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:

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

Table B1: Estimation of Current N:P Ratio
Figure B1: Location of Water Quality Stations

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Prepared By:
Maryland Department of the Environment
2500 Greenspring Highway
Baltimore, Maryland 21224

Map Production Date: 20 June 2002
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, $\bar{Z} = 0.61$ m
Surface Area of the Pond = $15,920$ m$^2$

The mean depth of Pond is assumed as 2 ft = 0.61 m
Volume of Pond = $15,920$ m$^2 \times 0.61$ 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

<table>
<thead>
<tr>
<th>Land Use</th>
<th>% of Total Area</th>
<th>Area in Acres</th>
<th>Runoff Coefficients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>63%</td>
<td>160</td>
<td>0.36</td>
</tr>
<tr>
<td>Forest</td>
<td>12%</td>
<td>30</td>
<td>0.31</td>
</tr>
<tr>
<td>Urban (paved)</td>
<td>21%</td>
<td>53</td>
<td>0.73</td>
</tr>
<tr>
<td>Water</td>
<td>4</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>252</strong></td>
<td></td>
</tr>
</tbody>
</table>


**Table B2: Land Use Runoff Coefficients For the Pond Watershed**
### Table B3: Loads attributed to Significant Non-Point Sources for Annual Average Flow TP TMDL

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Area (Acre)</th>
<th>TP Loads</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbs/acre/yr*</td>
<td>lbs/yr</td>
<td>% total</td>
</tr>
<tr>
<td>Agriculture</td>
<td>160</td>
<td>1.43836</td>
<td>230</td>
</tr>
<tr>
<td>Forest</td>
<td>30</td>
<td>0.02428</td>
<td>1</td>
</tr>
<tr>
<td>Urban</td>
<td>53</td>
<td>0.70426</td>
<td>37</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>243</strong></td>
<td><strong>268</strong></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Area (Acre)</th>
<th>TN Loads</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbs/acre/yr*</td>
<td>lbs/yr</td>
<td>% total</td>
</tr>
<tr>
<td>Agriculture</td>
<td>160</td>
<td>17.7145</td>
<td>2834</td>
</tr>
<tr>
<td>Forest</td>
<td>30</td>
<td>1.6943</td>
<td>51</td>
</tr>
<tr>
<td>Urban</td>
<td>53</td>
<td>9.6837</td>
<td>513</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>243</strong></td>
<td><strong>3398</strong></td>
<td></td>
</tr>
</tbody>
</table>

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

### UTLTC In-Stream Pond analysis without the point source load

Mean Runoff Coefficient = \( \{(0.662)(0.36)+(0.12)(0.31)+(0.22)(0.73)\}/1 = 0.339 \)

Mean annual precipitation at Salisbury from NOAA web site = 1.07 m/yr

Total annual unit runoff = \( r = (1.07 \text{ m/yr})(0.339) = 0.36 \text{ m/yr} \approx 0.400 \text{ m/yr} \)

= 243 acres \( \times 4048 \text{ m}^2/\text{acre} \times 0.40 \text{ m} = 393,470 \text{ m}^3/\text{yr} + 15,920 \text{ m}^2 \times 1.07 \text{ m} = 393,470 + 17034 \) = 410,504, or approximately 410,500 \( \text{m}^3/\text{yr} \).

Total flow to UTLTC In-Stream Pond = 410,500 \( \text{m}^3/\text{yr} \)

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 \( \text{m}^2 \)), total phosphorus loading can be converted to grams per square meter per year as follows:

121,600 g/yr \( \div 15920 \text{ m}^2 = 7.64 \text{ g/m}^2 \text{ yr} \)

Total phosphorus concentration = 121,600 g/yr \( /410,500 \text{ m}^3/\text{yr} = 0.296 \text{ g/m}^3 \)

### UTLTC In-Stream Pond Hydraulic Residence Time (\( \tau_w \)):

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, (9711 m\(^3\)) \( \div (410,510 \text{ m}^3/\text{yr}) \times 365 \text{ d/yr} = 8.6 \text{ days} \); 8.6 days \( \div 365 \text{ d/yr} = 0.0237 \text{ yr} \).
Ratio of Mean Depth to Hydraulic Residence Time ($Z/\tau_w$)

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

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

UTLTC In-Stream Pond analysis with the current point source load (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 = $r = (1.07 \text{ m/yr})(0.339) = 0.36 \text{ m/yr} \approx 0.40 \text{ m/yr}$

$= 243 \text{ acres} \times 4,048 \text{ m}^2 \times 0.40 \text{ m} = 393,470 \text{ m}^3/\text{yr} + 15,920 \text{ m}^2 \times 1.07 \text{ m} = 393,470 + 17,034 = 410,504 \approx 410,500 \text{ m}^3/\text{yr}$.

Total flow to UTLTC In-Stream Pond = $410,500 \text{ m}^3/\text{yr} + \text{flow from the plant} = 410,500 \text{ m}^3/\text{yr} + 198,195 \text{ m}^3/\text{yr}$

$= 608,700 \text{ m}^3/\text{yr}$

Total phosphorus load from Trappe WWTP = $(0.144 \text{ mgd} \times 3.05 \text{ mg/l} \times 8.34 \text{ lbs/gal}) \text{ lbs/day} = 3.663 \text{ lbs/day} = 606,500 \text{ g/yr}$

Total phosphorus load from nonpoint sources = $121,600 \text{ g/yr}$

Total phosphorus loading for the UTLTC In-Stream Pond = $(606,500 + 121,600) = 728,100 \text{ g/yr}$

Using the estimated UTLTC In-Stream Pond surface area (15,920 m²), total phosphorus loading can be converted to grams per square meter per year as follows: $728,100 \text{ g/yr} \div 15,920 \text{ m}^2 = 45.7 \text{ g/m}^2 \text{ yr}$.

Total phosphorus concentration = $728,100 \text{ g/yr} / 608,700 \text{ m}^3/\text{yr} = 1.196 \text{ g/m}^3$

UTLTC In-Stream Pond’s Hydraulic Residence Time ($\tau_w$):

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 m³ and an estimated 608,700 m³/year discharge rate. That is, $(9,300 \text{ m}^3) / (608,700 \text{ m}^3/\text{yr}) / 365 \text{ d/yr} = 5.8 \text{ days} ; 5.8 \text{ days} \div 365 \text{ d/yr} = 0.0159 \text{ yr}$.

Ratio of Mean Depth to Hydraulic Residence Time ($Z/\tau_w$)

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

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

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

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

Document version: December 27, 2002 B-5
Mean annual precipitation at Salisbury from NOAA web site = 1.07 m/yr
Total annual unit runoff = \( r = (1.07 \text{ m/yr})(0.339) = 0.41 \text{ m/yr} \approx 0.400 \text{ m/yr} \)
= 243 acres x 4048 m/0.40 m = 393,470 m/yr + 15,920 m/yr x 1.07 m = 393,470 +17,034 \approx 410,500 m/yr.

Total flow to the UTLTC In-Stream Pond = 410,500 m³/yr + flow from the plant = 410,500 m³/yr + 276,335 m³/yr = 686,900 m³/yr

Total phosphorus load from Trappe WWTP = \( 0.20 \text{ mgd x 0.30 mg/l x 8.34 lbs/gal} \) lbs/day = 0.50 lbs/day = 183 lbs/year = 83,000 g/yr

Total phosphorus load from nonpoint sources (40 % reduction) = 0.6 x 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 m²), total phosphorus loading can be converted to grams per square meter per year as follows: 174,160 g/yr ÷ 15,920 m² = 10.94 g/m² yr

Total phosphorus loading rate = 10940 mg/m² yr

Total phosphorus concentration = 174,160 g/yr / 686,900 m³/yr = 0.254 g/m³

**UTLTC In-Stream Pond’s Hydraulic Residence Time (\( \tau_w \))**:

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 m³ and an estimated m³/year discharge rate. That is, \( 9,711 \text{ m}^3 \div (686,900 \text{ m}^3/\text{yr}) = .0141 \text{ yr} \times 365 \text{ d/yr} = 5.1 \text{ days} \).

**Ratio of Mean Depth to Hydraulic Residence Time (\( Z/\tau_w \))**

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

Normalized P loading = 10940 mg/ m² yr/43.3 m² yr / \( 1 + 0.0141 \text{ yr}^{0.5} \) = 226 mg P/m³

The intersection of the phosphorus loading rates for these two analyses and the ratio of Mean Depth to Hydraulic Residence Time (\( Z/\tau_w \)) 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:

\[
\frac{174,160 \text{ g/yr}}{453.6 \text{ g/lb}} \approx 384 \text{ lbs/yr}
\]

Computing the Phosphorus Margin of Safety

The Margin of Safety is computed as 10% of the total allowable unit loading:

\[
0.10 \times (\text{Total allowable loading}) = \text{Annual loading}
\]

\[
0.10 \times 174,160 = 17,416 \text{ g/yr} = 38 \text{ lbs/yr}
\]

Actual allowable PS+NPS load = 0.9*174,160= 156,740 g/yr \(\approx\) 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 %.