Chapter 7

Wastewater Flows and Nitrogen Loading

CHAPTER 7

WASTEWATER FLOWS AND NITROGEN LOADINGS

7.1 INTRODUCTION

The wastewater flows and nitrogen loads developed as part of the Needs Assessment and discussed in this chapter present what the estimated conditions would be if development continued without taking any further wastewater management steps. This scenario presents the greatest nitrogen loads throughout project planning area (PPA).

7.2 BUILD-OUT ANALYSIS

In order to obtain a Town-wide, long range view of the nitrogen and other issues in Mashpee, a build-out analysis was performed by the Mashpee Planning Department. The build-out analysis is based on existing building permits, known (proposed) projects, zoning, and numerous other aspects that impact development.

The Mashpee Planning Department identified on a parcel-by-parcel basis the Town's development potential. This build-out approach was applied and a Build-out Dwelling Unit (DU) number was assigned to each residential parcel or parcel with residential development potential, based on the Town's assessment of the lot. This number represents the number of individual residences that are possible on a lot if developed to full potential and includes existing development. Commercial and industrial zoned lots are assigned a DU of 0, but the Town's analysis provided estimates of possible future uses (retail, office, warehouse, etc.) and potential building sizes.

Both the MEP analysis (to an extent) and the Needs Assessment analysis used the Town's build-out estimates to determine future wastewater flows and nitrogen loads. Build-out for Falmouth

and Sandwich were based on MEP efforts associated with those towns; Barnstable build-out estimates were based on information from the Barnstable Town Planner.

7.3 WASTEWATER GENERATION AND NITROGEN LOADINGS

The MEP analyses, as discussed in Chapter 4, focus on watersheds, which are not necessarily Town boundaries. Significant portions of both the Popponesset Bay and Waquoit Bay watersheds are within the boundaries of the Town of Mashpee. However, both watersheds include portions of neighboring towns – Barnstable, Sandwich, and/or Falmouth.

Although the watershed-based MEP analyses are the basis for the Town's management plan, the WNMP evaluates wastewater and nitrogen issues throughout the entire Town of Mashpee and the PPA, not just the areas that are within the Popponesset Bay and Waquoit Bay watersheds. The MEP analyses identified one scenario with discrete nitrogen removal levels necessary to maintain estuary health. With those nitrogen removal levels as the target, the WNMP will evaluate various alternatives that will meet the goals of the MEP and address the Town's needs (including areas that are not within the boundaries of either MEP watershed) in subsequent phases of the project. Because the MEP is the basis of the WNMP, the WNMP will, where appropriate, identify and address wastewater and nitrogen issues in neighboring towns. The WNMP analysis will follow the general framework of the MEP analysis.

As discussed in Chapter 6 of this report, Title 5 septic systems make up a significant portion of the wastewater treatment in the PPA. These systems typically discharge effluent with total nitrogen (TN) concentrations in the neighborhood of 35 mg/L, of which approximately 75% reaches the groundwater table (as identified by MEP). Even I/A technologies, which produce average effluent concentrations of 19mg/L TN (approximately 75% of which reaches the groundwater table), will not achieve drinking water standards of 10 mg/L. The permits governing the operation of small wastewater treatment plants in the PPA typically limit total nitrogen to 10 mg/L, which is based on accepted drinking water standards and regulated by MADEP. The estuaries have reached their nutrient-impacted conditions under these current practices; therefore, these concentrations must be reduced to see improvements in estuary health.

The means for reducing these concentrations and ultimately the TN loadings to the coastal embayments will be discussed in subsequent reports.

The MEP analysis generated wastewater flow estimates using average water use data for the years 1997 through 1999 (for Mashpee), 2000 (for Falmouth), or 1998-2000 (for Sandwich and Barnstable). The same data was used for the purposes of the WNMP analysis. However, the relevant data was obtained for *all* parcels in the Town of Mashpee. The same analysis methods used by MEP were followed for the WNMP analysis in order to obtain consistent flow and loading estimates PPA-wide. The following discussion describes the data and estimates used.

A. Development of Existing Wastewater Flows

- For properties with water consumption data, 90 percent of a property's water use is estimated to become wastewater.

- Properties without water consumption data were assigned an average water use based on either MEP assumptions or the land use type. The MEP reports used the following assumptions in their analysis:

TABLE 7-1

MEP WATER USE ASSUMPTIONS (1)

Land Use Type	Water Use	Wastewater Flow
Residential	154 gpd	90% of water use
Commercial/Industrial	81.5 gpd/1000 sq. ft. of building	90% of water use
(1) From Table IV-4 of the MEP technical reports.		

The following table summarizes the water use estimates used in this Report for the wastewater analysis. These averages are based on existing water users in Town. Obtaining an average for a commercial use category was desirable to obtain a more accurate estimate of nitrogen loading within the Town.

TABLE 7-2

WNMP WATER USE ASSUMPTIONS

Land Use Type	Water Use	Wastewater Flow
Residential	155 gpd	140 gpd
Restaurant(1)	200 gpd/1,000 sq. ft. of building	180 gpd/1,000 sq. ft. of building
Hotel/Motel(1)	60 gpd/room	55 gpd/room
Other (Retail, Office, Industrial, etc.)(1)	83 gpd/1,000 sq. ft. of building	75 gpd/1,000 sq. ft. of building

(1) Water use averages for these categories were based on averages from Mashpee water use data in order to obtain more accurate build-out estimates.

- The majority of properties without water data were single family residential parcels. These properties were assumed to consume 155 gpd of water. The water use average was multiplied by 90% and rounded to obtain a wastewater generation of 140 gpd.

- The "Other" commercial properties (as listed in Table 7-2) can be further divided into office/retail, warehouse/industrial, and miscellaneous. The wastewater generation for these uses (based on properties that have water use data) are 60, 90, and 80 gpd/1,000 square feet of building, respectively. These values were rounded to 75 gpd/1,000 square feet for calculation purposes. The difference between using the use-specific flows and the average for these types of properties is insignificant in the total commercial wastewater generation estimates.

B. Development of Future Wastewater Flows

- Undeveloped properties were assigned a water use/wastewater flow based on the same estimates described in Table 7-2.

- Future use and development potential of residential parcels was based on the Town's build-out analysis.

- Residential future flows equaled the greater of either 140 gpd or the existing wastewater flow. This was to account for seasonal properties that may become year round residences in the future.

- Existing commercial/industrial parcels with water data were estimated to remain at the same water use levels.

- New commercial and industrial properties created from vacant commercial and industrial properties were assigned a flow based on the use category, as described in the previous section.

After each parcel was assigned an appropriate wastewater generation estimate, the parcels were grouped according to land use. Table 7-3 summarizes the existing and future average annual wastewater flows, developed as described above.

TABLE 7-3

EXISTING AND FUTURE AVERAGE ANNUAL WASTEWATER FLOWS(1)

Land Use	**Existing Flow (gpd)(2)**	**Future Flow (gpd)(2)**
Multi-use	2,900	4,100
Residential	1,400,000	2,400,000
Commercial	93,000	200,000
Industrial	14,000	72,000
Institutional	15,000	67,000
Total	**1,600,000**	**2,700,000**

(1) Flows for the entire PPA.
(2) All numbers rounded to 2 significant figures.

After assigning wastewater flows to each parcel, nitrogen loads were determined. Wastewater nitrogen loadings were based on the following assumptions.

- Properties with a standard Title 5 septic system were assumed to have an effluent Total Nitrogen (TN) concentration of 35 mg/L. This concentration has been used regionally for several facilities planning projects. The MEP analysis assumes a level of nitrogen removal through a standard septic system; however, for planning purposes no reduction is considered in these evaluations. If wastewater is treated by means of a sewer system, no reduction of nitrogen will occur in the septic system and disposal field – all nitrogen reduction will be performed via the treatment plant.

- For those properties that were identified as connected to one of the wastewater treatment facilities (WWTF) in the PPA, the flow was assigned to the WWTF parcel, with a corresponding nitrogen concentration based on data provided for that particular WWTF. No flow or nitrogen load was assigned to the individual parcel connected to the WWTF. The effluent nitrogen concentration at each WWTF parcel was determined based on 12 months of reports (2004-2005) from the respective treatment plant. For example, the parcel where the Willowbend WWTF discharges its treated wastewater would be assigned a nitrogen concentration of 7.7 mg/L. The load would be based on that concentration and the associated flow. The TN concentrations used for each WWTF are summarized in Table 7-4.

- Properties with an advanced (I/A) septic system were assumed to achieve an effluent concentration of 19 mg/L TN.

TABLE 7-4

OCTOBER 2004-OCTOBER 2005 WWTF TOTAL NITROGEN CONCENTRATIONS

Wastewater Treatment Facility	**TN (mg/L)**
New Seabury	2.5
Willowbend	7.7
Southport	8.4
Southcape	9.5
Stratford Ponds	11.2
Mashpee Commons	6.3
High School(1)	43.5
Windchime Point	6.0
Forestdale School	NA
(1) For the Report, the High School nitrogen load was based on current performance. The permit limit for this facility is less than 10 mg/L TN.	

This approach takes into consideration that, if nitrogen issues were addressed with a wastewater treatment plant serving a portion of a planning zone, those properties with existing I/A systems are already providing some level of nitrogen removal and may or may not be required to immediately connect to a WWTP.

Wastewater nitrogen loads were developed for each parcel by converting the daily estimated wastewater flow and the estimated total nitrogen concentration to a load in kilograms (of nitrogen) per year (kg/yr). It is noted that in the following paragraphs, when reference is made to high, medium, and low nitrogen loading rates (kg/acre/yr), these are relative terms used to compare one planning zone to another as discussed below.

C. Figure 7-1 – Planning Zone Loading Map

Figure 7-1 displays the average wastewater nitrogen loads per acre per planning zone. This figure is based on the total nitrogen load in kilograms of nitrogen per year divided by the total acreage of the given planning zone (PZ). As discussed in previous chapters, there are 161 planning zones identified by the Mashpee Planning Department and 12 planning zones in the surrounding towns (identified as planning zones for this report only).

This map was generated to identify PZs that have or are expected to have high nitrogen loads relative to other PZs. The map is color coded based on these application rates, red indicating the highest loads (greater than 30 kg/acre/year) and yellow indicating the lowest loads (less than 10 kg/acre/year). The locations of the WWTFs are provided for reference on the map and indicate approximate location of individual wastewater treatment plant effluent recharge sites.

The following table provides a breakdown of the nitrogen loading rates of the planning zones.

TABLE 7-5

SUMMARY OF PLANNING ZONE LOADING RATES(1)

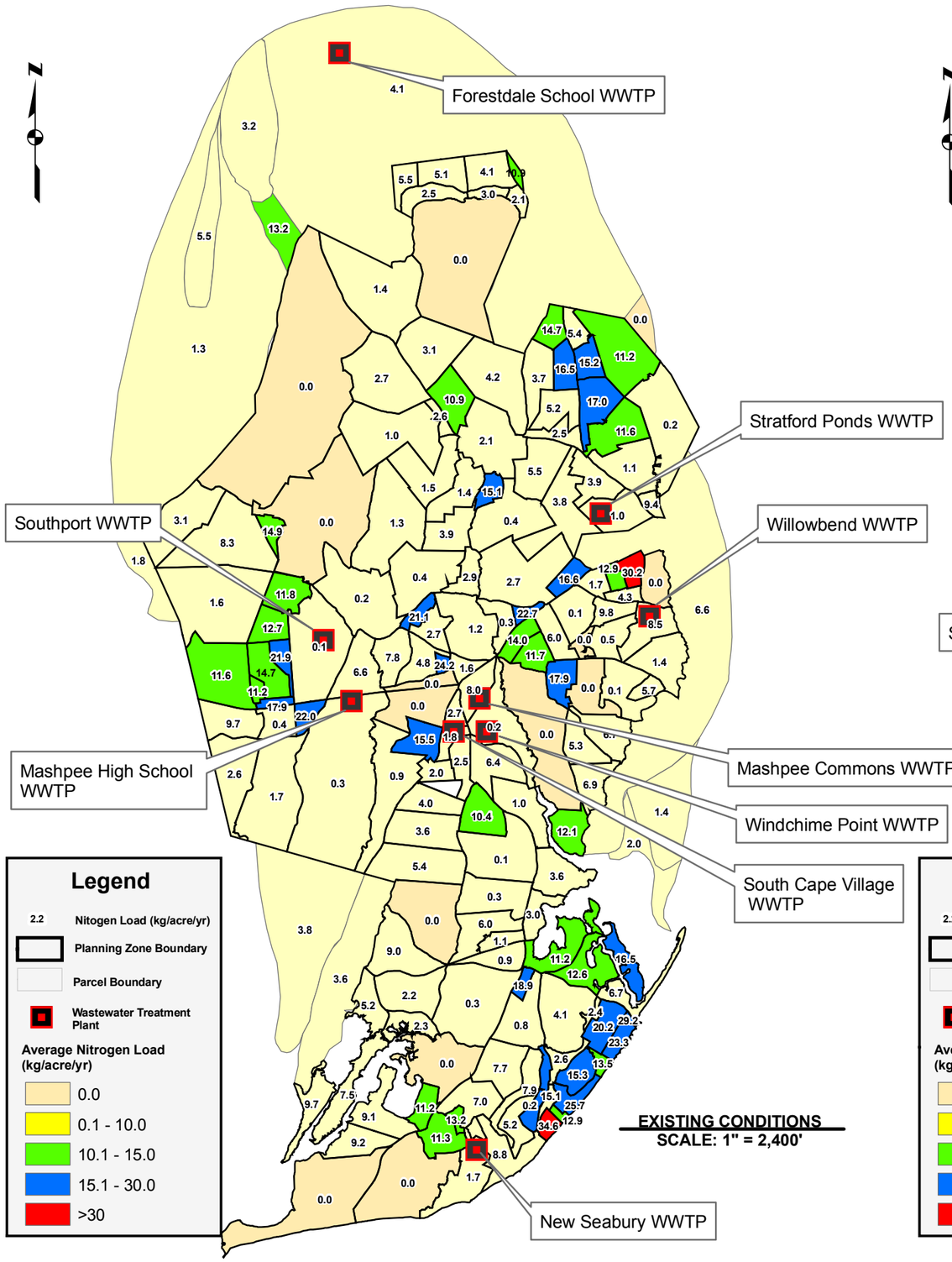
Relative Loading(2)	**Number of PZs (Existing conditions)**	**Number of PZs (Future conditions)**
High (Red – more than 30 kg/acre/yr)	2	12
Medium-High (Blue – 15.1-30 kg/acre/yr)	21	35
Medium (Green – 10.1-15 kg/acre/yr)	24	27
Low (Yellow – less than 10 kg/acre/yr)	112	87
No Wastewater Nitrogen Load	14	12

(1) Wastewater nitrogen loads only.

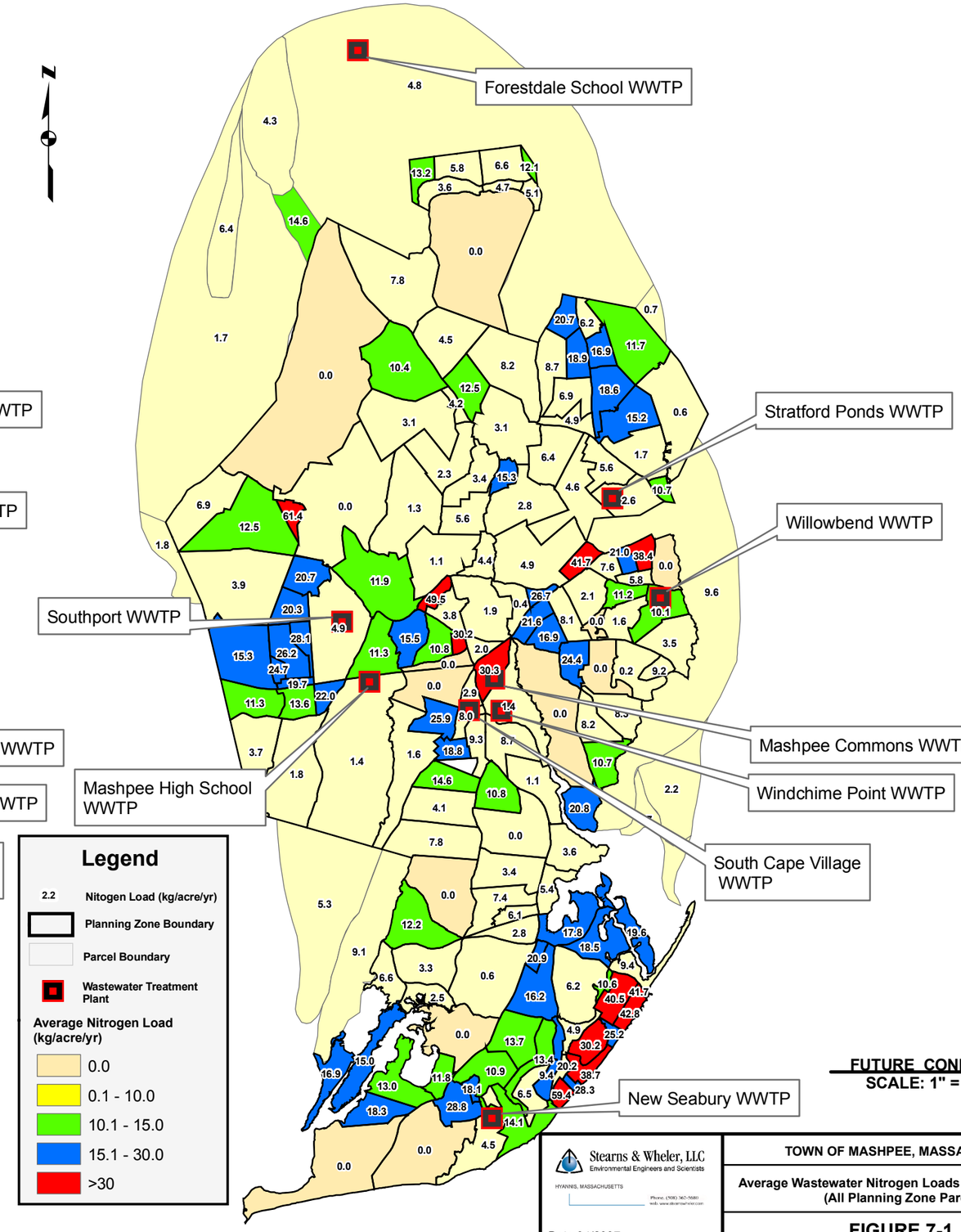
(2) Total wastewater load per year divided by total planning zone acreage.

D. Figure 7-2 – Wastewater Generator Loading Map

Figure 7-2 is a variation of the PZ Loading Map. However, the wastewater nitrogen load is divided by the total acreage of *only* the wastewater-generating parcels within a given PZ. For



EXISTING CONDITIONS
SCALE: 1" = 2,400'



FUTURE CONDITIONS
SCALE: 1" = 2,400'

Stearns & Wheler, LLC
Environmental Engineers and Scientists
HYANNIS, MASSACHUSETTS

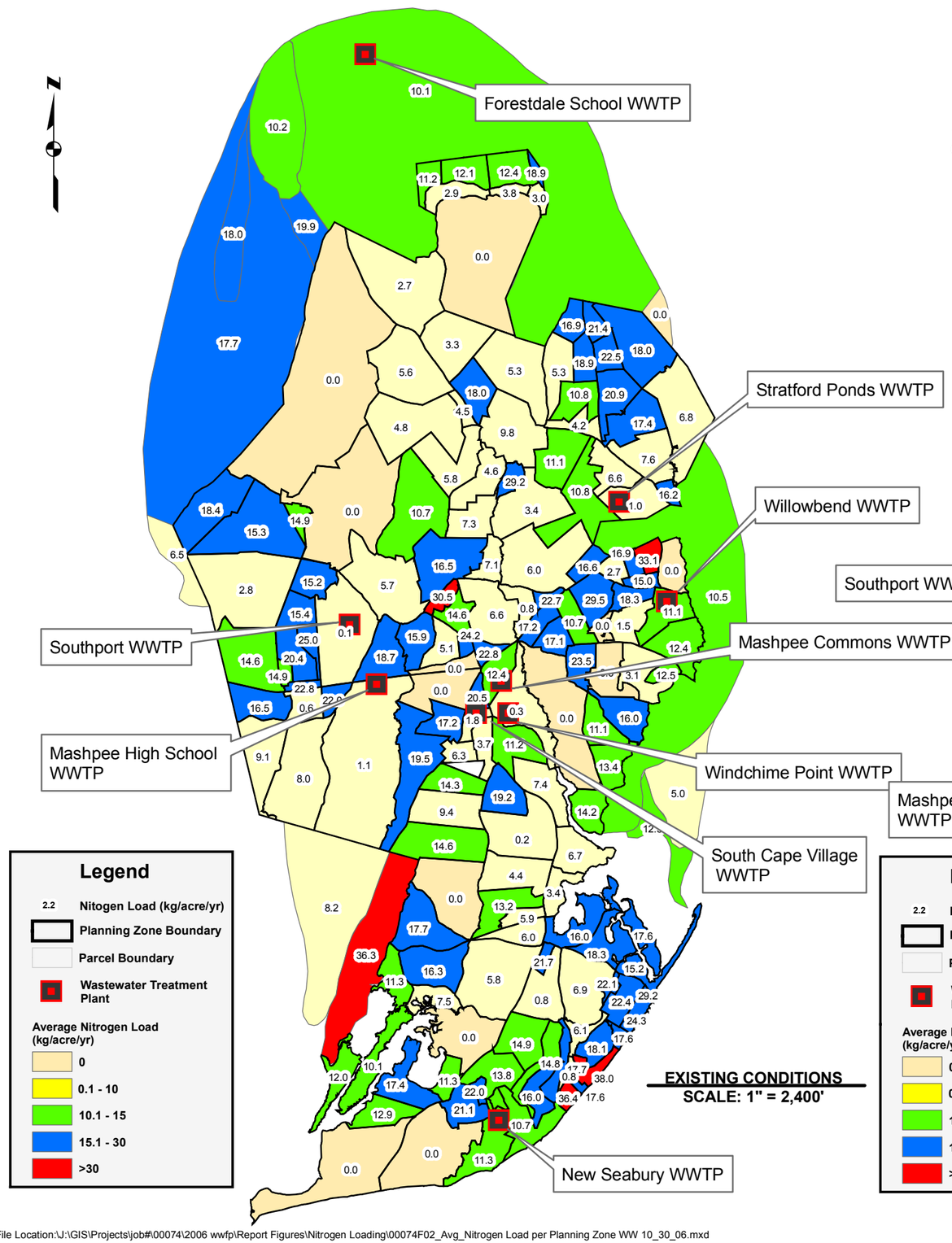
Date 04/2007

TOWN OF MASHPEE, MASSACHUSETTS

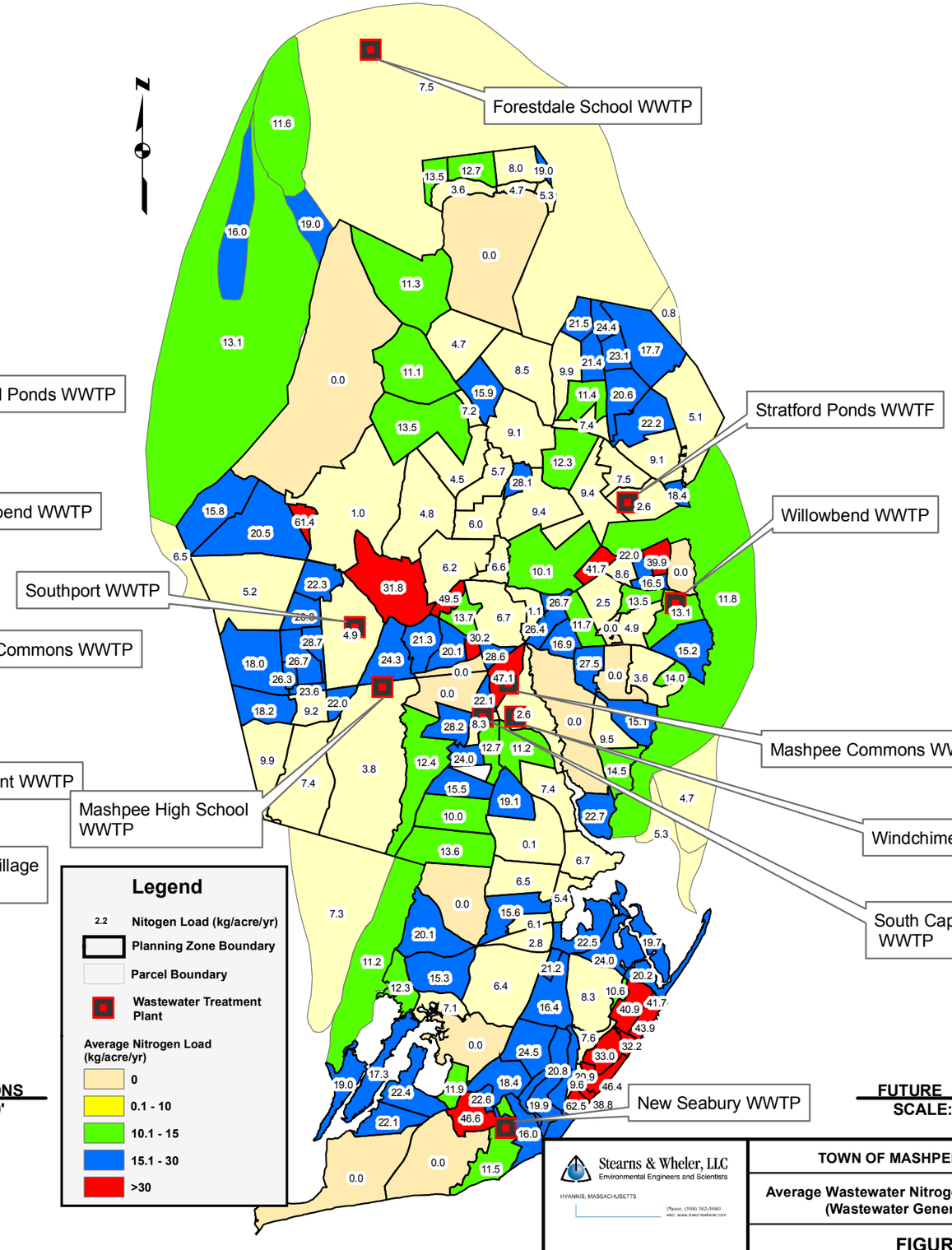
Average Wastewater Nitrogen Loads per Planning Zone
(All Planning Zone Parcels)

FIGURE 7-1

File Location:\J:\GIS\Projects\job#\00074\2006 wwfp\Report Figures\00074F07-1 Nitrogen Load per Planning Zone 11x17.mxd



EXISTING CONDITIONS
SCALE: 1" = 2,400'



FUTURE CONDITIONS
SCALE: 1" = 2,400'

Stearns & Wheler, LLC
Environmental Engineers and Scientists
HYANNIS, MASSACHUSETTS

TOWN OF MASHPEE, MASSACHUSETTS

Average Wastewater Nitrogen Loads per Planning Zone
(Wastewater Generating Parcels Only)

FIGURE 7-2

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example, a PZ may have a total of 100 acres, but there may be 50 acres of conservation land or other non-wastewater generating land in the PZ. Therefore, the nitrogen load per acre would be calculated by dividing the total nitrogen load by 50 acres (the wastewater nitrogen generating parcels) rather than the entire 100 acres.

This figure is also color coded to indicate PZs with high nitrogen loads. In addition to identifying PZs with high nitrogen loading, this figure will be used to identify which areas have or are projected to have dense development. Densely developed areas are typically the most cost-effective areas to consider for future sewering because larger numbers of homes can be connected while minimizing the total length of sewer.

In some PZs, the existing (developed) land use may not meet current zoning requirements and therefore the average nitrogen load per acre is relatively high. Future conditions are based upon full development of currently unoccupied lots and larger parcels that could be subdivided. It is presumed that the larger lots would be subdivided in conformance with existing zoning regulations. This would have the effect of lowering the average nitrogen loading per acre within the respective PZ.

For example, if a certain PZ has a total nitrogen load of 1000 kg/year and that nitrogen is generated by parcels totaling 100 acres, the average nitrogen load is 10 kg/acre/year. In the future, the total nitrogen load of that PZ may increase to 1200 kg/year, but the parcels to be developed in the future may be larger, resulting in a total area increase to 200 acres. This would result in a *decrease* in average nitrogen load to 6 kg/acre/year.

For most of the PZs that have a lower future average nitrogen load, the reason is that the average to-be-developed parcel size is generally larger than the average existing parcel size. For others, one high wastewater producer in the PZ (such as a hotel) may be counterbalanced by much smaller wastewater producers in the future, decreasing the average nitrogen load per acre.

The following table provides a breakdown of planning zones.

TABLE 7-6

SUMMARY OF WASTEWATER GENERATOR LOADING RATES[1]

Relative Loading[2]	**Number of PZs (Existing conditions)**	**Number of PZs (Future conditions)**
High (Red – more than 30 kg/acre/yr)	5	16
Medium-High (Blue – 15.1-30 kg/acre/yr)	60	62
Medium (Green – 10.1-15 kg/acre/yr)	38	26
Low (Yellow – less than 10 kg/acre/yr)	56	57
No Wastewater Nitrogen Load	14	12

(1) Wastewater nitrogen loads only.

(2) Total wastewater load per year divided by total acreage of wastewater generating parcels.

The following table illustrates the nitrogen load per acre that might be expected for some typical residential property sizes at various wastewater flows. This table illustrates the "sensitivity" of various sized parcels. For example, an average residential flow is 140 gpd. Based on the table, this can result in a relatively low loading rate on a two acre parcel to a much higher loading rate on a ¼ acre parcel.

TABLE 7-7

WASTEWATER NITROGEN LOADS FOR VARIOUS PARCELS (kg/acre/yr)

Wastewater Flow (gpd)	**Lot Size (Acre)**			
	1/4	**1/2**	**1**	**2**
50	9.7	4.8	2.4	1.2
100	19.4	9.7	4.8	2.4
150	**29.1**	14.5	7.3	3.6
300	58.1	**29.1**	14.5	7.3

Note: Colors correspond to loading range colors used in loading maps

1. Non-Wastewater Nitrogen Loads

Although wastewater is the primary source of nitrogen within a watershed, it is not the only source. Both the MEP and this WNMP considered the other primary contributors to nitrogen within a watershed – impervious surface runoff, direct precipitation, and lawn fertilizer.

Table 7-8 summarizes the factors used by both MEP and the WNMP for estimating non-wastewater nitrogen loads.

TABLE 7-8

NON-WASTEWATER NITROGEN SOURCES(1)

Nitrogen Source	Nitrogen Concentration or Load	Recharge Rate
Pavement Runoff	1.5 mg/L	40 in/year
Roof Runoff	0.75 mg/L	40 in/year
Precipitation to Natural Areas	0.072 mg/L	27.25 in/year
Lawn Fertilizer	0.49 kg/lawn(2)	NA

(1) From Table IV-4 of the MEP technical reports.

(2) MEP used 1.08 lb/lawn. The Nitrogen Load is shown as kg/lawn to correlate with the concentrations in mg/L.

Non-wastewater nitrogen loads were estimated on the planning zone level. For Mashpee and Falmouth parcels, GIS data was used to obtain road, driveway, sidewalk, parking, and roof areas. Lawn areas were estimated at 5,000 square feet of lawn per residential parcel, consistent with MEP. Golf courses were also identified due to the increased fertilization rates that are used on golf courses. Natural areas were accounted for by subtracting the total impervious surfaces and the total lawn/golf course areas from the total planning zone area. For the parcels in Sandwich and Barnstable (which had less GIS data available), the majority of the non-wastewater loads were estimated using the same methodology used by MEP – 5,000 square feet of lawn per residential parcel, 1,500 square feet of roof area per residential parcel, and 1,500 square feet of driveway area per residential parcel. The road areas for Sandwich and Barnstable were identified in the GIS files, which provided the area that was used for nitrogen loads resulting from paved roads.

The nitrogen concentrations and recharge rates, as listed above, were applied to obtain estimates of nitrogen loads (in kg/year) from each respective source. These nitrogen estimates were added to wastewater nitrogen to determine total nitrogen loads for each planning zone. To illustrate the predominance of wastewater nitrogen, the percent of total nitrogen load that comes from wastewater was calculated. Table 7-9 details the wastewater and non-wastewater nitrogen loads and the percentage of the nitrogen load that comes from wastewater. The analysis performed for this Report included the entire PPA, which includes portions of Towns outside of Mashpee.

TABLE 7-9

SUMMARY OF TOTAL NITROGEN LOADS PER TOWN(1)

Town	Wastewater Nitrogen Load (kg/yr)		Non-Wastewater Nitrogen Load (kg/yr)		Total Nitrogen Load (kg/yr)		% Wastewater Nitrogen Load(2)	
	Existing	Future	Existing	Future	Existing	Future	Existing	Future
Mashpee								
Waquoit Bay East	14,000	29,000	5,600	5,900	20,000	35,000	70%	83%
Popponesset Bay	28,000	41,000	7,700	8,100	36,000	50,000	78%	82%
Other	9,000	16,000	1,800	1,900	11,000	18,000	82%	89%
Total	51,000	87,000	15,000	16,000	66,000	100,000	77%	87%
Falmouth								
Waquoit Bay East	3,200	5,800	800	1,000	4,100	6,800	78%	85%
Sandwich								
Waquoit Bay East	4,500	5,400	1,200	1,300	5,700	6,700	79%	81%
Popponesset Bay	12,000	14,000	2,300	2,500	14,000	16,000	86%	88%
Barnstable								
Popponesset Bay	5,700	8,500	1,200	1,300	7,000	9,800	81%	87%

(1) The nitrogen loads presented in this table do not assume any natural attenuation. Wastewater nitrogen loads are based on septic system nitrogen concentrations of 35 mg/L. All numbers are rounded to two significant figures.

(2) Percent of total nitrogen load that comes from wastewater sources.

(3) Nitrogen loads were calculated as discussed in this chapter.

7.4 SUMMARY

The calculations performed as part of the WNMP were compared with the calculations performed for the MEP. The following table (Table 7-10) summarizes the daily nitrogen loads by subwatershed.

It can be seen from Table 7-10 that the results of the MEP analysis and this WNMP analysis, although when comparing the first two sets of numbers appear significantly different, are relatively close when the first and third sets of numbers are compared. The predominant reasons for the differences in nitrogen loads are the assumption of a nitrogen reduction in the septic system and natural attenuation through freshwater systems. Natural attenuation is important to consider when evaluating the health of water resources. However, natural attenuation is not considered for wastewater facility planning purposes. Natural attenuation would only be considered for on-site system treatment; when considering treatment at a facility requiring a Groundwater Discharge Permit, any facilities designed to treat wastewater nitrogen would need to account for all of the wastewater nitrogen that could be generated. The most significant differences between MEP and WNMP values are in the subwatersheds that receive groundwater flow from freshwater ponds. As discussed above, this is primarily due to the assumption of natural attenuation as septic system effluent flows through the ponds. This attenuation was not considered for either the WNMP analysis or the adjusted WNMP analysis (which only considered the 25% reduction of nitrogen from Title 5 septic systems).

As shown in Table 7-9, the predominant source of nitrogen is wastewater effluent. The percentage of nitrogen that comes from future wastewater ranges from 80% to 90%. These percentages are similar to the percentages obtained in MEP's analysis.

The percentages shown in Table 7-9 indicate the overwhelming need to address wastewater management issues, both within Mashpee and within surrounding towns.

TABLE 7-10

DAILY NITROGEN LOADS BY SUBWATERSHED

Subwatershed	**MEP Results[1]**		**WNMP Results[2,3]**		**Adjusted WNMP[3,4] Results**	
	Existing Load (kg/day)	Build-out Load (kg/day)	Existing Load (kg/day)	Build-out Load (kg/day)	Existing Load (kg/day)	Build-out Load (kg/day)
Popponesset Bay System						
Popponesset Bay	1.82	1.98	2.3	2.9	1.8	2.2
Popponesset Creek	4.94	5.35	6.3	9.1	4.9	7.1
Pinquickset Cove	0.76	0.98	1.1	1.6	0.9	1.3
Ockway Bay	3.15	4.25	4.1	7.4	3.3	5.7
Mashpee River[5,6]	27.67	54.2	75	110	59	87
Shoestring Bay[7]	30.77	39.55	38	55	30	43
Waquoit Bay System						
Hamblin Pond[8]	9.26	14.23	16	27	13	21
Jehu Pond[9]	8.35	10.23	10	15	7.7	12
Quashnet River[5, 10]	25.95	50.74	41	73	33	57

Notes:

(1) Total Nitrogen loads (all sources) from MEP reports (Table VI-4 of MEP's *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts*, September 2004 and Table VI-5 of MEP's *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Quashnet River, Hamblin Pond, and Jehu Pond in the Waquoit Bay System of the Towns of Mashpee and Falmouth, MA*, January 2005). Natural attenuation is considered for septic loads, meaning that these calculations assumed a wastewater nitrogen concentration of 26.25 mg/L.

(2) Total Nitrogen loads (all sources) from WNMP analysis. Nitrogen reduction in the septic system is not considered for septic loads, meaning that these calculations assumed a wastewater nitrogen concentration of 35 mg/L. WNMP analysis did not split parcels in the same manner that the MEP analysis did. WNMP analysis did not subtract public water supply withdrawals from the total nitrogen loads.

(3) All WNMP figures are rounded to two significant figures.

(4) The WNMP figures were adjusted *for comparison purposes only* by reducing the wastewater nitrogen load by 25% (from 35 mg/L to 26.25 mg/L) and leaving all other loads the same.

(5) This subwatershed includes freshwater subwatersheds. MEP values include attenuation as groundwater flows through the freshwater system. WNMP calculations are higher because they did not include any attenuation resulting from flow through the freshwater system, which likely accounts for the large discrepancy in nitrogen loads.

(6) Includes surface water loads from Mashpee River.

(7) Includes surface water loads from Santuit River and Quaker Run River.

(8) Includes subembayments of Red Brook, Upper Hamblin Pond, and Hamblin Pond.

(9) Includes subembayments of Little River, Upper Great River, Lower Great River, and Jehu Pond.

(10) Includes subembayments of Moonakis River, Upper Quashnet River, and Lower Quashnet River.