loadings from industrial point sources during the 1995-1998 period is at least partly the result of the higher than normal rainfall during this period. Those industrial facilities that are required to report monitoring data from both process water and stormwater runoff from their properties showed greater discharge during the high rainfall period of winter 1997-1998 than during the remainder of the 1995-1998 period.

2.4 Springs

Springs are also a source of pollutant loadings to Tampa Bay. Previous loading estimates have been developed for Sulphur Springs, Lithia Springs, and Crystal Springs, which were identified as significant discharges in the Tampa Bay watershed (Zarbock et al., 1994; 1996). Smaller springs do exist in the watershed, but have relatively small discharges and were not considered in this loading analysis or the previous estimates. Lithia Springs and Sulphur Springs are not in gaged portions of the Tampa Bay watershed, but are themselves gaged, so that loading estimates were derived for these springs. Crystal Springs is located in a gaged basin within the Hillsborough River watershed and its flow was accounted for by the downstream gage, so that pollutant loadings from Crystal Springs were not explicitly derived, but are included in the nonpoint source loading estimate, as done previously (Zarbock et al., 1994; 1996).

2.4.1 Methods

Pollutant loadings from Sulphur Springs and Lithia Springs were estimated. Spring discharge loadings were estimated based on measured discharge and water quality data obtained from USGS (Coffin and Fletcher, 1996; Coffin and Fletcher, 1997a; Coffin and Fletcher, 1997b; Coffin and Fletcher, 1999). Only periodic data were available. The pollutant concentrations were obtained by averaging measured data for each spring over the 1995-1998 period. If no pollutant concentrations were available for the 1995-1998 period, concentrations for the 1992-1994 period were used. Discharge estimates for months with no measured flow data were made by interpolating between preceding and succeeding months that did have measured data. For each spring, the monthly measured or estimated pollutant concentrations were multiplied by the monthly estimated or measured discharge to obtain monthly loads. Monthly loads were summed on an annual basis and averaged to obtain an average annual load for the 1995-1998 period. A database containing the 1995-1998 monthly spring flows and pollutant concentrations is provided on the accompanying CD.

2.4.2 Data Summary

All estimated 1995-1998 spring loads were to Hillsborough Bay. Annual average pollutant loads from springs for the 1995-1998 period were estimated at approximately

- TN - 205 tons/year,
- TP - 3 tons/year, and
- TSS - 1 ton/year.

The estimated 1995-1998 TN loadings were approximately 6% greater than those during the 1992-1994 period (Zarbock et al., 1996). Estimated loadings of TSS during the 1995-1998 period were approximately 10% greater than during the 1992-1994 period. The estimated 1995-1998 TP loadings were approximately 22% less than those during the 1992-1994 period. The increase in estimated TN loadings is due primarily to increased discharge. The observed mean nitrogen concentrations in Lithia Springs during the 1995-1998 period (2.75 mg/L) were less than those during the 1992-1994 period (3.0 mg/L). Mean nitrogen concentrations in Sulphur Springs were the same during both periods. The increase in estimated TSS loading is also a result of increasing discharge, as observed TSS concentrations did not change from the 1992-1994 period to the 1995-1998 period. The relatively large reduction in estimated TP loading is due to a reduction in observed phosphorus concentrations at Lithia Springs to less than half the value observed during the 1992-1994 period, from 0.07 mg/L during the 1992-1994 period to 0.03 mg/L during the 1995-1998 period.

2.5 Groundwater

Groundwater is a source of freshwater and nutrient loadings to many coastal areas. The surficial (water table), intermediate, and Floridan aquifers all contribute flows and loads to Tampa Bay. Estimates of groundwater pollutant loadings for the 1995-1998 period were derived using the same methods as in previous estimates (Zarbock et al., 1994; 1996).

2.5.1 Methods

Data sources used to estimate groundwater flows and loadings to Tampa Bay for 1995-1998 are as follows:

- Floridan and intermediate aquifer potentiometric surfaces for May (representing the dry season) and September (representing the wet season) for calendar years 1995 and 1998 were obtained from USGS Open File Reports (Metz and Stelman, 1995a; 1995b; Metz et al., 1996a; 1996b; Metz et al., 1997a; 1997b; Metz et al., 1998a; 1998b; Broska et al., 1999a; 1999b; Torres et al., 1999a; 1999b).

- Topography data for the Tampa Bay watershed and shoreline lengths of the bay were obtained from USGS quadrangle (7.5-minute) maps.

- TN and TP concentration data for the surficial, intermediate, and Floridan aquifers were obtained from the SWFWMD Ambient Ground Water Monitoring Program (AGWMP) (DeHaven, personal communications). Reported concentrations from monitor wells in the groundwater flow areas tributary to each bay segment were averaged to yield a representative groundwater concentration. If only a few monitor wells were present in an area, concentrations from several adjoining flow areas were averaged. It was desired to obtain a representative regional set of concentration values. Thus, the data set was reviewed and monitor wells deemed to not be representative of regional conditions (such as wells located adjacent to known groundwater pollution sources), were not used. Additionally, individual concentration values that were noted in the data set as being outside the normal range of concentrations for that station (potential outliers) were censored. Nitrate+nitrite (as N) concentrations were used to estimate nitrogen loads, as these species are most often cited as groundwater pollution threats. Few ammonia concentration data were available, and ammonia nitrogen concentrations were typically less than 10% of those of nitrate+nitrite nitrogen. Total phosphorus (as P) was used to estimate phosphorus loads due to the general lack of significant concentrations of organic phosphorus in groundwater.

- Surficial aquifer elevation data used by Brooks et al. (1993) were the most recent available information suitable for bay-wide loading calculations, and were used for this analysis.

Groundwater flows were estimated for each of the bay segments. Only groundwater inflow that entered the bay directly from the shoreline or bay bottom was considered. Groundwater and septic tank leachate inflow to streams was accounted for through measured or modeled surface water flow and was attributed as nonpoint source loading, and was not included in these groundwater loading estimates.

Existing estimates of wet and dry season groundwater inflow to Tampa Bay were completed using the methods of Hutchinson (1983) and Brooks et al. (1993). Flow estimates were calculated using a flow net analysis and Darcy's equation (Freeze and Cherry, 1979), a well-recognized analytical method for estimating groundwater flow. The flow net analysis is a graphical procedure used to identify groundwater flow paths based on water surface profiles. Darcy's Equation is:

$$Q = (7.48 \times 10^{-6})\,TIL$$

where:

Q = flow rate, in million gallons per day (MGD),
T = aquifer transmissivity, in ft^2/day,
I = hydraulic gradient (head difference/length of flow path),
L = width of flow path, in feet,

and

1 cubic foot = 7.48×10^{-6} million gallons.

Average wet season and dry season flows and loadings from the Floridan and intermediate aquifers, and annual flows and loadings from the surficial aquifer, were estimated using the following methods:

1) Values for transmissivity (T) for the Floridan and intermediate aquifers were taken from USGS and SWFWMD groundwater modeling reports

for the Tampa Bay area (Ryder et al., 1980; Wolansky and Corral, 1985; Jones, 1990). "T" values for different areas of the watershed were used as available. A single watershed-wide value for "T" for the surficial aquifer was taken from Brooks et al. (1993). These aquifer characteristic values are generally stable over time and did not change from previous loading estimates (Zarbock et al., 1994; 1996).

2) For all three aquifers, the regions of groundwater flow to each bay segment were identified as discrete flow zones. Flow zones were delineated using USGS potentiometric surface maps and a flow net analysis. Groundwater flow path lines were drawn perpendicular to the lines of equipotential (constant head). Flow paths leading to each bay segment were identified, and the associated flow zones were then delineated.

3) Values for "I" and "L" for the Floridan and intermediate aquifers were determined using USGS potentiometric surface maps as referenced above. Seasonal values for "I", the hydraulic gradient of the aquifer, were estimated by measuring the change in potentiometric surface elevation and the length of the groundwater flow path over the distance from the inland boundary of the groundwater flow area to the bay shoreline, for each bay segment tributary area. An average annual value of "I" for the surficial aquifer was estimated by measuring the change in land surface elevation over the horizontal distance from an inland topographic depression to the bay shoreline, and measuring the length of the groundwater flow path from the topographic depression to the bay shoreline, for each bay segment tributary area. It was assumed that the gradient of the surficial aquifer would follow the general gradient of the land surface. This value did not change from previous estimates.

4) "L", the width of the flow path, was estimated by measuring the length of the bay segment shoreline, expressed as a plane perpendicular to the groundwater flow path for each bay segment.

5) Using the above data and Darcy's equation, flow estimates were made for the Floridan and intermediate aquifers for wet and dry seasons using the appropriate potentiometric surface maps.

6) Because surficial aquifer gradients can change greatly over relatively small distances and time frames, it was not feasible to estimate surficial aquifer inflows on a seasonal basis. Therefore, surficial aquifer flow rates were estimated for average annual conditions only, also using Darcy's equation.

Monthly groundwater TN, TP, and freshwater loadings to each bay segment from each aquifer for the period 1995 through 1998 were then estimated as follows:

7) Wet and dry season Floridan and intermediate aquifer flow rates (expressed as million gallons per day) were multiplied by the average TN and TP concentrations (mg/L) for each bay segment flow zone. The resulting bay segment loading rates were converted to kg/month.

8) Surficial aquifer loading rates were estimated in the same manner, but with a constant monthly flow rate throughout the year, not seasonal rates.

9) Pollutant loads and flows from the Floridan, intermediate, and surficial aquifers were then summed on a monthly basis to yield total monthly pollutant loads (kg/month) and inflows (cubic meters/month) to each bay segment.

10) A review of USGS potentiometric surface maps revealed that the surface contours for both the Floridan and intermediate aquifers changed significantly during the 1995-1998 period, with these changes relatively linear and consistent on an inter-annual basis. In May 1995 (dry season) there was a large groundwater (Upper Floridan) depression along the east side of Tampa Bay reaching from upper Hillsborough Bay to the Manatee River. The depression acted as a sink for much of the groundwater from the eastern part of the Tampa Bay watershed, preventing westerly flows from reaching the bay. In May 1997 the depression was still evident but was very small, and hardly affected groundwater flows to the bay. By May 1998 there was no depression evident, and all groundwater flow was again directed towards the bay. The 1995 and 1998 loading estimates were based on data for those years. The regular recession of the depression, and the gradual diminution of its influence on loadings to the bay, allowed loading estimates for 1996 and 1997 to be derived through interpolation between the 1995 and 1998 loading estimates.

A database containing 1995-1998 groundwater flows and concentrations and resultant loadings to each bay segment is provided on the accompanying CD.

2.5.2 Data Summary

Annual average pollutant loads from groundwater to Tampa Bay for the 1995-1998 period were estimated at approximately

- TN - 2.1 tons/year and
- TP - 12.1 tons/year.

Annual average bay segment loads for TN ranged from 1.40 tons/year to Hillsborough Bay to <0.1 tons/year to Terra Ceia Bay. Annual average bay segment loads for TP ranged from 6.2 tons/year to Hillsborough Bay to 0.1 tons/year to Terra Ceia Bay.

The 1995-1998 annual average TN loading values (2.1 tons/year) were slightly higher than those for the 1992-1994 period (1.9 tons/year). TP loads for the 1995-1998 (12.1 tons/year), however, were significantly lower than during the 1992-1994 period (27.9 tons/year). The difference in TP loads is likely due to lower concentrations resulting from using an expanded and updated water quality data set, and lower freshwater inflows. Because water quality data from different wells were used in the analyses for the two time periods, it is not known whether the change in concentration is a result of trends in water quality or a function of diverse sampling locations being used.

Floridan aquifer flow patterns changed significantly over the 1995-1998 period. In May 1995 a groundwater depression existed in central Manatee and southern Hillsborough counties, causing groundwater to flow away from the bay in those regions. By 1998 the depression was gone, and regional flows resumed their westward path into the bay. Thus, freshwater inflows and loads to the southern bay segments increased each year from 1995 to 1998.

2.6 Material Losses

Fertilizer losses from loading docks at port facilities constitute a source of nutrient loading classified as material losses. In particular, bulk phosphate fertilizer is subject to product losses during its transfer from land carrier to storage facility, and onto vessels for shipping. Product is lost both through spilled product washing into the bay with stormwater runoff, and via fugitive dust. Material losses occur at facilities at the Port of Tampa, in the Coastal Hillsborough Bay basin, and at Port Manatee, in the Coastal Lower Tampa Bay basin.

2.6.1 Methods

Estimates of total nitrogen and total phosphorus loadings due to material losses were developed for handling facilities listed in Table 2-4. For previous loading estimates, facility personnel provided shipping tonnage estimates, to which were applied multipliers to represent loss fractions (Zarbock et al., 1994; 1996). For the 1995-1998 estimates, all facilities provided spreadsheets containing loss estimates due to handling losses and airborne (fugitive) losses on an annual basis for the 1995-1998 period. These estimates were requested and obtained through the assistance of Mr.

Craig Kovach, CF Industries, and provided to the TBEP in electronic format. The letter accompanying these electronic files is provided in Appendix A.

The loss estimates for the 1995-1998 period were much less than those from the 1992-1994 period (Zarbock et al., 1996). For the 1992-1994 estimates, facility personnel provided rock and chemical masses shipped. The shipped products were then converted to losses using conversion factors based on methods developed by Morrison and Eckenrod (1994). These methods suggested an overall loss rate of approximately 0.02% of product shipped, so that the total masses of nitrogen and phosphorus in the shipped product were multiplied by 0.0002 to derive the pollutant loadings from the phosphate handling facilities. The estimates for the 1995-1998 period, however, represent the best estimates by facility personnel of actual losses. These estimates reflect both actual reductions in nutrient losses from improved handling practices implemented by most facilities, and improved loss estimation techniques for both ship loading losses and air borne losses. A database containing material losses for each facility for the 1995-1998 period is provided on the accompanying CD.

2.6.2 Data Summary

Annual average pollutant loads from material losses to Tampa Bay for the 1995-1998 period were estimated at approximately

- TN - 33 tons/year, and
- TP - 106 tons/year.

Annual average bay segment loads for TN were 32.4 tons/year to Hillsborough Bay and 0.3 ton/year to Lower Tampa Bay. Annual average bay segment loads for TP were 105 tons/year to Hillsborough Bay and 1 ton/year to Lower Tampa Bay.

Table 2-4. Fertilizer handling facilities 1995-1998.

Facility Name	Bay Segment
CF Industries	Hillsborough Bay
CSX	Hillsborough Bay
Cargill	Hillsborough Bay
Eastern	Hillsborough Bay
IMC-Agrico Big Bend	Hillsborough Bay
IMC-Agrico Port Sutton	Hillsborough Bay
Pakhoed Port Manatee	Lower Tampa Bay
Pakhoed Port Sutton	Hillsborough Bay

The 1995-1998 estimated average annual TN loads to Tampa Bay (33 tons/year) are much lower than those of the 1992-1994 period (251 tons/year). Average annual TP loads to the bay for the 1995-1998 period (106 tons/year) are likewise much lower than those of the 1992-1994 period (368 tons/year). The lower loadings for the 1995-1998 period, as described above, are the result of improved handling practices at the facilities, and improved estimates of losses at the facilities compared to the estimates derived for the 1992-1994 period.

2.7 Nonpoint Sources

Nonpoint source pollutant loadings result from stormwater runoff from the Tampa Bay watershed and base flow from the rivers draining to the bay. The estimated nonpoint source loadings for the 1995-1998 period were derived using the same methods as those for the previous loadings estimates (Zarbock et al., 1994; 1996). The SWFWMD 1995 land use was utilized for the 1995-1998 nonpoint source loadings estimates, whereas previous estimates used the SWFWMD 1990 landuse.

2.7.1 Methods

Nonpoint source TN, TP, TSS, and BOD loadings for the gaged and ungaged portions of the watershed were estimated for the period 1995-1998. The methods for estimating loadings from gaged basins and ungaged basins are described below.

The methods for estimating pollutant loadings from the watershed are presented in Figure 2-1 below. It should be noted that the watershed pollutant loadings include loadings from nonpoint sources, domestic point sources, industrial point sources, and springs. The first method shown in Figure 2-1 is used for those gaged basins for which both measured flow and water quality data exist. The second method is used for those gaged basins for which measured flow data exist, but for which no measured water quality data exist. The third method is used for ungaged basins, for which neither flow nor water quality data are measured. Each of these methods is described below.

Streamflow data were obtained from USGS, SWFWMD, Manatee County, and the City of Bradenton. Water quality data were obtained from the USGS, EPCHC, Pinellas County Department of Environmental Management, and Manatee County.

Gaged Basins with Measured Streamflow and Water Quality Data. Measured streamflow data and measured water quality data were used to estimate nonpoint source loadings from the gaged basins where both data types existed. As shown in Figure 2-1, pollutant loadings from these basins were estimated by multiplying measured monthly flows (Q) at stream gage sites by pollutant concentrations (WQ) measured at or very near the same site, yielding monthly pollutant loads at each gaged point. The pollutant concentration for any missing month at a stream gage was estimated by interpolating between the nearest preceding and succeeding months. Pollutant loads for the most downstream gage in each gaged river and stream were estimated on a monthly basis. Data from the sites in Table 2-5 were used to estimate gaged area loadings.

To derive the nonpoint source loading estimates using this method, the contributions of domestic and industrial point sources in the gaged basins were subtracted from the total watershed loadings estimates. This provided estimates of the loadings from nonpoint sources only.

Gaged Basins with Measured Streamflow but no Water Quality Data. Measured streamflow and estimated water quality data were used to estimate nonpoint source loadings from the gaged basins for which measured water quality data did not exist.

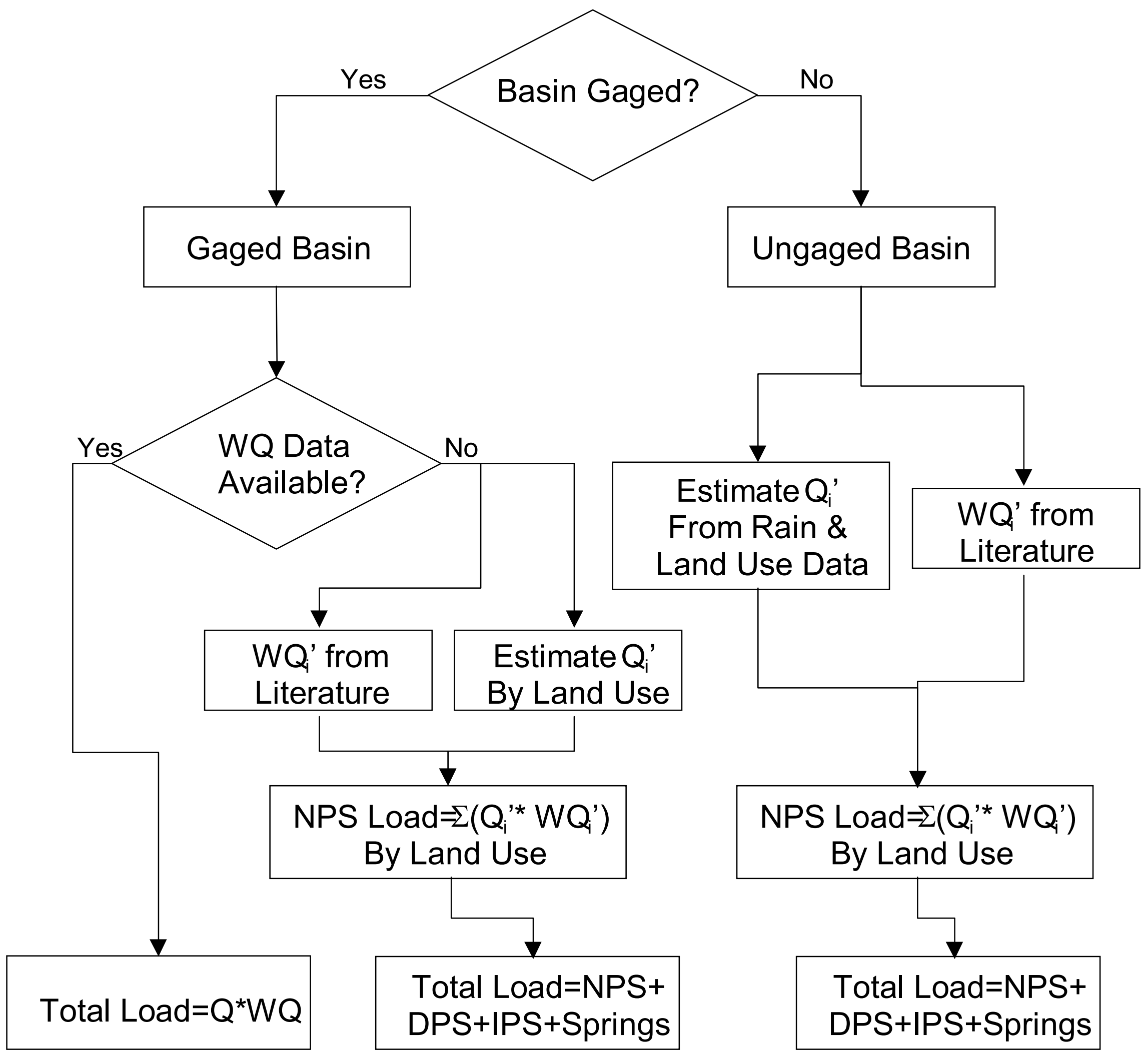

Figure 2-1. Process for estimated total watershed loadings from gaged and ungaged basins.

As in previous loading estimates, derivation of pollutant loadings from these basins involved utilization of streamflow data and data from GIS coverages for land use and subbasin boundaries, wet and dry season land use-specific runoff coefficients, and land use-specific water quality concentrations. Land use information was obtained from the SWFWMD GIS coverages based on 1995 aerial photographs and classified according to the Florida Land Use and Cover Classification System (FDOT, 1985). Land uses were aggregated into 21 categories (Appendix B) for loading calculations. Subbasin delineations were also obtained from SWFWMD, and were based on USGS subbasin boundaries (Foose, 1993). The land use categories and subbasin boundaries are the same as those used in the previous loading estimates (Zarbock et al., 1994; 1996).

Table 2-5. Downstream Stream Gage Stations

Stream Gage Site Name	Streamflow (Agency/Site Number)	Water Quality (Agency/Site Number)
Lake Tarpon Outfall Canal	SWFWMD/FLO12 (S-551)	PCDEM/3-9
Rocky Creek	USGS/02307000	EPCHC/103
Sweetwater Creek	USGS/02306647	EPCHC/104
Hillsborough River at Dam	USGS/02304500	EPCHC/105
Tampa Bypass Canal	SWFWMD/FLO13 (S-160)	EPCHC/147
Delaney Creek	USGS/02301750	EPCHC/138
Alafia River at Lithia	USGS/02301500	EPCHC/114
Bullfrog Creek	USGS/02300700	EPCHC/132
Little Manatee River at Wimauma	USGS/02300500	EPCHC/113
Manatee River at Lake Manatee Dam	Manatee County/Lake Manatee Dam	Manatee County/Lake Manatee Dam

As shown in Figure 2-1, for each land use category (i), specific water quality concentrations (WQ_i') were obtained from the literature (Appendix C). Runoff from each land use category was estimated by apportioning the nonpoint source streamflow among the constituent land use categories in the basin. The nonpoint source streamflow was derived from the gaged basin flow by subtracting domestic point source, industrial point source, and spring contributions from the gaged flow. The apportionment of the nonpoint source flows to each land use category was accomplished as follows:

$$Q_i' = \frac{Q_n A_i R_i}{\sum_i A_i R_i}$$

where:

Q_i' = total nonpoint source flow (m^3/month) from land use category *i*,

Q_n = total nonpoint source flow (m3/month) from the gaged basin,

A_i = area of land use category *i* in gaged basin, and

R_i = runoff coefficient for land use category *i* for the month, representing fraction of rainfall that runs off of the land (Appendix D).

As shown in Figure 2-1, nonpoint source pollutant loadings from these basins were estimated by multiplying the monthly nonpoint source flows apportioned to each land use category (Q_i') by the land use-specific pollutant concentrations (WQ_i'), yielding monthly pollutant loadings from each land use category in the basin. The monthly pollutant loadings from all land use categories were then summed over the basin to provide an estimate of the total nonpoint source pollutant loadings from the basin.

Ungaged Basins. The empirical model was used with NWS rainfall data, GIS coverages for 1995 land use, soils, and subbasin boundaries, seasonal land use-specific runoff coefficients (Appendix D), and land use-specific water quality concentrations (Appendix C) to estimate pollutant loads from ungaged areas of the watershed. Land use information was taken from the SWFWMD GIS coverages based on 1995 aerial photographs and classified according to the Florida Land Use and Cover Classification System (FDOT, 1985). Land uses were aggregated into 21 categories for loading calculations. Soils data were taken from the SWFWMD GIS coverages that included soil series and hydrologic soils group information from the Natural Resources Conservation Service Soil Surveys. Subbasin delineations were also obtained from SWFWMD, and were based on USGS subbasin boundaries (Foose, 1993).

The empirical model provides estimates of runoff from ungaged portions of the watershed. The empirical model was validated by comparison with measured flows from ten gaged basins in the watershed, as described in Zarbock et al (1994). A complete description of the model is provided in Zarbock et al. (1994). A summary of the model is provided here.

The empirical model predicts runoff as a function of rainfall and land use categories, using a log-linear relationship. Rainfall amounts for the current month and the two previous months were included in the formulation. The 21 land use categories were aggregated into four land use types: urban, agricultural, wetlands, and forests. The total monthly nonpoint source flow from each ungaged basin is estimated using the log-linear relationship. The nonpoint source flow is then apportioned to each of the 21 land use categories as a function of the area of the land use category in the basin and the seasonal land use-specific runoff coefficients, as described previously.

As shown in Figure 2-1, for each land use category (i), specific water quality concentrations (WQ_i') were obtained from the literature (Appendix C). Runoff (Q_i') from each land use category was estimated by the empirical model. The product of the literature-based land use-specific water quality concentrations and the estimated runoff from each land use category is summed over each basin to provide the pollutant loadings from each basin.

A modification to the methods of estimating nonpoint source loads was employed for one month of the 1995-1998 period for the Alafia River drainage basin. During December 1997, an unplanned release of process water occurred from the Mulberry Phosphate facility in the Alafia River basin. The release totaled approximately 50 million gallons of process water and associated nitrogen and phosphorus loads (Cardinale, 1998).

As shown in Table 2-5, the pollutant loadings from this basin are normally estimated using the USGS flow record at Lithia and the normal monthly water quality monitoring data at EPC Station 114. During December 1997, the normal EPC monitoring at Station 114 occurred shortly after the process water release, and reflected the effects of the release in the very high concentrations of nitrogen and phosphorous observed. Using these concentration data, unusually large loads of pollutants would result for this month.

In response to the process water release, the EPC performed additional water quality monitoring in the Alafia River during December 1997. The release occurred on December 7. The EPC monitored water quality near Station 114 on December 9, 10, and 15, with the December 10 monitoring as part of the normal monthly monitoring. Using these water quality data, a parametric spline interpolation was used to develop curves to represent the declining pollutant concentrations over time following the spill at Station 114. The daily pollutant concentrations estimated from the curves for TN and TP concentrations were multiplied by the daily flows from the USGS records to derive daily loading estimates for the Alafia River basin. These daily estimates were summed for December 1997 to provide a monthly loading estimate.

A database containing the data utilized to estimate 1995-1998 nonpoint source loadings, and the resultant loadings, is provided on the CD accompanying this report.

2.7.2 Data Summary

Annual average pollutant loads from nonpoint sources to Tampa Bay for the 1995-1998 period were estimated at approximately

- TN - 3,161 tons/year,
- TP - 1,686 tons/year,
- TSS - 54,077 tons/year, and
- BOD - 8,576 tons/year.

Annual average bay segment loadings for TN ranged from 1,422 tons/year to Hillsborough Bay to 16 tons/year to Terra Ceia Bay. Annual average bay segment loadings for TP ranged from 1,248 tons/year to Hillsborough Bay to 4 tons/year to Terra Ceia Bay. Annual average bay segment loadings for TSS ranged from 26,000 tons/year to Hillsborough Bay to 355 tons/year to Terra Ceia Bay. Annual average bay segment loadings for BOD ranged from 2,502 tons/year to Hillsborough Bay to 76 tons/year to Terra Ceia Bay.

The 1995-1998 average annual TN loadings to Tampa Bay (3,161 tons/year) are higher than those of the 1992-1994 period (1,723 tons/year). Average annual TP loadings to the bay for the 1995-1998 period (1,686 tons/year) are also much greater than those of the 1992-1994 period (581 tons/year). Average annual TSS loadings to the bay for the period 1995-1998 (54,086 tons/year) are also greater than those for the 1992-1994 period (26,707 tons/year).

The large increases in pollutant loadings to the bay during the 1995-1998 period in comparison to the 1992-1994 period were primarily attributable to the higher rainfall. Annual average rainfall during the 1995-1998 period was greater than during the 1992-1994 period. At Tampa International Airport, 1995-1998 annual average rainfall was 57 inches, compared to 40 inches during 1992-1994.

Annual average hydrologic loads to each bay segment during 1995-1998 were greater than those during 1992-1994 by factors ranging from 1.2 for Middle Tampa Bay to 2.2 for Old Tampa Bay and 2.6 for Boca Ciega Bay. The annual average hydrologic loadings to each bay segment resulting from the higher rainfall during the 1995-1998 period are shown in Table 2-6, with the annual average hydrologic loadings from the 1992-1994 period shown for comparison.

The relatively small increase in hydrologic load to Middle Tampa Bay is tied to the relatively small increase in estimated annual average rainfall to the segment's watershed. Average annual rainfall was approximately 59 inches during 1995-1998 and 53 inches during 1992-1994. The relatively large increases in hydrologic loads to Old Tampa Bay and Boca Ciega Bay are related to the relatively large increases in estimated annual average rainfall to the watersheds of these segments. In the Old

Tampa Bay watershed the estimated average annual 1995-1998 rainfall was 58 inches, whereas in 1992-1994 it was 45 inches. Similarly, in the Boca Ciega Bay watershed the estimated average annual 1995-1998 rainfall was 58 inches, whereas in 1992-1994 it was 44 inches.

Table 2-6. Average annual nonpoint source hydrologic loading estimates (10^6 m^3/year).		
Bay Segment	**1992-1994**	**1995-1998**
Old Tampa Bay	119	262
Hillsborough Bay	512	948
Middle Tampa Bay	250	306
Lower Tampa Bay	34	58
Boca Ciega Bay	36	95
Terra Ceia Bay	8	13
Manatee River	202	401

The increase in nonpoint source TN loadings for most bay segments generally follows the increase in hydrologic loading. The average annual nonpoint source TN loadings for the 1992-1994 and 1995-1998 periods are shown in Table 2-7 for each bay segment.

Table 2-7. Average annual nonpoint source TN loading estimates (tons/year).		
Bay Segment	**1992-1994**	**1995-1998**
Old Tampa Bay	174	340
Hillsborough Bay	596	1422
Middle Tampa Bay	415	467
Lower Tampa Bay	36	57
Boca Ciega Bay	69	179
Terra Ceia Bay	11	16
Manatee River	422	680

The greatest increase in estimated nonpoint source TN loading occurred to Hillsborough Bay, in terms of absolute magnitude. In addition to the higher rainfall during the 1995-1998 period than during the 1992-1994 period, an unplanned release of process water occurred in December 1997 from the Mulberry Phosphate facility in the Alafia River major basin, which drains to Hillsborough Bay. The average annual nonpoint source TN loading from the Alafia River major basin for the 1995-1998 period was 630 tons/year, accounting for approximately 44% of the average annual nonpoint source load to Hillsborough Bay.

The estimated TN loading from the Mulberry Phosphate process water release was 328 tons (FDEP, 2000), based on typical process water nitrogen concentrations. The estimated TN loading from all nonpoint sources in the Alafia River basin for December 1997 was 375 tons. For the other three years of the 1995-1998 period, December TN loadings averaged 15 tons. The hydrologic loading from the Alafia River basin during December 1997 was estimated at 114 million m^3, compared to an average 8 million m^3 during December 1995, 1996, and 1998. The nonpoint source TN loading per unit hydrologic load was approximately 3 tons/million m^3 in December 1997, and approximately 2 tons/million m^3 during the other three years of the period.

Considerable year-to-year variation was observed in the estimated nonpoint source TN loadings to the bay. An evaluation of the annual 1995-1998 TN loading per unit area of the watersheds of each bay segment was completed, with comparison to the mean annual 1992-1994 loading per unit area. The results of this evaluation are presented in Table 2-8.

Table 2-8. Estimated nonpoint source TN loadings per unit area (kg/ha/year), mean annual 1992-1994 and annual 1995-1998.

Segment	1992-1994	1995	1996	1997	1998
Old Tampa Bay	2.5	5.0	2.7	5.1	6.7
Hillsborough Bay	1.7	4.1	2.2	3.7	6.0
Middle Tampa Bay	3.0	7.6	2.8	5.8	6.5
Lower Tampa Bay	4.4	8.1	3.2	7.2	9.2
Boca Ciega Bay	3.1	13.6	2.7	8.0	7.9
Terra Ceia Bay	4.0	7.0	2.9	6.6	7.4
Manatee River	4.3	8.6	2.4	8.4	8.4

Estimated annual TN loadings per unit area from nonpoint sources were typically greater during 1995-1998 than during 1992-1994, as expected given the estimated hydrologic loadings (Table 2-6). In most bay segments, estimated TN loadings per unit area followed similar patterns, with low values in 1996 and higher values in 1995, 1997, and 1998. Estimated unit TN loadings during 1997 were typically 2-3 times those of 1996.

Contributions to nonpoint source loadings from specific land use types during the 1995-1998 period are addressed in a report currently in preparation. This report will address not only loadings from the 1995-1998 period, but also address updated future loadings for the 2010 period.

3. HYDROLOGIC LOADINGS

Changes in hydrologic loadings were examined to evaluate whether increases in pollutant loadings were due to increased hydrologic loadings, the results of higher rainfall totals, or to anthropogenic activities. If higher than expected pollutant loadings result, then anthropogenic activities may be suspected as a causative factor. For this reason, annual variations in hydrologic loadings were examined with respect to annual rainfall totals.

Annual rainfall totals were greater during the 1995-1998 period than during the 1992-1994 period, as discussed above. Table 2-6 presented the mean annual nonpoint source hydrologic loadings for the 1992-1994 period and the 1995-1998 period. Hydrologic loadings also increased from other sources as well, however. This section presents the estimated hydrologic loads from each loading source for each bay segment, as well as total hydrologic loads to the segments.

In comparison to the 1992-1994 period, 1995, 1997, and 1998 were relatively wet years, as shown in Table 3-1 below. Especially notable is the unusually high rainfall totals during 1997, the result of the El Niño event of 1997-1998. In particular, during 1997 the annual rainfall totals to the watersheds draining to each bay segment were typically 25%-60% greater than during the 1992-1994 period.

Table 3-1. Total rainfall (inches) to the watersheds draining to each bay segment, mean annual 1992-1994 and annual 1995-1998.

Year	Bay Segment						
	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River
1992-1994	44.9	51.6	53.3	55.4	44.0	56.4	58.2
1995	57.2	56.0	62.5	64.1	63.1	64.3	63.7
1996	49.6	49.7	45.3	47.0	44.0	47.7	47.0
1997	67.7	65.0	71.3	73.3	71.7	74.1	73.5
1998	55.4	58.2	58.3	56.4	54.8	57.2	59.6

The estimated hydrologic loadings from each source to the seven bay segments are shown in Tables 3-2 through 3-8. During 1995, 1997, and 1998, hydrologic loading contributions from atmospheric deposition and nonpoint sources accounted for larger proportions of the total hydrologic loading than during the 1992-1994 period. For example, these two sources accounted for approximately 67% of the total hydrologic loadings during the 1992-1994 period in Hillsborough Bay and approximately 84% of the total during 1998. Because rainfall drives the atmospheric and nonpoint source contributions to hydrologic loadings, the hydrologic loadings were typically higher during the 1995-1998 period than during the 1992-1994 period.

Table 3-2. Estimated hydrologic loadings (10^6 m^3/year) to Old Tampa Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	254	344	285	409	328
Domestic Point Sources	46	51	55	48	50
Industrial Point Sources	<1	0	0	1	2
Springs	0	0	0	0	0
Groundwater	28	37	38	40	40
Nonpoint Sources	102	256	141	281	369
TOTAL	430	687	514	780	789

Table 3-3. Estimated hydrologic loadings (10^6 m^3/year) to Hillsborough Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	127	159	131	189	154
Domestic Point Sources	91	103	97	104	113
Industrial Point Sources	63	137	68	44	59
Springs	62	68	68	57	82
Groundwater	93	54	56	56	57
Nonpoint Sources	512	925	580	820	1469
TOTAL	948	1447	1000	1270	1933

Table 3-4. Estimated hydrologic loadings (10^6 m^3/year) to Middle Tampa Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	345	466	328	532	411
Domestic Point Sources	15	17	16	14	16
Industrial Point Sources	32	26	15	27	51
Springs	0	0	0	0	0
Groundwater	4	3	4	6	7
Nonpoint Sources	252	400	146	296	383
TOTAL	648	912	509	875	869

Table 3-5. Estimated hydrologic loadings (10^6 m^3/year) to Lower Tampa Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	324	403	290	464	354
Domestic Point Sources	2	2	2	2	2
Industrial Point Sources	<1	0	0	<1	1
Springs	0	0	0	0	0
Groundwater	2	3	2	1	1
Nonpoint Sources	31	61	26	64	80
TOTAL	359	469	321	531	437

Table 3-6. Estimated hydrologic loadings (10^6 m^3/year) to Boca Ciega Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	106	147	102	168	127
Domestic Point Sources	3	3	4	14	6
Industrial Point Sources	0	0	0	0	0
Springs	0	0	0	0	0
Groundwater	2	<1	<1	1	1
Nonpoint Sources	36	159	31	95	95
TOTAL	147	310	138	278	229

Table 3-7. Estimated hydrologic loadings (10^6 m^3/year) to Terra Ceia Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	23	26	20	31	24
Domestic Point Sources	2	2	2	1	2
Industrial Point Sources	0	0	0	0	0
Springs	0	0	0	0	0
Groundwater	1	<1	<1	<1	1
Nonpoint Sources	8	14	6	14	16
TOTAL	33	43	28	47	42

Table 3-8. Estimated hydrologic loadings (10^6 m^3/year) to the Manatee River, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	60	68	51	79	60
Domestic Point Sources	10	11	10	11	11
Industrial Point Sources	2	2	2	2	2
Springs	0	0	0	0	0
Groundwater	5	2	2	2	2
Nonpoint Sources	296	440	174	478	509
TOTAL	372	524	239	573	585

4. POLLUTANT LOADINGS

This section examines the variation in annual TN loadings by bay segment for the 1995-1998 period. The focus is on the TN loadings because these loads are of most interest given the concerns of the Nitrogen Management Consortium. The TBEP adopted the "hold the line" strategy, aimed at keeping TN loadings to each bay segment at mean 1992-1994 levels, to aid in reaching the seagrass restoration goals of the program.

Rainfall and anthropogenic activities in the watershed and airshed are the major determinants of the TN loadings to Tampa Bay. Therefore, it is important to examine the relationship between the resultant hydrologic loadings and TN loadings on an annual basis. It is also important to examine the contributions of the different sources to arrive at explanations of the observed variations in TN loadings.

Figures 4-1 through 4-7 present the annual TN loadings to each bay segment for the 1985-1998 period. Similar presentations for TP, TSS, and BOD are provided in Appendix E. Loadings during 1995, 1997, and 1998 are typically among the highest observed during the 1985-1998 period in all bay segments. Examination of the rainfall and hydrologic loading data show that this result is not unexpected, as rainfall totals for 1995, 1997, and 1998 were among the highest observed during the 1985-1998 period. Specifically, TN loadings in Old Tampa Bay, Hillsborough Bay, Lower Tampa Bay, and the Manatee River were greatest in 1997 and 1998, as expected given the El Niño event of 1997-1998.

Table 4-1. Total annual rainfall (inches) to the watersheds draining to each bay segment watersheds.

Year	Bay Segment						
	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River
1985	47.6	49.7	48.8	51.3	48.7	50.0	46.3
1986	49.4	54.3	53.8	54.1	58.0	53.9	53.1
1987	54.7	56.6	54.5	55.1	57.2	55.8	55.8
1988	58.0	58.3	62.7	65.0	66.1	64.4	61.9
1989	43.2	45.4	48.8	52.2	43.5	53.0	52.5
1990	38.5	41.0	38.7	41.0	38.1	42.1	41.3
1991	48.3	49.8	48.2	46.6	48.4	47.3	49.6
1992	45.2	52.2	55.4	59.8	46.1	61.5	62.6
1993	41.8	44.7	48.3	50.0	41.5	50.5	52.3
1994	47.8	57.8	56.2	56.4	44.5	57.2	59.8
1995	57.2	56.0	62.5	64.1	63.1	64.3	63.7
1996	49.6	49.7	45.3	47.0	44.0	47.7	47.0
1997	67.7	65.0	71.3	73.3	71.7	74.1	73.5
1998	55.4	58.2	58.3	56.4	54.8	57.2	59.6

Statistical analyses were performed to examine if observed differences in loadings between the 1992-1994 baseline period and the 1995-1998 period were significant. Specifically, the annual TN loadings to each of the bay segments were compared using an analysis of variance, where the main effects or sources of variations included bay segment, year, or the interaction of the bay segment and year terms. It was found that using either un-transformed or log-transformed data (log-transformed to address the issue of non-homogeneity of variances or non-normality of data), no significant differences were found between years in any bay segment. However, significant differences did exist between bay segments. The data used for these analyses and the results are shown in Table 4-2.

Table 4-2. Data used and results of analysis of variance of annual TN loadings (tons).

Year	Bay Segment						
	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River
1992	435	1407	799	341	151	39	583
1993	444	1284	557	323	157	32	382
1994	555	1972	896	386	191	38	694
1995	653	2163	985	314	402	40	913
1996	475	1459	484	211	132	25	295
1997	758	2012	936	458	343	46	931
1998	811	3023	944	457	290	43	909
F	0.86	1.85	0.79	1.41	1.68	0.61	1.27
p>F	0.5286	0.1005	0.5782	0.2229	0.1381	0.7177	0.2789

Further analysis was performed to examine differences between the mean annual TN loadings for the baseline period and the 1995-1998 period. Using similar methods, significant differences were found between the periods only in Boca Ciega Bay (Table 4-3). However, for most bay segments, no significant differences were found between the two periods.

Table 4-3. Data used and results of analysis of variance of mean annual TN loadings (tons).

Period	Bay Segment						
	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River
92-94	478	1554	751	350	166	36	553
95-98	674	2164	837	360	292	39	762
F	3.03	2.78	0.36	0.04	4.22	0.2	1.2
p>F	0.0855	0.0994	0.5475	0.8444	0.0430	0.6556	0.2766

To further examine the influence of rainfall on TN loading to Tampa Bay, the relationship between annual TN loadings to each bay segment for the 1985-1998 period and the annual hydrologic loadings were examined, as shown in Figures 4-8 through 4-14. Assuming the relationships between TN loadings and hydrologic loadings are linear within each bay segment, there should be no changes in the ratios within each bay segment. If there were no major changes in anthropogenic activities between the 1985-1994 and 1995-1998 periods, the 1995-1998 TN loadings should fall along the same lines as those from 1985-1994. Deviations from the linear relationships suggest changes in the anthropogenic impacts on TN loadings.

As shown in Figures 4-8 through 4-14, the relationship of TN loadings to hydrologic loadings was similar during both periods in all bay segments. Despite the loadings generated by the Mulberry Phosphate release in 1997, the ratio of TN loading to hydrologic loading was relatively constant even in Hillsborough Bay.

Examination of the loadings by source provides important information concerning which sources have contributed to the loadings increases observed during the 1995-1998 period. Mean annual TN loadings during the 1995-1998 period were higher than those of the 1992-1994 period. The 1995-1998 TN loadings are presented in Figure 4-15. The greatest contributions were from nonpoint source loadings, which accounted for 62% of the TN loadings. During the 1992-1994 period, nonpoint source contributions were 45%. Atmospheric deposition contributions during 1995-1998 accounted for 21% of the TN loadings, compared to 29% during the 1992-1994 period. All other sources also declined in importance with respect to TN loadings.

Estimated annual TN loadings from each pollutant source for each year of the 1995-1998 period are presented by bay segment in Tables 4-4 through 4-10, along with the mean annual TN loadings from each source for the 1992-1994 period. Graphical presentations of annual TN, TP, TSS, and BOD loadings by source for the 1985-1998 period are shown in Appendix F. Tabular and graphical summaries of the mean annual 1992-1994 and 1995-1998 estimated TN loadings are provided in Appendix G for comparison purposes.

Clearly, the most obvious difference between the two periods is the much higher TN loadings to Hillsborough Bay in the 1995-1998 period, particularly from nonpoint sources. As discussed previously, the large increases in nonpoint source TN loadings during 1997 and 1998 were a function of the increased rainfall and the process water release in December of 1997.

The increases in nonpoint source loadings may also have been partially the result of land use changes between 1990 and 1995. The 1992-1994 loadings estimates utilized 1990 land use data, whereas the 1995-1998 loadings were developed using 1995 land use data. Land use changes from 1990 to 1995 resulted in increases in urban, agricultural, and mining land uses in the watershed, with associated decreases in pasture, rangeland, forest, and wetlands. The changes in land use within the watershed draining to each bay segment are shown in Table 4-11, represented as the percentage of the watershed.

As expected, atmospheric deposition contributions to TN loadings were also higher in each bay segment during the 1997-1998 period than those of 1992-1994. The relative contributions to TN loading due to atmospheric deposition were less during the 1995-1998 period than during 1992-1994, however. Domestic and industrial point source contributions to TN loadings in Hillsborough Bay also increased during the 1995-1998 period. Industrial point source discharges contributed approximately 6% of the TN loading to Hillsborough Bay in 1998, with much of the discharge attributable to the unusually high rainfall of the period. This proportion of the TN loading was the same as during the 1992-1994 period, however. In contrast, industrial contributions to TN loadings in Lower Tampa Bay in 1998 accounted for approximately 21% of the loading to the segment. As in Hillsborough Bay, however, this discharge was related to the unusually high rainfall for the period.

Table 4-4. Estimated TN loadings (tons/year and percentage of total) by source to Old Tampa Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	227 (47%)	219 (33%)	193 (41%)	308 (41%)	258 (32%)
Domestic Point Sources	85 (18%)	83 (13%)	95 (20%)	90 (12%)	81 (10%)
Industrial Point Sources	0 (0%)	0 (0%)	0 (0%)	3 (0%)	4 (0%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	174 (36%)	350 (54%)	186 (39%)	357 (47%)	467 (58%)
TOTAL	486	653	475	758	811

Table 4-5. Estimated TN loadings (tons/year and percentage of total) by source to Hillsborough Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	115 (8%)	102 (5%)	87 (6%)	143 (7%)	121 (4%)
Domestic Point Sources	220 (15%)	263 (12%)	262 (18%)	267 (13%)	286 (9%)
Industrial Point Sources	80 (6%)	123 (6%)	79 (5%)	77 (4%)	202 (7%)
Springs	205 (14%)	203 (9%)	203 (14%)	171 (8%)	245 (8%)
Groundwater	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Material Losses	233 (16%)	34 (2%)	33 (2%)	31 (2%)	32 (1%)
Nonpoint Sources	596 (41%)	1437 (66%)	794 (54%)	1321 (66%)	2135 (71%)
TOTAL	1451	2163	1459	2012	3023

Table 4-6. Estimated TN loadings (tons/year and percentage of total) by source to Middle Tampa Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	306 (38%)	298 (30%)	211 (44%)	408 (44%)	322 (34%)
Domestic Point Sources	20 (3%)	32 (3%)	26 (5%)	22 (2%)	23 (2%)
Industrial Point Sources	58 (7%)	29 (3%)	20 (4%)	30 (3%)	60 (6%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	415 (52%)	626 (64%)	228 (47%)	475 (51%)	538 (57%)
TOTAL	799	985	484	936	944

Table 4-7. Estimated TN loadings (tons/year and percentage of total) by source to Lower Tampa Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	288 (83%)	246 (78%)	184 (87%)	362 (79%)	277 (61%)
Domestic Point Sources	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Industrial Point Sources	<1 (0%)	0 (0%)	0 (0%)	36 (8%)	103 (23%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	24 (7%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Nonpoint Sources	36 (10%)	67 (21%)	26 (12%)	59 (13%)	76 (17%)
TOTAL	349	314	211	458	457

Table 4-8. Estimated TN loadings (tons/year and percentage of total) by source to Boca Ciega Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	93 (53%)	94 (23%)	66 (50%)	129 (38%)	99 (34%)
Domestic Point Sources	15 (9%)	5 (1%)	8 (6%)	37 (11%)	14 (5%)
Industrial Point Sources	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	69 (39%)	302 (75%)	59 (45%)	177 (52%)	176 (61%)
TOTAL	177	402	132	343	290

Table 4-9. Estimated TN loadings (tons/year and percentage of total) by source to Terra Ceia Bay, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	20 (57%)	15 (38%)	12 (48%)	24 (52%)	19 (44%)
Domestic Point Sources	4 (11%)	5 (13%)	5 (20%)	4 (9%)	4 (9%)
Industrial Point Sources	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	11 (31%)	19 (48%)	8 (32%)	18 (39%)	20 (47%)
TOTAL	35	40	25	46	43

Table 4-10. Estimated TN loadings (tons/year and percentage of total) by source to the Manatee River, mean annual 1992-1994 and annual 1995-1998.					
Source	**1992-1994**	**1995**	**1996**	**1997**	**1998**
Atmospheric Deposition	54 (11%)	39 (4%)	32 (11%)	62 (7%)	47 (5%)
Domestic Point Sources	16 (3%)	25 (3%)	19 (6%)	19 (2%)	27 (3%)
Industrial Point Sources	11 (2%)	6 (1%)	11 (4%)	25 (3%)	12 (1%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	422 (84%)	842 (92%)	232 (79%)	824 (89%)	823 (91%)
TOTAL	503	913	295	931	909

Table 4-11. Changes in land use between 1990 and 1995, presented as percentage change in total land use acreage for the watershed draining to each bay segment.						
Segment	**Land Use Type**					
	Urban	**Agriculture**	**Pasture & Rangeland**	**Mining**	**Forest & Barren**	**Freshwater & Wetlands**
Old Tampa Bay	+1.4	+0.1	-2.2	0	-0.6	+1.3
Hillsborough Bay	+1.3	+1.2	-2.3	+0.5	-0.5	-0.1
Middle Tampa Bay	+0.6	+5.5	-6.3	+1.0	-0.1	-0.6
Lower Tampa Bay	+1.8	-1.6	0	0	+0.4	-0.6
Boca Ciega Bay	0	+0.1	-0.8	0	-0.5	+1.2
Terra Ceia Bay	+2.1	+1.3	-2.2	0	+0.8	-2.1
Manatee River	+1.4	+5.3	-2.9	+0.1	-3.9	-0.1

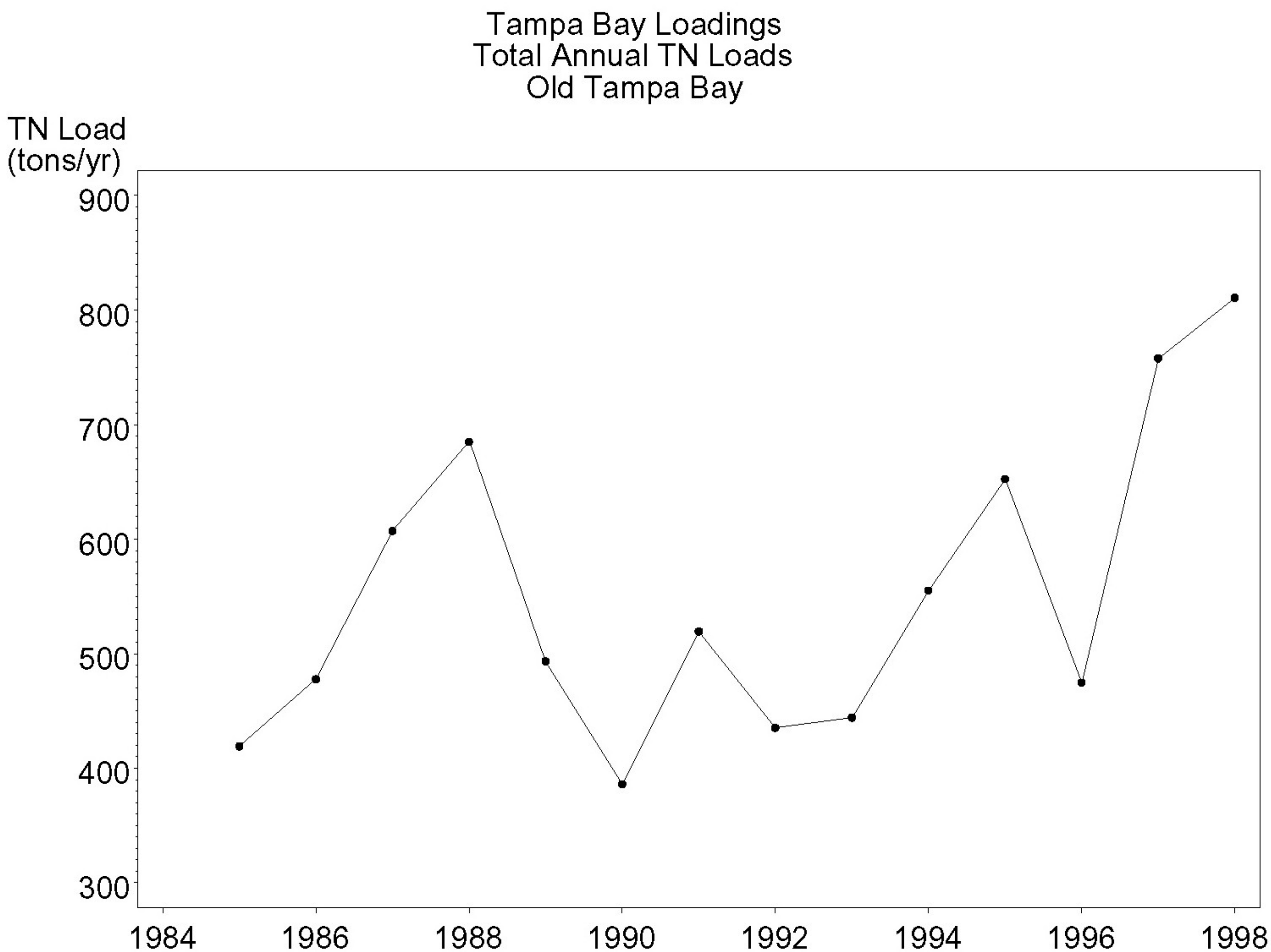

Figure 4-1. Estimated annual TN loadings to Old Tampa Bay, 1985-1998.

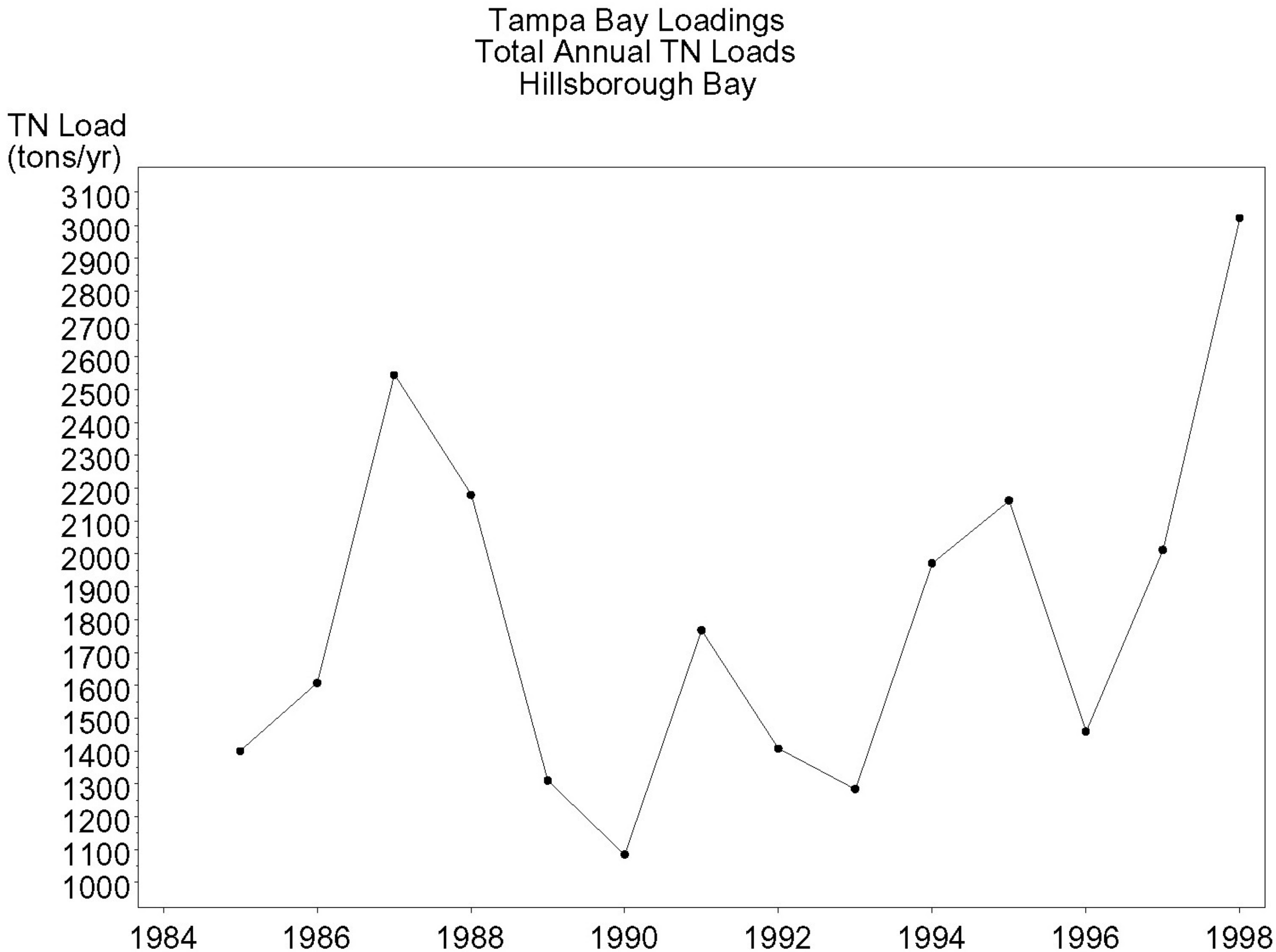

Figure 4-2. Estimated annual TN loadings to Hillsborough Bay, 1985-1998.

Figure 4-3. Estimated annual TN loadings to Middle Tampa Bay, 1985-1998.

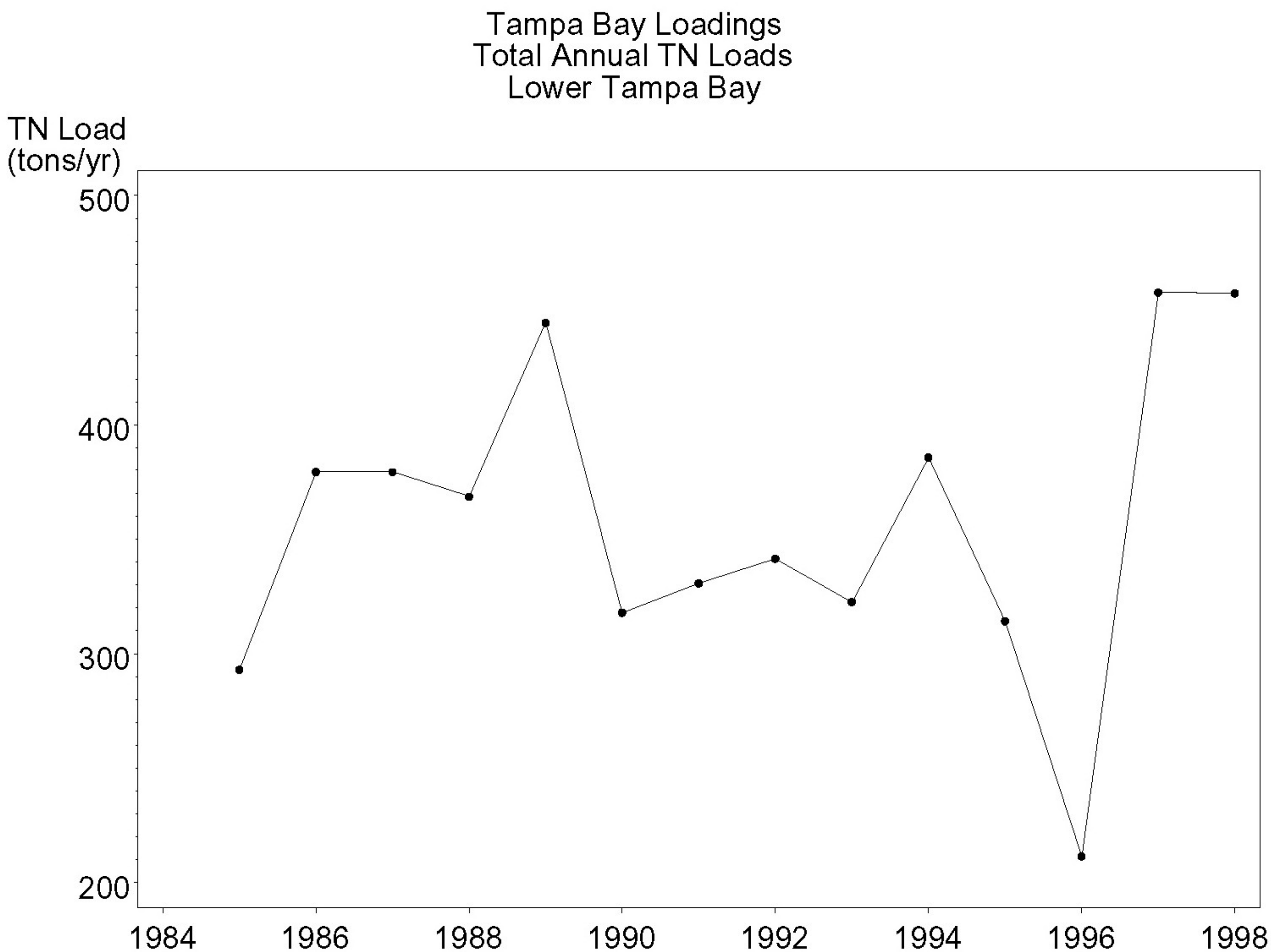

Figure 4-4. Estimated annual TN loadings to Lower Tampa Bay, 1985-1998.

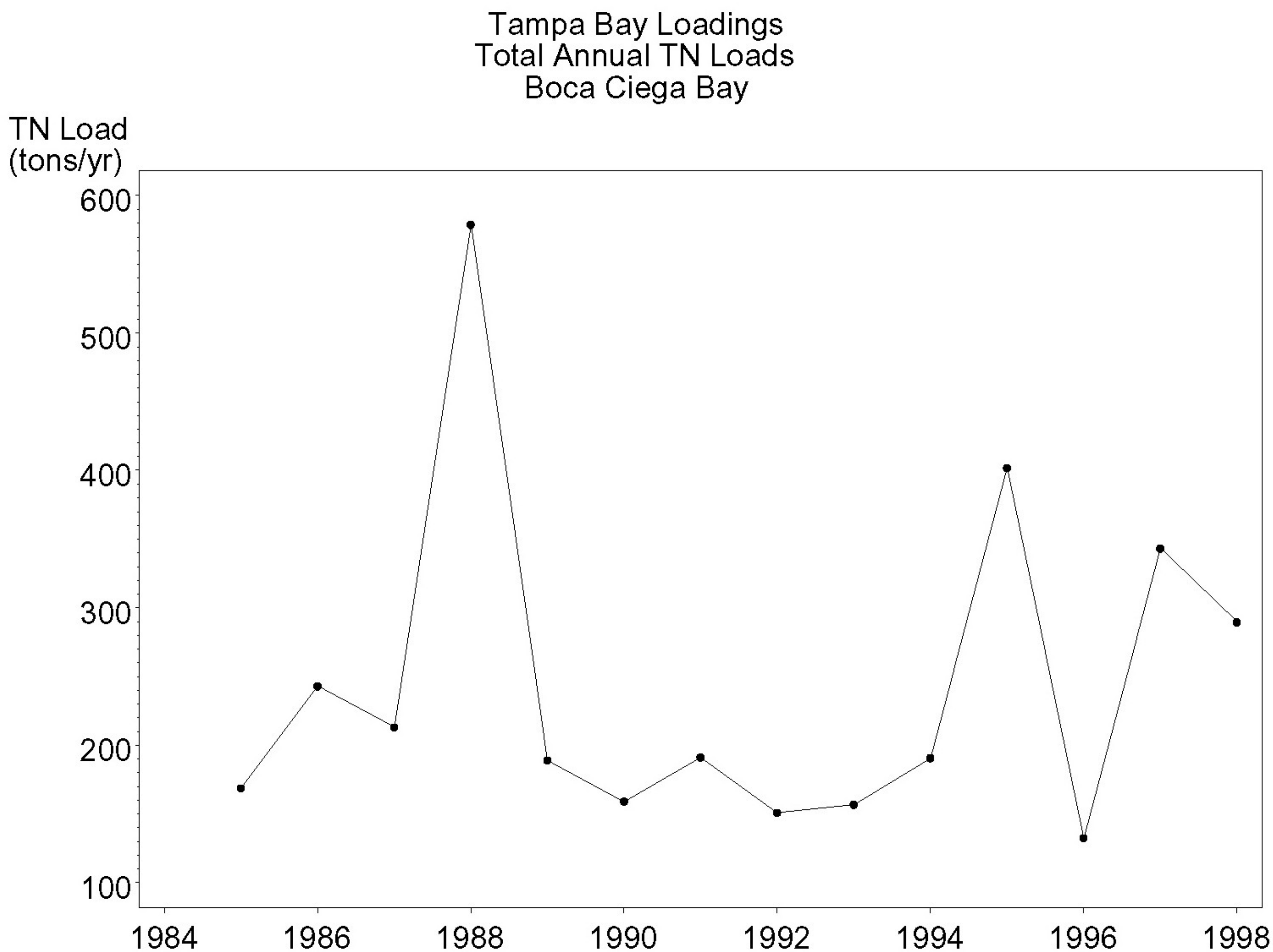

Figure 4-5. Estimated annual TN loadings to Boca Ciega Bay, 1985-1998.

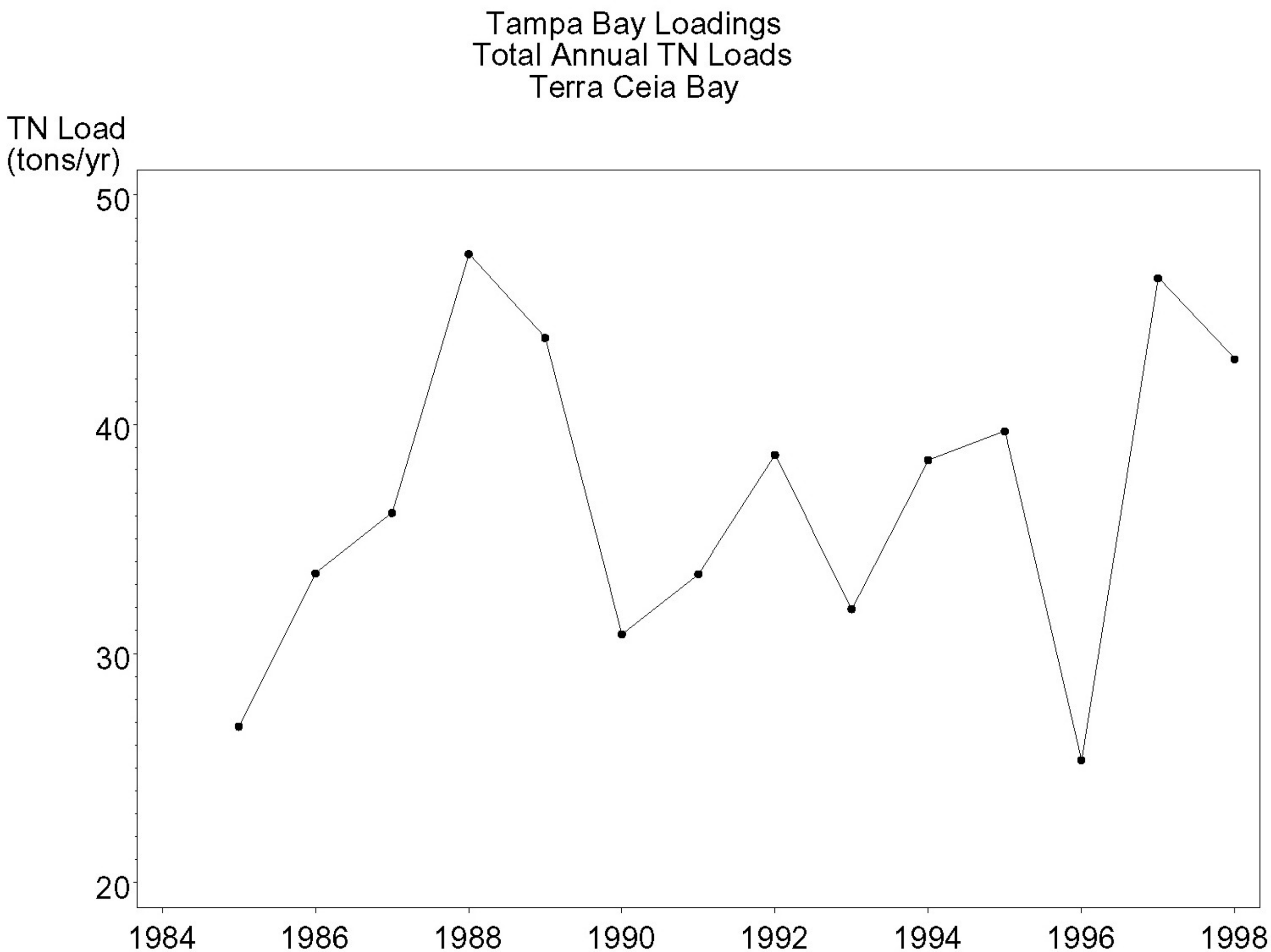

Figure 4-6. Estimated annual TN loadings to Terra Ceia Bay, 1985-1998.

Figure 4-7. Estimated annual TN loadings to the Manatee River, 1985-1998.

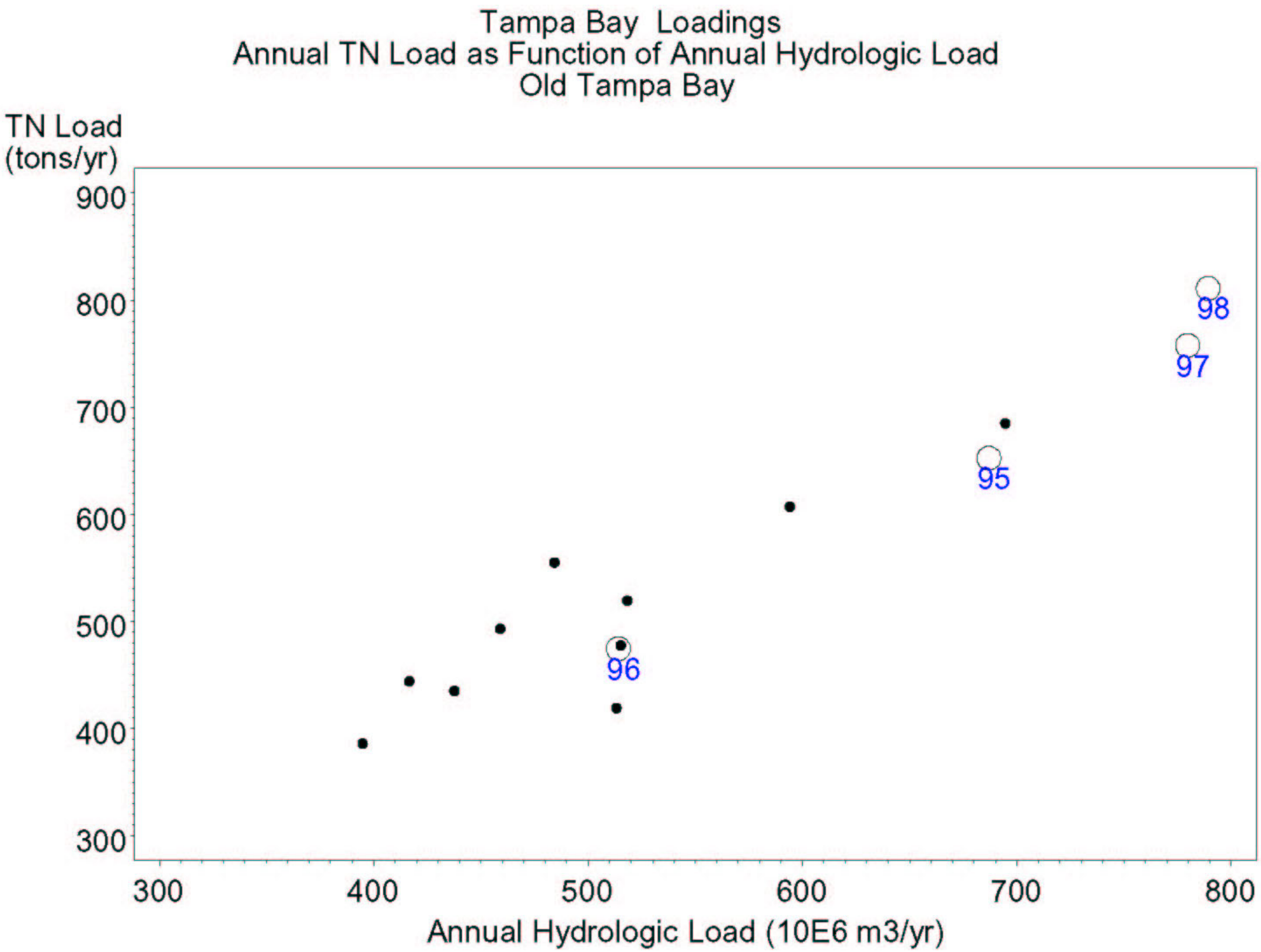

Figure 4-8. Relationship between TN and hydrologic loadings, Old Tampa Bay, 1985-1998.

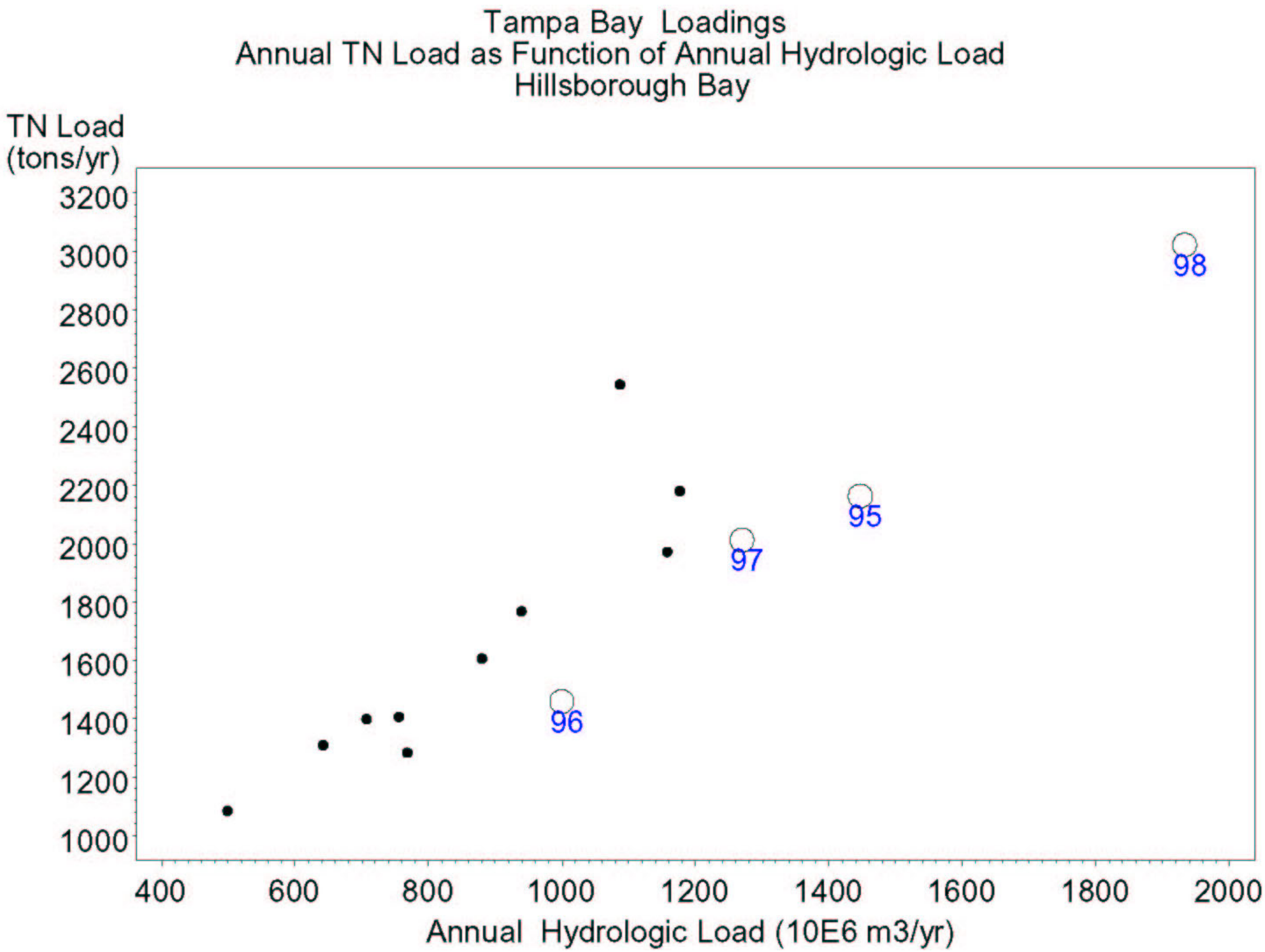

Figure 4-9. Relationship between TN and hydrologic loadings, Hillsborough Bay, 1985-1998.

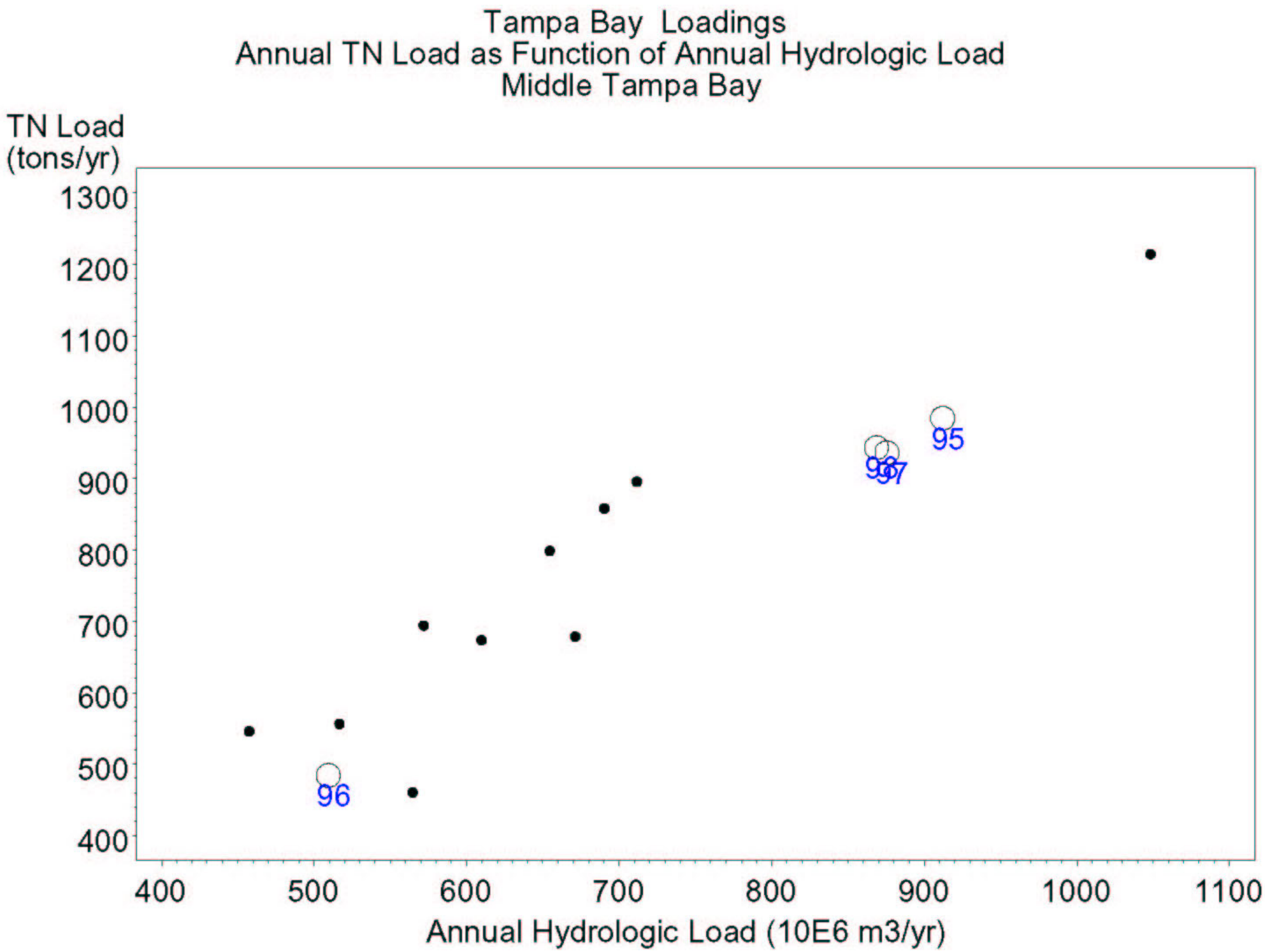

Figure 4-10. Relationship between TN and hydrologic loadings, Middle Tampa Bay, 1985-1998.

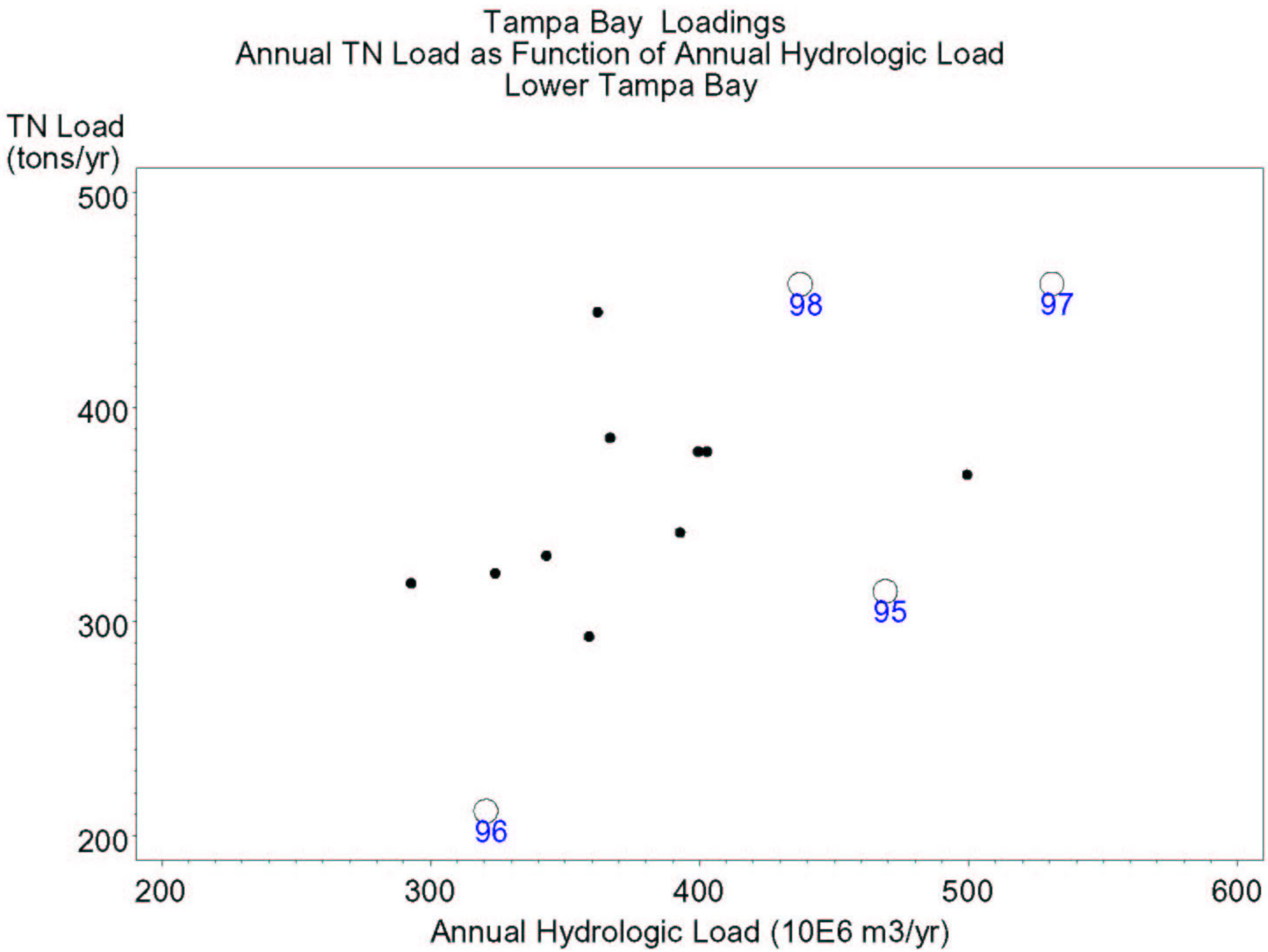

Figure 4-11. Relationship between TN and hydrologic loadings, Lower Tampa Bay, 1985-1998.

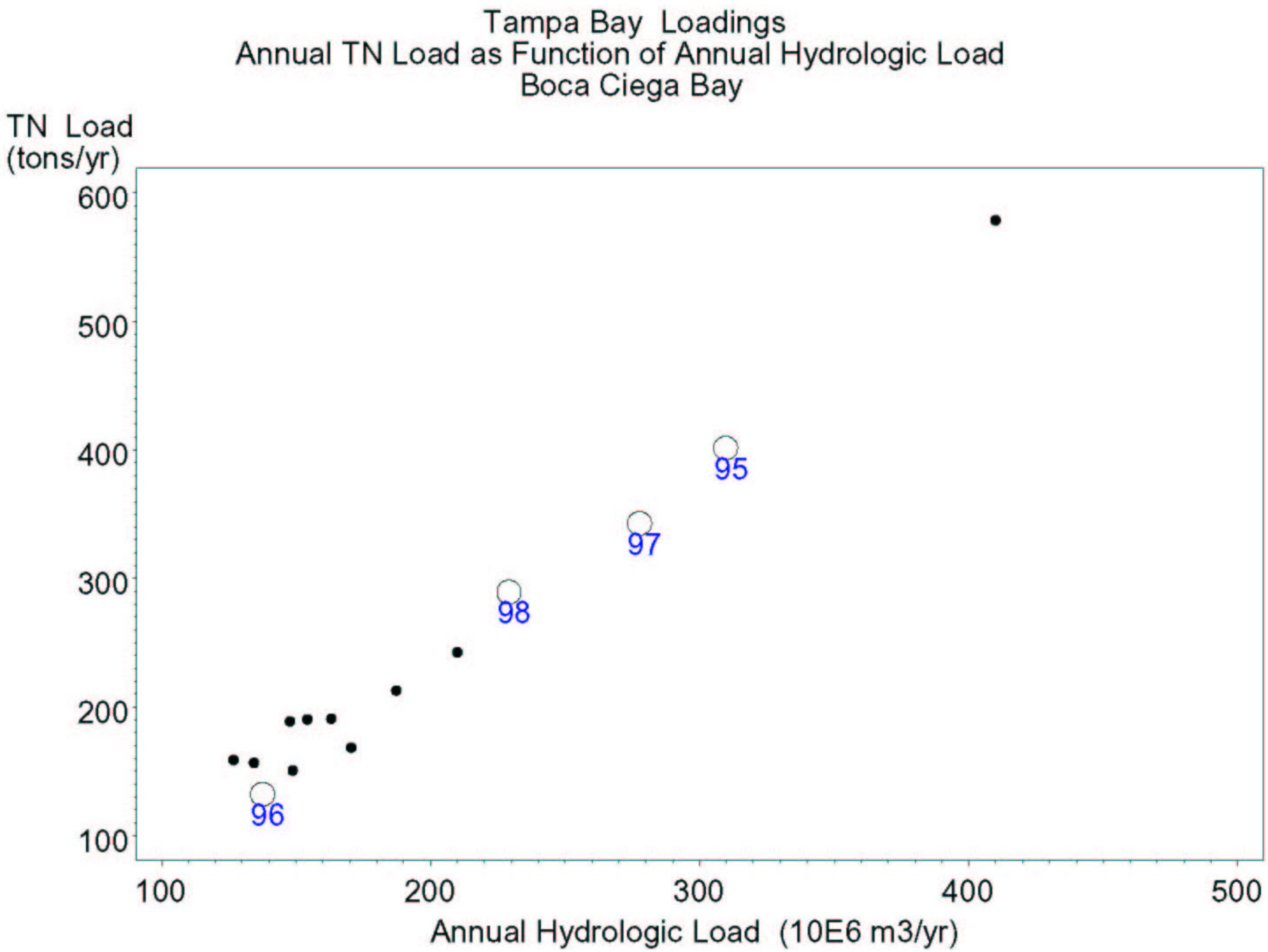

Figure 4-12. Relationship between TN and hydrologic loadings, Boca Ciega Bay, 1985-1998.

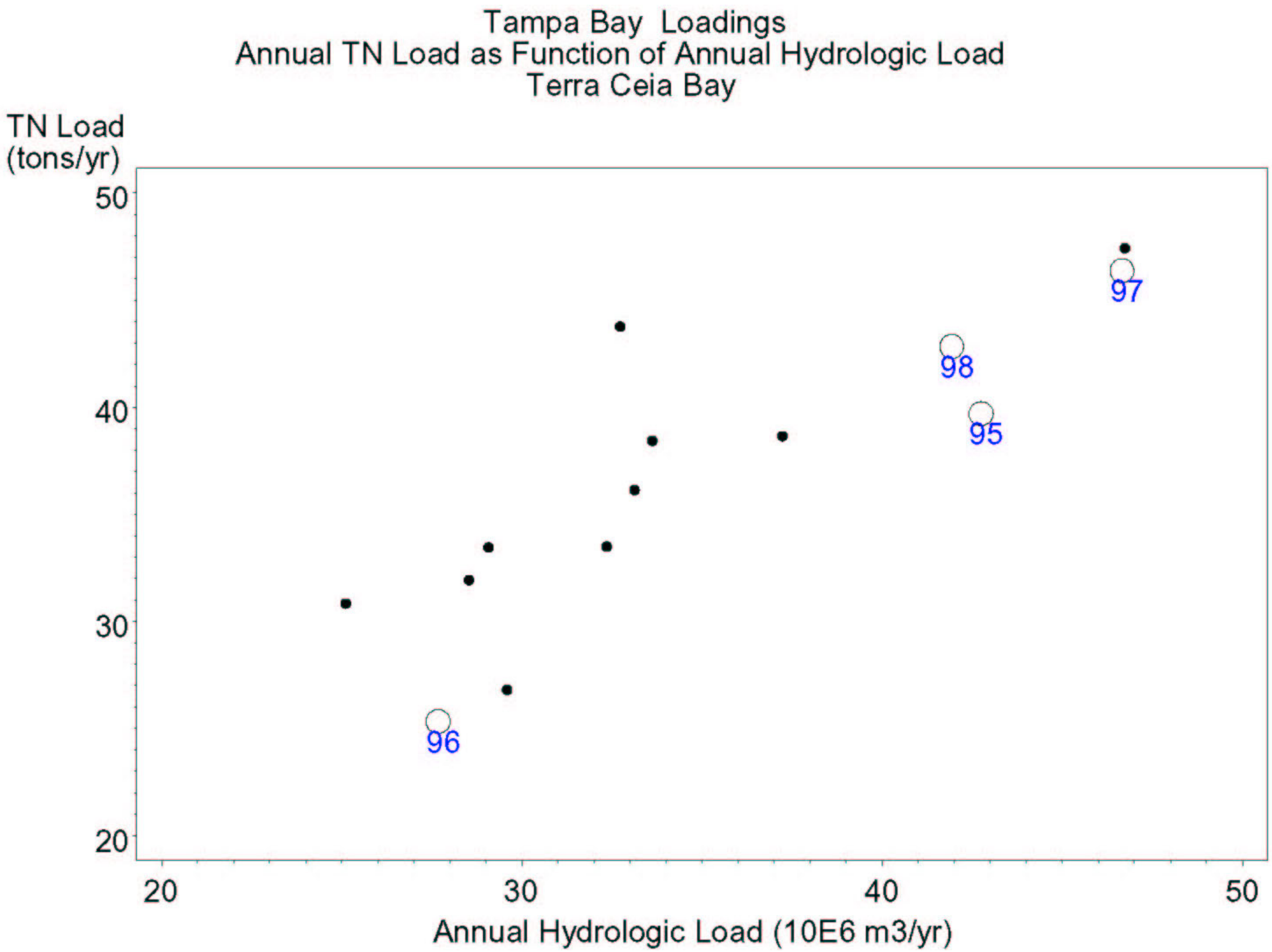

Figure 4-13. Relationship between TN and hydrologic loadings, Terra Ceia Bay, 1985-1998.

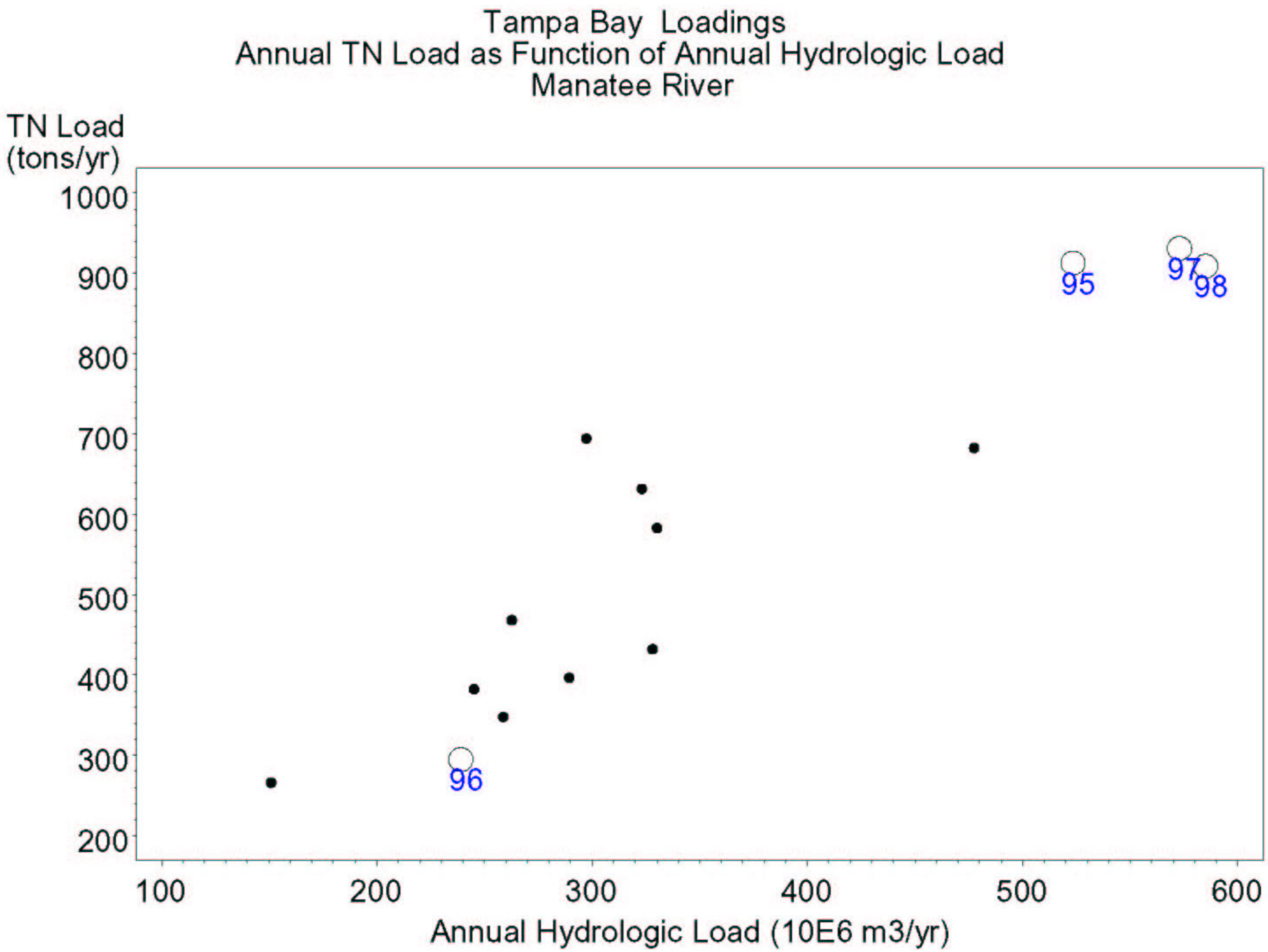

Figure 4-14. Relationship between TN and hydrologic loadings, Manatee River, 1985-1998.

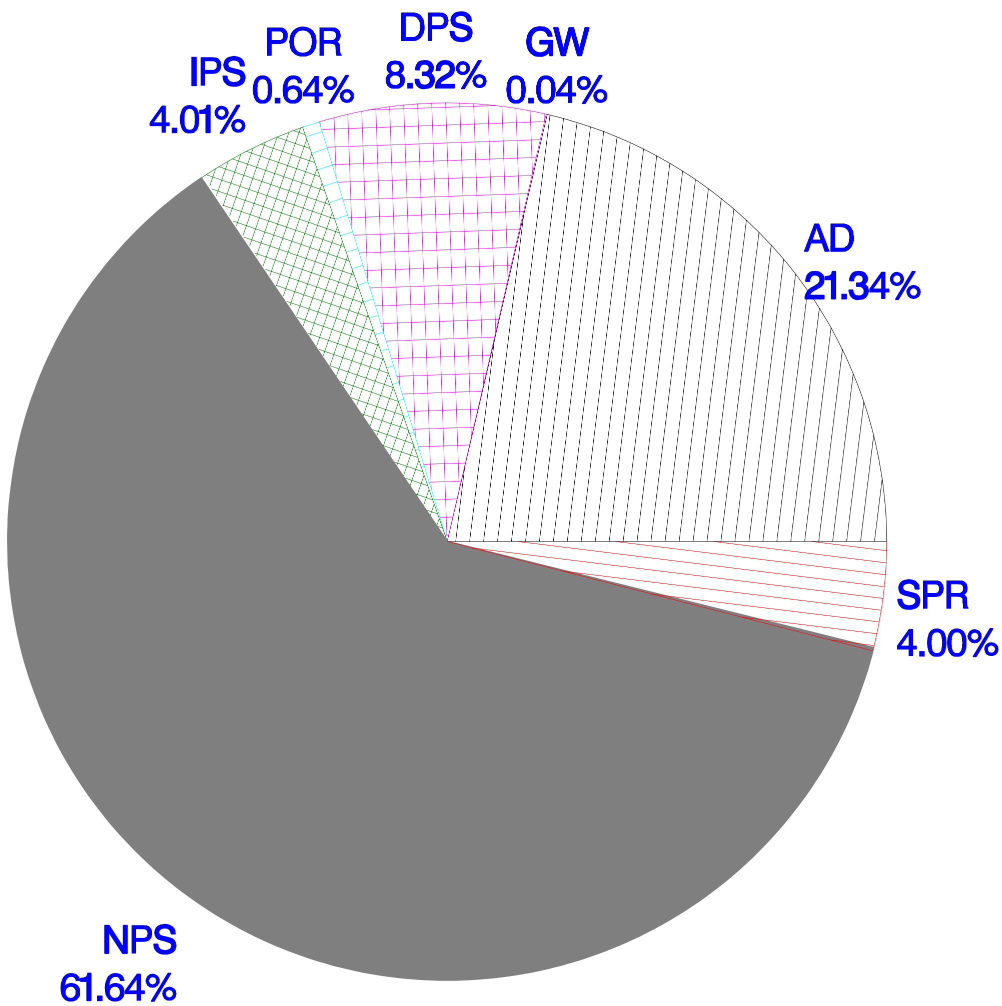

Figure 4-15. Percentage contributions from sources to mean annual TN loadings for the 1995-1998 period.

5. CONCLUSIONS

This loading update was performed to provide recent information on loadings to Tampa Bay for two purposes:

- to provide a comparison to baseline TN loadings established by the Nitrogen Management Consortium; and
- to provide additional data to assess the chlorophyll-loading empirical model.

The following provides the conclusions from this update.

- Annual loadings in 1995, 1997, and 1998 were generally higher than those observed during the 1985-1994 period. Specifically, the loadings during these three years exceeded the "hold the line" TN loadings adopted by the Nitrogen Management Consortium, which were based on the average TN loadings from the 1992-1994 period.
- Examination of the TN loadings data suggests that much of the increase in TN loadings could be explained by the higher rainfall and resultant hydrologic loadings observed in 1995, 1997, and 1998. Most noticeably, the El Niño event of 1997-1998 resulted in relatively higher rainfalls and loadings compared to observations from the period of record.
- Increases in nonpoint source loadings were the primary contributions to the increased annual loadings.
- Changes in loadings from each source were as follows:
    - Atmospheric deposition loadings increased in most bay segments, in comparison to the 1992-1994 period, especially during the wet years of 1995, 1997, and 1998.
    - Increases in estimated domestic point source loadings occurred primarily to Hillsborough Bay, and were largely due to increased loadings from a few facilities.
    - Higher industrial point sources loads during the 1995-1998 period could also be attributed to the higher than normal rainfall during this period, specifically from those sources with stormwater NPDES permits.

- Loading contributions from springs and groundwater remained relatively unchanged from those of the 1992-1994 period, except for the 20% greater TN loading from springs in 1998.

- Material losses declined during 1995-1998 to both Hillsborough Bay and Lower Tampa Bay, due to improvements in handling processes by several facilities.

- Contributions from nonpoint sources increased in direct proportion to increases in hydrologic loadings in all bay segments.

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APPENDIX A

Letter from Mr. Craig Kovach, CF Industries Inc.,
Accompanying Material Handling Loss Estimates from
Industrial Stormwater Discussion Group for 1995-1998

Mr. Richard Eckenrod
Executive Director
Tampa Bay Estuary Program
Mail Station I-1/NEP
100 8th Avenue S.E.
St Petersburg, Florida 33701

RE: Nutrient Loading Updates, 1995-1998

Dear Mr. Eckenrod:

The *Industrial Stormwater Discussion Group* is an ad hoc association of terminal operators from the Nitrogen Management Consortium who are committed to information sharing, open dialogue on complex issues, and peer review of individual performance as it relates to Tampa Bay water quality. On behalf of the Group, which is essentially comprised of active fertilizer shipping terminals around Hillsborough Bay, enclosed are nitrogen and phosphorous loading updates for the 1995 through 1998 time period for the following facilities.

- Cargill Fertilizer (Riverview)
- CF Industries (Port of Tampa)
- CSX Transportation (Rockport)
- IMC-Agrico (Port Sutton)
- Pakhoed Dry Bulk (Port Sutton)

These loading data have been voluntarily compiled, analyzed, peer reviewed, and reported by the participating companies in conjunction with our individual commitments to the goals and objectives of the Nitrogen Management Consortium. From that perspective, we trust that our collective reduction in nitrogen and phosphorous loading provide an example of the positive outcome of collaborative, private stakeholder involvement in watershed management.

While we are extremely pleased to report dramatic reductions in total nutrient loading to Tampa Bay by the close of the review period, we are also compelled to remind the TBEP in its communications with other Tampa Bay stakeholders, and in particular regulatory agency participants, that the information being provided is offered in good faith and strictly for the purpose of non-regulatory inclusion in the context of monitoring goals of the Comprehensive Conservation and Management Plan (CCMP). Moreover, we caution against direct comparison of data between facilities, as each is faced with different site specific factors and challenges, so discharge and loading data may vary significantly. Facility load *reduction* is the salient issue and the commonality being sought. Nonetheless, if a scorecard is to be kept, we firmly believe it should be for Tampa Bay as a whole, and not for individual participants in the Bay's continued recovery.

Please feel free to call me or any of the other company facility representatives if you have any questions or need additional information.

Sincerely,

Craig A. Kovach, P.G.
Industrial Stormwater Discussion Group
Superintendent, Environmental Affairs
CF Industries, Inc.

Enclosures

Cc: Melody Foley, Cargill Fertilizer w/ encl.
Carl Gerhardstein, CSX Transportation w/encl.
Tom Davis, Eastern Terminals w/encl.
Greg Williams, IMC-Agrico w/encl.
Chris Tolbert, Pakhoed Dry Bulk Terminals w/encl.
Holly Greening, TBEP, w/ encl.
Anthony Janicki, Ph.D., Janicki Environmental w/encl.
Jake Stowers, Co-chair, Nitrogen Management Consortium w/o encl.

APPENDIX B

Aggregated Florida Land Use, Cover and
Form Classification System Categories

URBAN LAND USE CATEGORIES

Coastal Land Use Code	FLUCCS Code
1 - Low Density Residential	1100
2 - Medium Density Residential	1200
3 - High Density Residential	1300
4 - Commercial	1400
5 - Industrial	1500
7 - Institutional, Transportation, Utilities	1700 8100 8200 8300

AGRICULTURAL LAND USE CATEGORIES

Coastal Land Use Code	FLUCCS Code
6 - Mining	1600
11 - Groves	2200 2210 2220 2230
12 - Feedlots	2300
13 - Nursery	2400
14 - Row and Field Crops	2100 2140 2150 2440

UPLAND FORESTED LAND USE CATEGORIES

Coastal Land Use Categories	FLUCCS Code
8 - Range Lands	1480 1800 1900 2420 2600 3100 3200 3300
9 - Barren Lands	7100 7200 7300 7400
10 - Pasture	2110 2120 2130
15 - Upland Forests	4100 4110 4120 4200 4300 4340 4400

WATER AND WETLANDS LAND USE CATEGORIES

Coastal Land Use Categories	FLUCCS Code
16 - Freshwater	2500 2540 2550 5100 5200 5210 5220 5230 5240 5300 5310 5320 5330 5340 5500 5600 6440 6450
17 - Saltwater	5400 9113 9116 9121
18 - Forested Freshwater Wetlands	6100 6110 6150 6200 6210 6240 6300
19 - Saltwater Wetlands	6120 6420
20 - Non-forested Freshwater Wetlands	6400, 6410, 6411, 6430 6530
21 - Tidal Flats	6500, 6510 6520

APPENDIX C

Land Use-specific Water Quality Concentrations

Land Use-Specific Nonpoint Source Water Quality Concentrations

URBAN LAND USES						
Land Use Classification			Land Use-Specific Water Quality Concentrations			
Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
1 (LDR)	Low Density Single Family Residential (SFR)	(1)	2.31	0.40	33.0	-
		(1)	2.14	0.32	28.0	-
		(1)	0.605	0.073	7.2	-
		(1)	1.18	0.307	3.5	-
		(1)	3.0	0.45	-	-
		(1)	2.2	0.25	-	-
		(4)	1.87	0.39	-	-
		(8)	1.46	0.401	19.0	-
		(9)	1.56	0.27	20.8	-
		(10)	2.04	0.593	49.7	-
		(11)	2.88	0.72	56.8	-
		(13)	-	-	-	4.4
		min	0.605	0.073	3.5	-
		mean	1.93	0.380	27.3	4.4
		max	2.88	0.598	56.8	-
2 (MDR)	Medium Density (See notes)	mean	2.04	0.44	33.5	- 7.4 -
3 (HDR)	Multifamily Residential	(1)	1.61	0.33	53.0	-
		(1)	2.57	0.45	36.8	-
		(1)	4.68	0.72	95.6	-
		(1)	1.91	0.73	-	-
		(1)	1.02	0.033	67.6	-
		(1)	1.91	0.51	14.3	-
		(4)	1.65	0.33	-	-
		(8)	2.05	1.34	29.0	-
		(9)	2.04	0.282	10.7	-
		(10)	2.05	0.150	8.3	-
		(11)	2.00	0.56	41	-
		(13)	-	-	-	11.0
		min	1.02	0.033	8.3	-
		mean	2.14	0.49	39.6	11.0
		max	4.68	1.34	95.6	-

Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
4	Low Intensity Commercial	(1)	1.19	0.15	22.0	-
		(1)	1.10	0.10	45.0	-
	High Intensity Commercial	(1)	2.81	0.31	94.3	-
		(1)	3.53	0.82	-	-
		(1)	2.15	0.15	-	-
	Commercial (Office)	(8)	2.38	0.305	36.5	-
		(9)	1.08	0.495	50.6	-
		(10)	1.40	0.113	6.2	-
		(11)	1.05	0.145	13.8	-
	Commercial (Retail)	(8)	1.69	0.253	9.3	-
		(10)	1.28	0.177	14.5	-
		(11)	2.12	0.22	36.3	-
	Combined Commercial	min	1.05	0.100	6.2	-
		mean	1.82	0.270	32.9	17.2
		max	3.53	0.495	94.3	-
5	Industrial	(1)	1.42	0.19	71.8	-
		(1)	1.42	0.31	102.0	-
		(4)	1.18	0.15	-	-
		(8)	2.28	0.332	18.2	-
		(9)	1.77	0.465	28.3	-
		(10)	1.92	0.490	84.3	-
		(11)	3.00	0.503	70.0	-
		(13)	-	-	-	9.6
6	Mining	(4)	1.18	0.15	35 (e)	-
		(13)	-	-	-	9.6
7	Institutional	(4)	1.18	0.15	35 (e)	-
		(13)	-	-	-	8.2

AGRICULTURAL LAND USES						
Land Use Classification			Land Use-Specific Water Quality Concentrations			
Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
10	Pasture	(1)	2.37	0.697	-	-
		(1)	2.48	0.27	8.6	-
		(2)	2.0	0.3	-	-
		(3)	3.0	0.25	-	-
		(4)	1.02	0.16	-	-
		(5)	5.1	3.2	-	-
		(13)	-	-	-	5.1
11	Grove	(7)	2.31	0.10	-	-
		(13)	-	-	-	2.55
11,13	Grove, Nursery	(4)	0.92	0.41	-	-
		(13)	-	-	-	2.55
12	Feed Lot	(3)	29.3	5.1	-	-
		(3)	3.74	1.13	-	-
		(5)	26.0	5.1	-	-
		(13)	-	-	-	5.1
14	Field Crop	(2)	2.5	0.25	-	-
		(3)	2.5	2.5	-	-
		(4)	3.75	1.13	-	-
		(13)	-	-	-	5.1
Mixed Agricultural						
10,11	Citrus + Pasture	(1)	1.57	0.09	-	-
		(1)	1.33	0.09	4.6	-
		(1)	2.58	0.046	180	-
		(1)	2.68	0.562	-	-
		(1)	3.26	0.24	28.0	-
11,14	Citrus + Row Crops	(6)	1.78	0.3	5.6	-

(See following page for summarized agricultural water quality concentrations.)

WATER/WETLAND AND FOREST/UNDEVELOPED LAND USES						
Land Use Classification			Land Use-Specific Water Quality Concentrations			
Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
8	Open Space/ Non-forested	(1)	1.38	0.07	17.3	-
		(1)	0.90	0.02	4.8	-
		(1)	1.47	0.07	-	-
		(4)	1.02	0.16	-	-
		(13)	-	-	-	1.45
15	Upland Forest	(2)	0.1	0.007	-	-
		(3)	0.2	0.007	-	-
		(4)	1.02	0.16	-	-
		(13)	-	-	-	1.45
16,17	Open Water	(1)	0.79	0.17	-	-
		(1)	0.73	0.04	0.00	-
		(1)	2.22	-	6.2	-
		(13)	-	-	-	0.00
18,20	Freshwater Wetland	(1)	2.26	0.09	13.4	-
		(1)	1.02	0.16	-	-
		(1)	1.24	0.018	4.6	-
		(1)	1.88	0.33	12.7	-
		(4)	0.79	0.17	-	-
		(13)	-	-	-	4.63
17	Saltwater		NA	NA	NA	NA
19	Saltwater Wetlands		NA	NA	NA	NA
21	Tidal Flats		NA	NA	NA	NA

Notes:

- Concentrations for CLUCCS code 2 (MDR) are an average of CLUCCS codes 1 (LDR) and 3 (HDR).
- Concentrations for CLUCCS code 4 (Commercial) are an average of reported values for "low intensity" and "high intensity" commercial.
- Estimated (e) agricultural values were based on similar land uses data when no land use specific data were identified.
- Row crop data were often reported with other agricultural uses.
- Saltwater and saltwater wetlands were assigned zero loads.

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APPENDIX D

Land Use-specific Seasonal Runoff Coefficients

Land Use-Specific Seasonal Runoff Coefficients

Coastal Land Use Classification and Land Use Type	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
1) Single Family Residential	A	0.15	0.25
	B	0.18	0.28
	C	0.21	0.31
	D	0.24	0.34
2) Medium Density Residential	A	0.25	0.35
	B	0.30	0.40
	C	0.35	0.45
	D	0.40	0.50
3) Multifamily Residential	A	0.35	0.50
	B	0.42	0.57
	C	0.50	0.65
	D	0.58	0.75
4) Commercial	A	0.70	0.79
	B	0.74	0.83
	C	0.78	0.97
	D	0.82	0.91
5) Industrial	A	0.65	0.75
	B	0.70	0.80
	C	0.75	0.85
	D	0.80	0.90

Land Use-Specific Seasonal Runoff Coefficients (cont)

Land Use	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
6) Mining	A	0.20	0.20
	B	0.30	0.30
	C	0.40	0.40
	D	0.50	0.50
7) Institutional, Transportation Utils.	A	0.40	0.50
	B	0.45	0.55
	C	0.50	0.60
	D	0.55	0.65
8) Range Lands	A	0.10	0.18
	B	0.14	0.22
	C	0.18	0.26
	D	0.22	0.30
9) Barren Lands	A	0.45	0.55
	B	0.50	0.60
	C	0.55	0.65
	D	0.60	0.70
10) Agricultural - Pasture	A	0.10	0.18
	B	0.14	0.22
	C	0.18	0.26
	D	0.22	0.30

Land Use-Specific Seasonal Runoff Coefficients (cont)

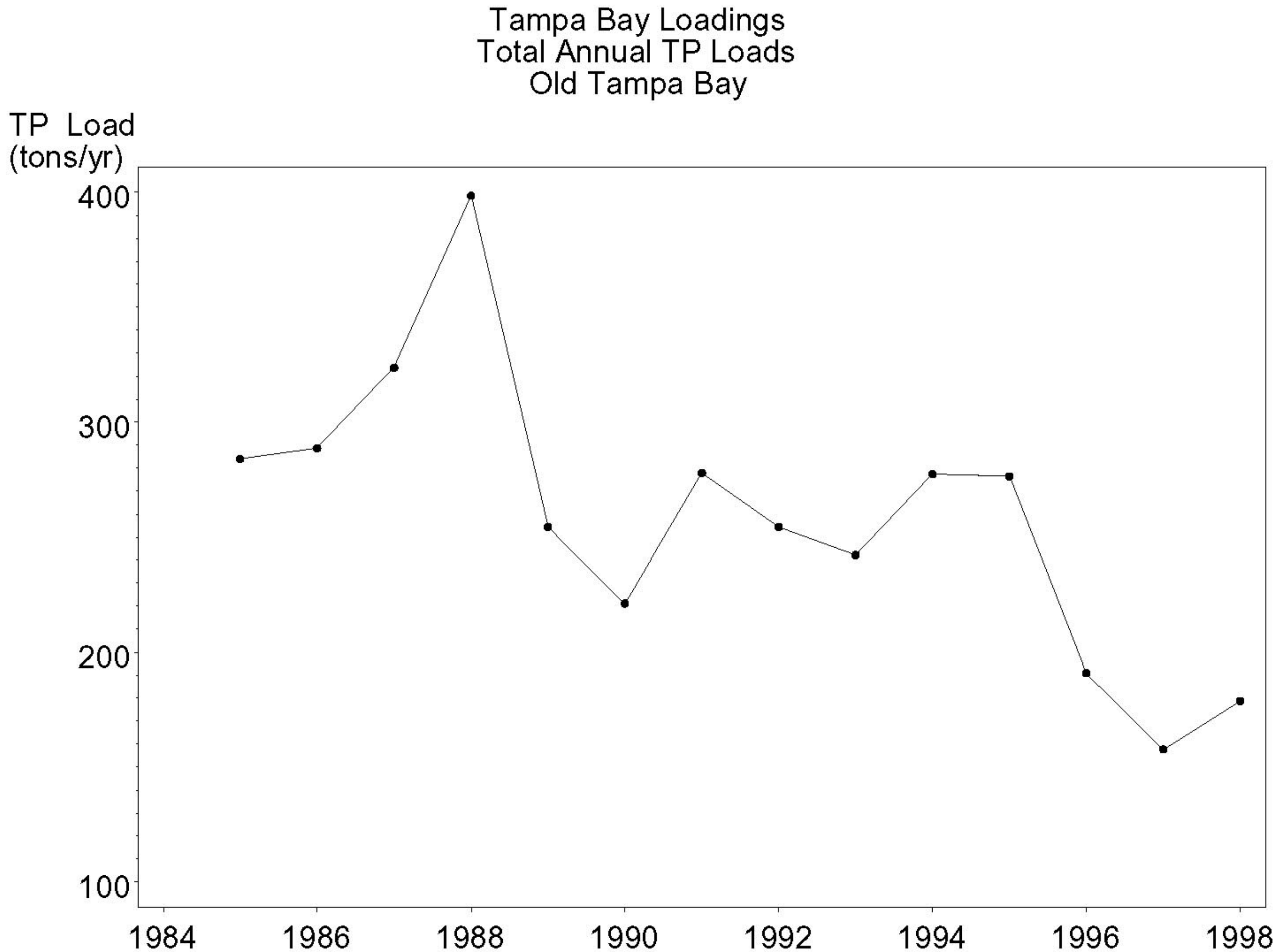
Land Use	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
11) Agricultural - Groves	A	0.20	0.26
	B	0.23	0.29
	C	0.26	0.32
	D	0.29	0.33
12) Agricultural - Feedlots	A	0.35	0.45
	B	0.40	0.50
	C	0.45	0.55
	D	0.50	0.60
13) Agricultural - Nursery	A	0.20	0.30
	B	0.25	0.35
	C	0.30	0.40
	D	0.35	0.45
14) Agricultural - Row and Field Crops	A	0.20	0.30
	B	0.25	0.35
	C	0.30	0.40
	D	0.35	0.45
15) Upland Forested	A	0.10	0.15
	B	0.13	0.18
	C	0.16	0.21
	D	0.19	0.24

Land Use-Specific Seasonal Runoff Coefficients (cont)

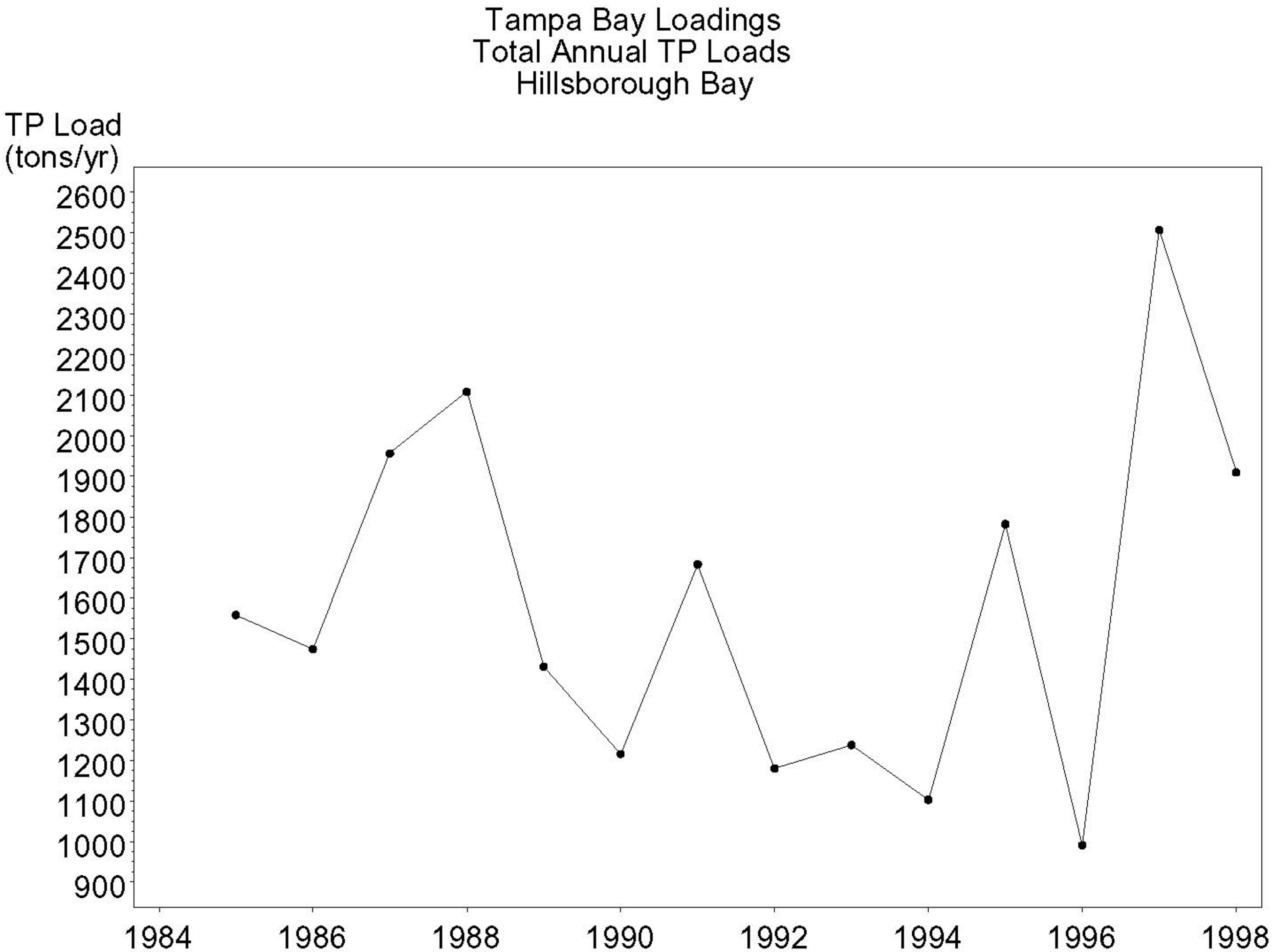
Land Use	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
16) Freshwater - Open Water	A	0.80	0.90
	B	0.80	0.90
	C	0.80	0.90
	D	0.80	0.90
17) Saltwater - Open Water	A	1.0	1.0
	B	1.0	1.0
	C	1.0	1.0
	D	1.0	1.0
18) Forested Freshwater Wetlands	A	0.50	.60
	B	0.55	0.65
	C	0.60	0.70
	D	0.65	0.75
19) Saltwater Wetlands	A	0.95	0.95
	B	0.95	0.95
	C	0.95	0.95
	D	0.95	0.95
20) Non-forested Freshwater Wetlands	A	0.45	0.55
	B	0.50	0.60
	C	0.55	0.65
	D	0.60	0.70
21) Tidal Flats	A	1.0	1.0
	B	1.0	1.0
	C	1.0	1.0
	D	1.0	1.0

APPENDIX E

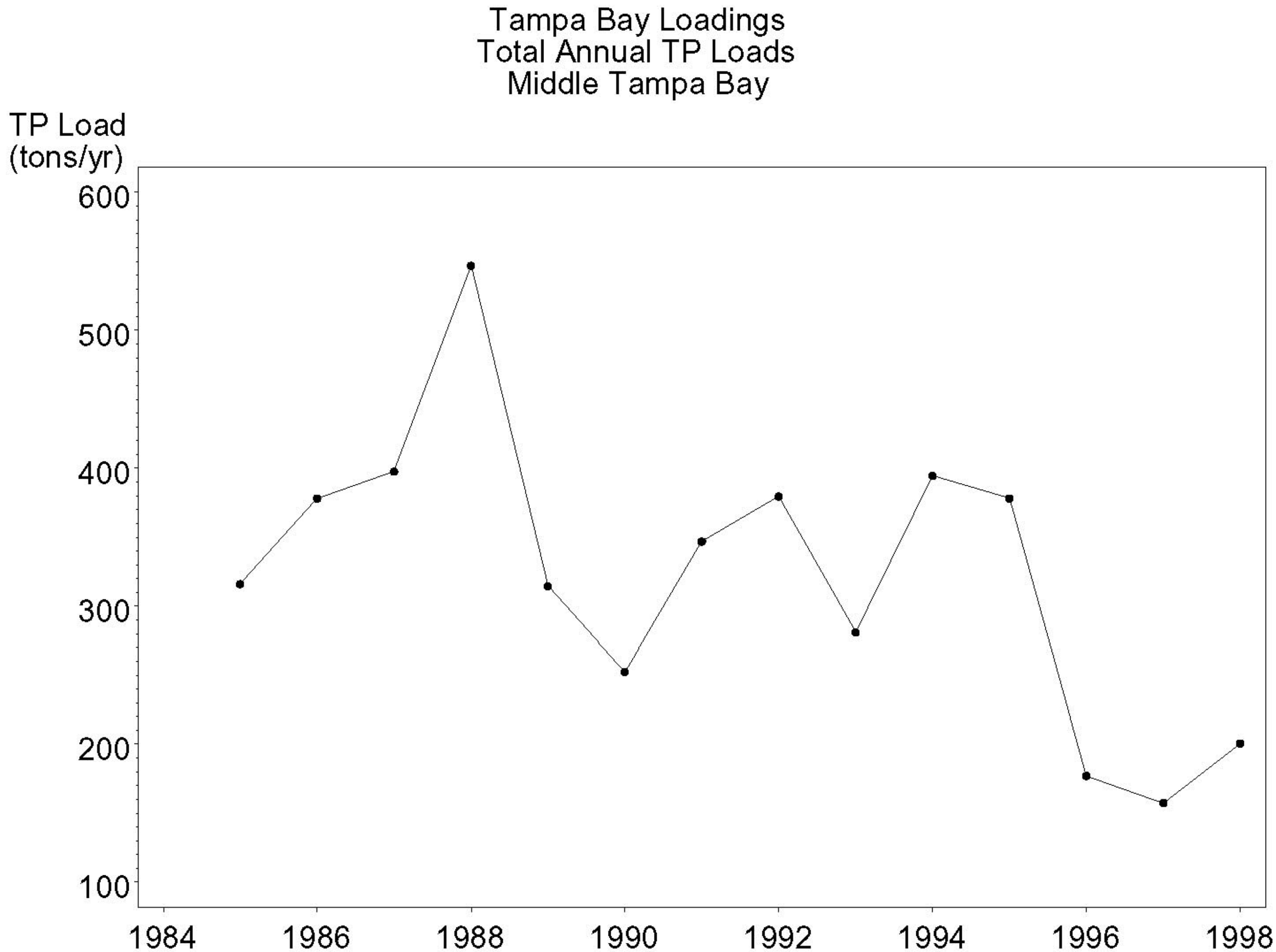
Annual Loadings of TP, TSS, and BOD
to Each Bay Segment, 1985-1998



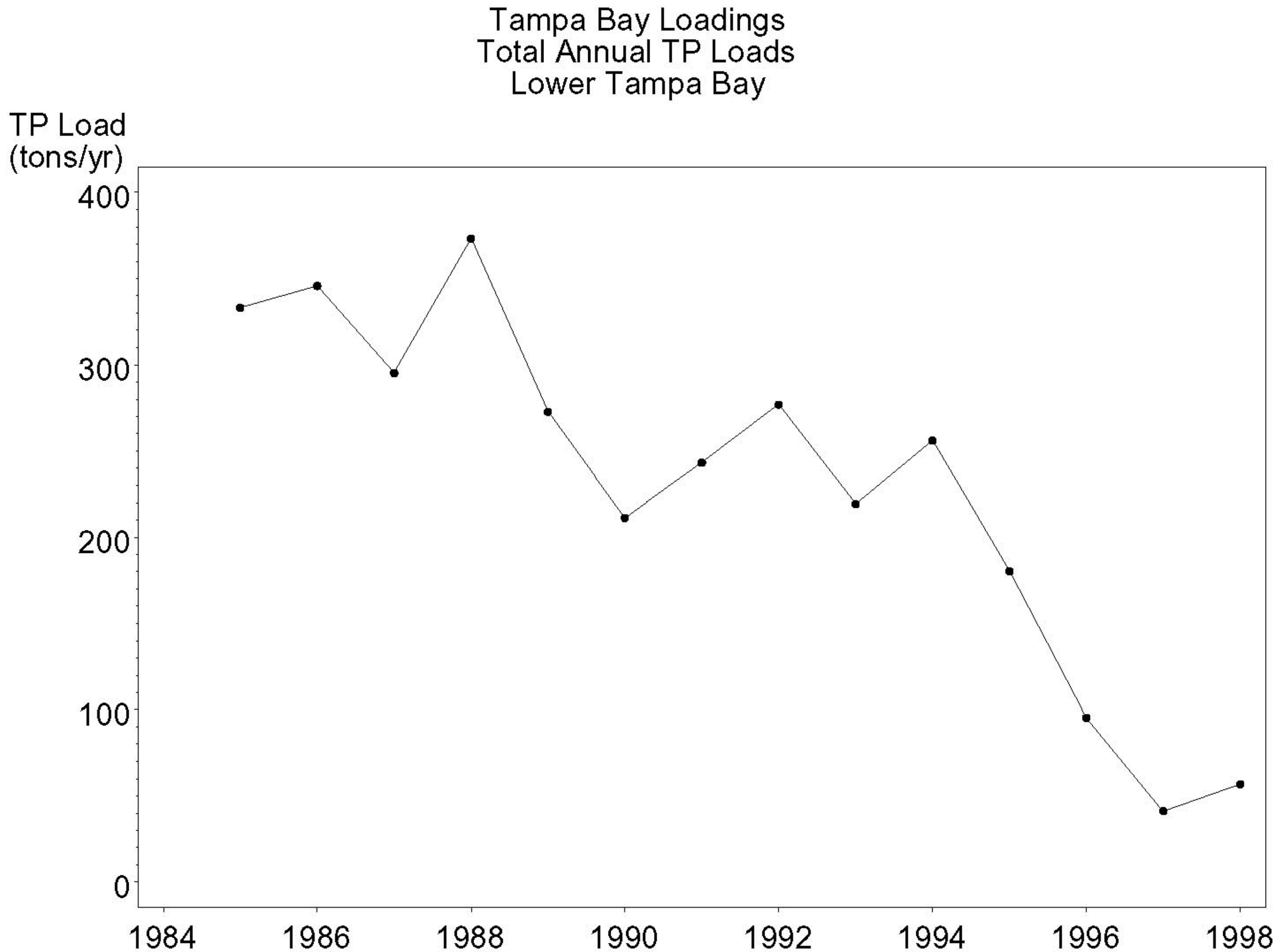
Tampa Bay Loadings
Total Annual TP Loads
Old Tampa Bay
TP Load
(tons/yr)
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998



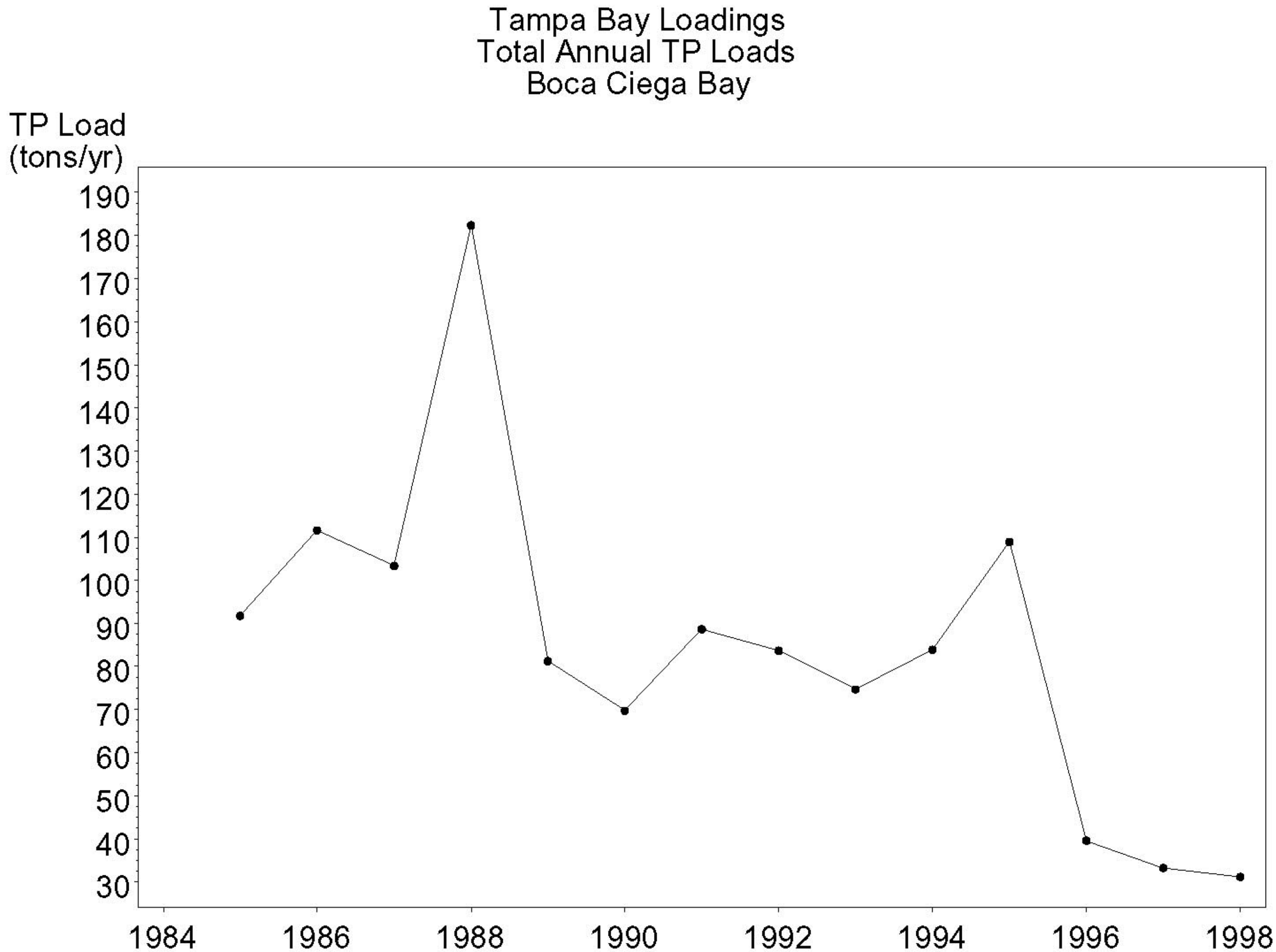
Tampa Bay Loadings
Total Annual TP Loads
Hillsborough Bay
TP Load
(tons/yr)
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
1984
1986
1988
1990
1992
1994
1996
1998

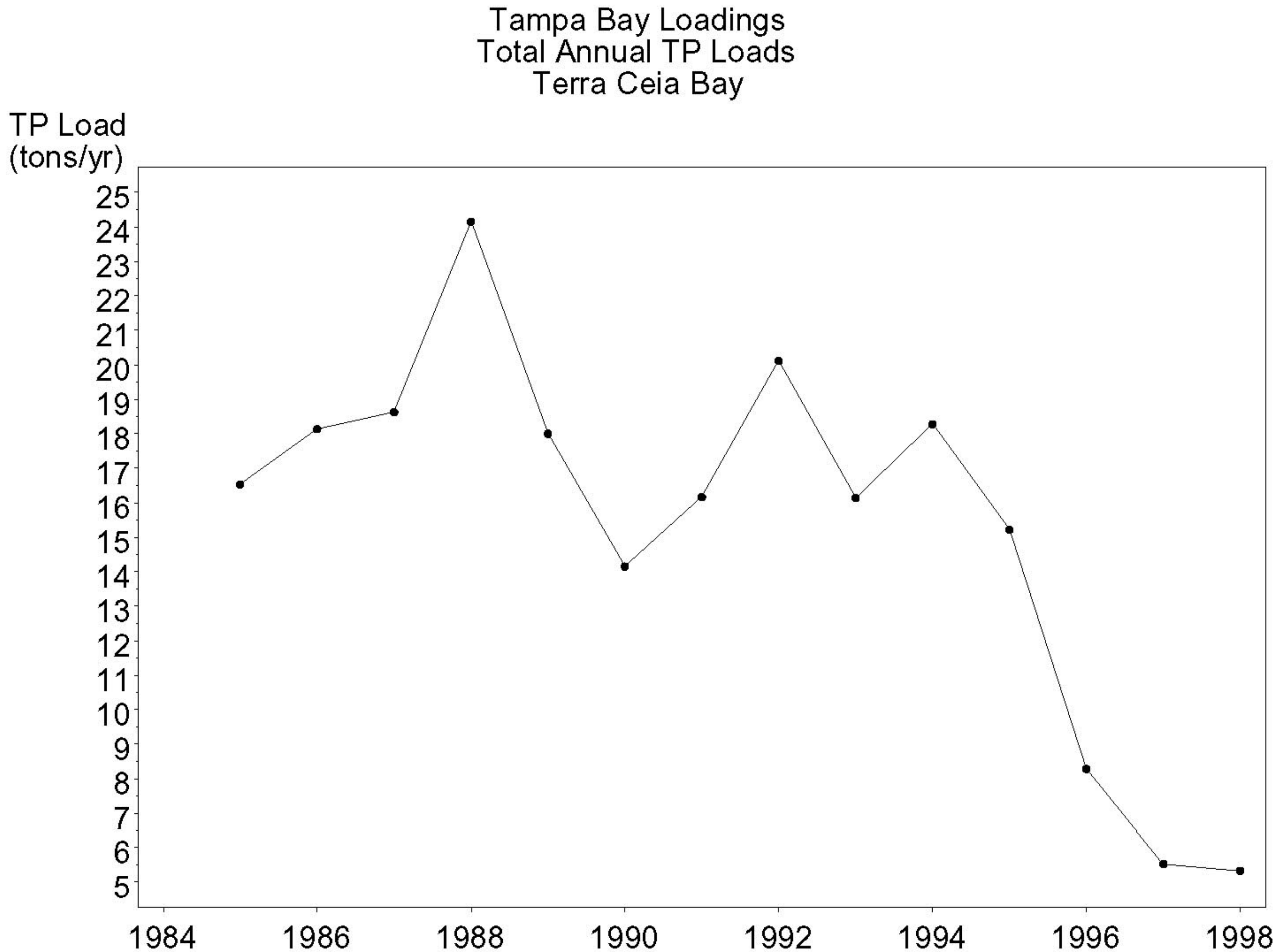


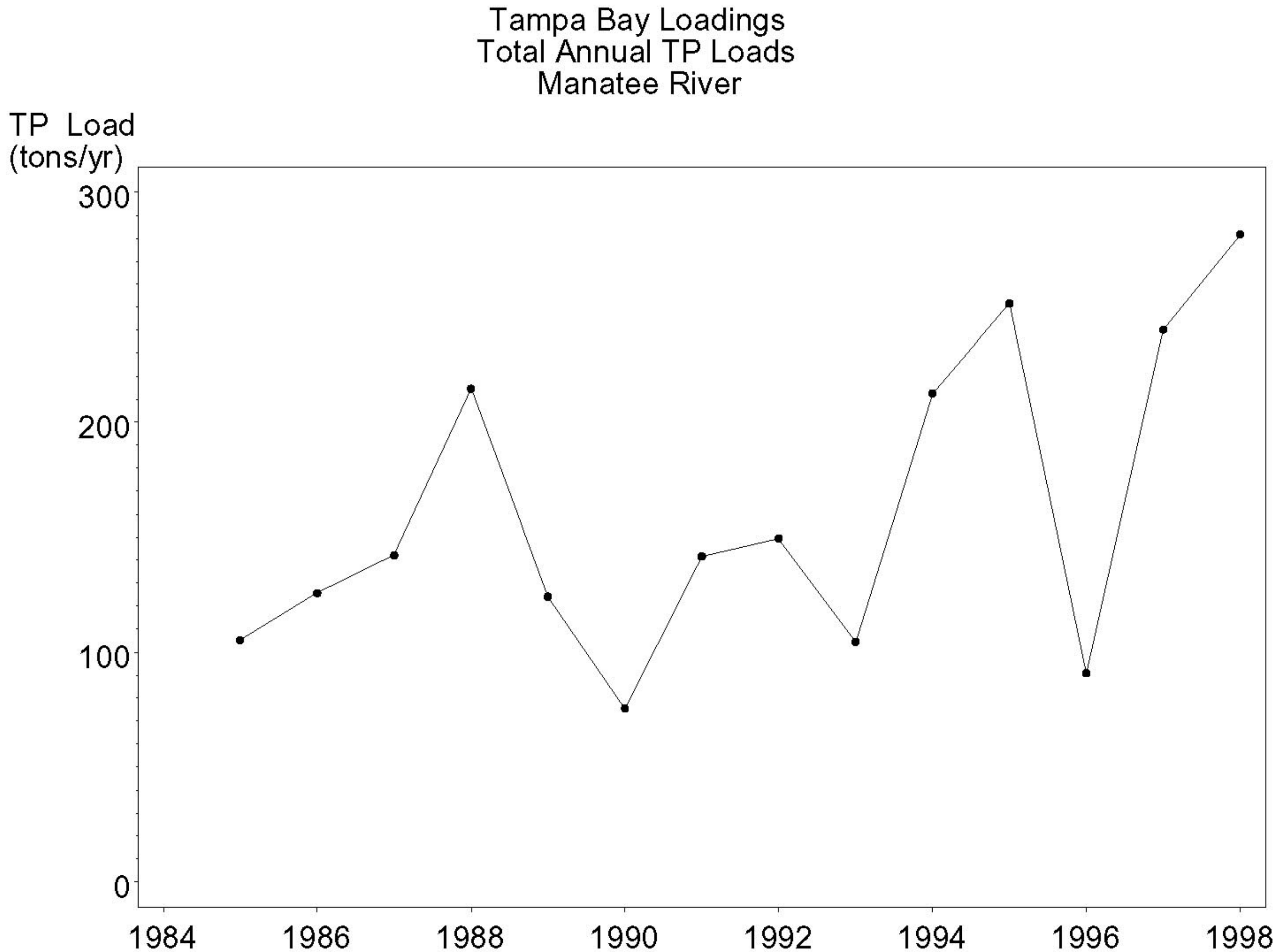
Tampa Bay Loadings
Total Annual TP Loads
Middle Tampa Bay
TP Load
(tons/yr)
600
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998

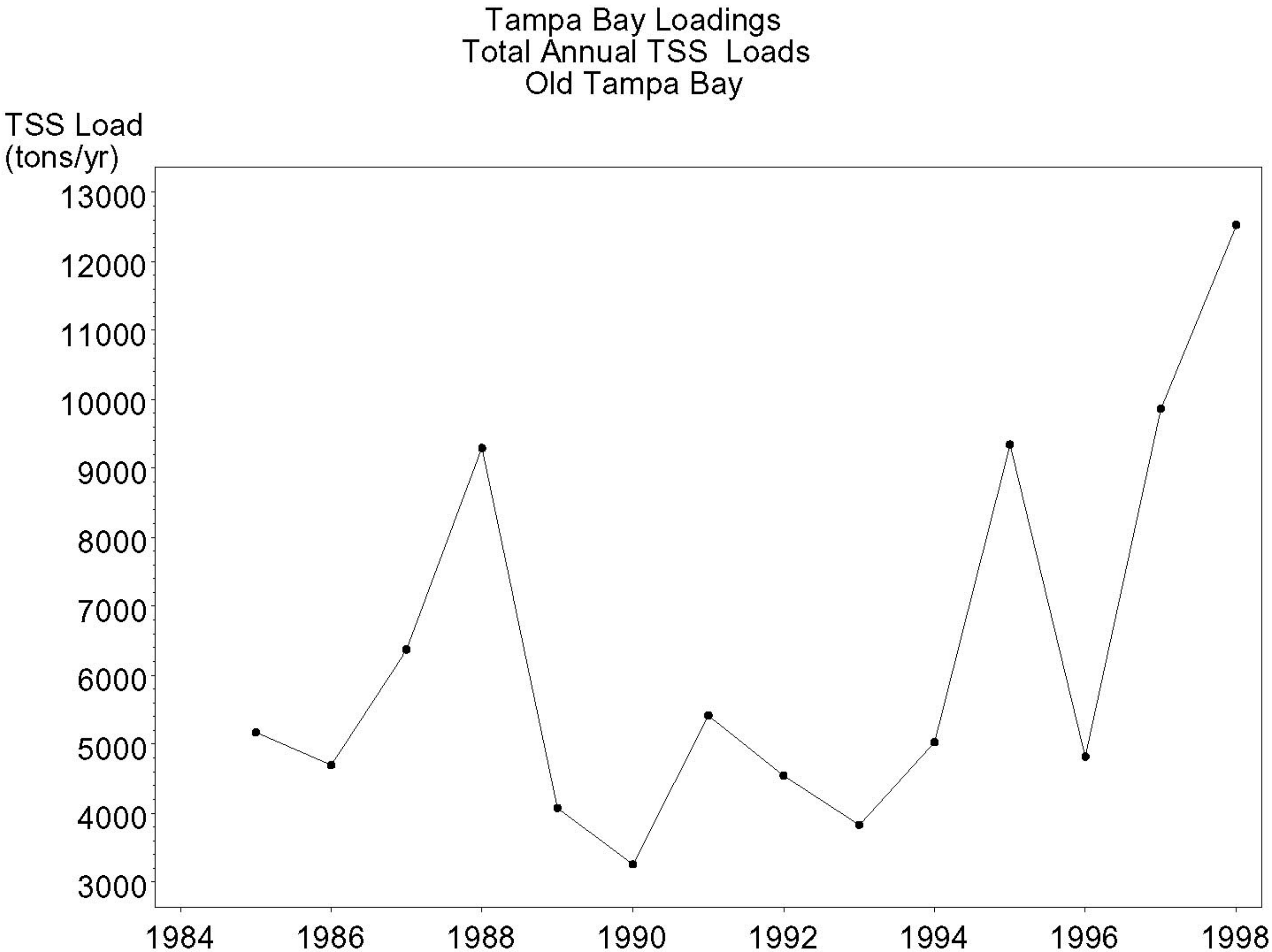


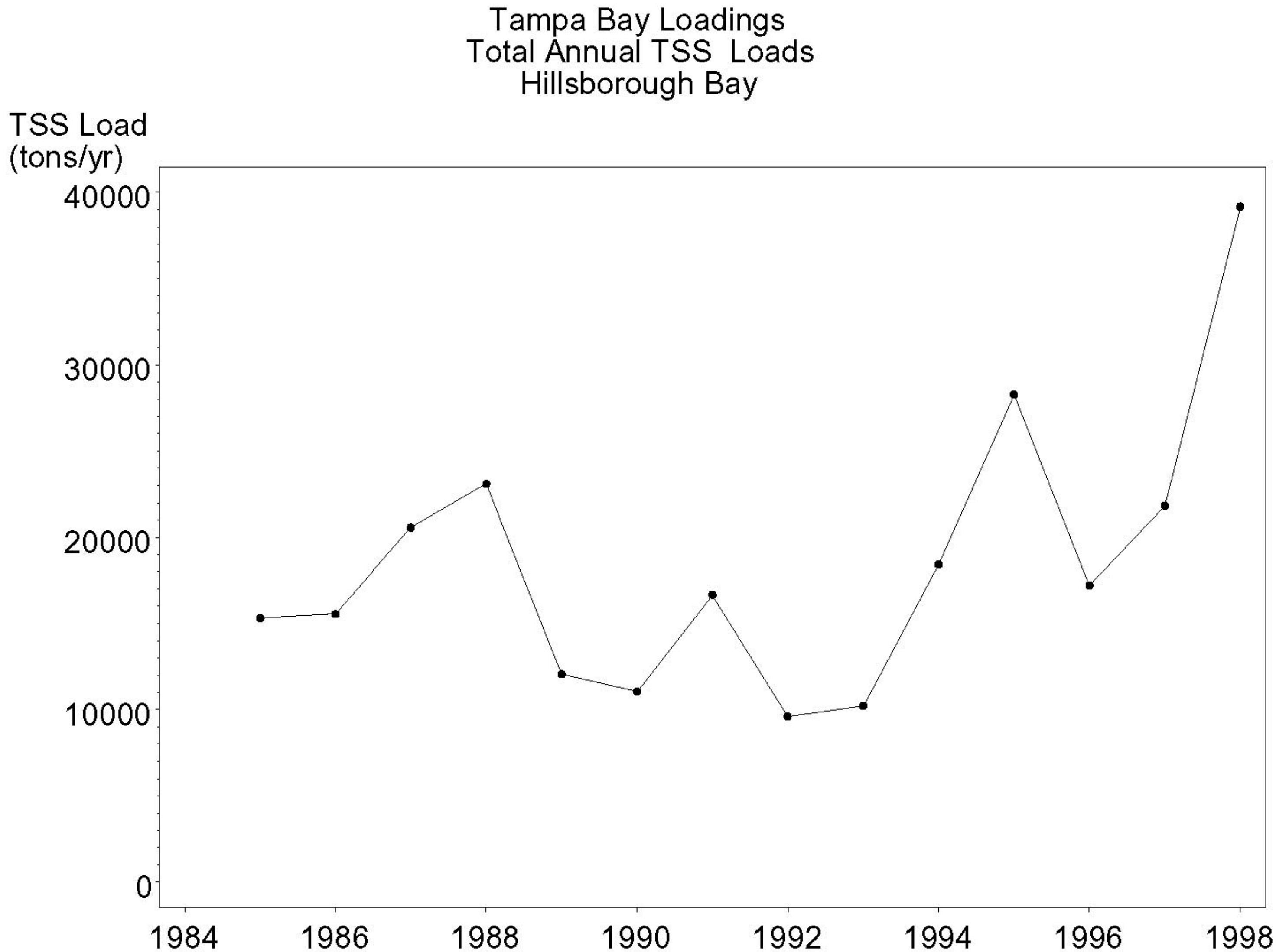
Tampa Bay Loadings
Total Annual TP Loads
Lower Tampa Bay
TP Load
(tons/yr)
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998

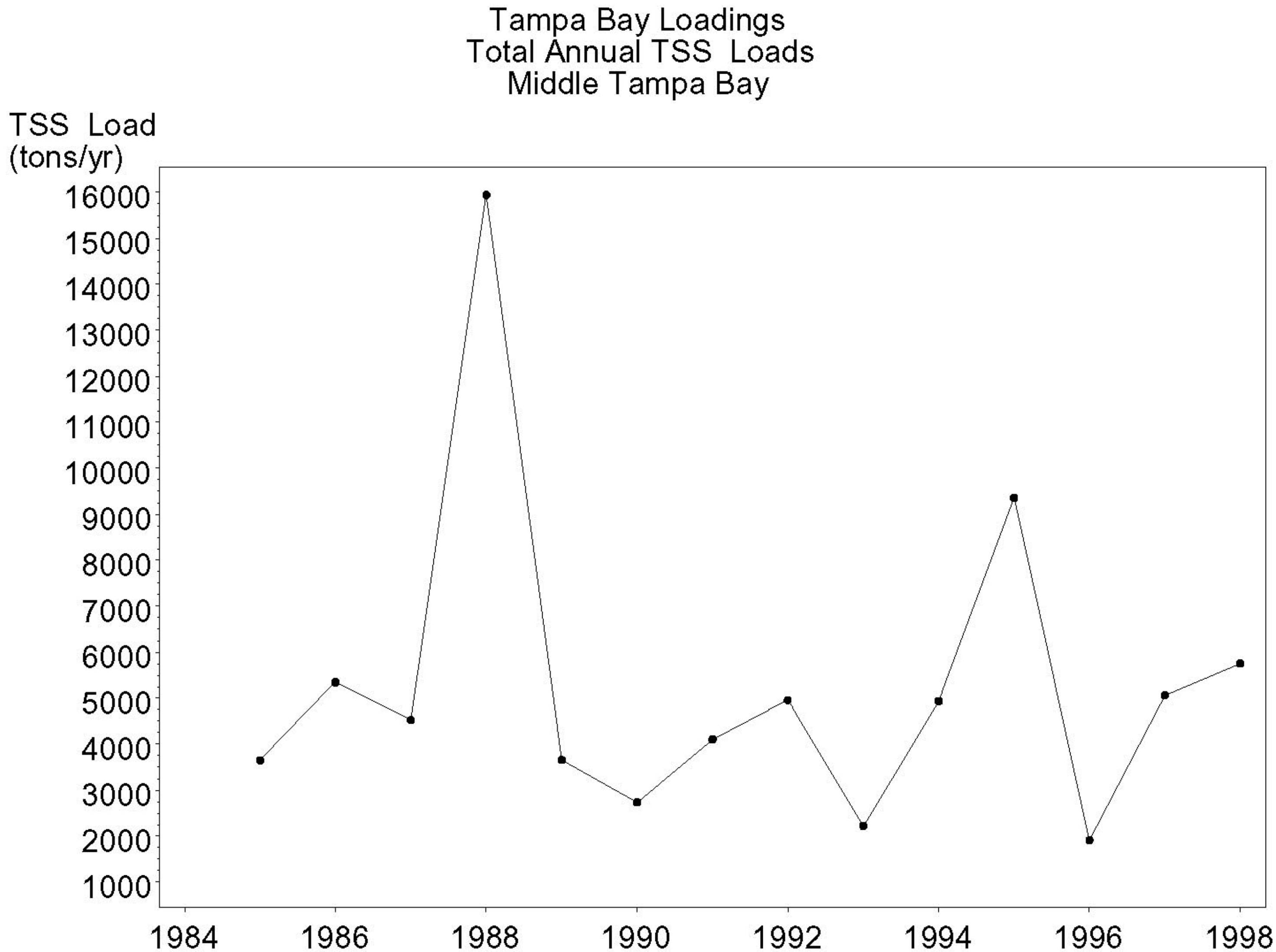

Tampa Bay Loadings
Total Annual TP Loads
Boca Ciega Bay
TP Load
(tons/yr)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
1984
1986
1988
1990
1992
1994
1996
1998


Tampa Bay Loadings
Total Annual TP Loads
Terra Ceia Bay
TP Load
(tons/yr)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
1984
1986
1988
1990
1992
1994
1996
1998

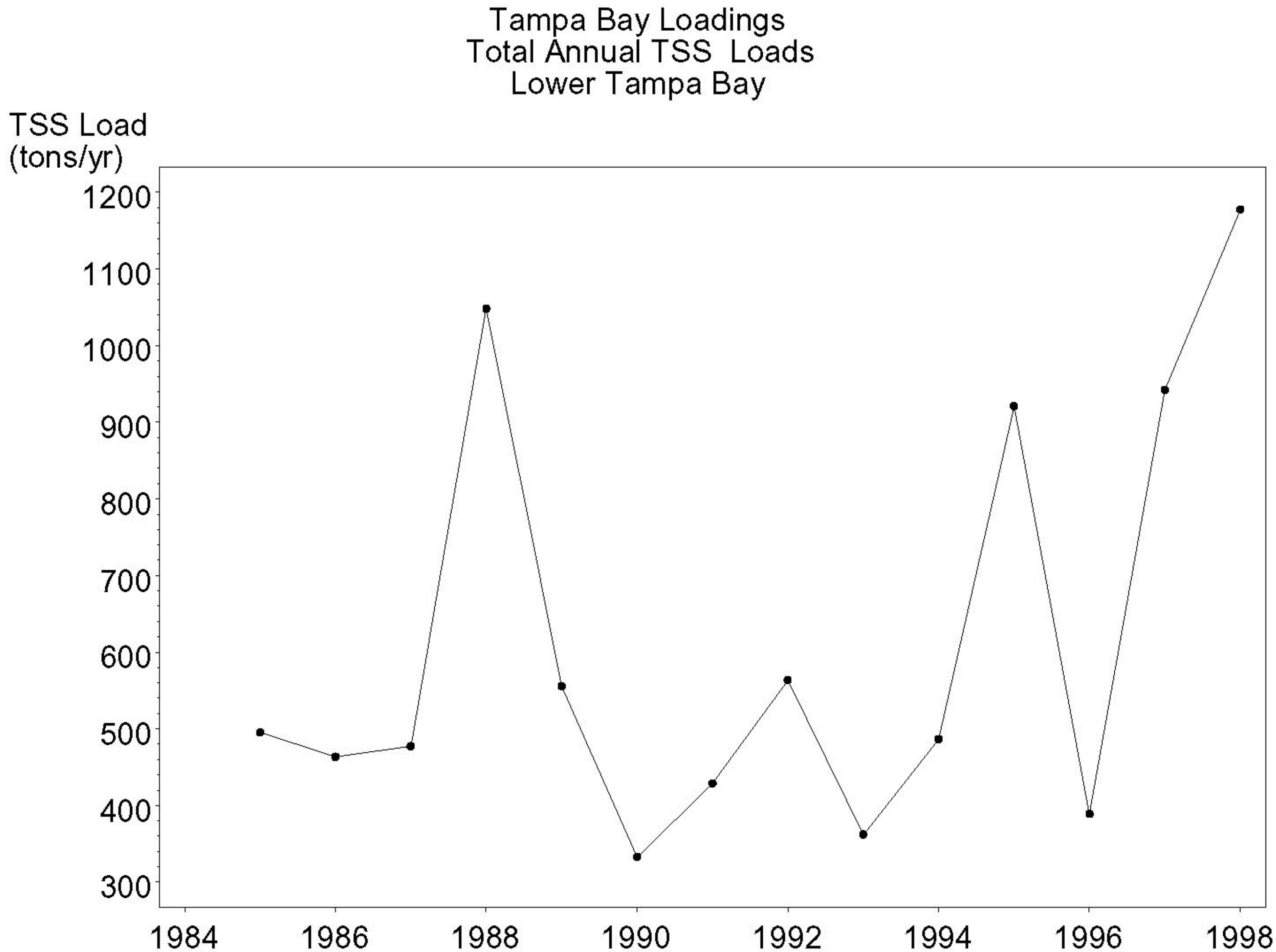

Tampa Bay Loadings
Total Annual TP Loads
Manatee River
TP Load
(tons/yr)
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998


Tampa Bay Loadings
Total Annual TSS Loads
Old Tampa Bay
TSS Load
(tons/yr)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
1984
1986
1988
1990
1992
1994
1996
1998

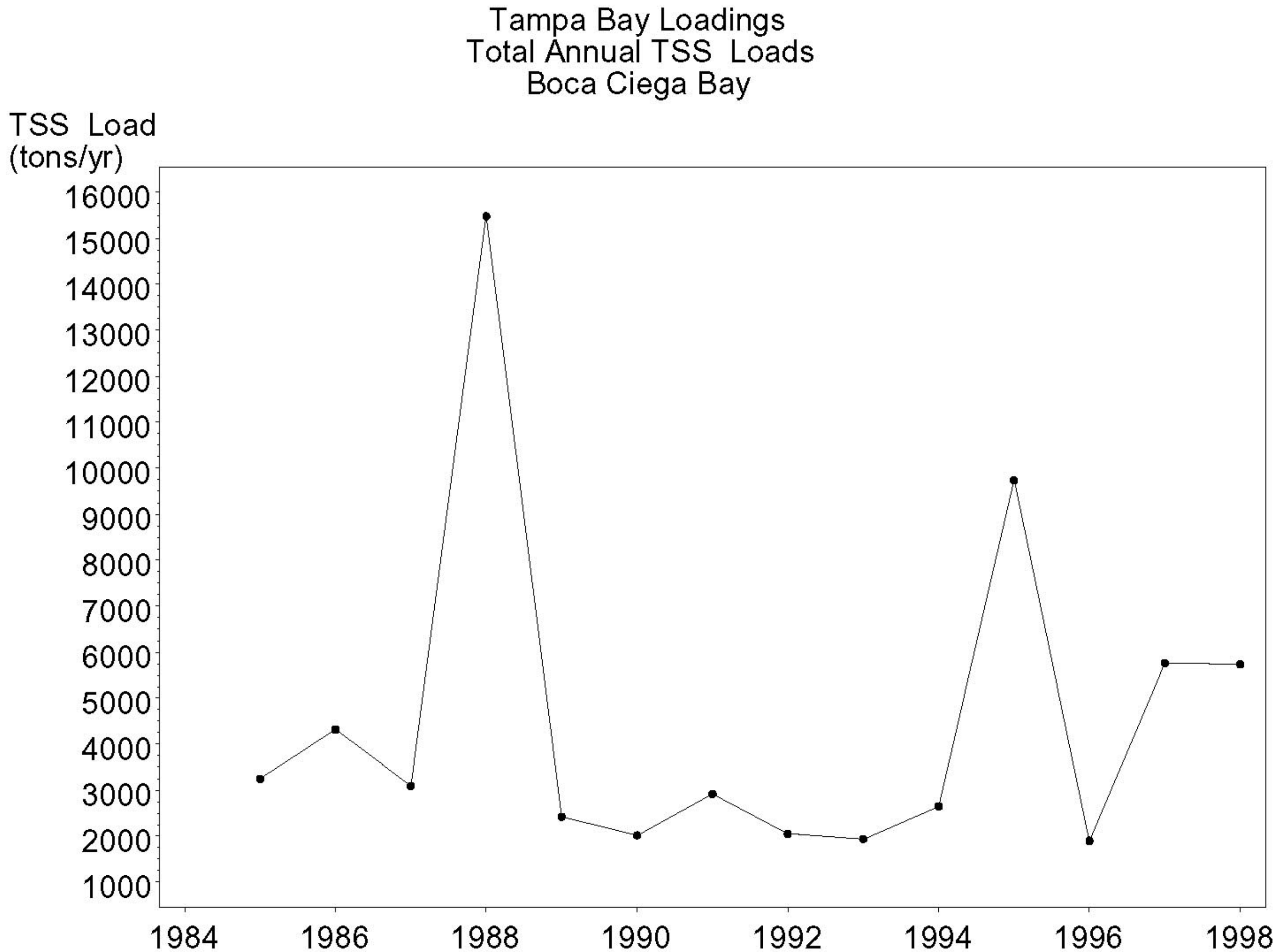

Tampa Bay Loadings
Total Annual TSS Loads
Hillsborough Bay
TSS Load
(tons/yr)
40000
30000
20000
10000
0
1984
1986
1988
1990
1992
1994
1996
1998

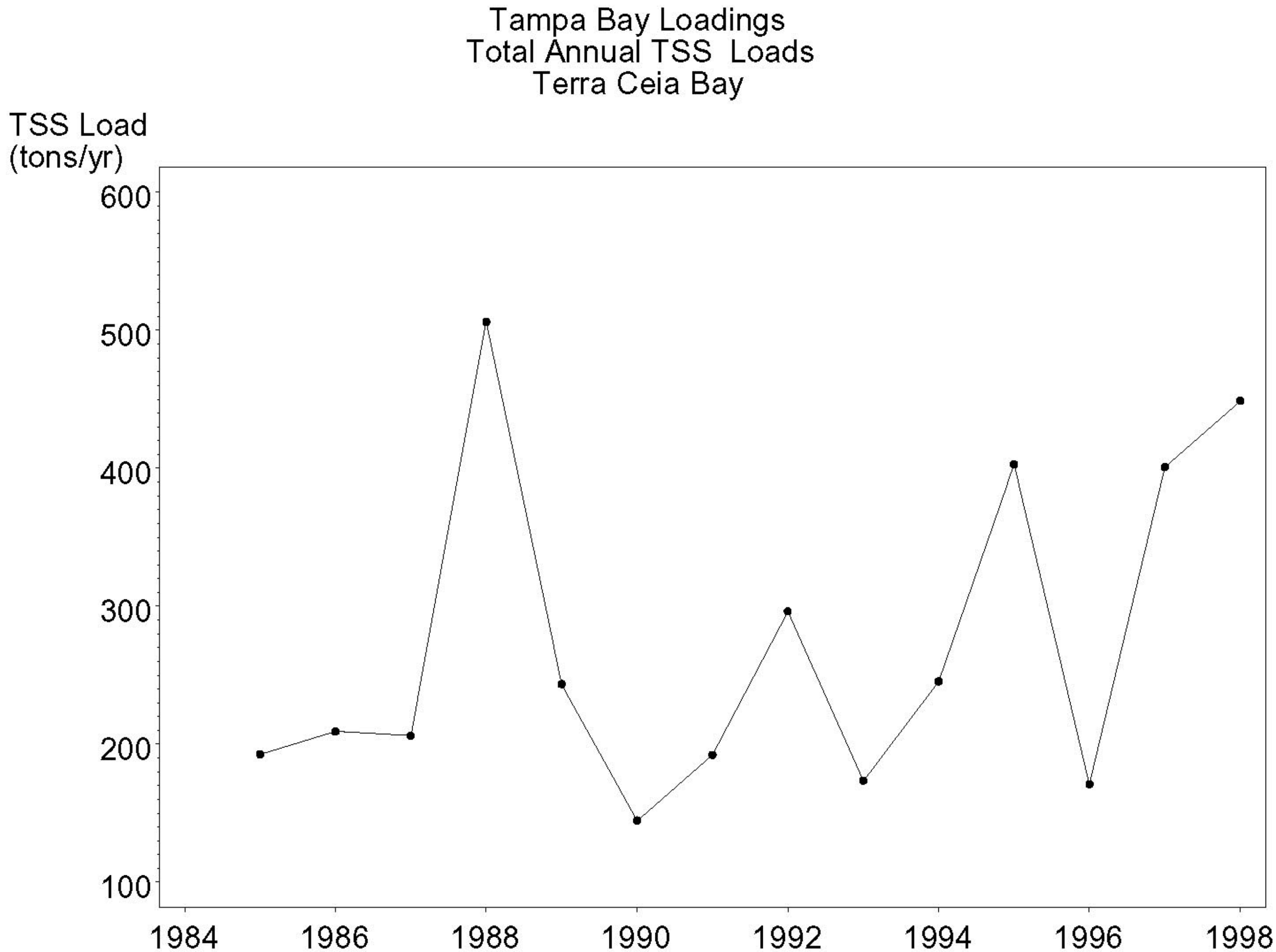


Tampa Bay Loadings
Total Annual TSS Loads
Middle Tampa Bay
TSS Load (tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1984
1986
1988
1990
1992
1994
1996
1998

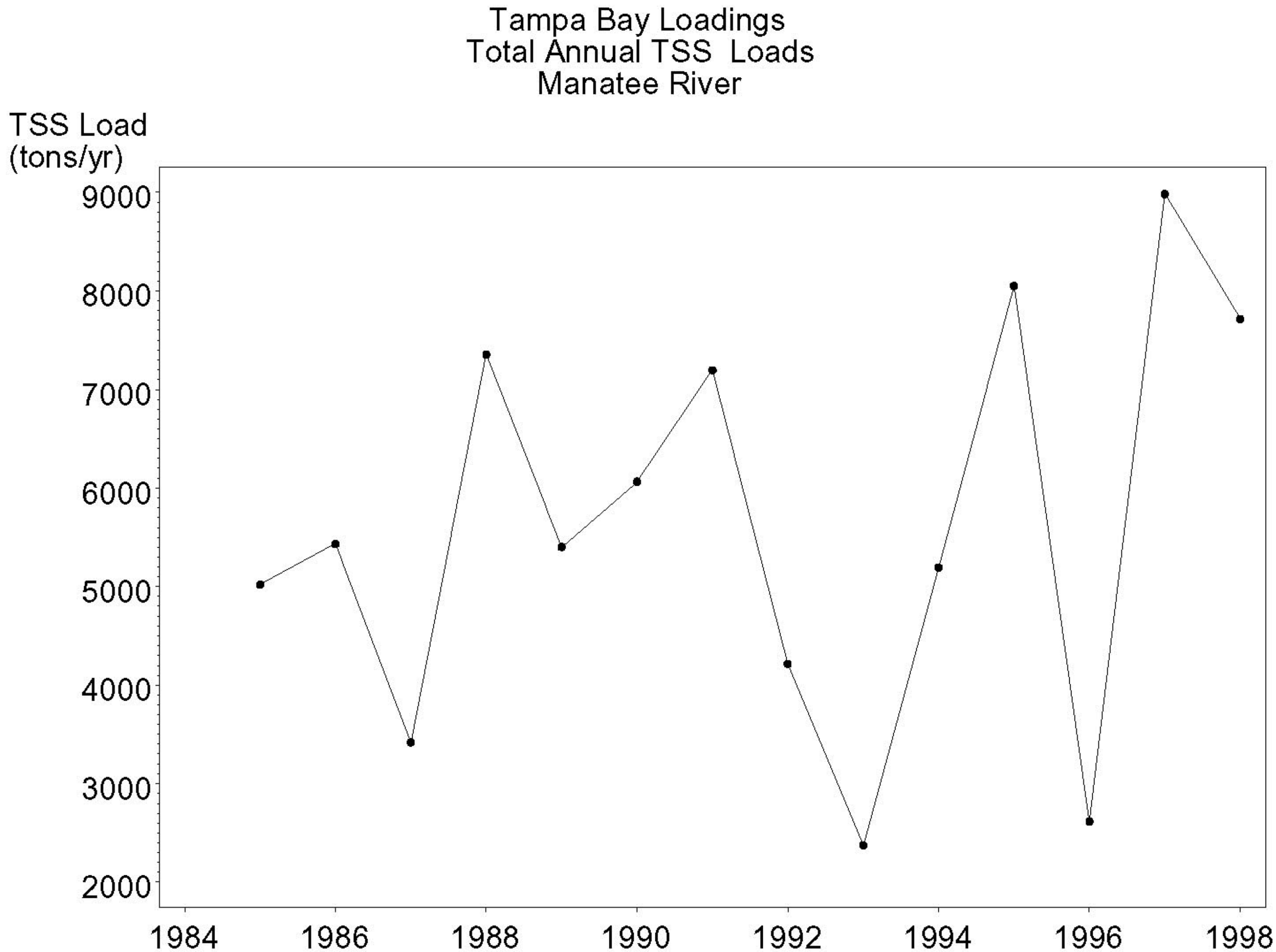


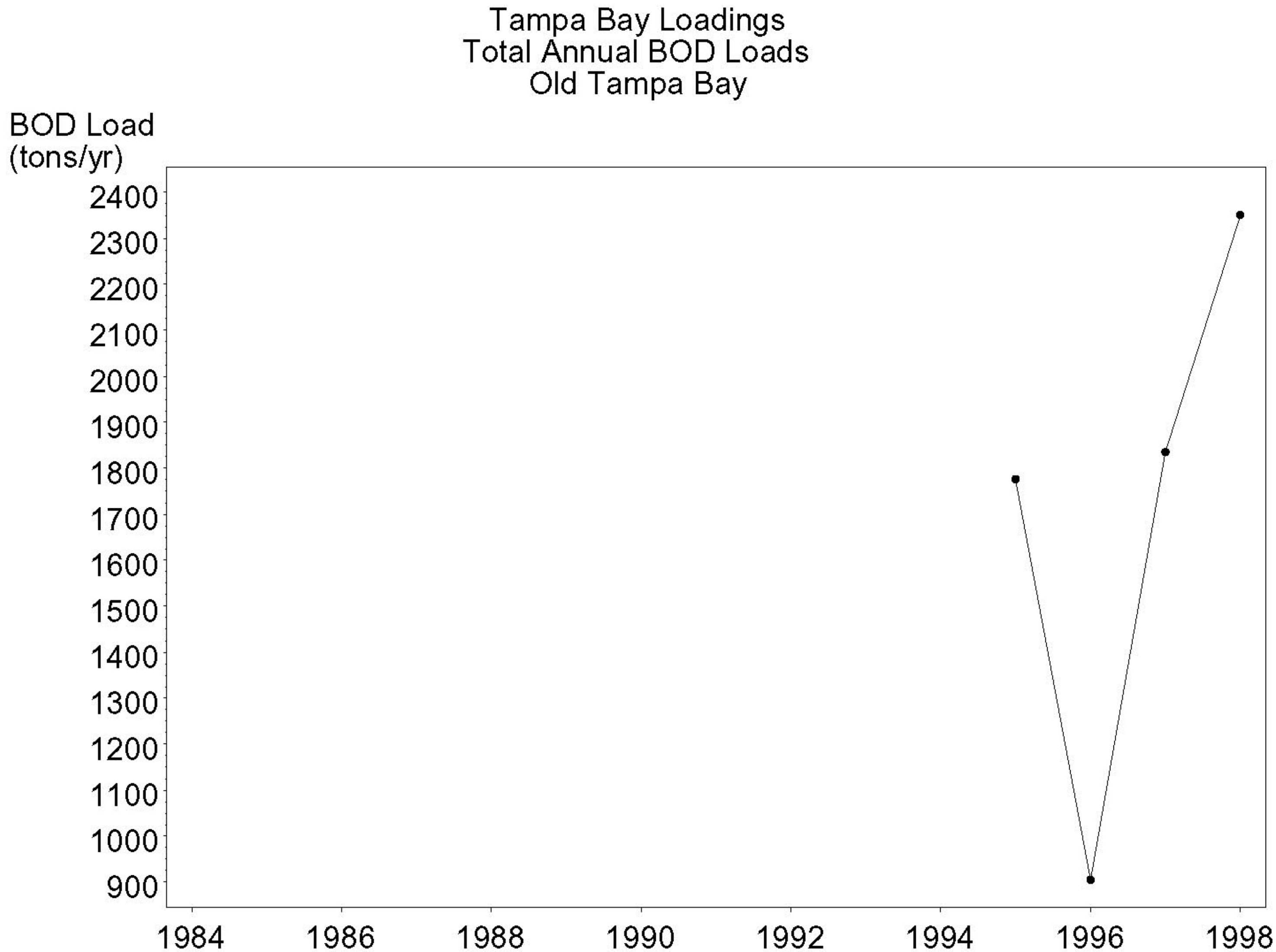
Tampa Bay Loadings
Total Annual TSS Loads
Lower Tampa Bay
TSS Load
(tons/yr)
1200
1100
1000
900
800
700
600
500
400
300
1984
1986
1988
1990
1992
1994
1996
1998


Tampa Bay Loadings
Total Annual TSS Loads
Boca Ciega Bay
TSS Load
(tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1984
1986
1988
1990
1992
1994
1996
1998

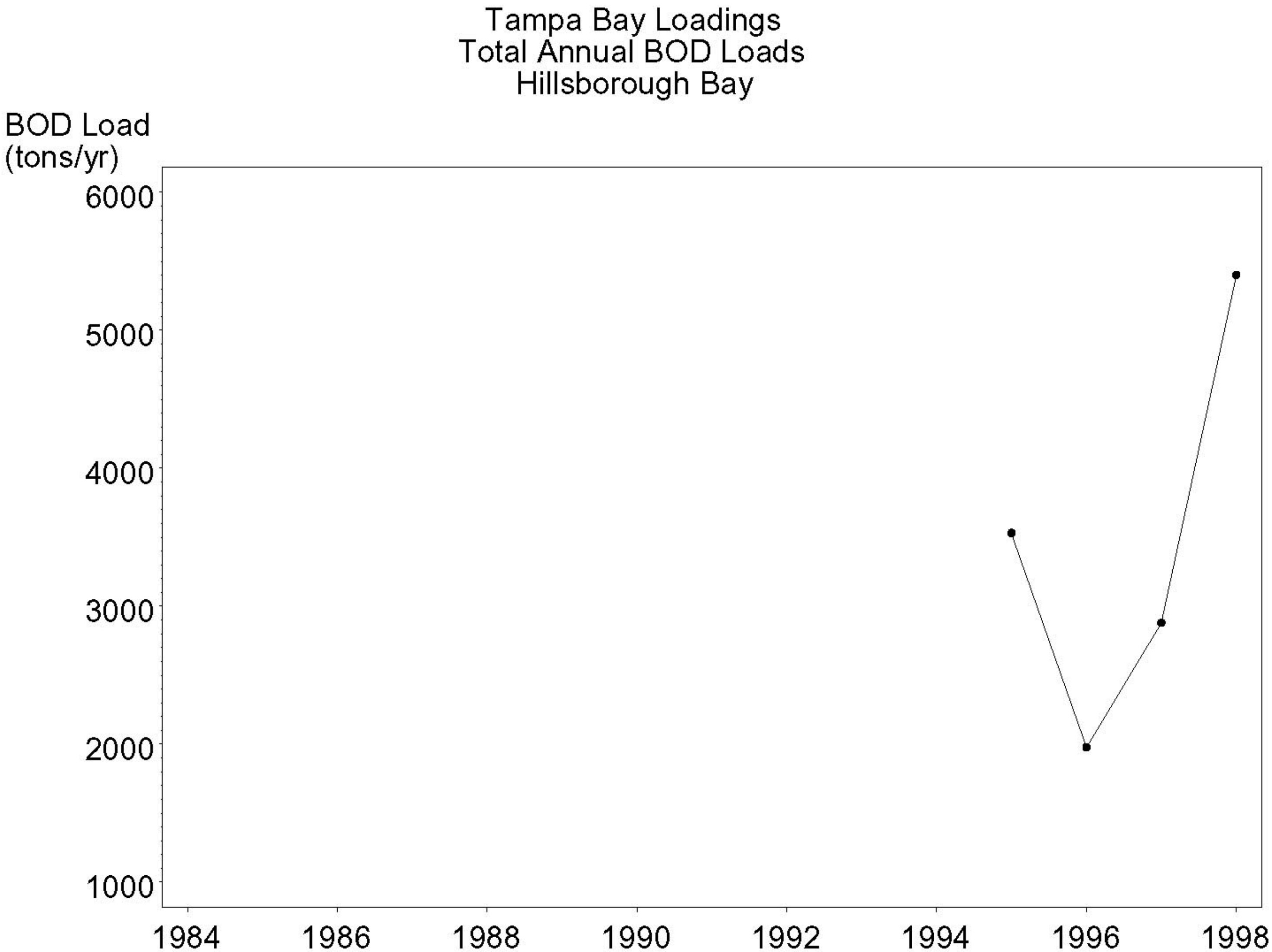


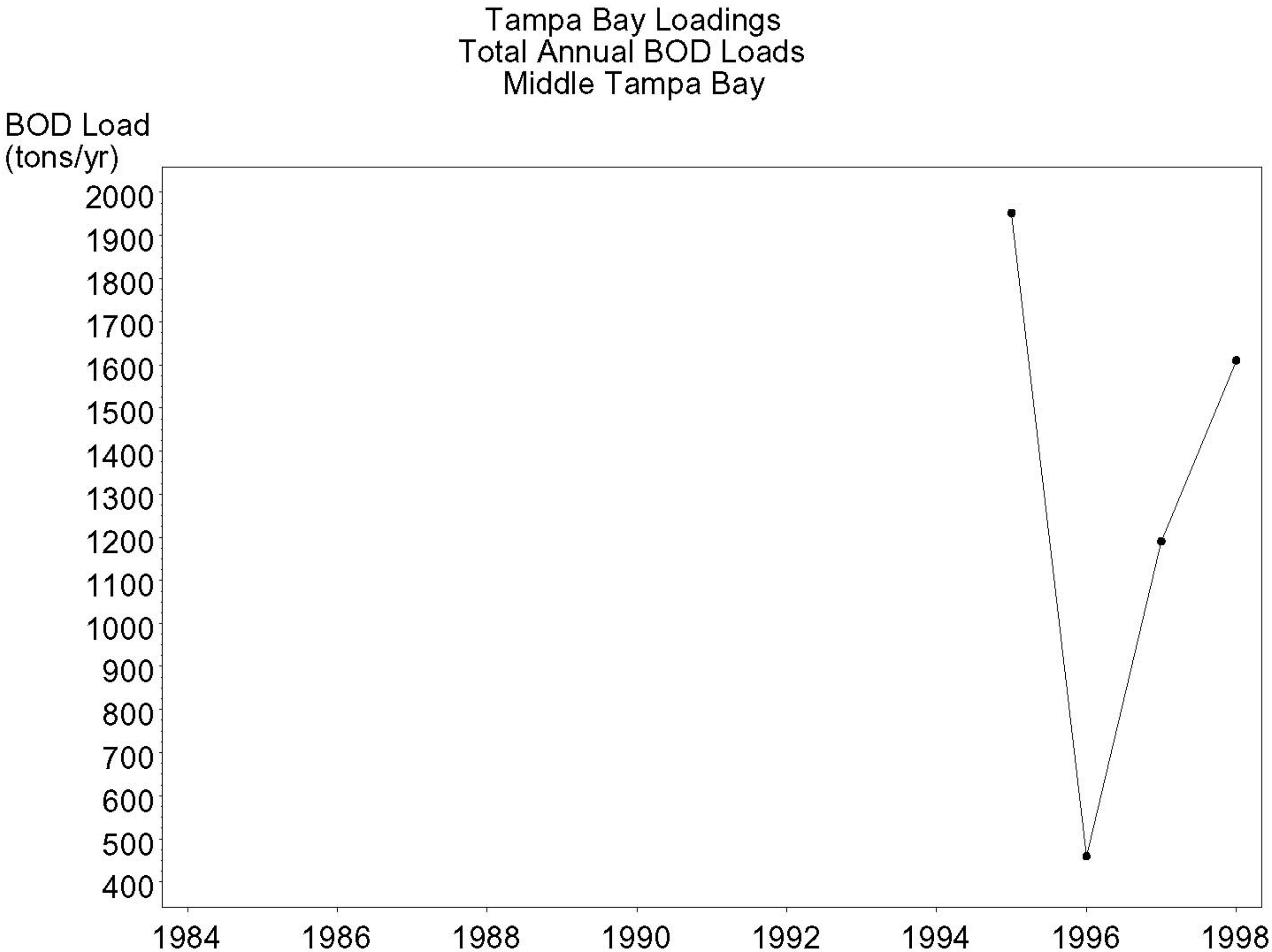
Tampa Bay Loadings
Total Annual TSS Loads
Terra Ceia Bay
TSS Load
(tons/yr)
600
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998

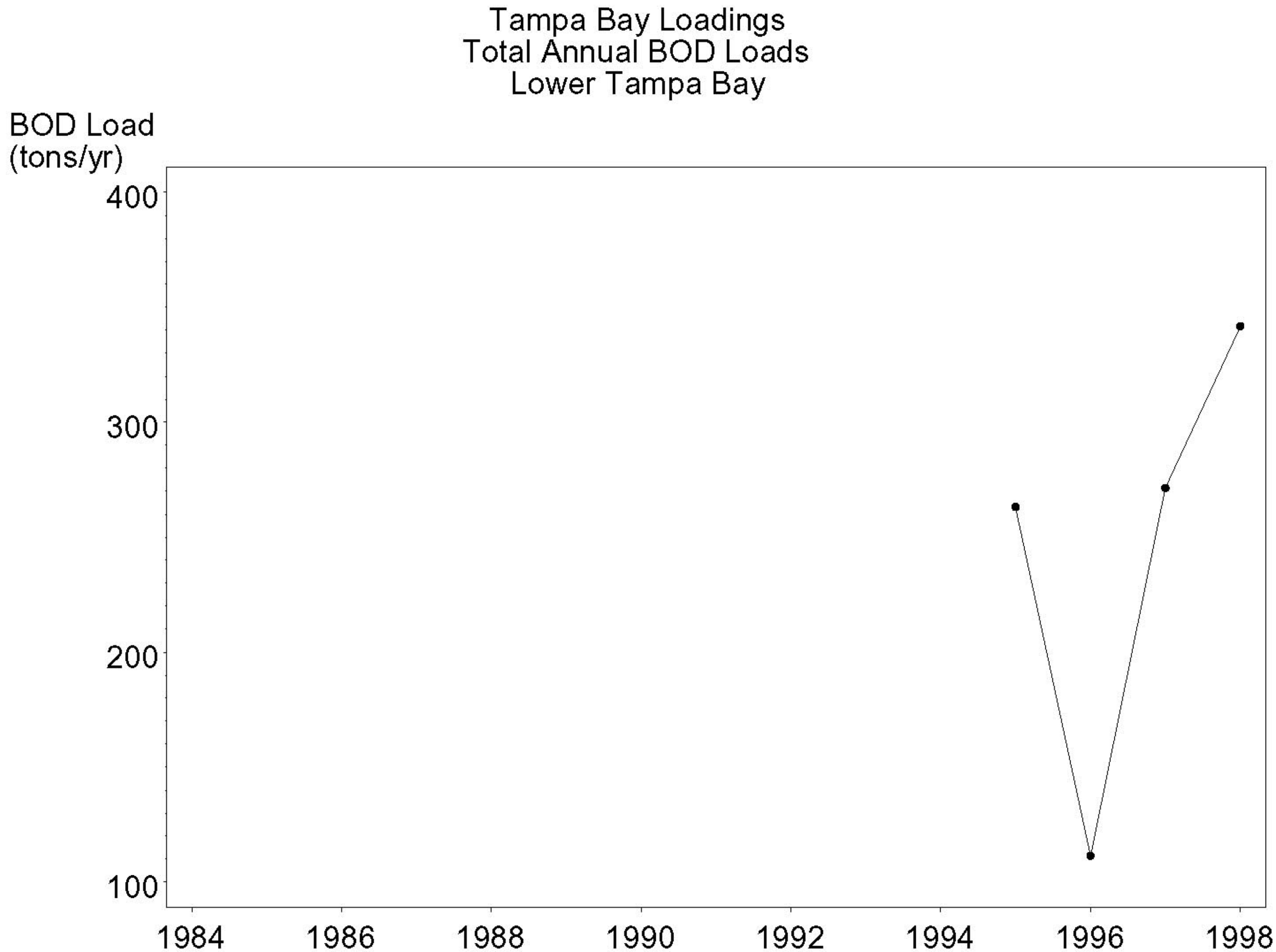

Tampa Bay Loadings
Total Annual TSS Loads
Manatee River
TSS Load
(tons/yr)
9000
8000
7000
6000
5000
4000
3000
2000
1984
1986
1988
1990
1992
1994
1996
1998

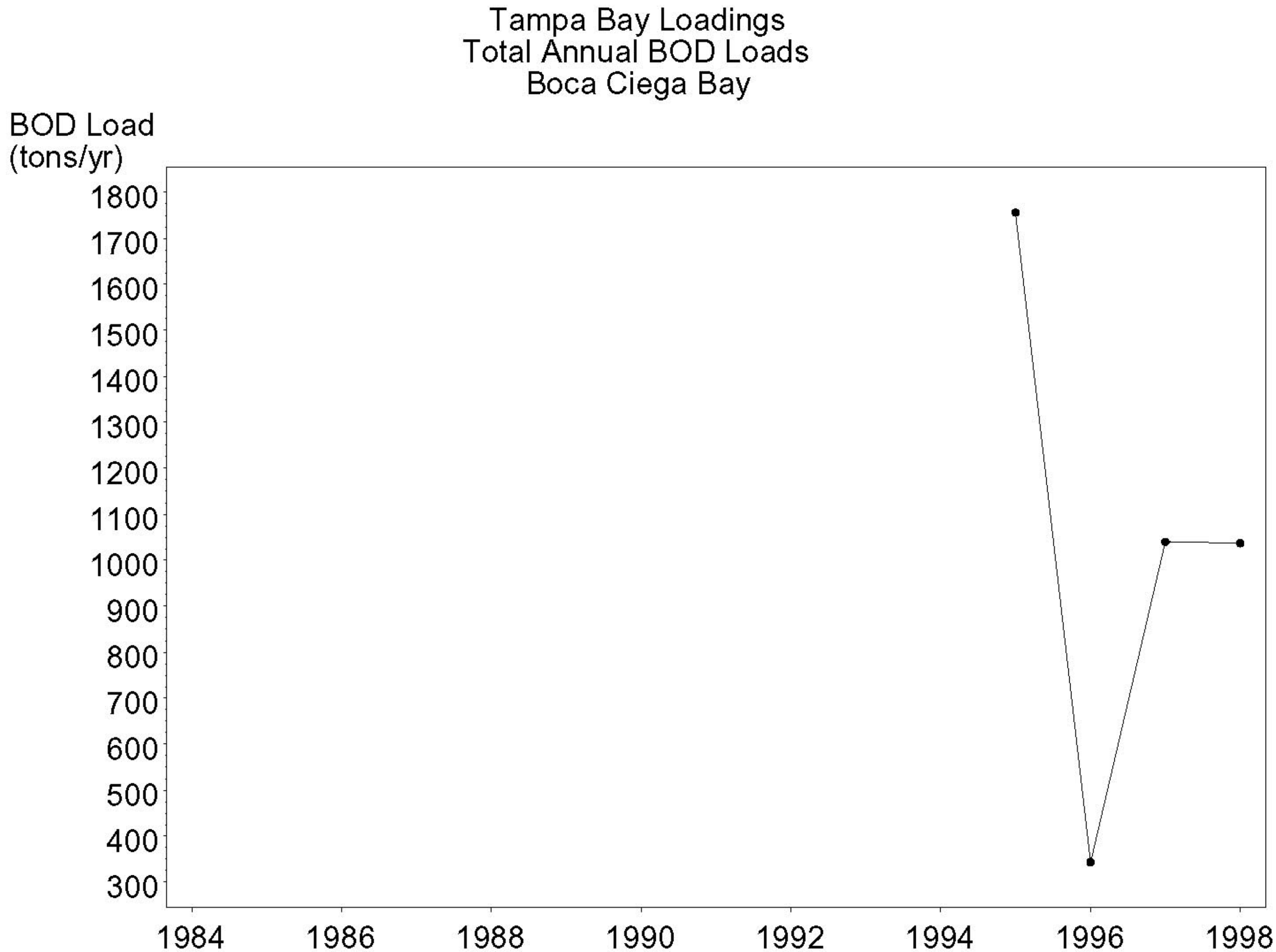


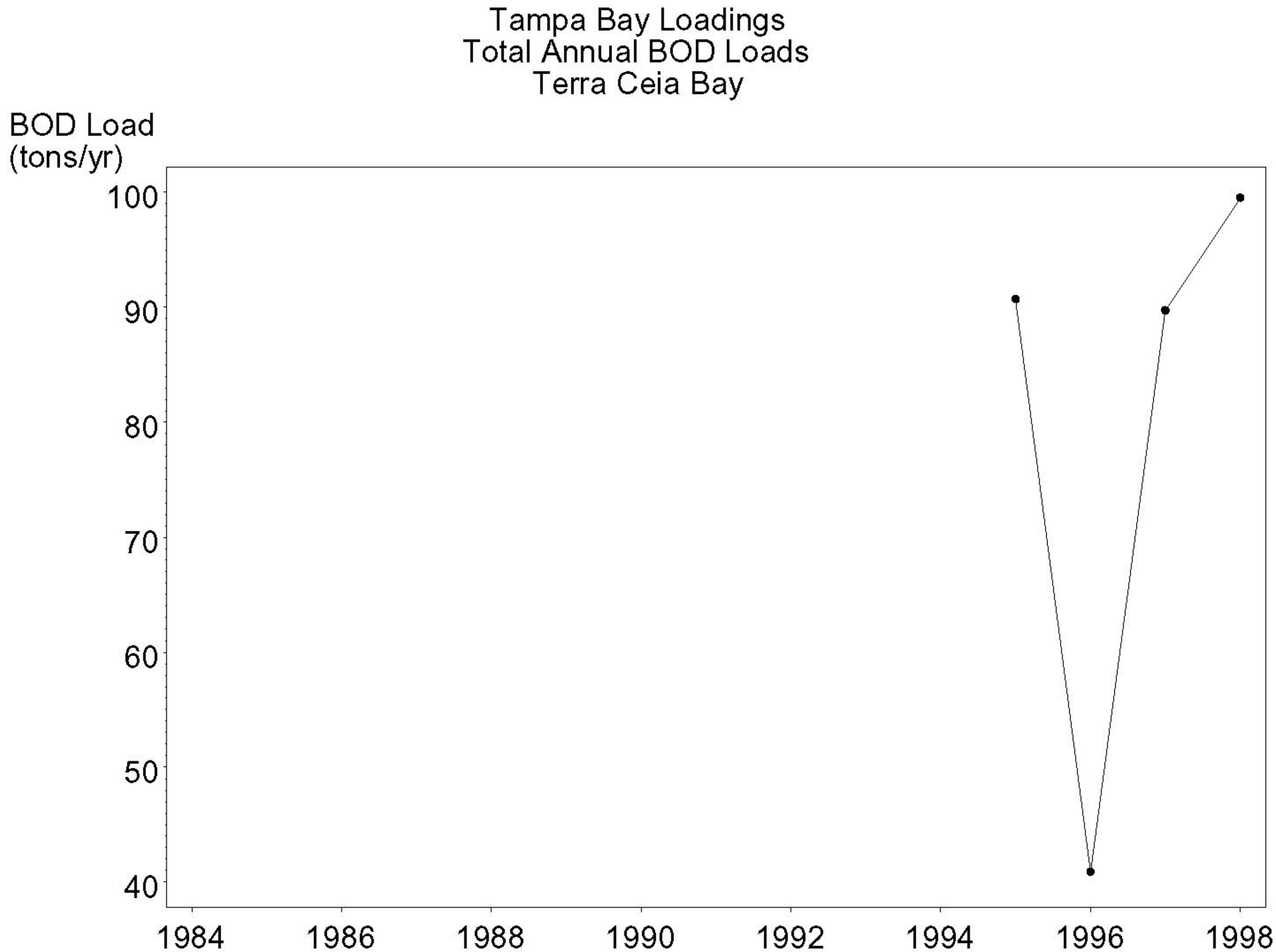
Tampa Bay Loadings
Total Annual BOD Loads
Old Tampa Bay
BOD Load
(tons/yr)
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
1984
1986
1988
1990
1992
1994
1996
1998

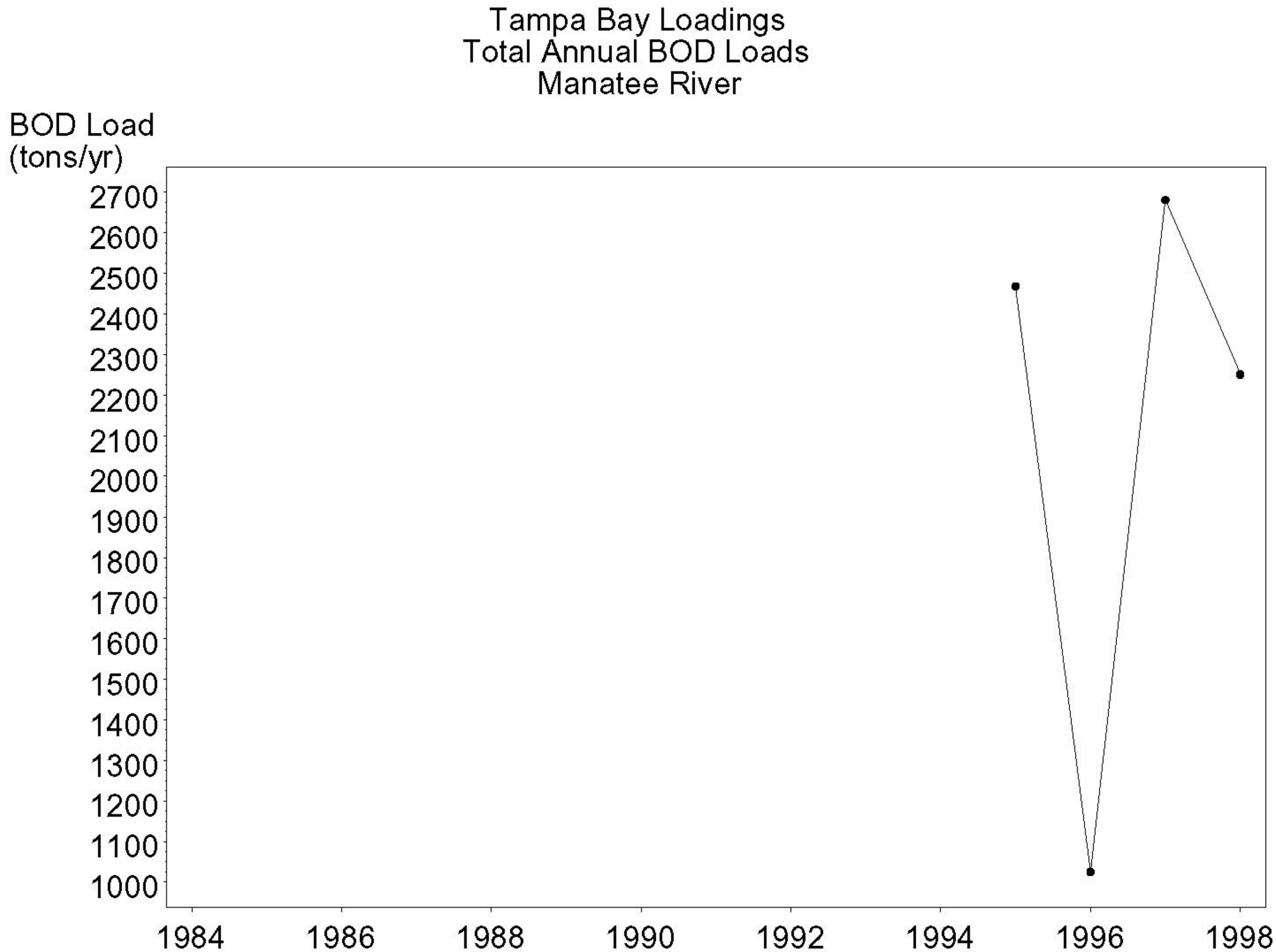

Tampa Bay Loadings
Total Annual BOD Loads
Hillsborough Bay
BOD Load
(tons/yr)
6000
5000
4000
3000
2000
1000
1984
1986
1988
1990
1992
1994
1996
1998


Tampa Bay Loadings
Total Annual BOD Loads
Middle Tampa Bay
BOD Load
(tons/yr)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
1984
1986
1988
1990
1992
1994
1996
1998


Tampa Bay Loadings
Total Annual BOD Loads
Lower Tampa Bay
BOD Load
(tons/yr)
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998

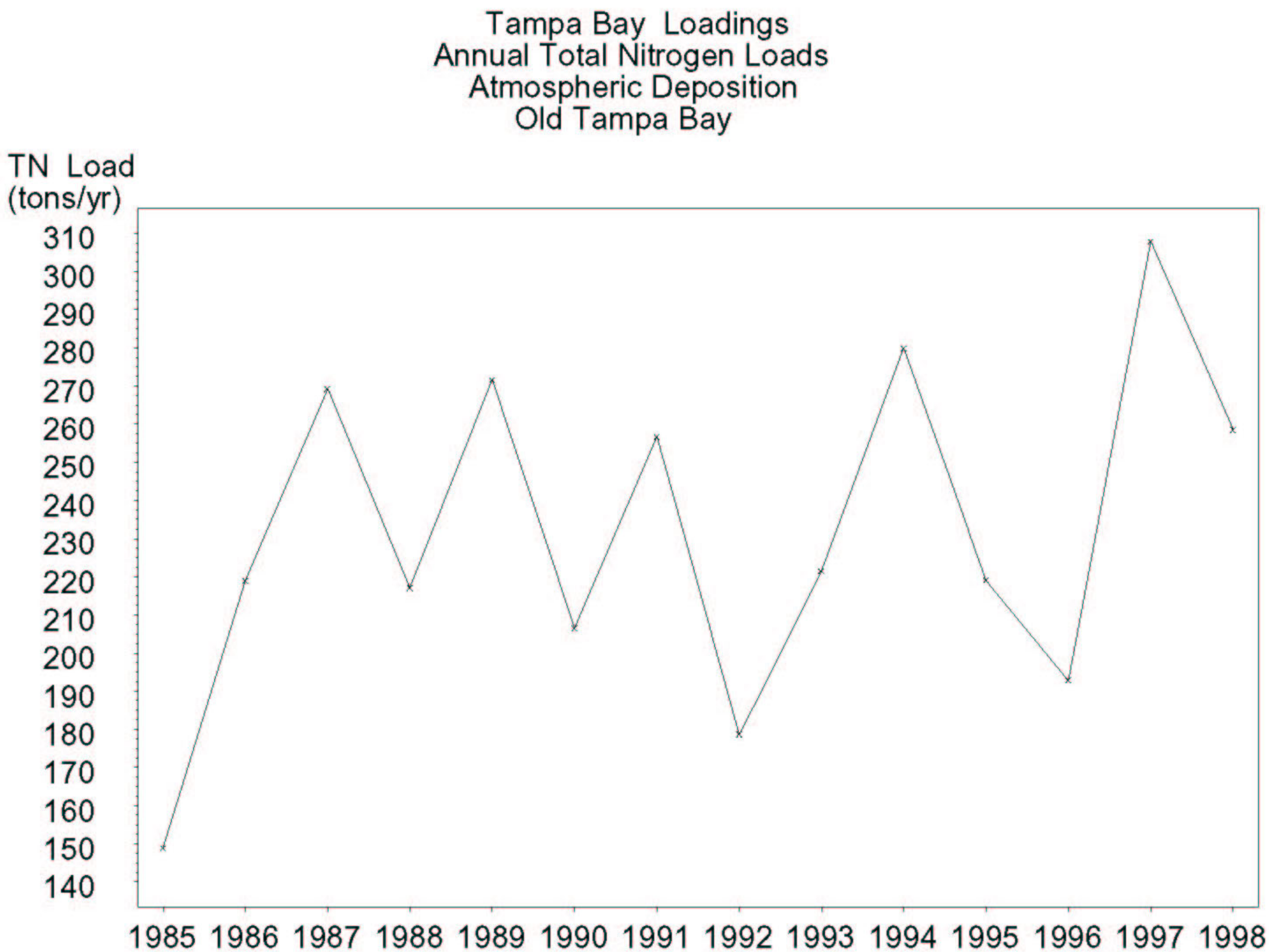

Tampa Bay Loadings
Total Annual BOD Loads
Boca Ciega Bay
BOD Load
(tons/yr)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1984
1986
1988
1990
1992
1994
1996
1998

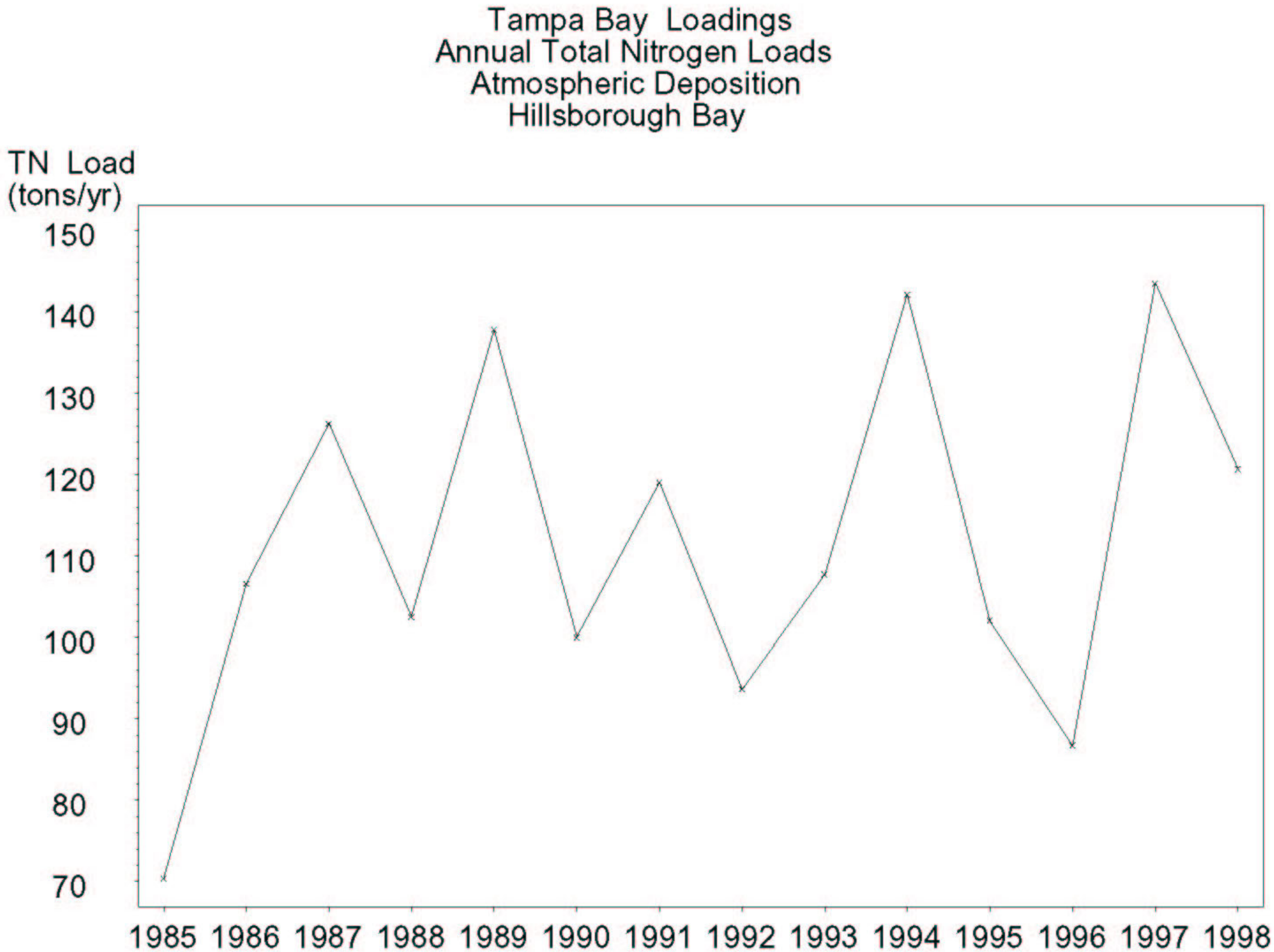

Tampa Bay Loadings
Total Annual BOD Loads
Terra Ceia Bay
BOD Load
(tons/yr)
100
90
80
70
60
50
40
1984
1986
1988
1990
1992
1994
1996
1998

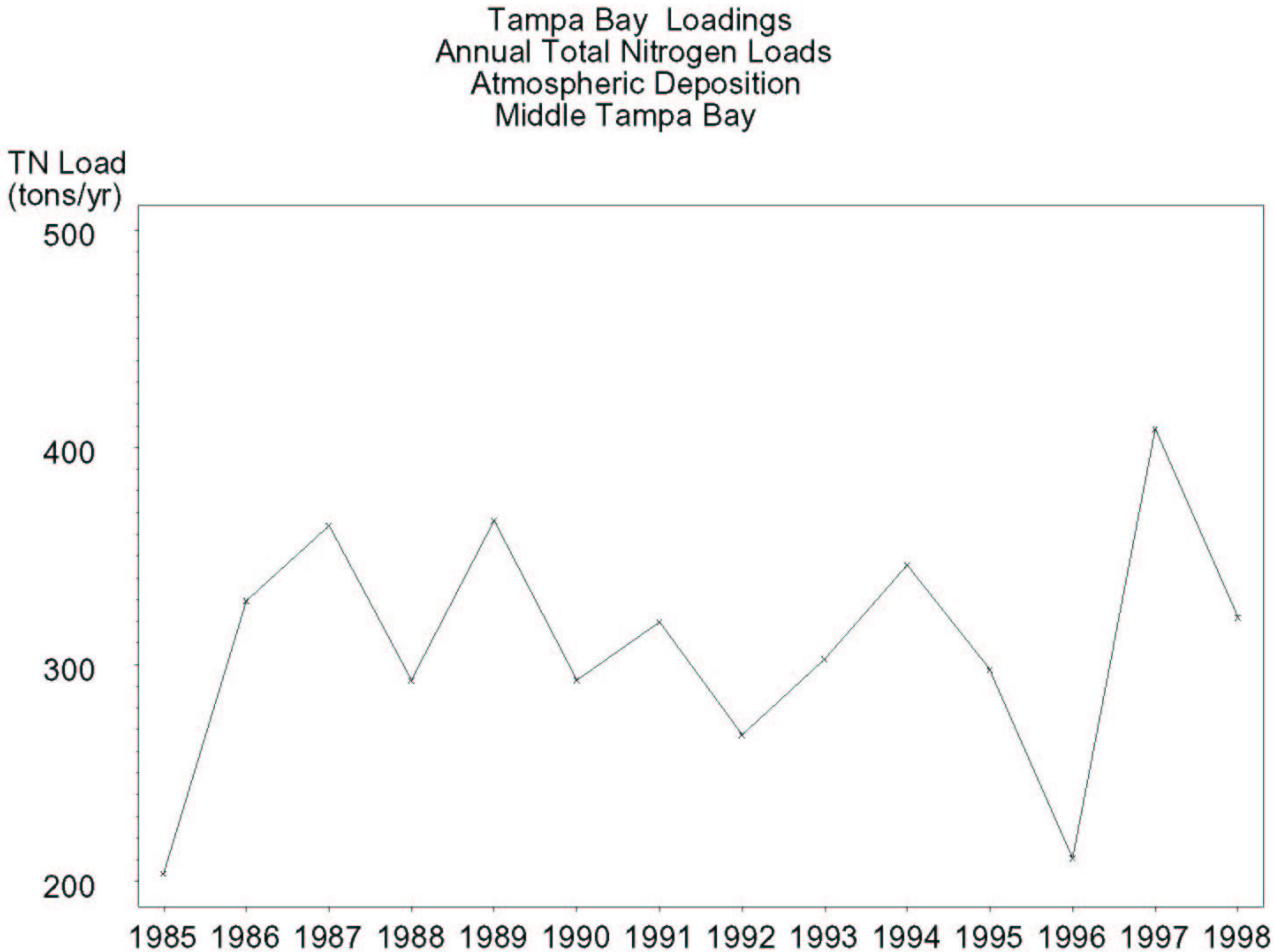

Tampa Bay Loadings
Total Annual BOD Loads
Manatee River
BOD Load
(tons/yr)
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
1984
1986
1988
1990
1992
1994
1996
1998

APPENDIX F

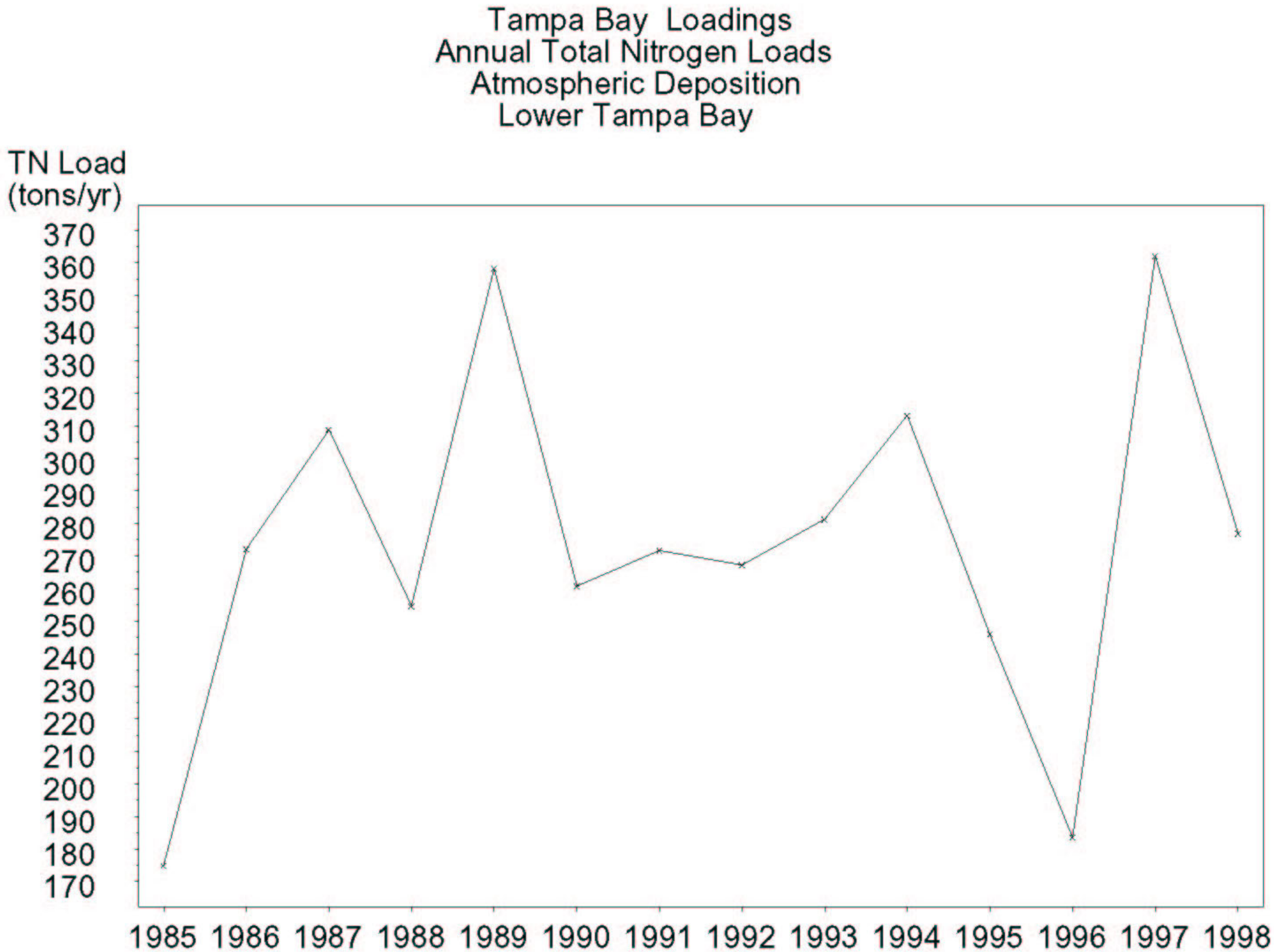
Annual Loadings of TN, TP, TSS, and BOD
to Each Bay Segment by Source, 1985-1998

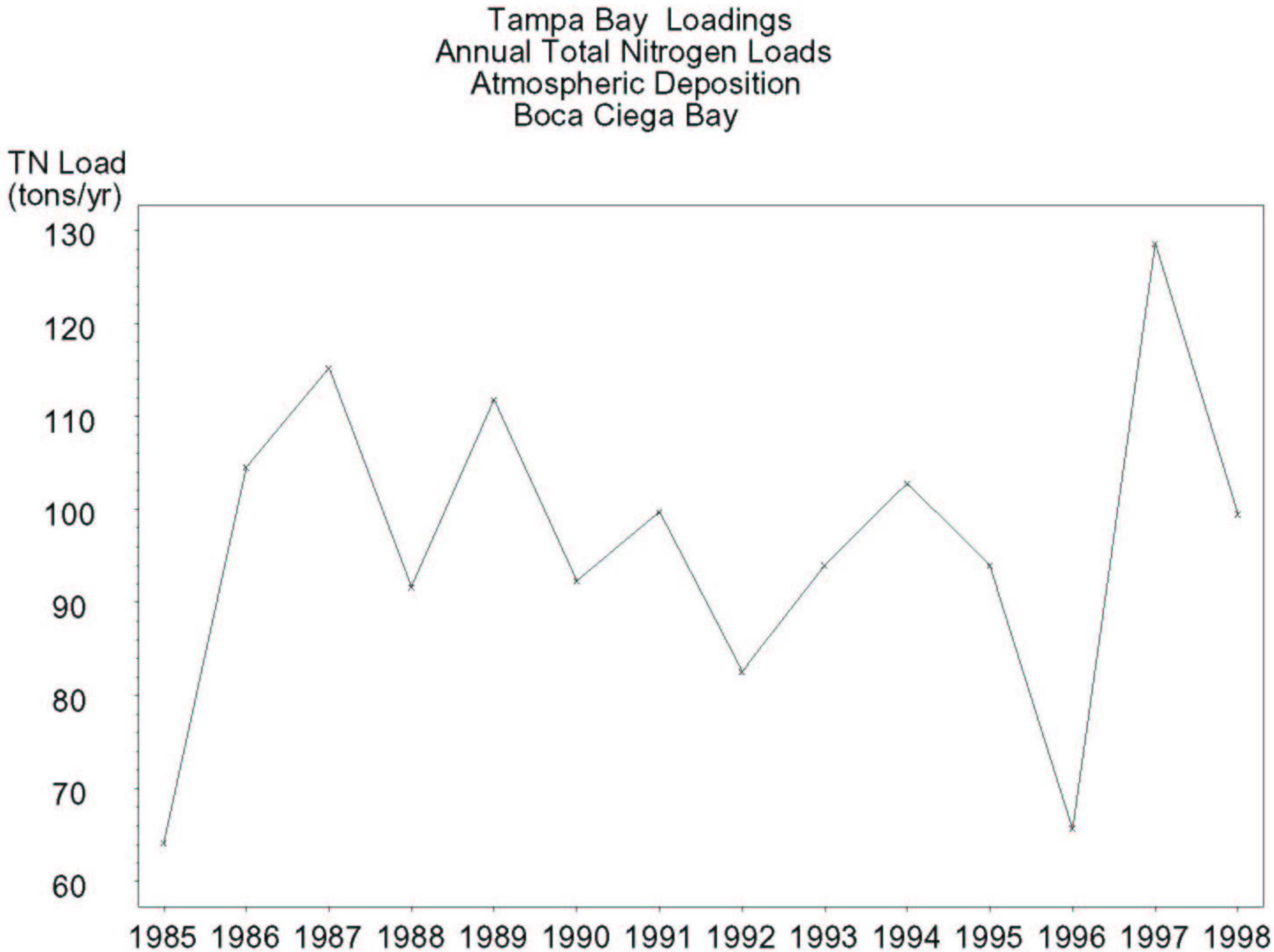

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Old Tampa Bay
TN Load
(tons/yr)
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

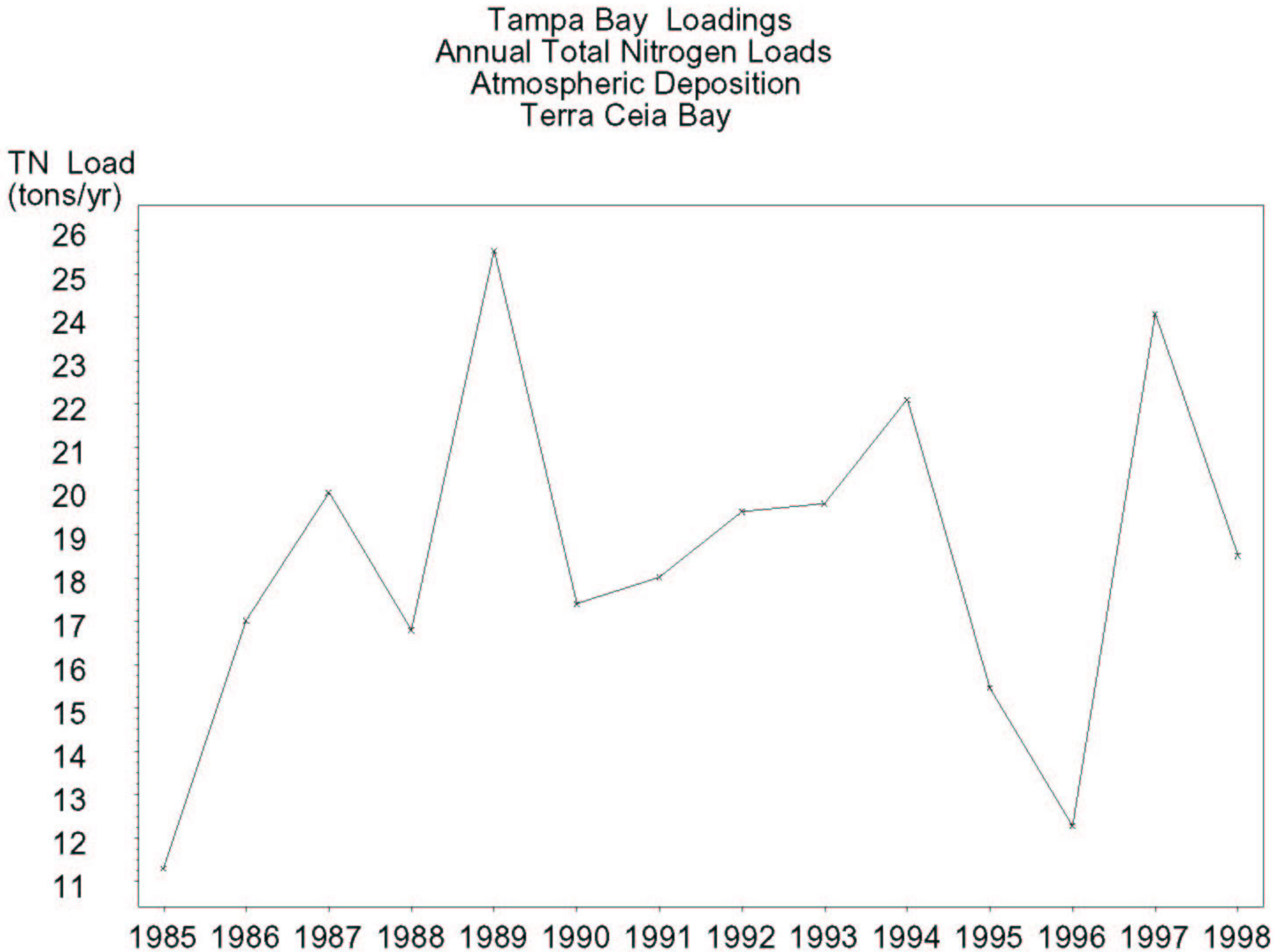

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Hillsborough Bay
TN Load
(tons/yr)
150
140
130
120
110
100
90
80
70
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



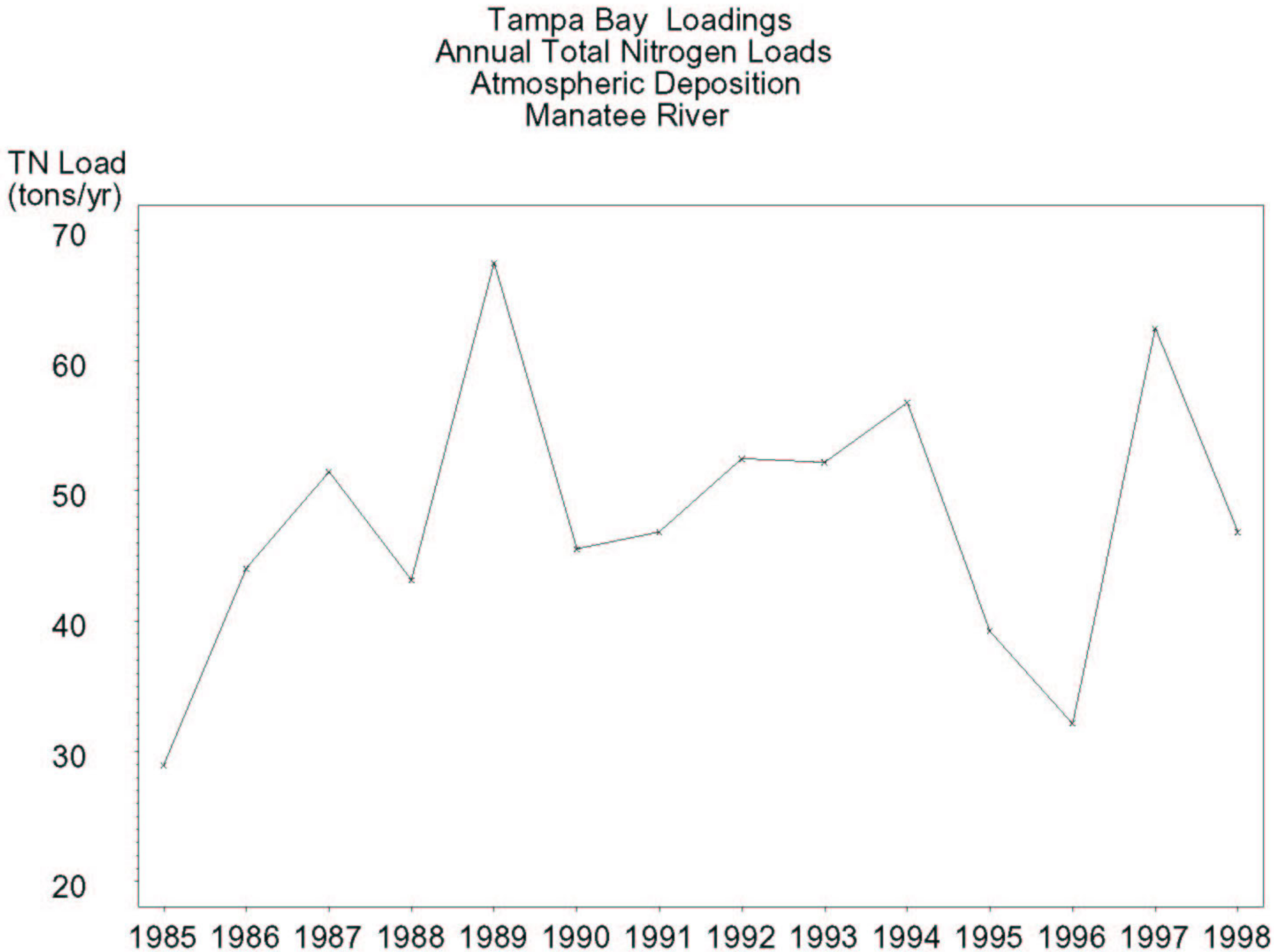
Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Middle Tampa Bay
TN Load
(tons/yr)
500
400
300
200
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

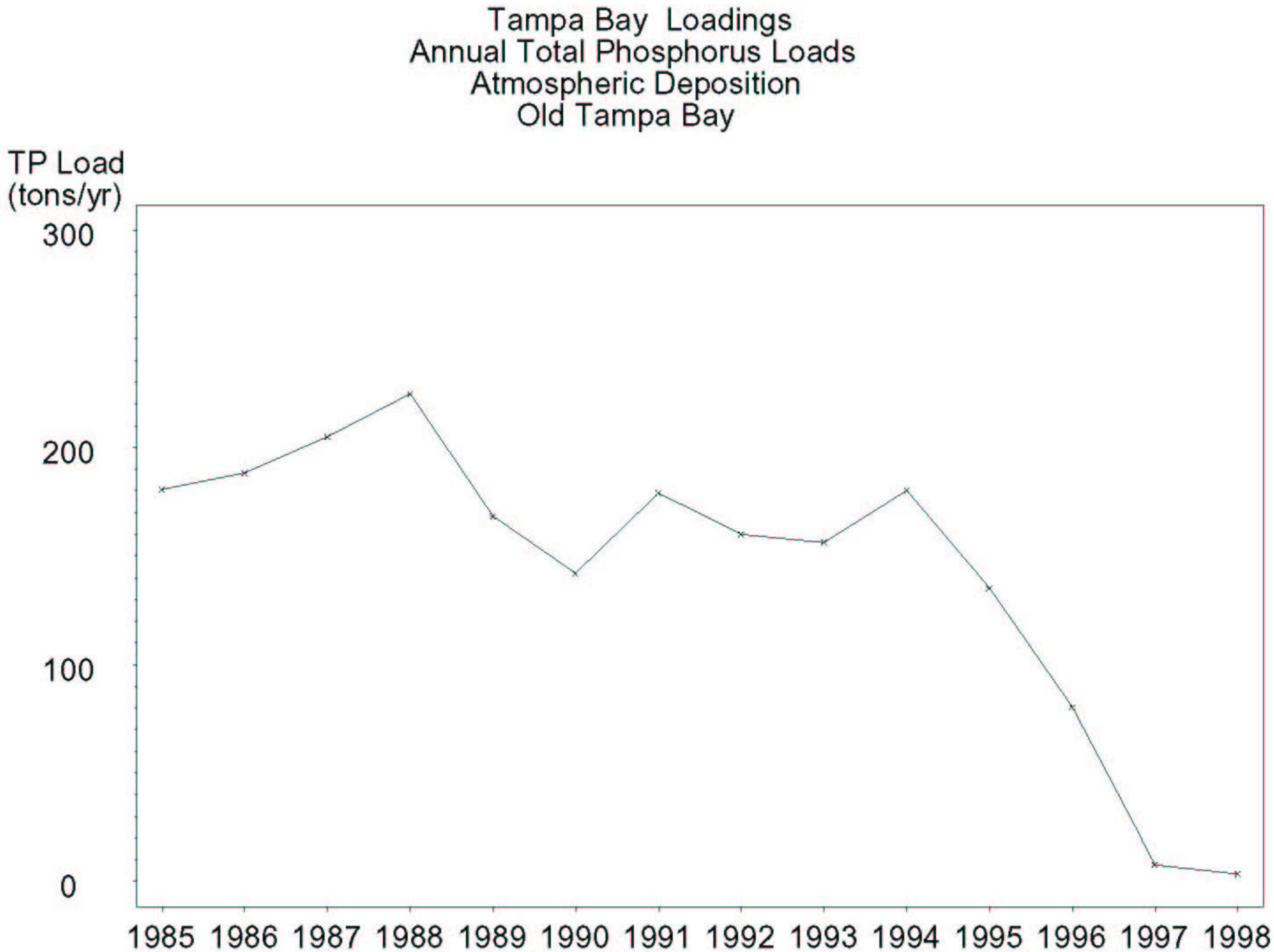

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Lower Tampa Bay
TN Load
(tons/yr)
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

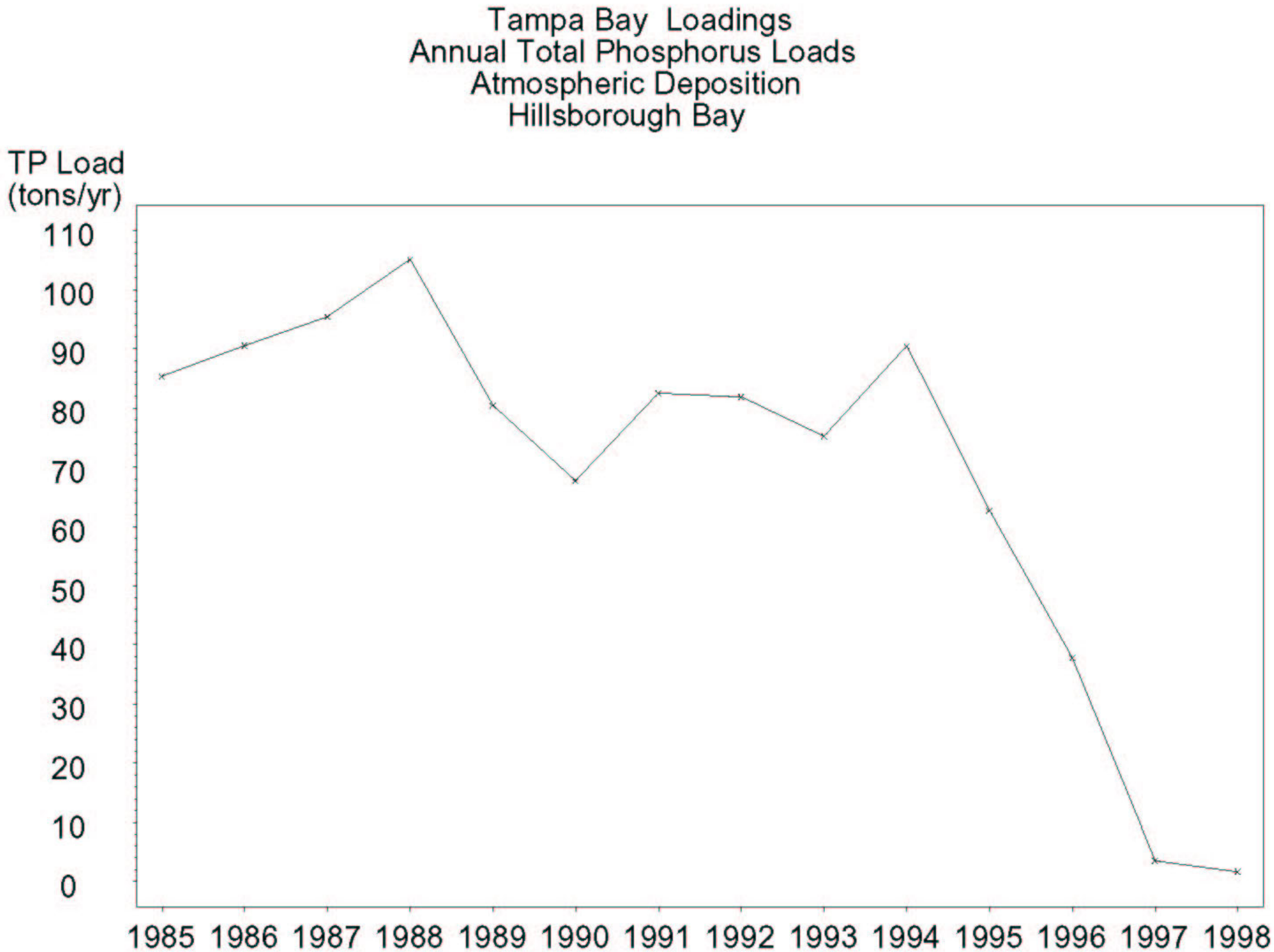

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Boca Ciega Bay
TN Load
(tons/yr)
130
120
110
100
90
80
70
60
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

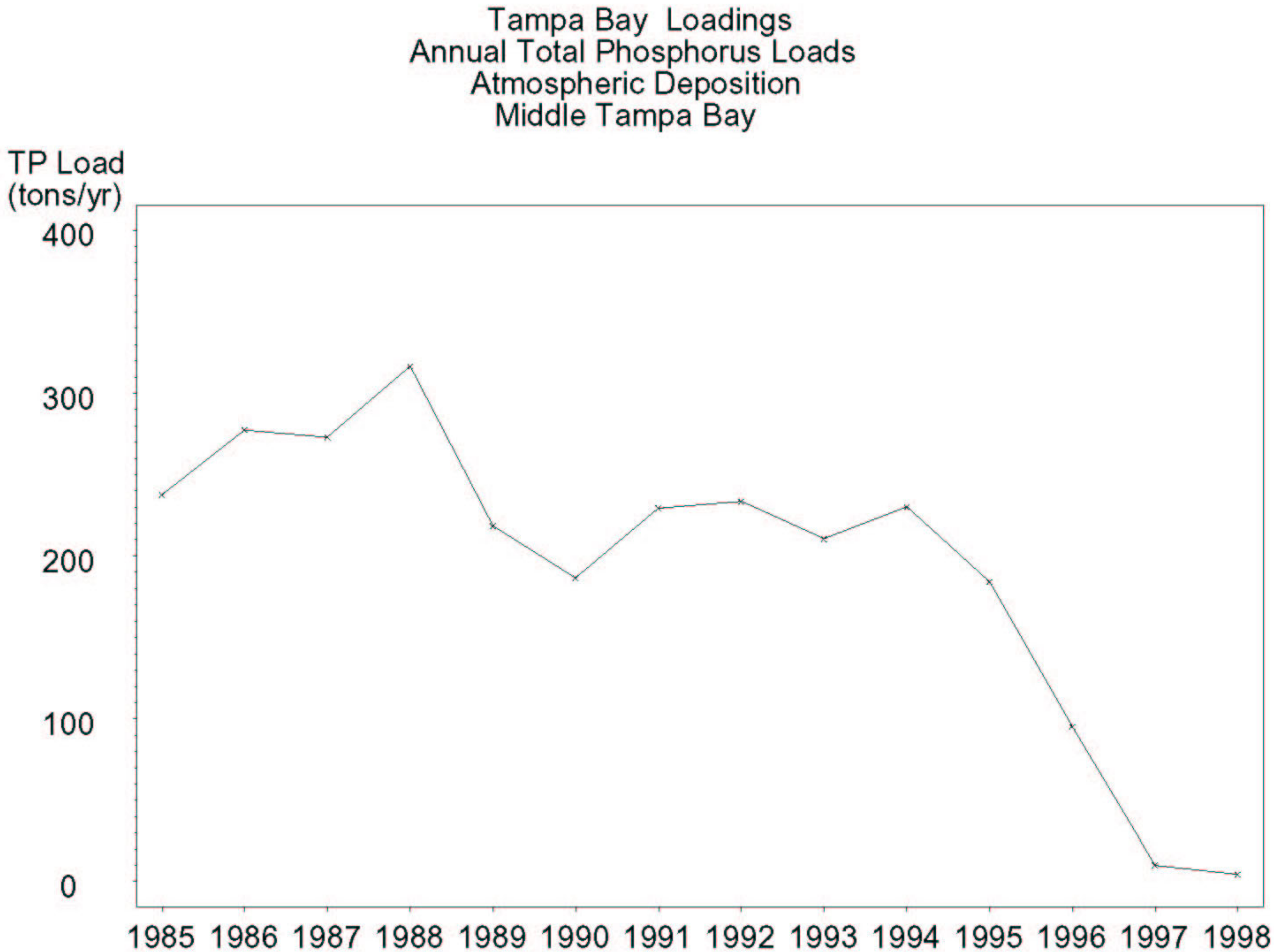


Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Terra Ceia Bay
TN Load (tons/yr)
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

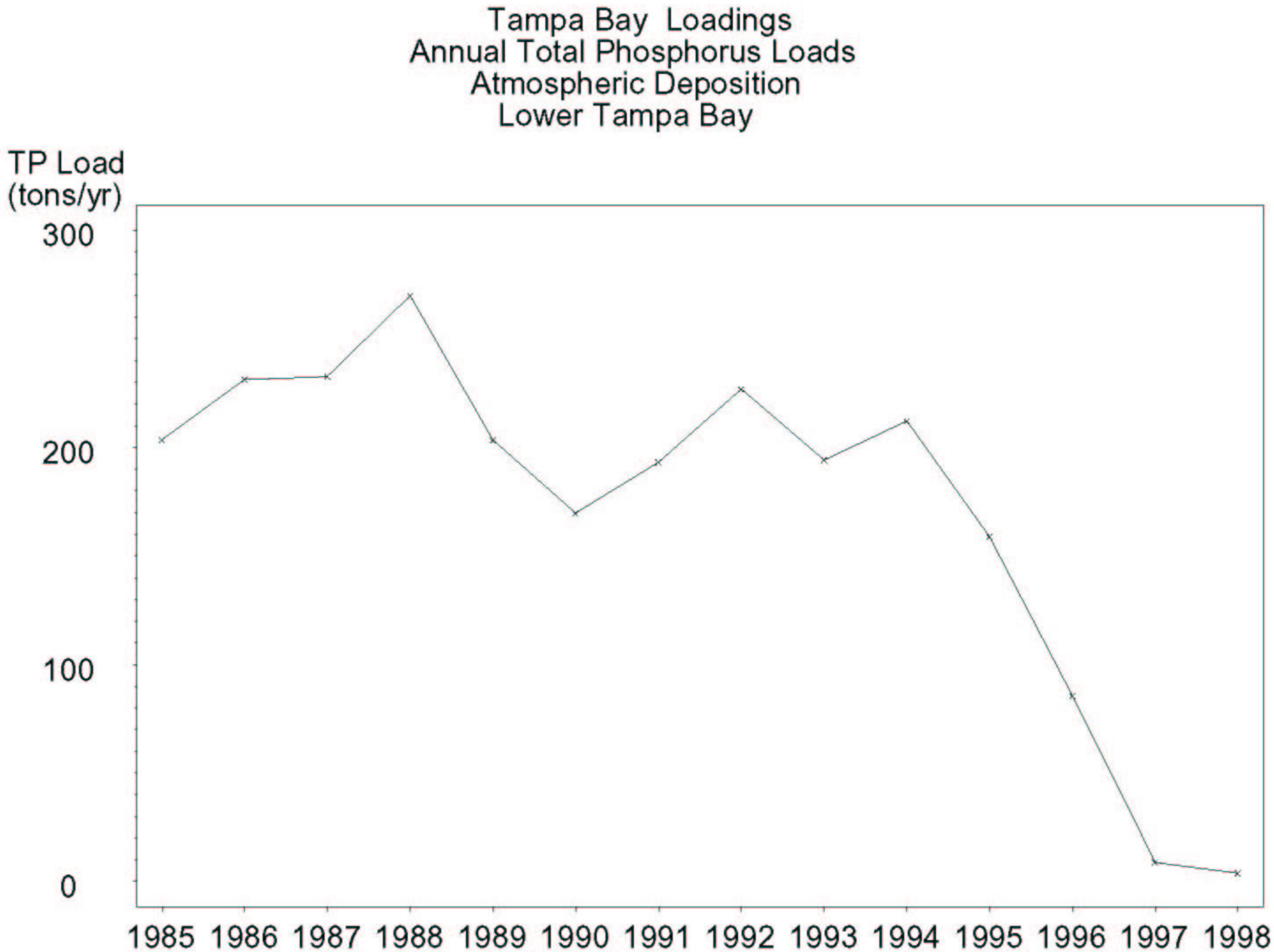

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Manatee River
TN Load
(tons/yr)
70
60
50
40
30
20
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

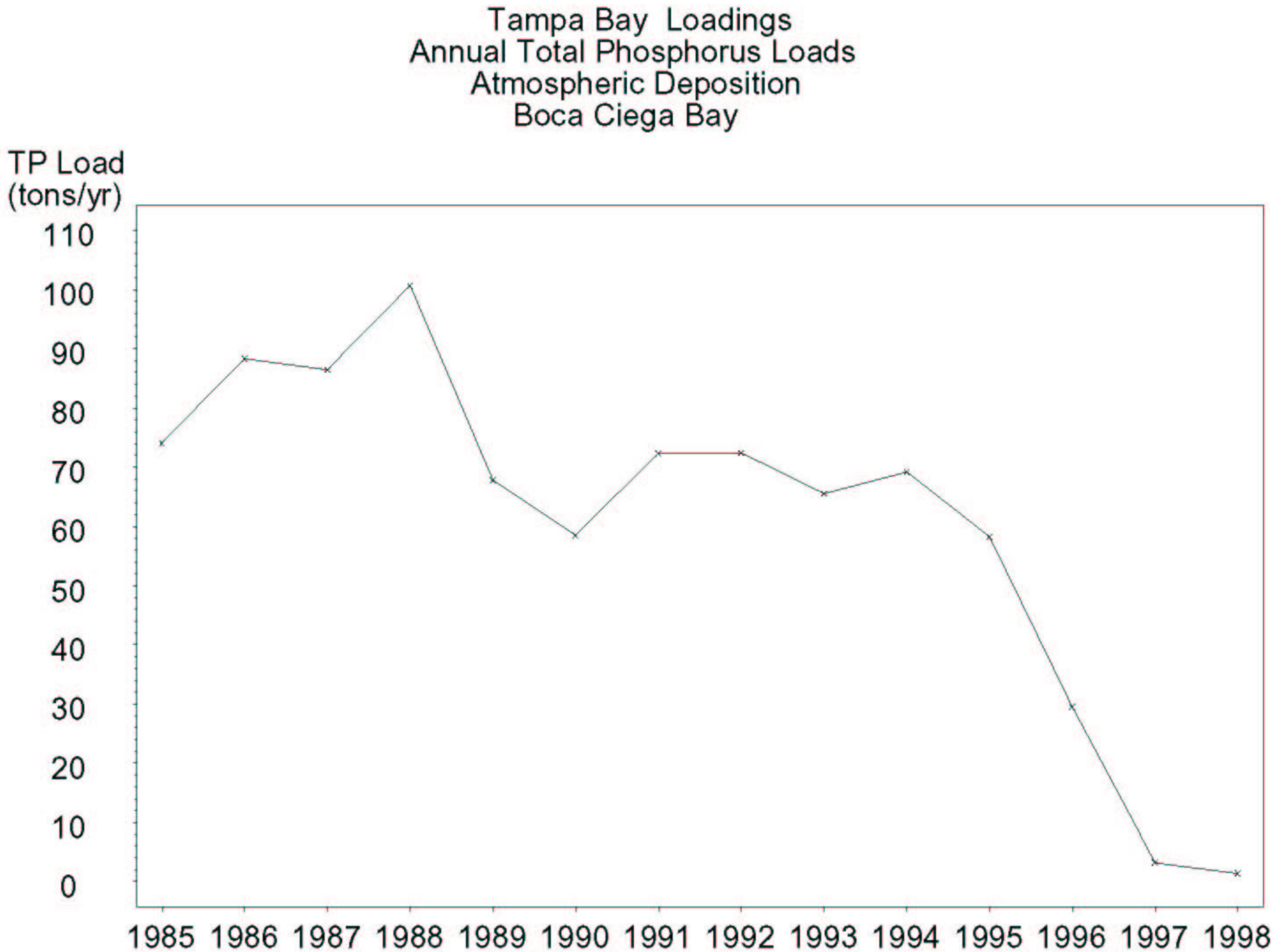

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Old Tampa Bay
TP Load
(tons/yr)
300
200
100
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

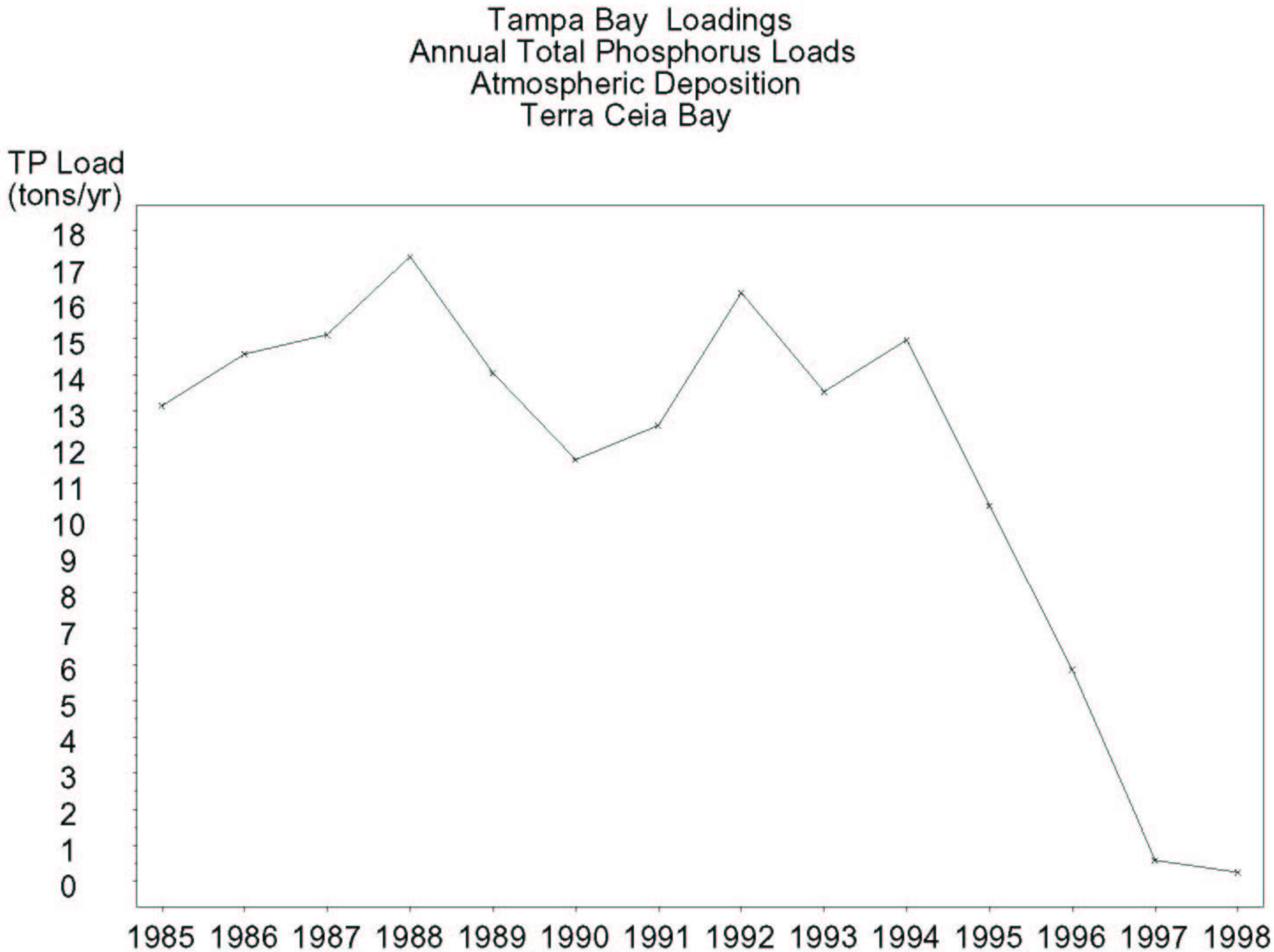

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Hillsborough Bay
TP Load (tons/yr)
110
100
90
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

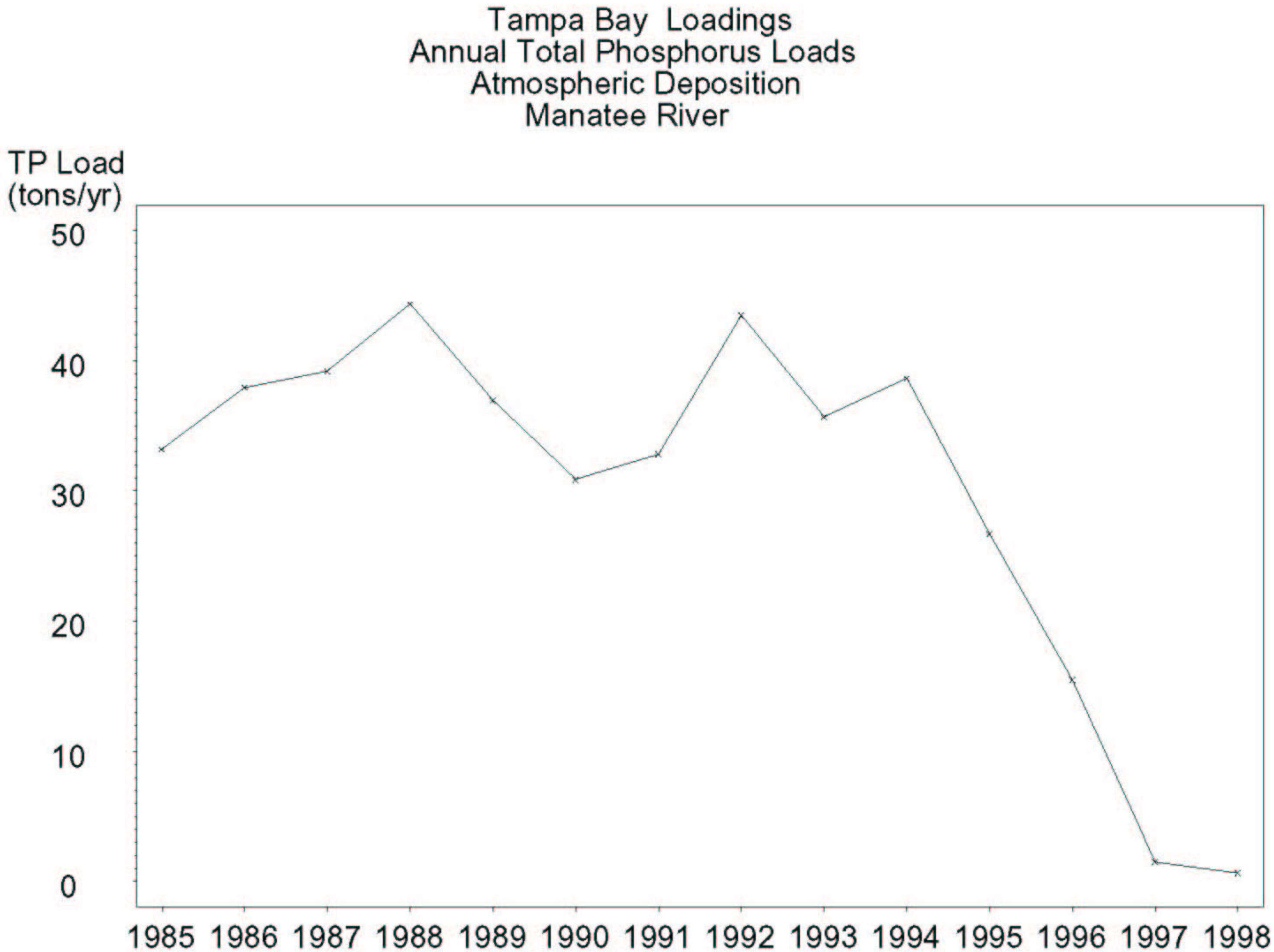


Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Middle Tampa Bay
TP Load
(tons/yr)
400
300
200
100
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

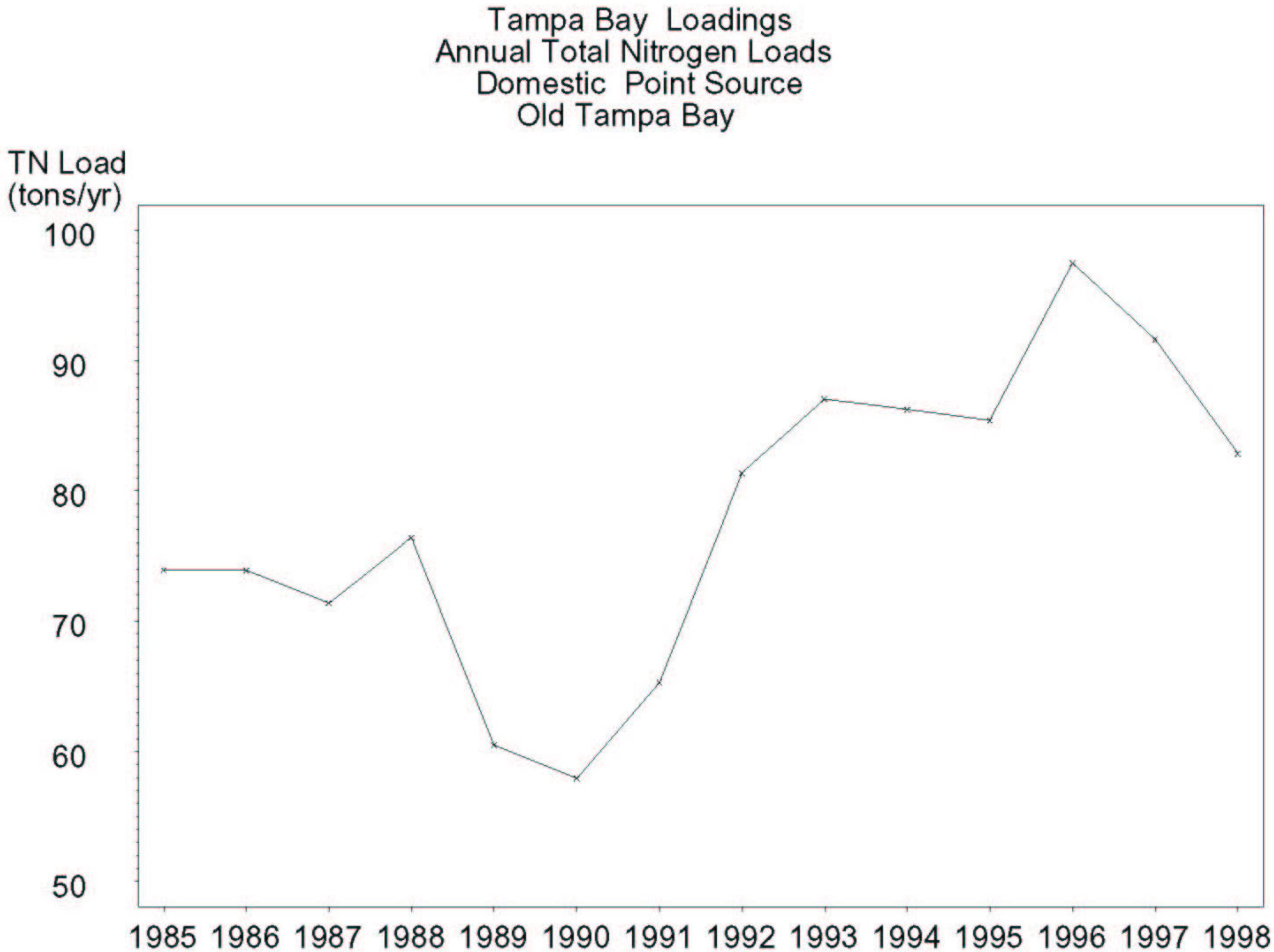

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Lower Tampa Bay
TP Load
(tons/yr)
300
200
100
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

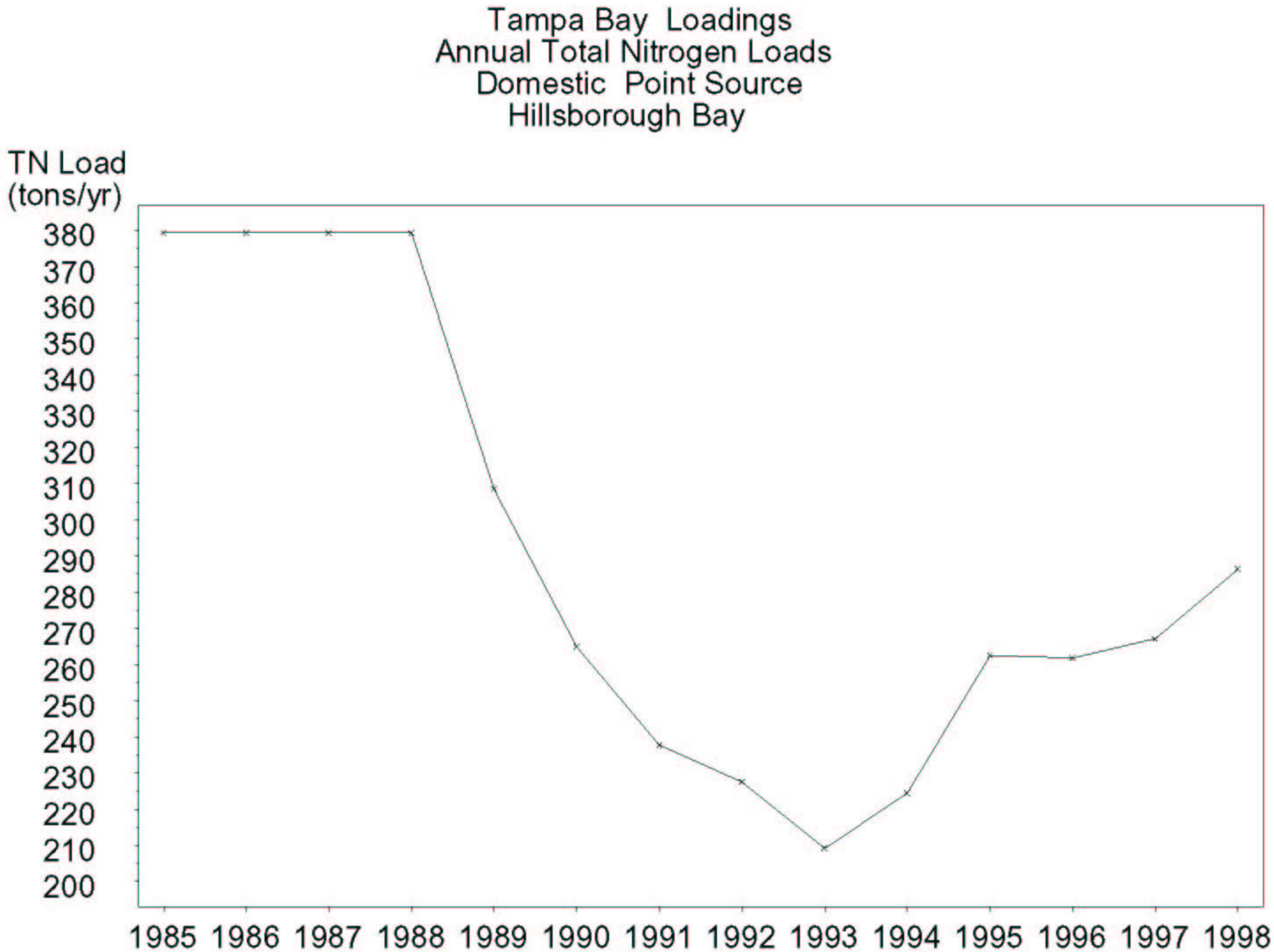

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Boca Ciega Bay
TP Load
(tons/yr)
110
100
90
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Terra Ceia Bay
TP Load
(tons/yr)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

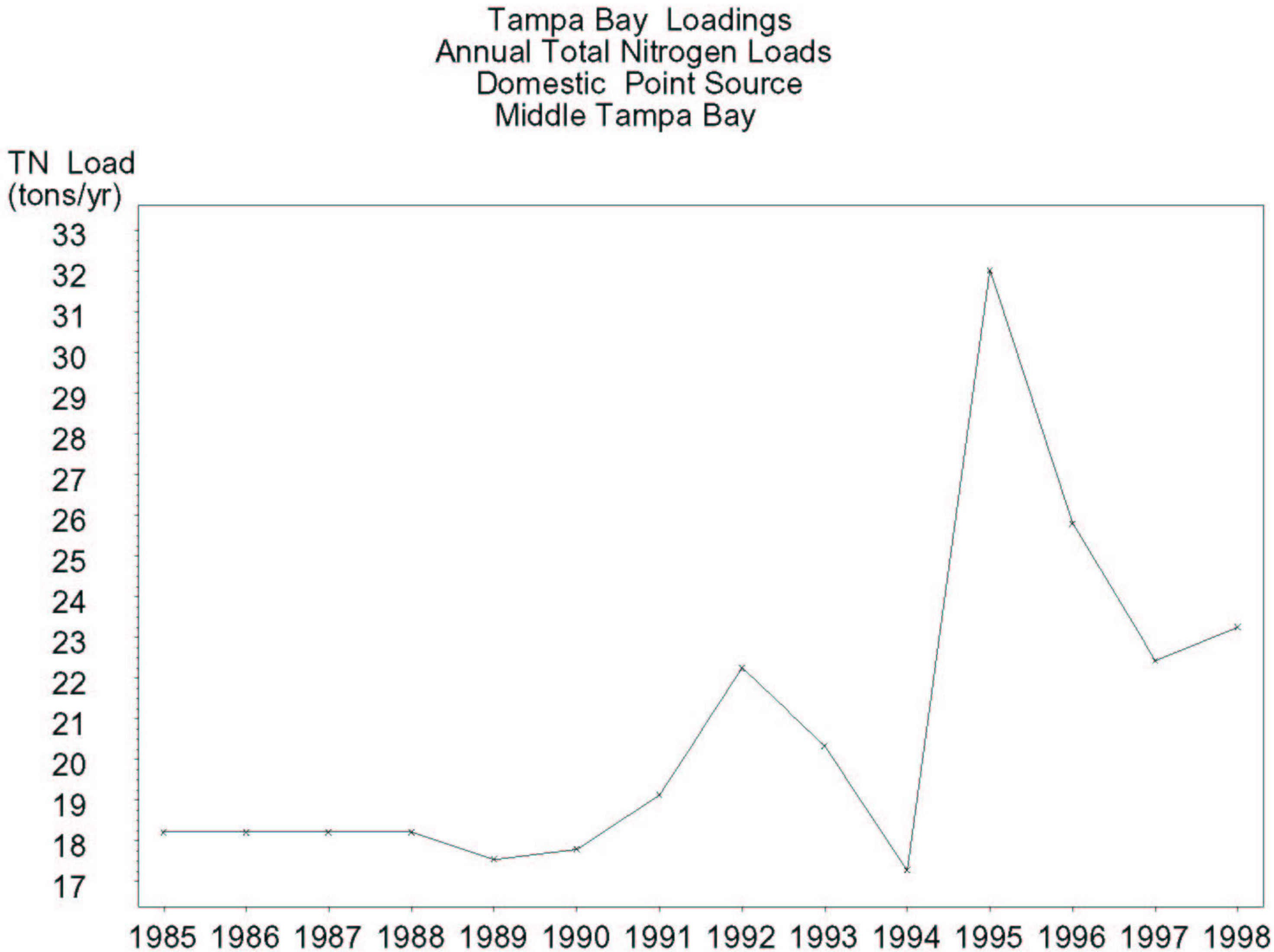


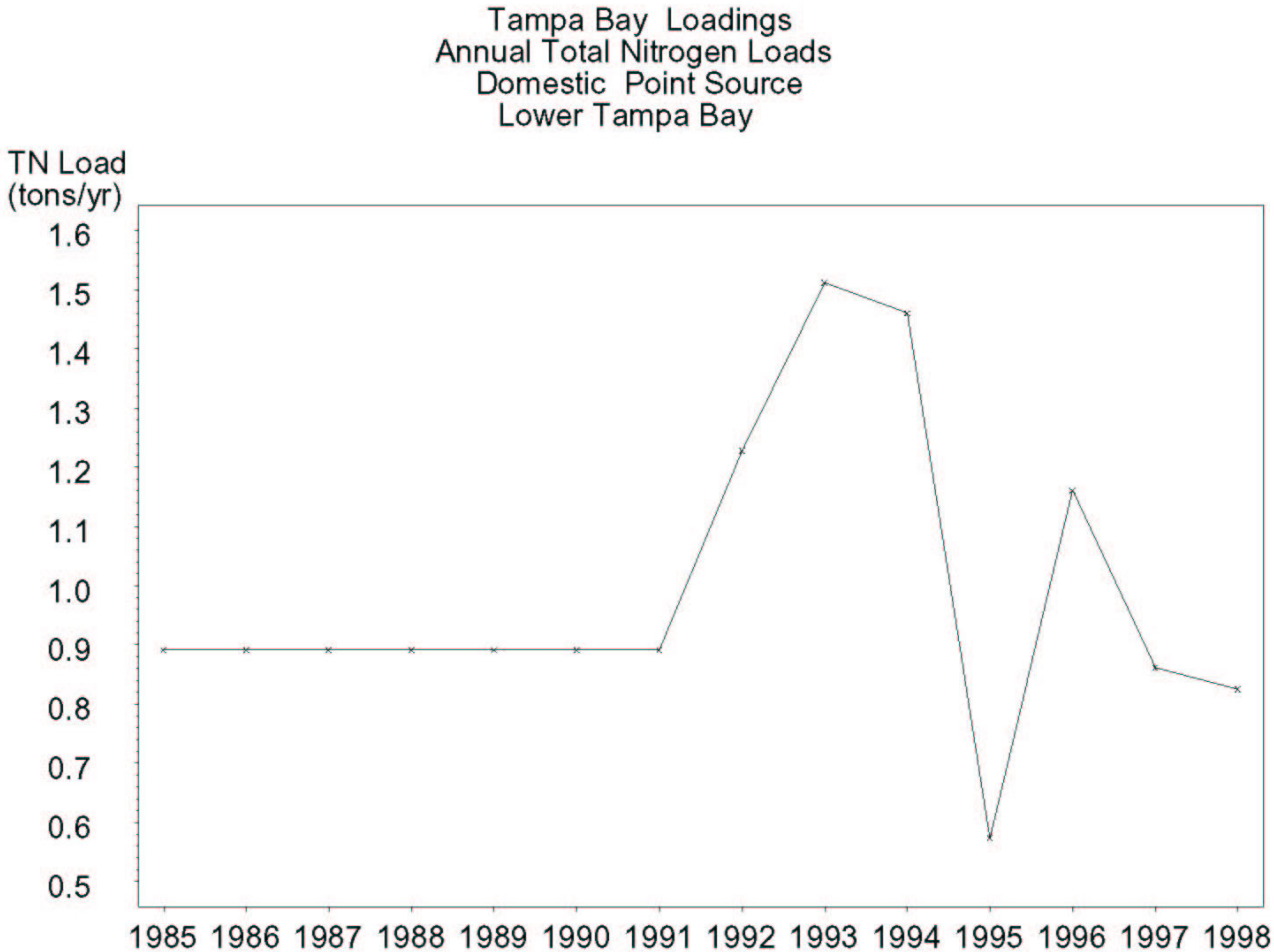
Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Manatee River
TP Load
(tons/yr)
50
40
30
20
10
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

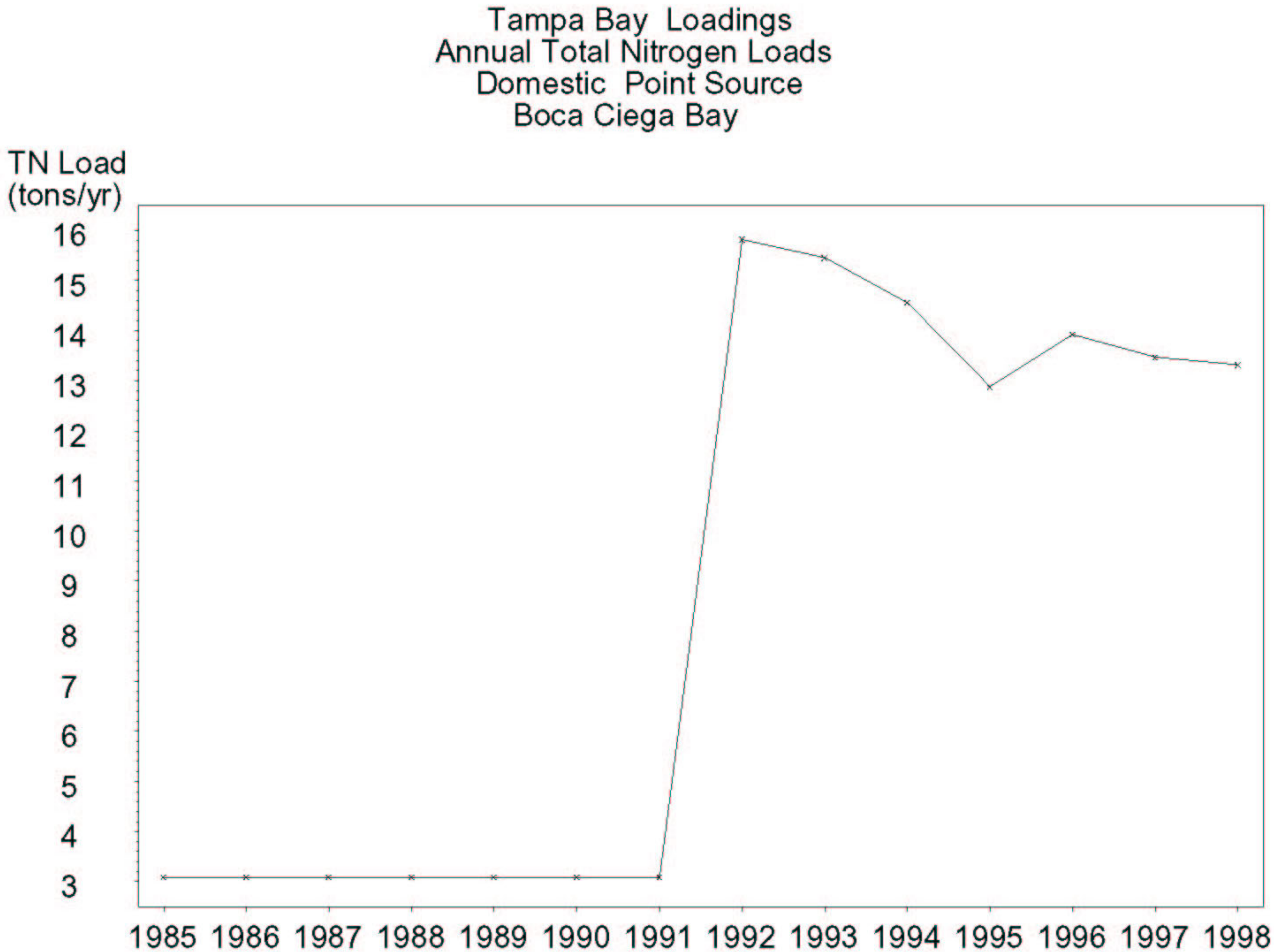

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Old Tampa Bay
TN Load
(tons/yr)
100
90
80
70
60
50
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

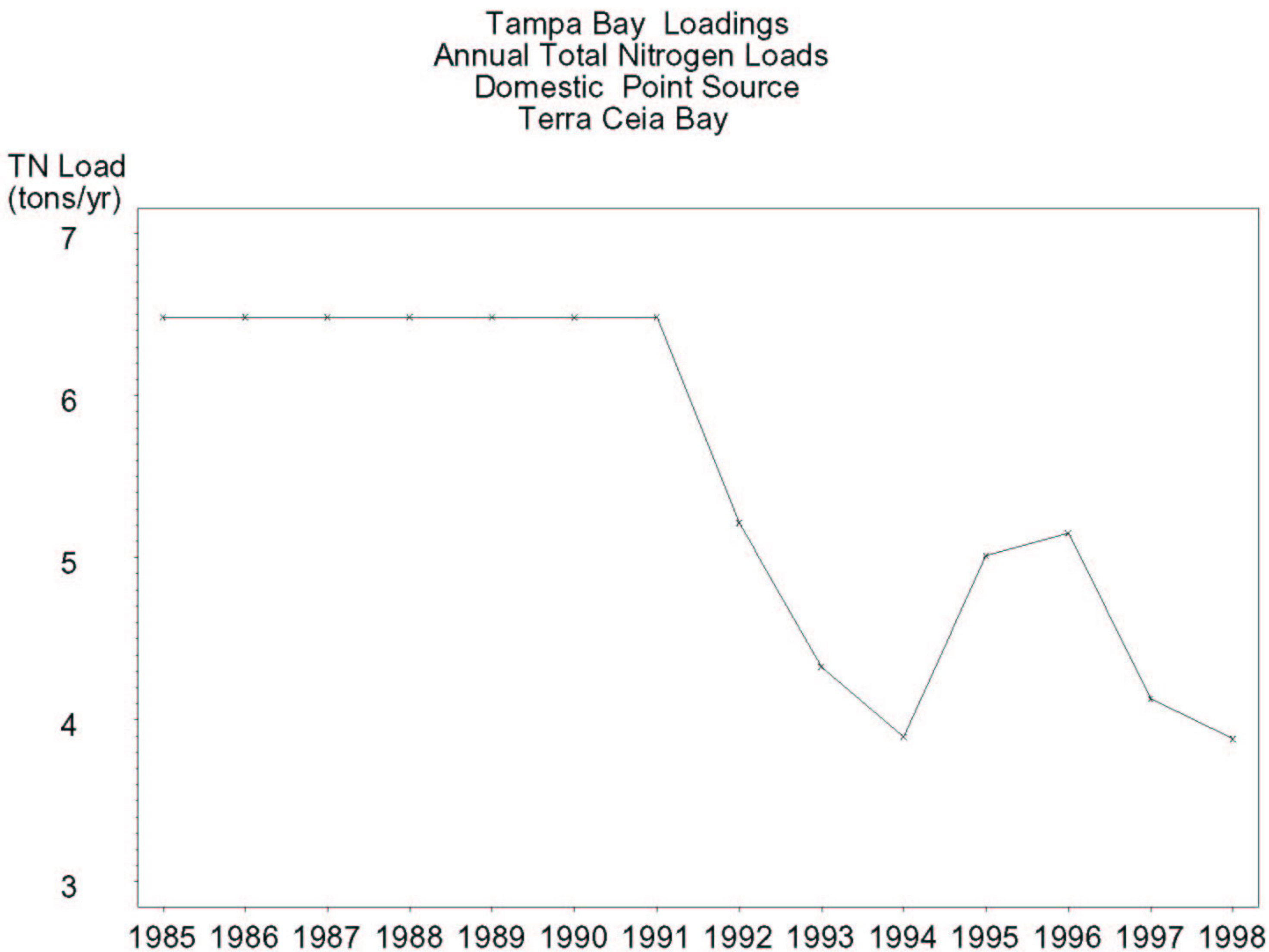


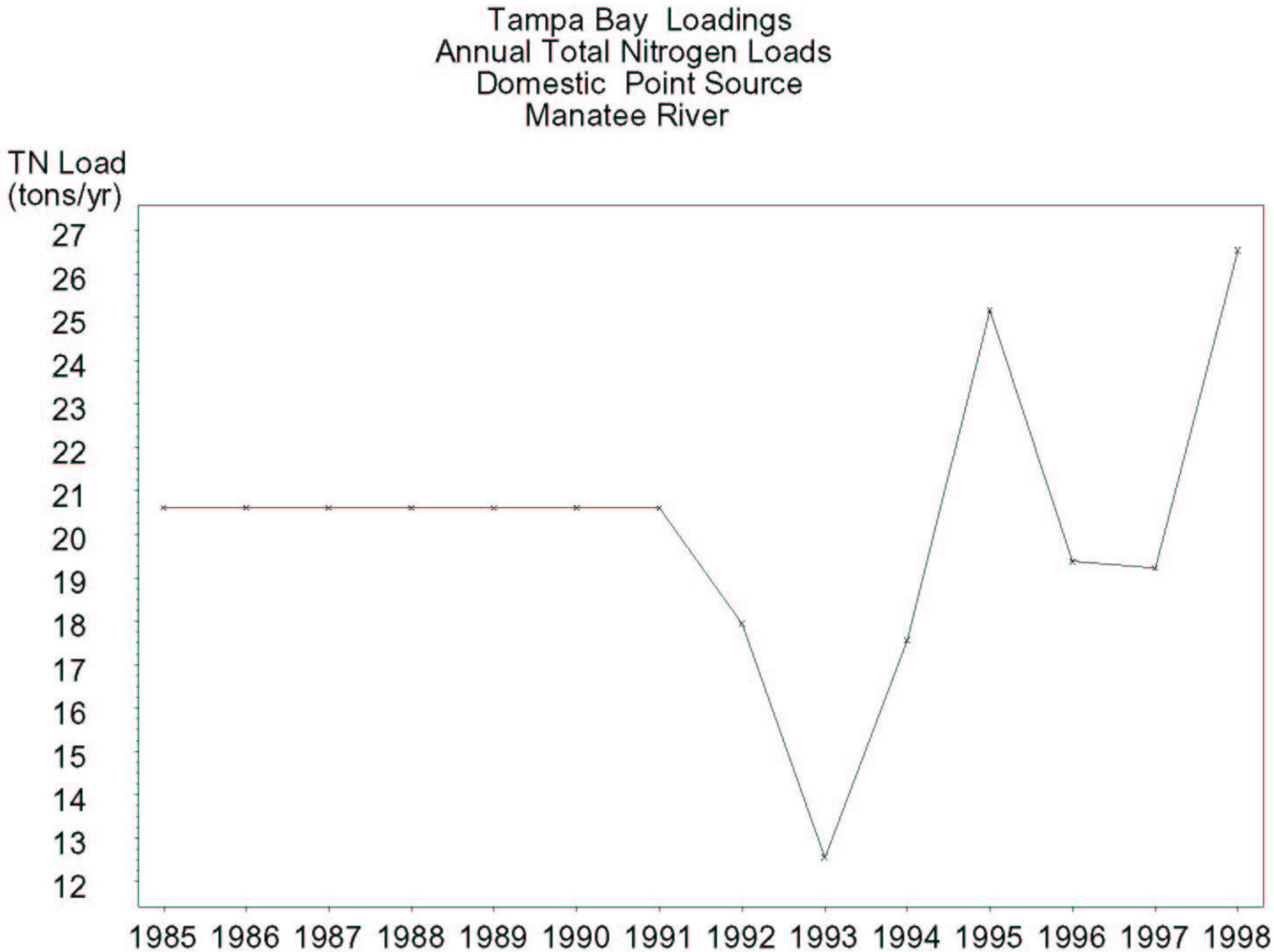
Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Hillsborough Bay
TN Load
(tons/yr)
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

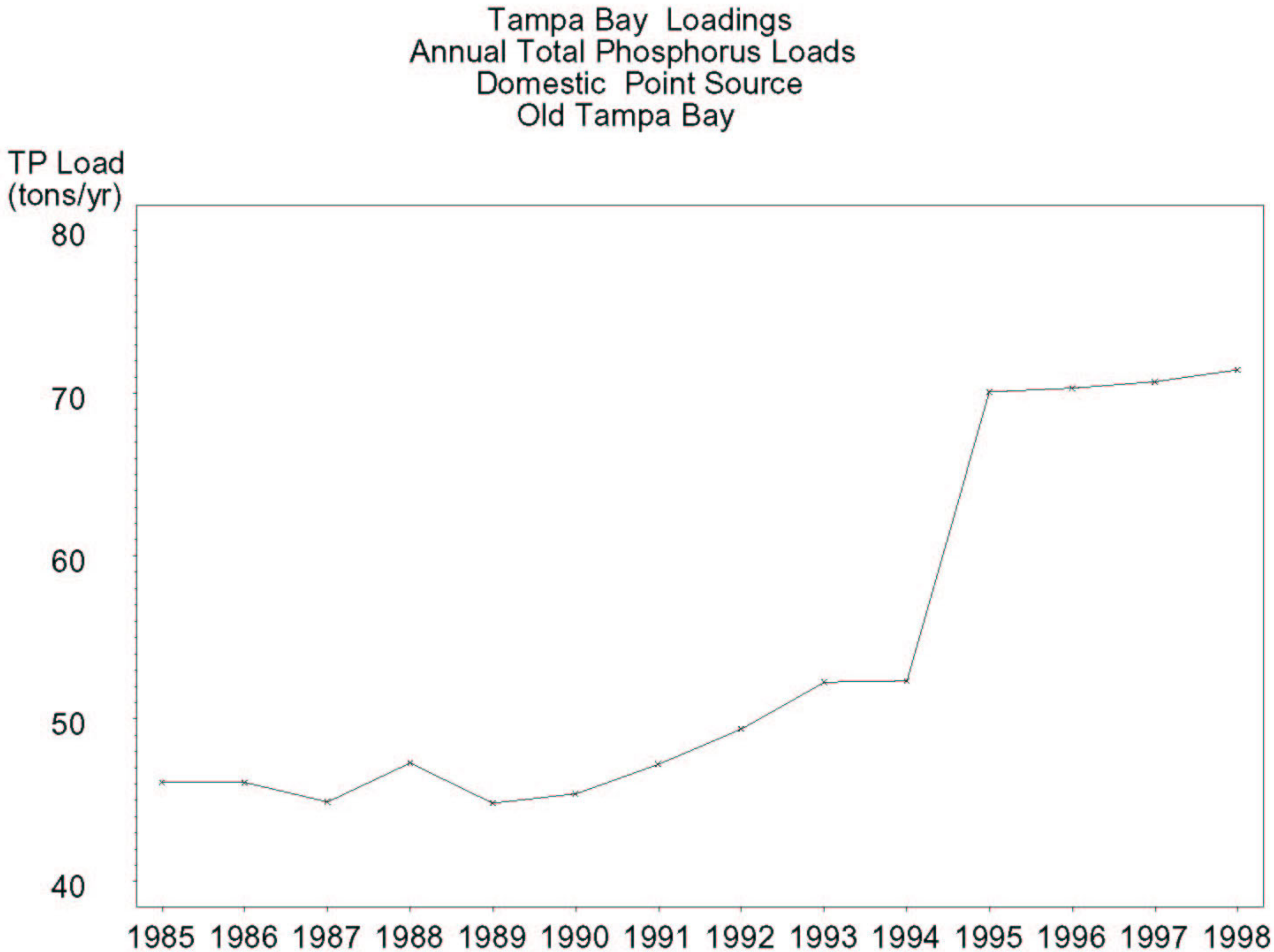

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Middle Tampa Bay
TN Load
(tons/yr)
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

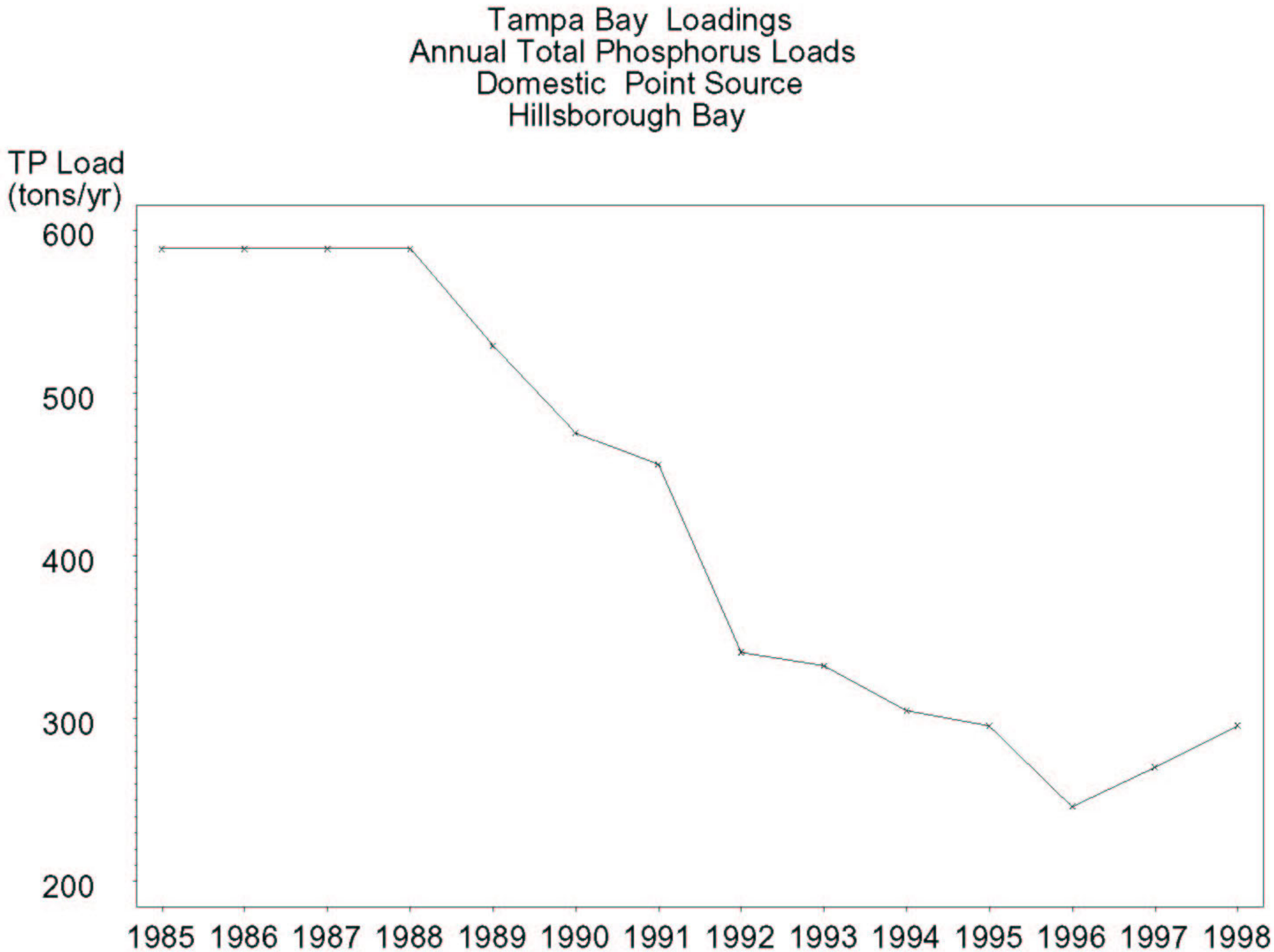

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Lower Tampa Bay
TN Load
(tons/yr)
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

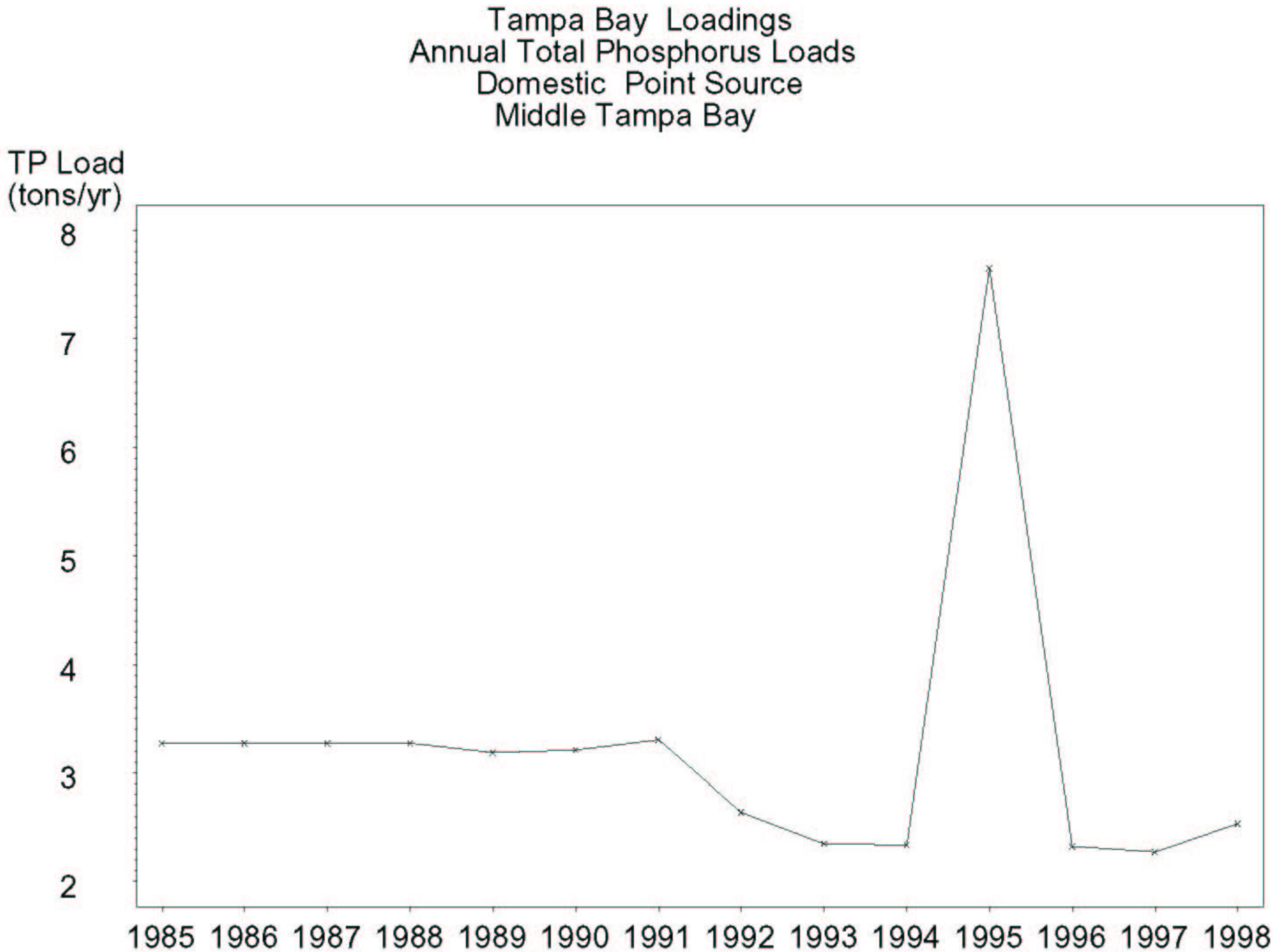

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Boca Ciega Bay
TN Load
(tons/yr)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Terra Ceia Bay
TN Load
(tons/yr)
7
6
5
4
3
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

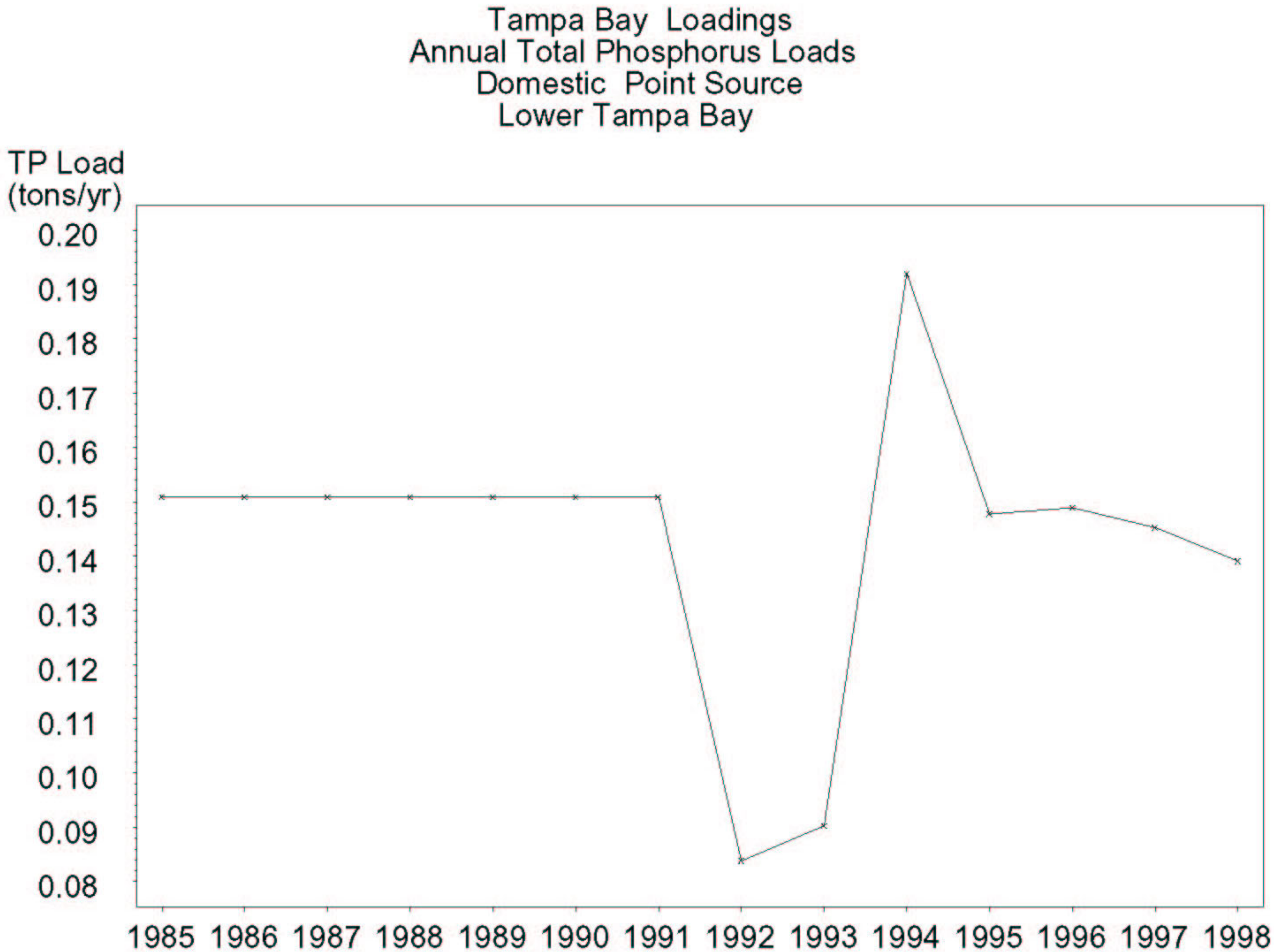

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Manatee River
TN Load
(tons/yr)
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

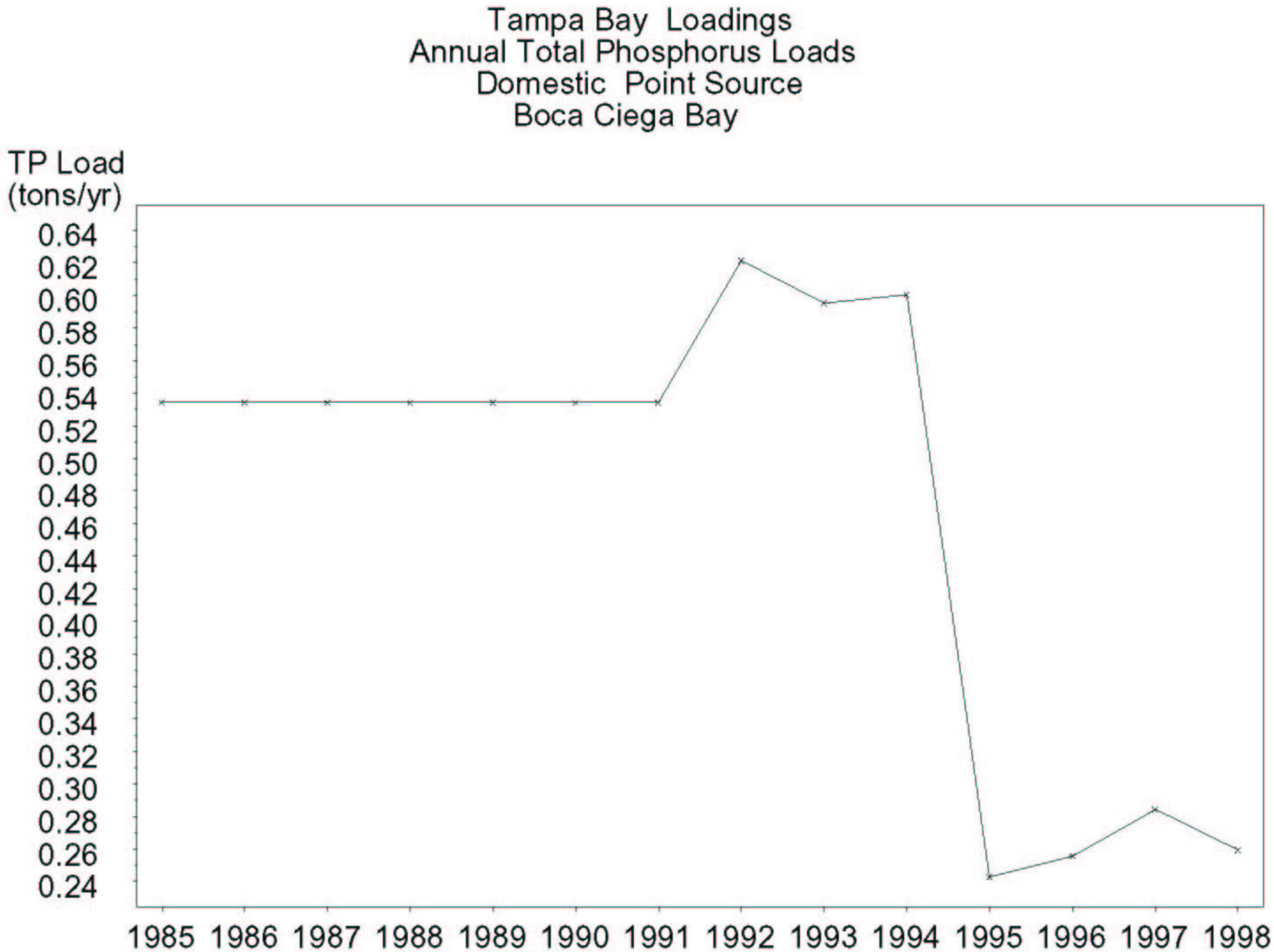

Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Old Tampa Bay
TP Load
(tons/yr)
80
70
60
50
40
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Hillsborough Bay
TP Load
(tons/yr)
600
500
400
300
200
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



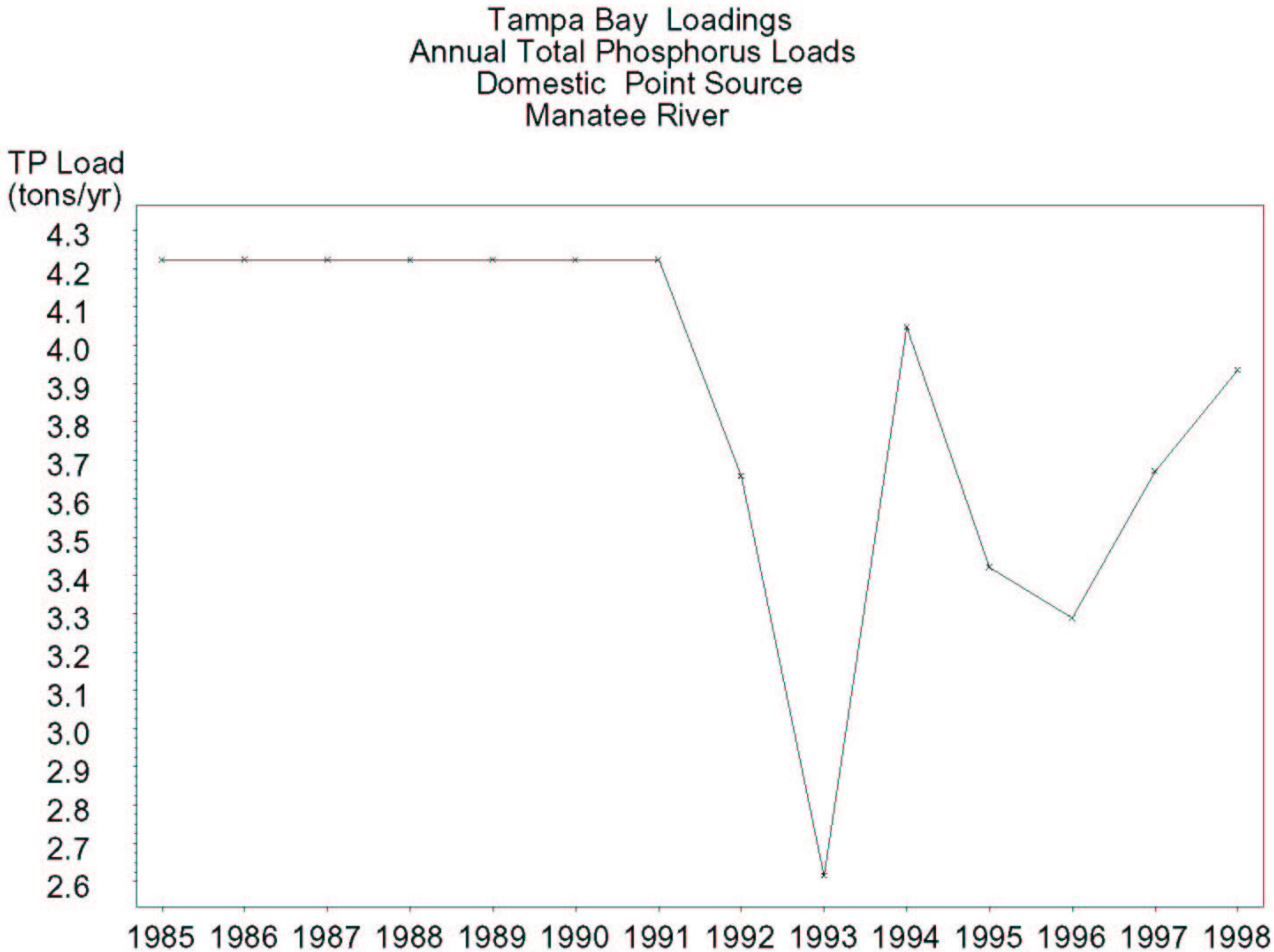
Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Middle Tampa Bay
TP Load (tons/yr)
8
7
6
5
4
3
2
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Lower Tampa Bay
TP Load
(tons/yr)
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

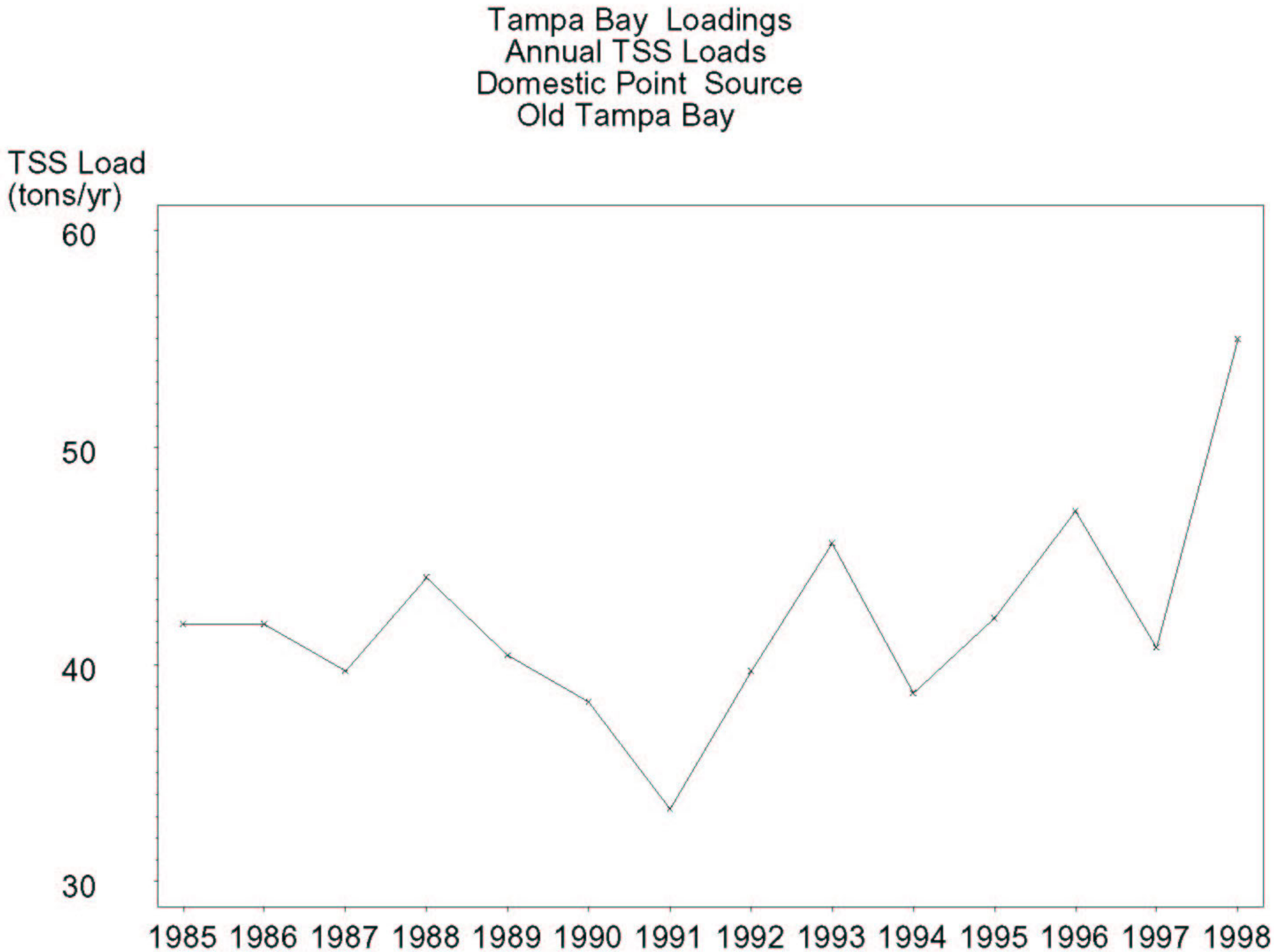


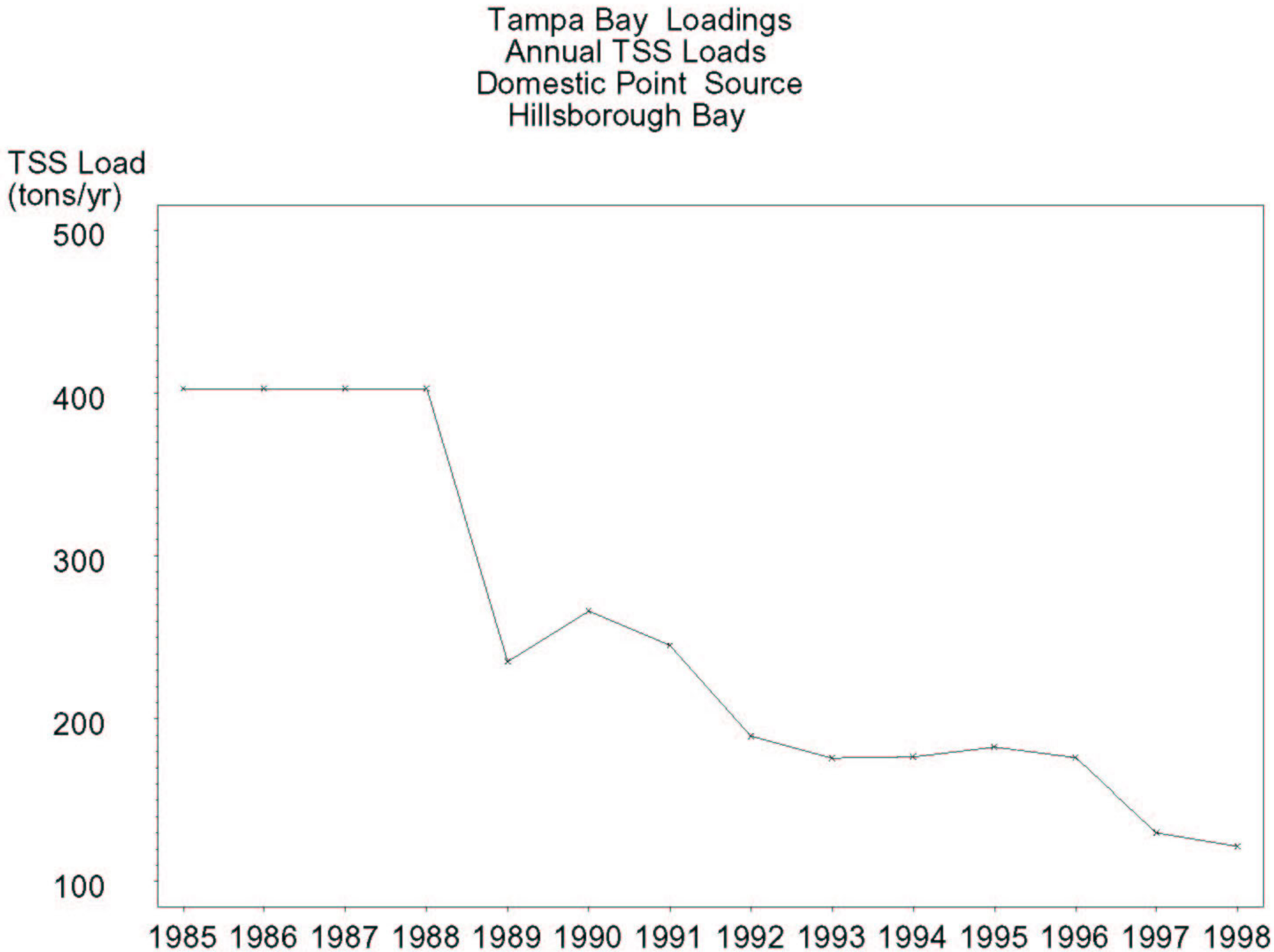
Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Boca Ciega Bay
TP Load
(tons/yr)
0.64
0.62
0.60
0.58
0.56
0.54
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

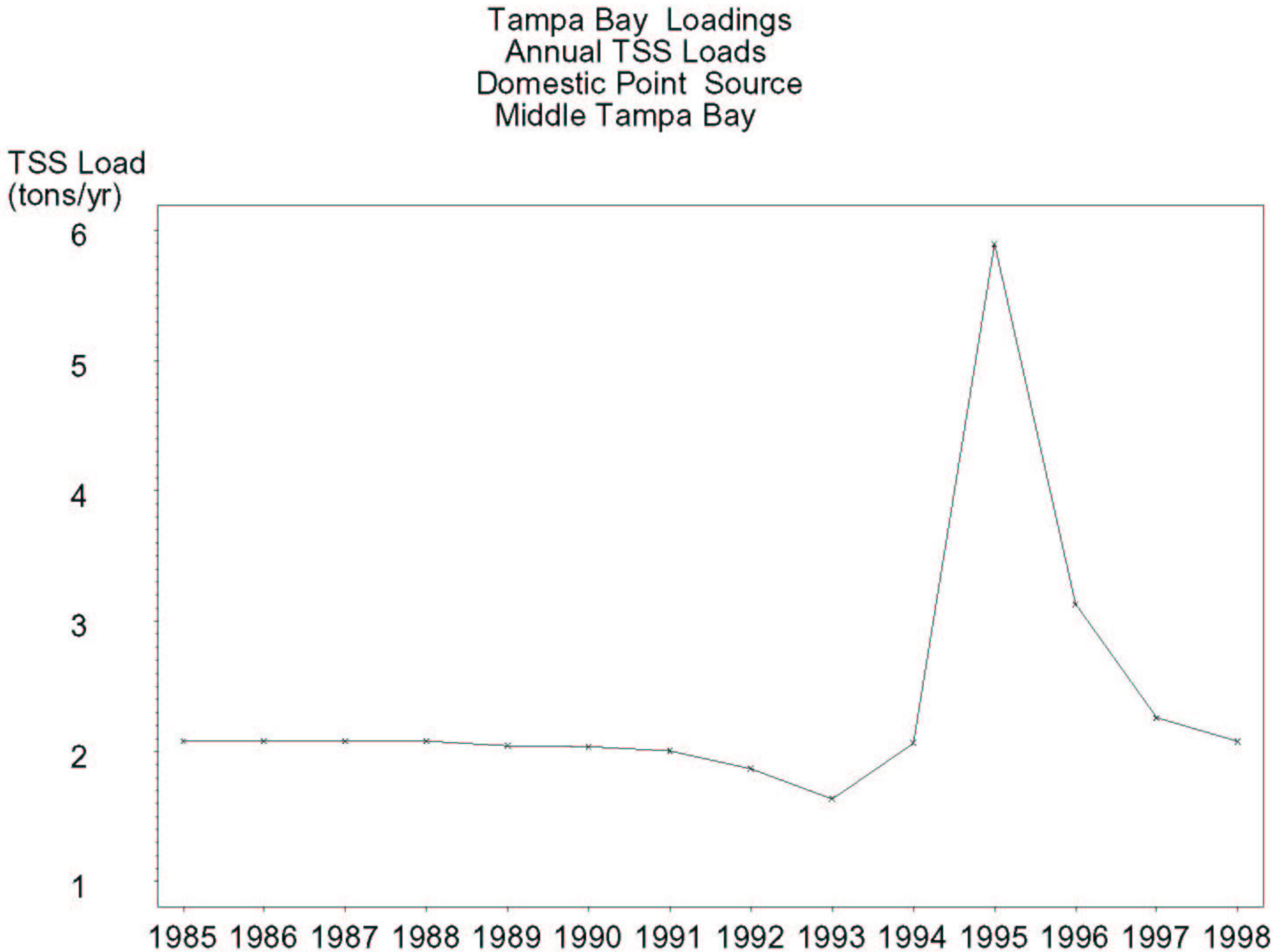
Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Terra Ceia Bay



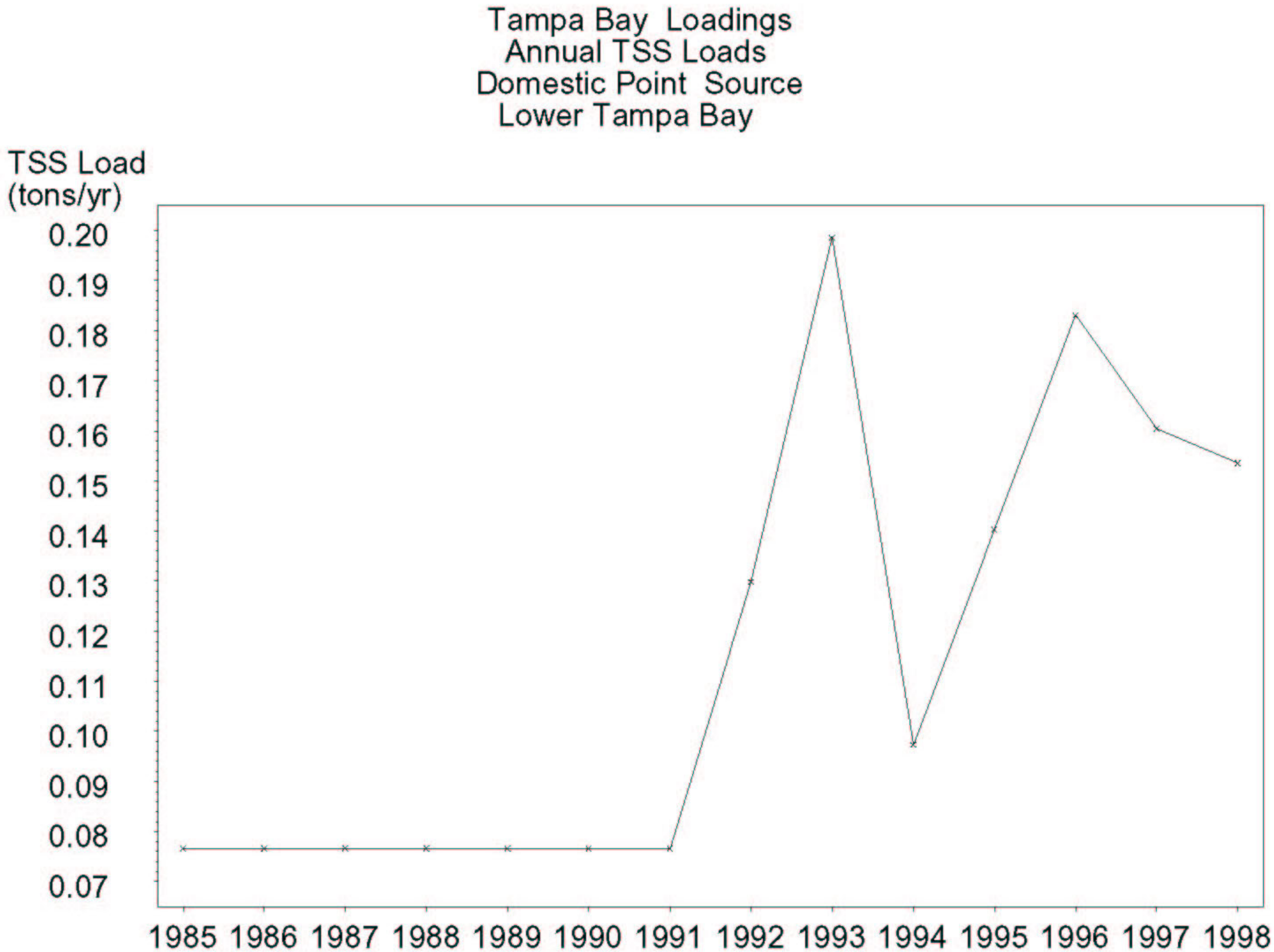
Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Manatee River
TP Load (tons/yr)
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Old Tampa Bay
TSS Load
(tons/yr)
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Hillsborough Bay
TSS Load
(tons/yr)
500
400
300
200
100
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

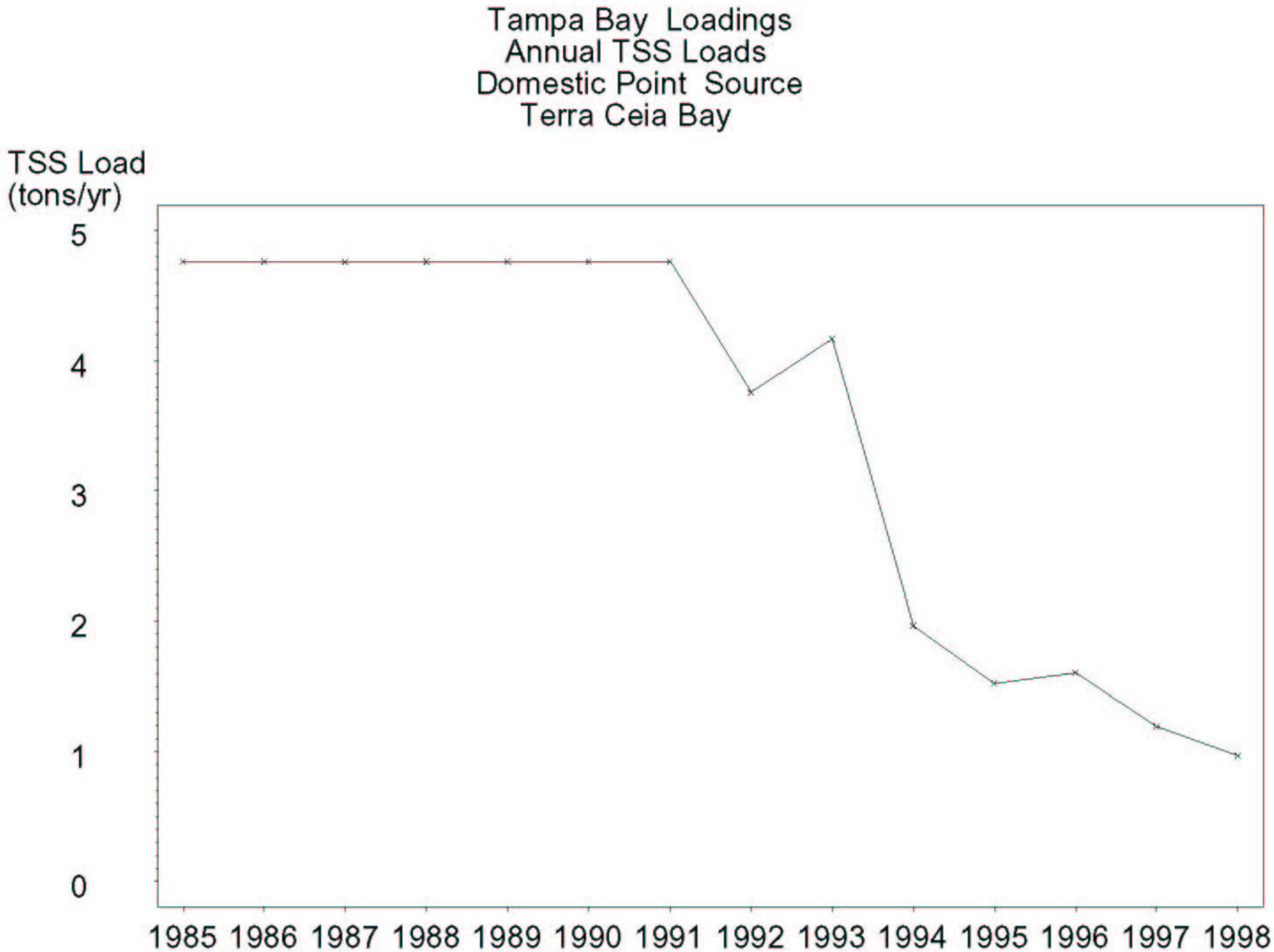


Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Middle Tampa Bay
TSS Load
(tons/yr)
6
5
4
3
2
1
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Lower Tampa Bay
TSS Load
(tons/yr)
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

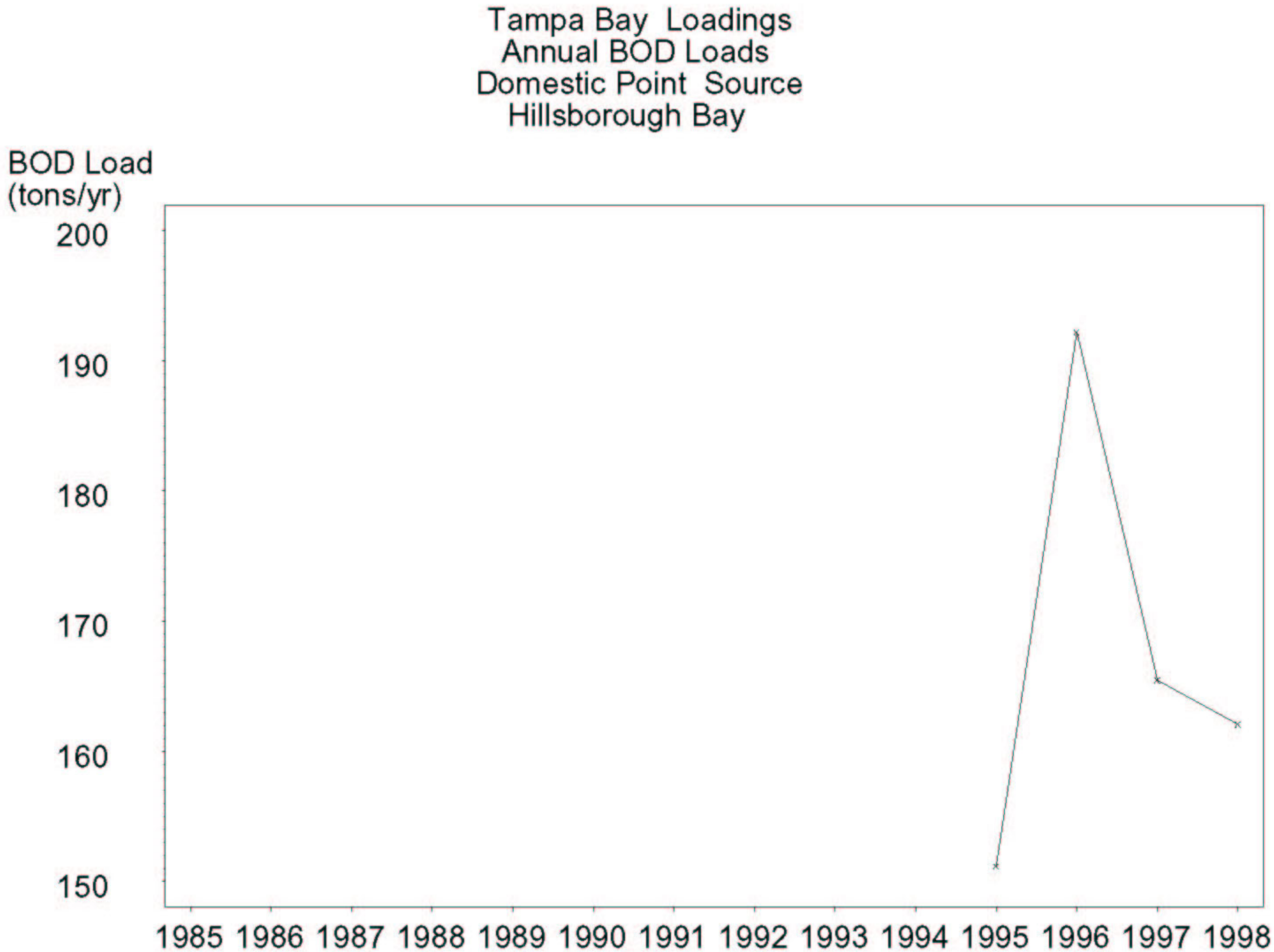
Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Boca Ciega Bay

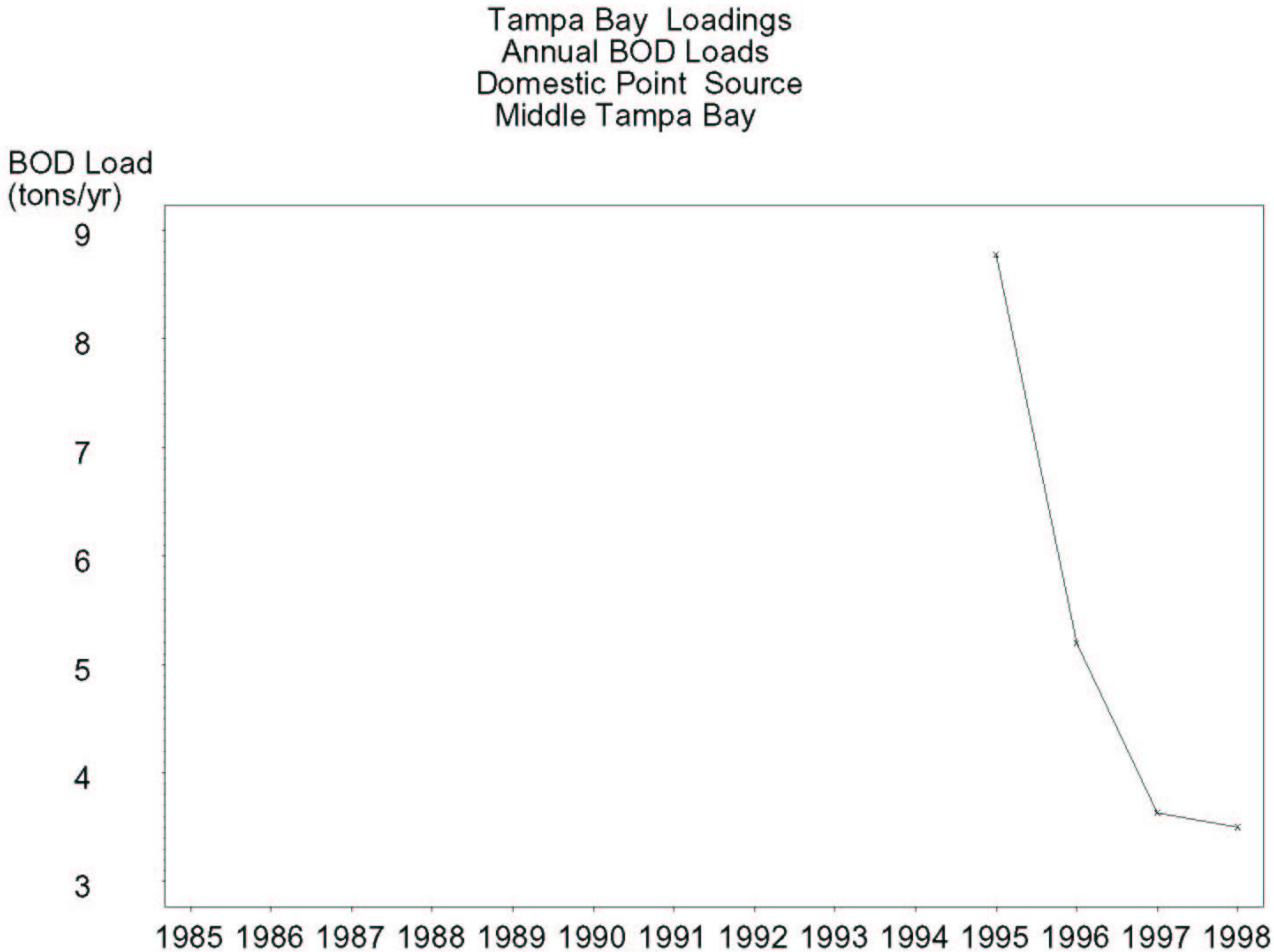


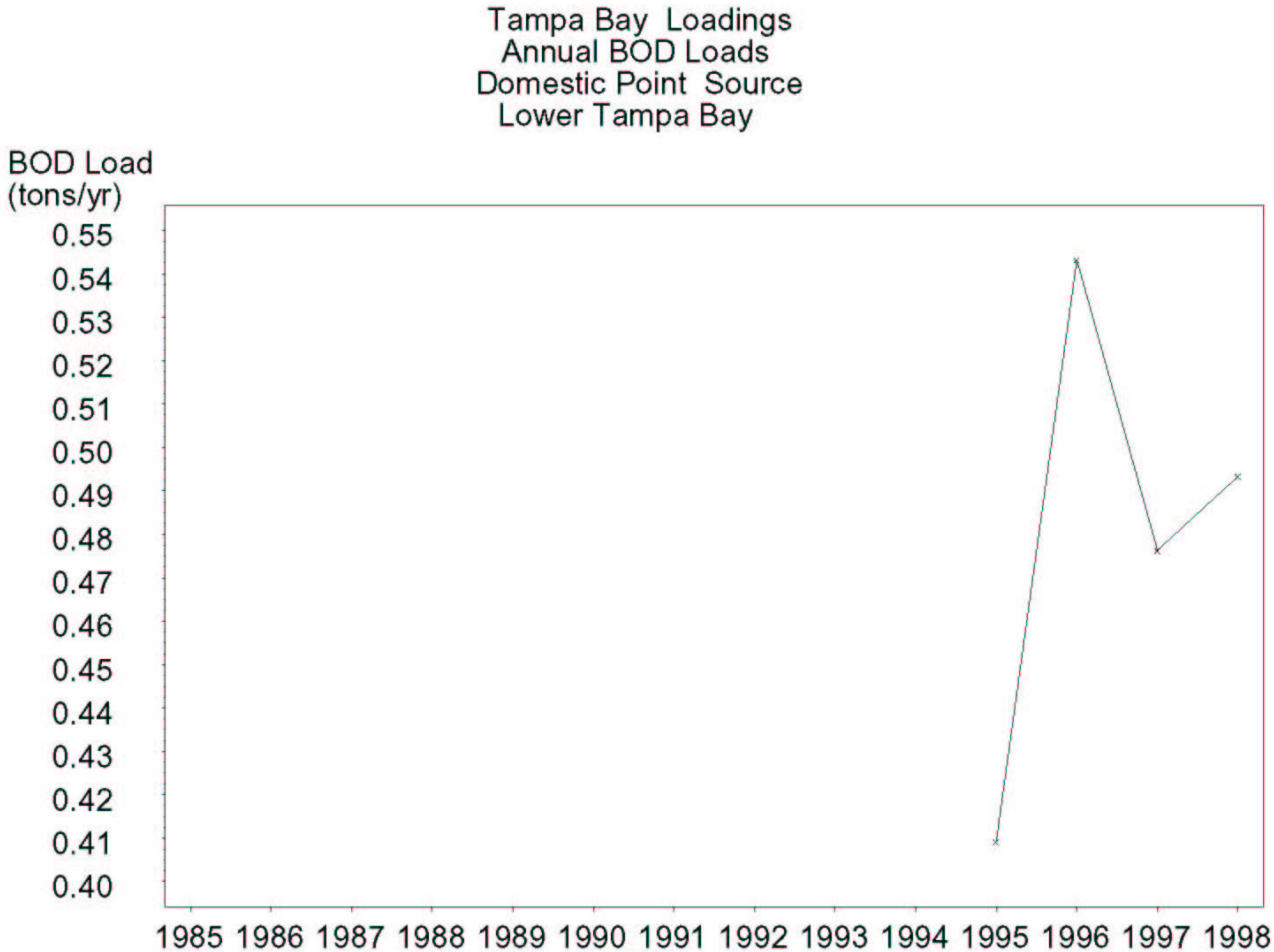
Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Terra Ceia Bay
TSS Load
(tons/yr)
5
4
3
2
1
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

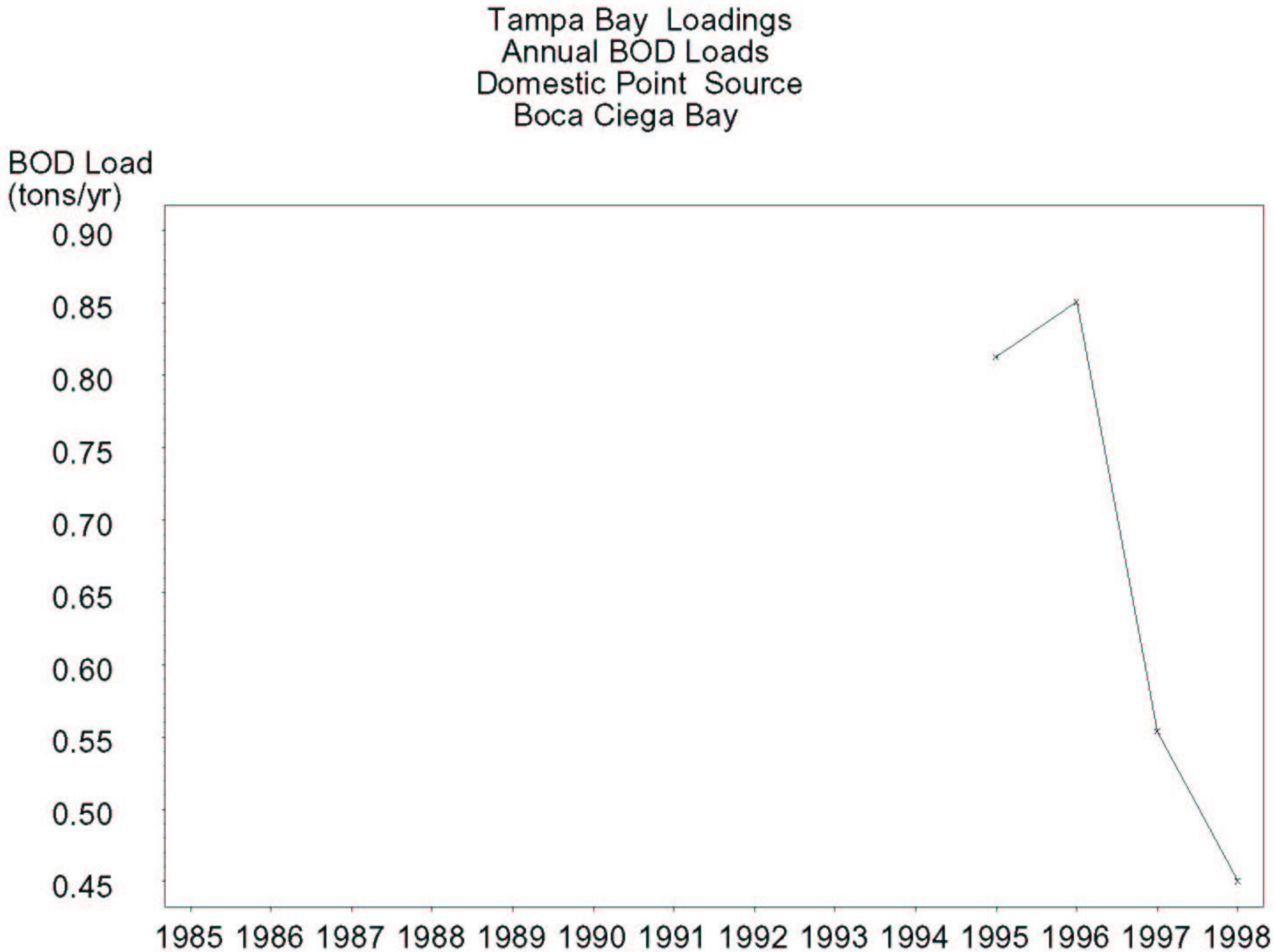

Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Manatee River
TSS Load
(tons/yr)
80
70
60
50
40
30
20
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

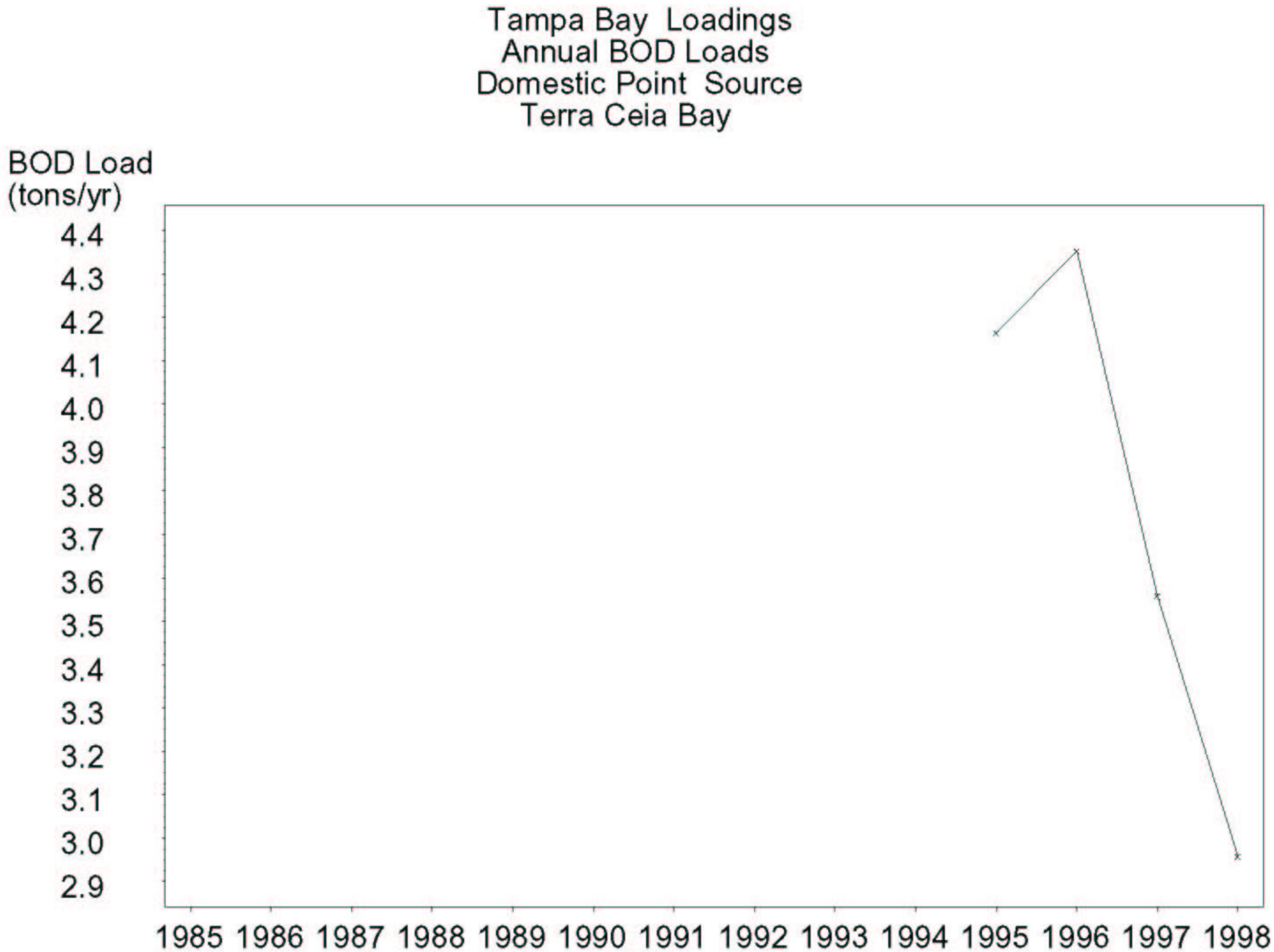

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Old Tampa Bay
BOD Load
(tons/yr)
100
90
80
70
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

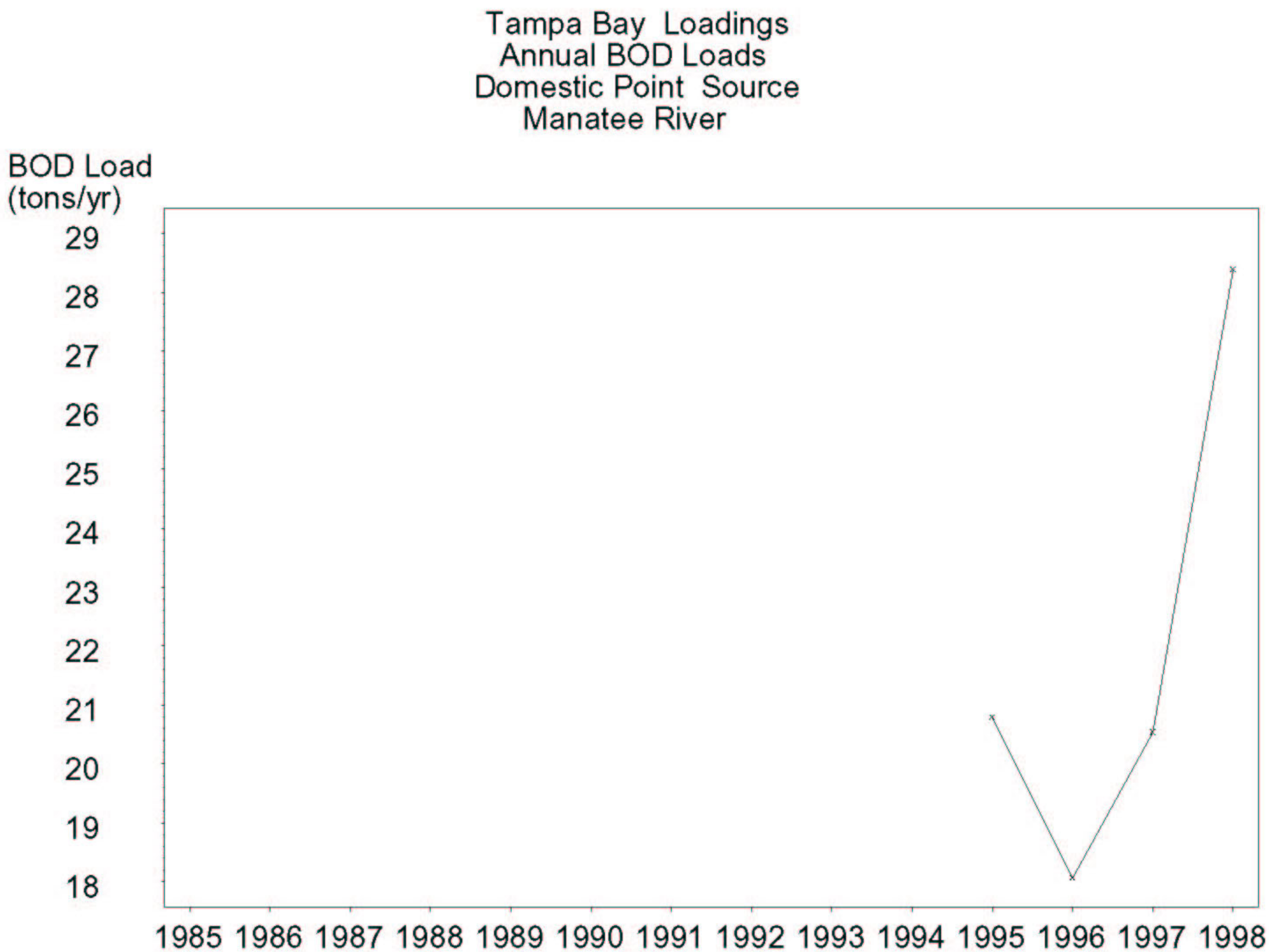

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Hillsborough Bay
BOD Load
(tons/yr)
200
190
180
170
160
150
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

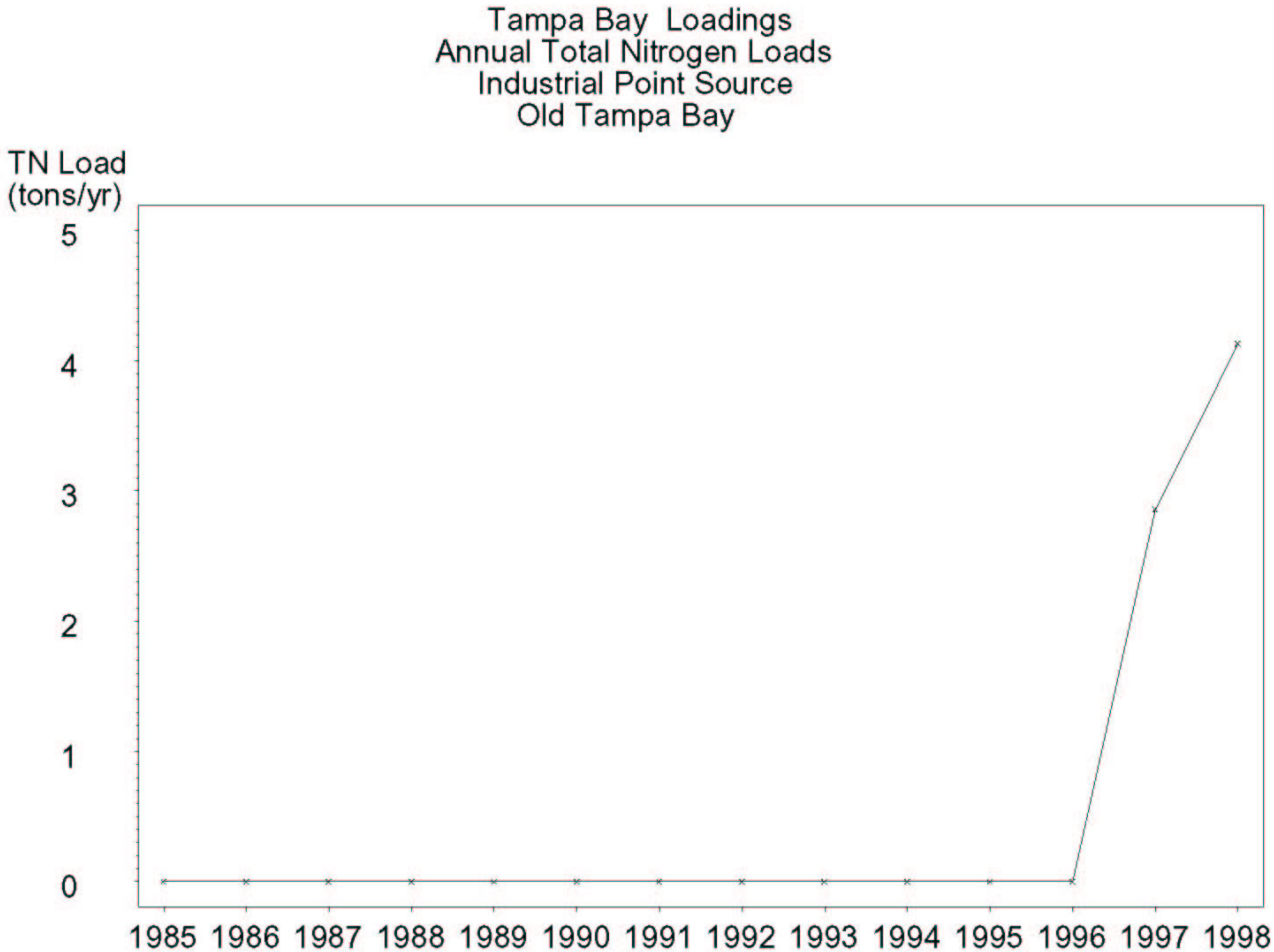

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Middle Tampa Bay
BOD Load
(tons/yr)
9
8
7
6
5
4
3
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

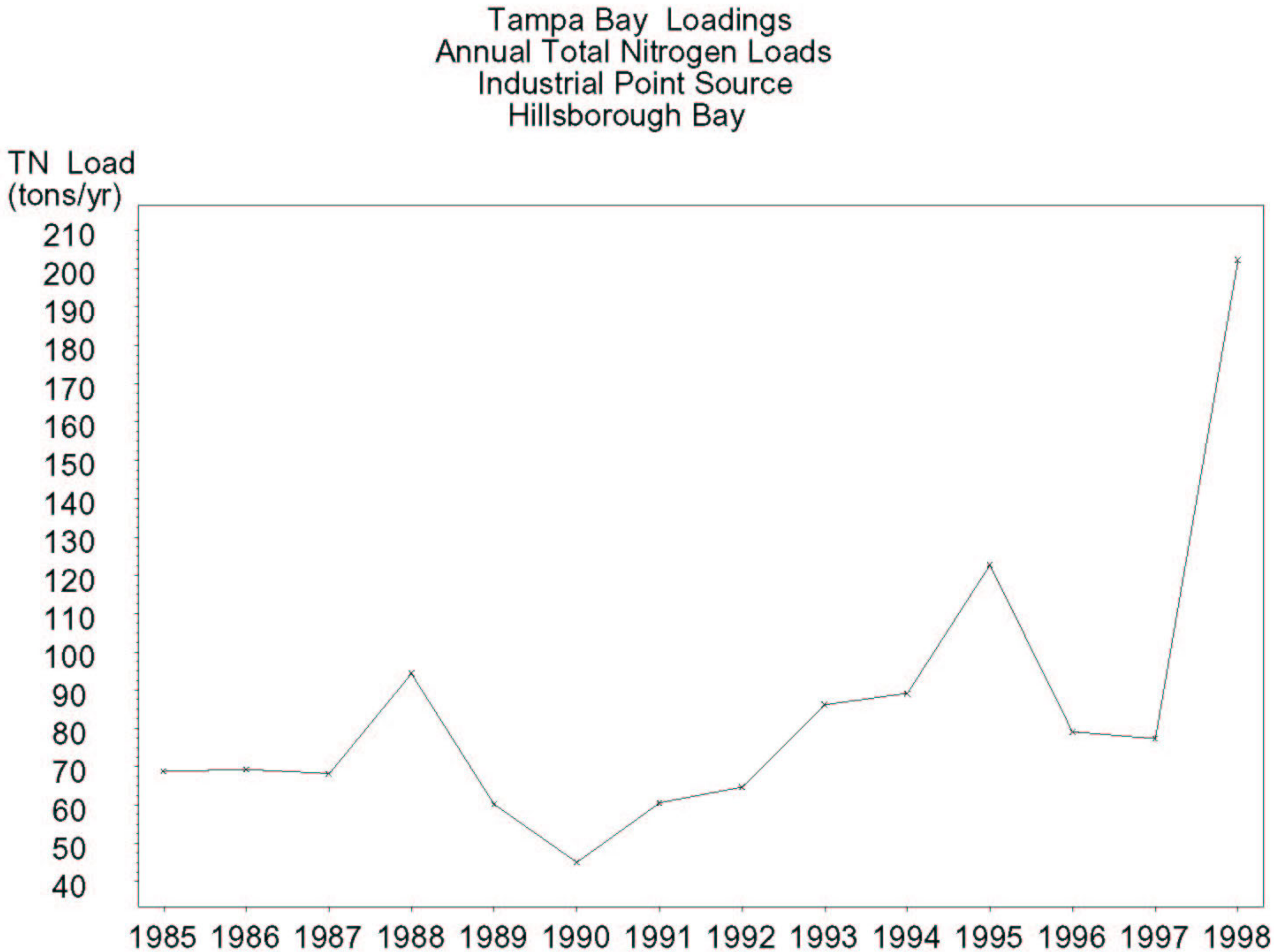

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Lower Tampa Bay
BOD Load
(tons/yr)
0.55
0.54
0.53
0.52
0.51
0.50
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.40
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

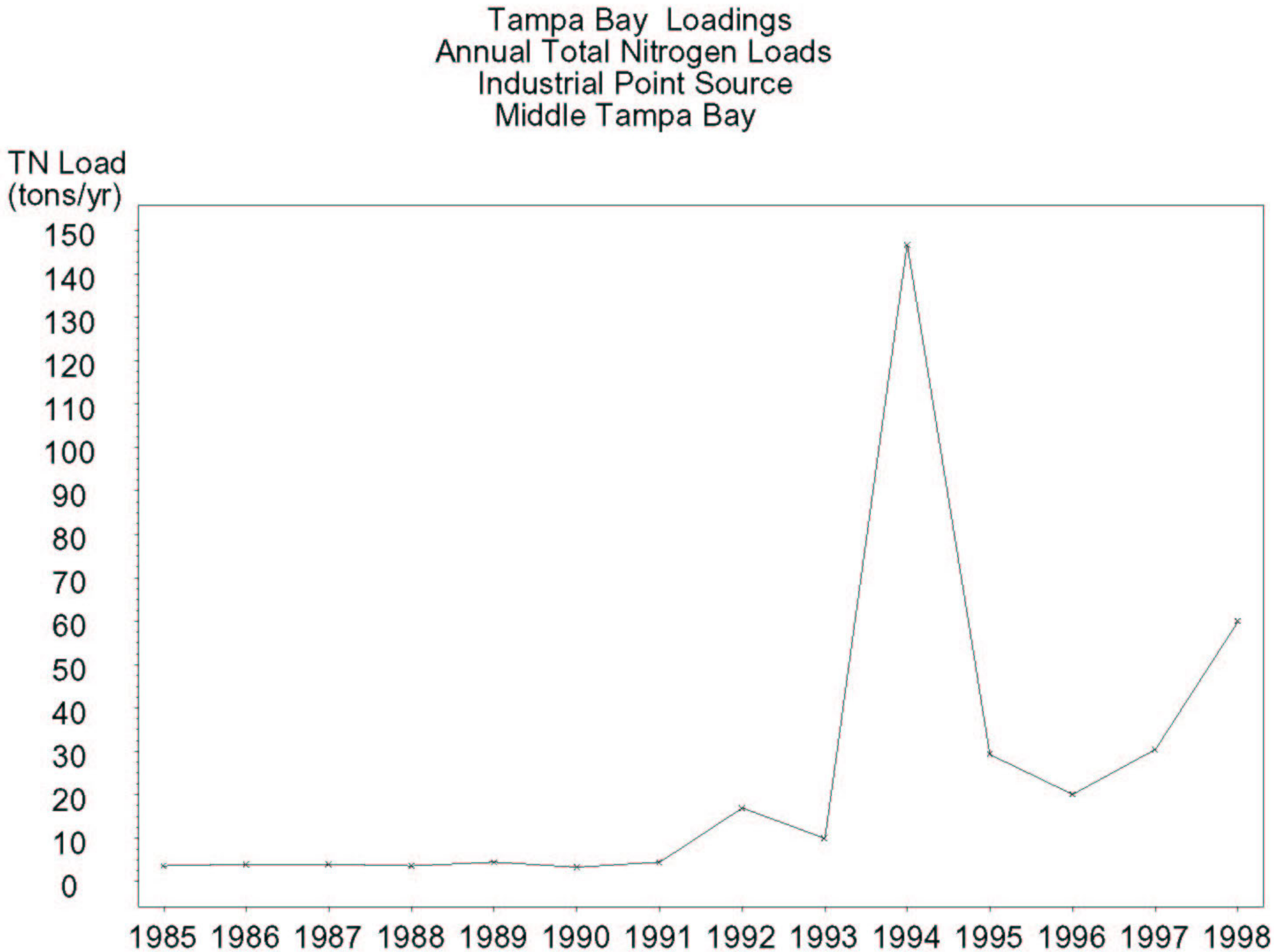

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Boca Ciega Bay
BOD Load
(tons/yr)
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Terra Ceia Bay
BOD Load
(tons/yr)
4.4
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

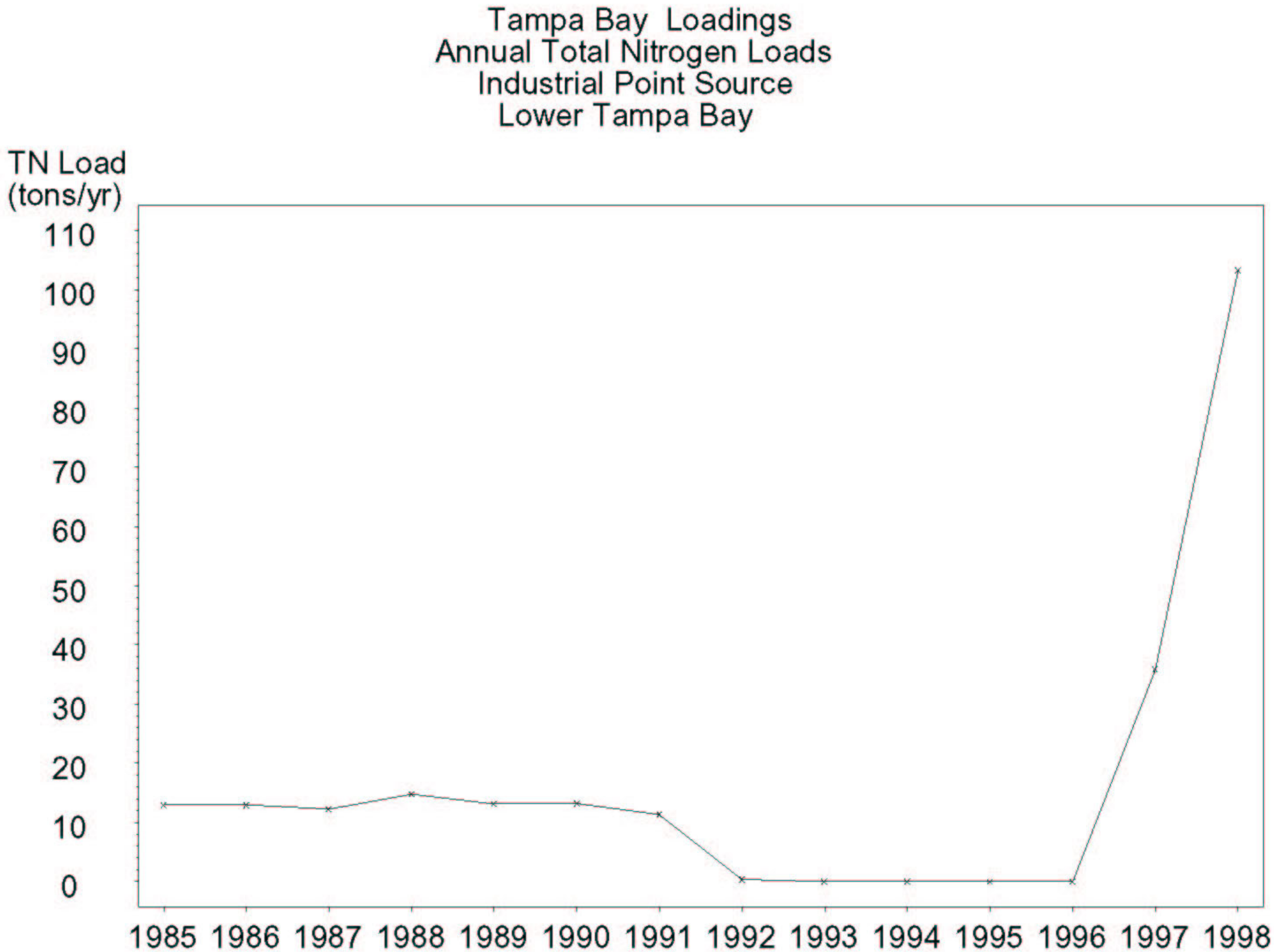

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Manatee River
BOD Load
(tons/yr)
29
28
27
26
25
24
23
22
21
20
19
18
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Old Tampa Bay
TN Load
(tons/yr)
5
4
3
2
1
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

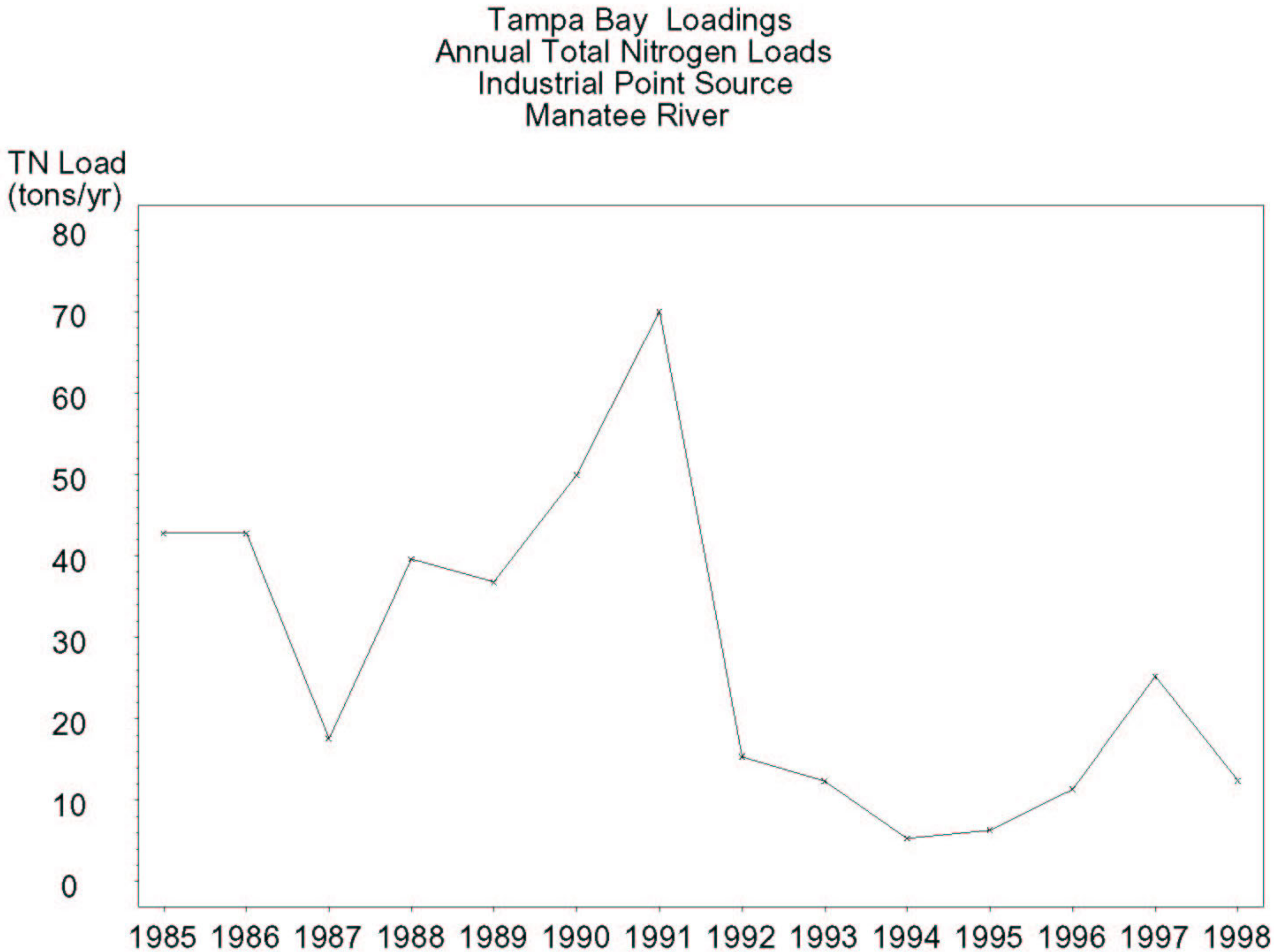

Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Hillsborough Bay
TN Load
(tons/yr)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

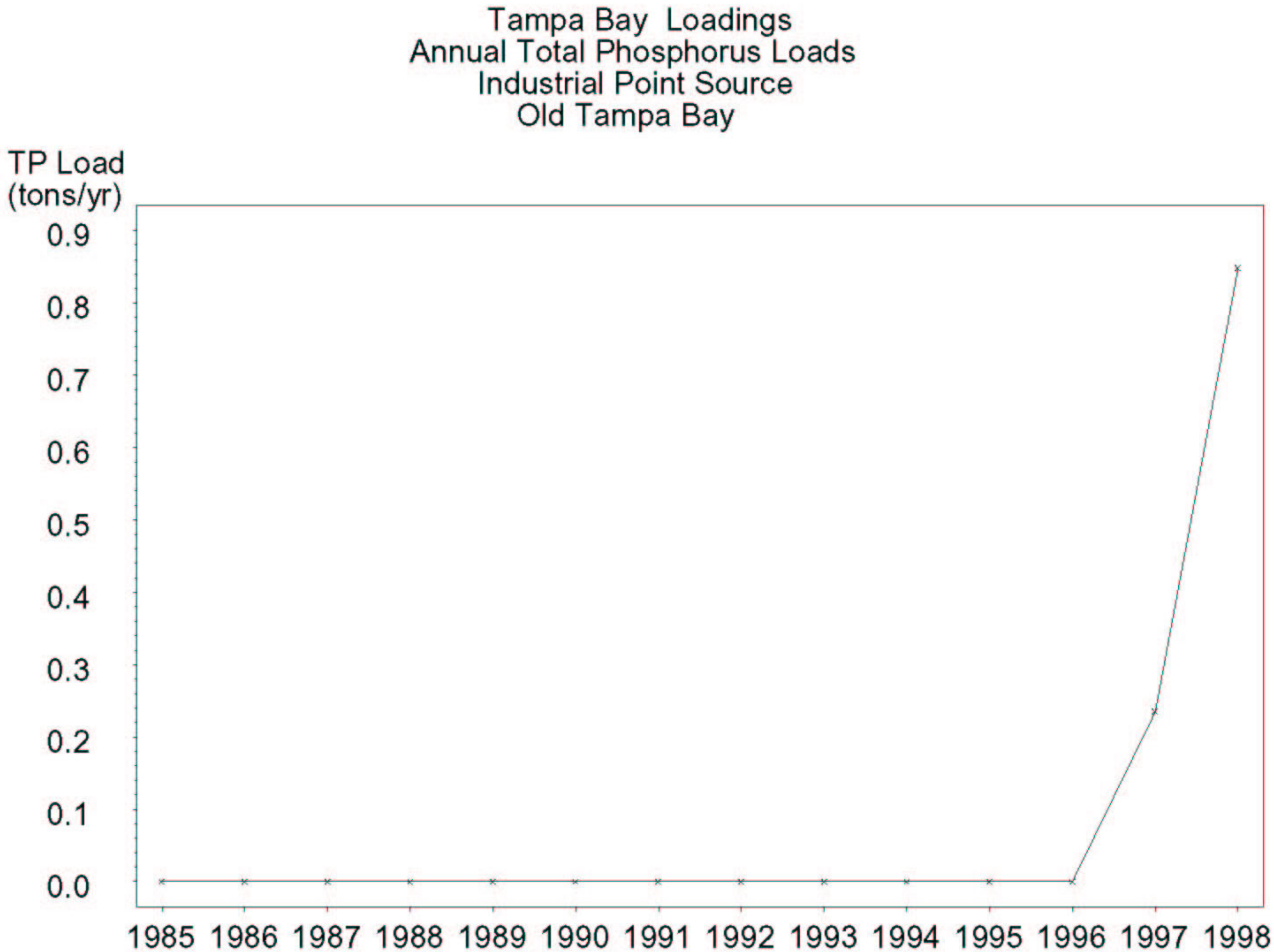


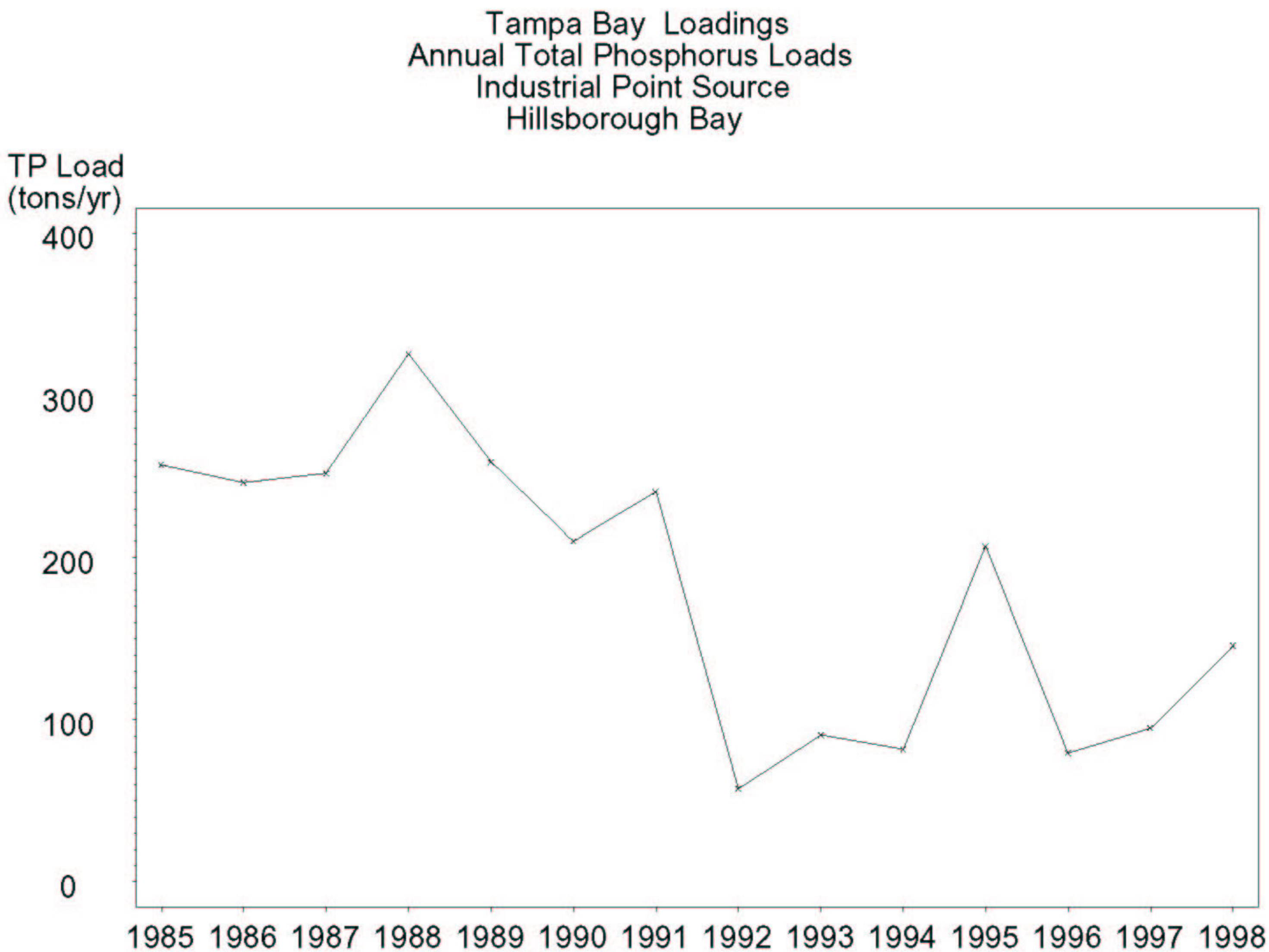
Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Middle Tampa Bay
TN Load
(tons/yr)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

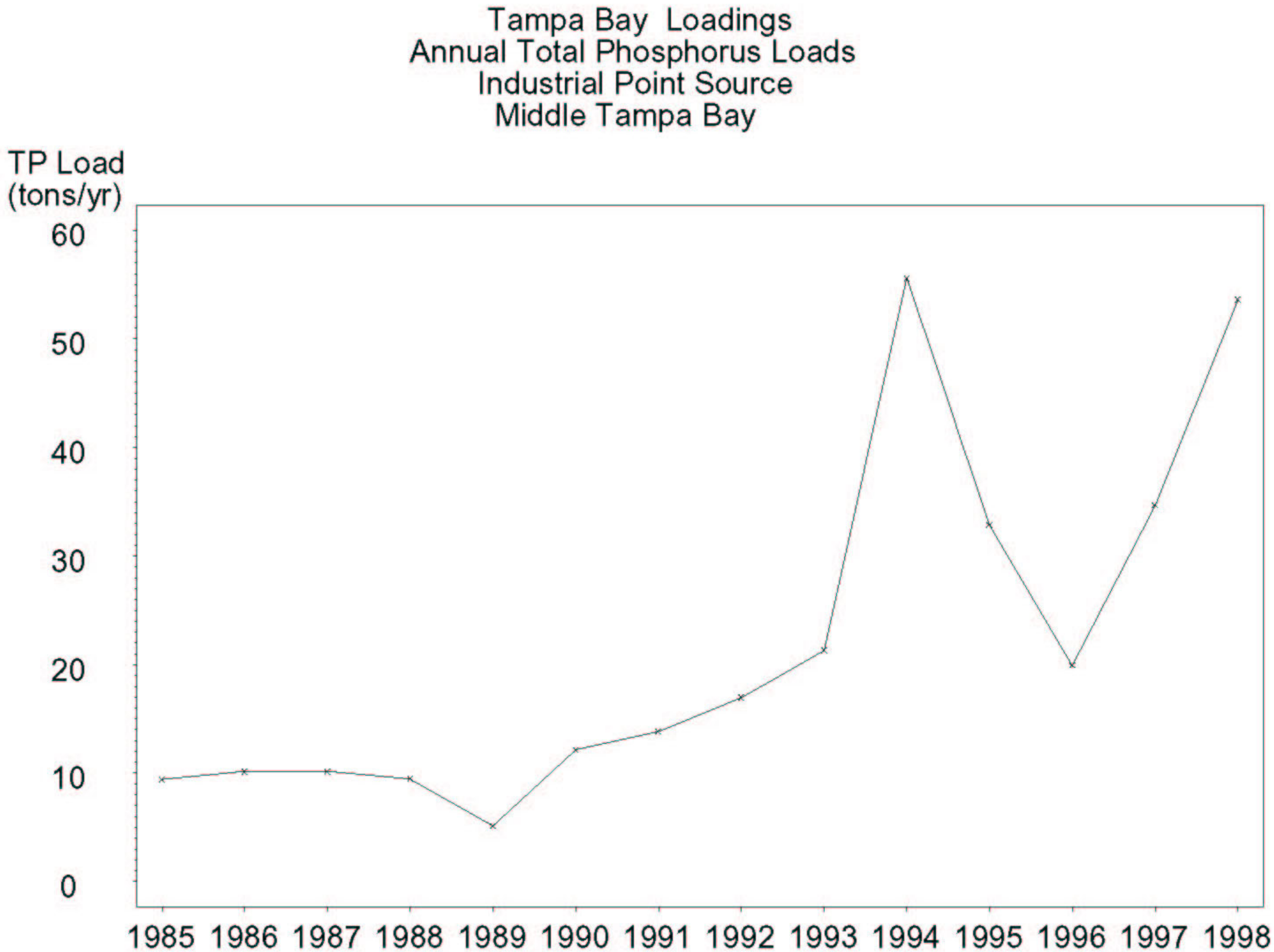


Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Lower Tampa Bay
TN Load
(tons/yr)
110
100
90
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

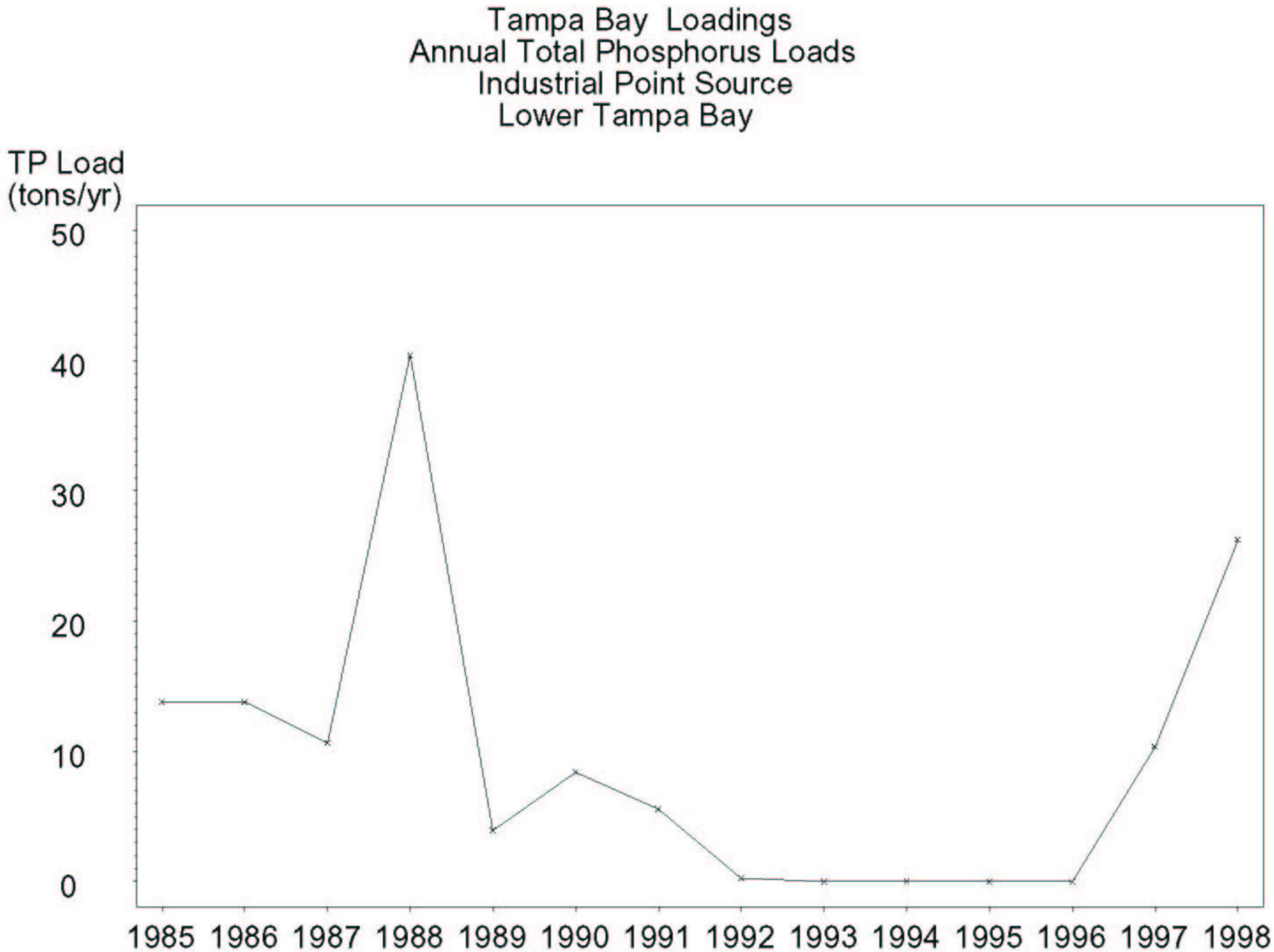

Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Manatee River
TN Load
(tons/yr)
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

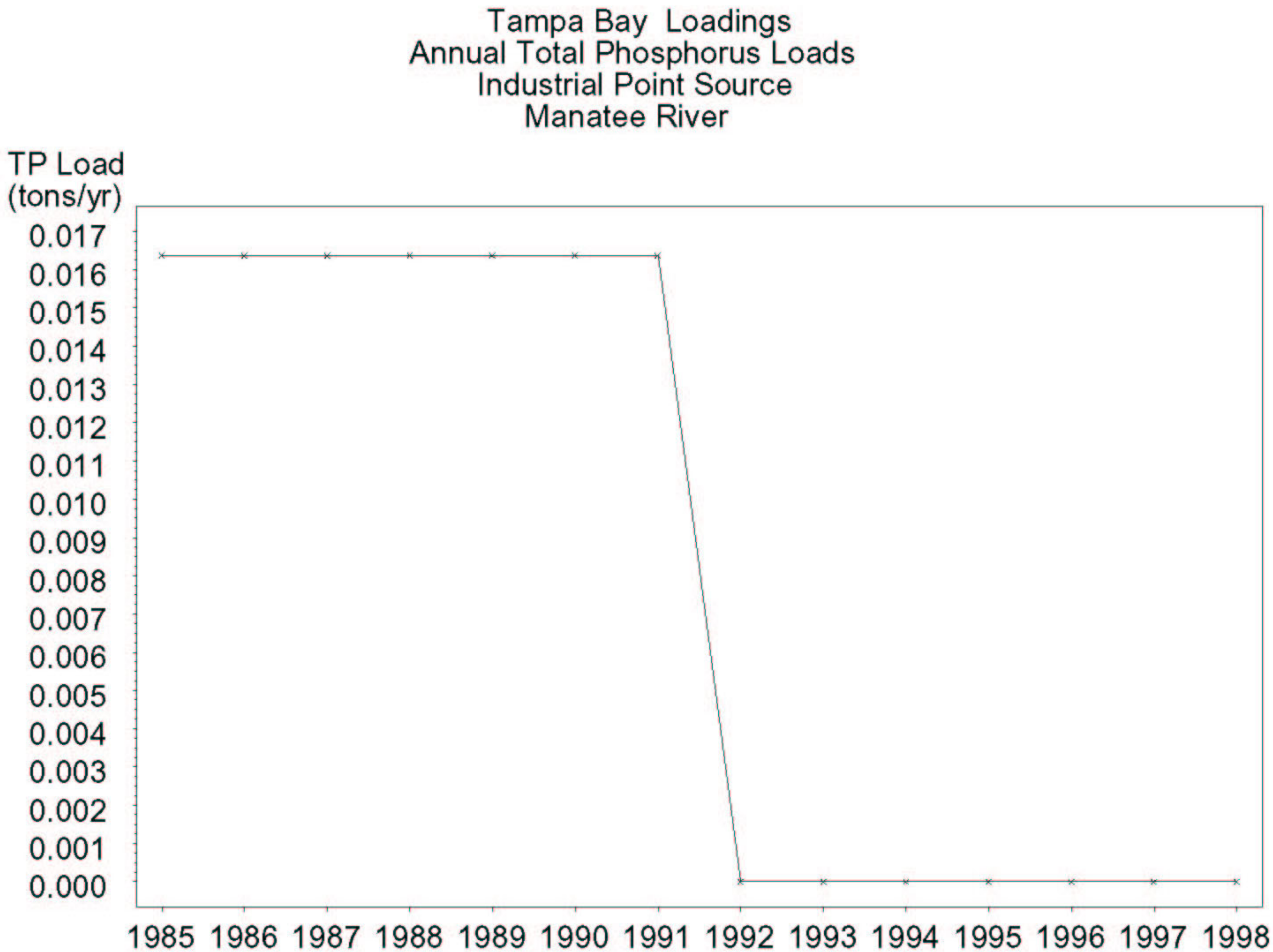

Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Old Tampa Bay
TP Load
(tons/yr)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Hillsborough Bay
TP Load
(tons/yr)
400
300
200
100
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



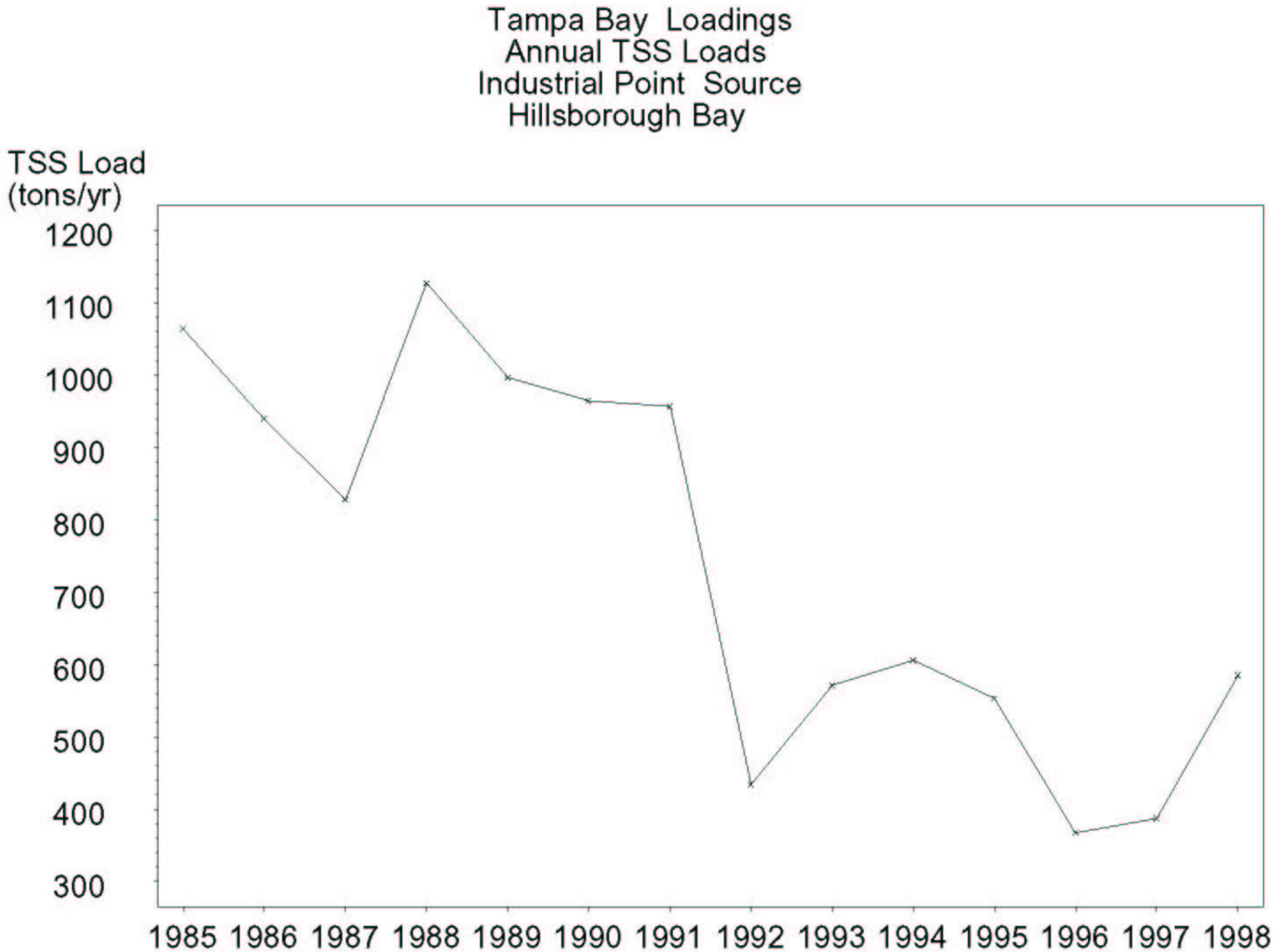
Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Middle Tampa Bay
TP Load
(tons/yr)
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Lower Tampa Bay
TP Load
(tons/yr)
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

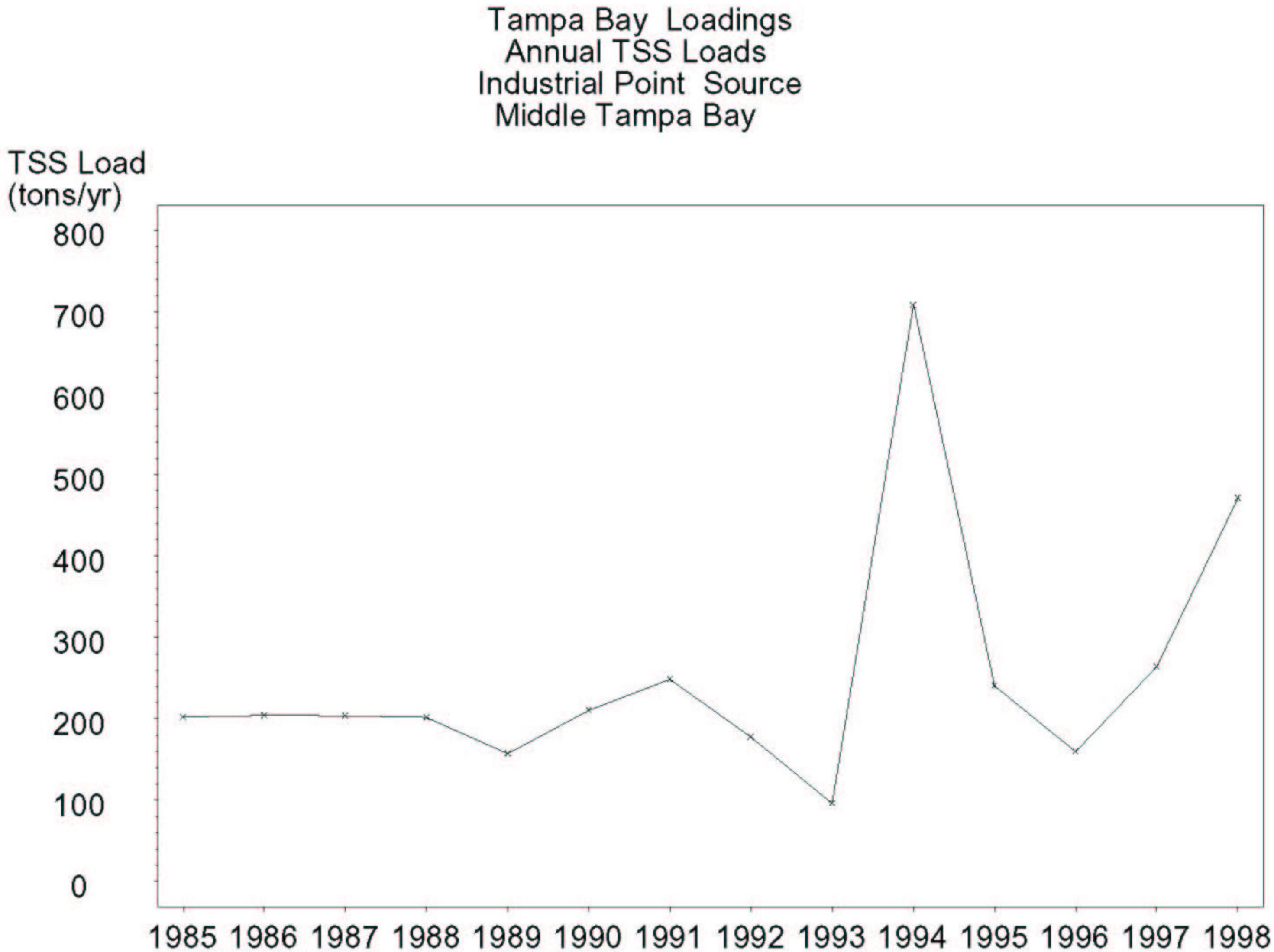


Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Manatee River
TP Load
(tons/yr)
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

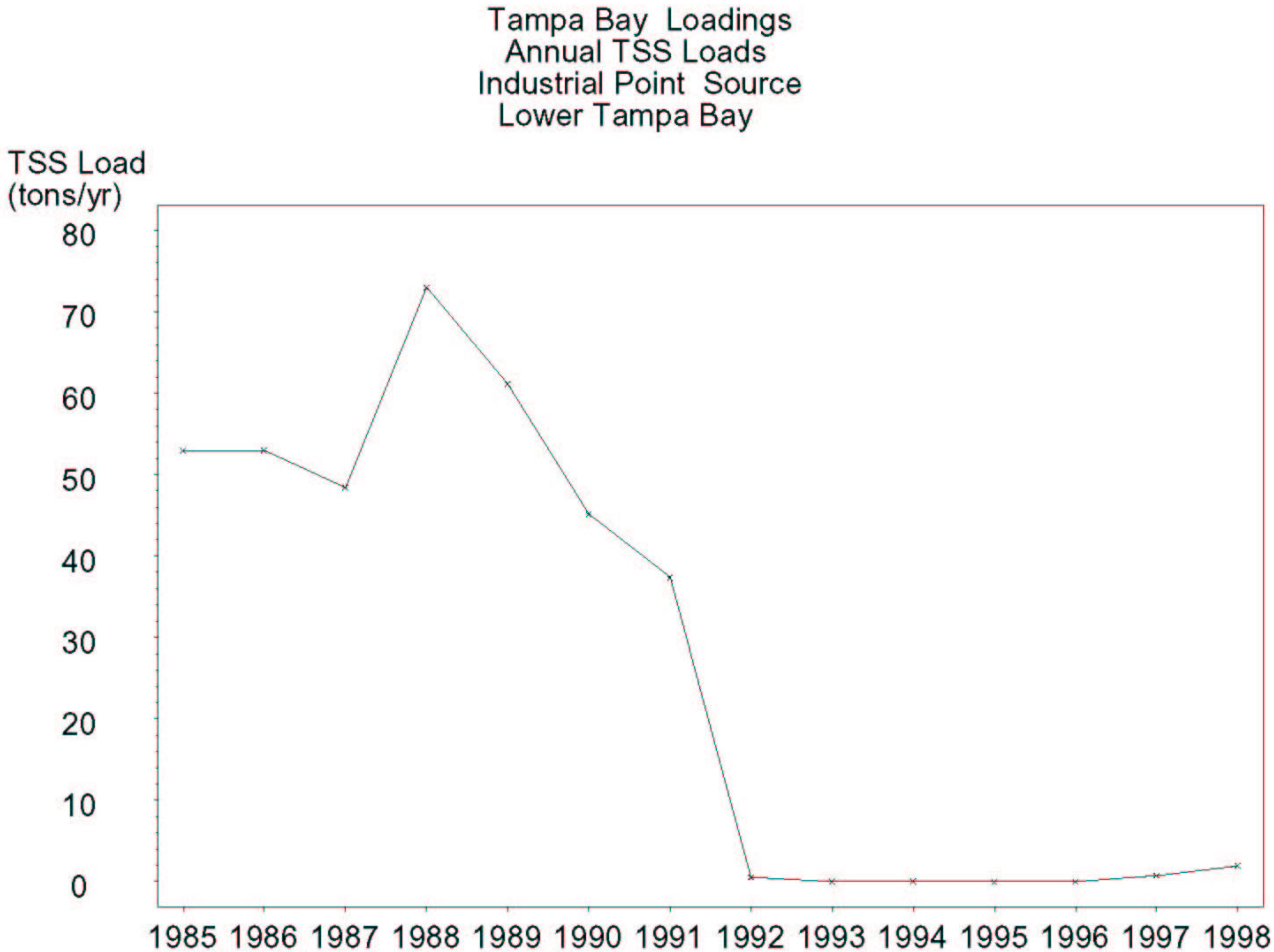

Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Old Tampa Bay
TSS Load
(tons/yr)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



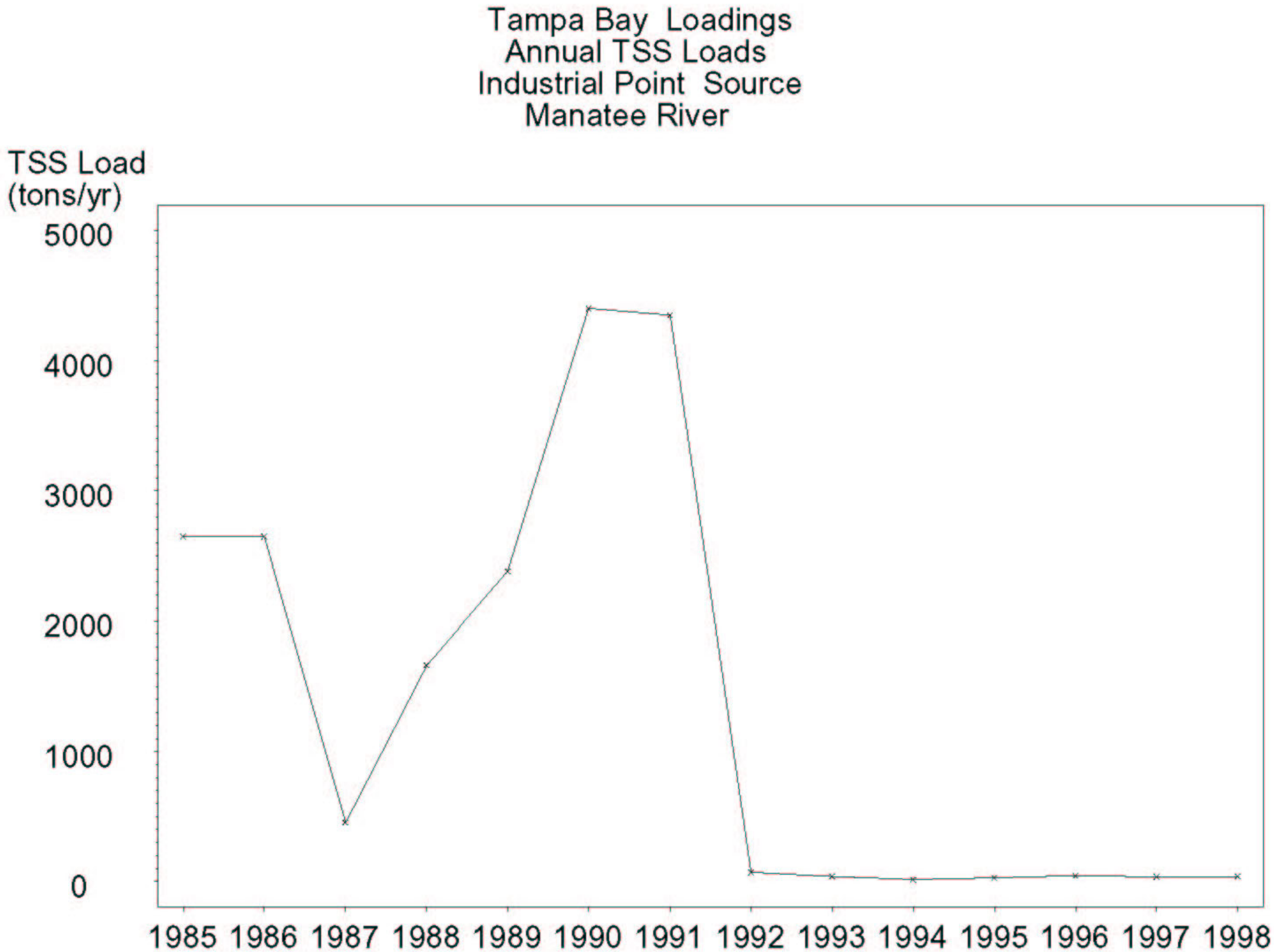
Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Hillsborough Bay
TSS Load
(tons/yr)
1200
1100
1000
900
800
700
600
500
400
300
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



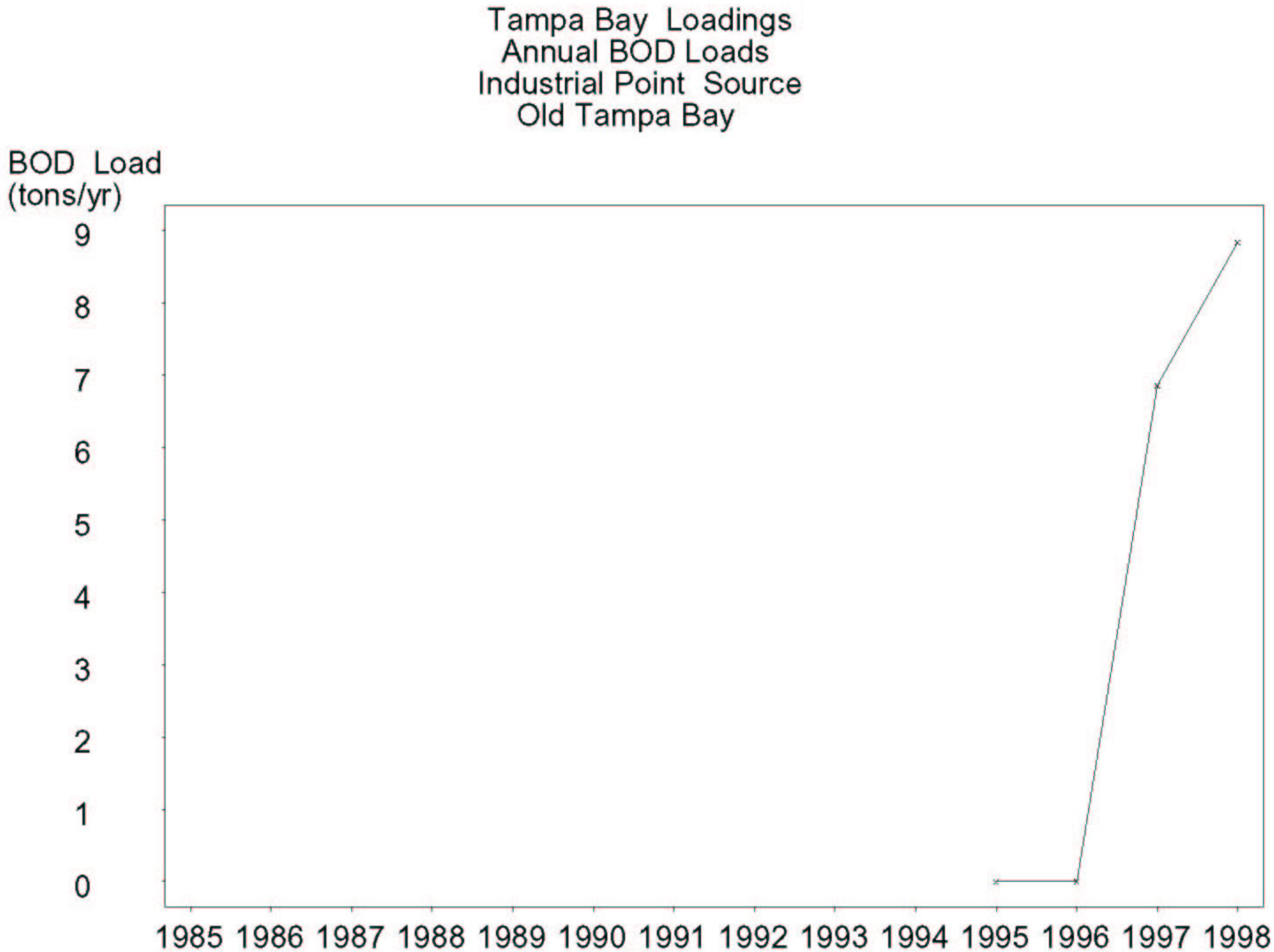
Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Middle Tampa Bay
TSS Load
(tons/yr)
800
700
600
500
400
300
200
100
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



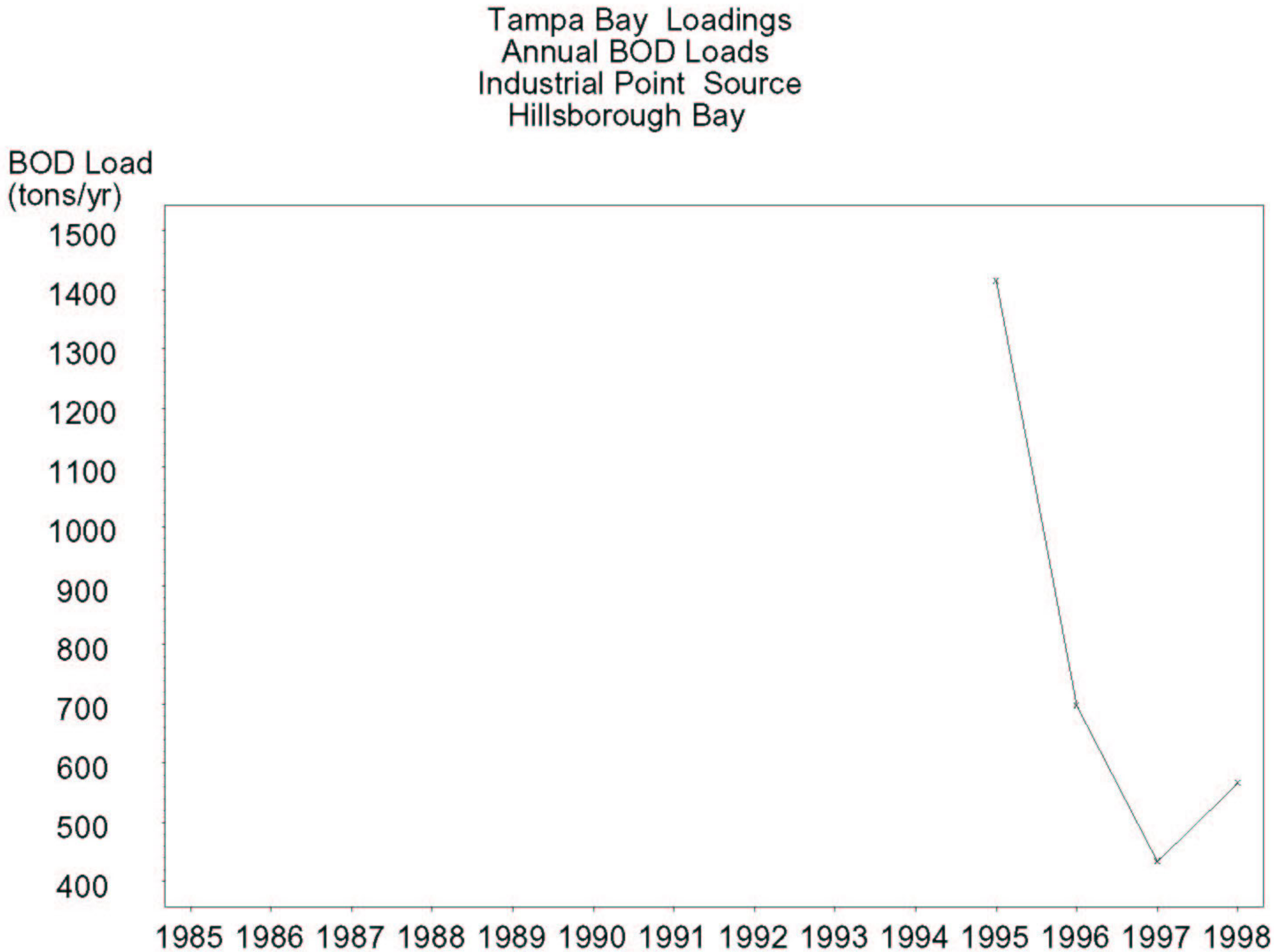
Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Lower Tampa Bay
TSS Load
(tons/yr)
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Manatee River
TSS Load
(tons/yr)
5000
4000
3000
2000
1000
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

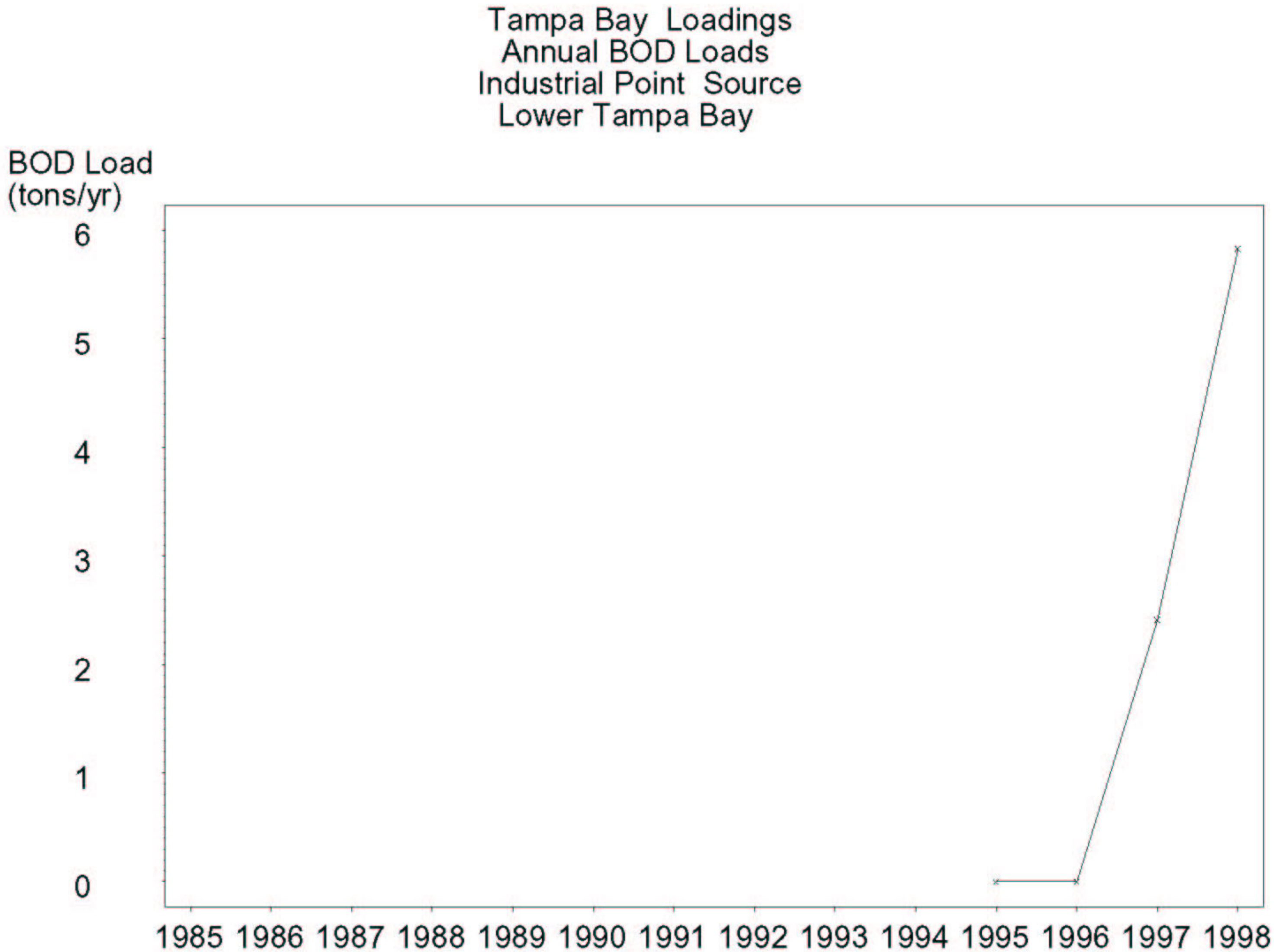


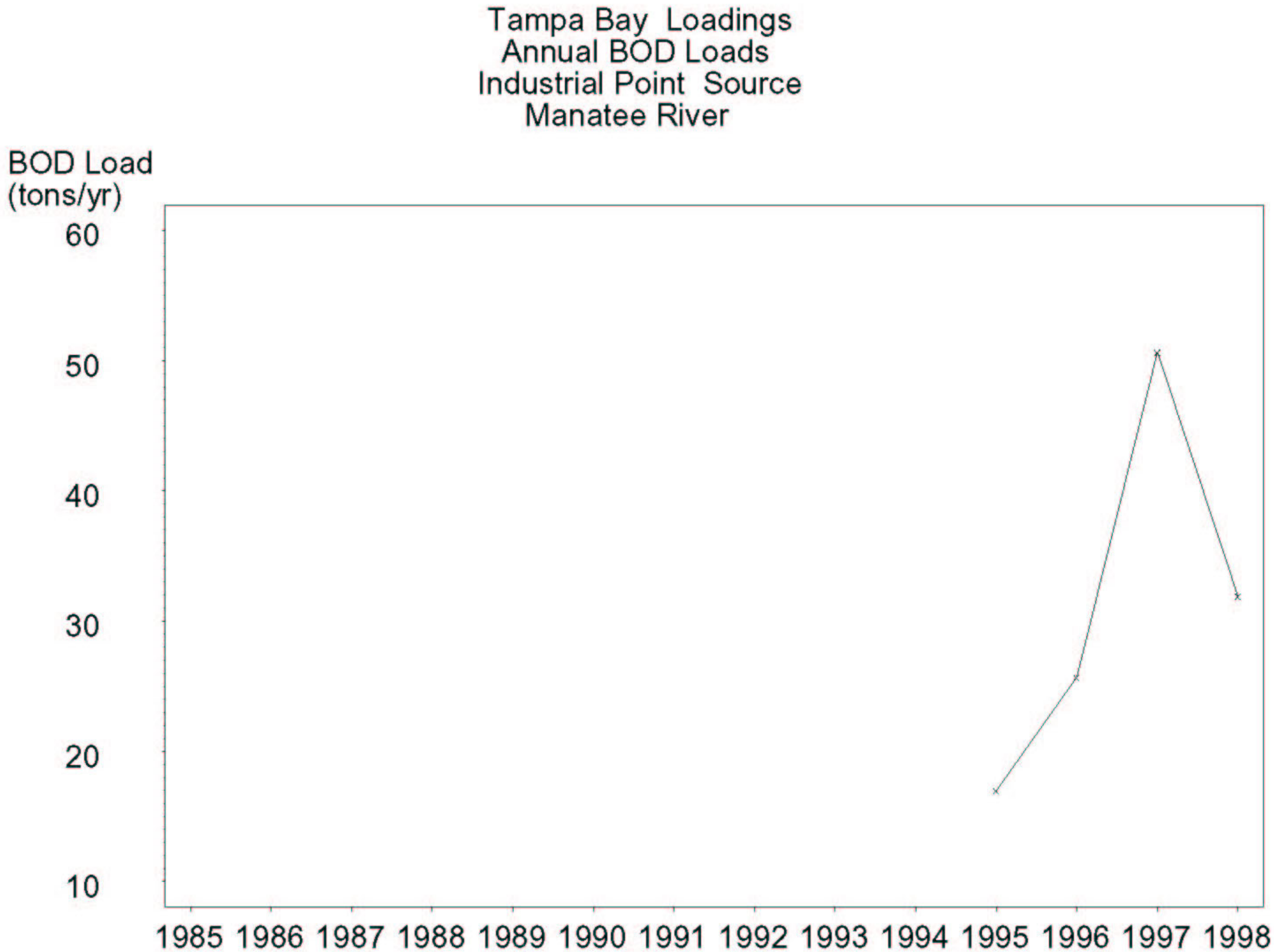
Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Old Tampa Bay
BOD Load
(tons/yr)
9
8
7
6
5
4
3
2
1
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

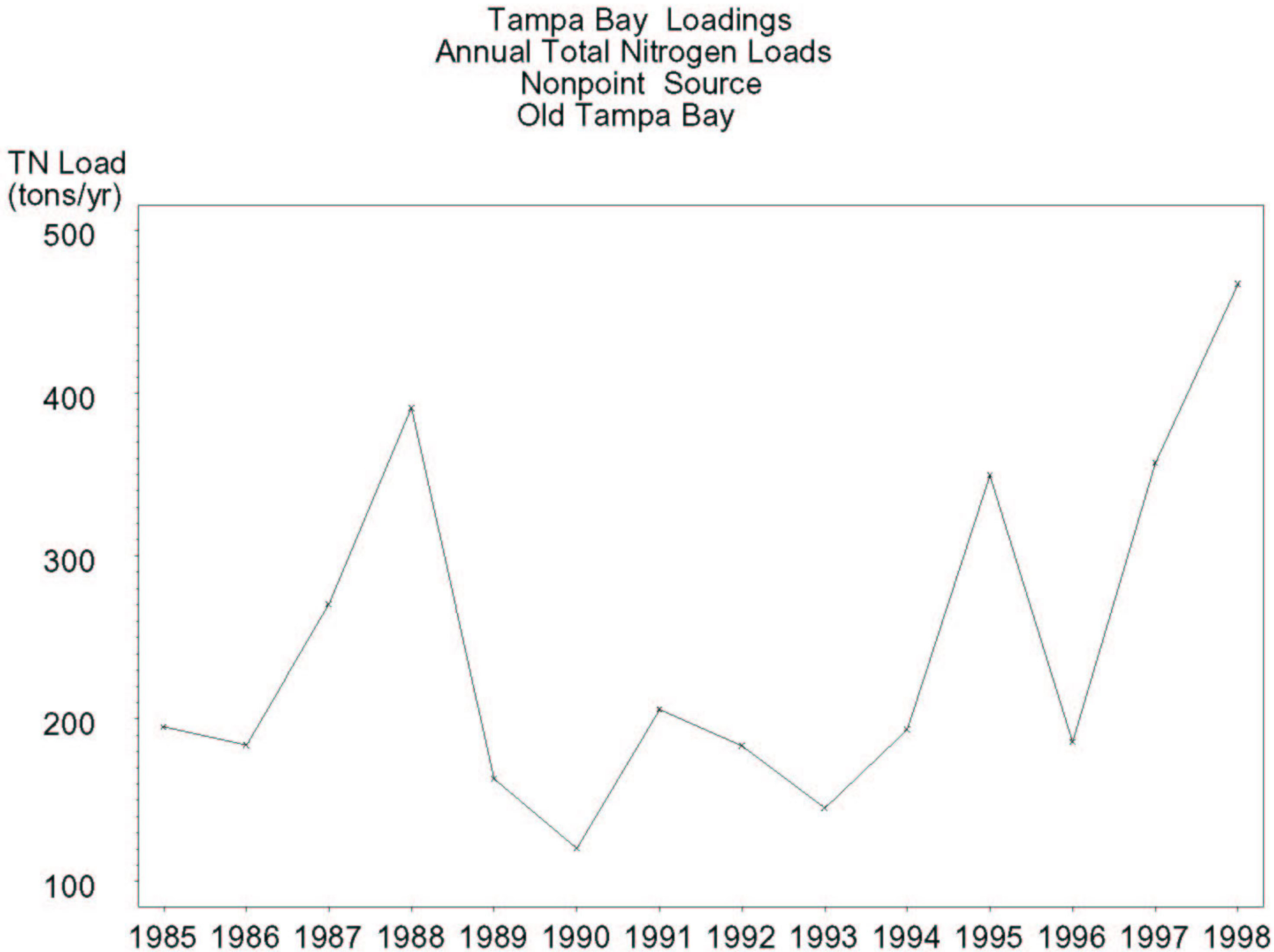


Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Hillsborough Bay
BOD Load
(tons/yr)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

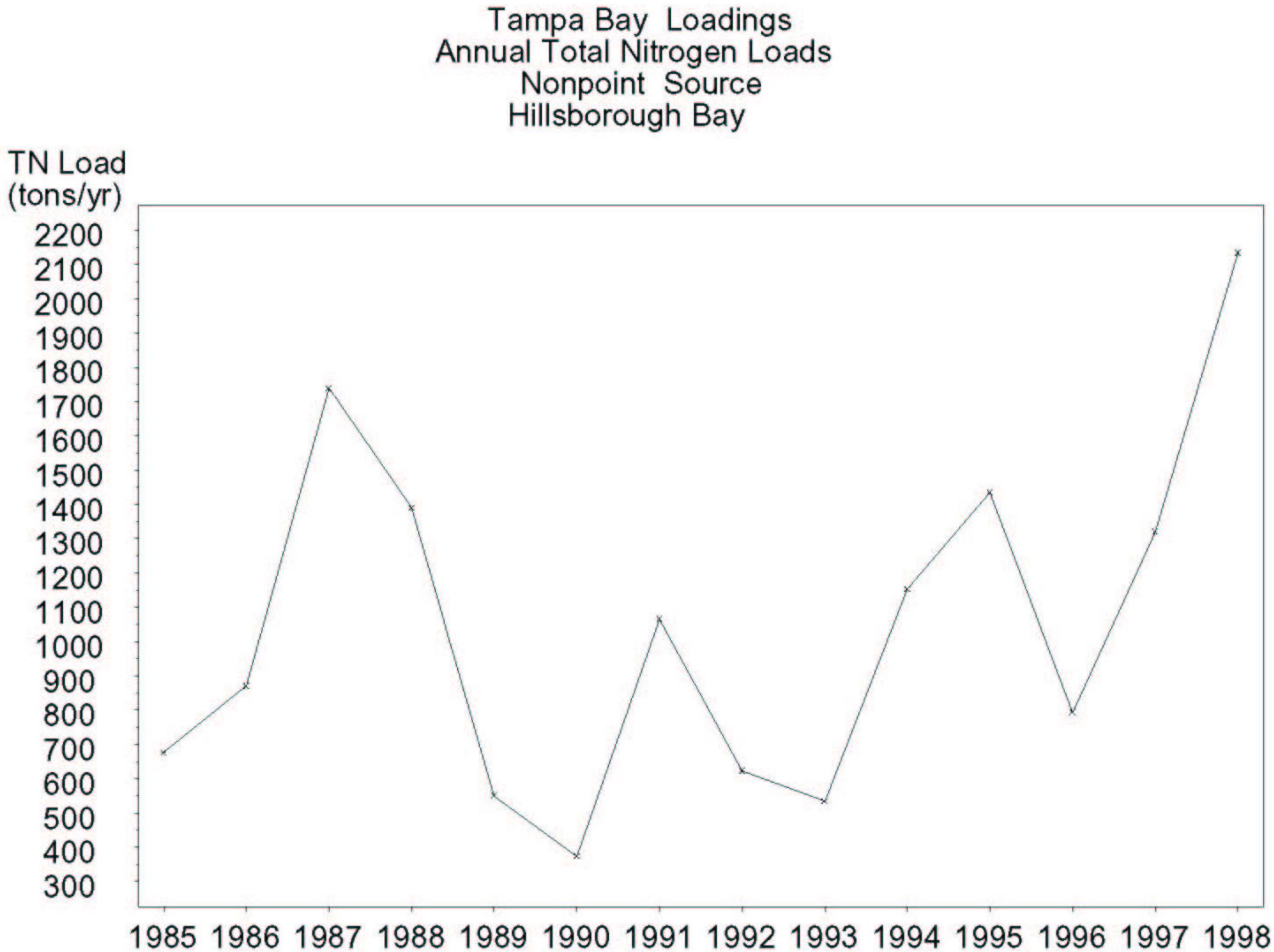
Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Middle Tampa Bay
BOD Load
(tons/yr)
500
400
300
200
100
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Lower Tampa Bay
BOD Load
(tons/yr)
6
5
4
3
2
1
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

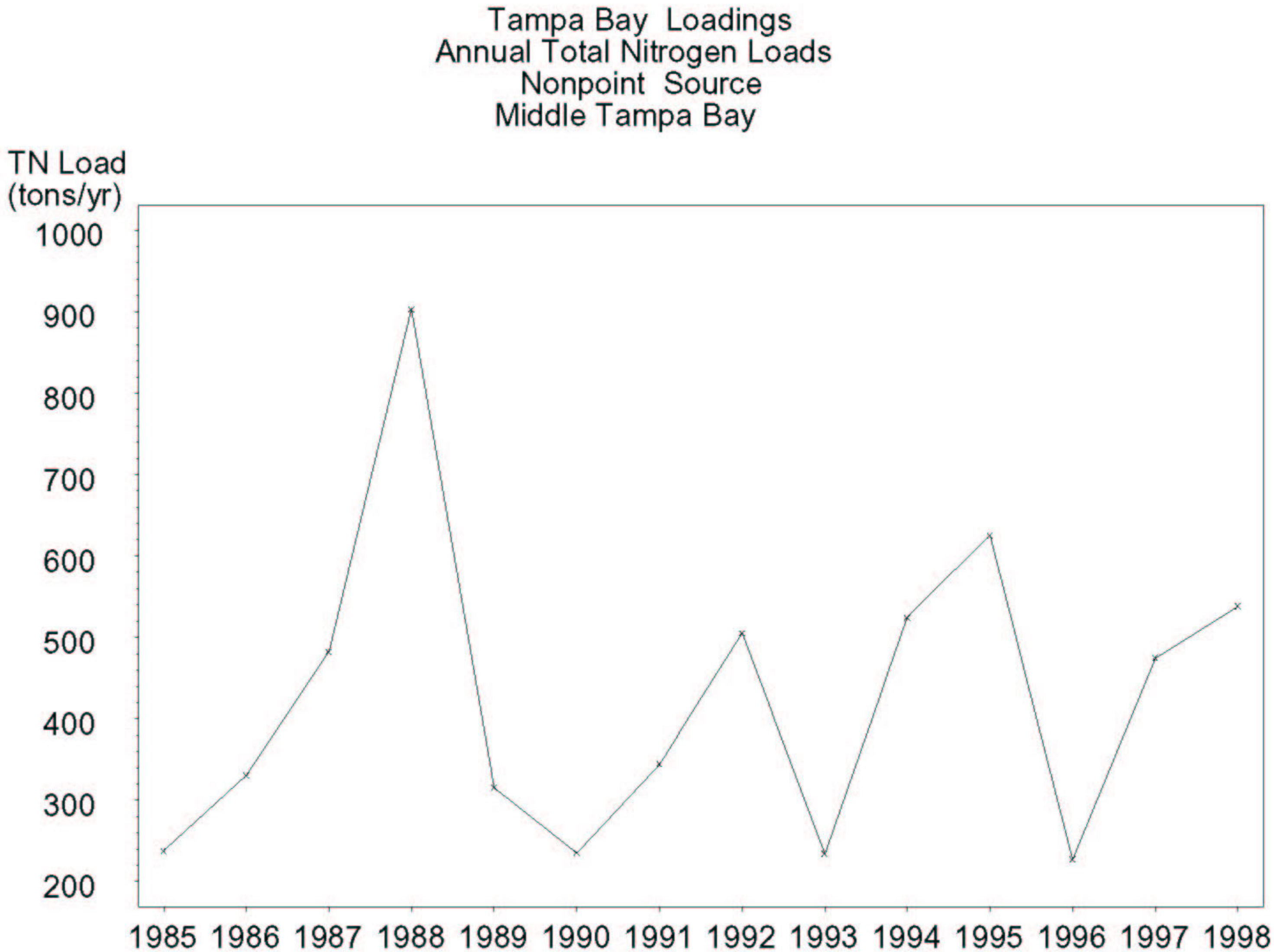

Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Manatee River
BOD Load
(tons/yr)
60
50
40
30
20
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

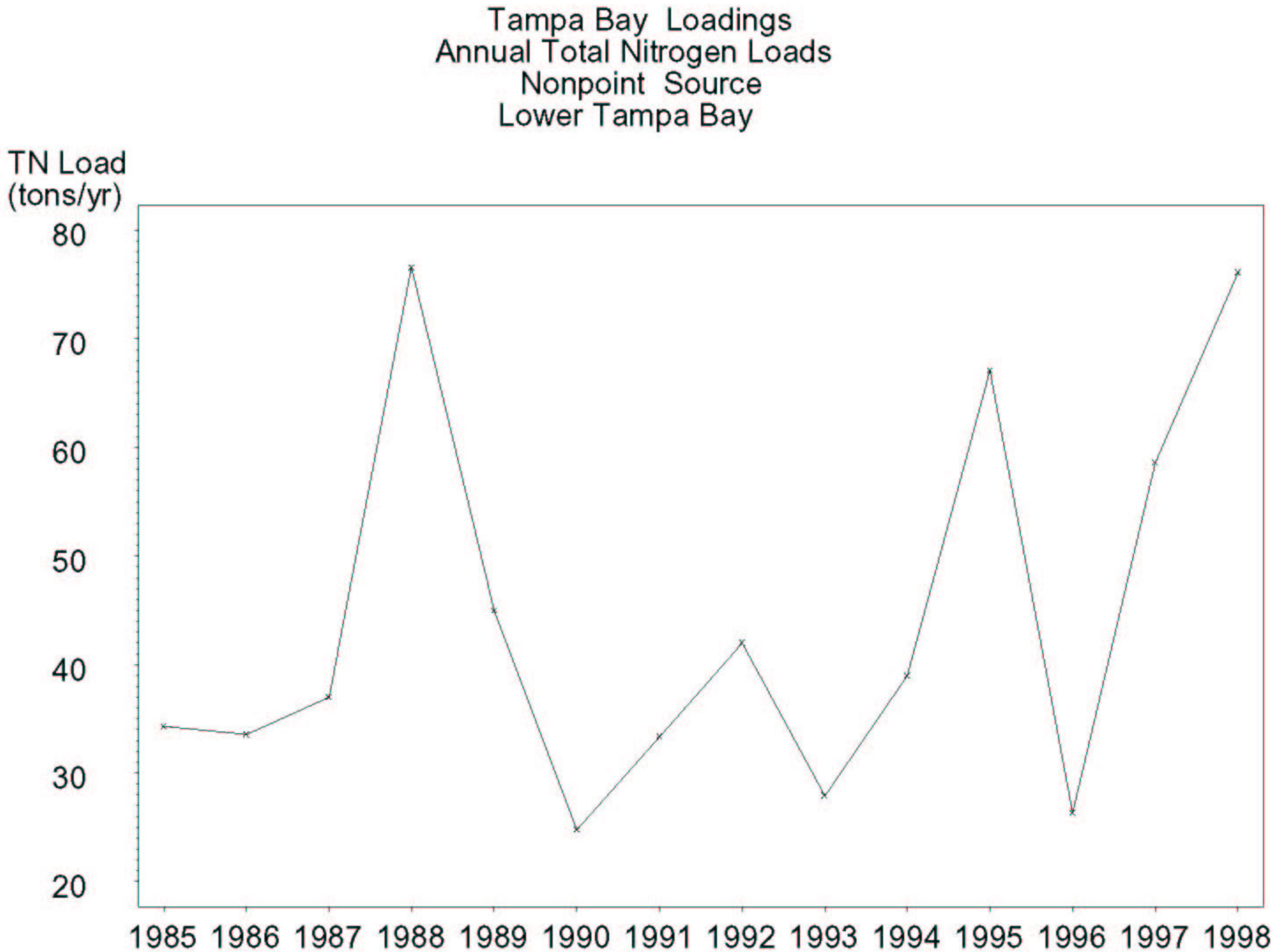


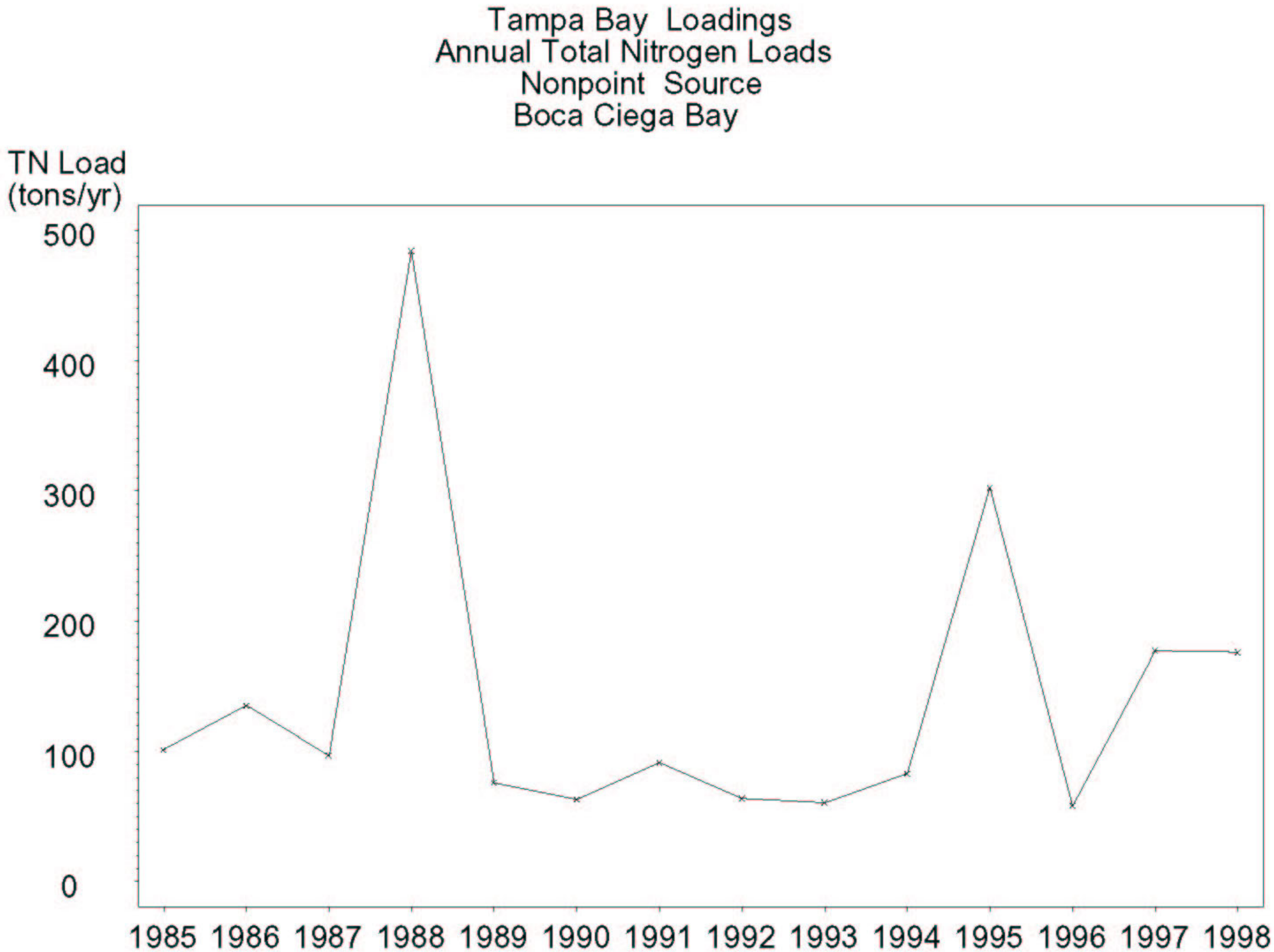
Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Old Tampa Bay
TN Load
(tons/yr)
500
400
300
200
100
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

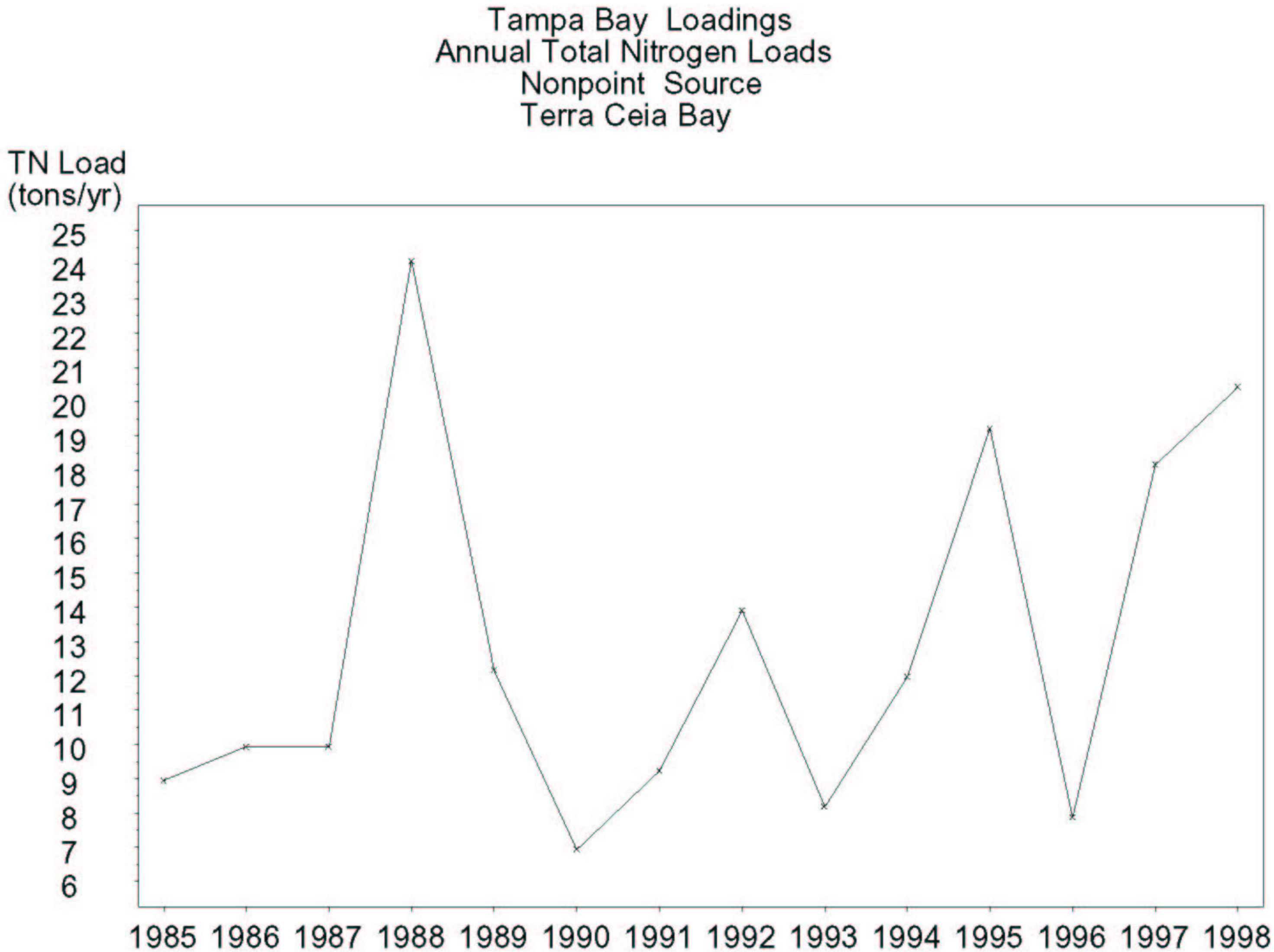


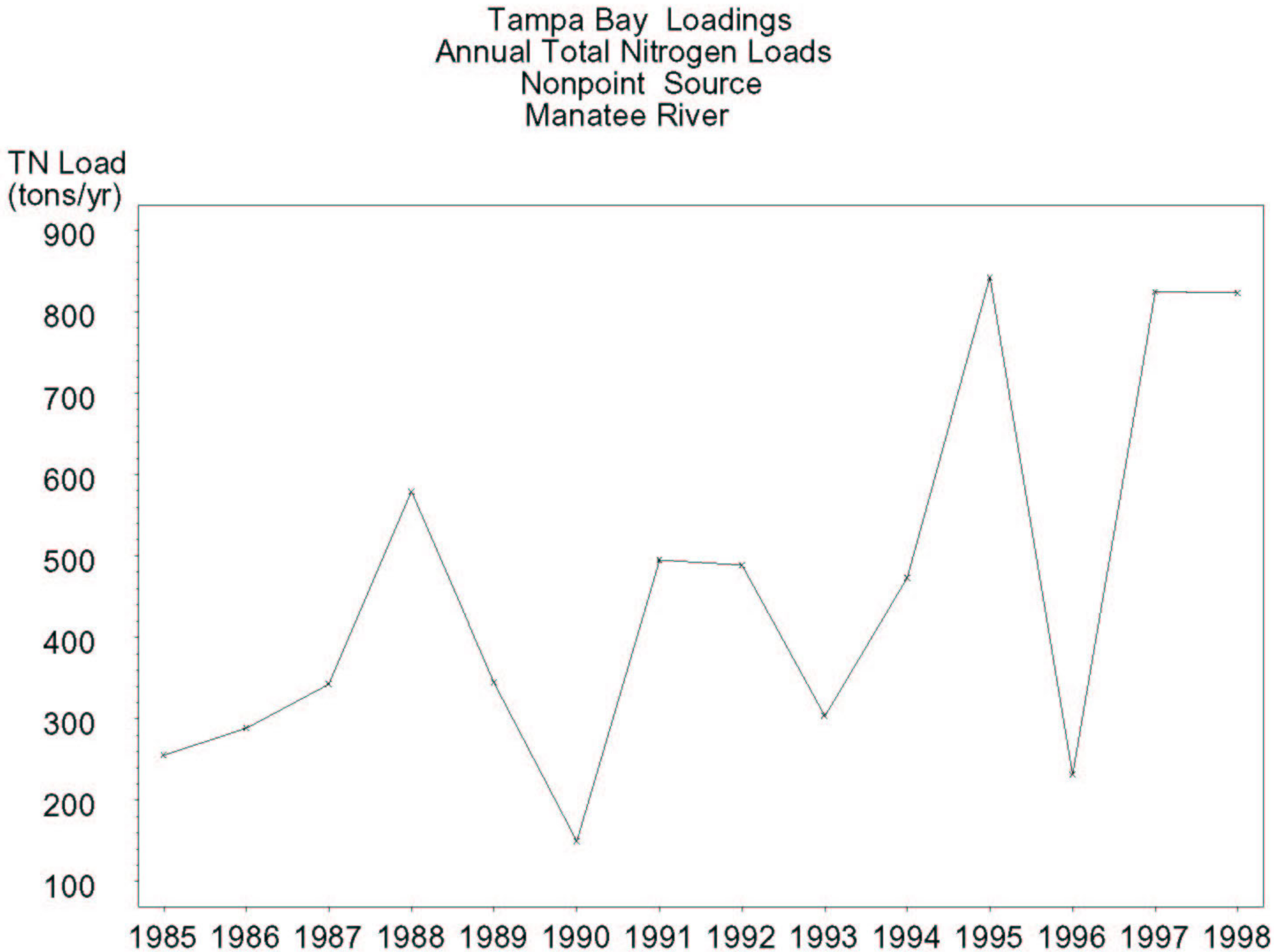
Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Hillsborough Bay
TN Load
(tons/yr)
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

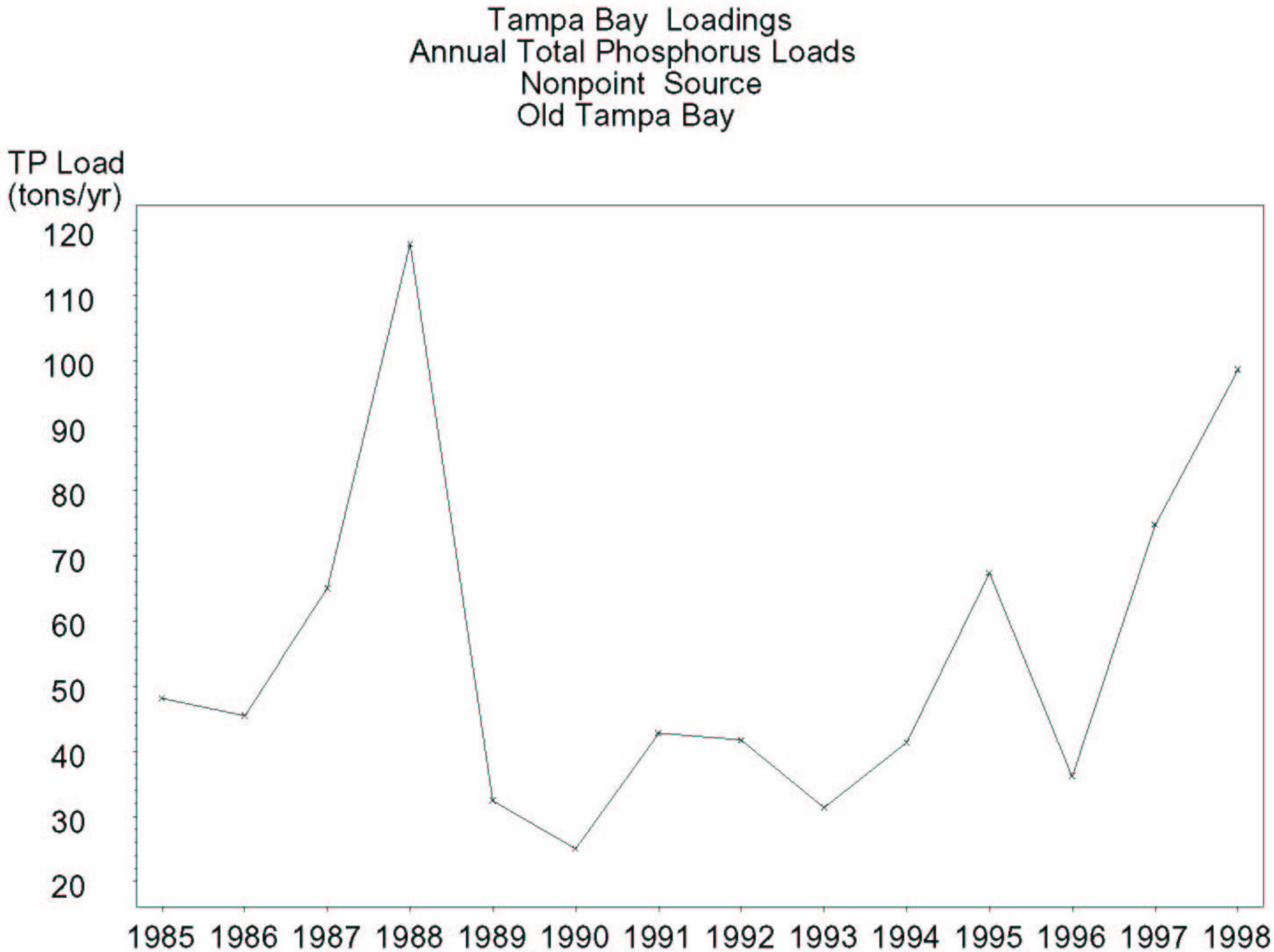

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Middle Tampa Bay
TN Load
(tons/yr)
1000
900
800
700
600
500
400
300
200
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Lower Tampa Bay
TN Load
(tons/yr)
80
70
60
50
40
30
20
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

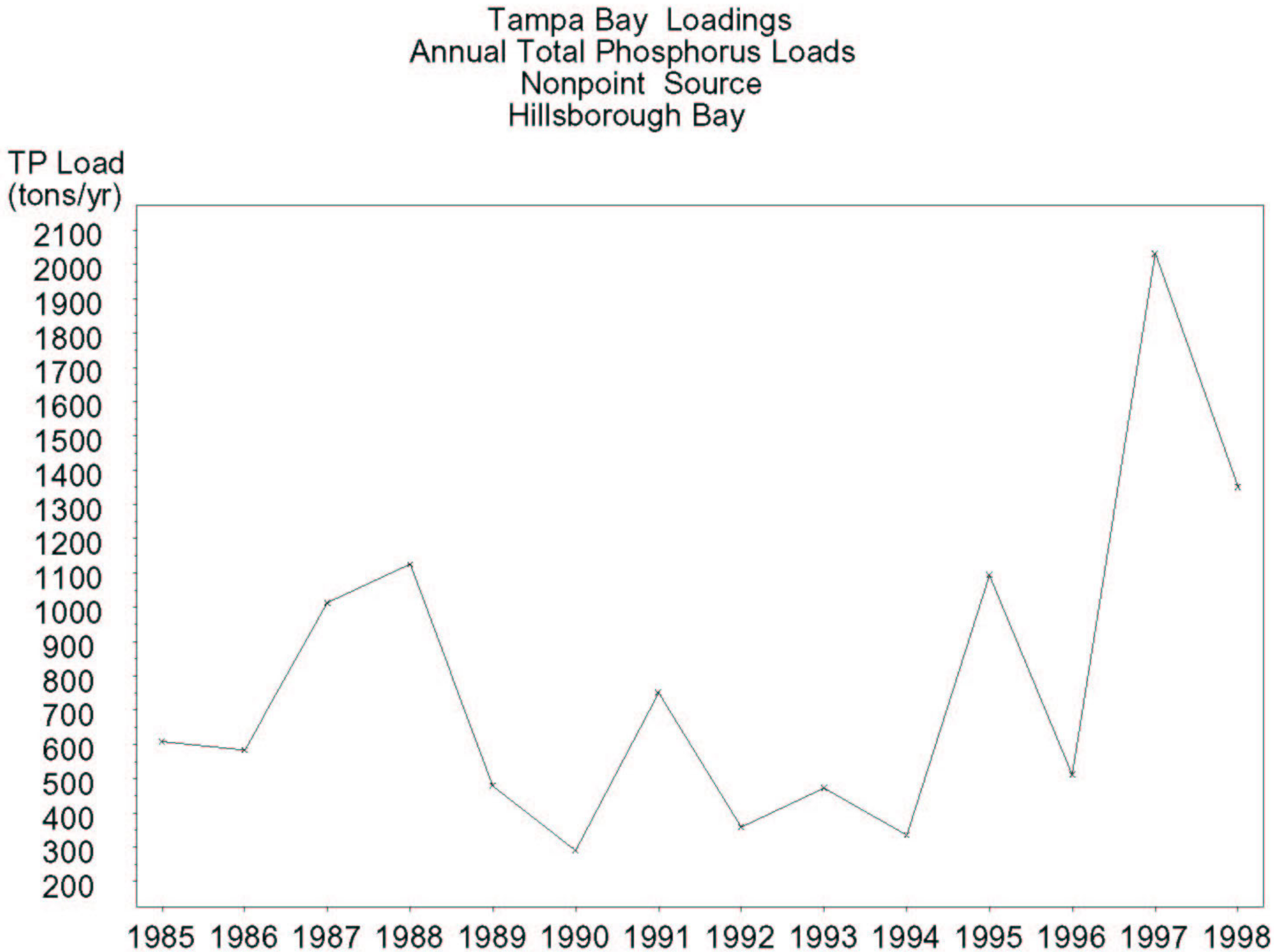

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Boca Ciega Bay
TN Load
(tons/yr)
500
400
300
200
100
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

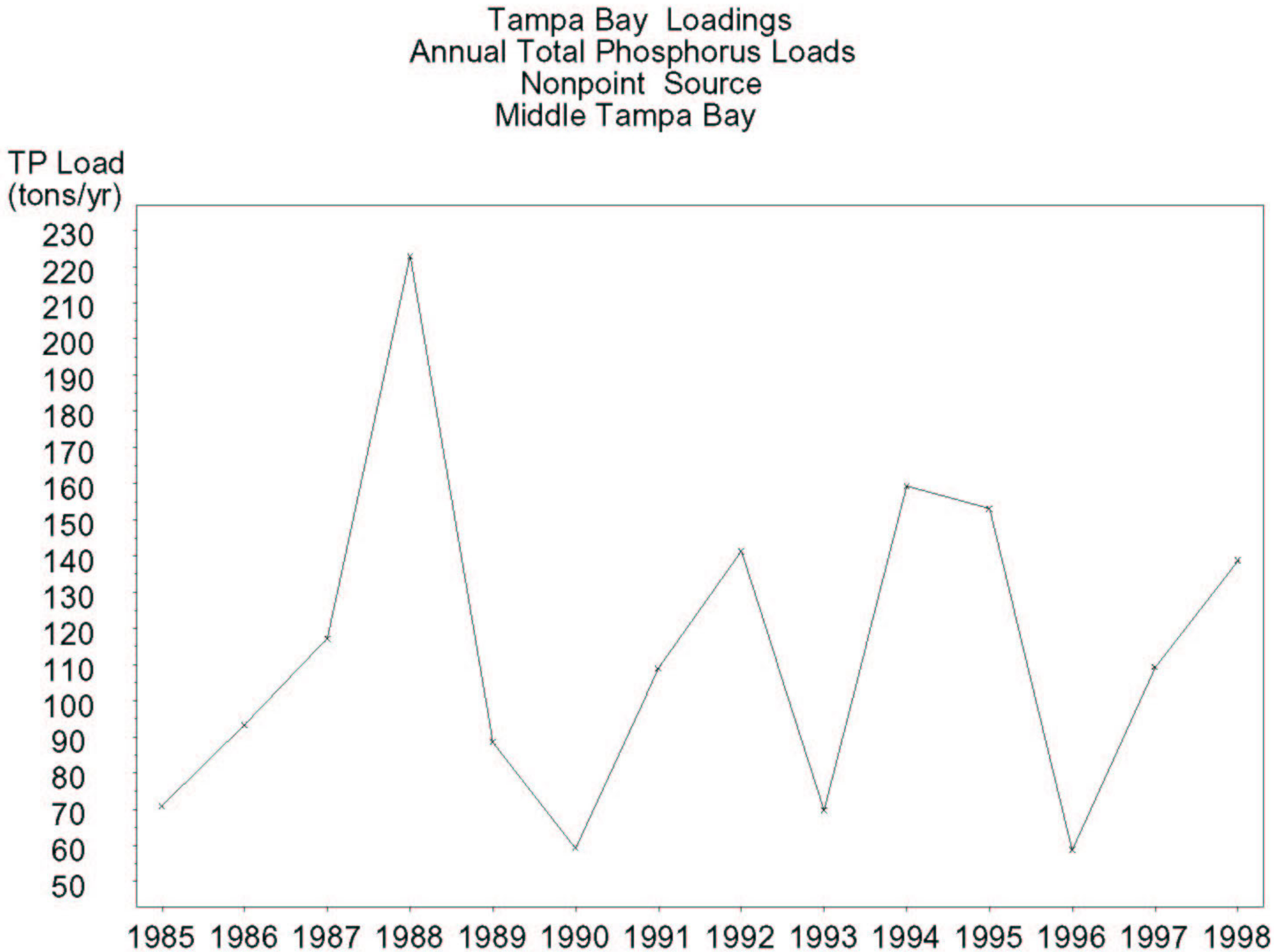

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Terra Ceia Bay
TN Load (tons/yr)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

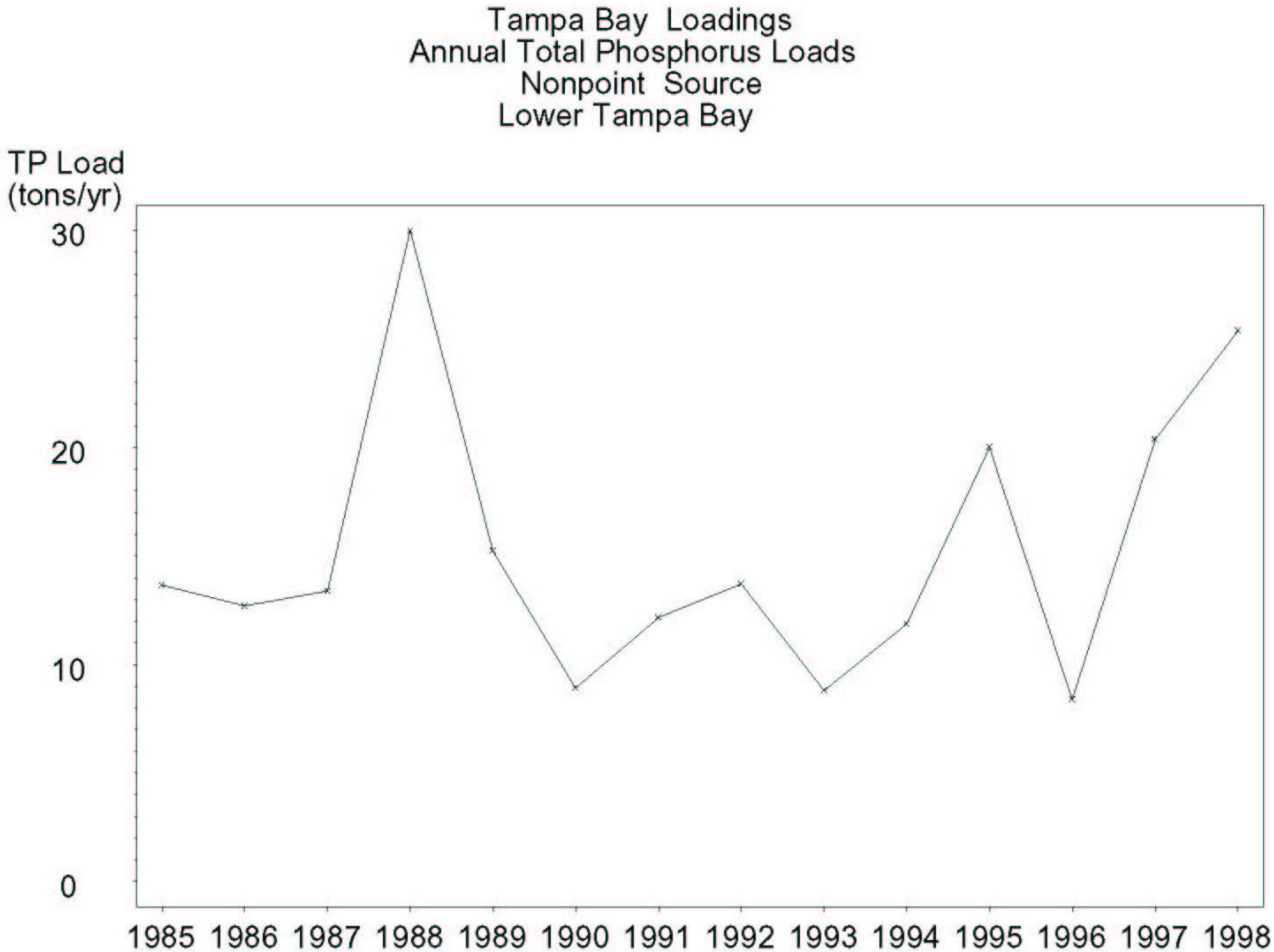

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Manatee River
TN Load
(tons/yr)
900
800
700
600
500
400
300
200
100
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

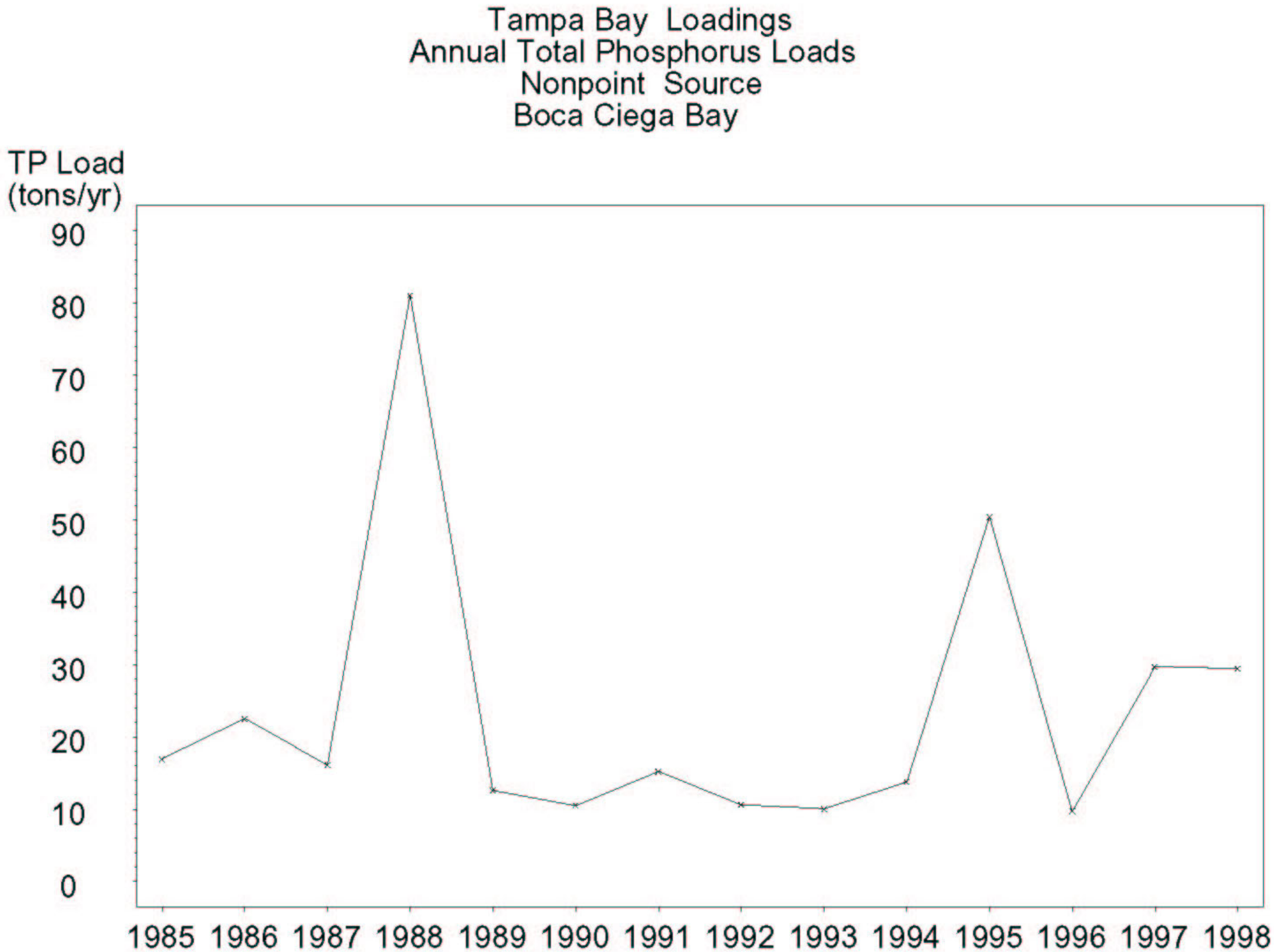


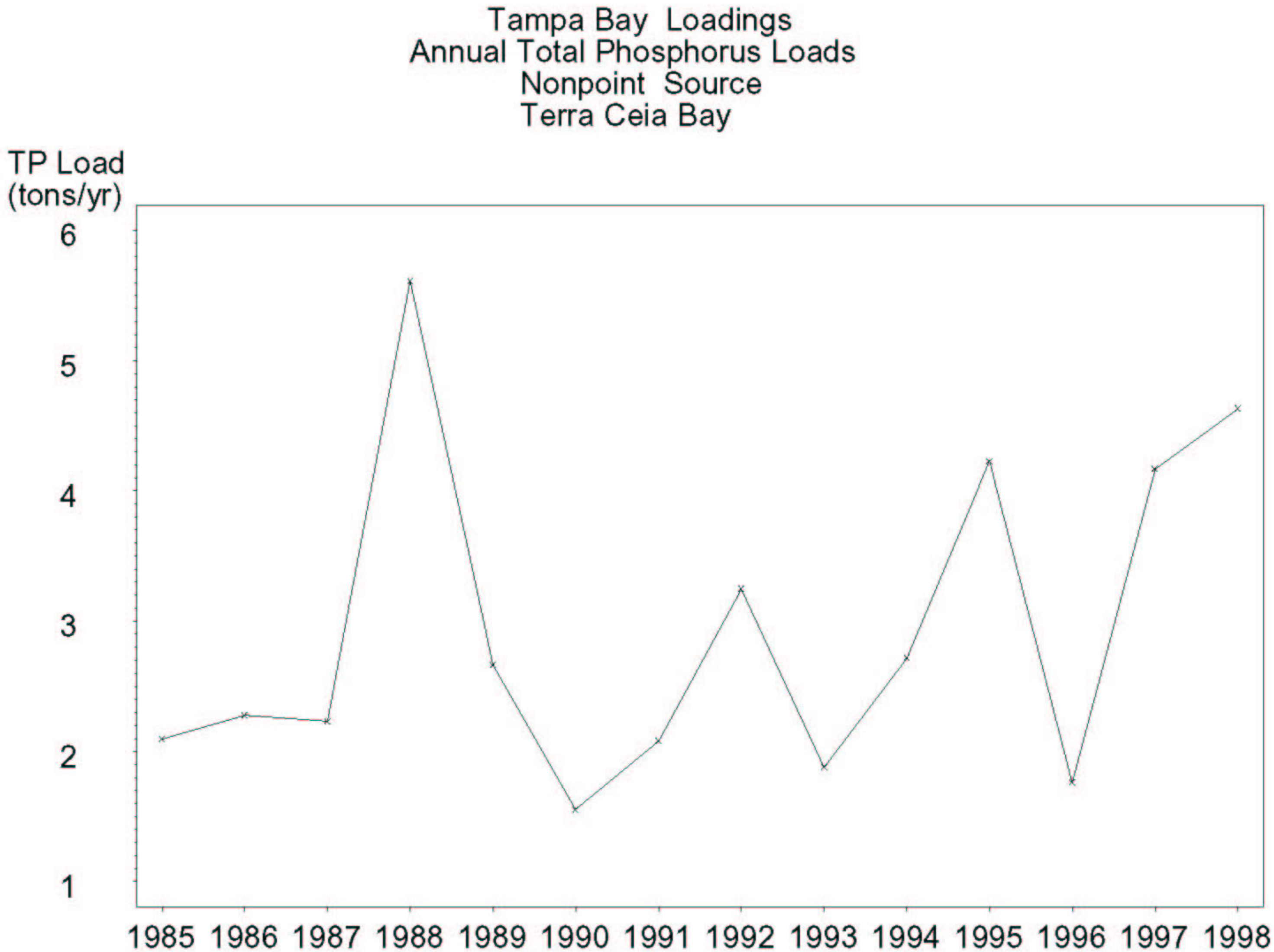
Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Old Tampa Bay
TP Load (tons/yr)
120
110
100
90
80
70
60
50
40
30
20
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Hillsborough Bay
TP Load
(tons/yr)
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Middle Tampa Bay
TP Load
(tons/yr)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

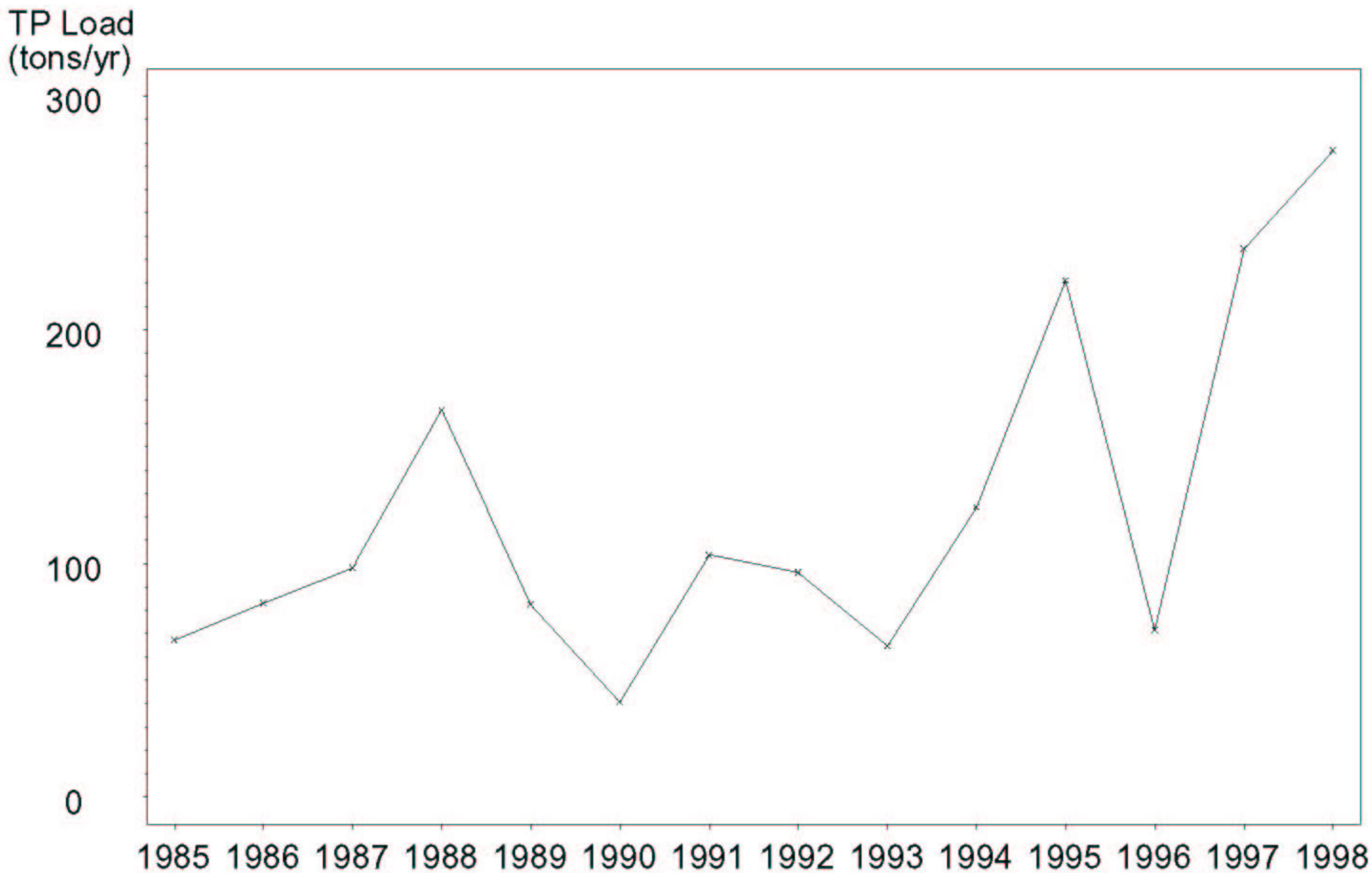

Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Lower Tampa Bay
TP Load
(tons/yr)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

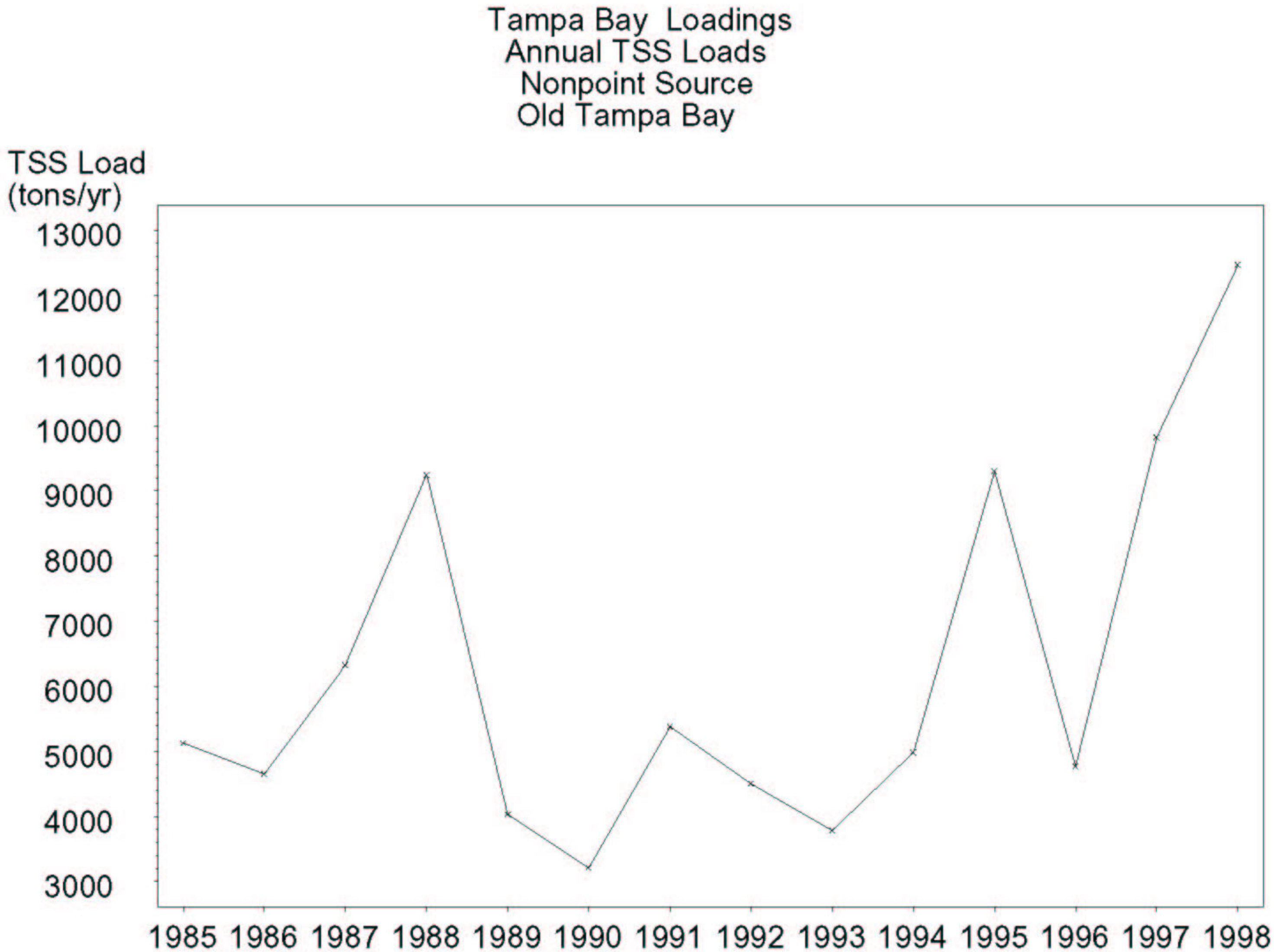

Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Boca Ciega Bay
TP Load
(tons/yr)
90
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

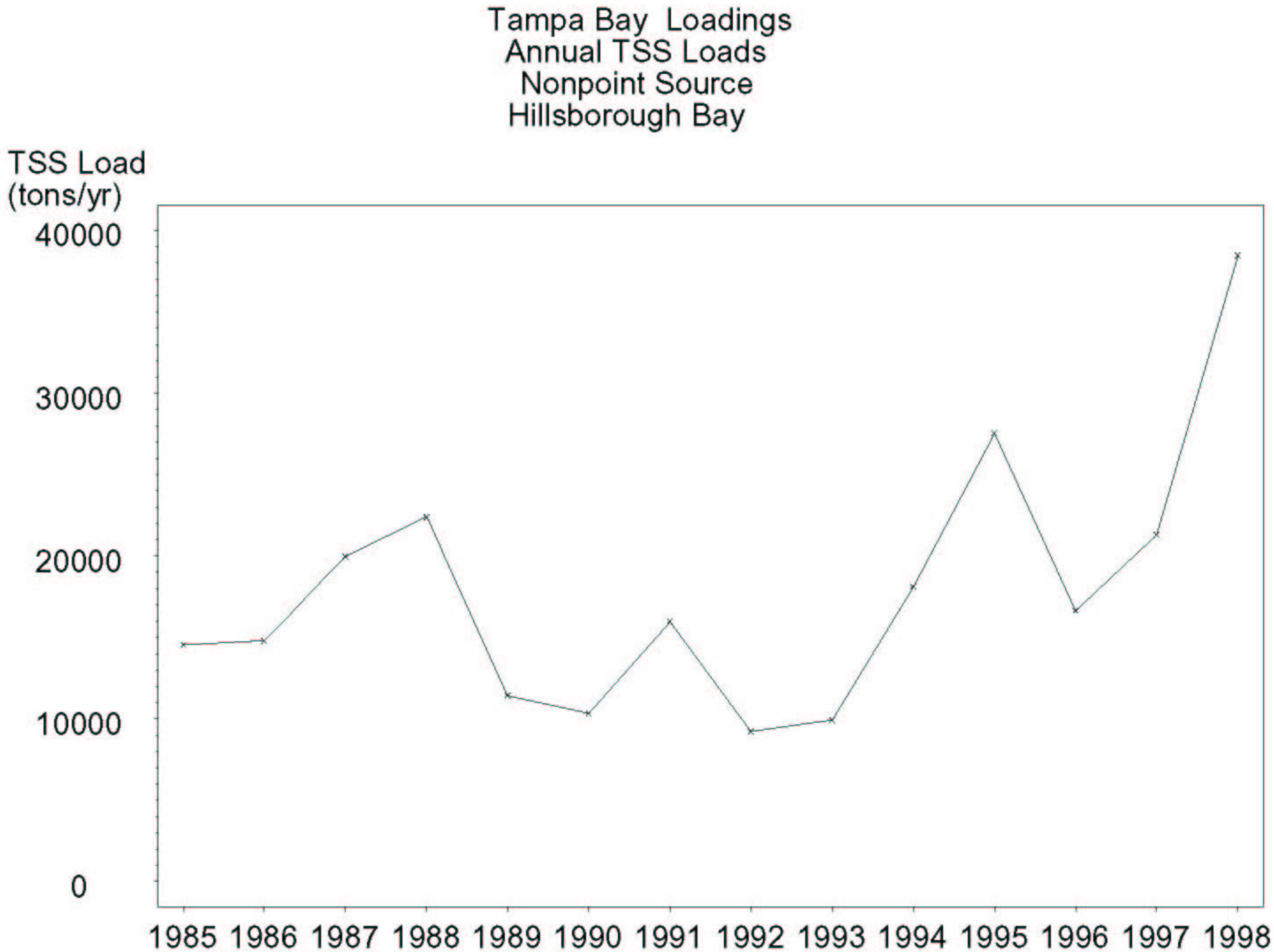


Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Terra Ceia Bay
TP Load
(tons/yr)
6
5
4
3
2
1
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

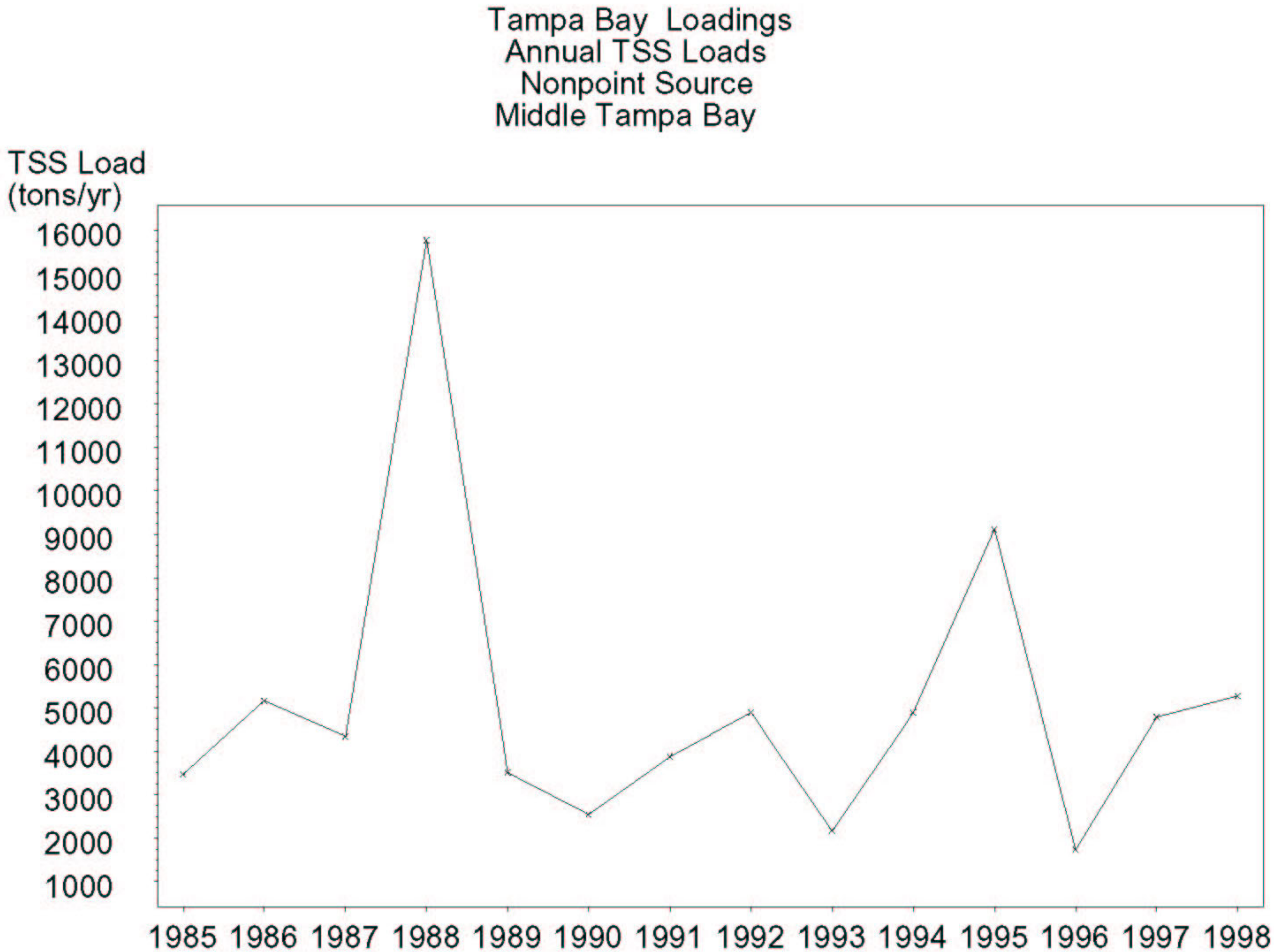
Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Manatee River

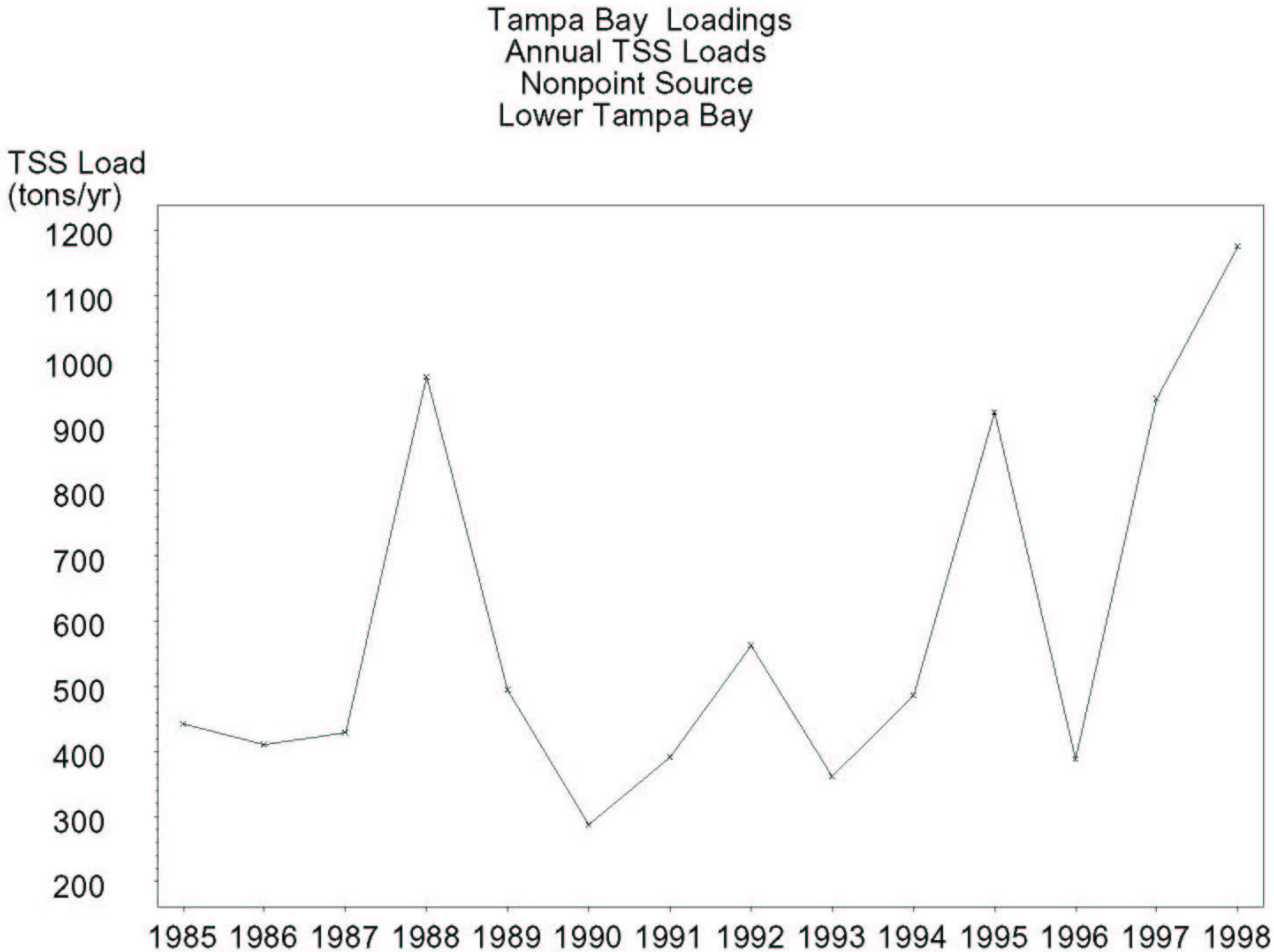


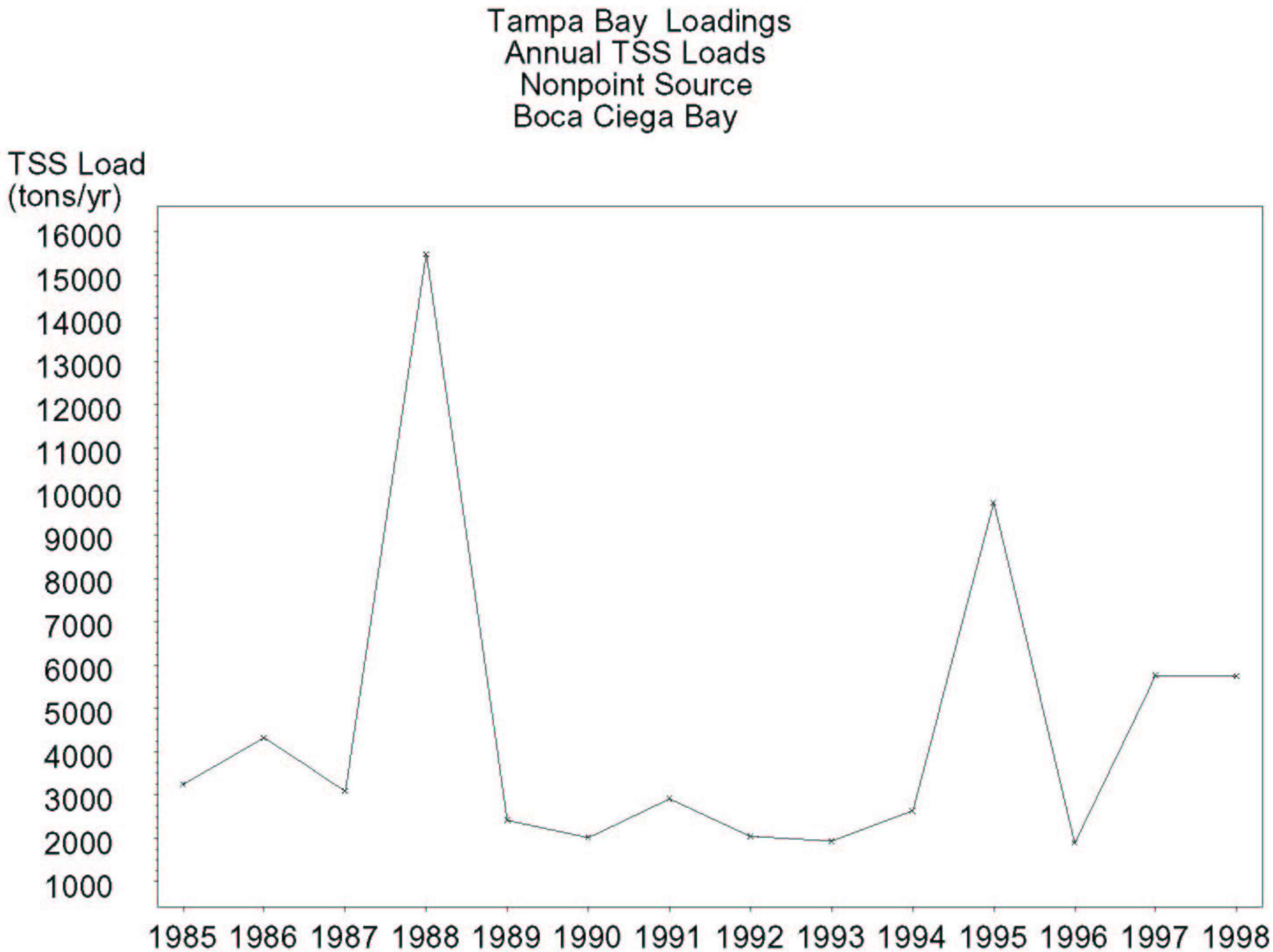

Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Old Tampa Bay
TSS Load
(tons/yr)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

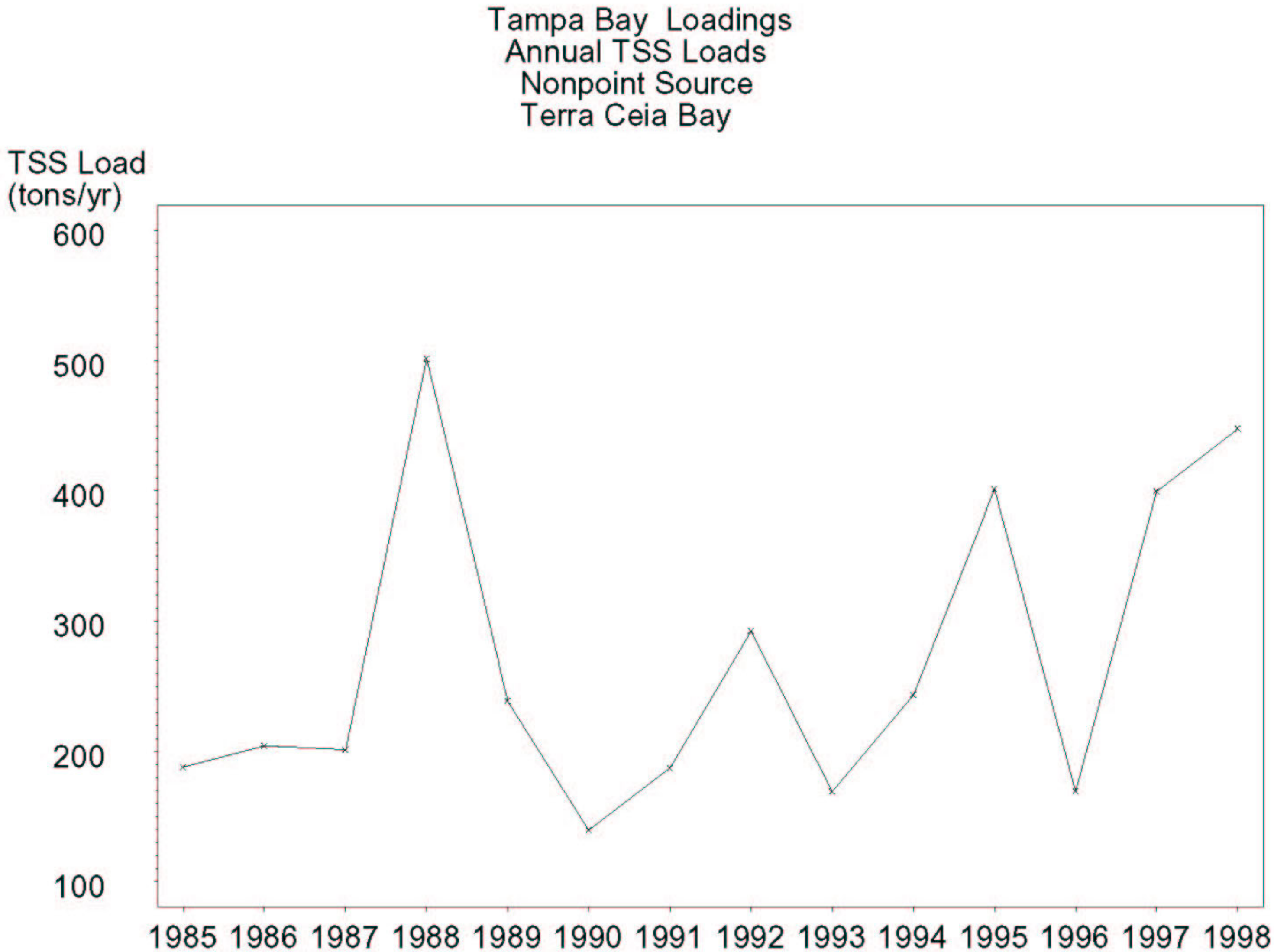


Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Hillsborough Bay
TSS Load
(tons/yr)
40000
30000
20000
10000
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

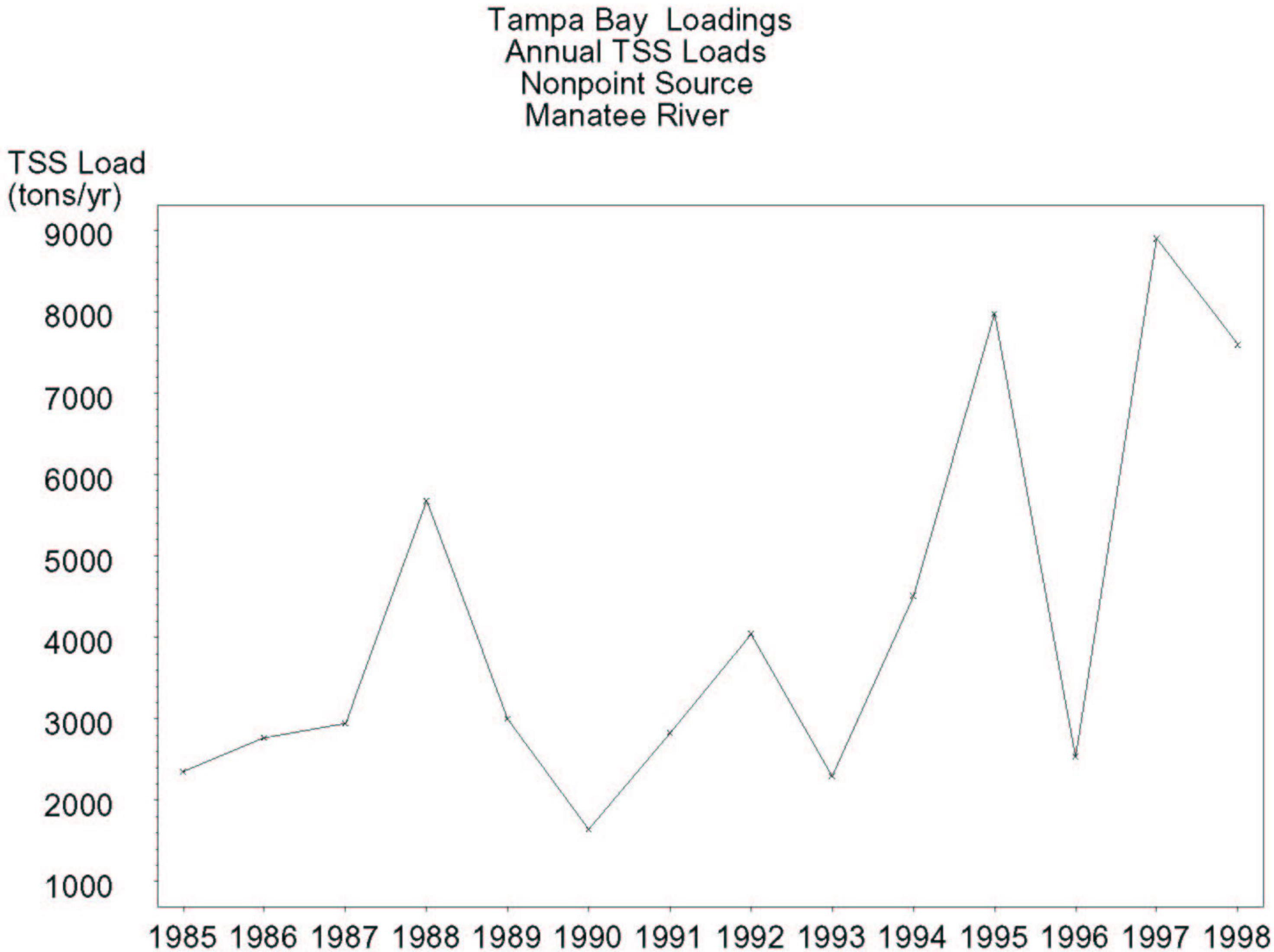

Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Middle Tampa Bay
TSS Load
(tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Lower Tampa Bay
TSS Load
(tons/yr)
1200
1100
1000
900
800
700
600
500
400
300
200
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

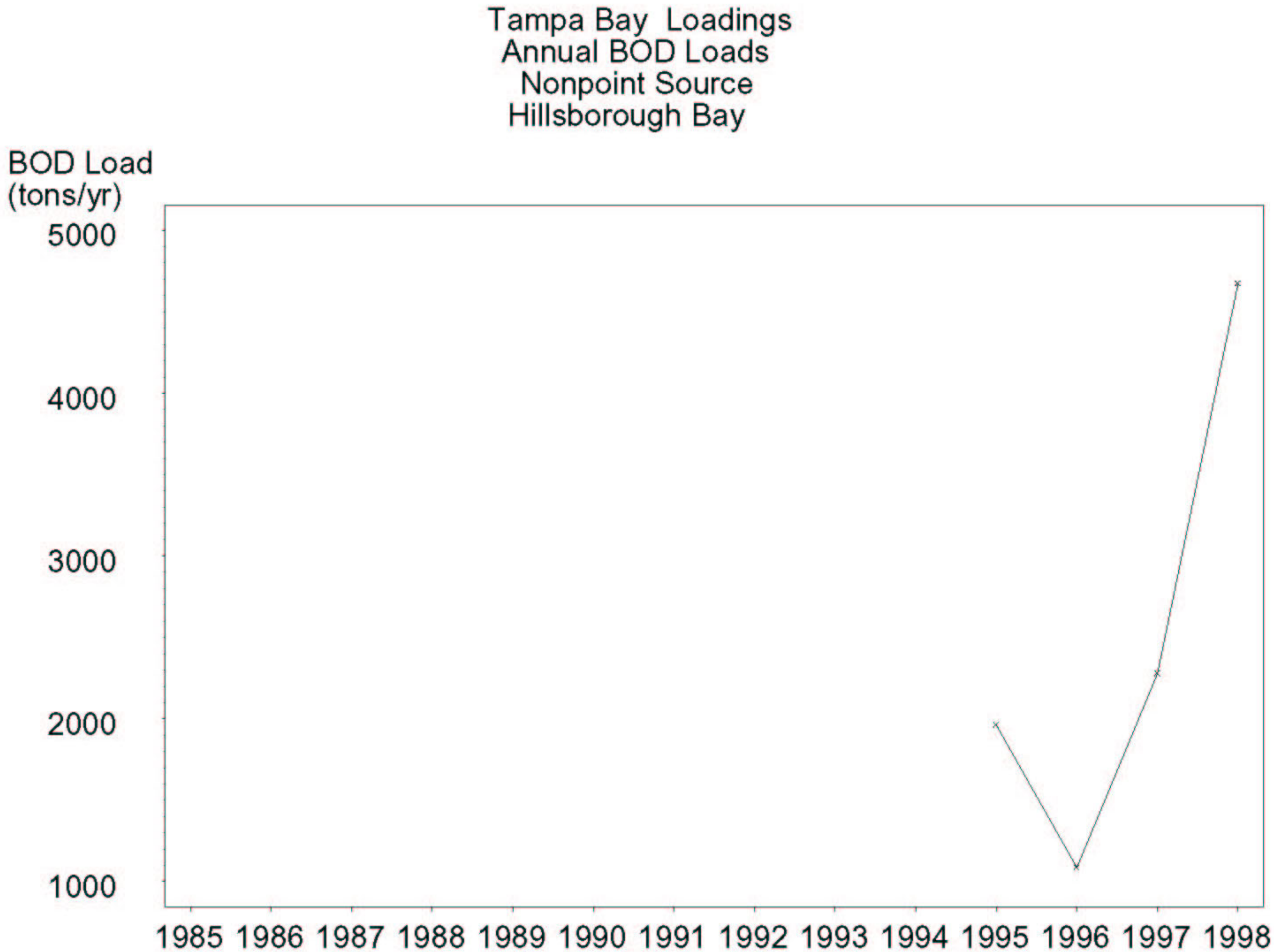

Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Boca Ciega Bay
TSS Load
(tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

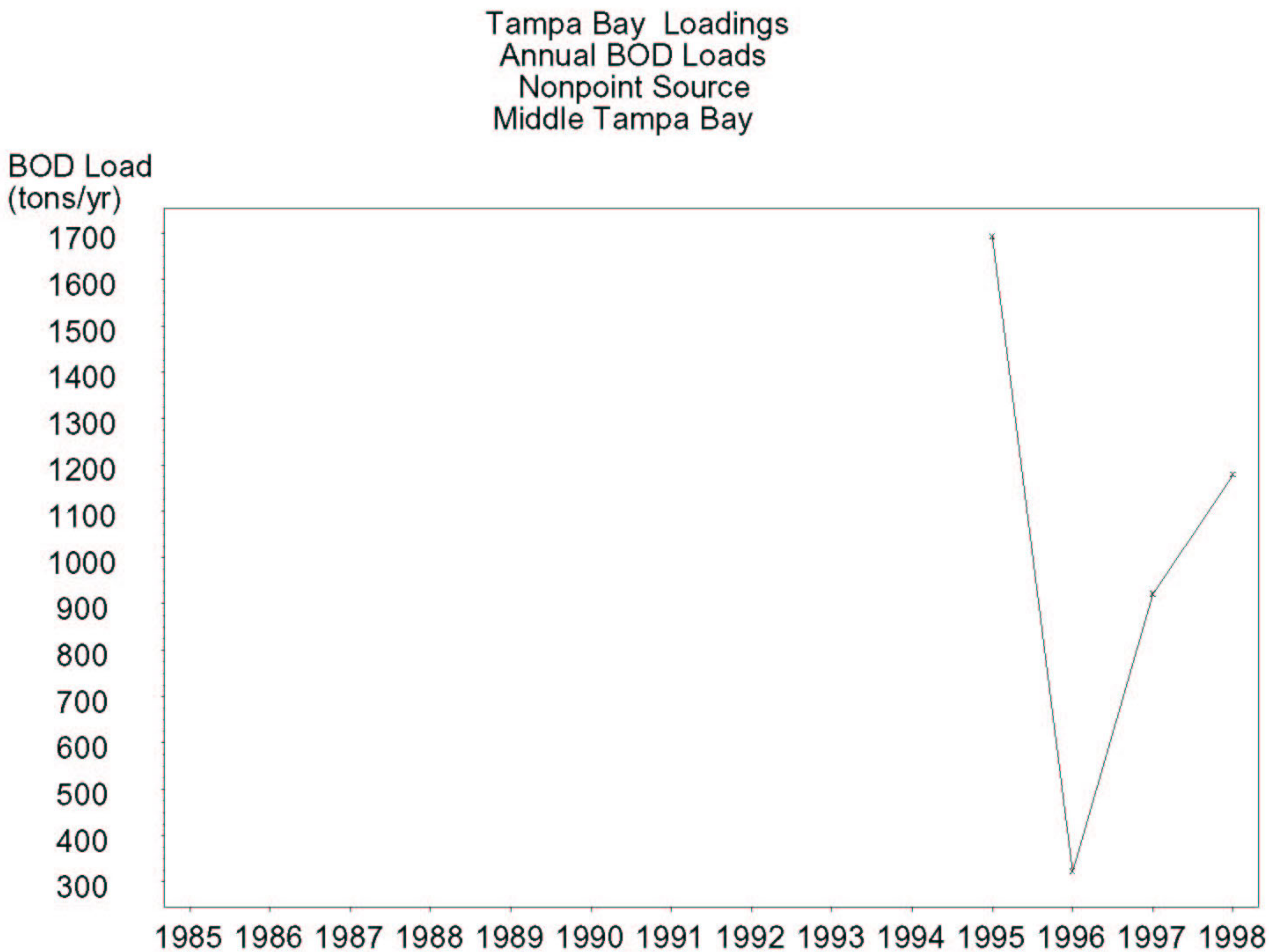


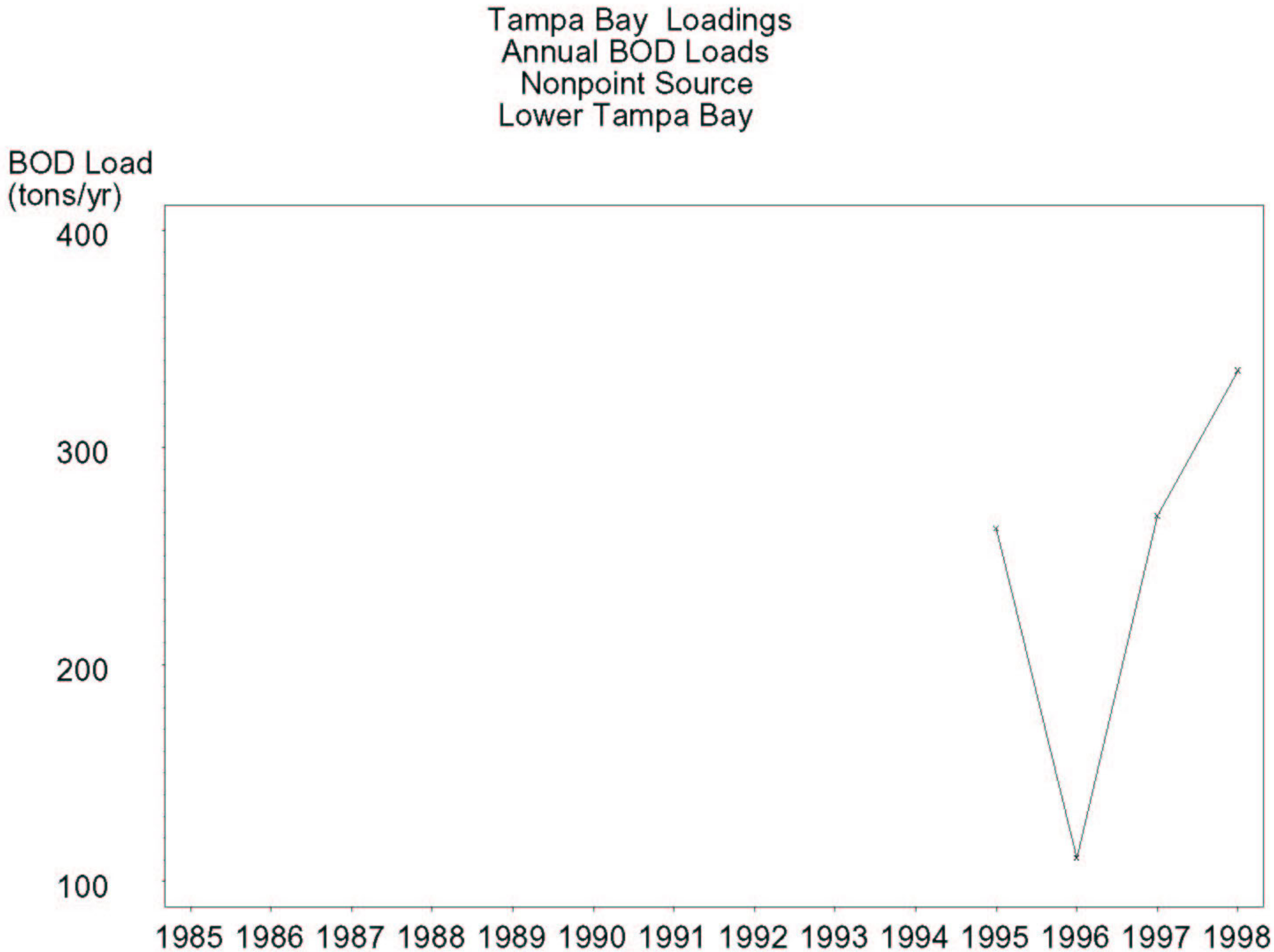
Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Terra Ceia Bay
TSS Load
(tons/yr)
600
500
400
300
200
100
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

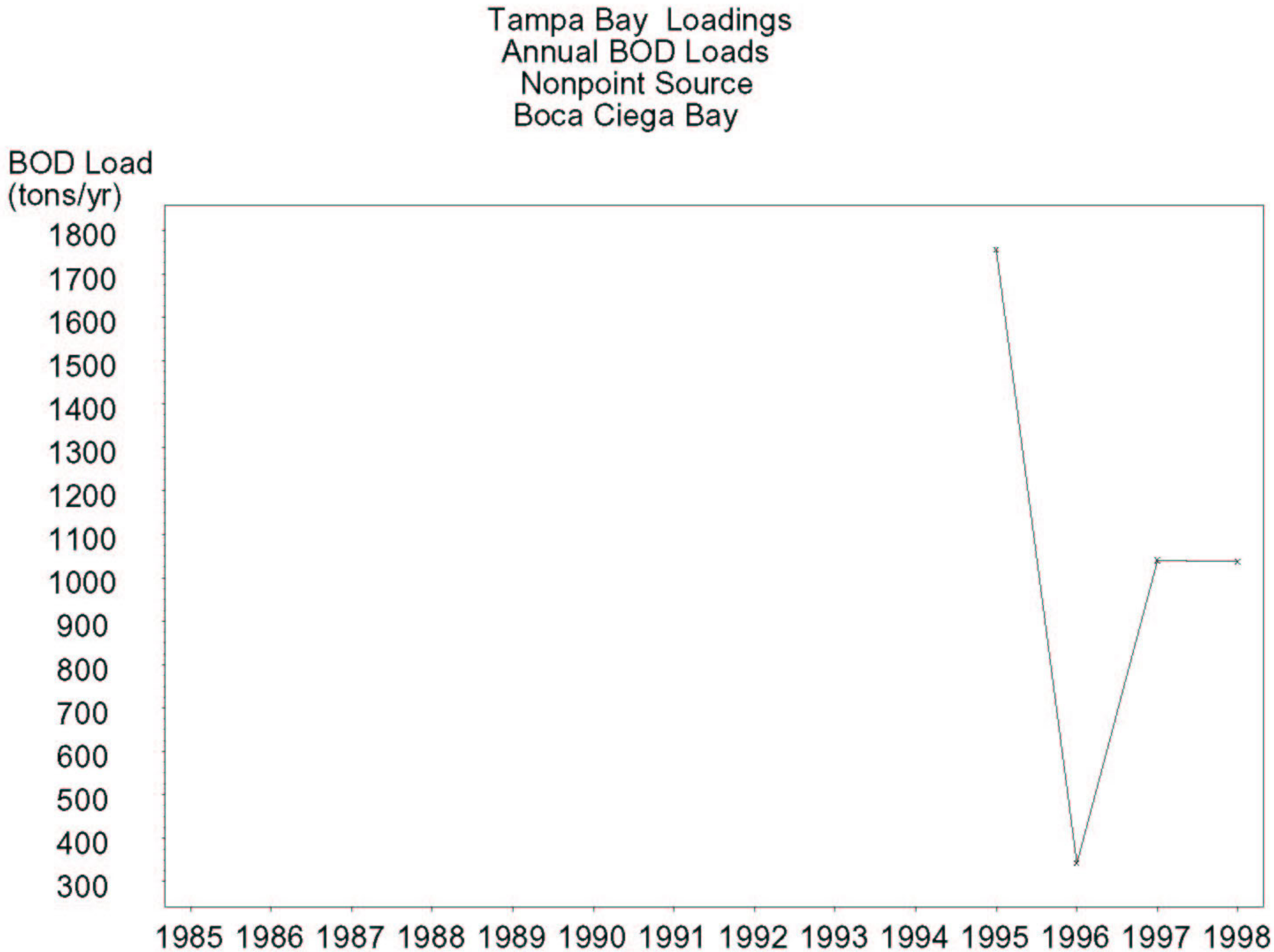

Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Manatee River
TSS Load
(tons/yr)
9000
8000
7000
6000
5000
4000
3000
2000
1000
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

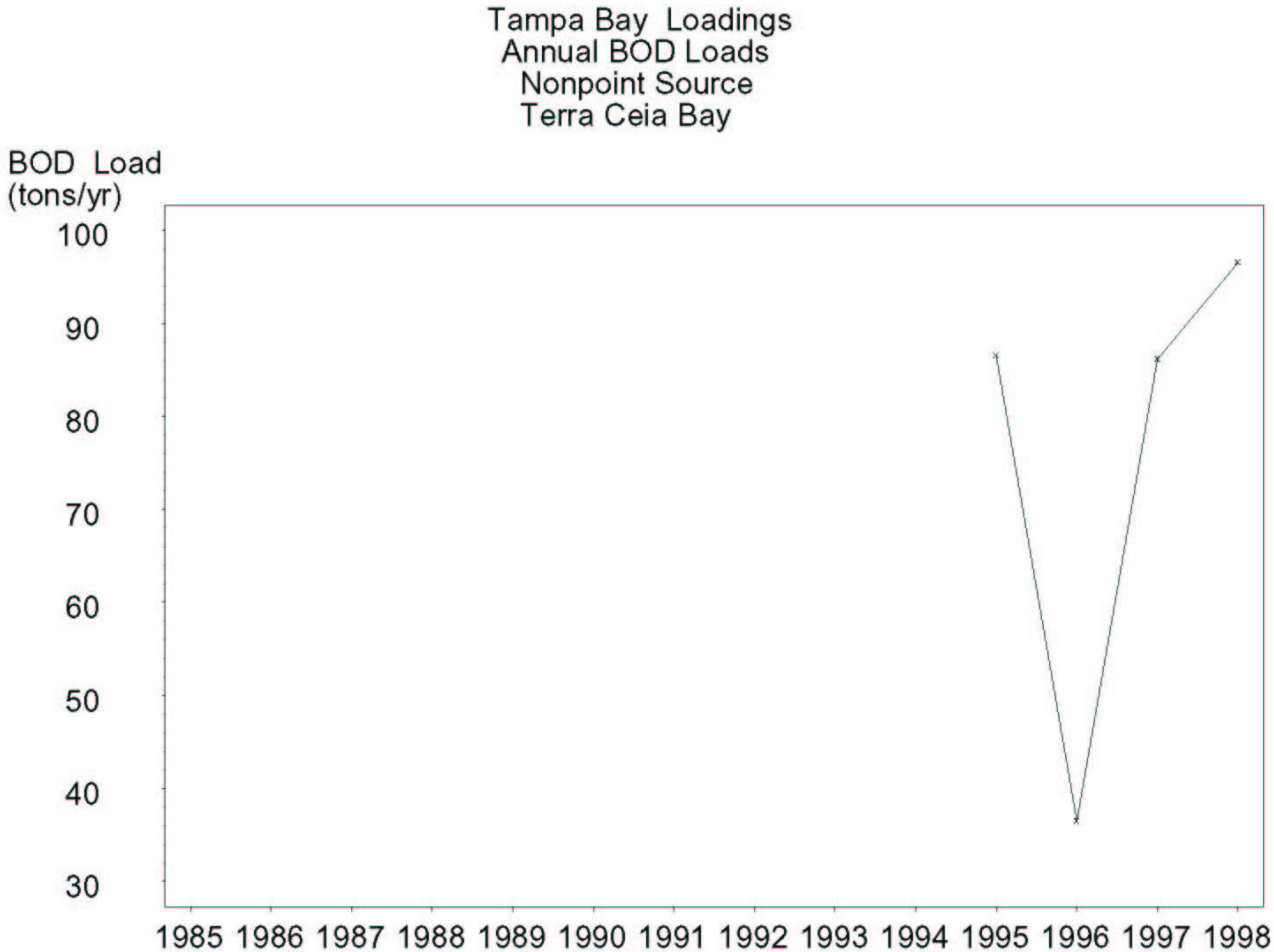
Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Old Tampa Bay
BOD Load
(tons/yr)
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

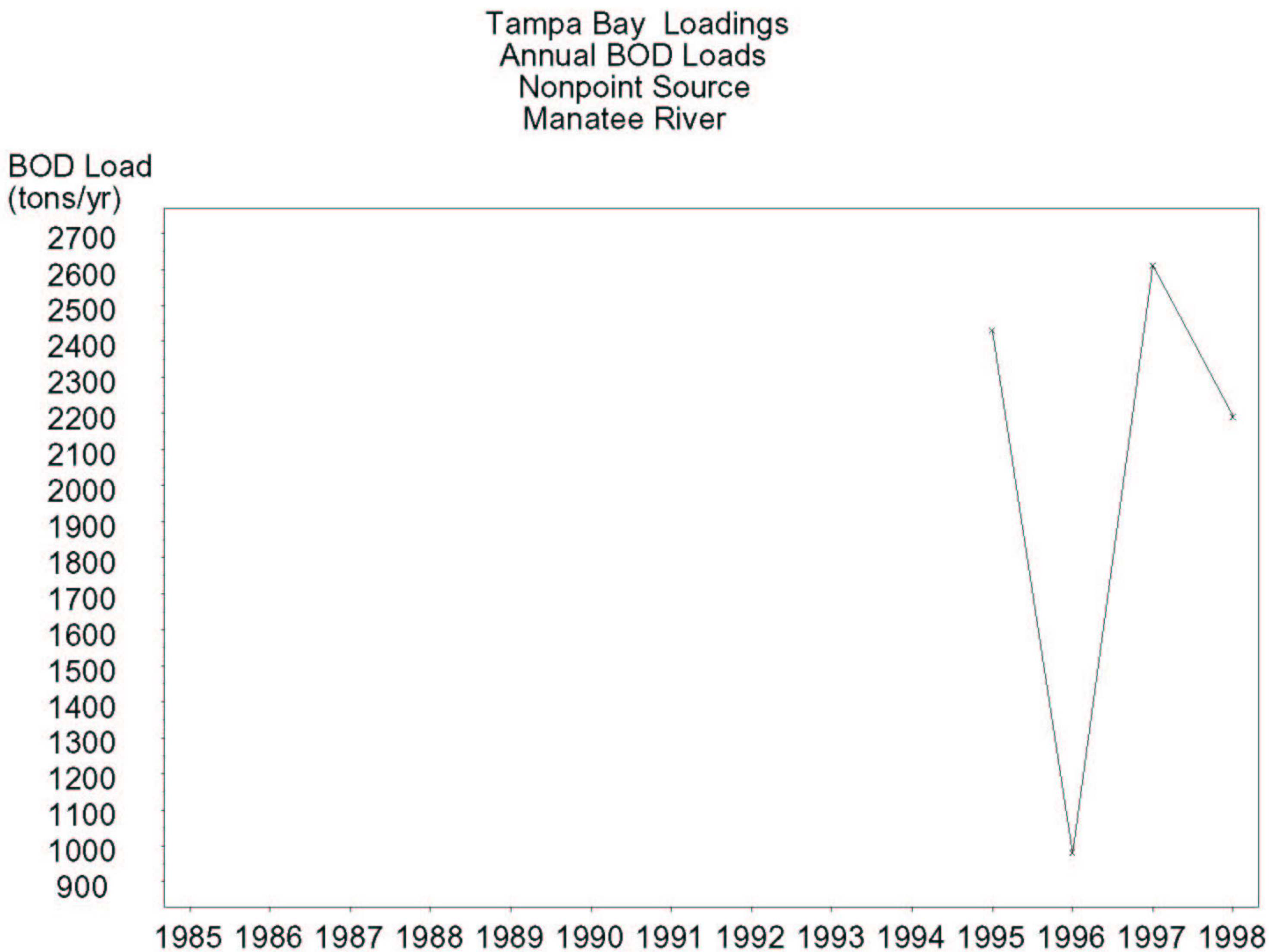

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Hillsborough Bay
BOD Load
(tons/yr)
5000
4000
3000
2000
1000
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

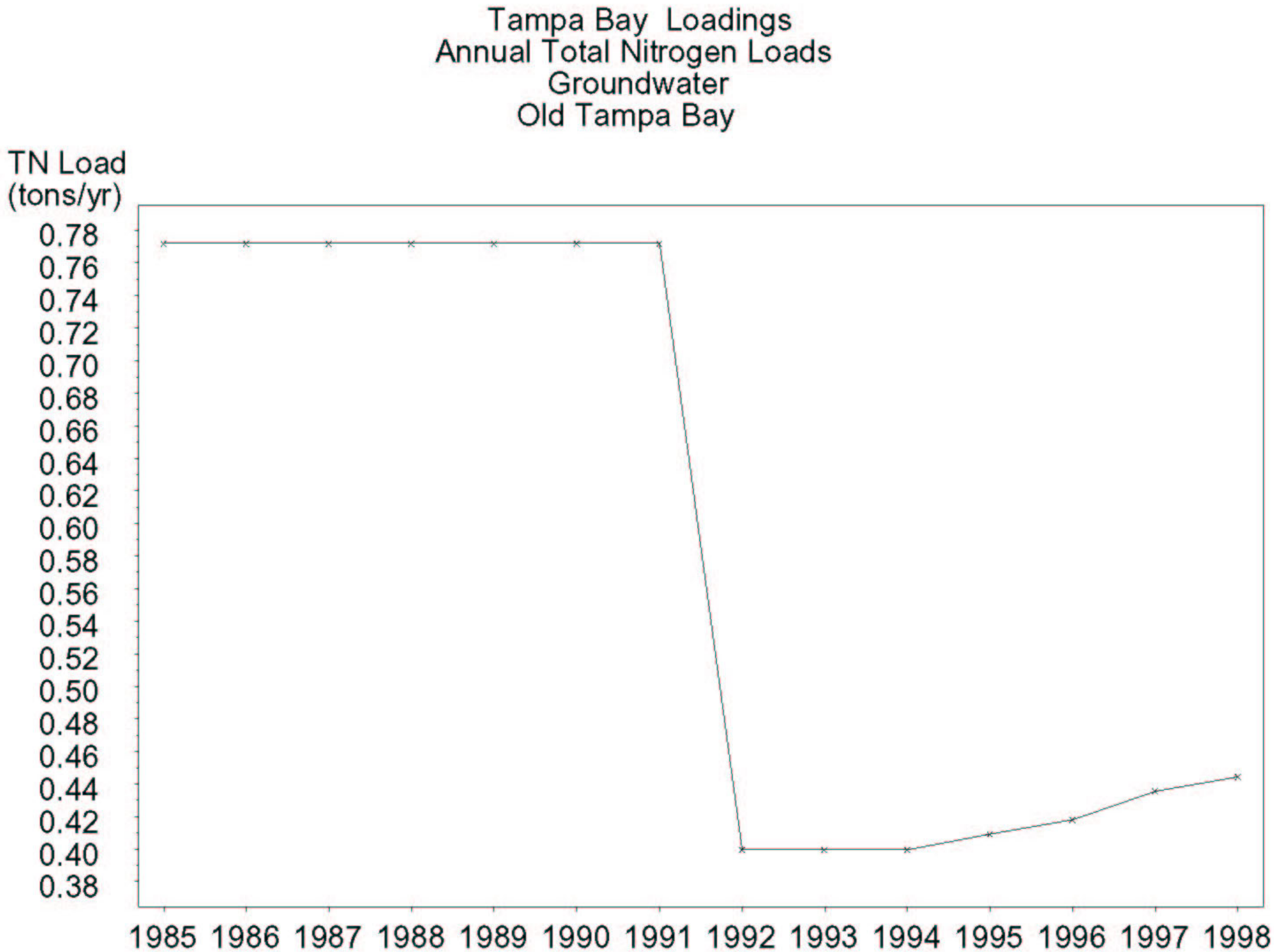

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Middle Tampa Bay
BOD Load
(tons/yr)
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

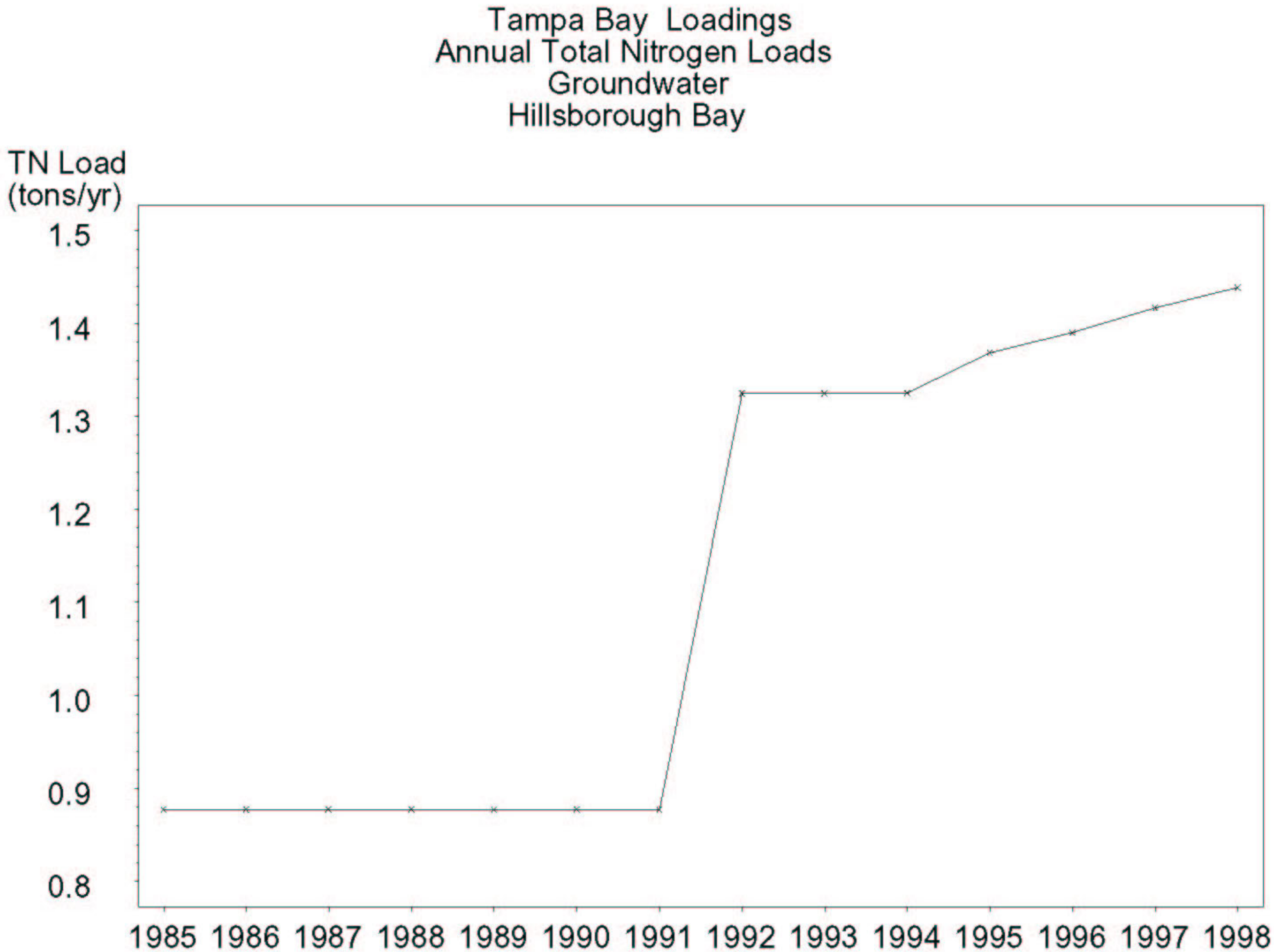

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Lower Tampa Bay
BOD Load
(tons/yr)
400
300
200
100
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Boca Ciega Bay
BOD Load
(tons/yr)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

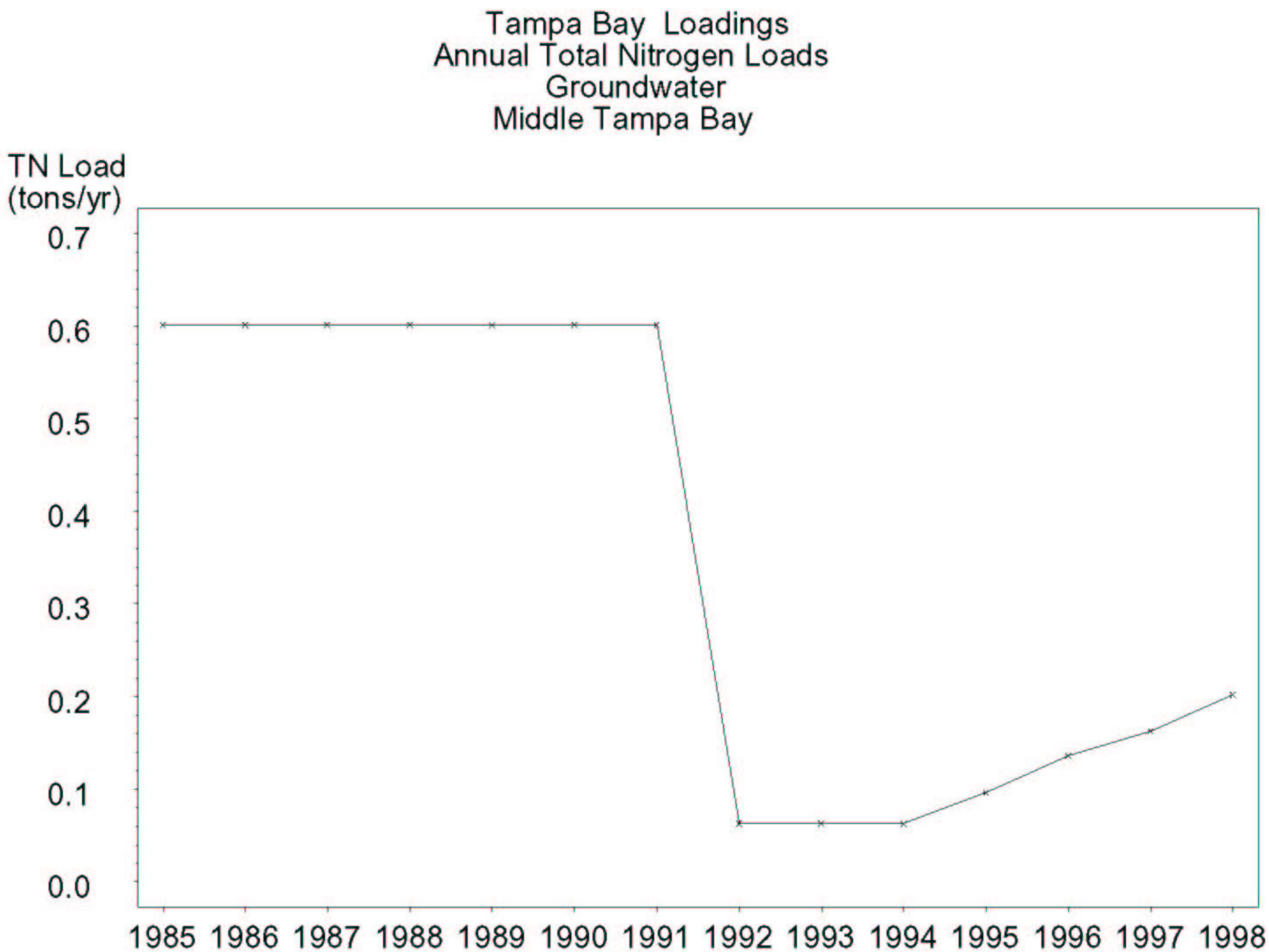

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Terra Ceia Bay
BOD Load
(tons/yr)
100
90
80
70
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

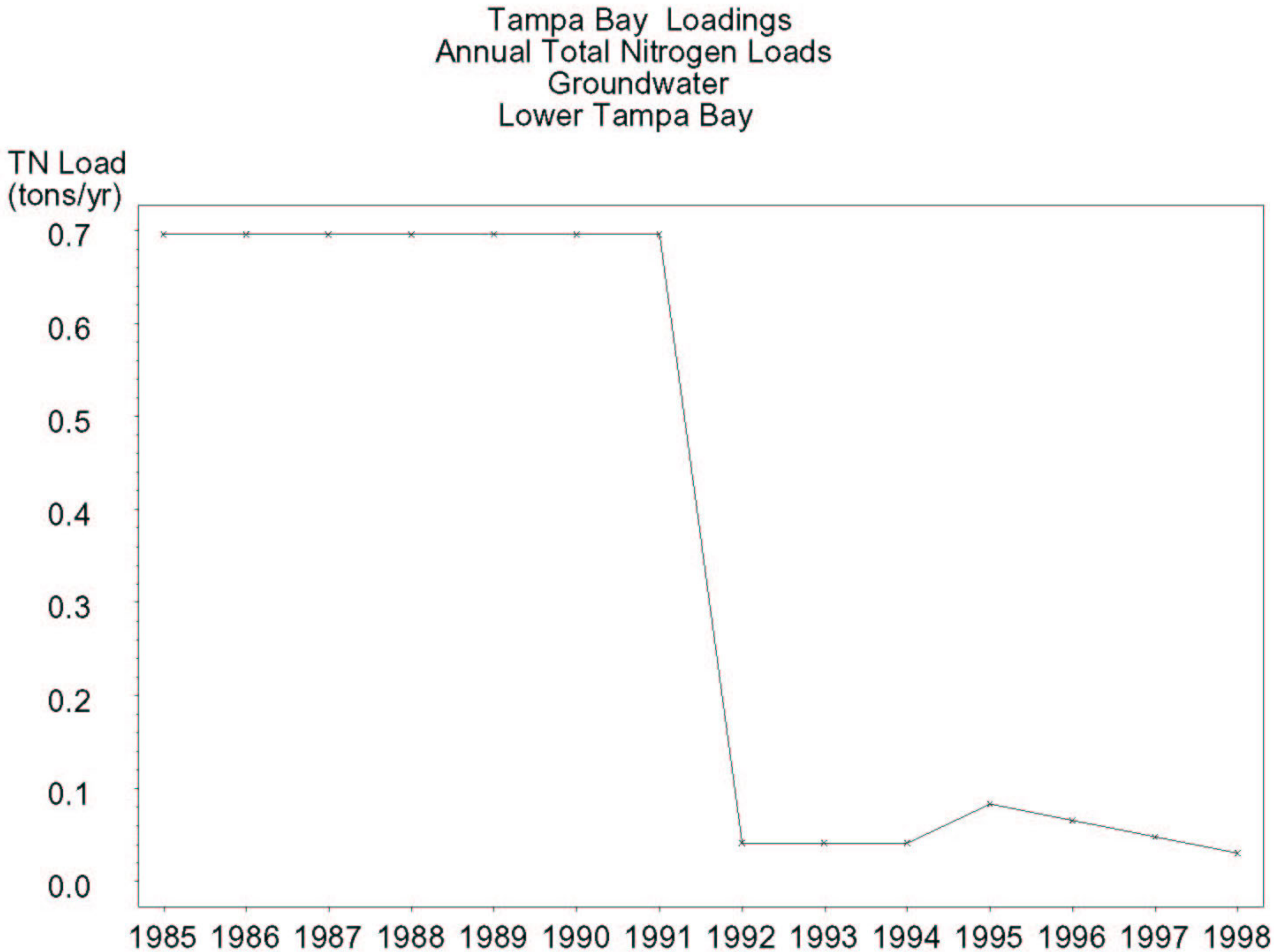

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Manatee River
BOD Load
(tons/yr)
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Old Tampa Bay
TN Load
(tons/yr)
0.78
0.76
0.74
0.72
0.70
0.68
0.66
0.64
0.62
0.60
0.58
0.56
0.54
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0.38
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

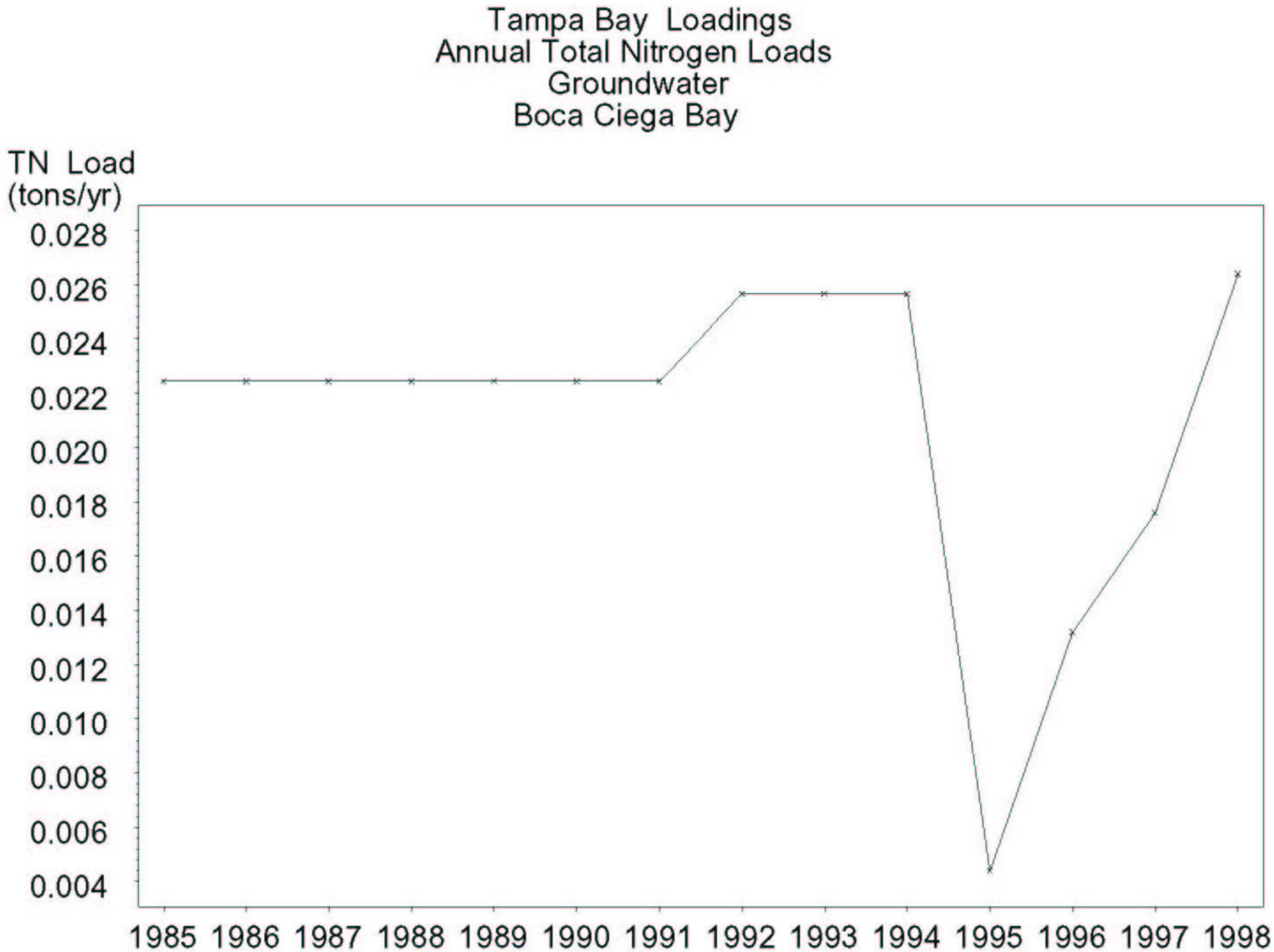


Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Hillsborough Bay
TN Load
(tons/yr)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

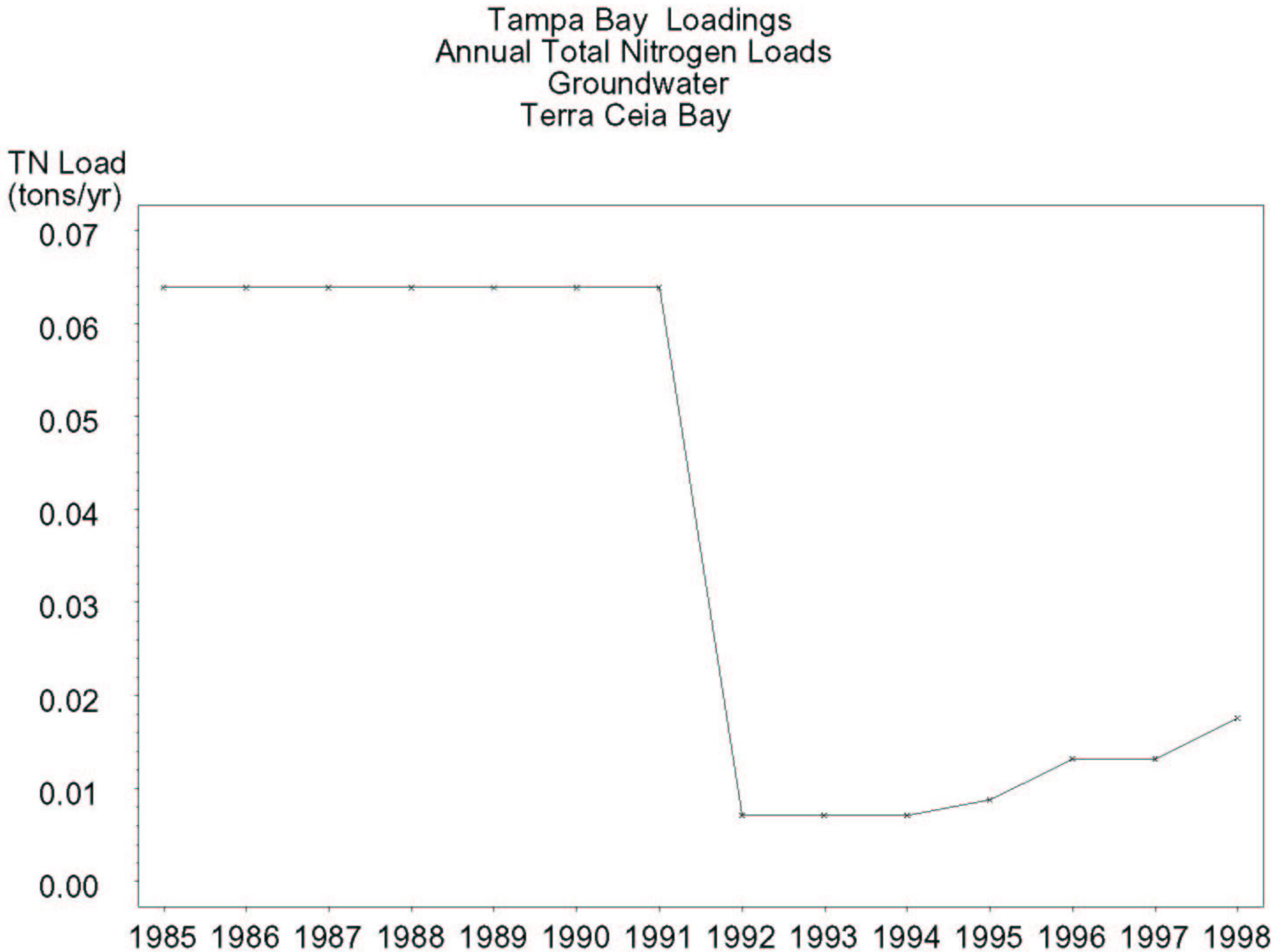

Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Middle Tampa Bay
TN Load
(tons/yr)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

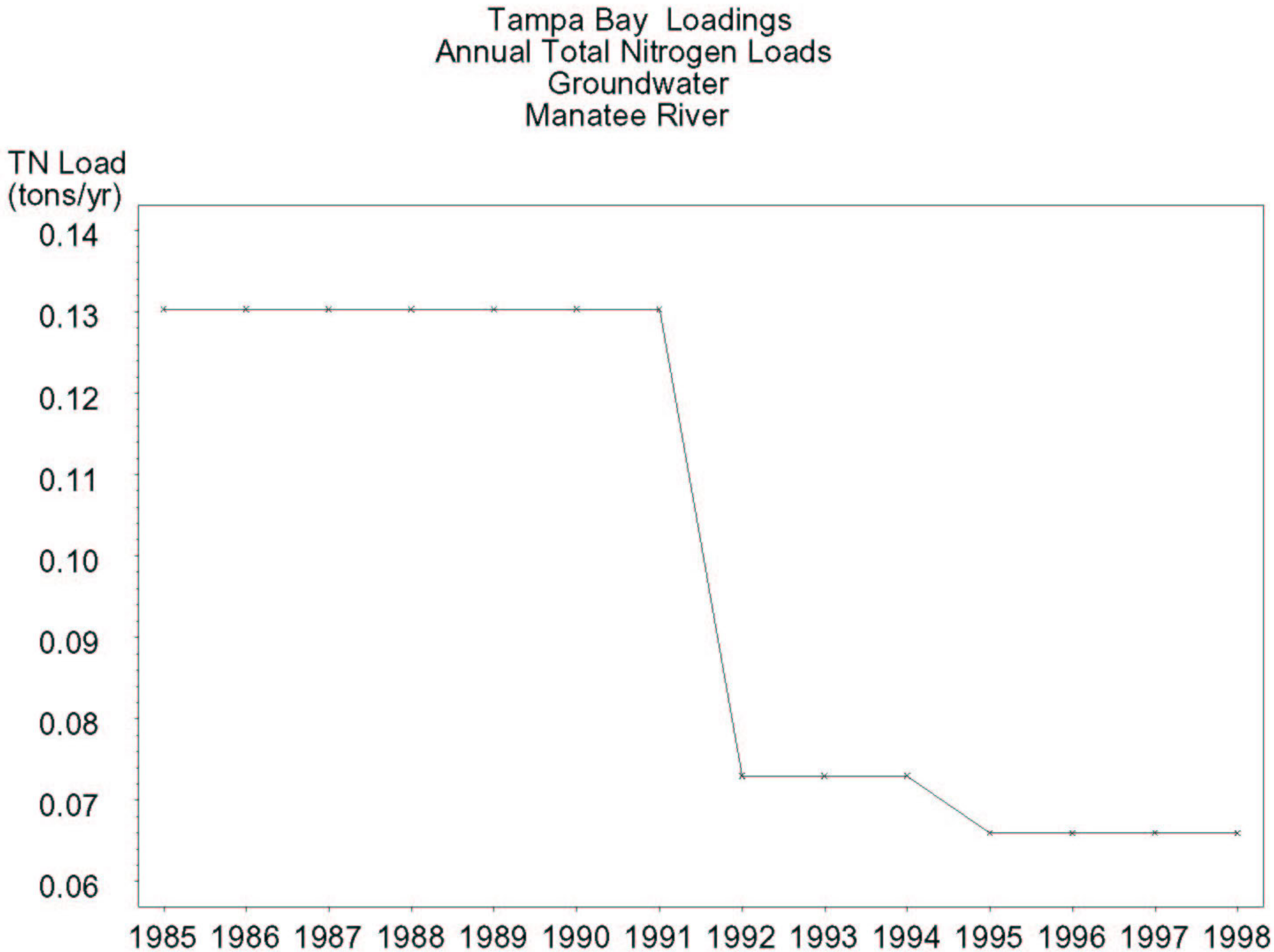


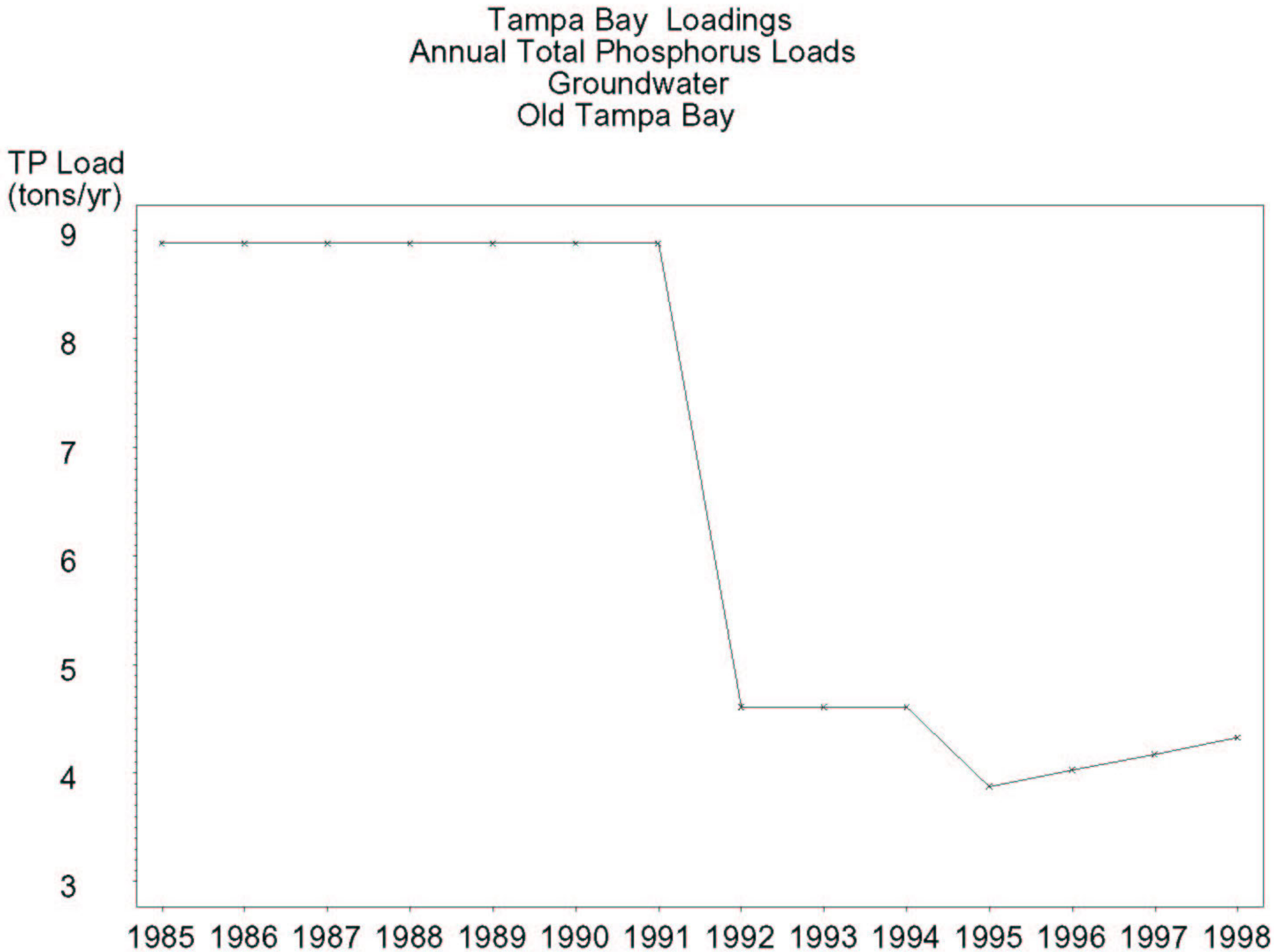
Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Lower Tampa Bay
TN Load (tons/yr)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

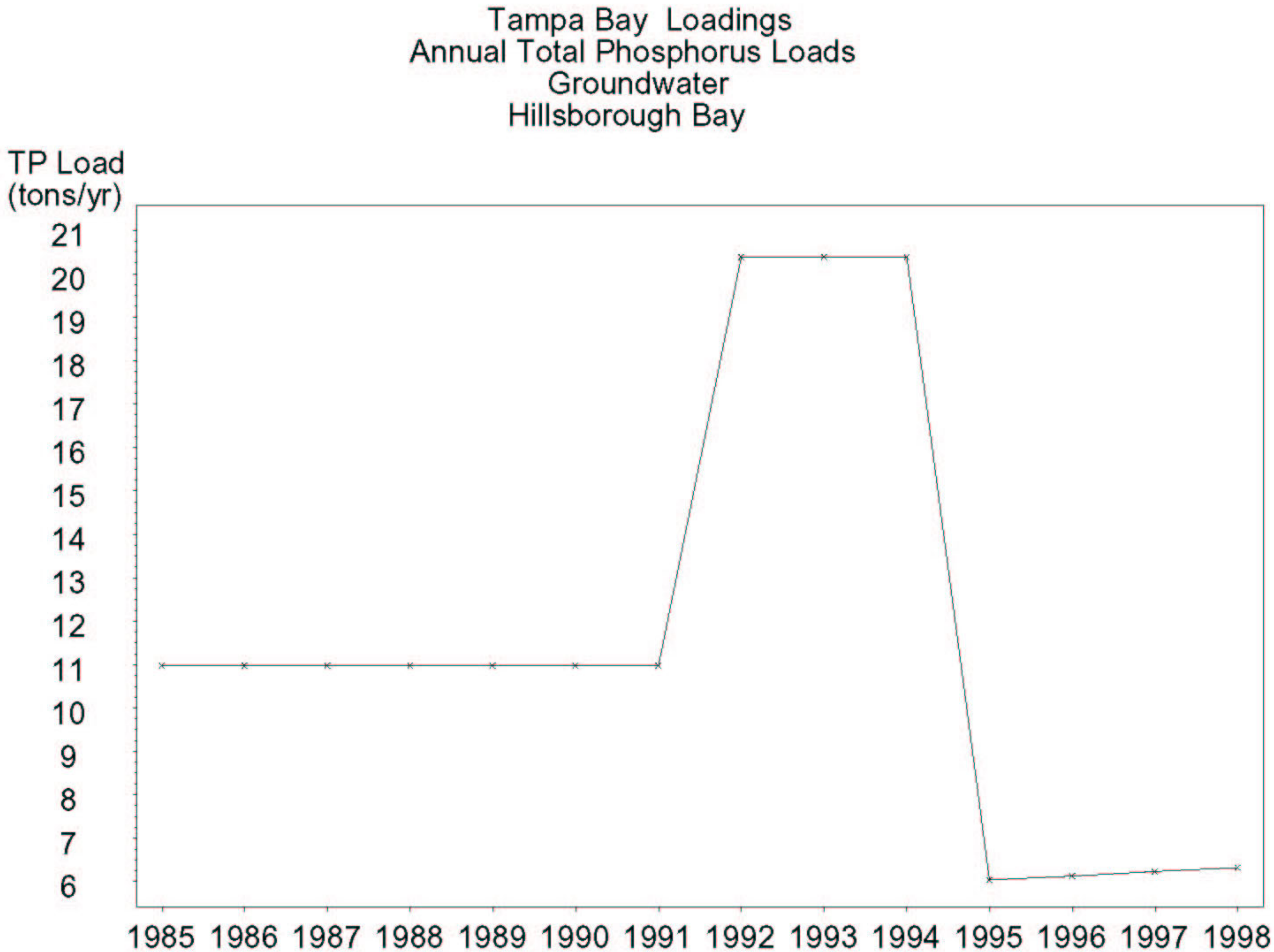


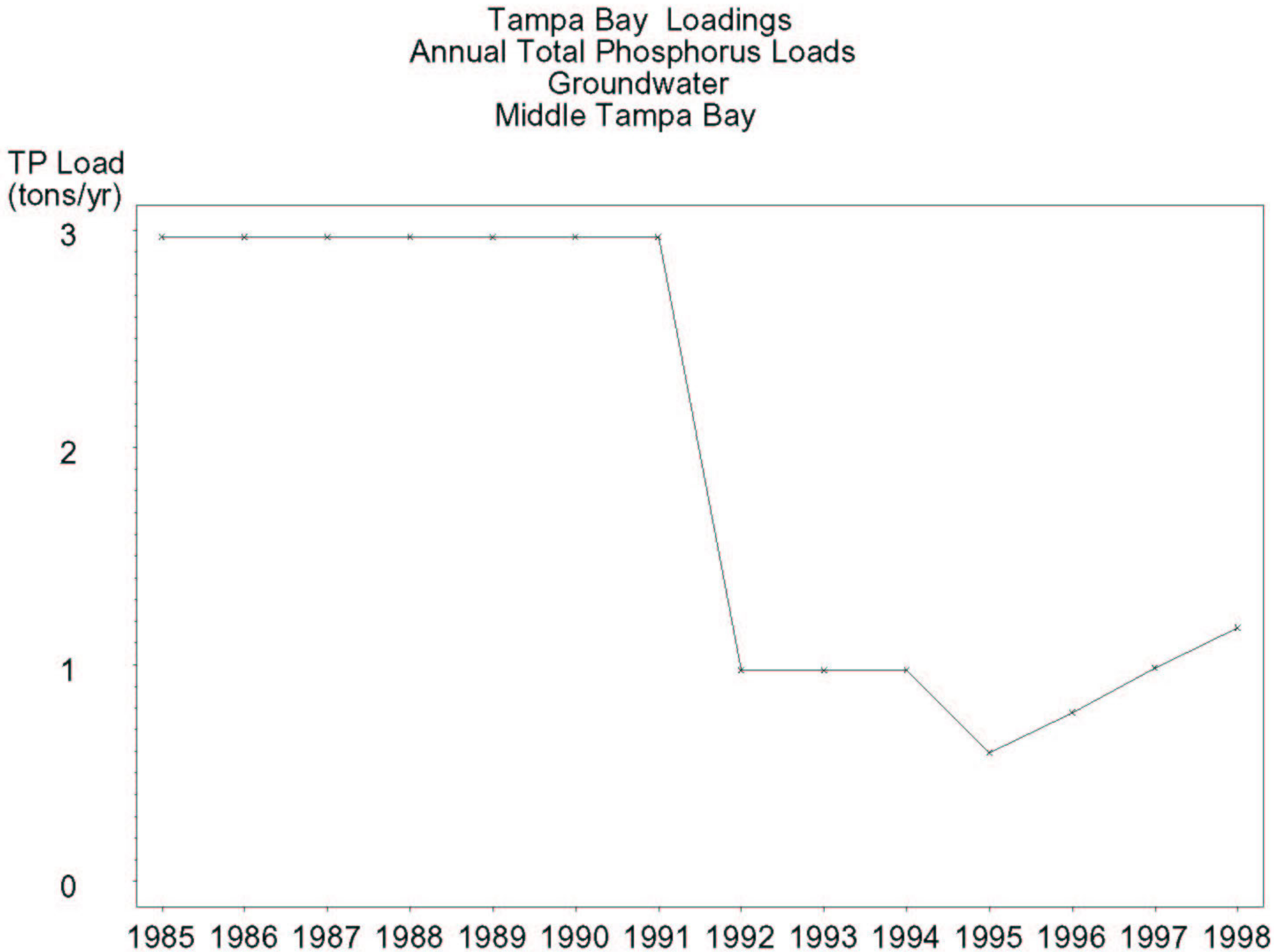
Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Boca Ciega Bay
TN Load
(tons/yr)
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Terra Ceia Bay
TN Load
(tons/yr)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

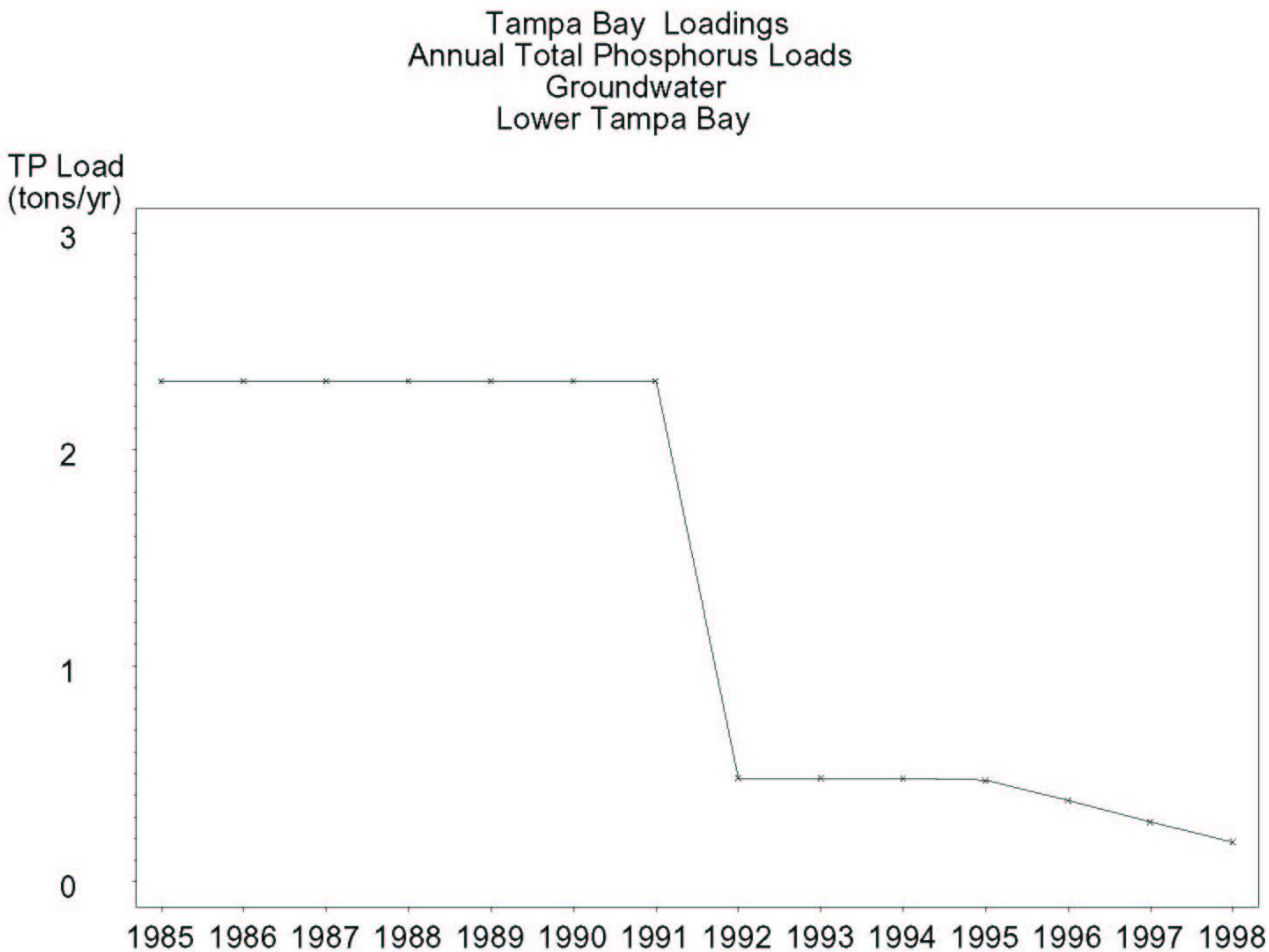

Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Manatee River
TN Load
(tons/yr)
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

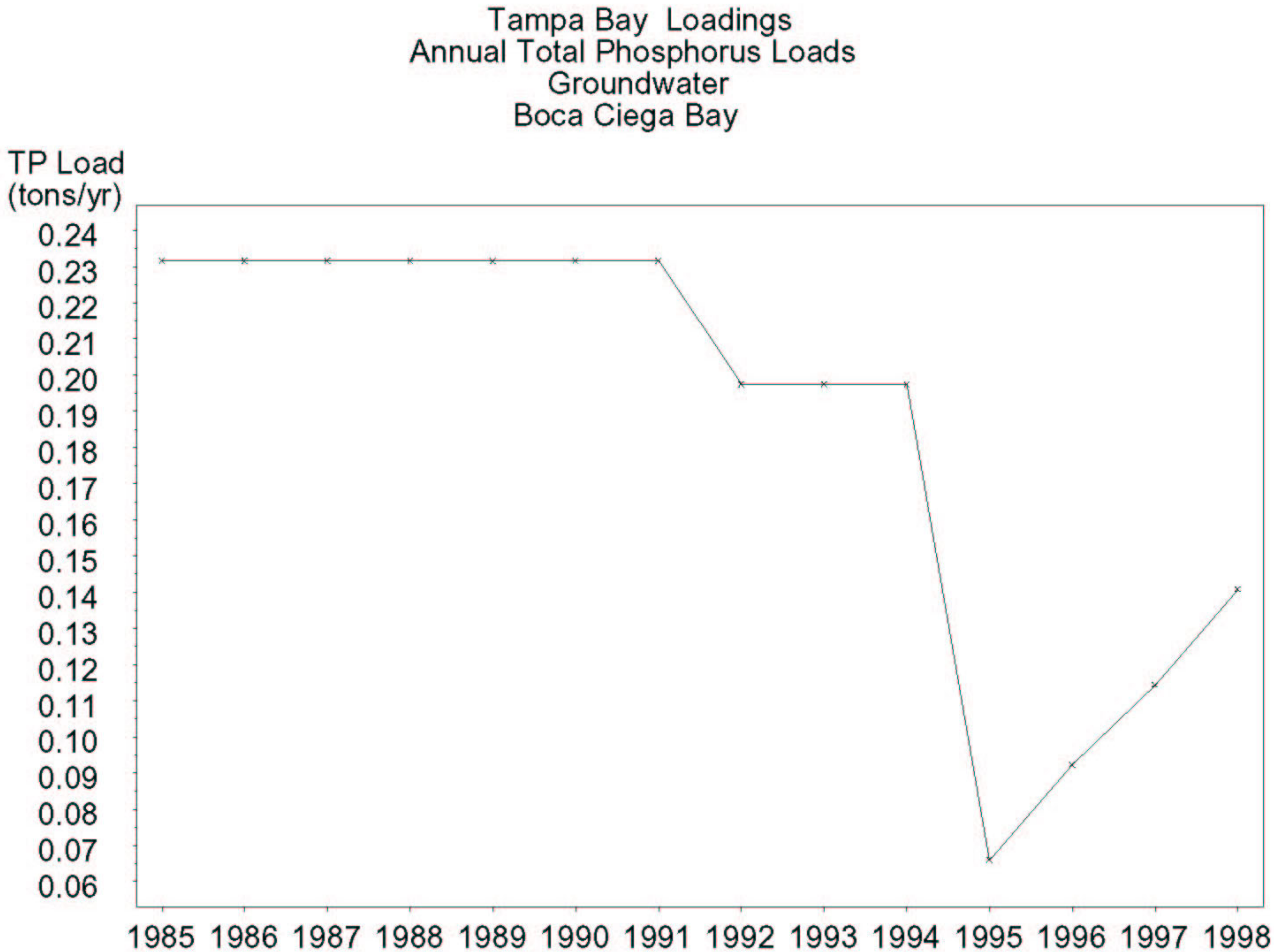

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Old Tampa Bay
TP Load
(tons/yr)
9
8
7
6
5
4
3
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

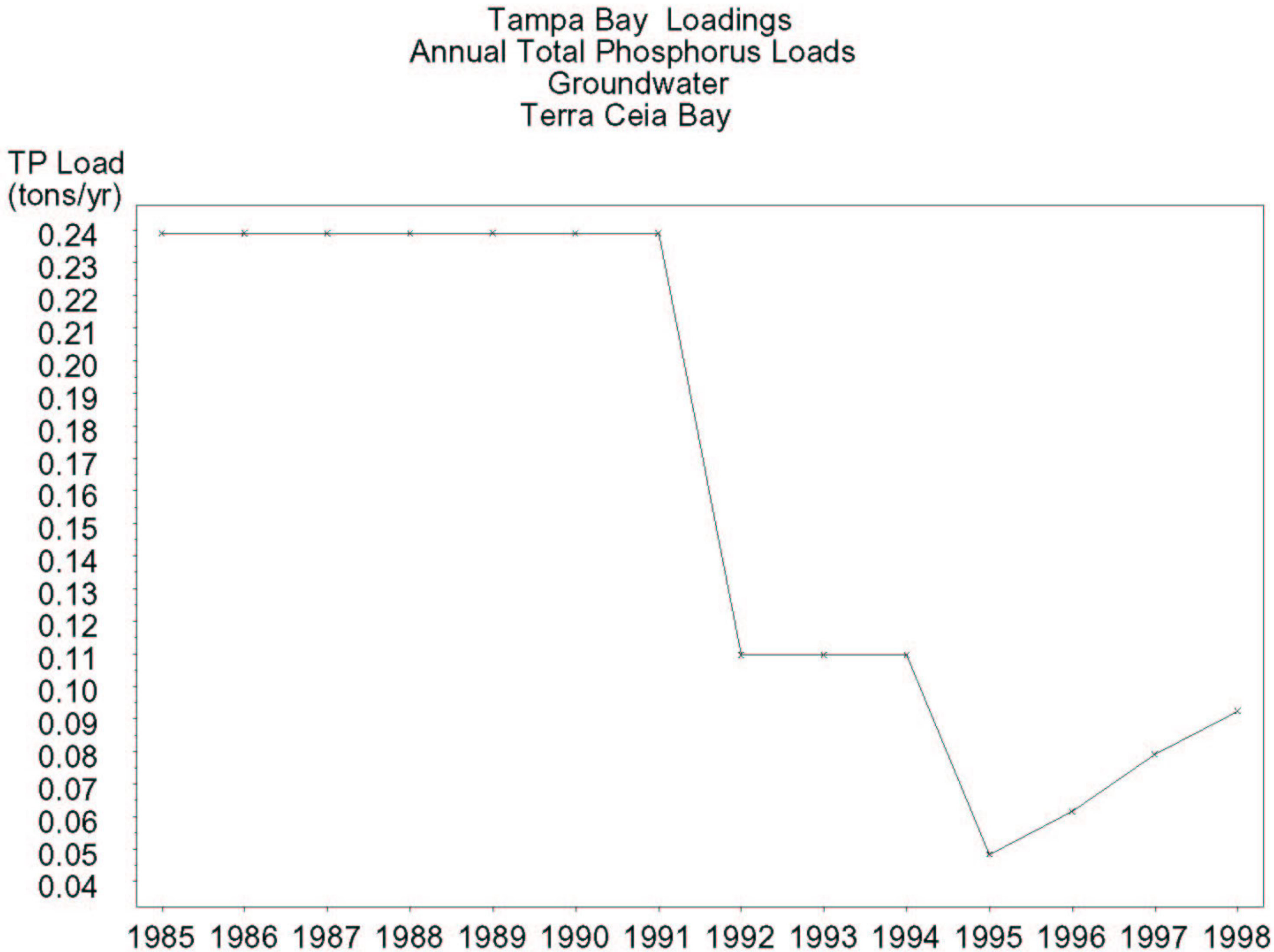

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Hillsborough Bay
TP Load (tons/yr)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Middle Tampa Bay
TP Load
(tons/yr)
3
2
1
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

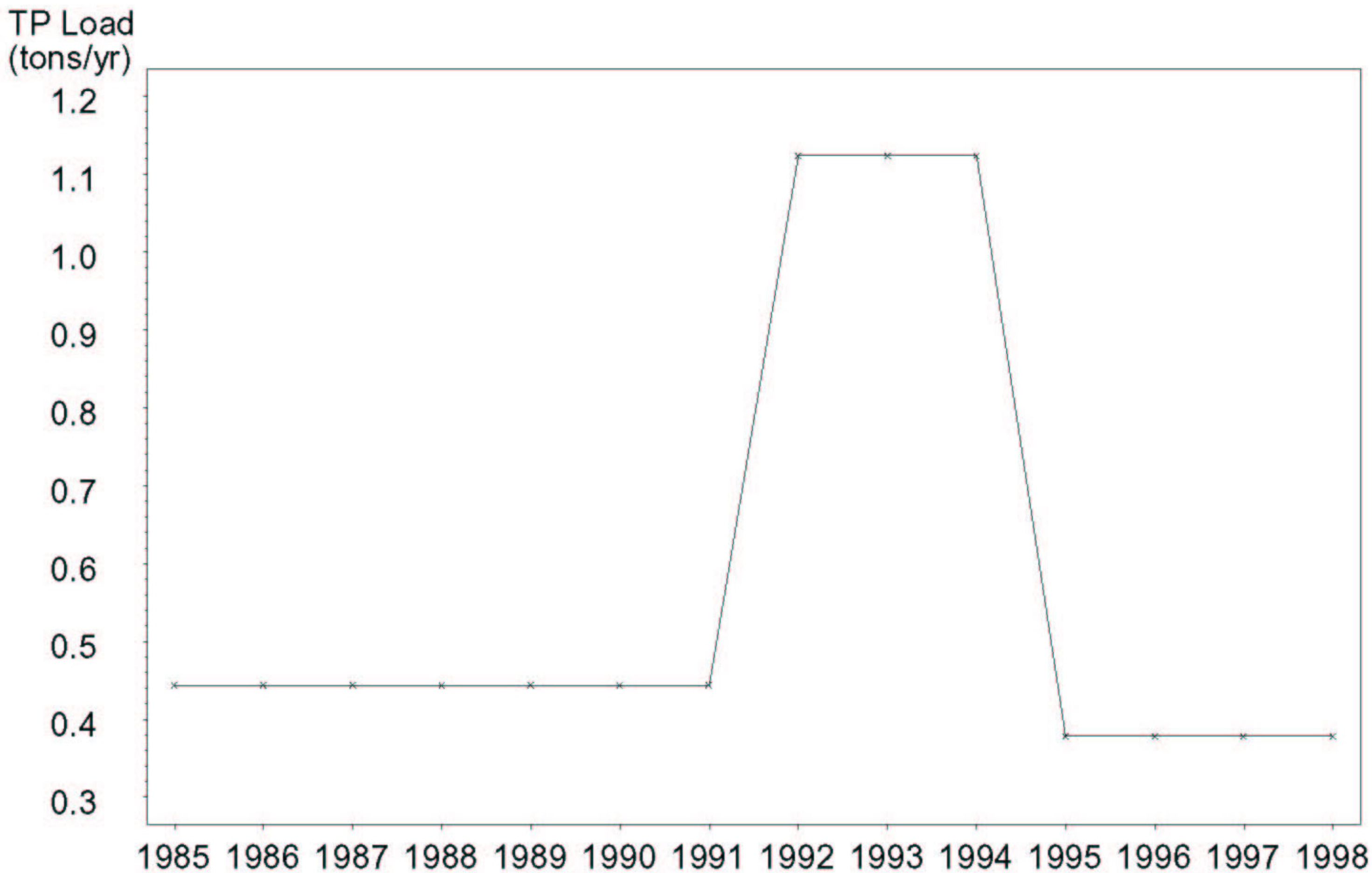

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Lower Tampa Bay
TP Load
(tons/yr)
3
2
1
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

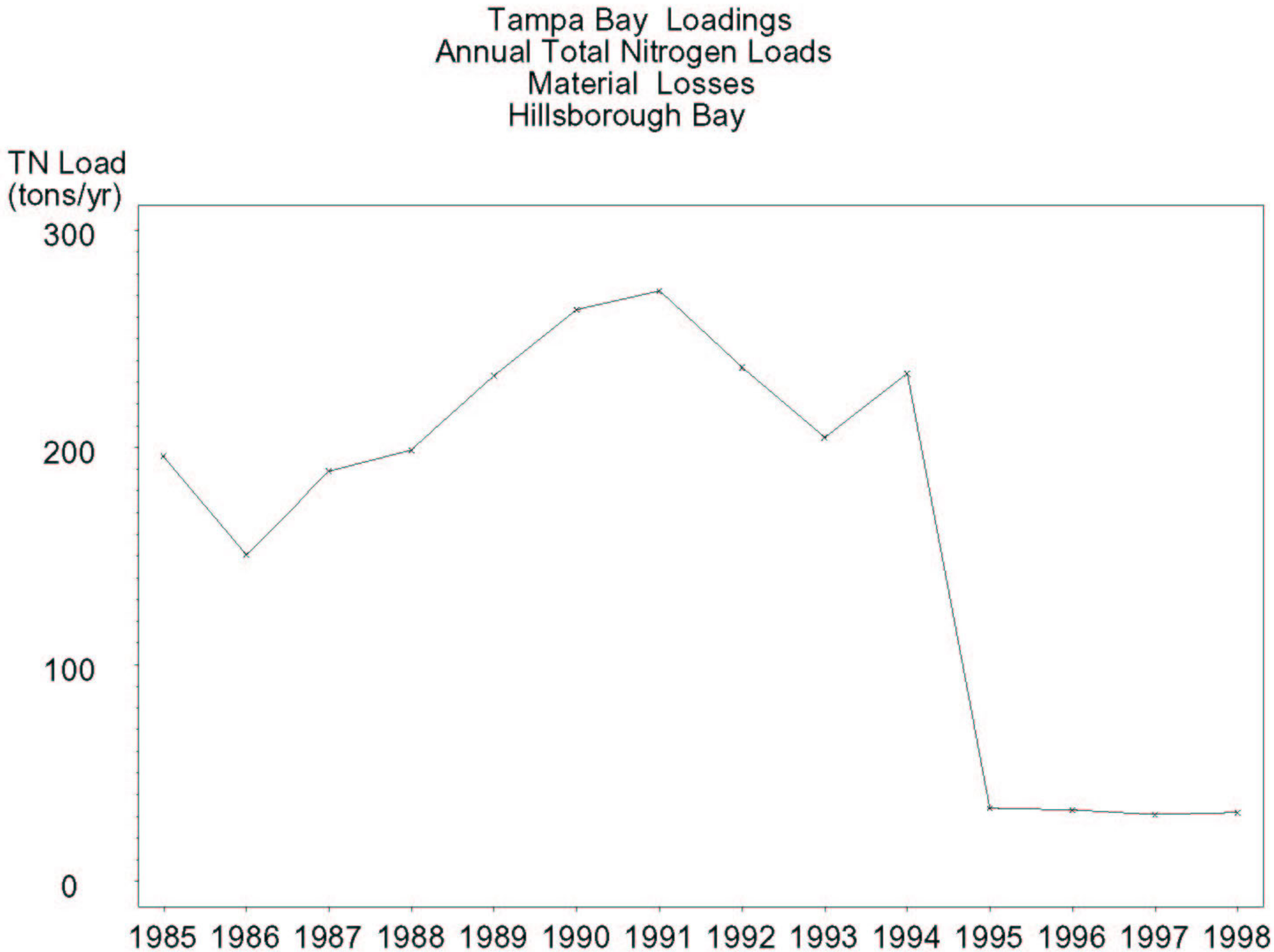

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Boca Ciega Bay
TP Load
(tons/yr)
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

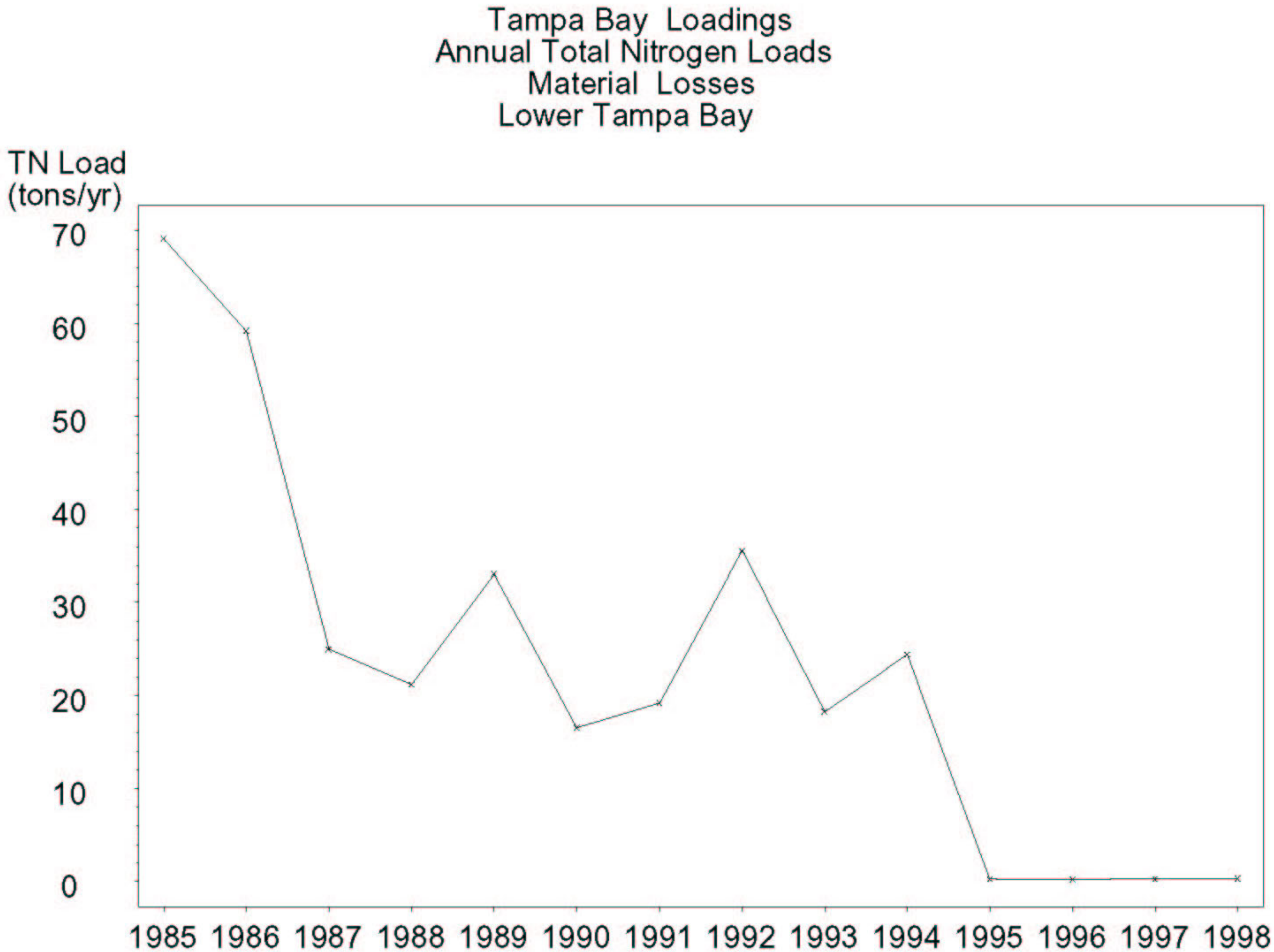


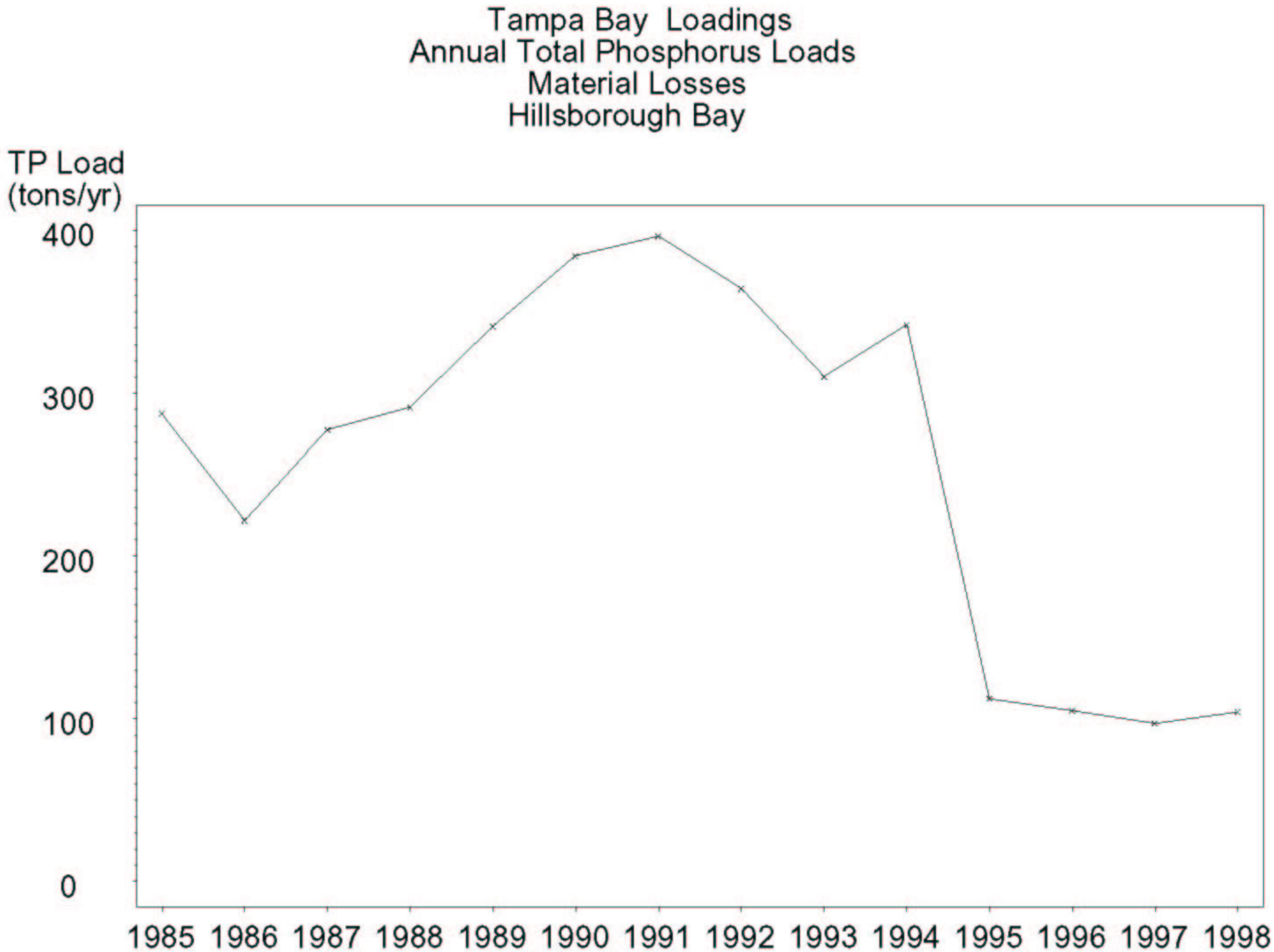
Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Terra Ceia Bay
TP Load
(tons/yr)
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Manatee River

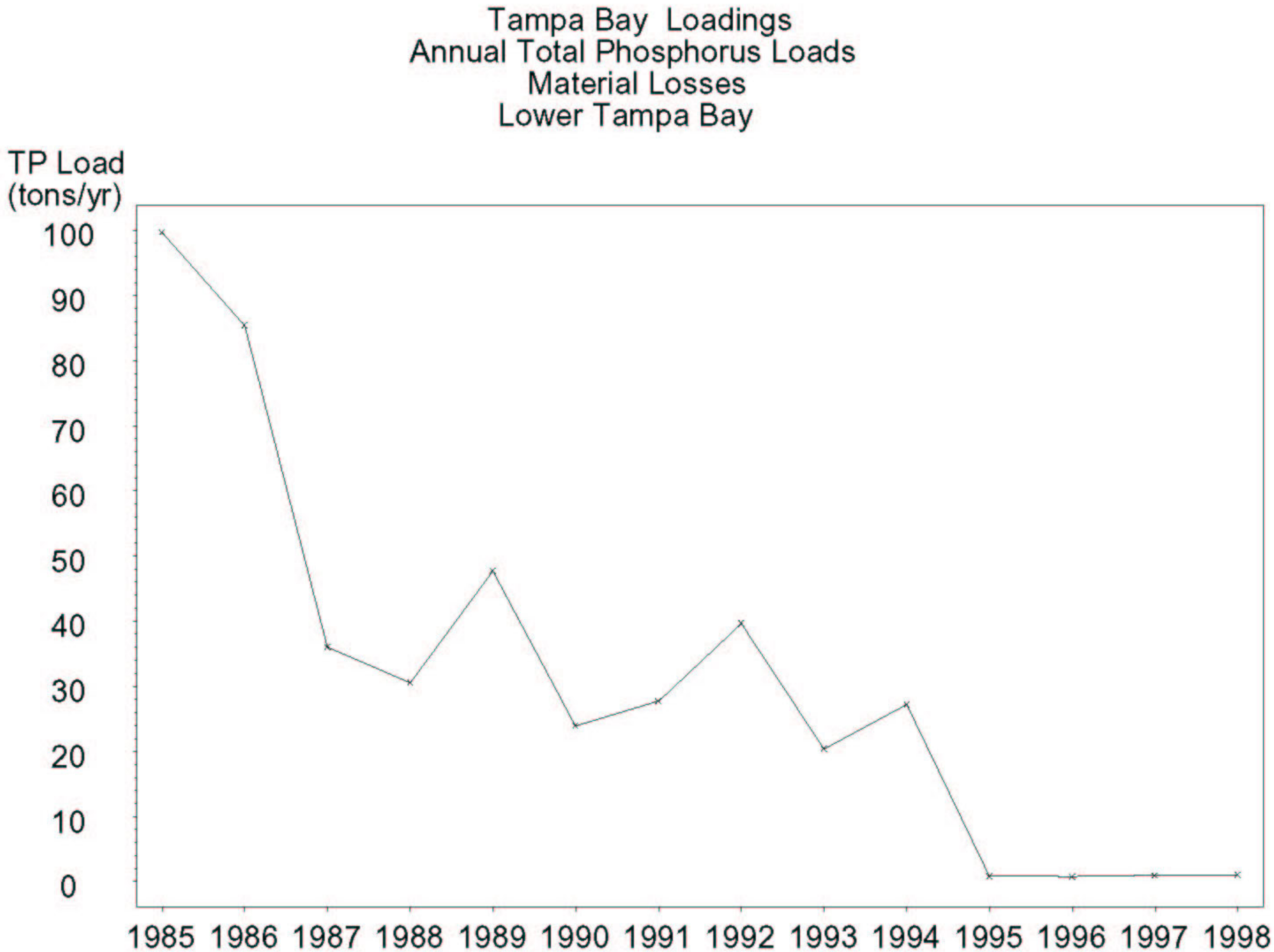


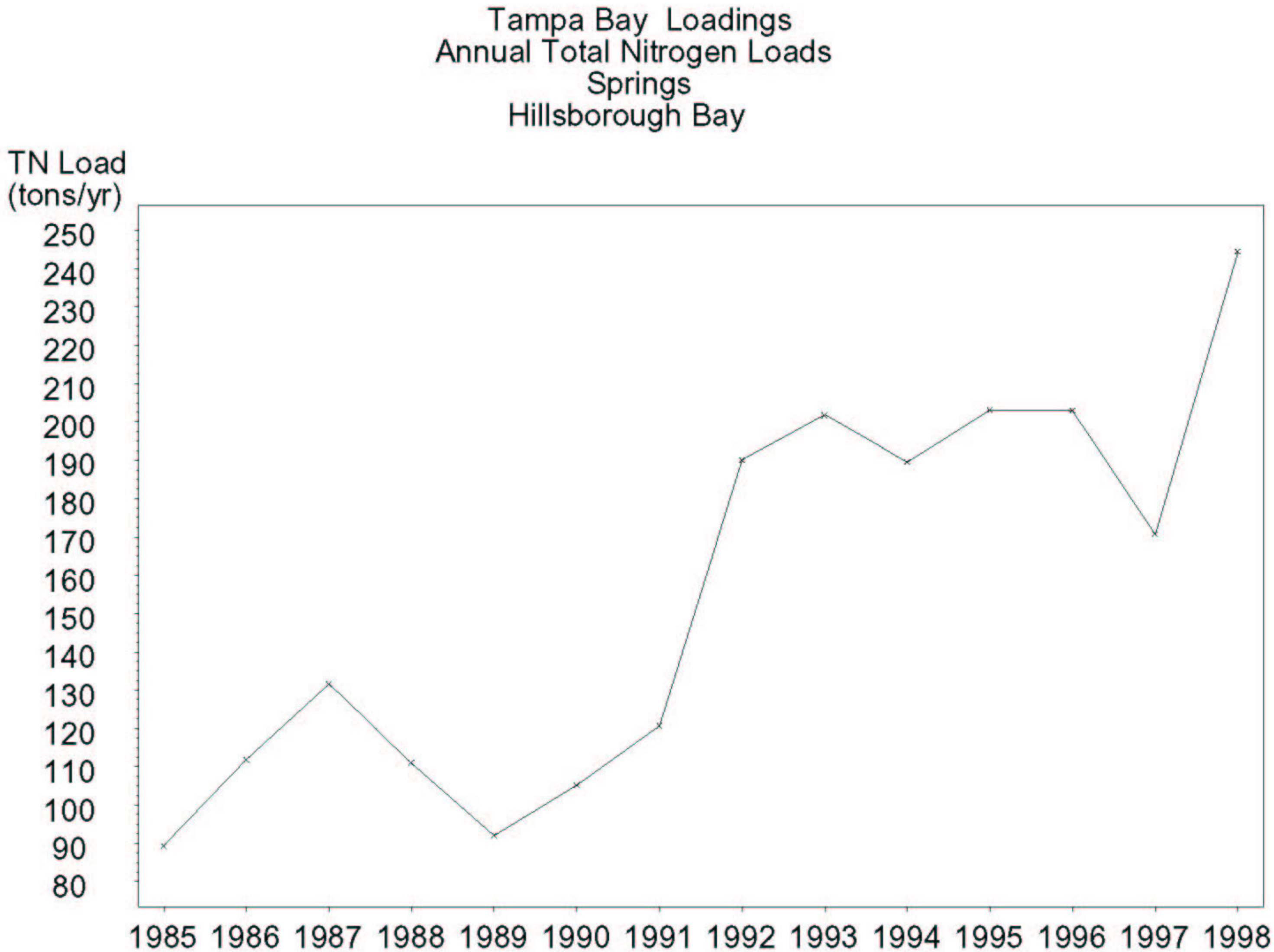

Tampa Bay Loadings
Annual Total Nitrogen Loads
Material Losses
Hillsborough Bay
TN Load
(tons/yr)
300
200
100
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

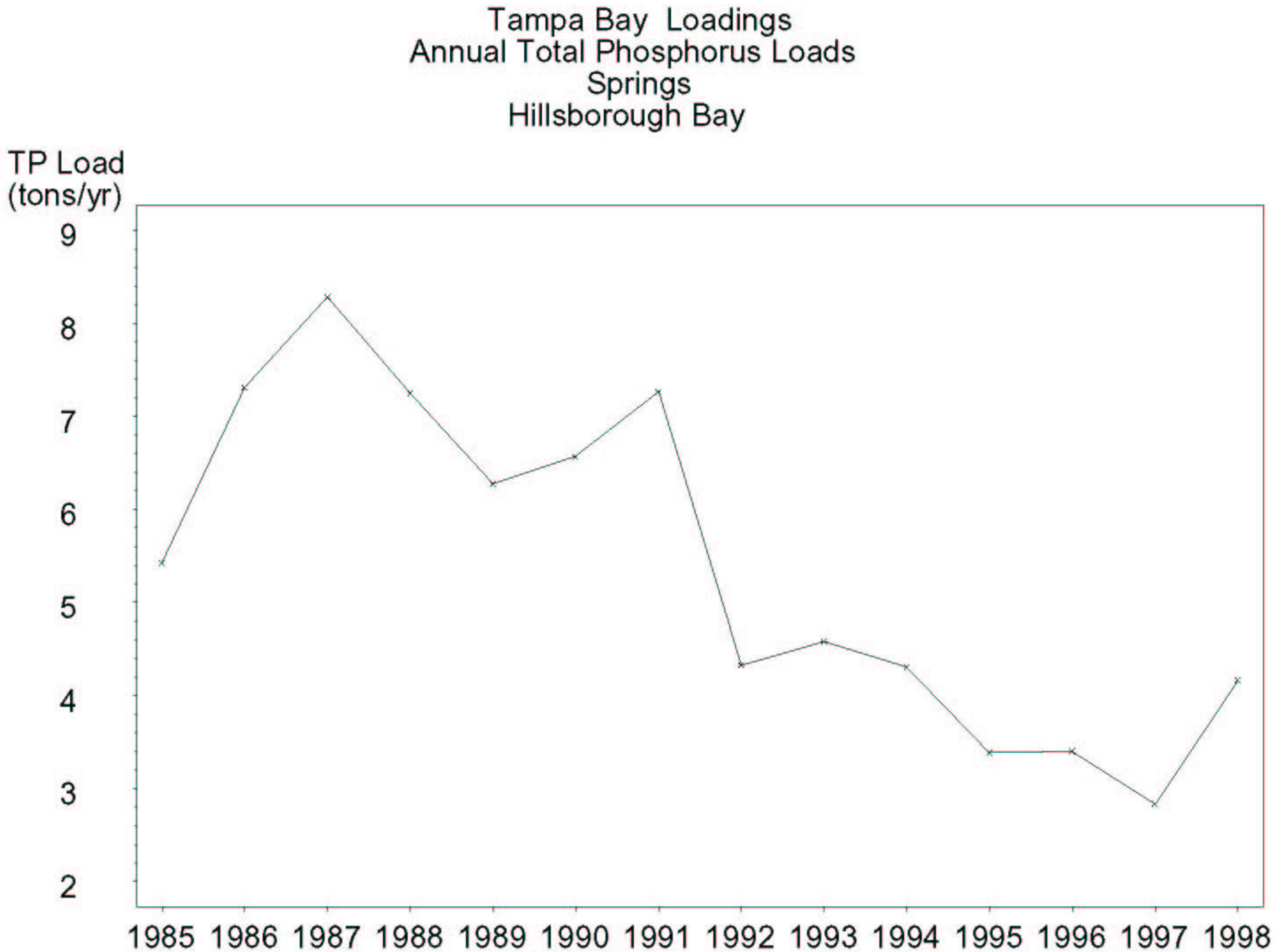

Tampa Bay Loadings
Annual Total Nitrogen Loads
Material Losses
Lower Tampa Bay
TN Load
(tons/yr)
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998



Tampa Bay Loadings
Annual Total Phosphorus Loads
Material Losses
Hillsborough Bay
TP Load
(tons/yr)
400
300
200
100
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Material Losses
Lower Tampa Bay
TP Load
(tons/yr)
100
90
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Nitrogen Loads
Springs
Hillsborough Bay
TN Load
(tons/yr)
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998


Tampa Bay Loadings
Annual Total Phosphorus Loads
Springs
Hillsborough Bay
TP Load
(tons/yr)
9
8
7
6
5
4
3
2
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

APPENDIX G

Comparisons of Mean Annual TN Loadings by Source
for 1992-1994 and 1995-1998,
and
Comparison of Annual TN, TP, and TSS Loadings
for 1995-1998 to Mean Annual 1992-1994 Loadings

Table G-1. Best estimate mean annual total nitrogen loadings to Tampa Bay for 1995-1998 (tons/year).							
	Loading Sources						
Bay Segment	**Nonpoint Source**	**Domestic Point Source**	**Industrial Point Source**	**Atmospheric Deposition**	**Groundwater and Springs**	**Material Losses**	**Total**
Old Tampa Bay	340	87	4	245* 279**	<1	0	674
Hillsborough Bay	1422	270	120	113* 129**	207	32	2,164
Middle Tampa Bay	466	26	35	310* 355**	<1	0	837
Lower Tampa Bay	57	1	35	267* 305**	<1	<1	360
Boca Ciega Bay	179	16	0	97* 111**	<1	0	292
Terra Ceia Bay	16	5	0	18* 20**	<1	0	39
Manatee River	680	23	14	45* 51**	<1	0	762
Total	3,161	427	208	1,094* 1,250**	207	33	5,130*

* Atmospheric deposition using TBADS data, dry:wet ratio derived from TBADS data.

** Atmospheric deposition using 1985-1994 method: Verna Wellfield wet TN concentrations, dry:wet ratio of 2.04:1.

Table G-2. Best estimate mean annual total nitrogen loadings to Tampa Bay for 1992-1994 (tons/year) (after Zarbock et al., 1996).

Bay Segment	Loading Sources						
	Nonpoint Source	Domestic Point Source	Industrial Point Source	Atmospheric Deposition	Groundwater and Springs	Material Losses	Total
Old Tampa Bay	174	85	0	227	<1	0	486
Hillsborough Bay	596	220	80	115	206	233	1,451
Middle Tampa Bay	415	20	58	306	<1	0	799
Lower Tampa Bay	36	1	<1	288	<1	24	349
Boca Ciega Bay	69	15	0	93	<1	0	177
Terra Ceia Bay	11	4	0	20	<1	0	35
Manatee River	422	16	11	54	<1	0	503
Total	1,723	361	149	1,103	206	257	3,800