Total Maximum Daily Load of Total Phosphorus (TP) for the Unnamed Tributary of La Trappe Creek In-Stream Pond

APPENDIX B

Unnamed Tributary of La Trappe Creek (UTLTC) In-Stream Pond Water Quality

A water quality survey for the UTLTC In-Stream Pond was conducted in 1998. The water quality data was collected at the overflow spillway of the dam (station TRP6 as shown in Figure B1). A summary of the water quality data was provided in the main body of this report. Table B1 provides the underlying data from which the summaries were derived.

Assessment of the N:P Ratio for UTLTC In-Stream Pond

Before considering the application of the Vollenweider Relationship, it is necessary to examine the ratio of total nitrogen (TN) to total phosphorus (TP) to establish whether phosphorus is the limiting nutrient. In general, an TN:TP ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the TN: TP ratio is greater than 10:1, phosphorus tends to be limiting, and if the TN:TP ratio is less than 5:1, nitrogen tends to be limiting (Chianudani, et al., 1974).

The UTLTC In-Stream Pond is fed by an unnamed tributary of La Trappe Creek, which receives effluent from the Trappe Wastewater Treatment Plant (WWTP), a significant point source input. The exact computation used to arrive at the TN:TP ratio of below 10:1 is documented in Tables B1 and B2. The data in Table B1 was collected by Maryland Department of the Environment (MDE). At the current condition the UTLTC In-Stream Pond is nitrogen limited, but will be made to be phosphorus limited by phosphorus removal conducted at the Trappe WWTP, as shown below in Table B2:

Station	Date	TN (mg/l)	TP (mg/l)	TSS (mg/l)	Chl-a (μg/l)
Unnamed Trib. Of La Trappe Creek-downstream of the Pond (TRP6)	8/17/98	5.50	2.39	29	128
	8/26/98	2.87	1.74	18	54
	9/14/98	3.12	1.92	8	64
AVERAGE		3.83	2.1	17	82

Table B1: Estimation of Current N:P Ratio

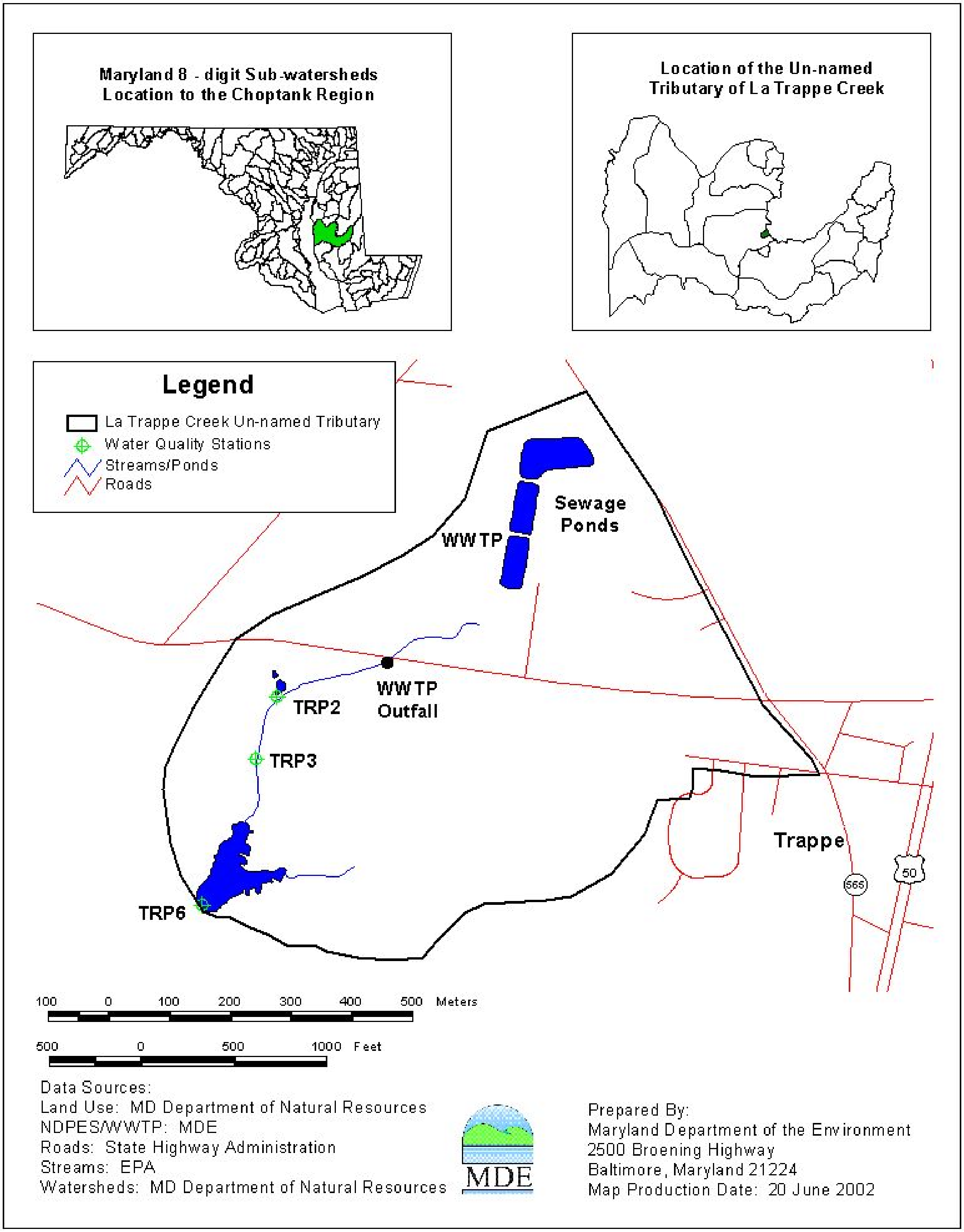

Figure B1: Location of Water Quality Stations

	TN Load (lb/yr)	TP Load (lb/yr)	N:P Ratio	Comments
Trappe WWTP	11,000	183		TN = 8.34x0.2 mgdx18 mg/l TP = 8.34x0.2 mgdx0.3 mg/l
Estimated NPS Load	2039	163		60% of NPS Loads of TP & TN (refer Table B3 and B4 on page B-3)
Total	13039	346	38:1	

Table B2: Estimation of Proposed TMDL N:P Ratio

The new Trappe Wastewater Treatment Plant is not being designed for nitrogen removal; therefore, 18 mg/l TN is assumed for the effluent. However, even if the facility does lower its TN to 8 mg/l, the TN load will be 4,870 lbs/yr from the plant, for a total of 6,910 lbs/yr including the NPS load. In this case, the TN:TP ratio would still be 20:1 and the Pond would still be phosphorus limited.

Supporting Calculations for the Updated Vollenweider-OECD Normalized P Loading/Chlorophyll Response Analysis

The assumed mean depth of the Pond, $\overline{Z}$ = 0.61 m
Surface Area of the Pond = 15,920 m^2
The mean depth of Pond is assumed as 2ft = 0.61 m
Volume of Pond = 15,920 m^2 x .61 m = 9,711 m^3

Phosphorus Loading to UTLTC Pond (Lp):

The total phosphorus loading was computed as follows:

From GIS, total drainage area contributing to UTLTC Pond = 252 acres

Land Use	% of Total Area	Area in Acres	Runoff Coefficients*
Agriculture	63%	160	0.36
Forest	12%	30	0.31
Urban (paved)	21%	53	0.73
Water	4	9	
Total	100%	252	

* Applied Hydrology, Crtow, et al 1988

Table B2: Land Use Runoff Coefficients For the Pond Watershed

Land Use Category	Area	TP Loads		
	Acre	lbs/acre/yr*	lbs/yr	% total
Agriculture	160	1.43836	230	85
Forest	30	0.02428	1	1
Urban	53	0.70426	37	14
Total	**243**		**268**	**100**

Table B3: Loads attributed to Significant Non-Point Sources for Annual Average Flow TP TMDL

Land Use Category	Area	TN Loads		
	Acre	lbs/acre/yr*	lbs/yr	% total
Agriculture	160	17.7145	2834	83
Forest	30	1.6943	51	2
Urban	53	9.6837	513	15
Total	**243**		**3398**	**100**

* Chesapeake Bay Program, Phase IV Areal Loading Rates for various land uses. (CBP model segment 400)

Table B4: Total Nitrogen Loads attributed to Significant Non-Point Sources for Annual Average Flow

UTLTC In-Stream Pond analysis without the point source load

Mean Runoff Coefficient = {(.662)(.36)+(.12)(.31)+(.22)(.73)}/1 = 0.339
Mean annual precipitation at Salisbury from NOAA web site = 1.07 m/yr
Total annual unit runoff = r = (1.07 m/yr)(0.339)= 0.36 m/yr ≈ 0.400 m/yr
= 243acres x 4048 m^2/acre x0.40 m = 393,470 m^3/yr + 15,920 m^2x 1.07 m =393,470 + 17034 = 410,504, or approximately 410,500 m^3/yr.
Total flow to UTLTC In-Stream Pond = 410,500 m^3/yr
Total phosphorus load from nonpoint sources = 268 lbs/yr = 121,600 g/yr
Total phosphorus loading for the UTLTC Pond = 121,600 g/yr
Using the estimated UTLTC In-Stream Pond surface area (15920 m^2), total phosphorus loading can be converted to grams per square meter per year as follows:
121,600 g/yr ÷ 15920 m^2 = 7.64 g/m^2 yr.
Total phosphorus concentration = 121,600 g/yr /410,500 m^3/yr =0.296 g/m^3

UTLTC In-Stream Pond Hydraulic Residence Time (τ_w):

The hydraulic residence time is computed as volume/outflow; it is the time it would take to drain the lake. The estimated hydraulic residence time of 8.6 days was estimated based on the lake volume of 9711 m^3 and an estimated 410,500 m^3/year discharge rate. That is, (9711m^3) ÷ (410,510 m^3/yr) x365 d/yr= 8.6 days; 8.6 days ÷ 365 d/yr = 0.0237 yr.

Ratio of Mean Depth to Hydraulic Residence Time (Z/τ_w)

The mean depth of UTLTC In-Stream Pond (Z) is 0.61 m, and the hydraulic residence time (τ_w) is 0.0237 yr. The ratio was computed as: 0.61m / 0.0237 yr = 25.7 m/yr.

Normalized P loading = 7640 mg/ m^2 yr/ 25.7 m/yr / (1 + 0.0237 yr $^{0.5}$) = 257 mg P/m^3

<u>UTLTC In-Stream Pond analysis with the current point source load</u> (0.144 mgd at 3.05 mg/l TP)

Mean Runoff Coefficient = {(.66)(.36)+(.12)(.31)+(.22)(.73)}/1 = 0.339
Mean annual precipitation at Salisbury from NOAA web site = 1.07 m/yr
Total annual unit runoff = r = (1.07 m/yr)(0.339)= 0.36 m/yr ≈ 0.40 m/yr
= 243 acres x 4,048 m^2 x 0.40 m = 393,470 m^3/yr + 15,920 m^2x 1.07 m = 393,470 + 17,034 = 410,504 ≈ 410,500 m^3/yr.
Total flow to UTLTC In-Stream Pond = 410,500 m^3/yr + flow from the plant = 410,500 m^3/yr + 198,195 m^3/yr
= 608,700 m^3/yr
Total phosphorus load from Trappe WWTP = (0.144 mgd x 3.05 mg/l x 8.34 lbs/gal) lbs/day = 3.663 lbs/day= 606,500 g/yr
Total phosphorus load from nonpoint sources = 121,600 g/yr
Total phosphorus loading for the UTLTC In-Stream Pond = (606,500 + 121,600) = 728,100 g/yr
Using the estimated UTLTC In-Stream Pond surface area (15,920 m^2), total phosphorus loading can be converted to grams per square meter per year as follows: 728,100 g/yr ÷ 15,920 m^2 =45.7 g/m^2 yr.
Total phosphorus concentration = 728,100 g/yr /608,700 m^3/yr =1.196 g/m^3

UTLTC In-Stream Pond's Hydraulic Residence Time (τ_w):

The hydraulic residence time is computed as volume/outflow; it is the time it would take to drain the lake. The estimated hydraulic residence time of 5.8 days was estimated based on the lake volume of 9,711 m^3 and an estimated 608,700 m^3/year discharge rate. That is, (9,300 m^3) ÷ (608,700 m^3/yr) /365 d/yr= 5.8 days; 5.8 days ÷ 365 d/yr = 0.0159 yr.

Ratio of Mean Depth to Hydraulic Residence Time (Z/τ_w)

The mean depth of the UTLTC In-Stream Pond (Z) is 0.61 m, and the hydraulic residence time (τ_w) is 0.0159 yr. The ratio was computed as: 0.61m / 0.0159 yr = 38.4 m/yr

Normalized P loading = 45,700 mg/ m^2 yr/38.4 m/yr / (1 + 0.0159 yr $^{0.5}$) = 1,057 mg P/m^3

<u>UTLTC In-Stream Pond analysis with the reduced point source load</u> (0.20 mgd at 0.30 mg/l TP)

Mean Runoff Coefficient = {(.66)(.36)+(.12)(.31)+(.22)(.73)}/1 = 0.339

Mean annual precipitation at Salisbury from NOAA web site = 1.07 m/yr
Total annual unit runoff = r = (1.07 m/yr)(0.339)= 0.41 m/yr $\approx$ 0.400 m/yr
= 243 acres x 4048 m^2 x0.40 m = 393,470 m^3/yr + 15,920 m^2x 1.07 m = 393,470 +17,034 $\approx$ 410,500 m^3/yr.
Total flow to the UTLTC In-Stream Pond = 410,500 m^3/yr + flow from the plant = 410,500 m^3/yr + 276,335 m^3/yr = 686,900 m^3/yr
Total phosphorus load from Trappe WWTP = (0.20 mgd x 0.30 mg/l x 8.34 lbs/gal) lbs/day = 0.50 lbs/day = 183 lbs/year = 83,000 g/yr
Total phosphorus load from nonpoint sources (40 % reduction) = 0.6x 121,600 = 72,960 g/yr
Total load (PS+NPS + MOS) for the UTLTC In-Stream Pond = 83,000 + 72,960 + 18,200 =174,160 g/yr
Using the estimated UTLTC In-Stream Pond surface area (15920 m^2), total phosphorus loading can be converted to grams per square meter per year as follows: 174,160 g/yr ÷ 15,920 m^2 =10.94 g/m^2 yr
Total phosphorus loading rate = 10940 mg/m^2 yr
Total phosphorus concentration = 174,160 g/yr / 686,900 m^3/yr =0.254 g/m^3

UTLTC In-Stream Pond's Hydraulic Residence Time (τ_w):

The hydraulic residence time is computed as volume/outflow; it is the time it would take to drain the lake. The estimated hydraulic residence time of 5.1 days was estimated based on the lake volume of 9,303 m^3 and an estimated m^3/year discharge rate. That is, (9,711 m^3) ÷ (686,900 m^3/yr) = .0141 yr x 365 d/yr = 5.1 days.

Ratio of Mean Depth to Hydraulic Residence Time (Z/τ_w)

The mean depth of the UTLTC In-Stream Pond (Z) is 0.61 m, and the hydraulic residence time (τ_w) is 0.0141 yr. The ratio was computed as: 0.61m / 0.0141 yr = 43.3 m/yr

Normalized P loading = 10940 mg/ m^2 yr/43.3 m/yr / (1 + 0.0141 yr $^{0.5}$) = 226 mg P/m^3

The intersection of the phosphorus loading rates for these two analyses and the ratio of Mean Depth to Hydraulic Residence Time (Z/τ_w) was plotted on log log paper to establish the current trophic status of the Pond as shown in the graph on page B-7.

The normalized phosphorus loading rates for the current loading and for the TMDL loading were plotted on the updated Vollenweider-OECD normalized P loading/chlorophyll response relationship graph on log-log paper to establish the current trophic status of the UTLTC In-Stream Pond as shown in the graph on page B-6 and the projected improvements. It is important to note that the projected chlorophyll *a* level of 80-85 µg/l was in the range of the observed chlorophyll *a* values in the UTLTC In-Stream Pond of 54, 64, and 128 µg/l.

The UTLTC In-Stream Pond is used as a wildlife pond and will remain somewhat eutrophic even without any point source contribution. A reasonable management goal is to enhance or maintain and support this use. A possible endpoint, seeking to maintain this goal, is to reduce the nutrient enrichment and thus avoid possible nuisance algal bloom. The reduced loadings shown above in Figure B2 should result in a 76% reduction in phosphorus loadings and subsequently 71% reduction in algae levels, even though the UTLTC In-Stream Pond may still remain somewhat eutrophic. Refer to Figure B3 for a graphical representation of the reduction in phosphorus loading.

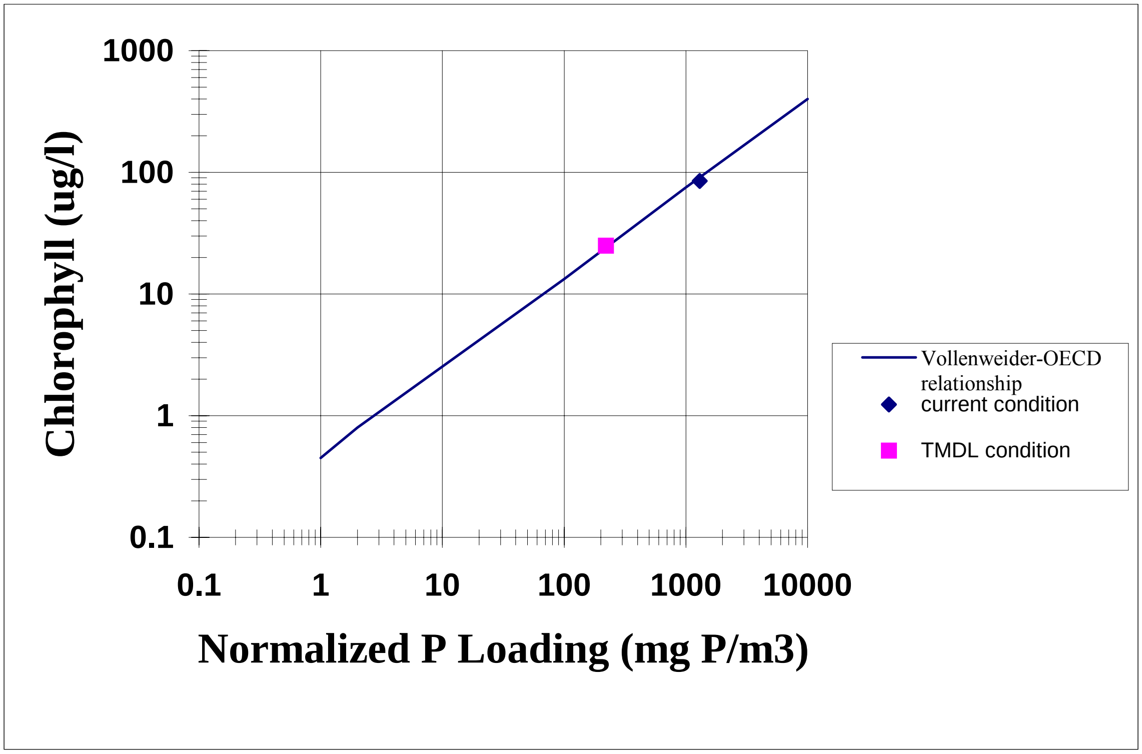

Figure: B2 Updated Vollenweider-OECD Results for the Pond

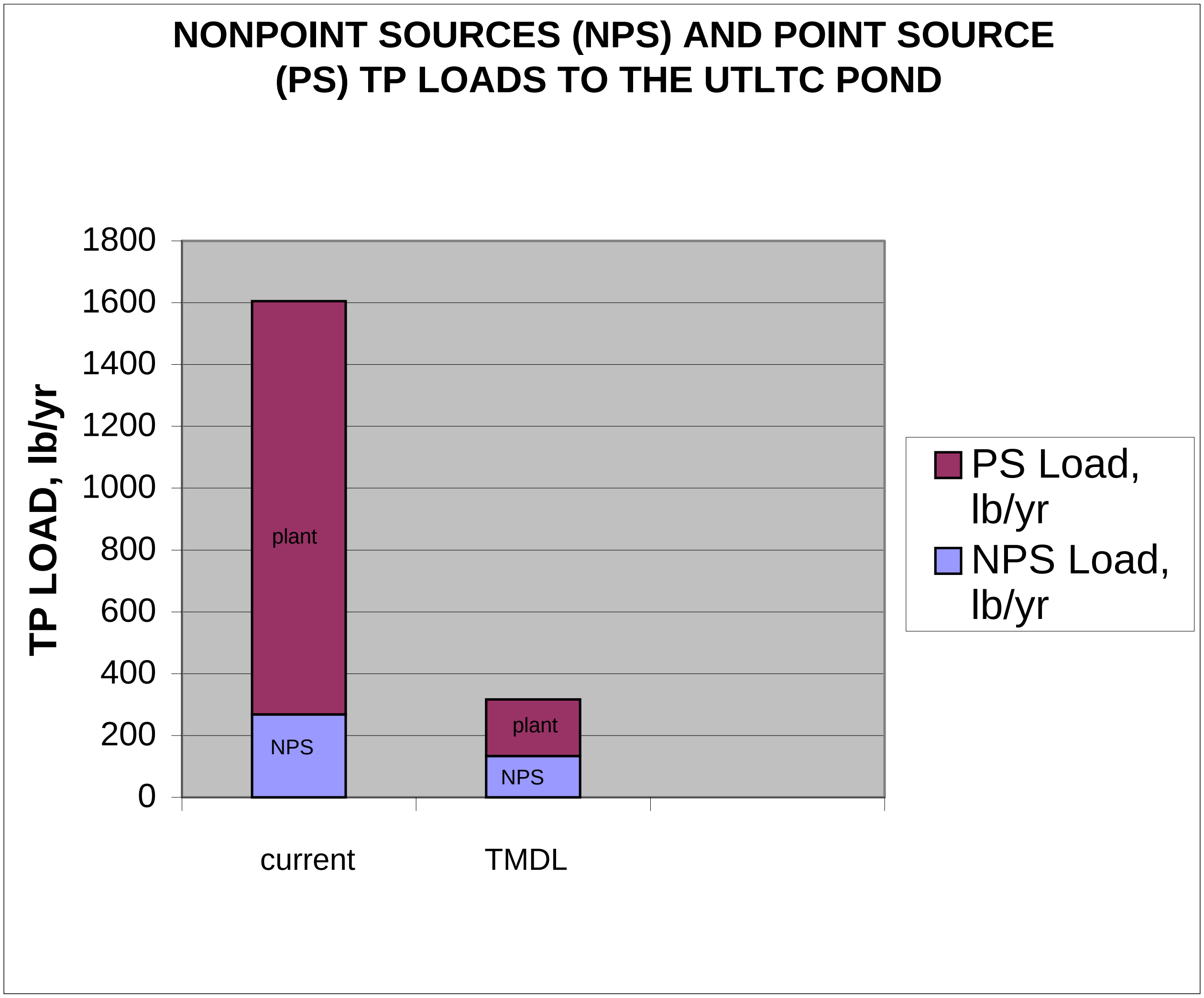

Figure B3: NPS and PS Loads to the UTLTC In-Stream Pond

Maximum Allowable Total Phosphorus Loading For TMDL

A value of 25 µg/l chlorophyll *a* was selected as the endpoint from which to determine the phosphorus TMDL load for the UTLTC In-Stream Pond, using the updated Vollenweider-OECD normalized P loading/chlorophyll response relationship (Figure B2).

Supporting Calculations for the TMDL Analysis

Computing the Phosphorus TMDL

Annual Allowable Loading = 174,160 ***g/yr*** (refer to figure B2 for the normalized allowable P loading for a chlorophyll *a* level of 25 ug/l)
Converted to pounds per year:
(174,160 g/yr) / (453.6 g/lb) ≈ **384 lbs/yr**

Computing the Phosphorus Margin of Safety

The Margin of Safety is computed as 10% of the total allowable unit loading:
0.10 x (Total allowable loading) = Annual loading
(0.10) x (174,160) = 17,416 **g/**yr = 38 lbs/ yr
Actual allowable PS+NPS load = 0.9*174,160= 156,740 g/yr ≈ **346 lbs/yr**

The annual TMDL for Phosphorus *(*lbs/yr*):* WLA = WLA Trappe
Current WLA = {0.144 mgd x 0.3 mg/l x 8.34x 365 d/yr) = 132 lbs/yr
Future WLA (FA) = {0.056 mgd x 0.3 mg/l x 8.34 lbs/gal x 365 d/yr) = 51 lbs/yr

LA = TMDL - WLA – F.A- MOS. = 384 -132 –51-38 = 163 lbs/yr = 73,937 g/yr

Computing the Percentage Phosphorus Reduction of Nonpoint Sources

The necessary reduction in phosphorus loads, as a percentage of the current estimated NPS load, was computed as follows:

$$\frac{\text{(current load)} - \text{(allowable load)}}{\text{(current load)}} = \frac{(121{,}600) - 73{,}937\ \text{g/yr})}{(121{,}600\ \text{g/yr})} = 39.2 \approx 40\%\ \text{reduction in NPS load}$$

% Reduction in NPS load = 40 %.