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North Coast Region
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Edmund G. Brown Jr.
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MEMORANDUM

Date: May 22, 2012

To: File: Laguna de Santa Rosa; TMDL Development and Planning

From: Steve Butkus

Subject: Assessment of the Total Nitrogen and Ammonia Nitrogen Goals from the 1995 Laguna TMDL

In 1995, a TMDL addressing nitrogen, ammonia, and dissolved oxygen in the Laguna was completed by the North Coast regional Water Quality Control Board (Regional Water Board) (Morris, 1995). The TMDL took the form of the *Waste Reduction Strategy for the Laguna de Santa Rosa* (Waste Reduction Strategy) and it addressed the reduction of nitrogen loading from point and nonpoint sources.

The 1995 TMDL established both concentration-based and mass-based loading capacities and seasonal allocations for both total nitrogen (TN) and total ammonia-N (NH_3-N). Excessive nitrogen loading can contribute to instream toxicity through conversion to the ammonia form of nitrogen. The term total nitrogen includes all forms of nitrogen: nitrate, nitrite, ammonia, and organic. Ammonia-nitrogen, a major component of the nitrogen cycle, is formed by chemical and bacterial decomposition or breakdown of animal wastes, principally urea and other protein-bearing materials. The purpose of this memorandum is to assess the attainment of the loading capacities and seasonal allocations established in the 1995 TMDL.

The 1995 TMDL relied on the USEPA's 1986 published criteria of unionized ammonia to protect against instream ammonia toxicity to freshwater aquatic life. In 1999, the USEPA revised the criteria, including the acute instream toxicity criterion, in order to address important technical issues identified with the original ammonia criteria development document. The change in the criteria has a significant effect on the interpretation of standard obtainment. However, the 1995 TMDL goals were not revised and remain as thresholds for data comparison.

TMDL Concentration-based Goals

The 1995 TMDL assumed critical temperature and pH values with the 1986 criteria to derive acute total ammonia toxicity criterion of 0.5 mg-N/L (Morris 1995). The NH_3-N acute criterion was converted to TN concentration limits based on an estimate of the percent of total NH_3-N in TN. The TMDL estimated that 13% of TN was in the form of total NH_3-N. Therefore, the TMDL established a TN concentration limit of 3.7 mg-N/L.

Water quality data from the following studies were collected over time from numerous agencies and compiled for analysis: Otis (1990), NCRWQCB (1992), Church and Zabinsky (2005), Sloop et al. (2007), and NCRQWCB (2008). The concentration data were compiled from 1989 through 2008.

The percentages of samples that did not meet the TMDL concentration goals were compiled for all four TMDL attainment locations and analyzed into three time periods (Tables 1 and 2):

- 1985 to 1994: This period represents the Laguna prior to the implementation of the Waste Reduction Strategy
- 1995 to 2000: Monitoring during this period captures the effect of operational improvements at the City of Santa Rosa's Laguna Wastewater Treatment Plant and improvements in waste storage and disposal activities at local dairies
- 2001 to 2010: During this period implementation of the Waste Reduction Strategy continued in a scaled-down fashion.

Comparisons of the percentage of samples not meeting the TMDL goal are presented in Figures 1 and 2. The period of time of the TMDL implementation (i.e., 1995-2000) showed a smaller goal exceedance rate than the pre-TMDL and post-TMDL periods for both total ammonia-N and total nitrogen concentration goals.

TMDL Mass-based Loading Goals

The 1995 TMDL estimated flow at four Laguna locations and applied the concentration-based limits to derive seasonal (i.e., quarterly) TN and NH_3-N mass-based loading capacities. To assess attainment of the TMDL loading goals, monthly loads were estimated from the concentration data and daily stream flow data at each ambient load attainment location using the USGS computer program LOADEST (Runkel et al. 2004). LOAD ESTimator (LOADEST) is a FORTRAN program for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables, and constituent concentration, LOADEST assists the user in developing a regression model for the estimation of constituent load (i.e, model calibration). The formulated regression model then is used to estimate loads over a user-specified time interval. The computer program was calibrated to select the "best" model based on the specified selection statistics. A review of the residuals from the selected model showed they were not normally distributed. Therefore, the Least Absolute Deviation (LAD) estimation method was selected for applying the LOADEST program.

Stream flow data are needed to compute loads. Stream flow data were not available for each location over the full period of time that concentration data exist. For these periods, stream flows were estimated through a relationship with the downstream stream flow gage on the Russian River near Guerneville (USGS Gage# 11467000), which has a long, unbroken period of record. The U.S. Geological Survey (USGS) only operates a stage gage at the Laguna location at Guerneville Road and no stream flow data are available. Flows at the Guerneville Road site were derived from combining the stream flow data from the two upstream gages (USGS Gages# 11465750 and 11466320) plus the area-weighted fraction of stream flow from the local drainage (0.2% of flow at USGS Gage# 11465750).

Daily mean stream flow data for each site were paired with flow data from the Russian River gage. The data were natural log-transformed and Pearson linear regression was conducted (Zar, 1984). All regressions were statistically significant and the percent explained variances from the regressions are shown in Table 3. Daily mean stream flow values predicted from the regression models were merged with measured values for a continuous daily flow record for each site from 1990-2008.

The estimated monthly mean ambient loads from the LOADEST Program were combined into the seasonal categories used for the TMDL loading goals (i.e., Winter: December-March; Spring: April-May; Summer: June-September; Fall: October-November). The derived seasonal ambient loads were compared to the TMDL loading goals. Figures 3 – 34 present the estimated annual seasonal total ammonia-N and total nitrogen loads compared to the seasonal TMDL loading goals for each attainment location. Figures 35 and 36 show the estimated annual total ammonia-N loads and total nitrogen compared to the seasonal TMDL loading goals for all seasons and attainment locations combined. A change in loading over time due to TMDL implementation was not visually apparent.

The percentages of time that the TMDL loading goals were not met were compiled for all four TMDL attainment locations into three time periods (Tables 4 and 5):

- 1985 to 1994: This period represents the Laguna prior to the implementation of the Waste Reduction Strategy
- 1995 to 2000: Monitoring during this period captures the effect of operational improvements at the City of Santa Rosa’s Laguna Wastewater Treatment Plant and improvements in waste storage and disposal activities at local dairies
- 2001 to 2010: During this period implementation of the Waste Reduction Strategy continued in a scaled-down fashion.

A comparison of the percent of the time the estimated seasonal load exceeds the TMDL loading goal are presented in Figures 37 and 38. The percentage of seasons that the TMDL loading goals were not met ranged between 10%-70%. The period of time of the TMDL implementation (i.e., 1995-2000) showed a greater goal exceedance rate than the pre-TMDL and post-TMDL periods for both total ammonia-N and total nitrogen loading goals. This is due to higher relative stream flows during that the period (Figure 39). Note that the TMDL goals were not formally established until 1995.

Goal Attainment Trends

Since the TMDL goals were not formally established until 1995, the question arises whether the observed loading and rate of exceeding the TMDL goals has changed over time. The estimated monthly ambient loads from the four attainment locations were assessed using the Seasonal Kendall test for trend (Helsel et al. 2006). This test has since become the most frequently used test for trend in the environmental sciences and has been applied to a variety of media at many different locations. The advantages of using the Seasonal Kendall trend test is that it is a rank-based procedure especially suitable for data that are not normally distributed, data showing seasonality, censored data, and data containing outliers and non-linear trends.

The results of the loading trend tests are shown in Table 6 and presented in Figures 40 – 47. All Laguna TMDL attainment locations show increases over time in both total nitrogen and ammonia-N estimated monthly loads. However, these increasing slopes do not represent statistically significant ($\alpha \leq 0.05$) increasing trends due to the large variability between the monthly load values.

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TABLES

Table 1. Percentage of Samples that did not meet the TMDL Goal for Total Ammonia-N Concentration.

Attainment Location	Total Ammonia-N TMDL Concentration Goals Not Met (%)			
	1990 - 1994	1995-2000	2001-2008	1990 - 2008
Stony Point Road	12%	7%	18%	7%
Occidental Road	43%	11%	40%	22%
Guerneville Road	-	7%	0%	7%
Trenton-Healdsburg Road	0%	3%	0%	3%
All Locations Combined	18%	7%	16%	10%

Table 2. Percentage of Samples that did not meet the TMDL Goal for Total Nitrogen Concentration.

Attainment Location	Total Nitrogen TMDL Concentration Goals Not Met (%)			
	1990 - 1994	1995-2000	2001-2008	1990 - 2008
Stony Point Road	10%	4%	14%	7%
Occidental Road	71%	22%	na	42%
Guerneville Road	na	4%	na	4%
Trenton-Healdsburg Road	na	6%	0%	5%
All Locations Combined	41%	9%	9%	16%

na – sampling data not available

Table 3. Explained Variance of Flow Prediction Models

Location	USGS Gage ID	Explained Variance
Laguna at Trenton-Healdsburg Road	11465750	78%
Laguna at Occidental Road	11465750	79%
Laguna at Stony Point Road	11465680	80%
Santa Rosa Creek at Willowside Road	11466320	86%

Table 4. Percentage of Time TMDL Goals for Total Ammonia-N Seasonal Loads were not Met.

Attainment Location	Total Ammonia TMDL Loading Goals Not Met (%)			
	1990 - 1994	1995-2000	2001-2008	1990 - 2008
Stony Point Road	50%	63%	59%	58%
Occidental Road	25%	26%	38%	37%
Guerneville Road	5%	29%	22%	20%
Trenton-Healdsburg Road	5%	33%	22%	21%
All Locations Combined	15%	42%	34%	33%

Table 5. Percentage of Time TMDL Goals for Total Nitrogen Seasonal Loads were not Met.

Attainment Location	Total Nitrogen TMDL Loading Goals Not Met (%)			
	1990 - 1994	1995-2000	2001-2008	1990 - 2008
Stony Point Road	14%	60%	44%	40%
Occidental Road	38%	70%	47%	51%
Guerneville Road	38%	60%	17%	34%
Trenton-Healdsburg Road	29%	50%	11%	26%
All Locations Combined	30%	60%	30%	38%

Table 6. Trends in Total Ammonia-N and Total Nitrogen Loads at TMDL Attainment Locations

Attainment Location	Total Ammonia-N TMDL Load Goal		Total Nitrogen TMDL Load Goal	
	Probability	Slope	Probability	Slope
Stony Point Road	0.44	increasing	0.46	increasing
Occidental Road	0.49	increasing	0.49	increasing
Guerneville Road	0.45	increasing	0.53	increasing
Trenton-Healdsburg Road	0.88	increasing	0.85	increasing

FIGURES

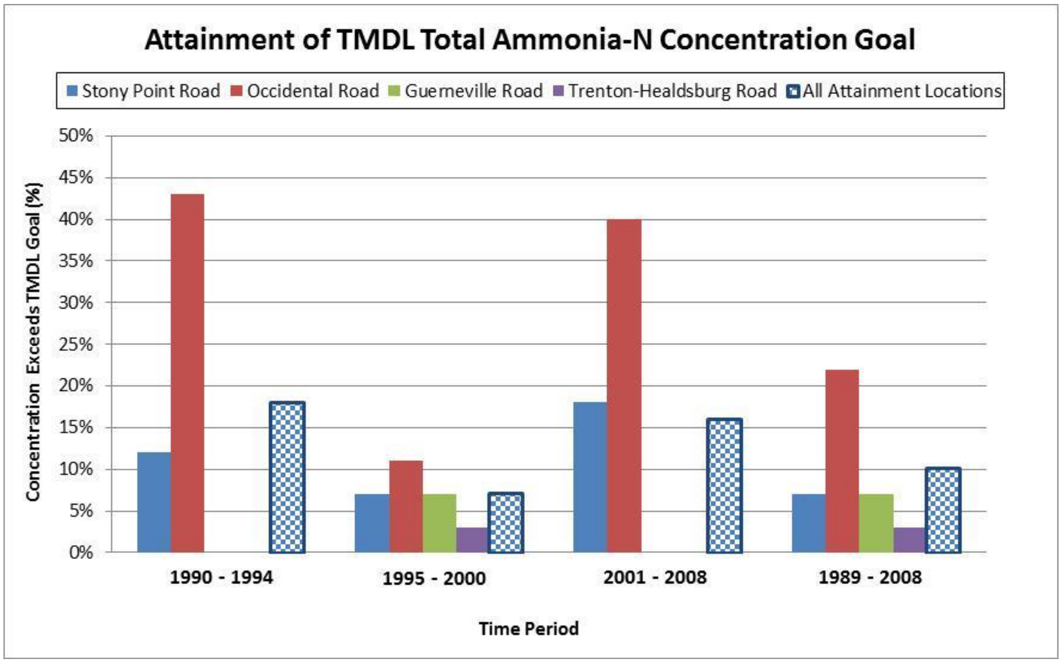

Figure 1. Attainment of Total Ammonia-N TMDL Concentration Goal by Time Period

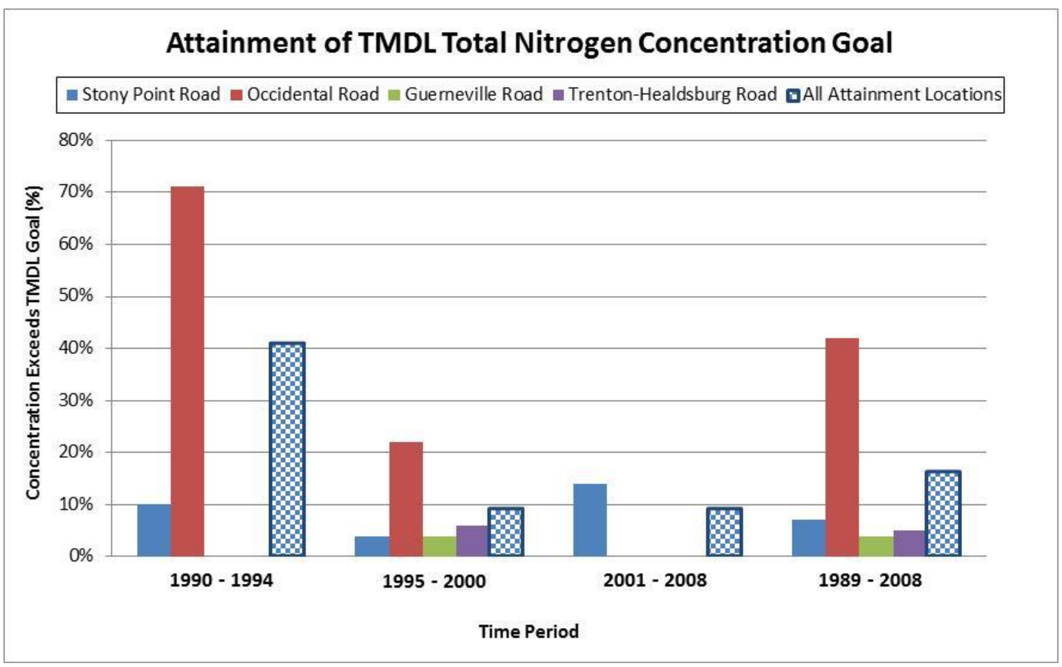

Figure 2. Attainment of Total Nitrogen TMDL Concentration Goal by Time Period

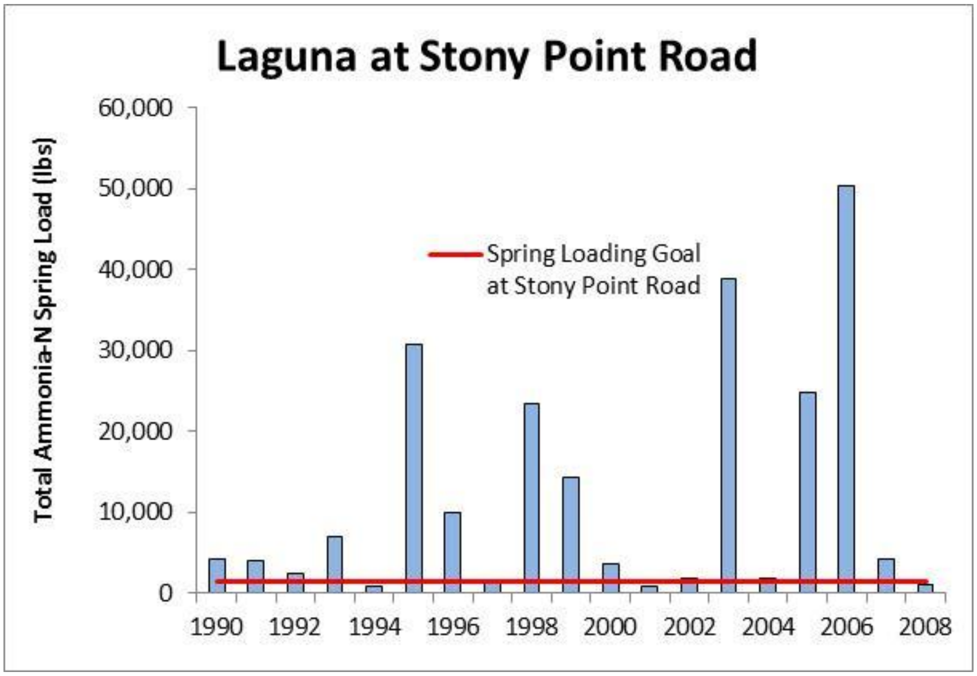

Figure 3. Spring Total Ammonia-N Loads at Stony Point Road

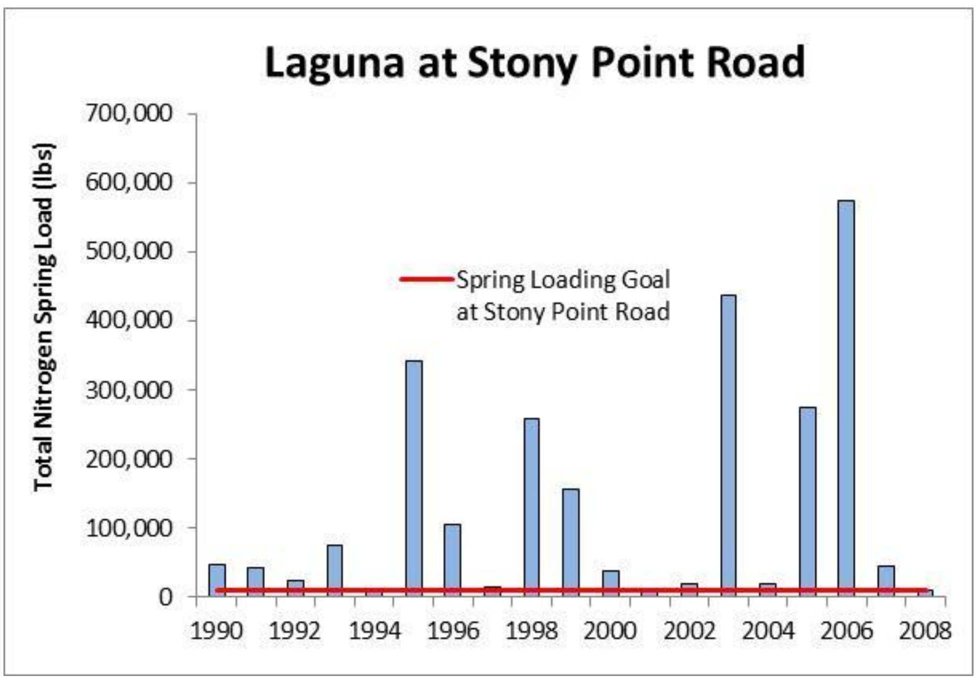

Figure 4. Spring Total Nitrogen Loads at Stony Point Road

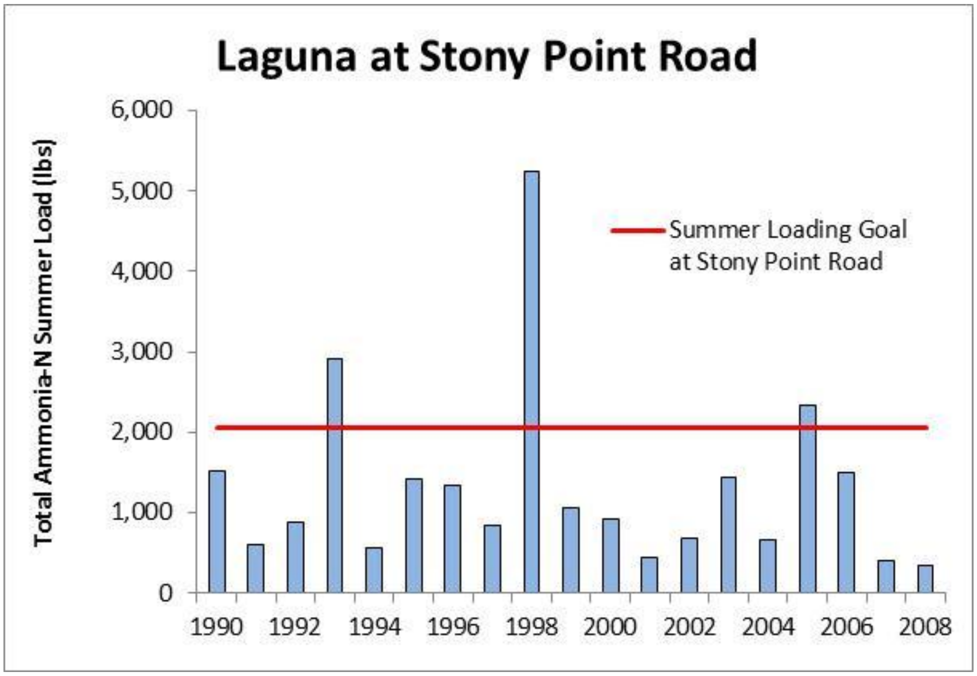

Figure 5. Summer Total Ammonia-N Loads at Stony Point Road

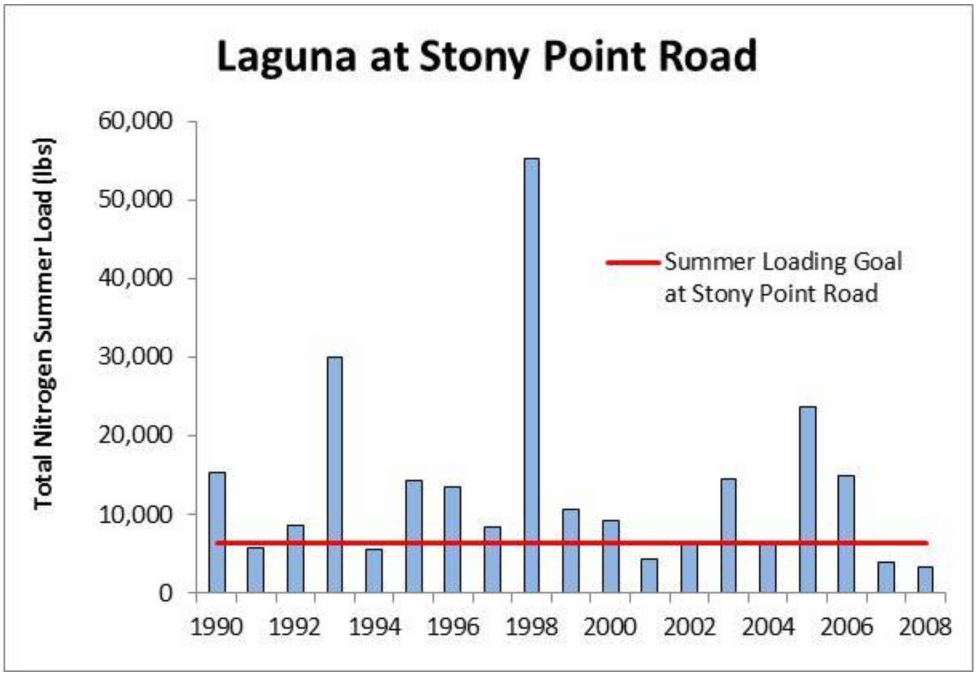

Figure 6. Summer Total Nitrogen Loads at Stony Point Road

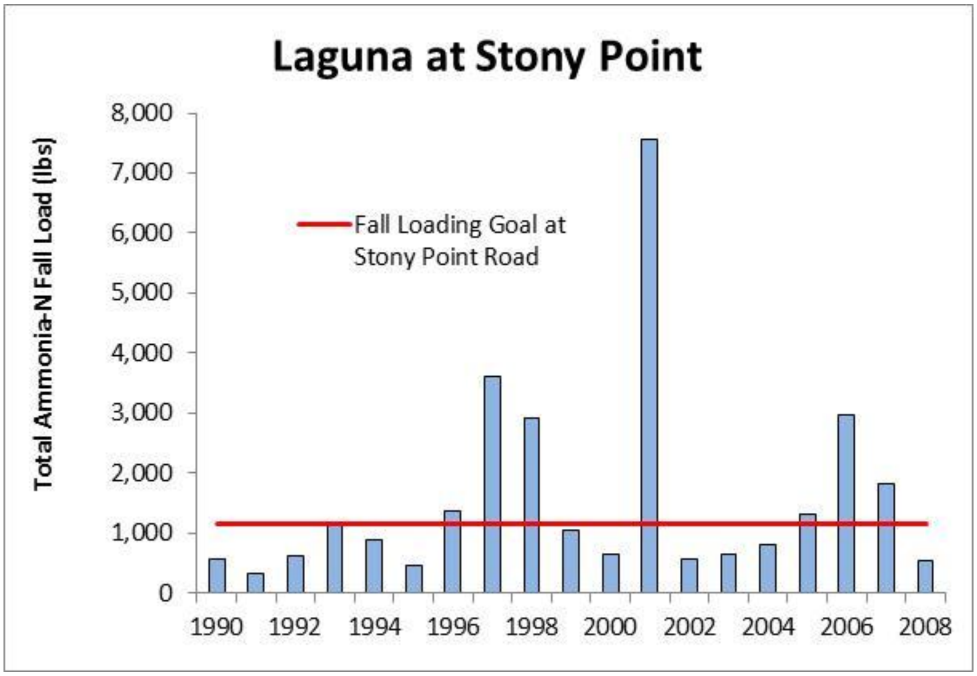

Figure 7. Fall Total Ammonia-N Loads at Stony Point Road

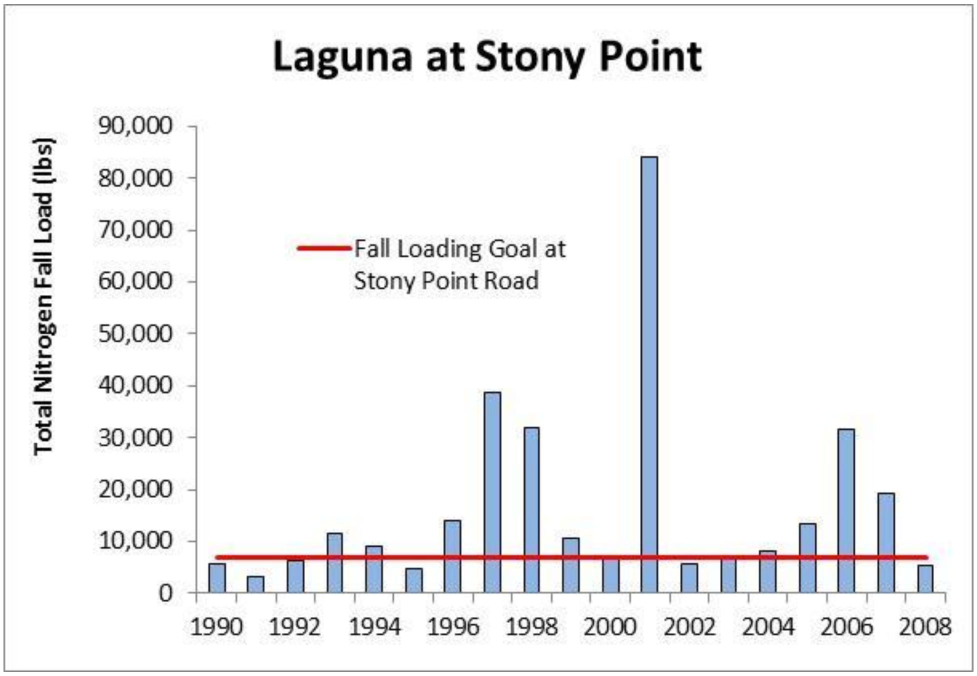

Figure 8. Fall Total Nitrogen Loads at Stony Point Road

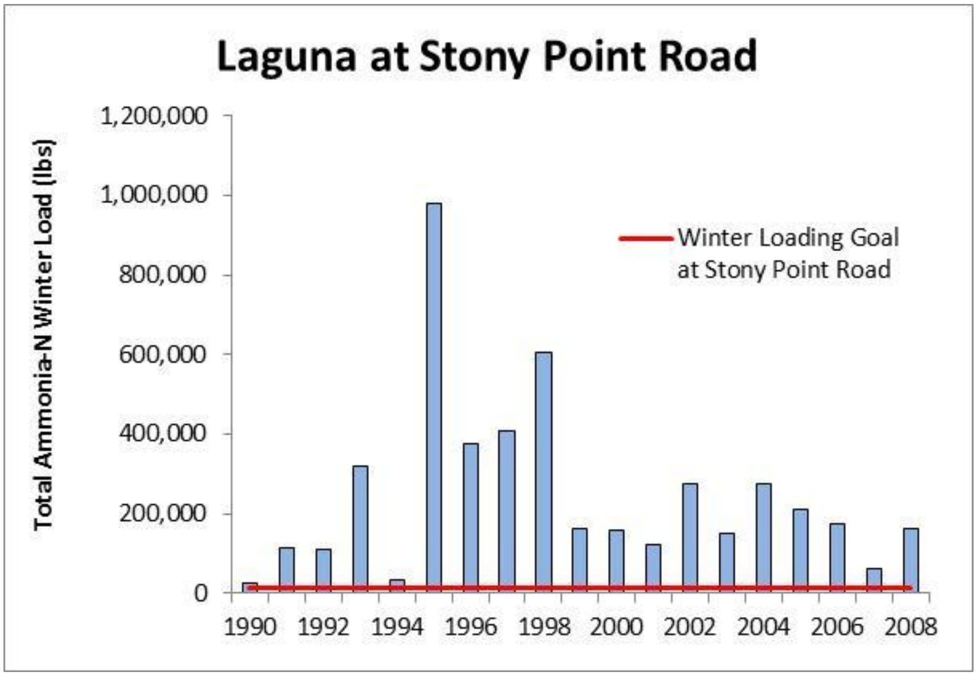

Figure 9. Winter Total Ammonia-N Loads at Stony Point Road

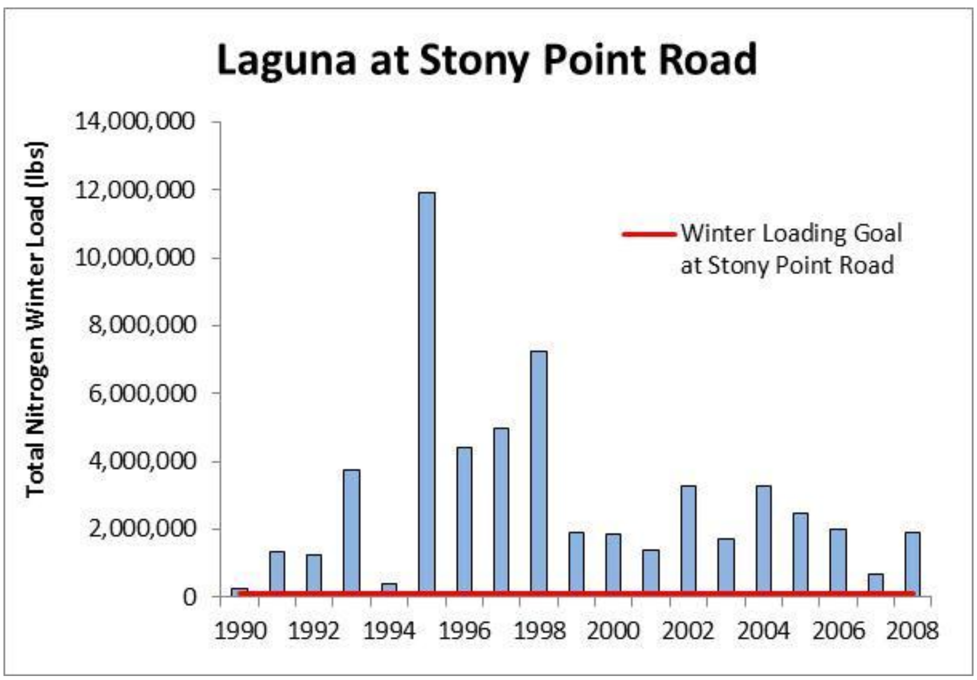

Figure 10. Winter Total Nitrogen Loads at Stony Point Road

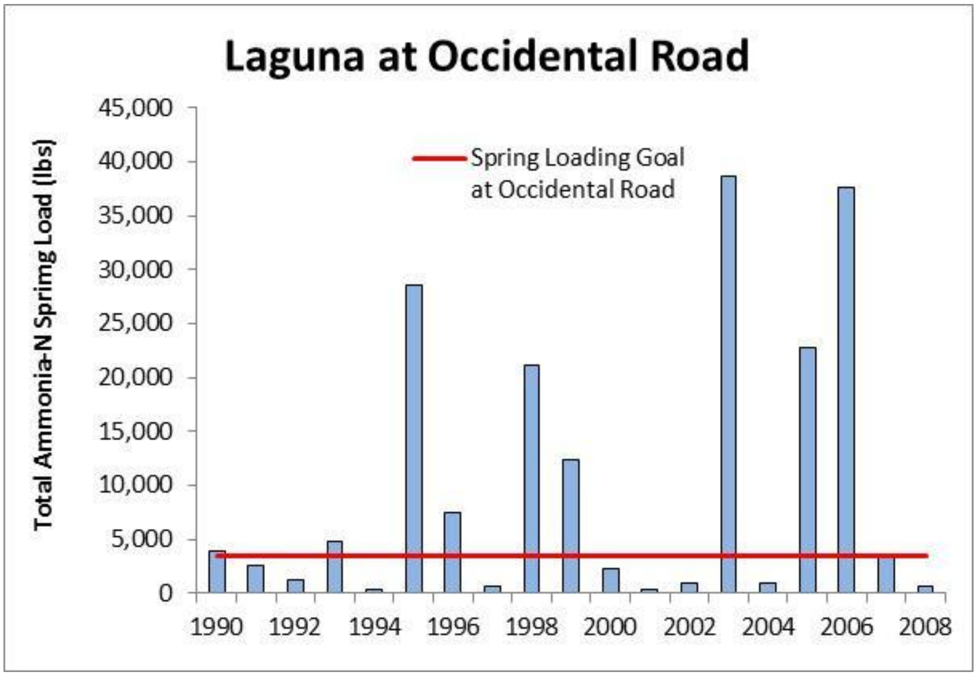

Figure 11. Spring Total Ammonia-N Loads at Occidental Road

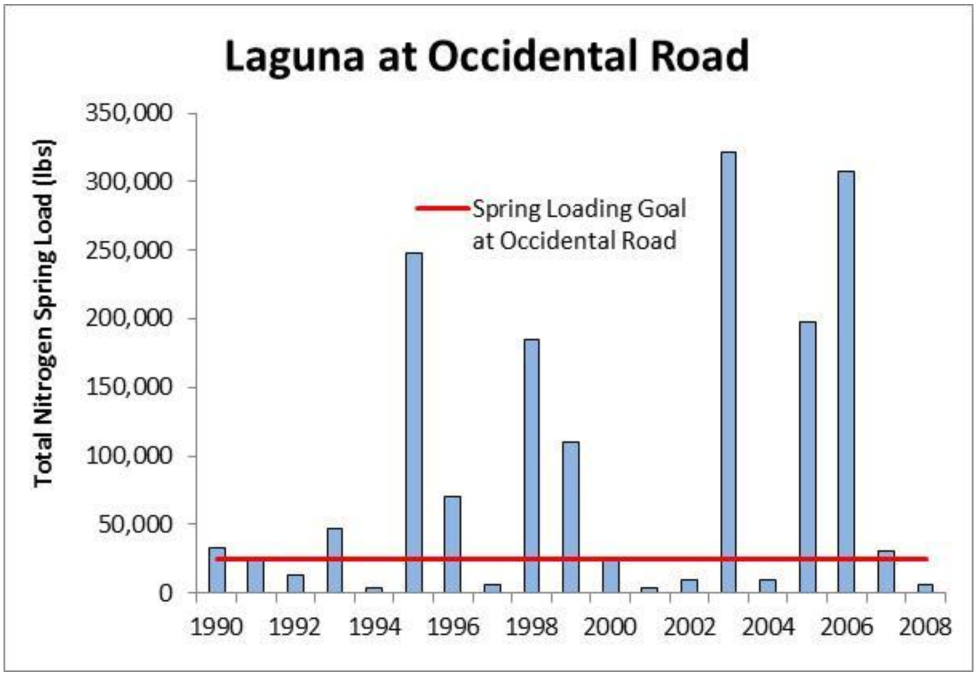

Figure 12. Spring Total Nitrogen Loads at Occidental Road

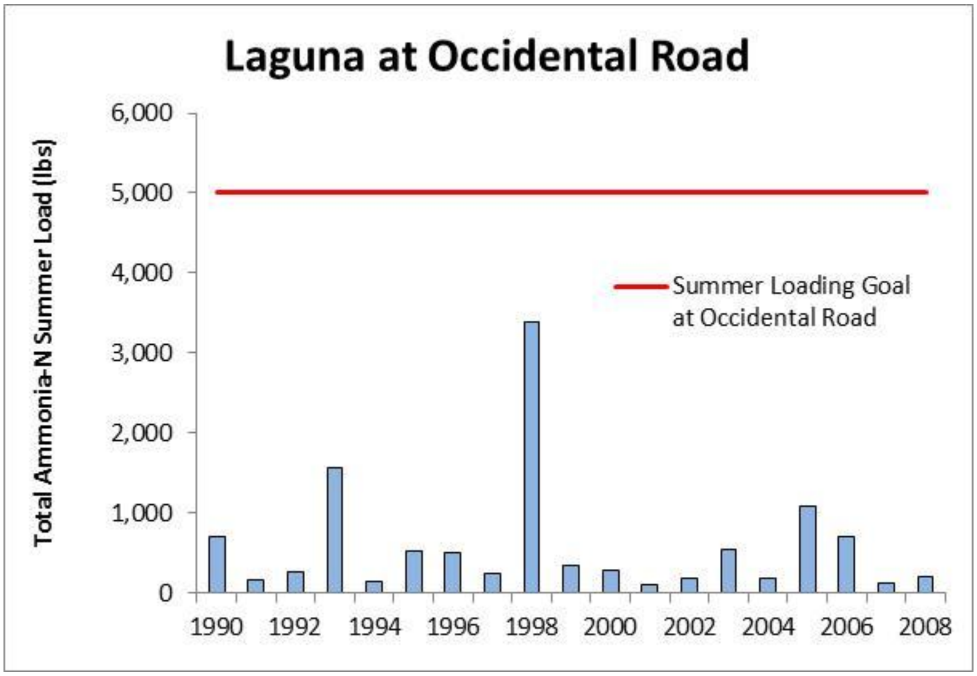

Figure 13. Summer Total Ammonia-N Loads at Occidental Road

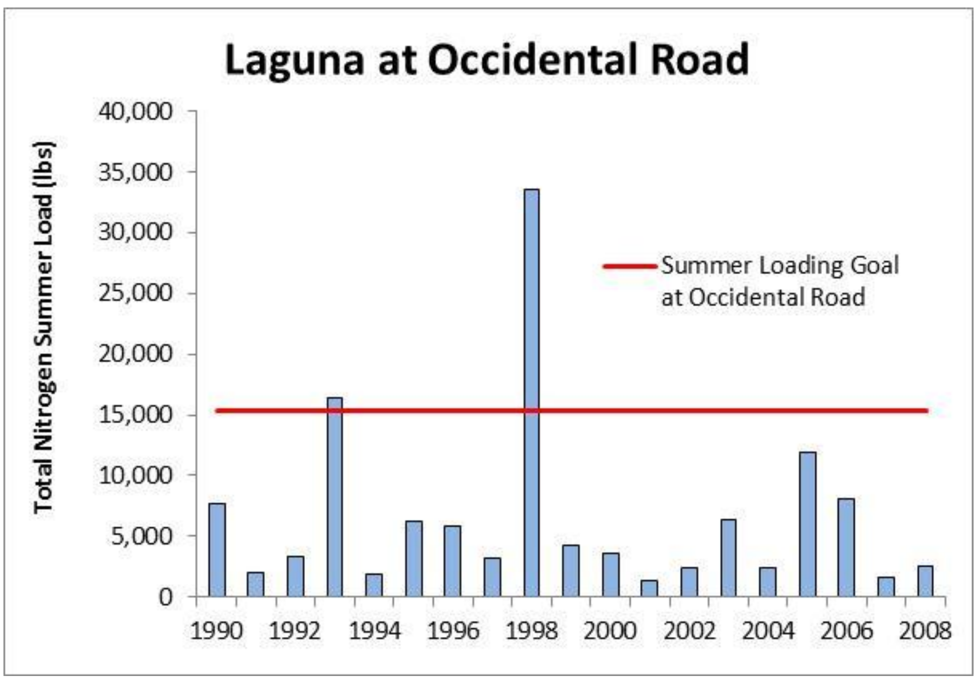

Figure 14. Summer Total Nitrogen Loads at Occidental Road

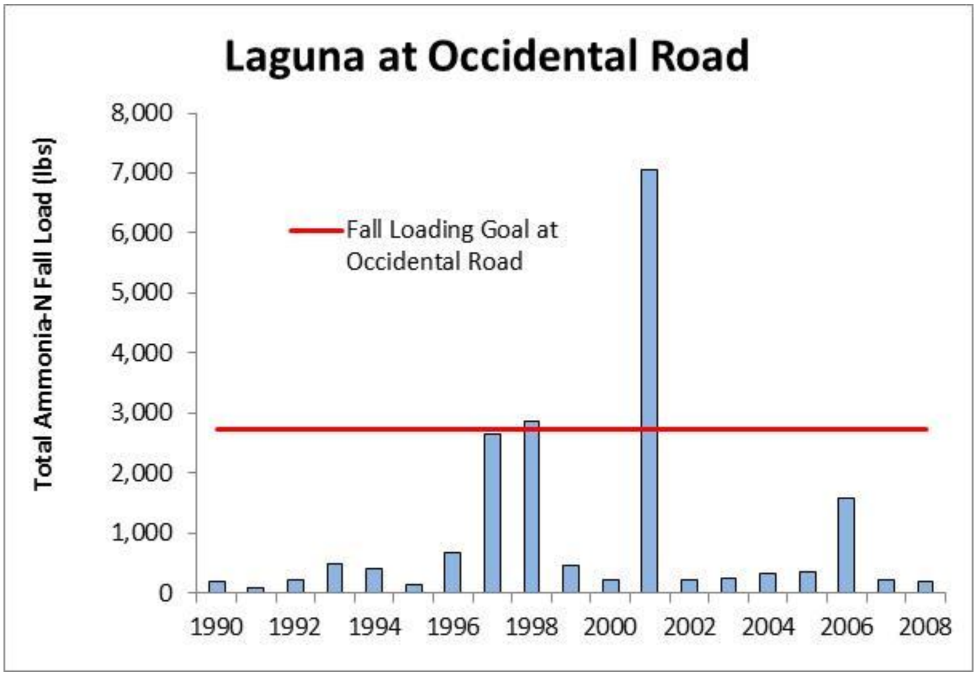

Figure 15. Fall Total Ammonia-N Loads at Occidental Road

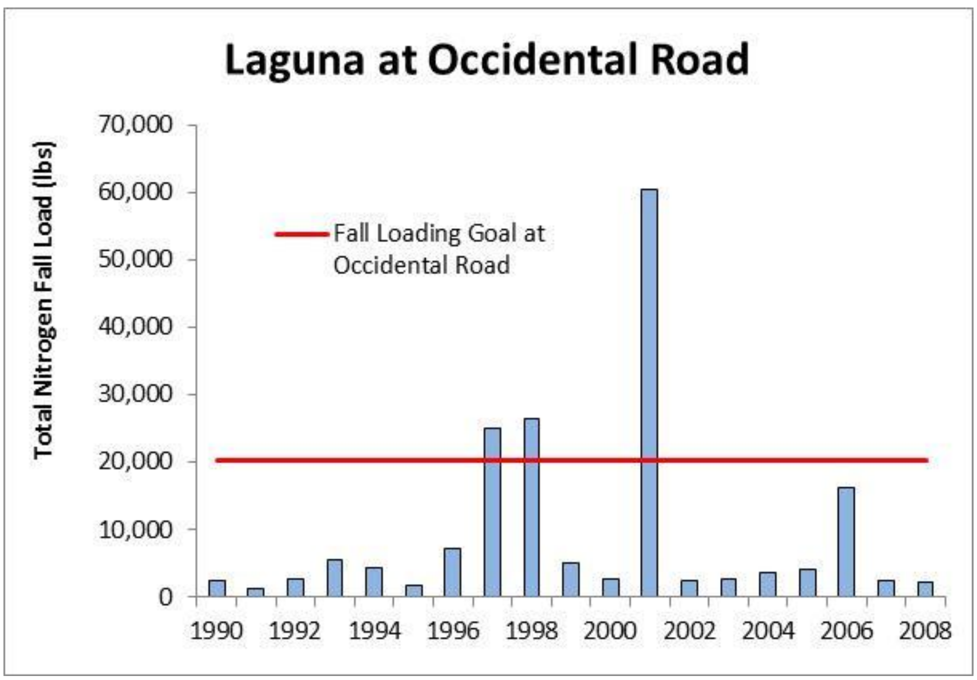

Figure 16. Fall Total Nitrogen Loads at Occidental Road

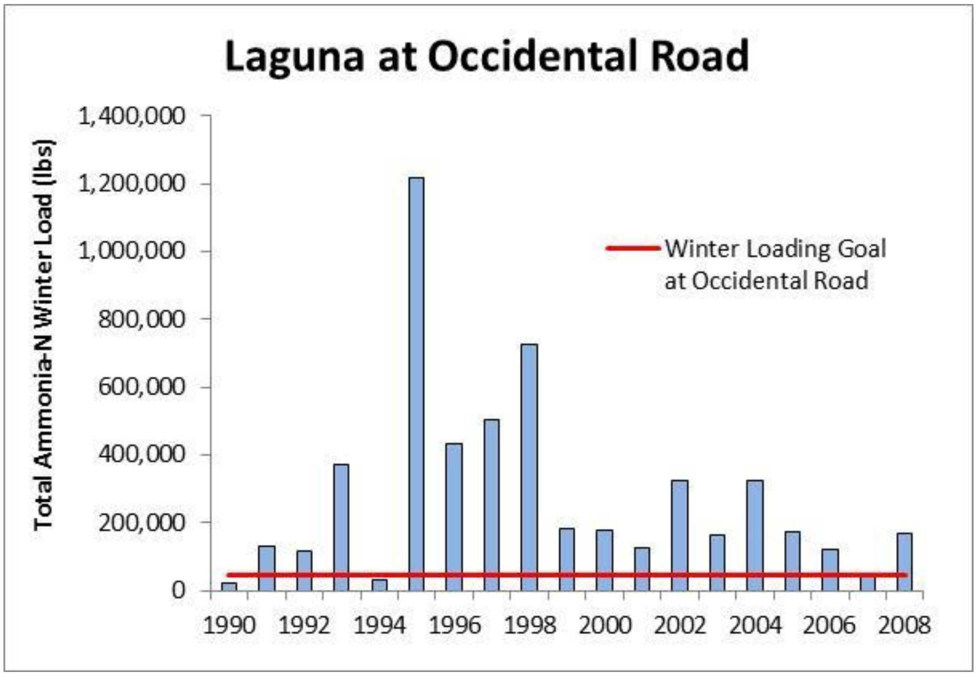

Figure 17. Winter Total Ammonia-N Loads at Occidental Road

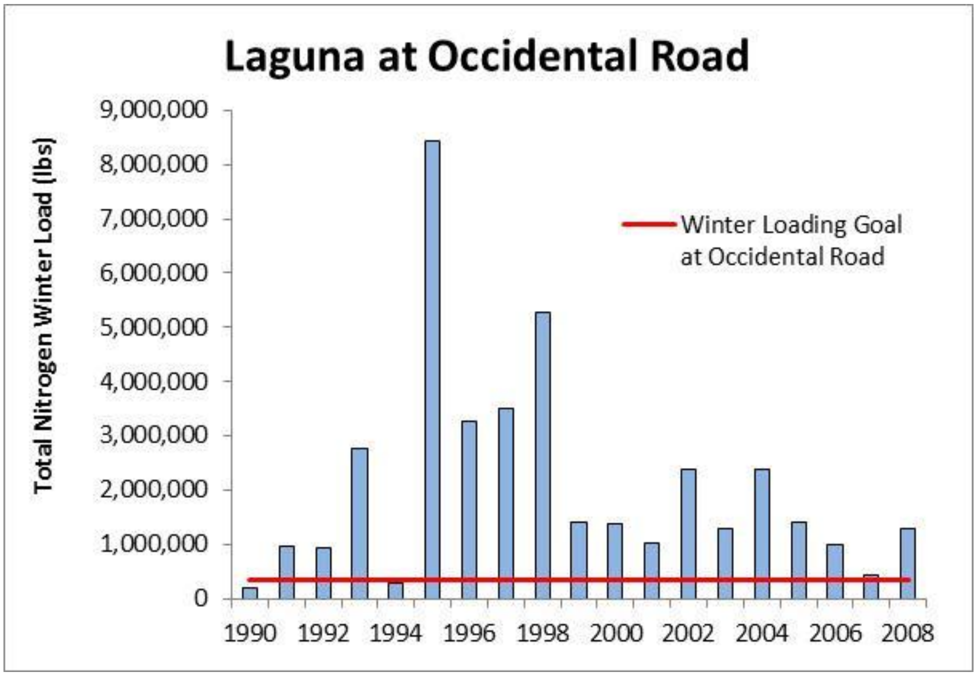

Figure 18. Winter Total Nitrogen Loads at Occidental Road

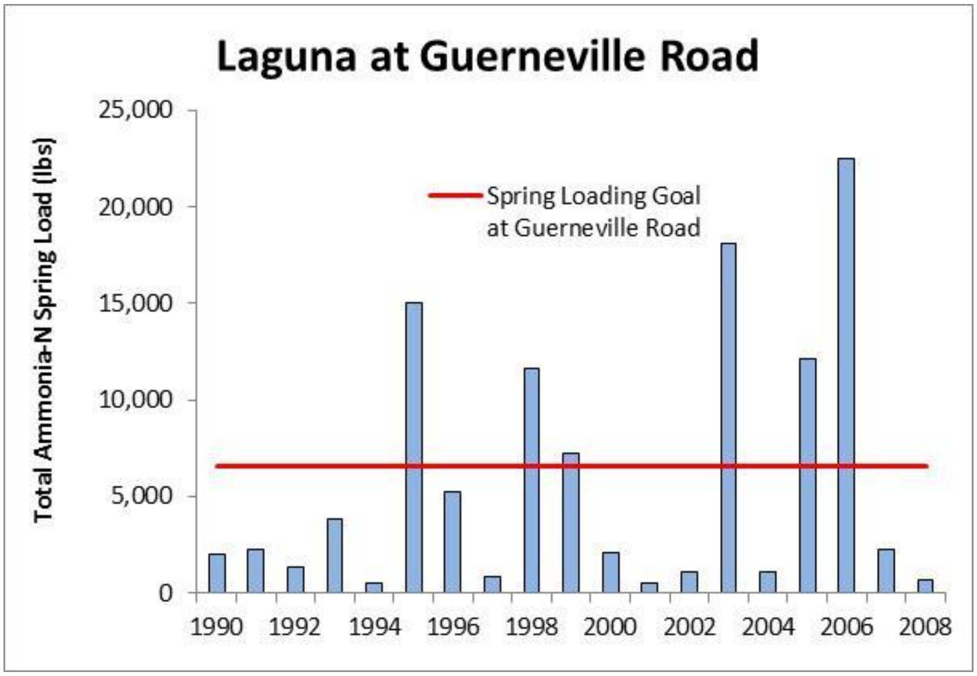

Figure 19. Spring Total Ammonia-N Loads at Guerneville Road

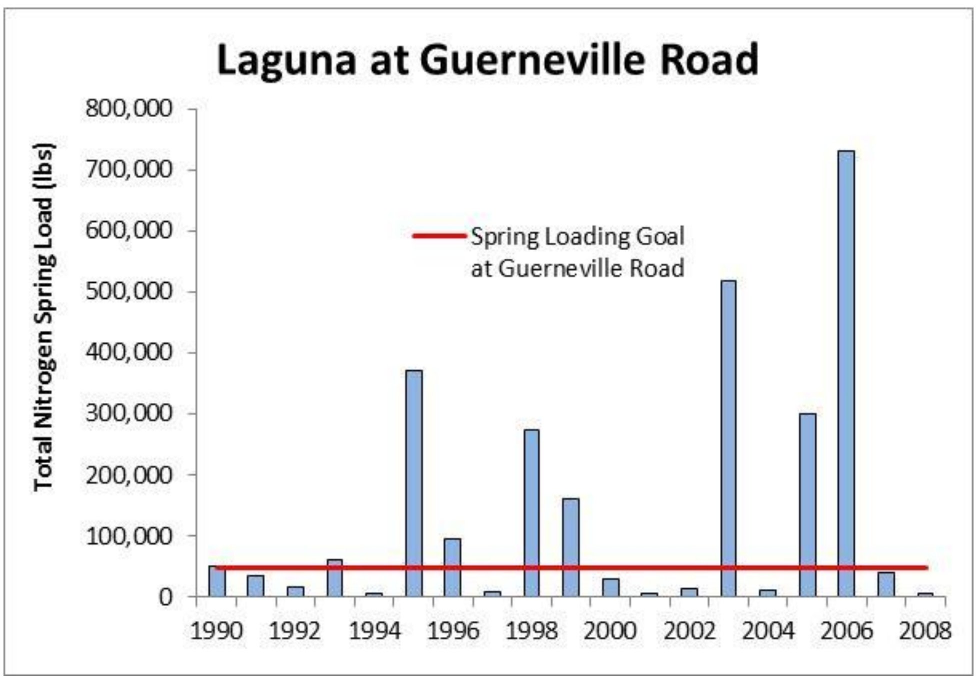

Figure 20. Spring Total Nitrogen Loads at Guerneville Road

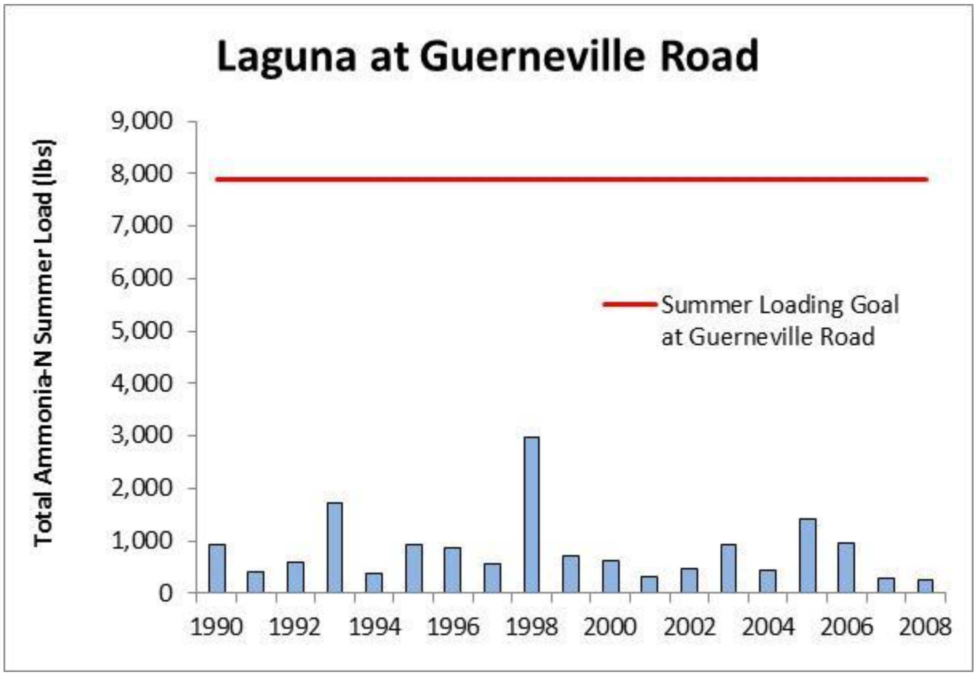

Figure 21. Summer Total Ammonia-N Loads at Guerneville Road

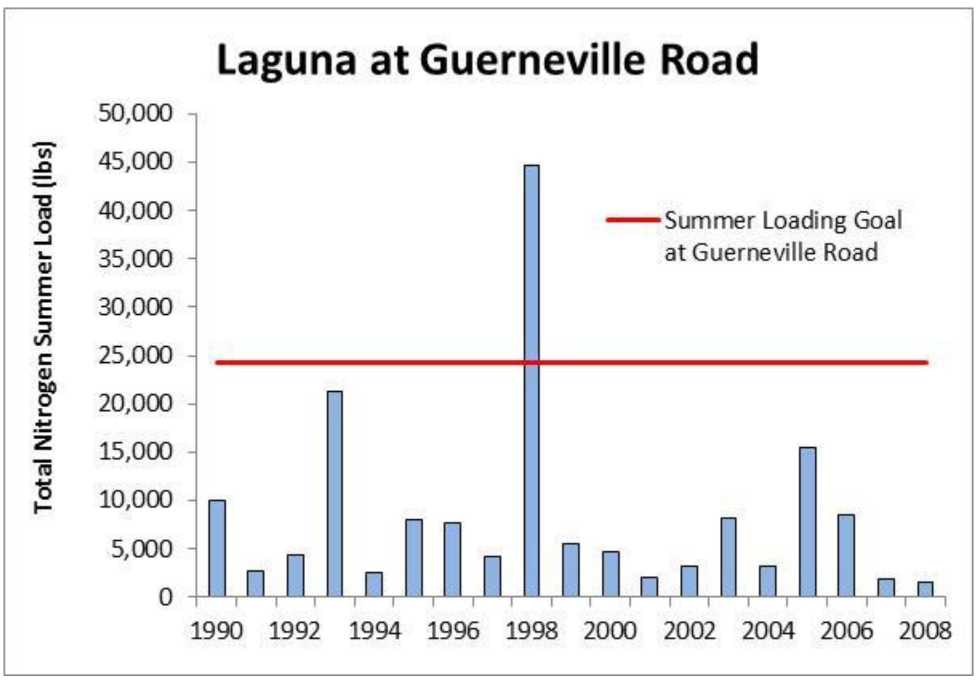

Figure 22. Summer Total Nitrogen Loads at Guerneville Road

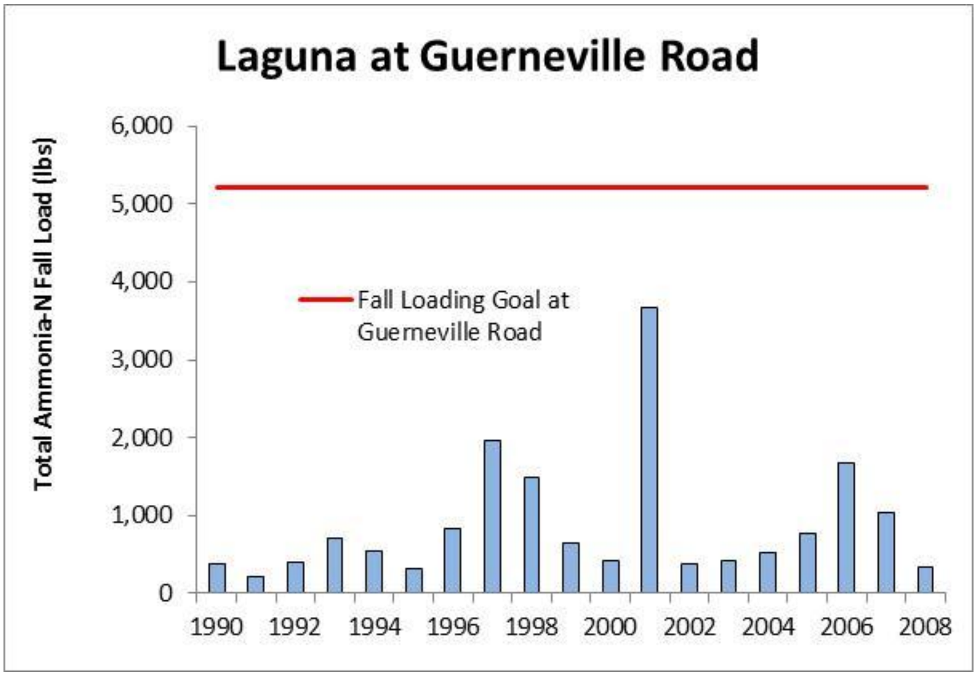

Figure 23. Fall Total Ammonia-N Loads at Guerneville Road

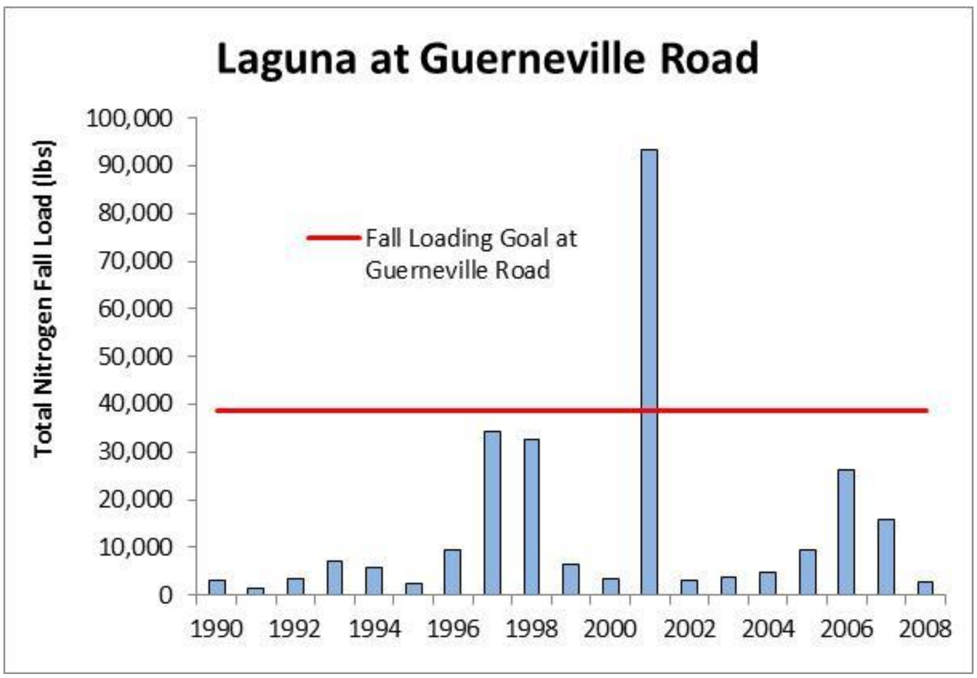

Figure 24. Fall Total Nitrogen Loads at Guerneville Road

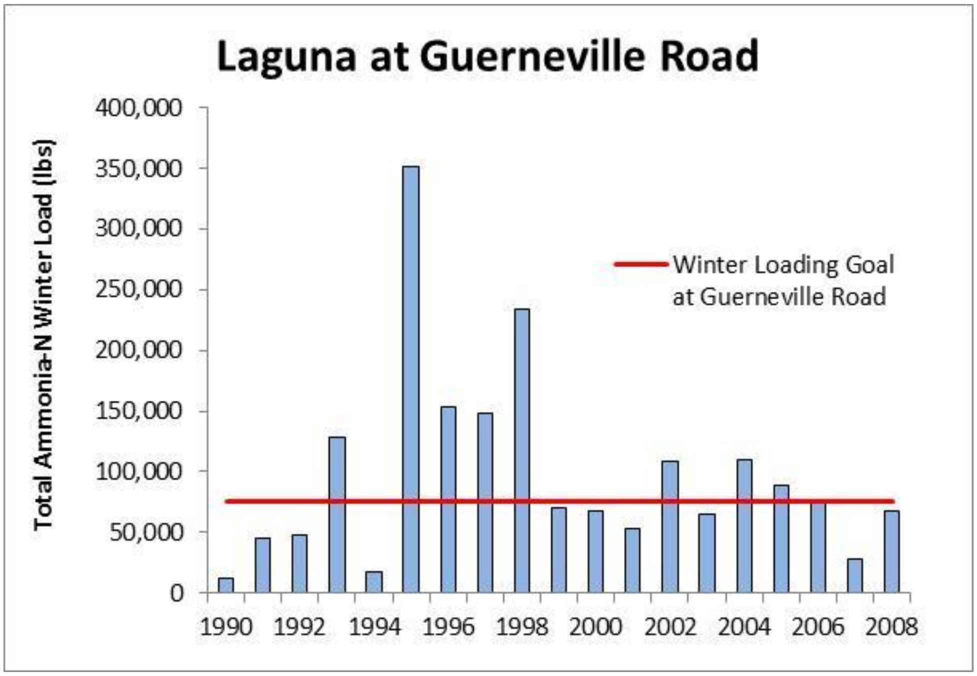

Figure 25. Winter Total Ammonia-N Loads at Guerneville Road

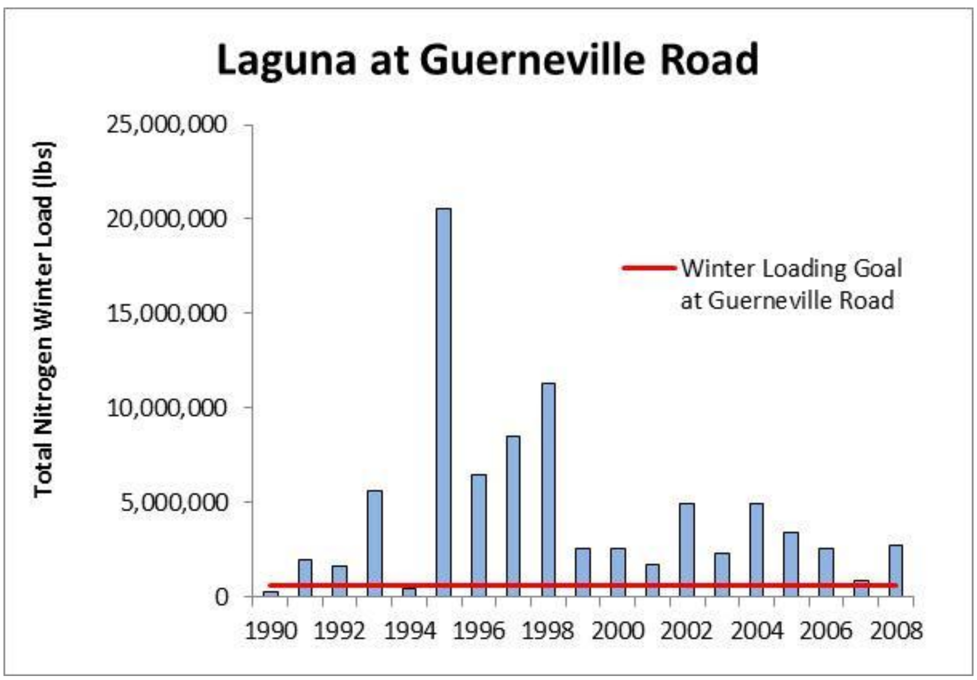

Figure 26. Winter Total Nitrogen Loads at Guerneville Road

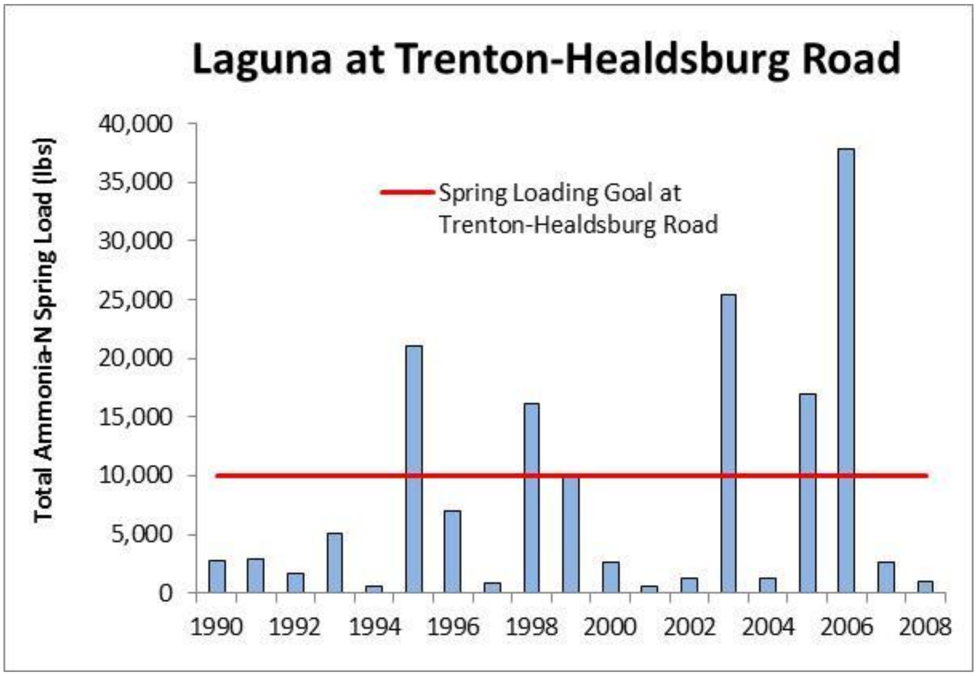

Figure 27. Spring Total Ammonia-N Loads at Trenton-Healdsburg Road

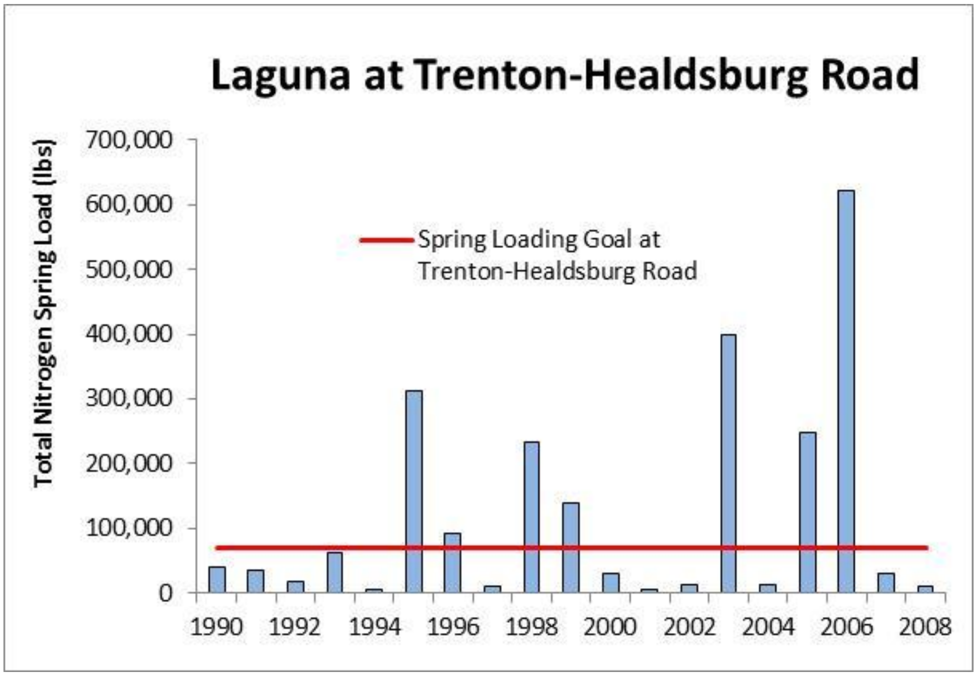

Figure 28. Spring Total Nitrogen Loads at Trenton-Healdsburg Road

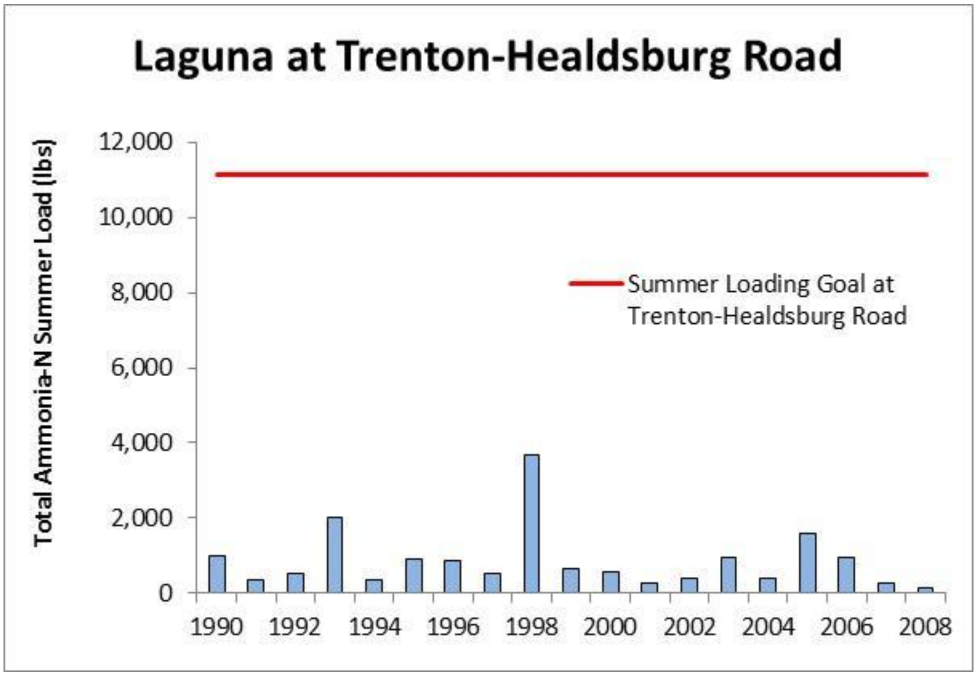

Figure 29. Summer Total Ammonia-N Loads at Trenton-Healdsburg Road

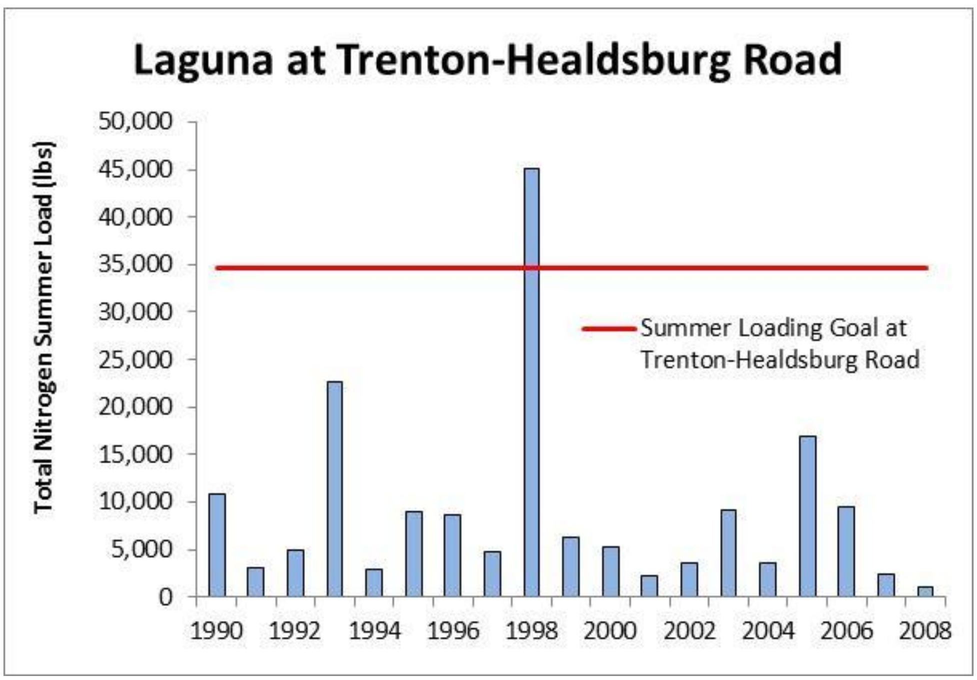

Figure 30. Summer Total Nitrogen Loads at Trenton-Healdsburg Road

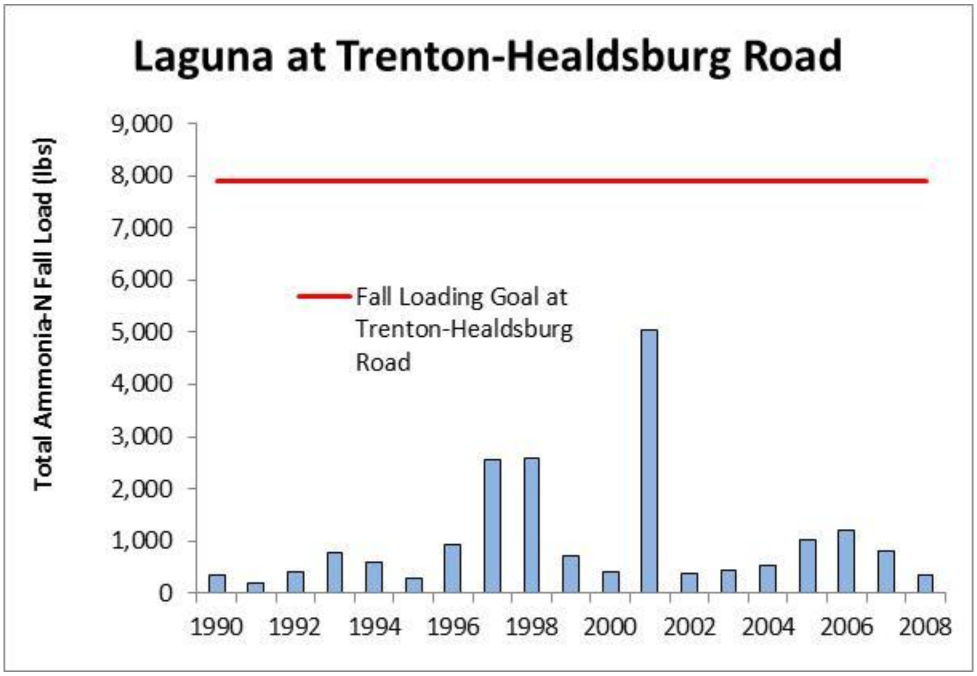

Figure 31. Fall Total Ammonia-N Loads at Trenton-Healdsburg Road

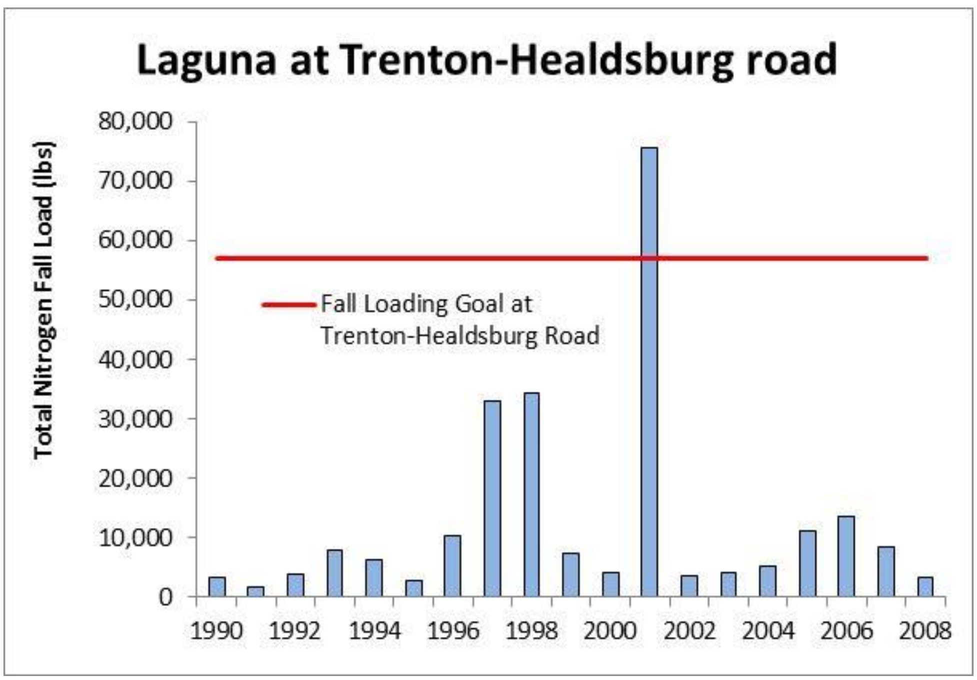

Figure 32. Fall Total Nitrogen Loads at Trenton-Healdsburg Road

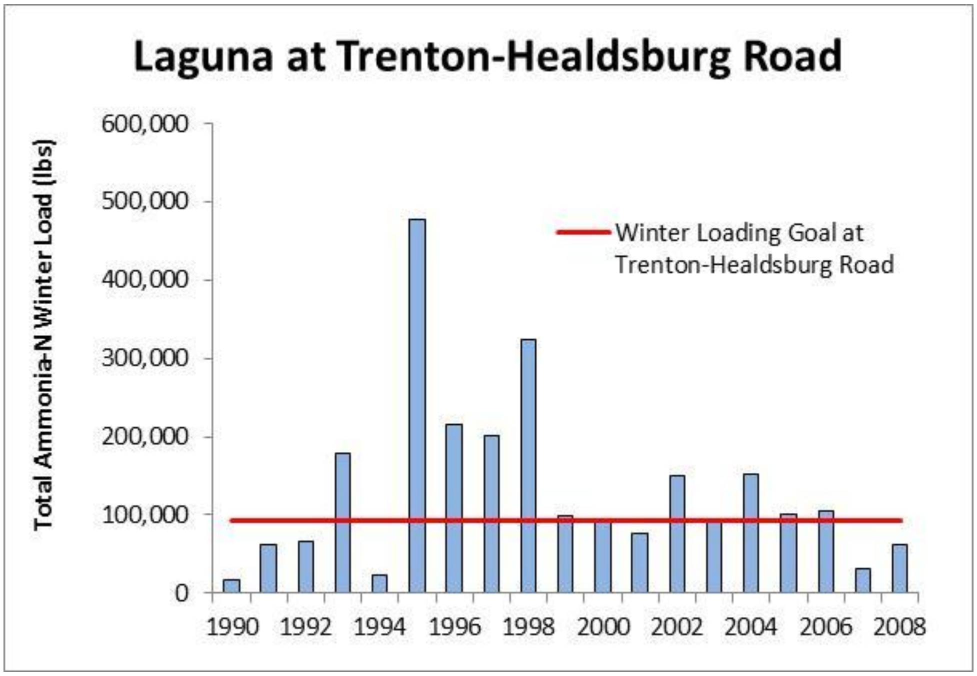

Figure 33. Winter Total Ammonia-N Loads at Trenton-Healdsburg Road

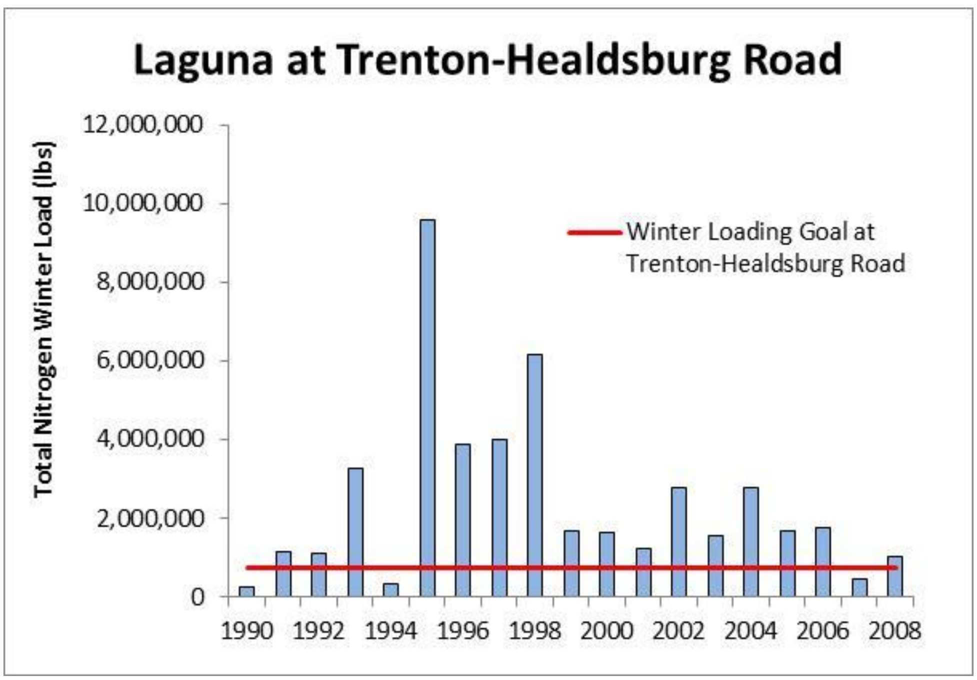

Figure 34. Winter Total Nitrogen Loads at Trenton-Healdsburg Road

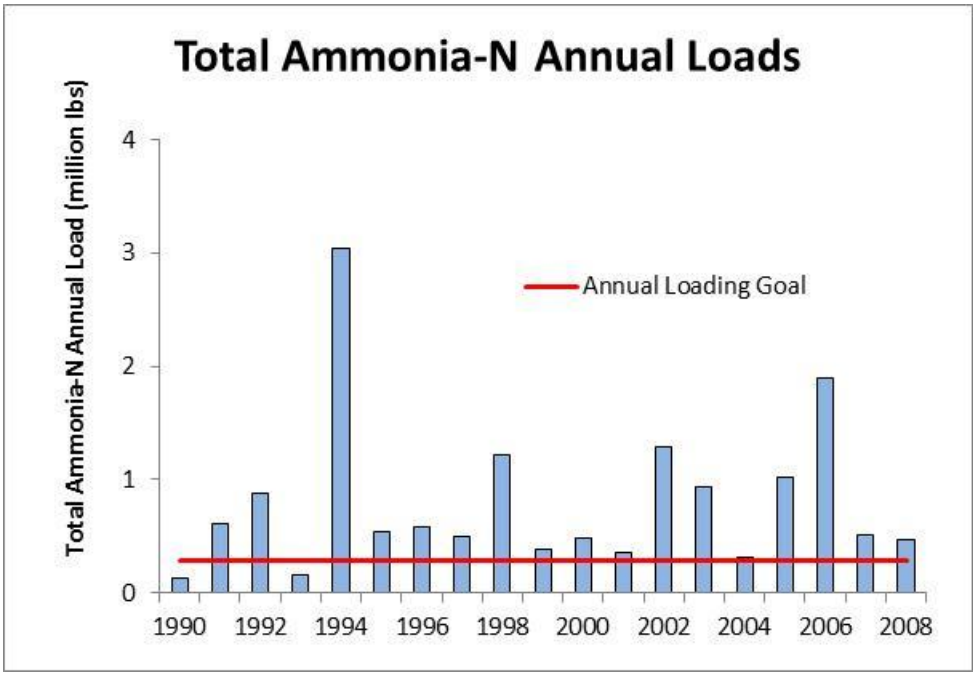

Figure 35. Annual Total Ammonia-N Loads from all Attainment Locations

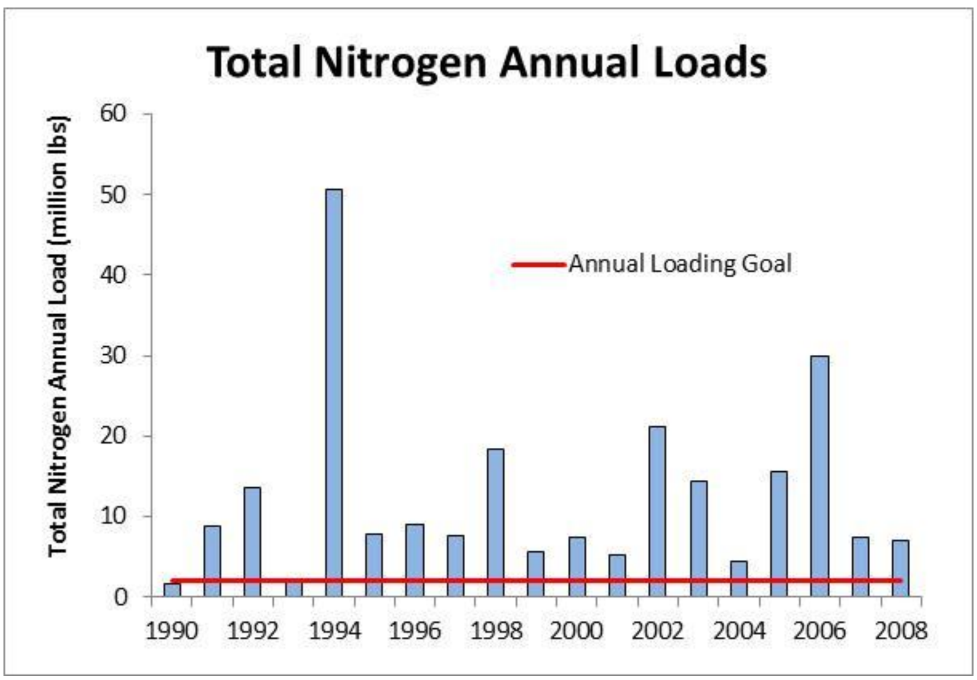

Figure 35. Annual Total Nitrogen Loads from all Attainment Locations

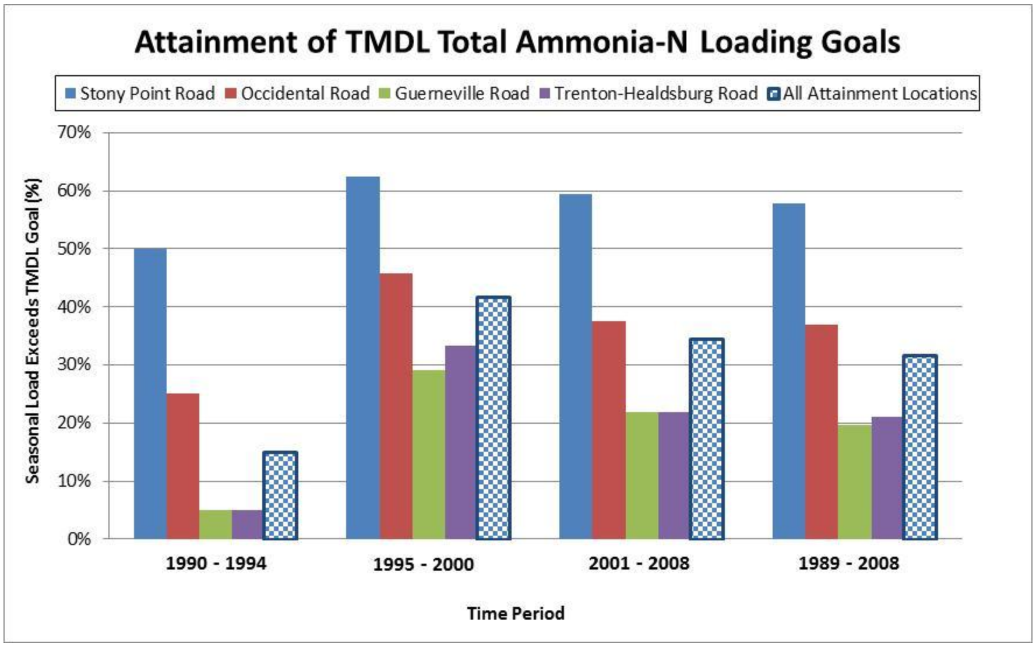

Figure 37. Attainment of Total Ammonia-N TMDL Loading Goals by Time Period

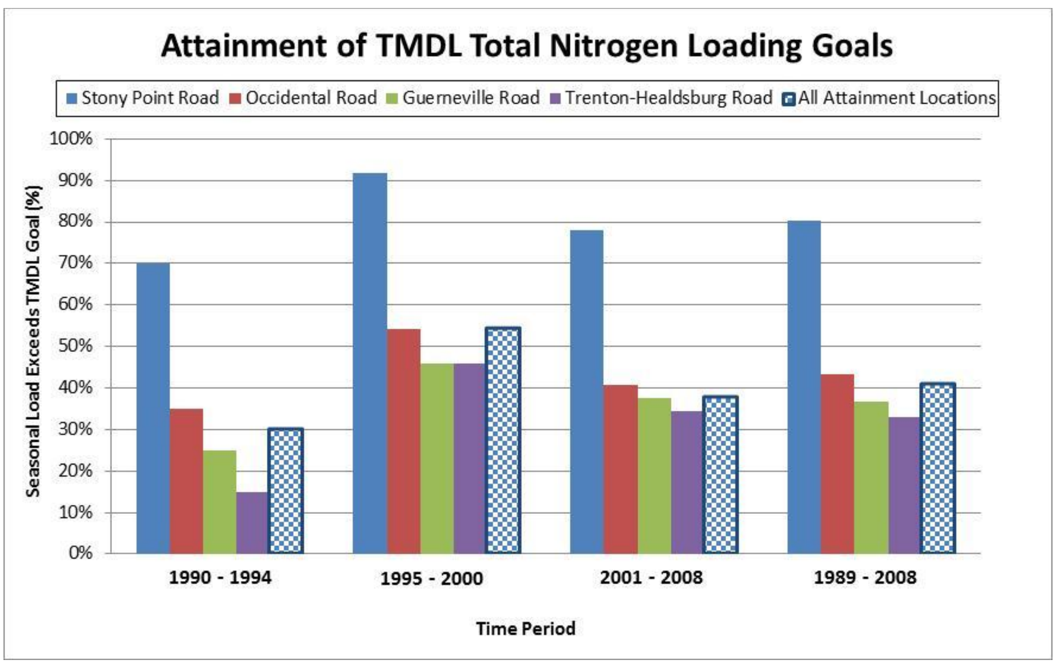

Figure 38. Attainment of Total Ammonia-N TMDL Loading Goals by Time Period

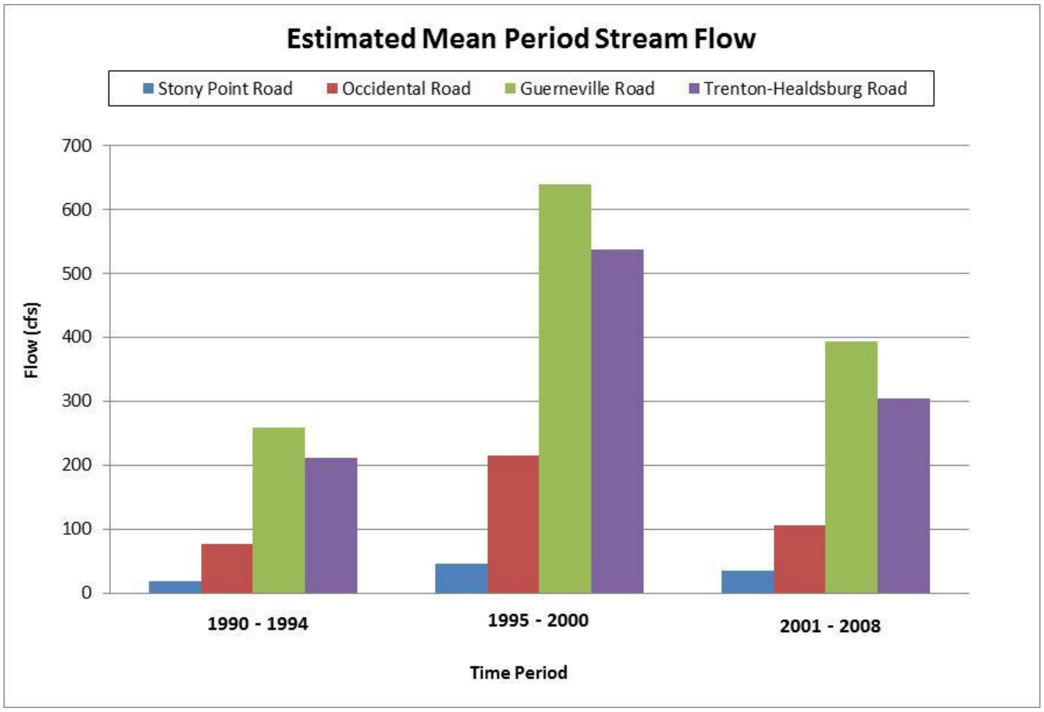

Figure 39. Estimated Means Daily Stream Flow for Three Time Periods

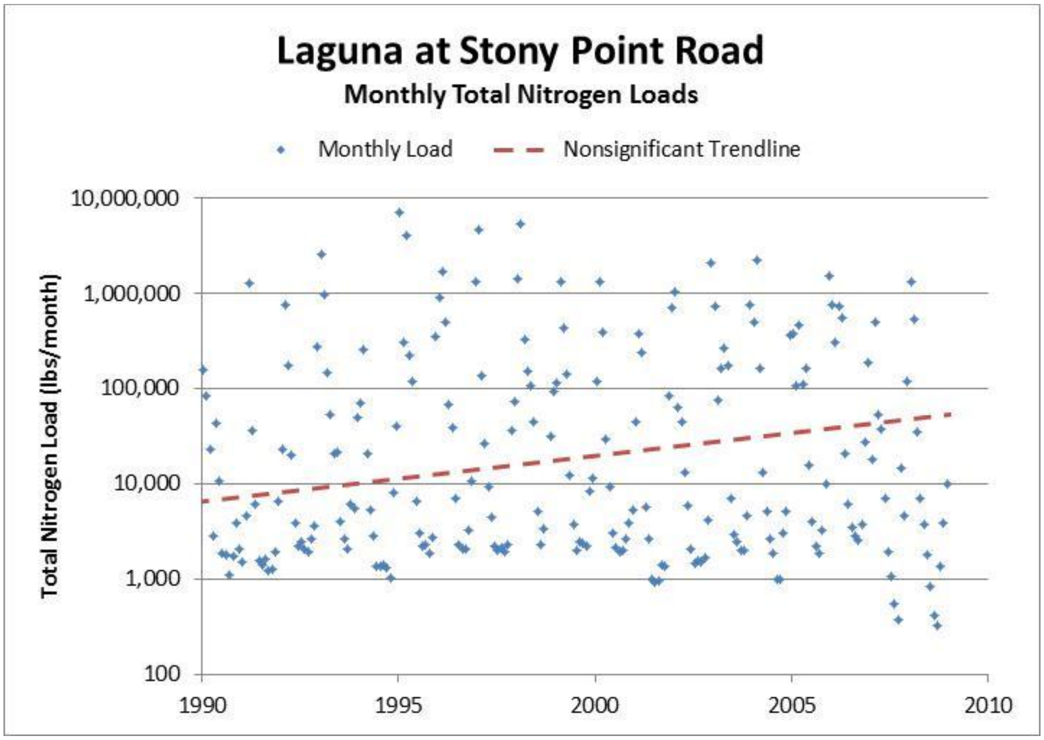

Figure 40. Monthly Total Nitrogen Loads Estimated at Stony Point Road

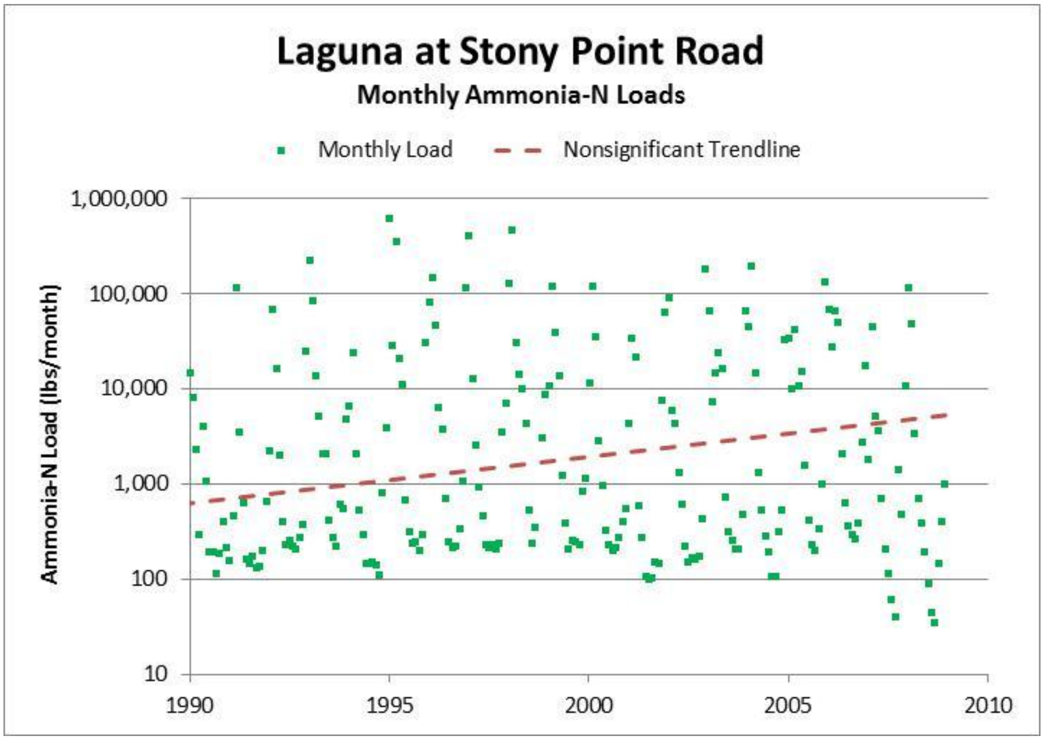

Figure 41. Monthly Ammonia-N Loads Estimated at Stony Point Road

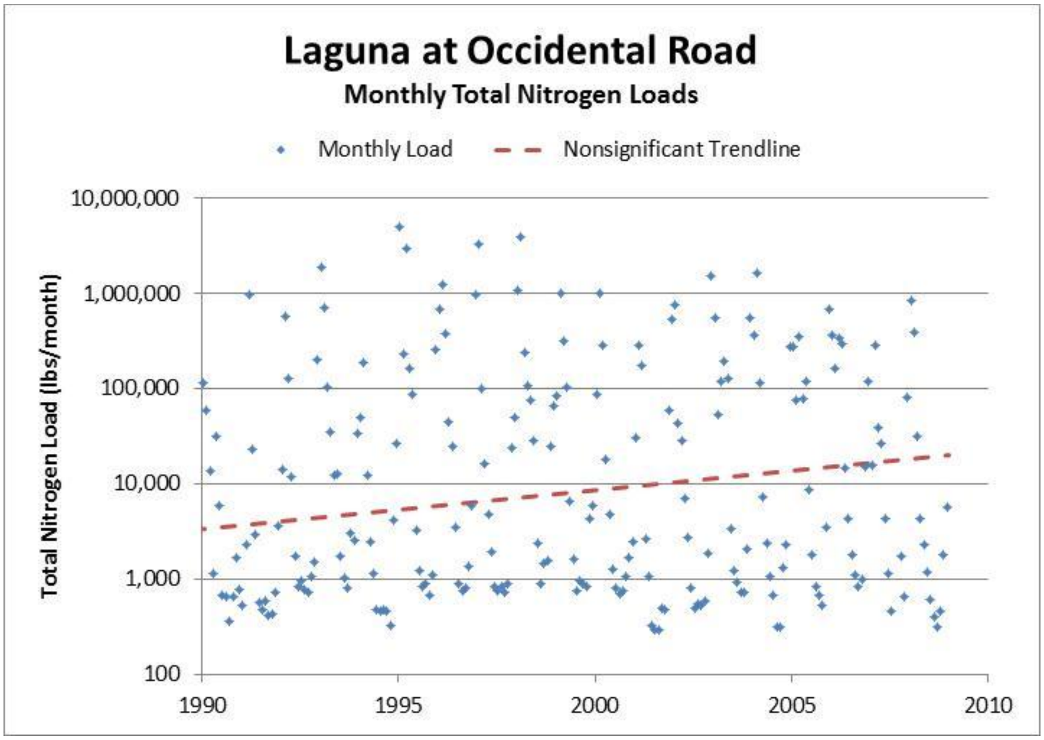

Figure 42. Monthly Total Nitrogen Loads Estimated at Occidental Road

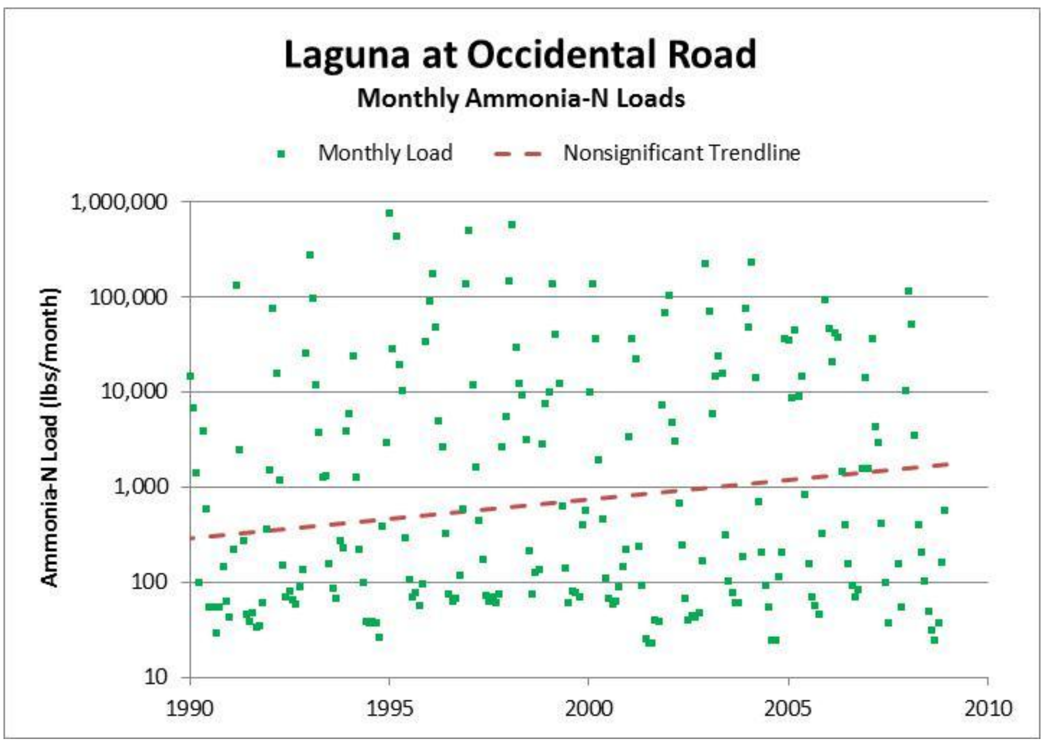

Figure 43. Monthly Ammonia-N Loads Estimated at Occidental Road

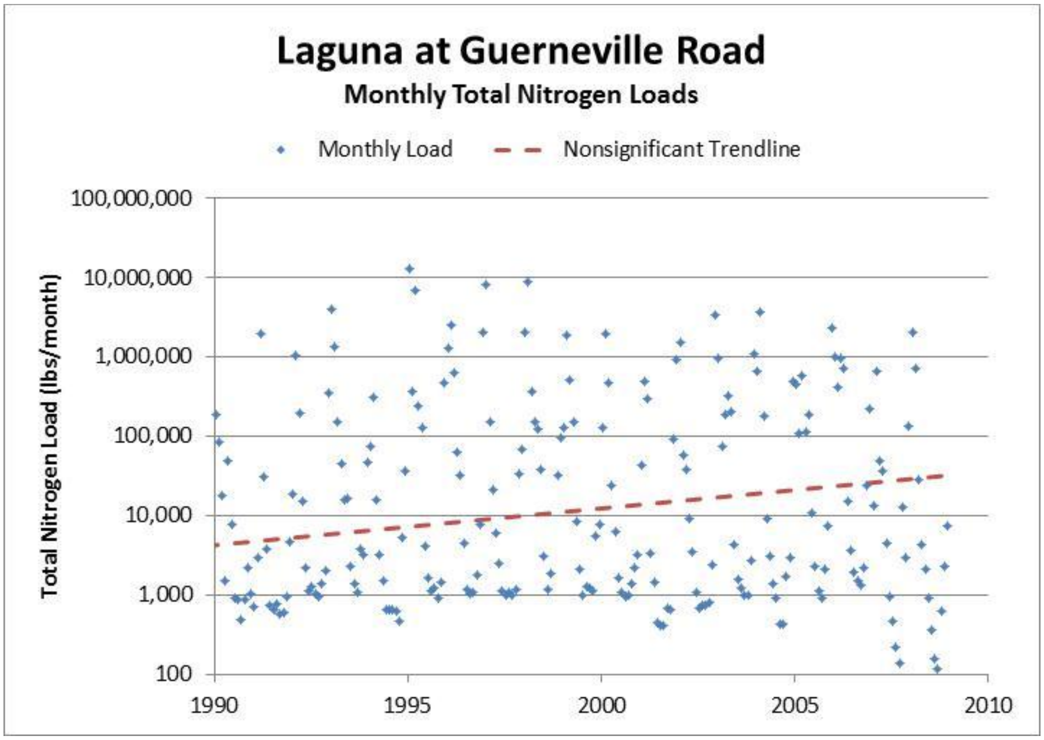

Figure 44. Monthly Total Nitrogen Loads Estimated at Guerneville Road

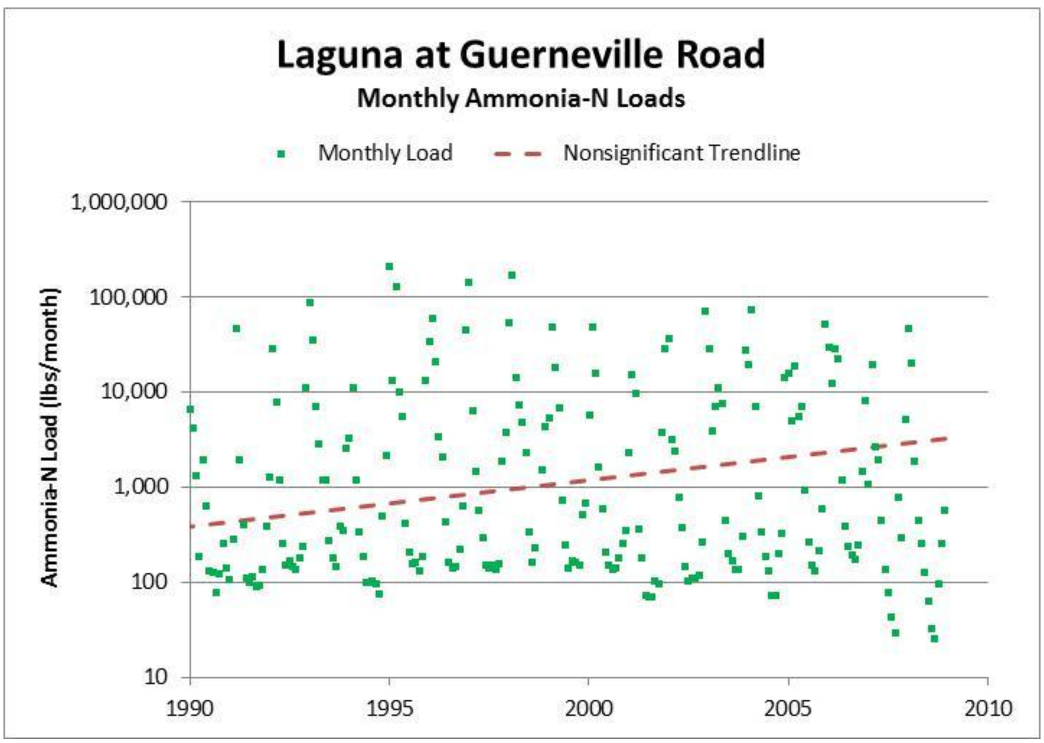

Figure 45. Monthly Ammonia-N Loads Estimated at Guerneville Road

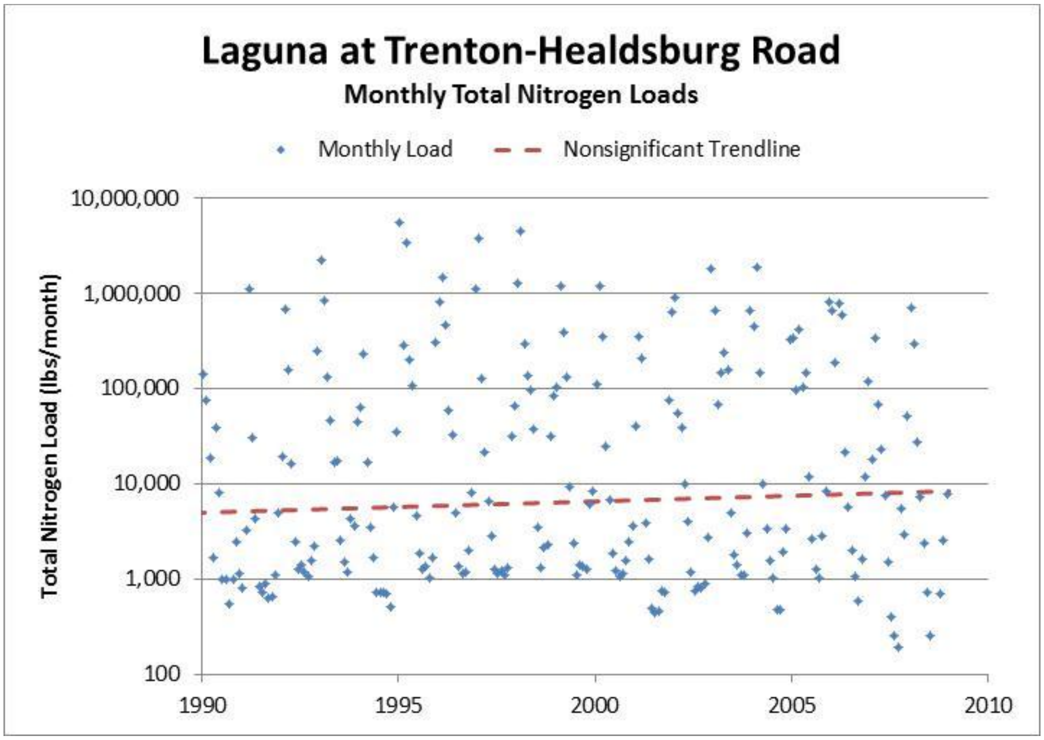

Figure 46. Monthly Total Nitrogen Loads Estimated at Trenton-Healdsburg Road

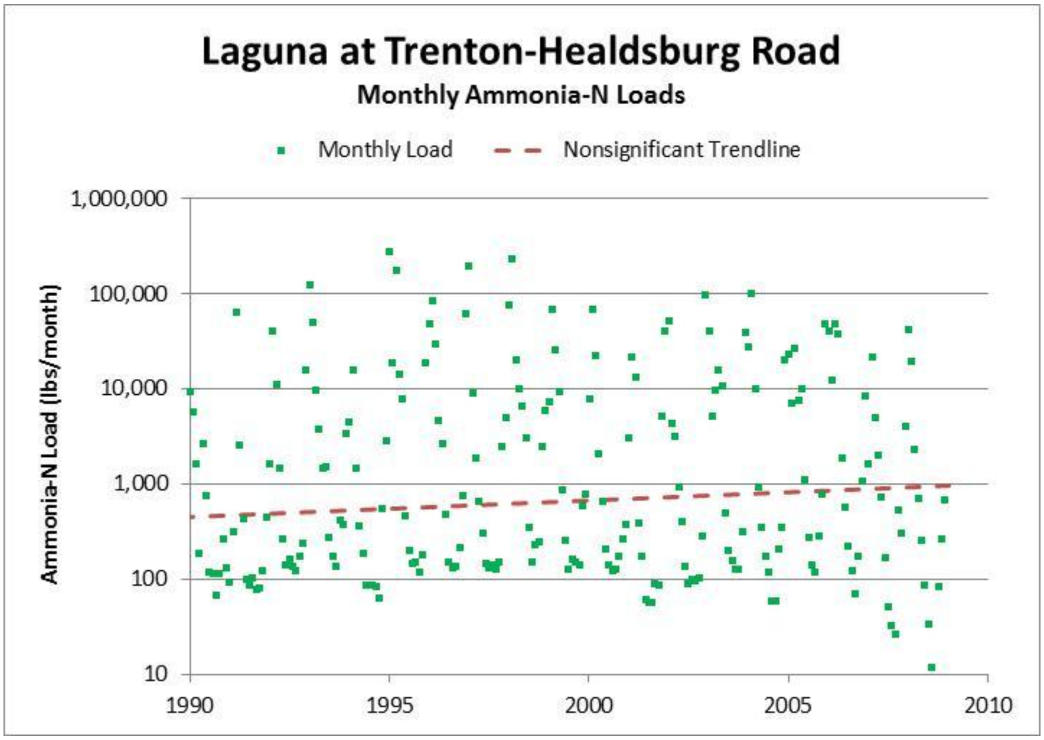

Figure 47. Monthly Ammonia-N Loads Estimated at Trenton-Healdsburg Road