Nitrogen Loading (SOOE Extended)

Please note that this section contains both "Methods and Data Sources" as well as "Additional Discussion" and over 15 additional tables and figures.

Methods and Data Sources

Nitrogen loads were estimated based on monthly wastewater treatment facility discharge and concentration data, monthly tributary concentration data, weekly nitrogen deposition in precipitation, and daily streamflow (using Loadest[30]). The methods used to estimate 2017-2020 nitrogen loads and a further breakdown of the point and non-point source loads are described below. For the purposes of this analysis, the following sources were identified that contribute to the nitrogen (N) load to the Great Bay Estuary (Figure 7.4; Figures 7.1 through 7.3 can be found in the State of Our Estuaries Report). It is assumed that these represent a complete accounting of contributing sources.

- Point Source (PS) N Loads from Wastewater Treatment Facilities (WWTFs)
- Non-Point Sources (NPS) N Loads from Major Tributary Watersheds
- NPS N Loads from Drainage Areas Adjacent to the Estuary
- Groundwater Discharge of N to the Estuary
- Atmospheric Deposition of N to the Estuary

Nitrogen loads were calculated for the portion of the Great Bay Estuary system north and west of Dover Point (Great Bay, Little Bay, and the Upper Piscataqua River – the "study area"; estuarine surface area of 13.4 square miles). A complete analysis of nitrogen loads to the Lower Piscataqua River was not completed, although the delivered loads from WWTFs in the Lower Piscataqua River were included in the calculations. The methods for the nitrogen loading calculations follow the procedures in NHDES (2010, Appendix A). Brief summaries of the methods and any deviations from the procedures are described below. Load estimates from 2003-2016 are from previous reports (2003-2008 loads are from NHDES 2010; 2009-2011 loads are from PREP 2012; 2012-2016 loads are from PREP 2018).

Point Source Nitrogen Loads from WWTFs

The annual and overall average TN and DIN loads from each WWTF for 2017-2020 were estimated by multiplying the average monthly effluent concentration by the average monthly effluent flow over the time period of interest (Table 7.1; Figure 7.5a). Monthly average effluent flows from the WWTFs were obtained from the EPA's Enforcement and Compliance History Online (ECHO) database (https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download) for national pollutant discharge elimination system (NPDES) monitoring data using individual NPDES permit numbers (Table 7.2). Monthly average effluent flows were then averaged over the time period of interest. Monthly average effluent nitrogen concentration data were either obtained from the EPA's ECHO database using individual NPDES permit numbers or general permit tracking numbers (Table 7.2) or directly from the WWTF operators (Table 7.1). Monthly average effluent nitrogen concentration data were then averaged over the time period of interest. If nitrogen concentration data were not available for a WWTF during the 2017-2020 reporting period, then either more recent (2021-2022) or historical (NHEP 2008 or

PREP 2018) data were used. If nitrogen concentration data were not available for a WWTF during any time period, then the average TN concentrations and average fraction of TN as DIN from monitored WWTFs were used to estimate TN and DIN.

For WWTFs that discharge to rivers upstream of the estuary, some of the nitrogen discharged from the WWTF is lost during transit to the estuary. For WWTFs that discharge to the Lower Piscataqua River, some of the nitrogen discharged from the WWTF does not reach as far upstream as Dover Point due to the limits of the tidal water movement. For these WWTFs, the nitrogen load should be reported in terms of its "delivered load" to the Great Bay Estuary study area. The delivered load was calculated by multiplying the discharged load by a "delivery factor," which represents the percent of the discharged load that is delivered to the study area (Table 7.1; Figure 7.5b). The delivery factors for discharges to freshwater rivers were calculated based on travel time to the estuary following the methods of NHDES (2010). The delivery factors for WWTFs that discharge to the Lower Piscataqua River were calculated from particle tracking models used in NHDES (2010) or models provided by Portsmouth and Kittery (ASA 2011a, ASA 2011b). These delivery factors were the same delivery factors used in PREP 2012 and PREP 2018.

Non-Point Sources from Major Tributary Watersheds

The TN and DIN loads to the estuary from the eight major watersheds were calculated using measurements of TN and DIN concentrations and stream flow. The U.S. Geological Survey (USGS) LOADEST model (Runkel et al. 2004) was used to develop a calibrated model relating TN and DIN concentrations and daily average stream flow. The LOADEST model was set to select the optimal model based on the calibration dataset (Table 7.3) and all the parameters in the chosen model were included. The inputs to the LOADEST model were monthly (March-December) measurements of TN and DIN concentrations and daily average stream flow at each major tributary monitoring station. Samples were collected from head of tide stations on the Winnicut, Exeter, Lamprey, Oyster, Bellamy, Cocheco, Salmon Falls and Great Works Rivers and analyzed acording to the Great Bay Estuary Tidal Tributary Monitoring Program (GBETTMP) Quality Assurance Project Plan (QAPP; Matso and Potter 2018). For TN and DIN concentrations, non-detected nitrogen in samples samples were represented by one-half of the reporting detection limit. Stream flows at the eight monitoring stations were estimated from USGS stream gages in five (Winnicut, Exeter, Lamprey, Oyster and Cocheco Rivers) of the watersheds and drainage area transposition factors (Table 7.4). The output of the LOADEST model was both the average load for the study period and the monthly loads during the study period. Monthly loads were summed to determine the annual loads during the 2017-2020 time period. The NPS delivered load from watersheds was calculated by subtracting the delivered PS nitrogen load from upstream WWTFs from the total modeled load at each of the eight major tributary monitoring stations (Table 7.5 and Figure 7.7).

Non-Point Sources from Drainage Areas Adjacent to the Estuary

Runoff from land adjacent to the estuary was not captured in the load measurements at the major tributary monitoring stations. Therefore, TN and DIN loads from these areas were estimated. Using the data from the major tributary watersheds, linear regression relationships were developed between the percent land use (2019 National Land Cover Database (NLCD); Dewitz, J. and U.S. Geological Survey 2021) and the 2017-2020 TN and DIN NPS area normalized loads (tons per year per square mile). These regressions spanned a range of developed land use (10.4 to 29.0%) and developed or agricultural land use (14.5 to 37.4%). The 2017-2020 TN and DIN NPS area normalized loads from drainage areas adjacent to the estuary were estimated using the percent of agricultural and/or developed land in the adjacent watershed and the corresponding regression equations (Figure 7.6). The adjacent Great Bay drainage area was slightly more developed (30.3%), and both the Great Bay and upper Piscataqua River drainage areas contained slightly more agricultural and developed land (39.9 to 40.7%) than the range among major tributary watersheds. The use of these regressions is an extrapolation of a linear model outside the calibration range, but the extrapolation is only 5% for developed and 9% for agricultural and developed land uses. A similar approach (using annual TN and DIN NPS area normalized loads from the major tributary watersheds) was used to estimate annual NPS loads from drainage areas adjacent to the estuary.

Groundwater Discharge of Nitrogen to the Estuary

Nitrogen loading from groundwater sources was partially accounted for in the NPS loading estimates from major watersheds. However, regional groundwater flow was also expected to contribute nitrogen loading directly to the estuary. Ballestero et al. (2004) measured the nitrogen loading rate from groundwater seeps to be 0.13 tons DIN/yr per mile of tidal shoreline. This loading rate was applied to the length of tidal shoreline in the estuary (111.9 miles) to estimate the groundwater loading rate of 14.55 tons DIN/yr. The groundwater loading rate was assumed to be constant over time because no other information was available. All of the nitrogen contributed by this source was assumed to be in the form of DIN (Table 7.6 and 7.7; Figure 7.8).

Atmospheric Deposition of Nitrogen to the Estuary

Atmospheric deposition of nitrogen directly to the estuary surface was estimated using wet deposition data provided by the University of New Hampshire Water Quality Analysis Laboratory (UNH WQAL). The UNH WQAL collected wet deposition (rain and snow) on a weekly basis at Thompson Farm (TF) in Durham, NH and analyzed the samples for total dissolved nitrogen (TDN) and DIN. Particulate nitrogen was assumed to be negligible in the wet deposition samples and therefore TDN in wet deposition was assumed to equal wet deposition TN. Volume weighted mean concentrations of TN and DIN in TF wet deposition were determined for the time period of interest and multiplied by the rainfall amount as recorded by the climate reference network (CRN) at TF (CRN station NH_Durham_2_SSW) over the same time period to determine wet deposition (as an area normalized load). Dry deposition was estimated as 58% of wet DIN deposition (ClimCalc ratio of 0.58 dry to wet DIN deposition for TF, Ollinger et al. 2001). Wet and dry deposition were summed to determine the total deposition of TN and inorganic N. For 2017-2020, this resulted in a wet deposition rate of 0.89 tons TN/sq mi/yr (0.75 tons DIN/sq mi/yr), a dry deposition rate of 0.44 tons TN/sq mi/yr (assumed to be 100% DIN) and a total deposition rate of 1.32 tons TN/sq mi /yr (1.19 tons DIN/sq mi/yr). This loading rate was assumed to be constant over the 13.4 sq mi estuary resulting in 17.8 tons of TN and 15.9 tons of DIN load to the estuary per year. Atmospheric deposition of nitrogen to the land surface is accounted for in the NPS load contribution from the major tributary watersheds and the land areas adjacent to the estuary. For annual estimates of deposition see Table 7.7a.

Nitrogen Load Summary

The 2017-2020 and annual TN and DIN loads were calculated by summing the individual components of the nitrogen load: Delivered PS loads from WWTFs, NPS loads from major tributary watersheds, NPS loads from drainage areas adjacent to the estuary, groundwater discharge to the estuary, and atmospheric deposition to the estuary (Table 7.6 and 7.7). Subtotals for PS (WWTFs) and NPS were also calculated.

Additional Discussion
The TN and DIN loads from the 17 WWTFs in the Great Bay Estuary watershed are shown in Table 7.1. The WWTF with the largest delivered nitrogen load was Exeter followed by Rochester and Dover. These three WWTFs accounted for 57% of the nitrogen delivered to the estuary by all WWTFs combined. Following these three WWTFs, Somersworth, Portsmouth, Durham, Berwick and Newmarket have the highest delivered nitrogen loads. It should be noted that these rankings do not account for the size of the population or the number of connections these municipalities serve. Over the years, several municipalities have made substantial improvements to their WWTFs to reduce the amount of nitrogen they discharge. From 2017 to 2020, WWTF delivered total nitrogen load decreased by 48% and delivered DIN load decreased by 40%. Please see Table 7.7 to see changes by each year in this period in the amount of N delivered from WWTFs to the Great Bay Estuary.

The TN and DIN loads from the eight major tributaries are shown in Table 7.5 and Figure 7.7. The Lamprey, Salmon Falls and Cocheco River watersheds delivered the most NPS total nitrogen, but this is in part due to watershed size and the extent to which the watershed is developed. For example, the Salmon Falls watershed has the second highest delivery of total nitrogen, but it has the lowest level of "area-normalized" total nitrogen loading; at 235 sq mi, it is the largest watershed and has the second lowest level of developed or agricultural area (Table 7.5). On an area-normalized basis, the Winnicut, Oyster, and Bellamy watersheds deliver the most total nitrogen to the estuary area (Table 7.5).

The EPA has recommended a total nitrogen loading threshold of 100 kilograms per hectare per year in the Great Bay Total Nitrogen General Permit (TNGP; NPDES General Permit No. NHG58A000), issued in 2020. This equates to 384 tons TN per year for the tidal area of Great Bay, Little Bay, and the Upper Piscataqua River (13.4 square miles). To meet that long-term goal, the TN load for 2017-2020 (895 tons TN per year) would need to be reduced by 511 tons per year, or 57% and reductions in both point source (197 tons TN per year for 2017-2020) and non-point source (699 tons TN per year for 2017-2020) nitrogen loads would be required.

Additional Data, Tables, and Figures

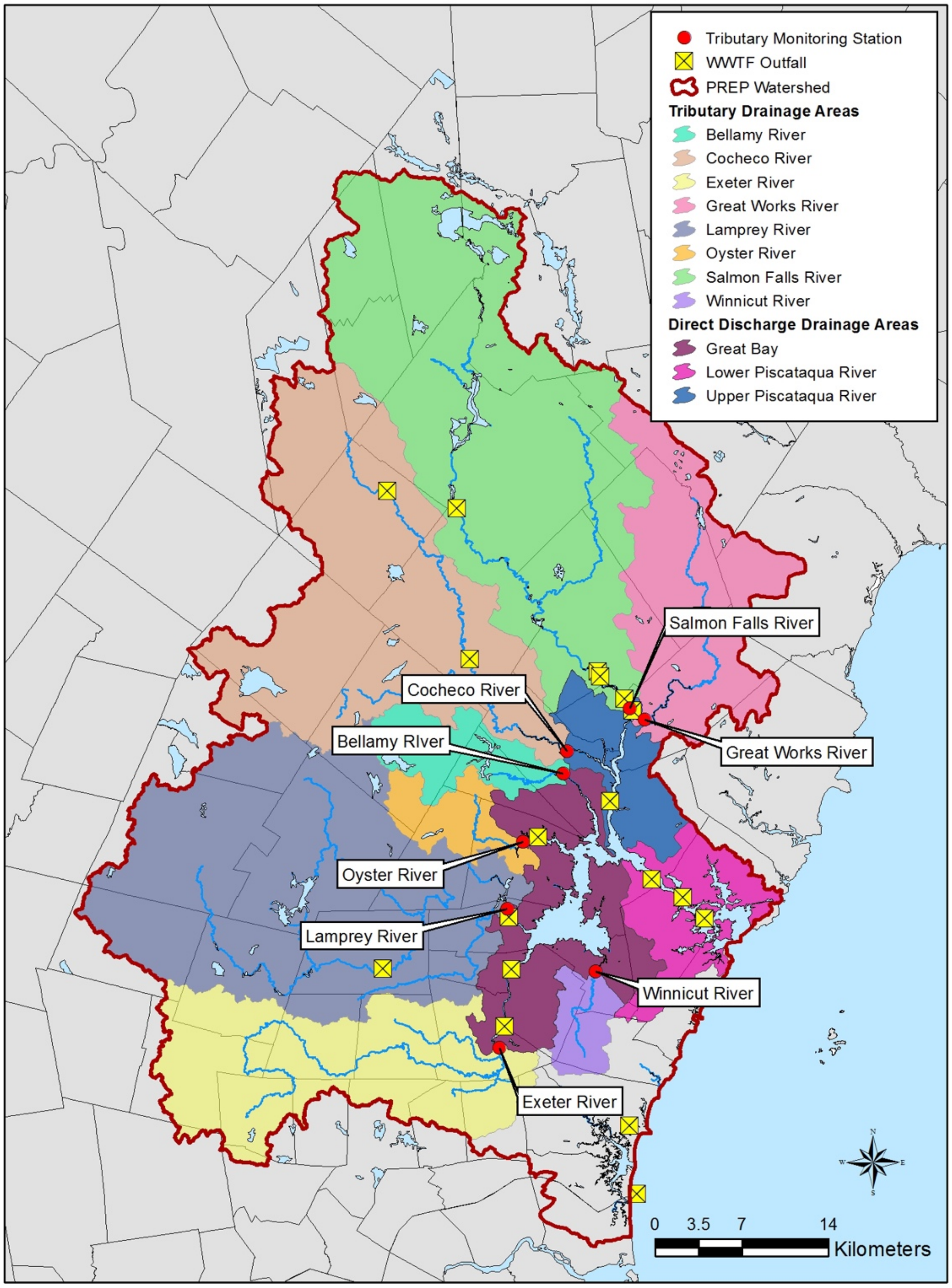
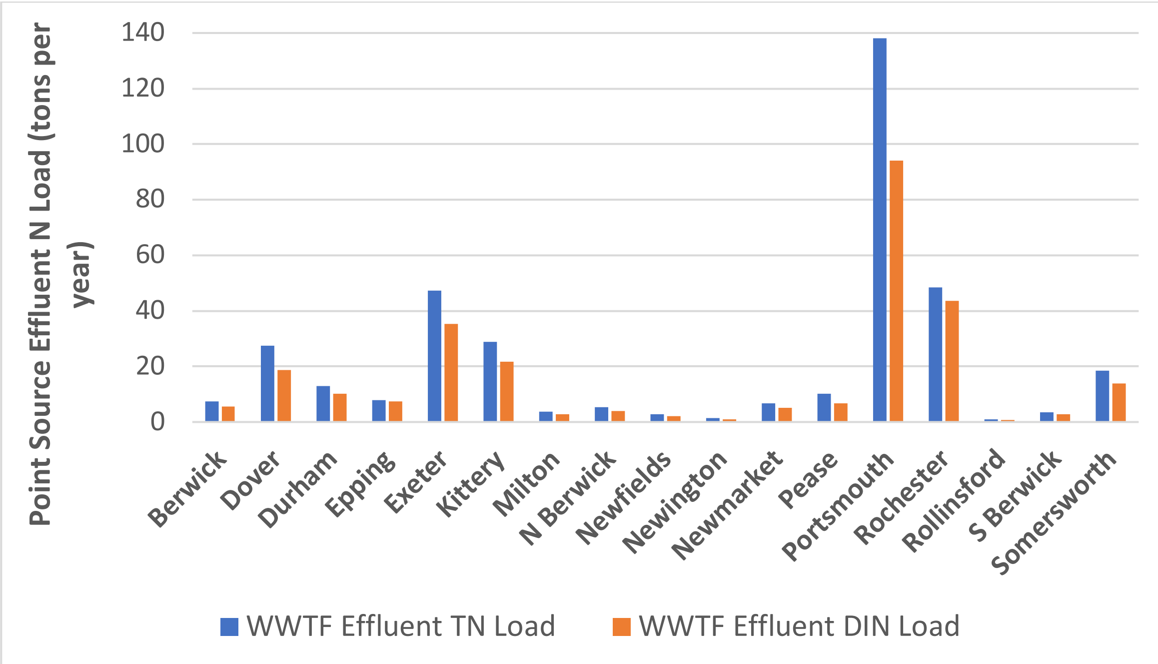


Figure 7.4. Watersheds draining to the Great Bay Estuary. Wastewater treatment plant facilities indicated with yellow markers. Major tributary monitoring stations indicated with red circles.

(A) WWTF effluent N Load



(B) WWTF Delivered N Load

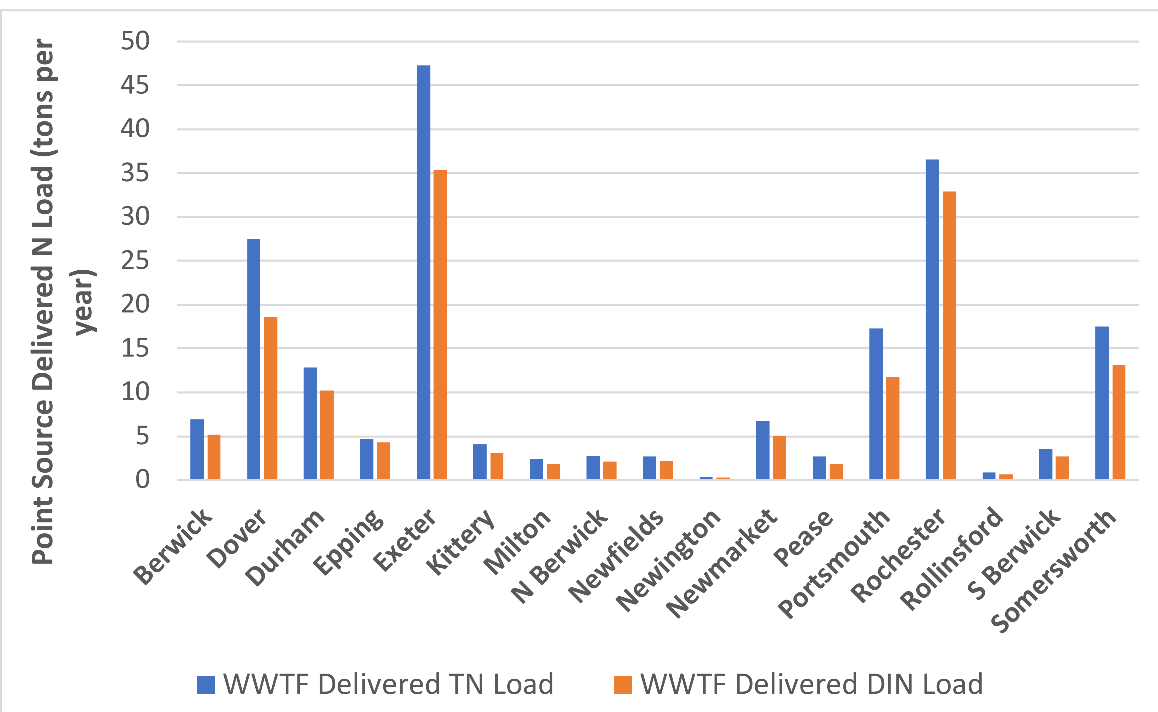
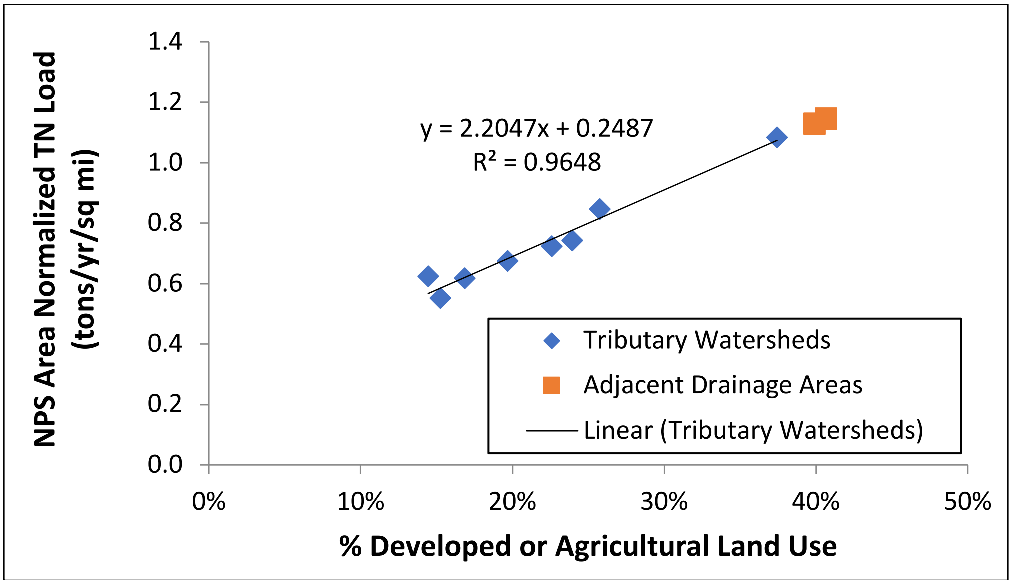


Figure 7.5: Estimated average total nitrogen (TN) and dissolved inorganic nitrogen (DIN) loads from wastewater treatment facility (WWTF) (A) effluent and (B) loads delivered to the Great Bay, Little Bay and Upper Piscataqua River Estuaries 2017-2020. Note the different scales on the vertical axes.

1. Farmington's WWTF is not listed because this WWTF discharges to rapid infiltration basins and thus the effluent is considered to be a non-point source, rather than a point source, to the Cocheco River.

(A) Total Nitrogen



(B) Dissolved Inorganic Nitrogen

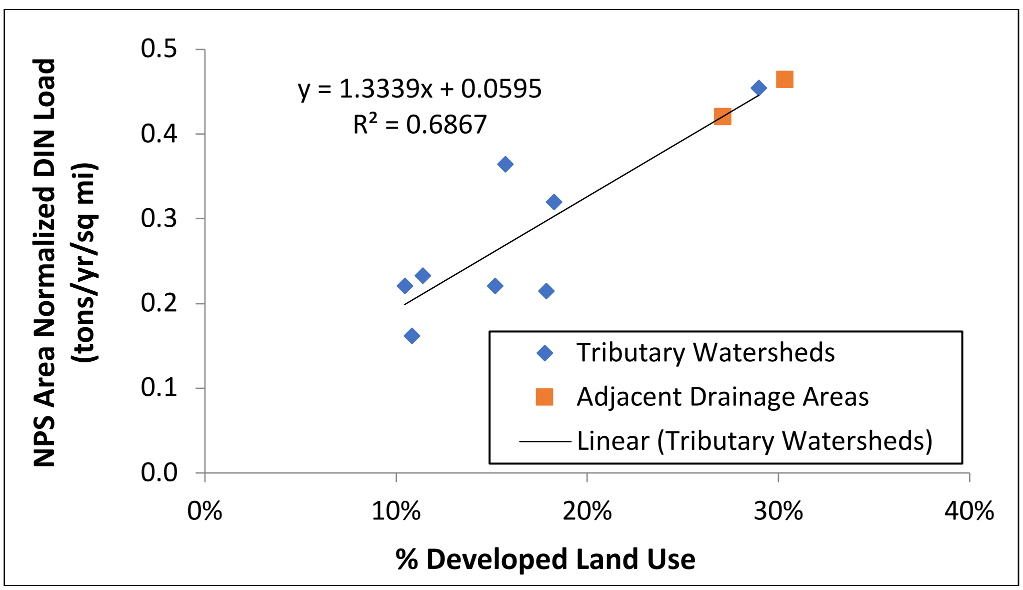
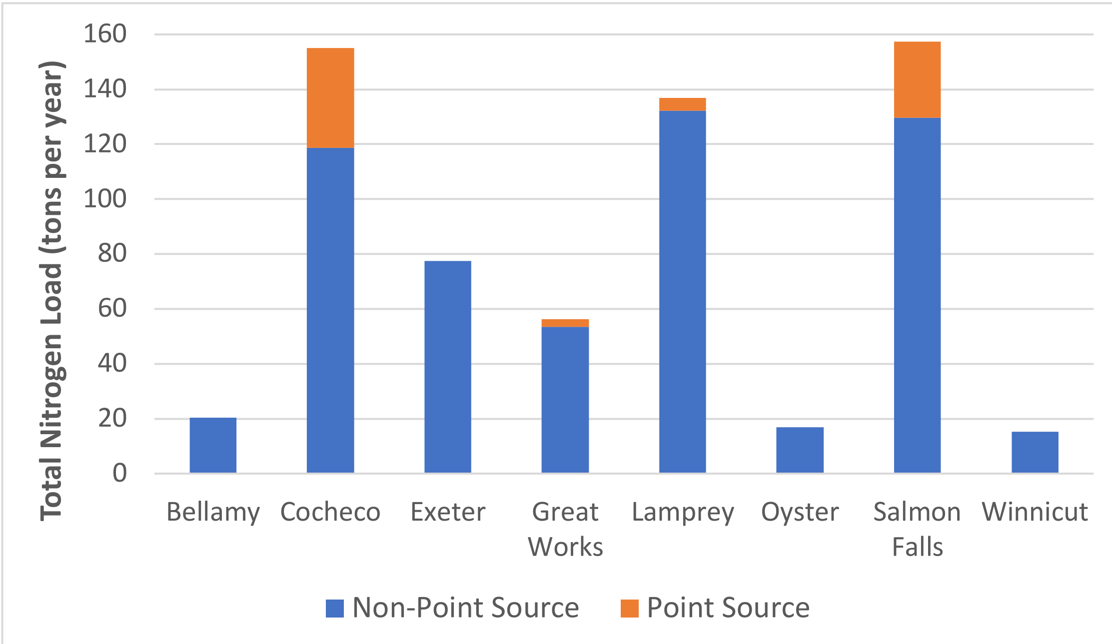


Figure 7.6. Relationship between non-point source (NPS) area normalized nitrogen loads (2017-2020) and land use in major tributary watersheds and extrapolations to drainage areas adjacent to the estuary for (A) Total Nitrogen (TN) and (B) Dissolved Inorganic Nitrogen (DIN). Note the different scales on the vertical axes.

(A) Total Nitrogen



(B) Dissolved Inorganic Nitrogen

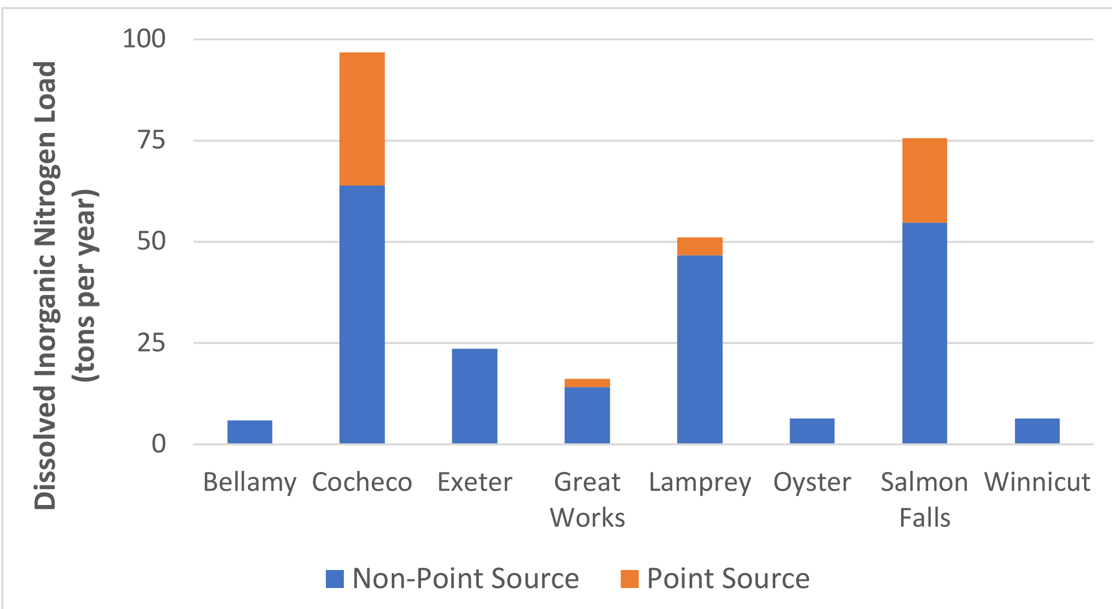


Figure 7.7. Estimated nitrogen loads from major tributaries in 2017-2020 for (A) total nitrogen and (B) dissolved organic nitrogen. Note the different scales on the vertical axes.

1. **Values reported above combine data from 2017 through 2020, which does not reveal improvements made by WWTFs during this period. Please see Table 7.7a to see changes by each year during this period in the amount of N delivered from WWTFs to the Great Bay Estuary.**

(A) Total Nitrogen Load = 895.4 tons per year (22.0% Point Source (PS); 78.0% Non-Point Source (NPS))

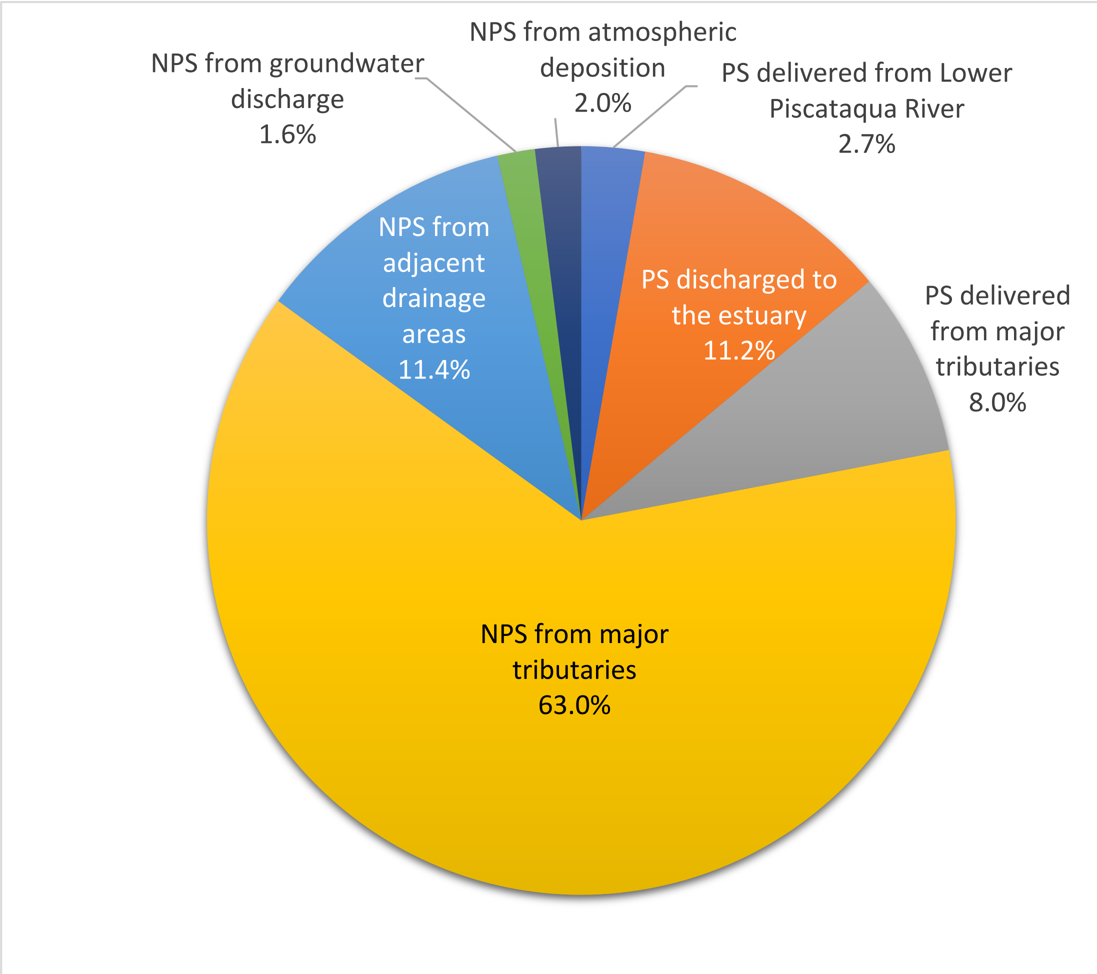


Figure 7.8. Sources of nitrogen loads to the Great Bay Estuary from 2017-2020 for (A) Total Nitrogen and (B) Dissolved Inorganic Nitrogen.

(C) Dissolved Inorganic Nitrogen Load = 443.9 tons per year (34.1% Point Source (PS); 65.9% Non-Point Source (NPS))

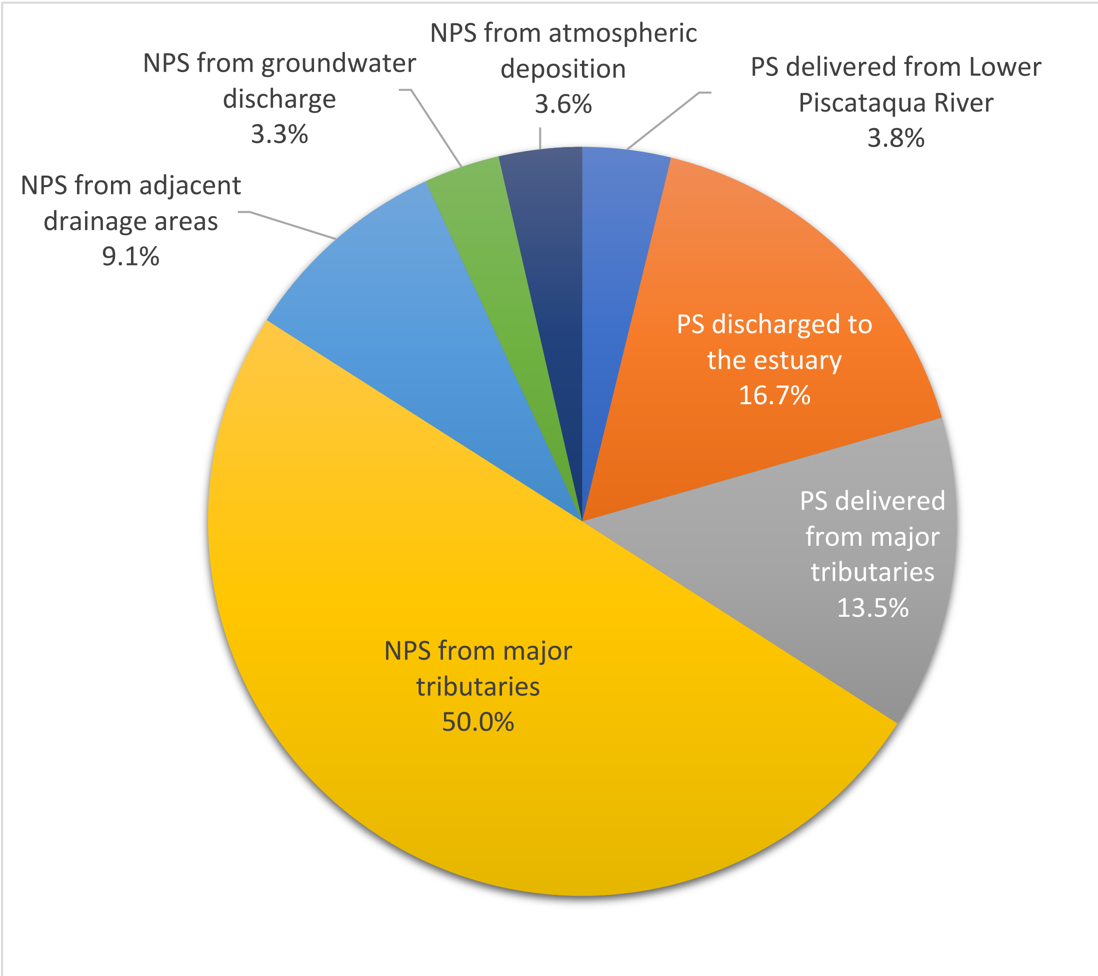


Figure 7.8. Sources of nitrogen loads to the Great Bay Estuary from 2017-2020 for (A) Total Nitrogen and (B) Dissolved Inorganic Nitrogen.

Table 7.1: Estimated average nitrogen loads from wastewater treatment facilities (WWTF) in 2017-2020.

WWTF	Discharge Location (River)	Ave. monthly effluent flow (mgd)	N Data Source	# of months with TN data	Ave. monthly TN (mg/L)	# of months with DIN data	Ave. monthly DIN (mg/L)	TN load (tons/yr)	DIN load (tons/yr)	Delivery Factor	Delivered TN load (tons/yr)	Delivered DIN load (tons/yr)
Rochester	Cocheco	3.20	City of Rochester	48	9.9	48	8.9	48.4	43.5	75.6%	36.5	32.9
Somersworth	Salmon Falls	1.56	City of Somersworth (TN)	48	7.8	0	5.8	18.5	13.8	94.9%	17.5	13.1
N Berwick	Great Works	0.30	Estimated	0	11.8	0	8.8	5.4	4.0	51.6%	2.8	2.1
Berwick	Salmon Falls	0.29	NHEP (2008) for TN	0	16.7	0	12.5	7.3	5.5	94.5%	6.9	5.2
Epping	Lamprey	0.28	Epping GBTNGP (2021-2022)	12	18.8	11	17.6	8.0	7.5	58.2%	4.6	4.3
Rollinsford	Salmon Falls	0.08	Rollinsford GBTNGP (2021-2022; TN)	12	7.4	0	5.5	0.9	0.7	99.0%	0.9	0.7
Milton	Salmon Falls	0.08	Milton GBTNGP (2021-2022; TN)	12	30.8	0	23.1	3.7	2.8	65.7%	2.4	1.8
Dover	Upper Piscataqua	2.64	City of Dover	47	6.8	47	4.6	27.5	18.6	100.0%	27.5	18.6
Exeter	Exeter (tidal)	1.73	Exeter NPDES permit (TN)	48	18.0	0	13.5	47.3	35.4	100.0%	47.3	35.4
Durham	Oyster (tidal)	0.91	Town of Durham	48	9.2	48	7.3	12.9	10.2	100.0%	12.9	10.2
Newmarket	Lamprey (tidal)	0.47	Newmarket NPDES permit (TN)	48	9.4	0	7.0	6.7	5.1	100.0%	6.7	5.1
S Berwick	Salmon Falls (tidal)	0.32	S Berwick Sewer District	44	7.3	18	5.4	3.6	2.7	100.0%	3.6	2.7
Newfields	Exeter (tidal)	0.09	Town of Newfield (2020)	4	20.0	3	16.3	2.7	2.2	100.0%	2.7	2.2
Portsmouth	Lower Piscataqua	4.16	City of Portsmouth	48	21.8	48	14.8	138.2	94.2	12.5%	17.3	11.8
Kittery	Lower Piscataqua	0.98	NHEP 2008 and Kittery 2015 (TN)	0	19.4	0	14.5	28.9	21.6	14.2%	4.1	3.1
Pease	Lower Piscataqua	0.71	City of Portsmouth	34	9.5	34	6.3	10.2	6.8	26.3%	2.7	1.8
Newington	Lower Piscataqua	0.10	Town of Newington	47	9.7	47	6.9	1.5	1.1	26.3%	0.4	0.3
								371.6	**275.7**	**Total Load**	**196.9**	**151.2**

1. **Italicized WWTFs (N Berwick, Berwick, S Berwick and Kittery) are located in Maine. The other 13 WWTFs are located in New Hampshire.**
2. **Average (Ave.) monthly WWTF effluent flows are reported in million gallons per day (mgd). The monthly average effluent flows from NPDES discharge monitoring reports were averaged over the 48 months in the 4-year study period (2017-2020).**
3. **North (N) Berwick WWTF does not discharge June 1-Sept 30, thus 0 mgd was assigned to those 4 months of each year. A few months of effluent flow were not reported for N Berwick (3-5 mo/yr) and were excluded from the average effluent flow at this WWTF (32 total months with flow data, including June-Sept months with 0 mgd). All other WWTFs reported 48 months of effluent flow data.**
4. **Data are sorted by average monthly effluent flow (from highest to lowest) within each of the following groupings: WWTFs discharging to major tributaries, WWTFs discharging to the estuary and WWTFs discharging to the lower Piscataqua River.**
5. **National pollutant discharge elimination system (NPDES) 2020 Great Bay Total Nitrogen General Permit (GBTNGP; NHG58A000) N data were obtained for Epping, Rollinsford and Milton WWTFs from May 2021 to April 2022.**
6. **Light grey cells: a) No TN data were available. TN was estimated as the average of TN concentrations among WWTFs monitored during 2017-2020 (11.8 mg/L).**

b) **No DIN data were available. DIN was estimated based on the average ratio of DIN to TN in WWTFs monitored during 2017-2020 (74.9%).**

7. **Delivery factor is the percent of the discharged load that is delivered to the Great Bay (GB), Little Bay (LB), and Upper Piscataqua River (UPR) estuaries. For WWTFs in the major tributary watersheds, attenuation loss was estimated using the travel time for water between the WWTF outfall and the estuary and a first order loss coefficient. For the Lower Piscataqua River WWTFs, the delivery factor was estimated from the percent of particles in GB, LB, and UPR at steady state in the Dartmouth particle tracking model (NHDES 2010) or particle tracking models provided by Portsmouth and Kittery (ASA 2011a, 2011b). These delivery factors were the same delivery factors used in PREP 2012 and PREP 2018.**

Table 7.2. Wastewater treatment facility (WWTF) total nitrogen general permit tracking numbers and individual NPDES permit numbers.

WWTF	General Permit Tracking Number	Individual NPDES Permit Number
Rochester	NHG58A001	NH0100668
Portsmouth	NHG58A002	NH0100234
Dover	NHG58A003	NH0101311
Exeter	NHG58A004	NH0100871
Durham	NHG58A005	NH0100455
Somersworth	NHG58A006	NH0100277
Pease ITP	NHG58A007	NH0090000
Newmarket	NHG58A008	NH0100196
Epping	NHG58A009	NH0100692
Newington	NHG58A010	NHG581141
Rollinsford	NHG58A011	NH0100251
Newfields	NHG58A012	NH0101192
Milton	NHG58A013	NH0100676
Berwick		ME0101397
Kittery		ME0100285
N Berwick		ME0101885
S Berwick		ME0100820

Table 7.3. LOADEST models for total nitrogen (TN) and dissolved inorganic nitrogen (DIN) loads from major tributary watersheds in 2017-2020.

	Loadest TN (tons/yr) Model			Loadest DIN (tons/yr) Model		
Tributary	**R^2 (%)**	**PPCC**	**Model**	**R^2 (%)**	**PPCC**	**Model**
Lamprey	98.5	0.972	8	92.5	0.991	6
Bellamy	98.1	0.927	6	89.7	0.993	6
Cocheco	97.6	0.981	8	90.3	0.933	5
Exeter	98.9	0.990	7	92.7	0.984	2
Great Works	99.0	0.990	6	92.4	0.958	2
Oyster	98.6	0.985	8	94.4	0.987	5
Salmon Falls	98.3	0.985	4	95.4	0.982	3
Winnicut	99.2	0.988	2	96.5	0.994	8

1. **TN and DIN loads estimated using USGS software "LOADEST" with water quality data from the PREP Tidal Tributary Monitoring Program and streamflow data from USGS.**
2. **R^2 is a measure of the quality of the loadest regression model (0=worst, 1=best).**
3. **PPCC (probability plot correlation coefficient) is a measure of the normality of the residuals (0=worst, 1=best).**
4. **The model number refers to the specific model chosen. The models are defined in the LOADEST user's manual (Runkel et al. 2004).**

Table 7.4. USGS stream gages and drainage area transposition factors for estimating stream flow at the tributary monitoring stations.

Tributary Monitoring Station	Watershed Area for Station (sq miles)	USGS Streamgage Number	Flow Multiplier for Transpositions	USGS Watershed Area for Streamgage (sq miles)
Bellamy River[1]	27.26	Cocheco 01072800	0.341176	79.9
		Oyster 01073000	2.252893	12.1
Cocheco River	175.28	Cocheco 01072800	2.193742	79.9
Exeter River	106.9	Exeter 01073587	1.683465	63.5
Great Works River	86.69	Cocheco 01072800	1.084981	79.9
Lamprey River	211.91	Lamprey 01073500	1.145459	185
Oyster River	19.85	Oyster 01073000	1.640496	12.1
Salmon Falls River	235	Lamprey 01073500	1.27027	185
Winnicut River	14.18	Winnicut 1073785	1.005674	14.1

1. **Stream flow in the Bellamy River was estimated by averaging cubic feet per second (cfs) transposition estimates from the Cocheco and Oyster Rivers.**

Table 7.5. LOADEST, point (WWTFs) and non-point source nitrogen loads and area normalized loads from major tributary watersheds 2017-2020.

Site	Area (mi^2)	LOADEST TN Load (tons/yr)	LOADEST DIN Load (tons/yr)	Area Normalized TN Load (tons/yr/mi^2)	Area Normalized DIN Load (tons/yr/mi^2)	Upstream WWTF Delivered TN (tons/yr)	Upstream WWTF Delivered DIN (tons/yr)	NPS TN Load (tons/yr)	NPS DIN Load (tons/yr)	Area Normalized NPS TN Load (tons/yr/mi^2)	Area Normalized NPS DIN Load (tons/yr/mi^2)	% Developed Land	% Developed or Agricultural Land
Bellamy	27.26	20.28	5.86	0.74	0.21	0.00	0.00	20.28	5.86	0.74	0.21	17.9%	23.9%
Cocheco	175.28	155.13	96.82	0.89	0.55	36.53	32.88	118.60	63.94	0.68	0.36	15.7%	19.7%
Exeter	106.90	77.40	23.63	0.72	0.22	0.00	0.00	77.40	23.63	0.72	0.22	15.2%	22.6%
Great Works	86.69	56.35	16.14	0.65	0.19	2.78	2.08	53.57	14.05	0.62	0.16	10.8%	16.9%
Lamprey	211.91	136.93	51.09	0.65	0.24	4.65	4.34	132.29	46.75	0.62	0.22	10.4%	14.5%
Oyster	19.85	16.80	6.35	0.85	0.32	0.00	0.00	16.80	6.35	0.85	0.32	18.2%	25.8%
Salmon Falls	235.00	157.43	75.55	0.67	0.32	27.74	20.78	129.69	54.77	0.55	0.23	11.4%	15.2%
Winnicut	14.18	15.36	6.45	1.08	0.45	0.00	0.00	15.36	6.45	1.08	0.45	29.0%	37.4%
Total	**877.07**	**635.70**	**281.87**			**71.71**	**60.08**	**563.99**	**221.79**				

1. **TN and DIN loads estimated using USGS software "LOADEST" with water quality data from the PREP Tidal Tributary Monitoring Program and streamflow data from USGS.**
2. **Seven WWTFs discharge upstream of major tributary monitoring stations. The Epping WWTF is upstream of the Lamprey River station. The Rochester WWTF is upstream of the Cocheco River station. The Milton, Berwick, Somersworth and Rollinsford WWTFs are upstream of the Salmon Falls River station. The North Berwick WWTF is upstream of the Great Works River station. The Farmington WWTF is also upstream of the Cocheco River station, but Farmington discharges to the groundwater and thus is considered a NPS within the Cocheco watershed.**
3. **Upstream WWTF loads were reduced using an attenuation loss model to estimate the delivered load to the estuary.**
4. **Percent of watershed land area (excluding open water) in developed and agricultural land use classes are from the 2019 National Land Cover Dataset.**

Table 7.6: Summary of average nitrogen loads (tons per year) to the Great Bay (GB), Little Bay (LB) and Upper Piscataqua River (UPR) Estuaries (2017-2020). Percentages by source are also included.

Source	TN Load (tons/yr)	DIN Load (tons/yr)	% TN load	% DIN load
PS delivered from Lower Piscataqua River	24.5	16.9	2.7%	3.8%
PS discharged to GB, LB and UPR Estuaries	100.7	74.2	11.2%	16.7%
PS delivered from major tributaries	71.7	60.1	8.0%	13.5%
NPS from major tributaries	564.0	221.8	63.0%	50.0%
NPS from drainage areas adjacent to the estuaries	102.2	40.4	11.4%	9.1%
NPS from groundwater discharge to the estuaries	14.6	14.6	1.6%	3.3%
NPS from atmospheric deposition to the estuaries	17.8	15.9	2.0%	3.6%
Subtotal - Point Sources (WWTFs)	**197**	**151**	22.0%	34.1%
Subtotal - Non-point sources	**699**	**293**	78.0%	65.9%
Grand Total	**895**	**444**	**100.0%**	**100.0%**

1. **PS = Point Source.**
2. **WWTF = Wastewater Treatment Facility.**
3. **NPS = Non-Point Source.**

Table 7.7: Annual average nitrogen loads to the Great Bay (GB), Little Bay (LB) and Upper Piscataqua River (UPR) Estuaries (2017-2020) reported as (A) tons per year and (B) as percentages.

(A) average nitrogen loads as tons per year

	2017		2018		2019		2020	
Source	**TN Load (tons/yr)**	**DIN Load (tons/yr)**	**TN Load (tons/yr)**	**DIN Load (tons/yr)**	**TN Load (tons/yr)**	**DIN Load (tons/yr)**	**TN Load (tons/yr)**	**DIN Load (tons/yr)**
PS delivered from Lower Piscataqua River	32.7	20.3	30.2	19.7	24.0	17.4	12.2	10.2
PS discharged to GB, LB and UPR Estuaries	149.4	99.5	117.8	78.9	84.4	62.3	56.4	43.5
PS delivered from major tributaries	73.0	59.2	80.4	63.7	69.6	58.8	63.2	53.5
NPS from major tributaries	573.5	245.3	760.5	288.6	533.4	209.3	385.8	149.1
NPS from drainage areas adjacent to the estuaries	99.7	45.2	108.4	47.3	101.6	38.7	81.3	30.0
NPS from groundwater discharge to the estuaries	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
NPS from atmospheric deposition to the estuaries	18.6	17.6	20.5	17.4	18.5	17.3	13.5	11.4
Subtotal - Point Sources (WWTFs)	255	179	228	162	178	138	132	107
Subtotal - Non-point sources	706	323	904	368	668	280	495	205
Grand Total	**961**	**502**	**1132**	**530**	**846**	**418**	**627**	**312**

(B) average nitrogen loads as percentages

	2017		2018		2019		2020	
Source	**% TN load**	**% DIN load**	**% TN load**	**% DIN load**	**% TN load**	**% DIN load**	**% TN load**	**% DIN load**
PS delivered from Lower Piscataqua River	3.4%	4.0%	2.7%	3.7%	2.8%	4.2%	1.9%	3.3%
PS discharged to GB, LB and UPR Estuaries	15.5%	19.8%	10.4%	14.9%	10.0%	14.9%	9.0%	13.9%
PS delivered from major tributaries	7.6%	11.8%	7.1%	12.0%	8.2%	14.1%	10.1%	17.1%
NPS from major tributaries	59.7%	48.9%	67.2%	54.4%	63.0%	50.0%	61.5%	47.8%
NPS from drainage areas adjacent to the estuaries	10.4%	9.0%	9.6%	8.9%	12.0%	9.2%	13.0%	9.6%
NPS from groundwater discharge to the estuaries	1.5%	2.9%	1.3%	2.7%	1.7%	3.5%	2.3%	4.7%
NPS from atmospheric deposition to the estuaries	1.9%	3.5%	1.8%	3.3%	2.2%	4.1%	2.1%	3.6%
Subtotal - Point Sources (WWTFs)	26.5%	35.7%	20.2%	30.6%	21.0%	33.1%	21.0%	34.3%
Subtotal - Non-point sources	73.5%	64.3%	79.8%	69.4%	79.0%	66.9%	79.0%	65.7%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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References

ASA. 2011a. Preliminary Modeling Results from Long-Term Lagrangian Simulations of Releases to the Great Bay / Piscataqua River System. Memorandum from Craig Swanson and Ata Bilgili to Peter Rice (City of Portsmouth) and Tupper Kinder (NMKS). Applied Sciences Associates, Inc., South Kingstown, RI. March 12, 2011.

ASA. 2011b. Long-term Simulations of the Transport and Fate of the Kittery Wastewater Treatment Facility Discharge into the Great Bay Estuarine System. Prepared by Craig Swanson, Ata Bilgili, Nicholas Cohn, Daniel Lynch. Applied Sciences Associates, Inc., South Kingstown, RI. December 22, 2011.

Ballestero TP, Roseen RM, Brannaka LK. 2004. Inflow and loadings from groundwater to the Great Bay, New Hampshire: A final report to the NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology. University of New Hampshire, Durham, NH. http://scholars.unh.edu/prep/399/

Dewitz, J. and U.S. Geological Survey. 2021. National Land Cover Database (NLCD) 2019 Products (ver. 2.0, June 2021): U.S. Geological Survey data release. https://doi.org/10.5066/P9KZCM54.

Matso, K and Potter, J.D. 2018. Great Bay Estuary Tidal Tributary Monitoring Program: Quality Assurance Project Plan, 2018". PREP Reports & Publications. 406. https://scholars.unh.edu/prep/406

NHDES. 2010. Analysis of Nitrogen Loading Reductions for Wastewater Treatment Facilities and Non-Point Sources in the Great Bay Estuary Watershed. PREP Publications. 384. http://scholars.unh.edu/prep/384

NHEP. 2008. Total Nitrogen Concentrations in Wastewater Treatment Plant Effluent in the Great Bay Estuary in 2008. New Hampshire Estuaries Project, Durham, NH. http://scholars.unh.edu/prep/85/

Ollinger S, Aber J, Lovett G, Federer C. 2001. ClimCalc: a Model of Physical and Chemical Climate for the New England/New York Region. http://www.pnet.sr.unh.edu/climcalc/

PREP 2012. Final Environmental Data Report December 2012: Technical Support Document for the 2013 State of Our Estuaries Report. REP Reports & Publications. 265. http://scholars.unh.edu/prep/265/

PREP 2018. State of Our Estuaries Data Report. https://www.stateofourestuaries.org/2018-reports/data-report

Runkel RL, Crawford CG, Cohn TA. 2004. Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers: U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p. https://pubs.usgs.gov/tm/2005/tm4A5/pdf/508final.pdf