APPENDIX L

SAMPLE CALCULATIONS

Step 1: Define land uses
Using the methods described in section III of this report, land use maps for 1990 and 2006 were generated using GIS.

Step 2: Compare 1990 and present land uses
Using GIS analysis, an overlay of the 1990 and 2006 land use map was created. The acreages of the individual land uses for each period of time can be found in **Table 5** of the report. Areas where land use changed were classified based on the type of change that occurred **(Figure 8).**

Step 3: Estimate annual runoff volume based on land use
In undeveloped areas, the land use maps generated in **Step 1** were combined with the soils data using overlay analysis in GIS. This generated a breakdown of land use by hydrologic soil group for each time period. An example for agricultural land use is shown below.

1990			
Land Use - Hydrologic Soil Group	AREA (AC)	Impervious Percent	RUNOFF (AF)
Ag-A	116	6%	21
Ag-B	1868	6%	571
Ag-C	0	6%	0
Ag-D	36	6%	20
Ag - Total	2020		612

Table A

2006			
Land Use - Hydrologic Soil Group	AREA (AC)	Impervious Percent	RUNOFF (AF)
Ag-A	5	6%	1
Ag-B	457	6%	139
Ag-C	0	6%	0
Ag-D	18	6%	10
Ag - Total	12401		150

Table B

In the tables above, the area in acres was calculated using the GIS data sets. The impervious percent was calculated from the City-wide GIS-based impervious data set.

Accumulated direct runoff (inches) was calculated using SCS methodology and 10 years of rainfall data collected at the Osseo station. Variables and formulas used to determine runoff are as follows:

Variables
CN = Curve Number (from MN Hydrology Guide)
P = Precipitation in inches taken from daily rainfall data
S = Potential maximum retention. Assume antecedent moisture condition (AMC) II (moderate).
Pe = Runoff volume (inches)

Formulas

$$S = \frac{1000}{CN} - 10$$

$$Pe = \frac{(P - .2S)^2}{P + .8S}$$

The accumulated direct runoff was calculated for the different land use classifications and impervious surface based on the actual rainfall data. These values can be found in **Appendix J.** The runoff volumes shown in **Table 5** in the report and in **Table A** and **B** above were then based on the accumulated direct runoff (inches) and the following formula:

Runoff (AF) = [("Area" x "Impervious%" x "Accumulated Direct Runoff") + ("Area" x (1-"Impervious%")* "Accumulated Direct Runoff")] / 12 (in/ft)

Where:

Area = Calculated Area

Impervious% = Impervious percentage calculated from City-wide impervious coverage

Accumulated Direct Runoff = Average annual runoff depth calculated from rainfall data. These values are show in **Appendix J1** for the various land use soil combinations.

Note that left side of the equation calculates the runoff for the impervious part of the land use while the right side of the equation calculates the runoff for the pervious portion of the land use.

Using agricultural land use with hydrologic soils group A as an example:

Runoff (2006) AF = 5AC x [(0.06 x 20.11 in) + (0.94 x 1.07 in)] / 12 ft/in = 1 AF

Runoff (1990) AF = 116AC x [(0.06 x 20.11 in) + (0.94 x 1.07 in)] / 12 ft/in = 21 AF

This calculation is then repeated for all soil types (when applicable) with the calculated values being added to generate a composite runoff for land use by year (some rounding occurs).

Ag(2006) = 1 AF+ 140 AF + 0 AF + 10 AF = 150 AF
Ag(1990) = 21 AF + 570 AF + 0 AF + 20 AF = 612 AF

These values are the runoff values that can be found in **Table 5** (Volume and Runoff Generated for Various Land Uses) for specific land uses as well as the runoff volume used in the Phosphorus and TSS calculations (**Table 6** and **Table 7**).

After runoff volumes are calculated for each land use, a composite runoff per acre volume is calculated for each land use type.

Runoff Per Acre = Annual Runoff Volume / Acreage

For agricultural land use this would be:

150 AF / 480 AC = 0.31 AF/AC

For commercial land use this would be:

420 AF / 351 AC = 1.20 AF/AC

This number becomes important when examining the impacts of land use change. For example, when converting an acre of agricultural land use to commercial land use you would expect to see a change in runoff volume of:

Post Development Land Use Composite Runoff - Predevelopment Land Use Composite Runoff

1.20 AF/AC - 0.31 AF/AC = 0.89AF/AC

The conversion of an acre of agricultural land use to commercial land use would result in an increase in runoff of 0.89 AF annually before infiltration and evaporation. These values can be found for all land use conversions that were found in the City **(Table 8).**

Step 4: Review Research Documents for Event Mean Concentrations
See Section III of the report for more details.

Step 5: Estimate Event Mean Concentrations
See Section III of the report for more details.

Step 6: Compute annual loading of pollutants generated by land use.
The average pollutant loadings generated from each land use and time frame were computed based on the data generated from **Step 3** and **Step 5.** The acreages of the various land uses can be found in **Table 4** of the report. The first step in this calculation is converting the Event Mean Concentrations from **Step 5** to lbs/Acre-Feet.

$$\frac{mg}{L} \times \frac{2.205x10^{-6}\,lbs}{mg} \times \frac{L}{0.0353 ft^3} \times \frac{43{,}560 ft^2}{ac} = \frac{lbs}{acre-feet}$$

Using agriculture as an example, a phosphorus concentration of **0.75 mg/L** converts to **2.0407 lbs/acre feet.**

Once the Event Mean Concentration has been converted to lbs/acre-feet annual loading is calculated using the following equation on a per acre basis:

Pollutant Event Mean Concentration x Annual Runoff Volume = Loading (lbs/year)

Using agriculture as an example again:

PLoad(1990) = 2.0407 lbs/acre-feet x 612 Acre-Feet = 1248 lbs
PLoad(2006) = 2.0407 lbs/acre-feet x 150 Acre-Feet = 307 lbs

Using Commercial as an example for developed conditions:

Pollutant Event Mean Concentration x Annual Runoff Volume = Loading (lbs/year)

PLoad(1990) = 0.5986 lbs/acre-feet x 114 acre-feet = 68 lbs
PLoad(2006) = 0.5986 lbs/acre-feet x 420 acre-feet = 251 lbs

As in the case of runoff, an annual average phosphorus load per acre is also calculated.

Loading Per Acre = Annual Average Loading / Acreage

For agricultural land use this would be:

307 lbs / 480 AC = 0.64 lbs/AC

For commercial land use this would be:

251 lbs / 351 AC = 0.72 lbs/AC

This number becomes important when examining the impacts of land use change. For example, when converting an acre of agricultural land use to commercial land use you would expect to see a change in loading (prior to NURP) of:

Post Development Land Use Loading - Predevelopment Land Use Loading

0.72 lbs/AC - 0.64 lbs/AC = 0.08 lbs/AC

The conversion of an acre of agricultural land use to commercial land use would result in a increase in phosphorus loading of 0.08 AF annually. These values can be found for all land use conversions that were found in the City in **Table 8.**

The calculation of TSS loading is identical to the calculation of Phosphorus loading. The only difference being the Event Mean Concentration values and the removal efficiencies.

Step 7: Compare 1990 loadings to present loadings.

The comparison of 1990 to present loading for volume, phosphorus, and TSS loading is very straight forward. Using either the numbers from the calculations above or from **Tables 6-8**:

Runoff(2006) – Runoff(1990) = Change in Runoff Volume
420 AF – 114 AF = 306 AF

PLoad(2006) – Pload(1990) = Change in Annual Average Phosphorus Load
251 lbs – 68 lbs= 183 lbs

TSS(2006) – TSS(1990) = Change in Annual Average TSS Load
51 tons – 14 tons= 37 tons

Step 8: Define treatment practices and removal efficiencies employed in 1990 and present.

See Section III of the report for more details.

Step 9: Estimate and compare annual runoff and pollutant loadings of each land use based on BMP treatments provided.

For developed land uses, it was necessary to calculate the change in runoff volume, phosphorus, and TSS load after BMP treatments were provided. For volume this was accomplished by accounting for infiltration and evaporation that occurs in the NURP ponds that were installed as part of all development that occurred since 1990.

For Commercial land use:

Newly Created Pond Acreage = Developed acres x 3%
= (351 AC – 95 AC) x 0.03 = 7.7 AC

Evaporation Volume = 3' of evaporation per acre of newly created ponds
= 7.7 AC x 3' = 23 AF

Infiltration Volume = 0.03 inches / hour over 240 days for each acre of newly created ponds = 14.4 acre-feet per acre of newly created ponds
= 7.7 AC x 14.4 x 75% = 83 AF

Annual Runoff Considering Losses = Runoff(2006) – Infiltration Volume – Evaporation Volume
= 420 AF – 23 AF – 83 AF = 314 AF

For phosphorus and TSS loading, accounting for NURP treatment requires the formula used in **Step 6** to be modified. This is done so that NURP treatment is only applied to the additional volume generated between 1990 and 2006 so the formula becomes slightly more complex:

Pollutant Event Mean Concentration x Annual Runoff Volume(1990) + Pollutant Event Mean Concentration x [Annual Runoff Volume(2006) – Annual Runoff Volume(1990)] x (1 – Treatment Efficiency) = Loading (lbs/year)

Since **Pollutant Mean Concentration x Annual Runoff Volume** has already been calculated the formula can be simplified to:

PLoad(1990) + [PLoad(2006)-PLoad(1990)] x (1 – Treatment Efficiency) = Loading After Nurp (lbs/year)

Using Commercial land use as an example:

PLoad(2006) = 0.5986 lbs/acre-feet x 114 acre-feet + 0.5986 lbs/acre-feet x (420 – 114 acre-feet) x 0.4 = 141 lbs

Or

PLoad(2006) = 68 lbs + (251 lbs – 68 lbs) x 0.4 = 141 lbs

This results in a Change in Annual Average Phosphorus Load of:

PLoad(2006) – Pload(1990) = Change in Annual Average Phosphorus Load
141 lbs – 68 lbs= 73 lbs

The methodology for calculating the effect of BMP's on TSS are the same as for Phosphorus.

In addition to the City-wide calculations, it is also necessary to account for NURP treatment on a land use conversion basis:

Post Development Land Use Loading x (1-Treatment Efficiency) - Predevelopment Land Use Loading

So for the conversion of Agricultural to Commercial land use:

0.72 lbs/AC x (1-0.6) - 0.64 lbs/AC = -0.35 lbs/AC

These values can be found in **Table 8.** It should be noted that this method calculates Phosphorus in a conservative manner that accounts for all runoff and does not account for infiltration and evaporation.

Step 10: Complete 2006 to 2020 Analysis
The above sample calculations can be directly applied to the 2020 analysis. In addition to the BMPs quantified in Step 8, the 2006 to 2020 analysis accounts for a new City Policy that requires new developments to abstract a volume of stormwater runoff equal to 0.5 inches of runoff from new impervious surfaces within 48 hours. The method used to quantify these volumes are described in **Section IV B**, and calculated in **Appendix K**. The results of the 2006 to 2020 analysis are shown on **Tables 5b, 6b, 7b, 8b**, and discussed in **Section IV**.

Step 11: Determine impact on water bodies.
In addition to the City-wide calculations it is necessary to calculate the impact that changes in land use have in runoff volume and pollutant loading on a watershed basis. This was accomplished by generating a GIS map depicting the changes in land use that occurred **(Figure 8)** and performing an overlay with the sub-watershed map **(Figure 2).** This allowed the calculation of the changes in land use by watershed and subsequently the change in loading that occurred as a result of land use conversion based on the values from **Table 8.** The results of this can be found in **Figures 9-12.**

Step 12: Develop mitigation plan.
See Methodology